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Included in this Issue

Making it Happen

Global System for Mobile Communications

200 Futures for 2020

The Journal of The Institution of British Telecommunications Engineers

BRITISH TELECOMMUNICATIONS ENGINEERING

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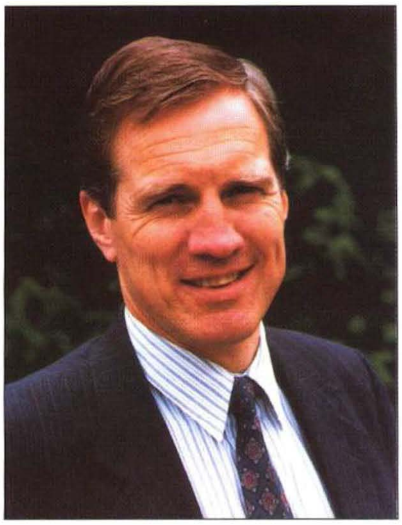
GUEST EDITORIAL (I)

Alan Bealby

Making it Happen



BT is recognising how critical it is for business success that we identify and implement 'winners'—in other words we 'Make it Happen'

The labours of specifying, designing and planning any initiative, improvement or change are worth nought unless it happens. In the world stakes, there is no doubt that BT is a leader when it comes to creativity. We have a tremendous track record of innovatory products, support systems and visionary platforms and plans, many of which do reach fruition. Implementation is, however, sometimes less than perfect due to inherent complexity or lack of project management. Increasingly, BT is recognising how critical it is for business success that we identify and implement 'winners'—in other words we 'make it happen'.

But what do we understand by 'making it happen'? An individual or team could claim to have 'made it happen' on completion of a particular piece of work along the product path; but did it really happen as far as the end users or paying customers are concerned? Making it happen in their eyes is when they are using a product which meets their expectations, both in quality and cost.

To bring 'delivery' to the fore, therefore, and build and learn from the success of successful initiatives, I am pleased to introduce the 'Making it Happen' theme. Over the next few months, articles reflecting this theme will be included, and Nigel Milway and Brian Wright's article on 'NAIP–The Realisation of a Network Vision' (p. 268) and Colin Tuerena, Peter Mabey and Neil Barnes's on 'Phone-ins: Their Impact and Management' are the first in the series.

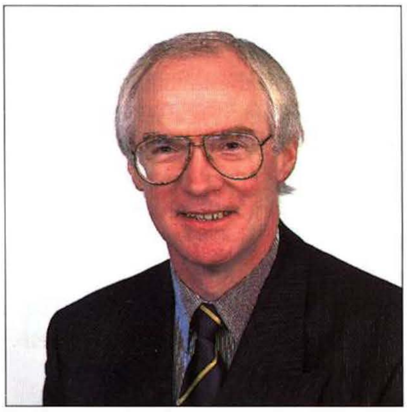
The management scientist, R. M. Belbin, identified nine key attributes, including creators, shapers and facilitators. The *Journal* to date has a wealth of articles extolling the success of these attributes. We aim, through the 'Making it Happen' theme, to ensure that the other Belbin categories, including the 'implementors' and 'completors', are given equal exposure.

Alan Bealby
General Manager,
Southern Home Counties
BT Worldwide Networks

Nigel Wall and Ian Groves

Communications on the Move

Nigel Wall



Ian Groves

Within 10 years, 50% of all telephone calls will originate or terminate on a mobile handset, according to the predictions of the European RACE mobile project. In the UK, over 3 million cellular telephone users are connected to the six networks run by the four cellular and personal communications network (PCN) operators. The growth rate for connections is running at around 50% per annum, reflecting a trend observed worldwide. Within the UK alone, conservative estimates suggest a market size for cellular of 10 million users by the year 2000. Mobile is big business!

The ability to contact anyone, anywhere and at any time has become a recognised real customer need, as has the means to manage unwelcome calls. As we enter the Information Age, customers will expect to be able to obtain any information, at any time, from wherever they are; and to have information that is relevant to their needs and interests automatically identified and sent to them.

Undoubtedly, mobility is one of the key themes for the future of telecommunications. Competition is well established and certain to increase, supported by an ever increasing rate of technological advance. The increasing diversity of handsets and networks may confuse customers, slowing down the market's development. The choice becomes more difficult as each operator offers a different set of value-added services within its network. A key challenge for BT will be to operate a seamless set of services across the fixed and mobile networks, to make life easier for customers.

In general, the term 'mobility' is taken to imply the use of two key elements: untethered, or cordless access (radio or optical), supported by an intelligent fixed network infrastructure. There are various networks and customer premises equipment (CPE) that support degrees of mobility.

A cellular radio network, such as the new Global System for Mobile Communications (GSM) operated by Cellnet and its competitors, implements both these elements, with a network of radio base stations giving total radio coverage of the desired geographical area. The mobile network's fixed infrastructure must allow service to be provided to the user wherever the handset is, and maintains the service without interruption (even while a call is being made) as the user moves over an extended geographical area, managing the switching of the call between the different radio base stations involved.

By comparison, the cordless telephone implements tetherless operation when attached to the public switched telephone network (PSTN) and operates only while the user is within range of the base station; the PSTN cannot manage the handover of the call from one base station to the next.

Not all customers will need the full capability of a cellular telephone, and the BT Group will continue to develop a set of services that supports the needs of different customers. People's communications needs while 'out and about' are different from when they are permanently at home or in the office. In many cases, mobility on the fixed network (having calls switched through to the nearest telephone) could meet their needs, whereas in other cases, cordless connection within a limited geographical zone (office or home) is what is needed. It is envisaged that fixed and mobile network technology will converge as it evolves towards the third-generation vision of the universal personal communicator.

Beginning on p. 281 of this issue of the *Journal*, are the first two articles in a series on Mobile and Radio Communications. These initial articles relate to GSM. The first gives an overview of GSM from a system operator's viewpoint, indicating the importance of the improved digital service and the ambitions that Cellnet has for delivering a platform on which to build mobile solutions. The second article introduces the GSM architecture, describing the system components and how they interact.

Further articles are planned that will expand on the mobile and radio communications theme. These will include explanations of the technology that is being deployed currently and views of the further evolution of networks, and the services and applications that we might expect to see used over these networks.

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Customer Programme Manager for Mobile
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Nigel Milway and Brian Wright

NAIP—The Realisation of a Network Vision

Since its inception some six years ago, BT's Network Administraion Implementation Programme (NAIP) has changed the way BT manages the administration of its network. The two key aspects of the programme were to establish the network operations units (NOUs) and the network field units (NFUs). This article reviews the NAIP visions and records the achievements of the programme. It also investigates the impact of the wider changes that have taken place within BT and considers the people whose working lives have been affected by the programme.

Introduction

In May 1994, BT's Network Administration Implementation Programme (NAIP) was formally closed, six years after it had begun. For many people in BT, the closure of NAIP meant very little. Like many large programmes of work, the changes and achievements had become part of day-to-day business. The programme had achieved what it had set out to do: to change the way BT administered its network.

From Local to Central Control—Time for Change

Before examining the programme in detail, it is important to understand the environment in which NAIP was created (Figure 1). The year was 1986. The network was expanding rapidly, with digital equipment being introduced into the network at an impressive speed. The network contained Strowger, crossbar, TXE2, TXE4, System X, AXE10 and other exchanges, all controlled and managed differently.

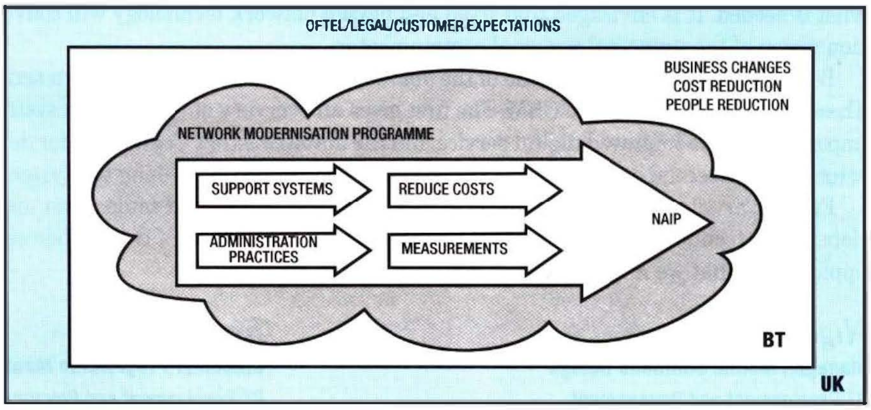
Operations and maintenance for the trunk and local equipment were controlled by separate parts of the company. The digital trunk network had been established and comprised approximately 60 interconnected digital main switching units (DMSUs), administered by Trunk Networks, with its own operations and maintenance, in parallel with Local Communications Services (LCS).

New digital local exchanges were being connected directly to DMSUs and not to the GSCs; thus the network was moving closer and closer to an all-digital, 'hands-free' network. Operating the digital equipment was radically different and it was clear that fewer people would be required.

Generally, maintenance centres tended to work with out-of-date, over-bureaucratic, paper-based systems and a growing multitude of disparate support systems and databases. The centres were fragmented and concentrated on parts of the network and not the whole. There were separate centres for external plant, local exchange equipment, the junction network and the trunk network.

Meanwhile, outside the company, the public were pressing BT to provide better quality of service. The press were hounding the company on what seemed like a daily basis,

Figure 1—The role of NAIP in the changing telecommunications environment



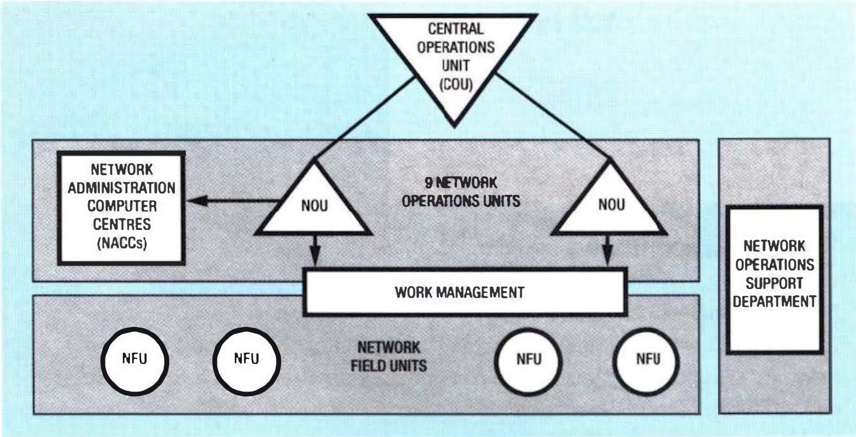


Figure 2—Network administration hierarchy

insisting it improve now it was accountable to shareholders.

Opportunities to reduce costs and improve quality were emerging from the new equipment. The first major digital revelation for network administration was the operations and maintenance centre (OMC). The OMC was developed by BT and it allowed both technical and non-technical people to interact with the systems. Even more important, it allowed remote access and real-time surveillance of the equipment. Better still, it was possible to poll and store information to be analysed at a later time.

Vision

It was from this environment that the need for an administration vision had evolved. The opportunities for reducing administration costs were evident, and, in 1987, a team of

> *the partnership of field and centre was critical to the success of the programme*

senior BT field, centre and Development & Procurement managers combined to form the Network Administration Task Force (NATF). From the very beginning, this partnership of field and centre was critical to the success of the programme.

They began by looking to centralise the operations and maintenance functions but quickly widened their scope to include all administration functions.

The NATF identified their objectives and investigated possible solutions. Primarily, their objectives were:

- to control and manage the network from central locations using shared support systems;
- to reduce costs in the network and improve quality of service;
- to introduce measurement systems into the network; and
- to change administration procedures to enable efficient operations and maintenance.

The output from the task force was a report presented to the BT Board which contained over 100 recommendations for restructuring the network administration.

Strategy

The NATF recommended the development of a hierarchy which comprised the following elements (Figure 2):

- network operations units (NOUs),
- network field units (NFUs),
- network administration computer centres (NACCs),
- Network Operations Support Department (NOSD), and
- the central operations unit (COU).

The Realisation

NAIP was created to implement the recommendations of the NATF report. It was managed by a 'core' team which included people from headquarters and the field.

The programme was delivered in two phases, Platform and Follow-On.

The phases, sometimes referred to as 'sub-programmes', were to deliver the process improvements and standard practices in 'builds'.

NAIP Platform was the term used to describe the first phase of projects which delivered a standalone foundation for the phased introduction of future support systems and processes.

The early builds introduced standard practices for the functions which would be rationalised into the NOU. Once established, these standard practices could be automated by future support systems.

NAIP Follow-On was a dull yet practical title for a number of projects which followed on from the platform projects and delivered support systems to complement the NAIP Platform.

Project management principles were incorporated into the delivery of the programme and many concepts and working practices were introduced; for example,

- programme management,
- steering groups,
- functional working groups (FWGs)
- integrated employee communications,
- union consultation meetings, and
- issue-resolution procedures.

Messages

It was decided at an early stage of the programme that employee communications and consultation would be a major element of NAIP. BT had undergone privatisation, the security of peoples' work was under review and Project Sovereign was about to impact on BT and re-construct the management reporting hierarchy.

The vision explained

Network operations unit
It was envisaged that the NOUs would be the major control centres for the network bringing together people from administration-related functions into one building. Nine NOU sites have been established in the UK.

Major savings would be made from economies of scale by bringing the following functions closer together:

- operations and maintenance units (OMUs),
- regional network management centre,
- digital network alarms (and TXE4 alarms),
- performance management,
- transmission systems monitoring,
- power and building engineering services, and
- work allocation and control.

Note: Analogue alarms were included at the discretion of the individual Zones.

Network field unit (NFU)
The network field unit (which was defined in terms of its geographic boundaries) would comprise a field force—people who could perform network activities which could not be handled remotely from the NOU. The NFU would provide an operational engineering skilled workforce to modernise, extend and support the network.

Network administration computer centres (NACCs)
These computing centres contain the systems necessary to support the NOU functions.

In parallel with NAIP, a NACC rationalisation was underway to reduce the NACCs to 10. As a result of NAIP requirements for the geographical positioning of the NOUs, some NACC realignment with the Zones was necessary.

Network Operations Support Department (NOSD)
This central (HQ) management unit would provide the policies and manage the development of the support systems and processes.

Central operations unit (COU)
The COU, based at Oswestry, would monitor all of the processor-controlled trunk exchanges and local units. It would give a national picture for traffic management and allow control of network re-routing to relieve congestion.

The COU was not part of the NAIP deliverables but had a major role in the NATF vision. The COU was delivered under the management of another programme and was brought into service before the first NOU had officially opened.

It was clear that the project would not succeed without managing the level of commitment of the people involved or affected. This 'management of commitment' was addressed in two ways.

Firstly, NAIP had dedicated support for employee communications. Articles appeared in *Connect* and *Connect Plus* (BT Worldwide Networks publications) and a forerunner publication, *The Networker*. The programme also provided a newsletter, *NAIP National News*, which delivered updates to key NAIP personnel.

Secondly, people issues from the field were managed centrally, and responses were provided through the various channels available. The unions were also consulted regularly using the Joint Network Engineering Forum (JNEF) made up of representatives from the NCU and STE.

Control

From the 12 NOUs proposed for the UK network, nine were realised at the following locations:

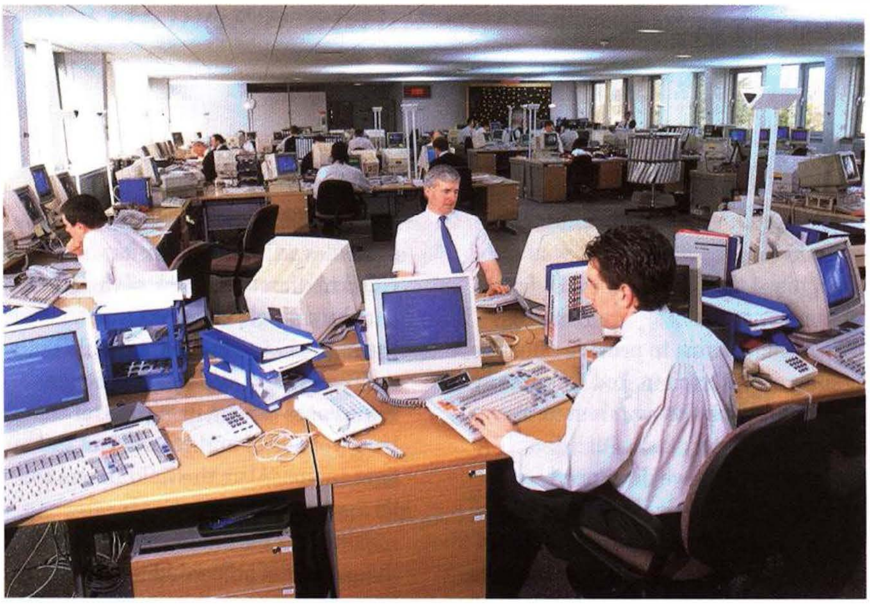
Belfast	Bristol	Cambridge
Edinburgh	Leeds	London
Manchester	Walsall	Worthing

The implementation of the NOUs was the most visible part of the programme. Walsall and Manchester were the two pilot sites for the network operations unit.

The NOUs were declared open when the first build was achieved. It was not recognised as fully operational until all the defined controls were relocated into the building. Each NOU had a migration plan which was used to control this activity.

To appreciate the scale of activity, London NOU, based in Columbo House, involved considerable refurbishment and the installation of 175 workstations with flexible data and voice communications for 41 standalone networked applications.

The functions which were rationalised into the NOU as part of Platform are explained in detail below:



Edinburgh NOU

Network surveillance
Real-time information is supplied to the 'corrals', which are workstations positioned in a C-shape. Alarm information, from the network operations management systems (NOMS1), for example, is used to direct reactive and proactive action quickly to minimise disruption to the network. The alarms, displayed on NOMS1 terminals, are received from the field via Gateway REM+ and the alarm handling system (AHS).

Outage management
When transmission systems fail, it is possible to re-route customers to an alternative route automatically by using the UK stand-by transmission network. The NOU can manage the restoration of the cable or radio system and minimise disruption to the customers, sometimes before they are aware that a problem exists.

Planned works
With over 3 million PSTN customers in a catchment area and over 2 million kilometres of optical fibre in the network, it is inevitable that a significant amount of work has to be completed to continue modernising and enhancing facilities. The NOUs programme this activity ensuring that any risk to the network is minimised.

Network support group
This second level of support has direct links to BT development engineers and suppliers and is available at all times to provide technical support for enhancements, network problems and queries.

Performance management
An abundance of real- and elapsed-time information is available from modern digital equipment. The NOUs collect, analyse and report this data to produce statistics and correlate the information and perform 'trend' or 'black-spot' analysis on the data. The analysis can be used to identify difficulties in the network before equipment fails.

Network integrity
BT's network has extensive security protection to prevent corruption of information either by accident or design. Particular attention is given to all aspects of customer metering and billing.

Project Sovereign

NAIP and Project Sovereign were to some extent, dependent on each other to succeed fully. NAIP not only survived the largest reorganisation of a British company to date, it furthered its implementation by facilitating the creation of the Sovereign 'template'. Sovereign built on the geographic boundaries defined by the NOUs, aligning a management structure to the catchment areas. In a relatively short time, Districts and Regions disappeared and were replaced by nine Zones with one Zone operational manager in each (with the responsibility for their NOU/NFUs in their catchment). In some cases, this realignment facilitated the completion of the NOUs and the realisation of the original business cases.

Network Field Teams

NAIP altered the role of the network field teams significantly. Before NAIP,

Some of the key events in the delivery of NAIP are shown below.

- Walsall Pilot NOU opened October 1988.
- Manchester Pilot NOU opened in advance of national roll-out in March 1989.
- Edinburgh NOU opened 19 November 1990.
- BT Board gives full approval for NAIP Platform in November 1989 and Follow-On, November 1990.
- Leeds NOU opened 29 April 1991.
- Bristol NOU opened with core functions in April 1991 and opened as operational on 17 June in the same year.
- Cambridge NOU opened 17 August 1991.
- Belfast NOU opened January 1992.
- BT Chairman, Sir Iain Vallance, visits Manchester NOU, 20 February 1992.
- Worthing NOU opened March 1992.
- London NOU opened on 30 October 1992 with all appropriate functions migrated by 14 December 1992.
- Programme closed, May 1994.

Footnote: NOUs opened at Build 1.1

field managers and their teams provided a maintenance and support service and delivery of provision and works to a network plan.

Modern equipment brought with it a promise of lower maintenance and, therefore, repair operations would decrease. If the work allocation process was automated, the two spheres of field management could be administered together.

As mentioned earlier, procedures for new equipment were evolving and managed differently across the organisation. It was recognised that the work performed by the field teams was of a very high standard and necessary for the continuing evolution of the network. It was also recognised that it was difficult for managers to monitor, prioritise or direct their teams to provide effective resource. Work originated from many directions with the usual immediacy attached to every task. Also, team members may have developed experience in particular pieces of equipment where others had not and were not as efficient. If the experience was not linked to a training plan it may not even be recorded.

NOMS2, the support tool, was the solution designed to automate the process of getting the right person to the right place at the right time. The system was designed for use by the NOU to direct the work of the NFU people, a single source of work, with the skill-sets of the NFU people built in. The system allows visibility, in some cases for the first time, of the true work-load and capacity of the field teams. Also, the field teams can be applied more effectively after considering the 'network-view' of all the problems presented to the NOU from the support systems.

The introduction of NOMS2 was the first major step taken toward centrally automated work-force management across the Zones. This has since been developed and expanded into what is now known as the *Work Manager*.

Before allocating tasks, the work-force management systems take into account many factors which include:

- Peoples' skill-lists—are they trained to perform the task?
- Peoples' mobility and ability to enter the building—have they got transport? have they got the key?
- Peoples' whereabouts.
- The priority of the task—is the task linked to a service level agreement? Could it be done at a later or earlier date? Is there a network problem causing the local fault report?

Below, a few key network events have been highlighted to show how the network evolved in complexity, for the 30 years prior to NAIP.

- In 1956, there were 4 million exchange connections in the UK, with 5 million telephones. 23% of those telephones were connected to manual exchanges. The main network comprised 26 fully interconnected 'zone-centres' and about 250 'group-centres'.
- In 1958, Her Majesty the Queen dialled the inaugural subscriber trunk dialled (STD) call from Bristol to Edinburgh and the UK network entered a 21 year era, reaching full automation in 1979.
- The STD scheme was limited by the existing network which consisted of 2-wire switched Strowger systems connected to parent group switching centres (GSCs). A separate transit network was then established consisting of nine main switching centres (MSCs) and 28 district switching centres (DSCs), collectively known as *transit switching centres* (TSC).
- In 1967, the UK Trunk Task Force (UKTTF) studied the problems of the network and produced long-term proposals for its modernisation. The recommendations were for an integrated digital network using CCITT terminology.
- Similarly, the local exchanges were investigated leading to a policy of complete replacement of Strowger local exchanges by the 1990s.
- Meanwhile, in the mid-1970s, sector switching centres were added to relieve the expanding network.
- Viable digital switching and transmission equipment emerged in the 1970s bringing step improvements in functionality, quality of service, surveillance capability and maintenance costs.
- In 1985, the first System X exchanges with operations and maintenance centres (OMCs) were brought into service.
- In 1986, the OMC was quickly extended to AXE10 exchanges.

The NFU provides the operational engineering skilled workforce to modernise, extend and support the network

NAIP was a major enabler for BT to compete successfully in the present market environment

Removing the responsibility for the allocation of tasks allows the role of the field manager to become one of coach, trainer, monitor and above all, leader. It is an important change of management style since the field manager concentrates on people-effectiveness in terms of cost and quality.

Also, the skill-sets of the team can be managed and developed to meet the changing needs of the network within the NFU boundary. The NFU people perform a major role in improving the processes and recommending improvements to existing practices.

Other business strategies have also impacted on the field unit and the continuing people reduction has added momentum to the drive for efficiency. Many technicians now work within larger boundaries, fewer resources and a lot less contact with other team members.

Future

To push the network further and gain quality of service levels, previously thought impossible, will require process re-engineering. It is evident that the network administration must move toward proactive operations and maintenance. The information which is currently used to report failures and disruption will be used to direct resource to preventative action, so that problems can be eliminated before they impact on service.

New technologies, which are emerging now, will bring the price of wide-band services far below the current rates, challenging further the current administration costs.

Conclusion

NAIP established a foundation for future improvement. The original functions rationalised into the NOU have been there for some time now and are still improving with the help of the support systems considered in the NAIP vision. It can be seen that NAIP was a major enabler for BT to compete successfully in the present market environment. NAIP also demonstrated the power of partnership between Worldwide Networks, centre, field and Development & Procurement teams.

Acknowledgements

Although this article has highlighted many of the NAIP achievements it would not be complete without recognising the effort it took to deliver the programme.

The authors would like to thank Dick Silk and Liam Kelly for their help in producing this article.

This article is dedicated to all the people who helped to convert the NAIP vision into a reality.

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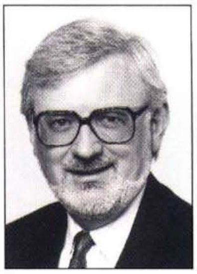


Nigel Milway
BT Worldwide Networks

Nigel Milway joined BT directly from university, where he studied applied physics, to work on the emerging System X programme. After that he became heavily involved with the modernisation of the switch network and with the restructuring of network operations. He led the Network Administration Task Force in the late-1980s and, following that, the implementation of its recommendations through extensive process re-engineering and the deployment of advanced integrated computer support systems. He now heads the Network Design and Service Launch Department in BT Worldwide Networks and has responsibility for the engineering design and acquisition of network technologies covering access, core, overlay, intelligence and broadband.

Brian Wright

Brian Wright graduated from Aston University with a degree in Electrical and Electronic Engineering. Before leaving BT, he worked for Operational Policy and Systems (OPS), part of Performance, Policy and Planning (PPP). He began his career in the System X Product Support Group in London and, after Sovereign, managed NAIP employee communications before moving on to deliver employee events and communications for the department. Brian was a former member of the Board of Editors of *British Telecommunications Engineering*.

Colin Tuerena, Peter Mabey and Neil Barnes

Phone-ins: Their Impact and Management

This article describes the impact of phone-ins on the BT network and how such events are managed. It describes the development of phone-ins in recent times and the techniques to manage them. The article also discusses the potential of phone-ins as products and looks at some possible future developments.

Introduction

Modern telephone networks are dimensioned to operate efficiently and provide a good quality of service at or below normal peak traffic levels. Under 'normal' traffic conditions, calls will be originating and terminating throughout the network with no particular concentration of calls other than would be expected with normal calling patterns. Under such circumstances, customer behaviour can be modelled using suitable statistical and simulation techniques, and the allocation of switching and transmission resources necessary to maintain an adequate quality of service can be predicted.

Unfortunately, customer behaviour and other prevailing conditions are often unpredictable, and conditions often arise where the network is exposed to excessive calling demand. Excessive loads can be caused by factors internal to the network, such as element failure, or can be caused by factors external to the network such as social, business or political events which result in unusual patterns or volumes of traffic. The network has a certain amount of inbuilt resilience to deal with heavy loads provided that the traffic is distributed widely; however, if the extra demand is due to customers trying to access an individual telephone number, or group of numbers, congestion is focused on one particular part of the network. This situation is known as a *focused overload*, or *phone-in*, and its control is one of the major activities of network management.

Phone-ins have occurred ever since the introduction of telephone networks. However, it is the introduction of modern digital technology and the massive increase in the use of phone-ins by the media that have caused them to be a significant concern to network management. Since unrestricted access to the telephone network is available to the vast majority of customers, calling rates in excess of normally expected loads can build up rapidly, so when a totally unexpected event occurs, severe network problems may result. In the absence of action to control such abnormal loads, severe network disruption may arise.

This article describes the impact of phone-ins on the BT network today and how such events are managed.

Some Early Phone-Ins

One of the earliest phone-ins which had a major impact on the network was that caused by the BBC TV programme 'Noel Edmond's Multicoloured Swap Shop' which was broadcast from 1976 to 1982. The effect of the programme was to cause massive congestion in the then analogue network which disrupted much of the service for several hours on Saturday mornings. The problem was overcome by introducing Television and Radio Audience Participation Programme (TRAPP) routes from each of the group switching centres (GSCs) around the country. These were limited routes of two or three circuits to which special codes used for phone-ins were diverted. This had the effect of allowing only a limited number of calls through to the phone-in while other calls had access to the full capacity of the trunk routes. This was the first form of restrictive network management in the STD network.

Figure 2—The BT worldwide network management centre

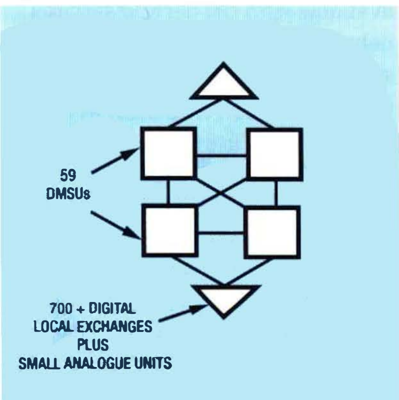
The introduction of the analogue derived services network (ADSN), particularly with the introduction of premium rate services, led to an increase in phone-ins. Service providers saw opportunities to use the 0898 service in novel ways to generate revenue with some leading to excessive demands on the ADSN. As a result the derived services network route access control facility (DRACF) was introduced to control traffic. Dedicated phone-in number ranges (0898 99) were established which were only allowed access to a limited route, in a similar manner to TRAPP control.

These two methods, TRAPP and DRACF, were the primary means of controlling phone-ins in the mid–1980s. This was adequate with the analogue network and the limited number of services then offered by BT. However, this period coincided with the introduction of the digital network which required a totally different approach to network management.

Phone-Ins and Modern Networks

The core BT network has been fully digital since 1990 and comprises 59 fully interconnected digital main switching units (DMSUs). Most of BT's customers now have their lines connected to digital local exchanges (DLEs). There are over 700 DLEs, each of which is connected to at least two DMSUs. Remaining customers are still connected to analogue exchanges which connect to the digital network. A diagrammatic representation of the BT network is shown in Figure 1.

Figure 1—The BT network



Modern digital networks provide the platform for delivering the products and services required in the fast-moving telecommunications market-place. However, they are vulnerable to traffic overloads. The characteristics of a phone-in are for a surge in call attempts to the target telephone number(s) with very few of the calls reaching the destination due to congestion. With 700 DLEs passing call attempts in to 59 DMSUs and all destined for a single local exchange the situation can soon lead to processing overload and, if unchecked, lead to unit failure.

The situation can be saved by controlling the number of call attempts that are passed across the network by limiting them to a level which will keep the target lines busy, but will not cause overload of network elements. The principle of managing phone-ins is to apply such controls as close as possible to the source of the calls and so minimise the affect on the network. This is the role of network traffic management (NTM).

NTM is part of the role of the worldwide network management centre (WNMC) at Oswestry in Shropshire (Figure 2). The aim of NTM is to ensure that, at all times, the network is carrying the maximum number of effective calls. This requires complete visibility of the performance of the network and, with regard to phone-ins, also requires the ability to remove ineffective calls from the network in order to allow other calls to succeed.

The WNMC has at its disposal a number of tools to manage phone-ins. The primary tool is the network traffic management system (NTMS), which has been described in a previous *Journal* article[1]. NTMS provides network managers with a view of network performance in close to real time.

The second tool in the armoury of the network manager in dealing with phone-ins is the protective network management control called *call gapping*. It is applied either to all calls on a route (*route* call gapping) or to calls to a particular digit string (*destination* call gapping). The effect of call gapping is to block calls attempting to seize a route by allowing through only one call in *t* seconds, where *t* is a variable set according to the capacity of the called customer to answer calls.

Call gapping is currently applied to System X and AXE10 exchanges by using the operations and maintenance control system (OMC) by the NMC, or by network operations units (NOUs) in response to instructions issued by the NMC (Figure 3). The next release of NTMS will have the capability to broadcast call gapping controls, via the OMC, to any number of digital exchanges.

Call gapping is a very effective protective control; however, while it is crucial to protect the network from overload, it is also important to take care not to over-control and restrict calls unnecessarily.

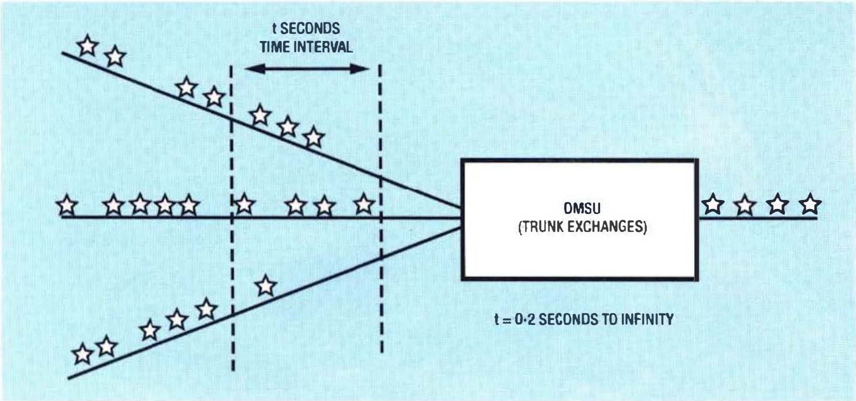


Figure 3—Call gapping

The third tool in the network manager's armoury is a measurement called *NM3* which is used for destination number analysis. This measurement is used to analyse particular number strings which are receiving large numbers of calls and thus can be used to identify numbers that are the target of a focused overload.

One of the significant phone-ins from the early days of the digital network which has become part of the folklore of NTM was the impact of Tina Turner in July 1990. An advertisement in a national newspaper promised free tickets for a Tina Turner concert to fans who bought a bottle of cola, slotted two digits from its barcode into gaps in a Bristol phone number, and rang the number at a certain time. The result was a surge in calls to Bristol, more than 100 000 calls in 15 minutes, with little more than 50 getting through to the destination. The company running the phone-in had only 10 lines to answer calls and so were quite happy—but the network was not. The Bristol local exchange and both of its 'parent' DMSUs (Bristol and Gloucester) began to overload. The situation was restored by the application of call gapping at all DMSUs which reduced the load on the destination local exchange and parent DMSUs to a level which prevented overload yet allowed sufficient calls to mature to satisfy the needs of the promotion.

This example shows how prompt network management can control unexpected phone-ins. However, if the NMC had been forewarned of the event, controls could have been applied in advance and there would have been no disruption at all. This emphasises the crucial point that the best form of network management is preventative network management.

Types of Phone-Ins

All phone-ins are triggered by the publication of a number, or numbers, in the media. The main reasons for publication of such numbers are as follows:

Civil emergencies

Whenever there is a civil emergency leading to major injuries and loss of life, a number of enquiry lines are manned by the police to deal with anxious relatives. The publication of such numbers on TV and radio can cause major focused overloads. This is what happened following disasters such as the Lockerbie aeroplane crash and the Sheffield football disaster. Under such circumstances, it is particularly important for protective network controls to be applied so that other calls, especially those of the emergency services dealing with the incident, are not disrupted.

Entertainment phone-ins

The last five years have seen a dramatic increase in the use of phone-ins by the entertainment industry. It is now a daily occurrence for TV and radio shows to hold televotes and phone-in competitions. As stated above, Noel Edmonds was among the first to affect the UK telephone network with the 'Swap Shop' and he's still doing it today with his 'Houseparty' which causes huge demands on Saturday evenings.

Information lines

Telephone information lines are now an everyday part of modern life ranging from weather forecasts and stock market movements through to horoscopes. The majority of such services do not generate enough traffic to cause focused overloads; however, a few do catch the public's imagination and may lead to network problems.

Direct response TV

Telephone numbers published in TV advertisements can cause network overloads. An example of this was when Ford first advertised their new car the 'Probe' during the break in the 'News at Ten'. The information line advertised was an 0800 number which was translated by the network into the destination number which was hosted on an exchange in Guildford. The response was such that more than 18,000 calls were generated in 5 minutes to a customer that had only 30 lines.

Charity phone-ins

Programmes such as 'Comic Relief' and 'Children in Need' have become national institutions. Such events require a large number of answering locations and numbers with the emphasis on answering as large a number of calls as possible over a period of several hours. The use of many different numbers spread across the country presents a major logistical problem to network management. Network controls have to be applied for all the numbers used and the traffic flows carefully monitored. The ideal solution to this problem is to use a single national number which can be delivered to local answering points around the country. The technology to do this is now available with the derived services network (see below) and was used successfully for the first time for Children in Need 1994.

Terminating Phone-In Calls

Various methods for terminating calls are available to phone-in promoters. The simplest method is to use a basic public switched network (PSN) number and provide a group of lines to answer calls. This is the method

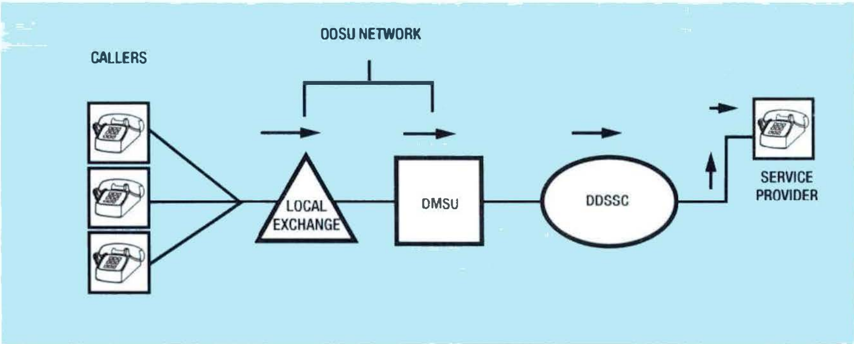


Figure 4—Digital derived services network

that has been used for all early phone-ins and remains the method of choice for many.

For other promoters, basic PSN does not provide the facilities required. The introduction of the derived services network (DSN) introduced a number of value-added services which opened up a range of potential opportunities for phone-in promoters. The DSN was originally provided as an analogue overlay network in the mid-1980s. This soon became unable to deal with the demands made upon it and a digital DSN (DDSN) consisting of a fully interconnected network of nine AT&T 5ESS exchanges was provided in 1988 (Figure 4).

The DDSN provides several facilities which are used for terminating phone-ins as follows:

Service provider bureaux

The service provider bureaux (SPB) are independent companies who are contracted to manage phone-in events on behalf of the various media companies. They provide three basic services:

- answering of calls by a human operator to record the callers' details;
- answering of calls using interactive voice service equipment to record the callers' details; and
- counting the number of calls to a particular vote line.

Most bureaux are equipped with sophisticated call answering equipment capable of handling large volumes of calls. This, in turn, necessitates the provision of a large number of lines by BT between the SPB and one or more of the digital derived services switching centres (DDSSCs). Many bureaux have several hundred or even thousands of lines.

DSN RIDE

Service provider bureaux allow very great flexibility in the range of services that are available, but cannot provide the answering capacity required for some applications. The DSN recorded information distribution equipment[2] (RIDE) is a system for providing economic mass access to recorded announcements and provides much greater answering capacity than offered by any bureau (Figure 5). RIDE consists of a network of specialised switches installed at the DDSSC sites. Each is connected to the national announcement centre (NAC) at Oswestry enabling the NAC to feed announcements to each RIDE switch. Calls to the announcements access their local RIDE switch via the DSN. RIDE provides answering capacity of more than 6000 lines which represents a capacity far greater than on offer from any of BT's competitors and has the added advantage that calls do not transit the DSN thus reducing congestion in that network.

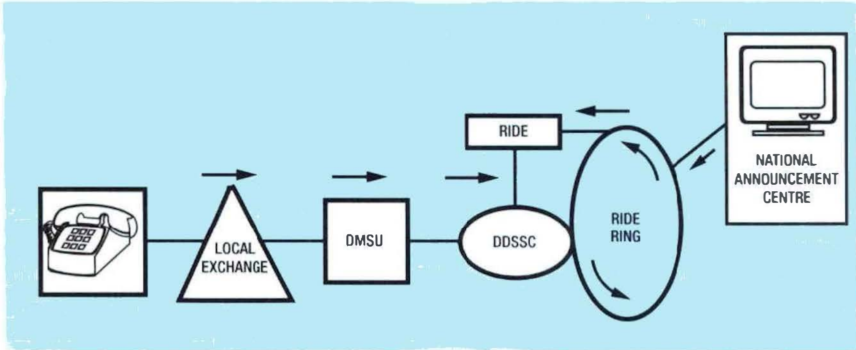


Figure 5—Enhanced Callstream network

DSN Intelligent Network

In conventional digital networks the call processing logic is distributed across all the network switching elements. Intelligent network technology allows much of the call processing logic to be controlled from central databases thus enabling much faster delivery of services. The DSN intelligent network is the first use of IN technology by BT and provides a range of facilities[3]. One of these facilities is the ability to route calls by calling line identity (CLI) so that calls can be delivered to a local answering point. This is used to good effect by motoring organisations and has recently been used for a major phone-in—'Children in Need'. For this event, a single national number was used with calls being delivered to 62 answering locations around the country.

Phone-Ins as Products

Phone-ins are a growing phenomenon. Hardly a day passes when there are not several dozen phone-ins which, if not managed, would cause network overload. TV producers are finding phone-ins an essential component of their programmes and, working together with service providers, they are looking for novel ways of using them. The Callstream products, with 0891 being the most significant, are used to the greatest extent as they provide a valuable source of revenue which helps to fund programme production. Phone-in competition lines have been most popular as they generate longer holding times and hence greater revenue. Televotes make good TV, but generate far less revenue as the calls are generally held for less than ten seconds.

During 1995, a new development is planned that offers the potential to improve televote revenues by situating the RIDE at DMSU level. This service will provide the capacity to terminate more than 10 000 simultaneous calls.

One important aspect of the service BT offers to customers is the call statistics package. This provides customers with 'near real time' call statistics for their particular phone-in. The information is updated every minute and can be used to inform viewers of the televote performance, allowing the programme makers to 'manage' the televote during the broadcast.

Customer Behaviour

Managing phone-ins effectively relies upon understanding how customers will respond to media promotions. Phone-ins by their very nature result in massive calling levels in very short periods of time, but the way the customer reacts to the event advertised is sometimes very difficult to predict. Network managers need to be able to predict customer behaviour if the audience response is to be estimated and network controls are to be set at the appropriate level.

The factors affecting the potential size of a phone-in are:

- The size of the audience—this depends upon the medium (TV, radio, press), the channel and the time.
- The make-up of the audience—young audiences are more likely to use the phone and 'participate' in TV shows.
- The 'prize' on offer—phone-ins that offer a car to the twentieth caller receive a massive and immediate response that tails off quite quickly. Other, less valuable prizes, can also generate large responses; for example, obtaining information leaflets about TV programmes.
- The level of audience involvement—televotes in particular are used by TV producers to involve the audience. The responses to votes for 'Song for Europe' and 'The British Comedy Awards' have produced two of the largest televotes ever seen.

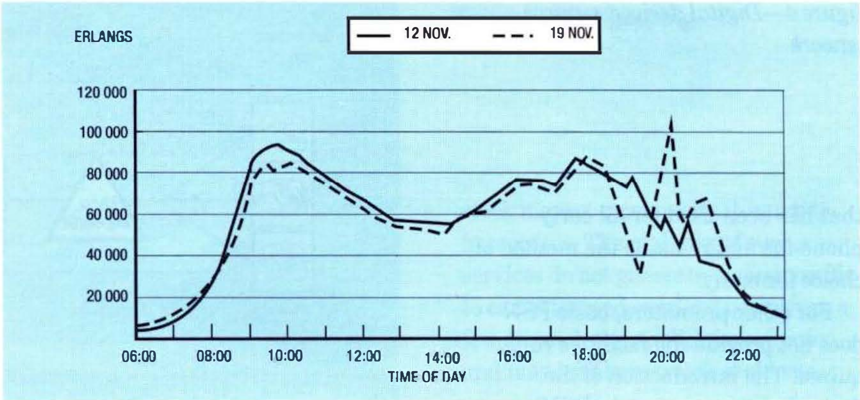


Figure 6—Effects of the first national lottery; inter DMSU traffic

The situation becomes more complex because most customers do not get an answer at the first attempt. Having made the decision to call, most customers will make several repeat attempts to get through. If the phone-in is over a long period, the build up of repeat attempts increases the load on the network.

The impact that TV can have on customer behaviour is shown quite graphically by the impact of the first national lottery draw (Figure 6). The network traffic profile for 19 November (date of the first lottery draw) is shown compared with the previous Saturday. The network was very quiet during the programme, but traffic levels surged immediately after the draw was made.

Media Liaison

Effective network management depends upon good systems to monitor and manage the network and highly skilled people to use these tools. In addition, it is essential that network managers have as much forewarning of major events, particularly phone-ins. This requires that effective communications links are maintained between the NMC, the product lines and the customer.

A set of guidelines on how to run phone-ins has been given to service providers. The guidelines set out the information that BT requires from the service provider, which is as follows:

- full details of the type of event (competition, televote, charity pledge line, etc.),
- date/time and duration of the event,
- an estimate of the audience size,
- estimated response rate,
- the number of lines available to answer calls,
- the advertising medium,
- when the numbers will be advertised,
- the telephone number(s) to be used,
- expected call duration (generally about 10 seconds for a televote and a minute or more for a competition call), and
- the region(s) covered by the event.

This information is passed via the service management centre to the NMC where it is used to calculate whether network controls are required and, if so, what level of control needs to be applied and at what points in the network.

This process works effectively for most phone-ins, but for some a much closer liaison with the customer is required. Customers have increasing expectations of BT's network and it is necessary to work closely with them to achieve the best results for both parties. The media liaison function has been established at the NMC to work with the customer and product lines to ensure the best use of the network to manage phone-in events. The role of media liaison is:

- to liaise with media companies including TV, radio and service providers,
- to liaise with BT product lines and Corporate Relations, and
- to prepare plans for phone-ins and to ensure their timely implementation.

An effective working relationship between the customer, the product lines and the NMC is very effective insurance against major network failure.

Some Examples of Major Phone-Ins

Atlantic 252

On 20 October 1992, the Irish radio station Atlantic 252 ran a phone-in where they promised that the 20th caller would win a car with £4000 in the glove compartment. The competition went ahead without the knowledge of the NMC and the result was a massive surge in traffic to Dublin from the North and West of England which led to severe problems at the gateway units in Dublin, and major congestion at the BT gateway DMSUs. The situation was controlled by the NMC by the application of appropriate call gapping controls.

In the days following this event, the NMC made contact with Atlantic 252 who were unaware of the affect that their phone-in had had on the UK network. They followed up with further phone-ins, but ensured that the NMC had advance warning. They have since changed the format of their promotions and use an 0891 number and so cover some of the costs of the prizes.

The Health Programme

On 26 April 1992, the BBC ran a programme hosted by Terry Wogan on the benefits of healthy living. The programme ran for several hours and viewers were told that they could obtain an information leaflet by calling an 0800 number. The response was totally unexpected and quite unprecedented with an estimated 22 million call attempts made in the first hour of the programme. Despite the fact that call gapping controls had been applied in advance of the event, there were several overloads on DSN exchanges and further intervention was required from the NMC to control the situation. This event shows how unpredictable public response to a phone-in can be.

Stars in their Eyes

The final of the TV talent show 'Stars in their Eyes' in July 1994 had the greatest response ever seen to a phone-in in the UK. The format of the show was for nine people to sing a famous song—the performers were not professionals. The audience for the programme was the second highest of the week only surpassed by the World Cup final (which only had 200 000 more viewers) and viewers were asked to vote for their favourite act over a 25 minute period. On a normal Saturday evening, the network handles about 1·5 million call attempts over a 25 minute period—on 16 July there were in excess of 30 million call attempts during the 'Stars in their Eyes' voting window. This level of calls is such that if unrestrained it would lead to overloads at most DMSUs and has the potential to take the whole inter-DMSU network off the air. Fortunately, call gapping had been applied to all digital exchanges with the result that there were no significant problems at any digital exchange.

Possible Future Developments

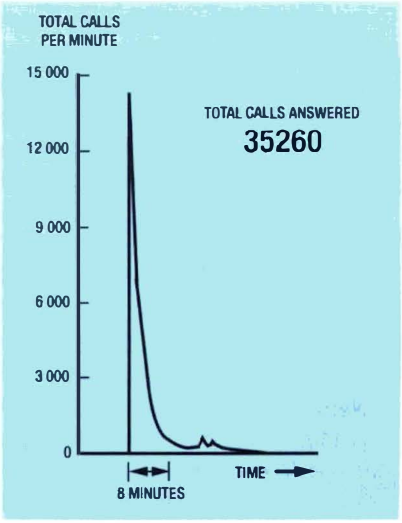
DMSU RIDE

Phone-ins cause problems because they focus calls from across the network onto a small number of elements. Network management allows control of phone-ins by limiting the number of calls that cross the network. A better solution is to use dispersed answering equipment to terminate the calls locally. DSN RIDE is one step towards this, but in the future extra capacity may be made available for phone-ins on DMSU RIDE. This system is very similar in principle to DSN RIDE and routes calls to announcement equipment at each DMSU. DMSU RIDE is currently used to terminate Timeline calls and announcements for the national code change. The capacity available is much greater than DSN RIDE (in excess of 10 000 circuits) and has great potential for meeting customers' requirements for bigger and better televotes and tremendous revenue earning potential. This potential is shown by the graph which shows the calls-answered profile for a trial televote held on 25 November 1994 as part of the 'Children in Need' programme (Figure 7). Calls were made to this phone-in using the 0894 number range.

Automatic call restriction

Management of phone-ins today depends upon application of controls by the network management centre

Figure 7—Children in Need; 'Do the Right Thing' Phonepoll—25 Nov. 94



either in advance of the event or in response to an unexpected focused overload. The controls applied tend to be applied at the same level at all units and there is very little scope for adjustment according to prevailing conditions. A possible future improvement on this is to distribute intelligence across all digital switches through the use of automatic call restriction. BT Laboratories at Martlesham Heath have developed and patented an algorithm; if installed in digital exchanges it would automatically detect the telephone numbers which are the targets for focused overloads and apply appropriate call restrictions. The algorithm allows for the automatic adjustment of the restriction levels in response to rises and falls in the calling rate. Whether this scheme, or something similar, is eventually implemented is dependent upon its adoption by switch manufacturers.

Acknowledgements

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Biographies

Colin Tuerena
BT Worldwide Networks

Colin Tuerena is presently head of the Network Traffic Management Team based at the Central Operations Unit at Oswestry in Shropshire.

He joined BT International in 1983 as a direct entrant level 1 and two years later moved to Oswestry where he has been involved in a number of areas related to network management, routing control and capacity management. He took on his present role in October 1992. He has a degree in Biochemistry from Oxford University and a Ph.D from Nottingham University.

Peter Mabey
BT Worldwide Networks

Pete Mabey started his career with the GPO in Manchester in October 1970 as an apprentice. He moved to Oswestry in 1987 to work on the DSEA project where he was promoted to MPG2 in 1990. In February 1994 he joined the NTM team as Media Liaison Manager.

Neil Barnes
BT National Business Communications

Neil Barnes joined BT's Private Circuit Allocation duty at Stanmore in 1983. After a spell in Group Finance, he joined the private circuit product line in 1988. In 1989 he moved to the PSTN product line where he developed and implemented the spread connection charges, free sameday takeover of exchange lines and restructured BT's policy on credit management. In 1992, he joined the Telemarketing Services product line with responsibility for Quality of Service and Costs, managing a cross-divisional team, developing and implementing 'best of breed' quality of service for the telemarketing portfolio of services.

Glossary

ADSN Analogue derived services network.
CLI Calling line identity.
DDSN Digital derived services network.
DDSSC Digital derived services switching centre.
DLE Digital local exchange.
DMSU Digital main switching unit.
DRACF Derived services network route access control facility.
DSN Derived services network.
GSC Group switching centre.
IN Intelligent network.
NMC Network management centre.
NOU Network operations unit.
NTM Network traffic management.
NTMS Network traffic management system.
OMC Operations and maintenance control.
RIDE Recorded information distribution equipment.
SPB Service provider bureau.
TRAPP Television and radio audience participation programme.
WNMC Worldwide network management centre.

Ken Hall

Global System for Mobile Communications

A Foundation for Successful Competition, Consumerisation and Convergence

For Europe-wide and worldwide success, new telecommunications system standards must be developed by bringing together the industry's best technical expertise, and the operational and commercial skills and knowledge of the network operators. This article outlines how this has been achieved for the Global System for Mobile Communications (GSM), and how GSM now forms a key element for the converging mobile and fixed networks.

Introduction

The Global System for Mobile Communications (GSM) is an outstanding telecommunications success story. From its early start in 1982, GSM has grown into a worldwide standard, adopted by some 102 operators in 60 countries. The last five years have been characterised by the rapid conclusion of trials, ever increasing international GSM coverage and a growth to around 4 million customers worldwide at the end of October 1994. The criticisms of a few years ago that GSM was over-engineered, too complex and too expensive for the mass market are no longer heard. The industry experts who championed and worked determinedly over many years to make GSM a reality can now see the results with some pride.

This article shows how GSM was, and continues to be, set up for success. It also discusses some of the challenges to be faced by operators over the next five years, and concludes with some likely trends.

The Early Years

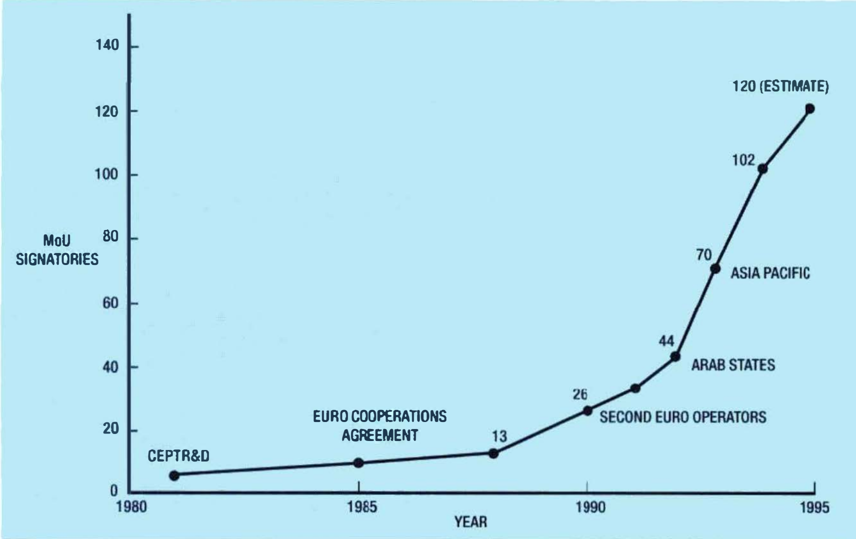
In the pre-cellular years of the late-1970s the vision of a world of wire-free communications was but a gleam in the eye of a few. The pre-cellular years were associated with many trials of radio technology, some of which led to the analogue cellular systems of today. These systems have been very successful with close to 50 million customers worldwide in October 1994. Approximately 45% of these cellular customers are in the USA and 24% in Europe.

However, the thoughts on how to get more from the limited spectrum available were largely a digital vision shared by only a few. In 1982, the CEPT (European Conference of Postal and Telecommunications Administrations) vision for such a digital system began to be addressed by some leading operators, who wanted to exploit the advances available through microelectronics and seek more efficient usage of the spectrum to provide radio-based services for a more significant market.

By 1987, European regulatory backing led to the common allocation of spectrum across all EU member states, a policy of mutual recognition of cellular terminals, and a harmonised framework of milestones leading to a memorandum of understanding (MoU) between network operators and their governments (or regulators).

Critical to the success of GSM has been the bringing together of the commercial and operational requirements of network operators to support the preparation of technical standards in CEPT and later in ETSI (European Telecommunications Standards Institute). The formation of the GSM-MoU and its working groups provided a key driver and focus for the standard. Cellnet, BT's subsidiary, has taken a significant role in this work and Mike Short, a Director of Cellnet, is presently the Chairman Elect of the MoU for 1995/96.

Figure 1—GSM time line



Launching GSM

As the worldwide potential for GSM was recognised, and commitment made by operators, the standard was renamed *Global System for Mobile Communications*. The GSM time line for MoU signatories in Figure 1 clearly shows the growth of this commitment with the estimated number of signatories at 120 by the end of 1995. It is expected that roaming agreements will be agreed and fully working between Cellnet and 34 other operators by January 1995, with another six agreements foreseen by mid-1995.

The open architecture of GSM, the large potential market with consequent economies of scale, and confidence in the robustness of the technical standard has led to this widespread acceptance.

Within Europe, GSM was seen as the first basis for cellular operator competition and the pioneering activities of the UK were soon being emulated in other countries. The advantages of GSM as the base technology for personal communications networks (PCN) and personal communications services (PCS) were soon seen in Europe with its adaptation leading to 1800/1900 MHz services in the UK, Germany, France and the USA.

The worldwide mix of operators in the MoU group as at October 1994 can be seen in Table 1. The GSM worldwide base of customers includes PCN and customers outside Western Europe, and is believed to have exceeded 4 million at the end of October 1994. The forecasts worldwide typically identify 5 million customers by the end of 1995 and at least 8 million customers by the end of 1996.

Table 1 GSM—Distribution Based on MoU, July 1994

	Signatories	Countries
Europe	50	28
Arab States	10	9
Asia-Pacific	24	17
Africa	6	4
Totals	90	58

Living with GSM

The design of GSM is better than previous cellular systems in many ways to the benefit of customers and operators.

SIM card and mobile equipment

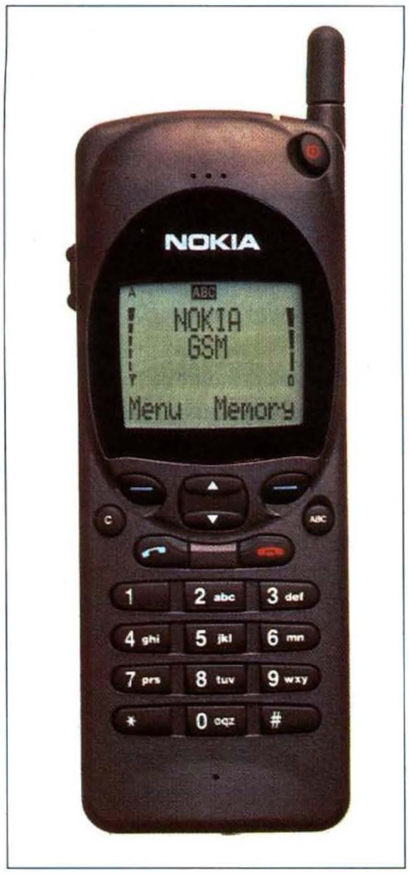
The SIM or subscriber identity module is a smart card which plugs into a GSM cellphone and uniquely identifies the customer to the network. This enables customers to use any public or private GSM cellphone at home or abroad. The SIM stores security information for authenticating and producing individual cypher keys to encrypt every call. The SIM also stores a variety of data including personal abbreviated dialling codes, alphanumeric messages received using the GSM short message service, recent physical location information to assist network efficiency, and information on preferred and forbidden networks when roaming.

Mobile equipment has to be designed to certain GSM standards to operate correctly with the networks; however, these mobile equipment specifications are as unrestrictive as possible to encourage innovative design by manufacturers and further impetus towards consumerisation. For the UK customer, TACS (Total Access Communications System) analogue handsets were difficult to match, but by 1994 the size, weight and cost became virtually the same for both TACS and GSM.

Voice quality

Those familiar with analogue cellphones will know the voice quality problems that can occur particularly in marginal coverage areas. Very significant improvements have been achieved with GSM's digital technology using novel voice codec designs and channel coding to reduce the required digital information stream to 13 kbit/s compared to 64 kbit/s in

Typical GSM handset



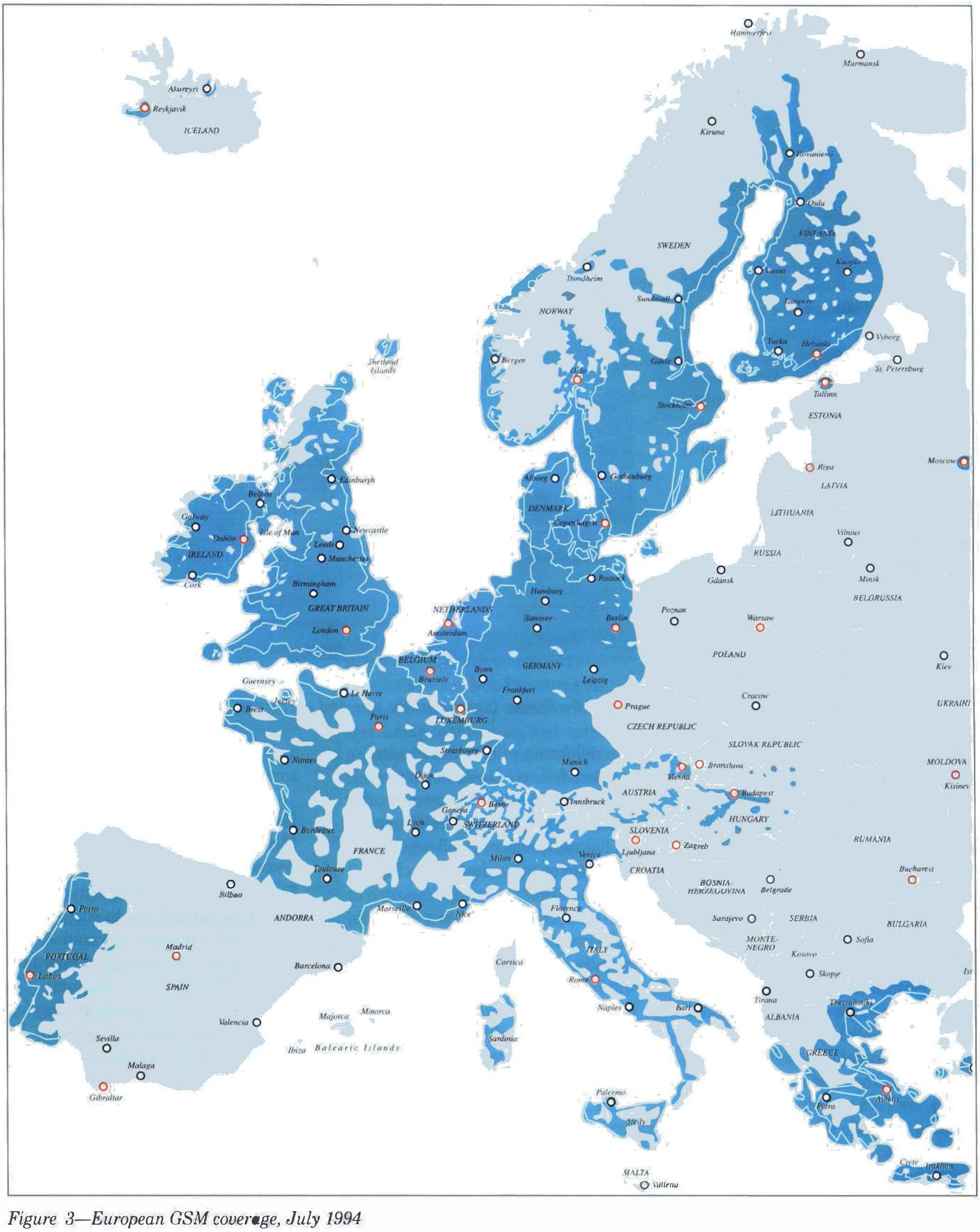


Figure 3—European GSM coverage, July 1994

the normal fixed network. The additional encryption algorithms also ensure that the potential for eavesdropping is very dramatically reduced.

Short message service (SMS)

This new service allows alphanumeric messages of up to 160 characters to be sent to or from a cellphone. If the cellphone is switched off, messages are stored and then offered to the cellphone later when it is switched on. When a message is received, an acknowledgement is sent back to the network—an important step forward from normal paging. Another application is support to voice messaging services such as Cellnet's Callback, where SMS messages are used to inform a customer of voice messages to be collected. To assist applications worldwide, character displays are under development for the Greek, Cyrillic, Arabic and Chinese alphabets.

Figure 2—Cell site

Bearer services

A wide range of bearer services supporting data rates up to 9·6 kbit/s are available with GSM. No modems are required with the cellphone which can be connected to a lap-top PC or a data terminal via a data adapter. Powerful error correction techniques are available over the air interface ensuring extremely low data error rates.

Supplementary services

A comprehensive list of supplementary services has been designed into GSM including a range of call forwarding and call barring options, call waiting, call hold, multi-party and many other services. Compatibility with integrated services digital network (ISDN) services has been sought wherever possible with most services being introduced in GSM ahead of equivalent services in the fixed network.

Benefits for operators

The specification of open interfaces between the key system elements of GSM has enabled multivendor options for operators and increased competition among manufacturers. Operators such as Cellnet with existing 900 MHz analogue systems have been able to share cell site infrastructure between the networks; Figure 2 shows a cell site incorporating antennas for both analogue TACS and GSM systems.

Achieving the best use of spectrum and the highest possible system capacity is a prime objective for operators. GSM includes the design of a half-rate codec which is expected to be available from 1996. This will provide the means for a very large increase in capacity—theoretically doubling it. However, compatibility issues arise and new cellphones with half-rate codecs will need full-rate functionality when roaming to old networks (or when using bearer services above 4·8 kbit/s), and old full-rate cellphones will need to be supported on networks introducing half-rate codecs.

Another feature aimed at improving perceived network quality is frequency hopping, which, when used, will reduce radio deadspots and interference from other radio signals.

The GSM standard and networks have been developed and implemented in three phases, each new phase having a greater range of services with enhanced signalling protocols to support them. Achieving cross-phase compatibility has been an essential and challenging task as networks in Europe and the world will exist at different phases, and mobiles of all phases will be in use on all networks.

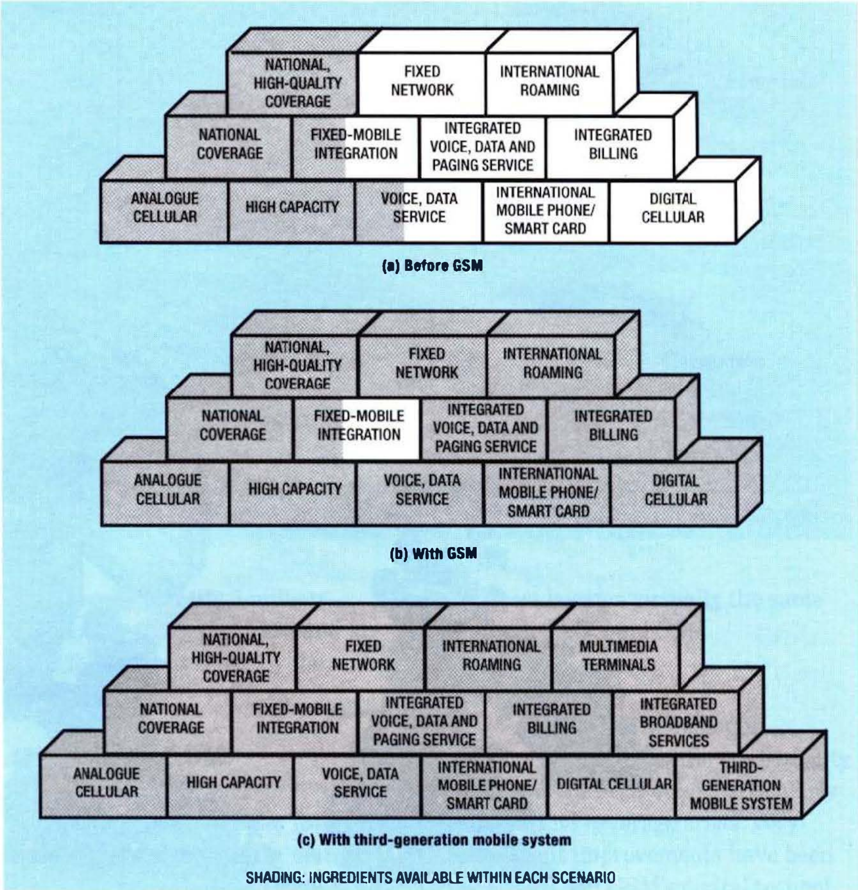


Figure 4—System ingredients for now and the future

European coverage

The roll-out of coverage across Europe has been extremely rapid. The situation as at July 1994 is shown in the map in Figure 3 on p. 283 to which can be added the fast-growing coverage of many other countries in the world.

System Ingredients for Now and the Future

The vision of the leading network operators can perhaps be summarised as providing 'instant information everywhere', nationally and internationally. The brick wall diagrams shown in Figure 4 identify the key ingredients required for achieving this vision. Before GSM many of the building blocks were missing although some data services were provided and a first level of fixed-mobile integration was achieved with direct access services linking private networks to mobile closed and open user groups (see Figure 4(a)).

At this time, Cellnet has 98% population coverage with its TACS analogue network and its GSM digital network. The GSM network provides an integrated service offering with voice, data, and a two-way messaging service, all based on ISDN principles. International roaming is specifically designed into the GSM system extending these

The strong emphasis on competition, together with the widespread adoption of the GSM standard, has created volume production which is driving handset and service prices down

services across the world. With high-capacity high-quality coverage, and the ability to integrate billing information from national and international roaming use, the concept for instant information everywhere has good foundations. Further detailed information on the range of services provided by GSM will be included in a future issue of the *Journal*. Many commercially important products and services are being enabled through GSM including mobile personal digital assistants (using the GSM bearer services)and road transport informatics services (using the short message service, bearer services and later the general packet radio service). These will be addressed in later issues of the *Journal*. (See Figure 4(b).)

The brick wall is always being built wider, and the third-generation mobile networks envisaged for deployment early in the next century should support integrated broadband services and the use of mobile multimedia terminals. (See Figure 4(c).)

The 3C Trends

Three principle trends and challenges in cellular telecommunications are:

- competition,
- consumerisation, and
- convergence.

Taking each of the trends in turn:

Competition

Within this major growth industry, GSM competition is planned or in place at the network level in 14 out of 17 Western European countries. Only Luxembourg, Switzerland and Austria are known absentees. Additional competition is provided in major countries at the service provider level. Service providers buy bulk air time from network operators and retail this air time to individuals or groups of customers. This new layer in the industry has encouraged a more creative and dynamic approach to the marketplace as a whole. This vertical market disintegration is being further encouraged by a recent EU Mobile Green Paper.

The strong emphasis on competition in cellular telephony, together with the widespread adoption of the GSM standard, has created volume production which is already driving handset and service prices down and expanding service and feature development. The cost of complexity in providing the very highly featured GSM handsets, a concern in the earlier stages of GSM development, has been overcome by anticipated technology steps providing lower-cost processing power.

Competition has certainly stimulated innovation in both network operators and suppliers, and in the areas of product development and channels to market. Pressures on costs have naturally arisen with increasing competition, and operators are closely investigating cost reduction opportunities in the areas of infrastructure, interconnect and transmission. For example, the use of self-provided microwave is still limited among operators due in part to national regulations and spectrum allocation policies. However, this is likely to be a major area where cellular operators will need and seek more choice in the future.

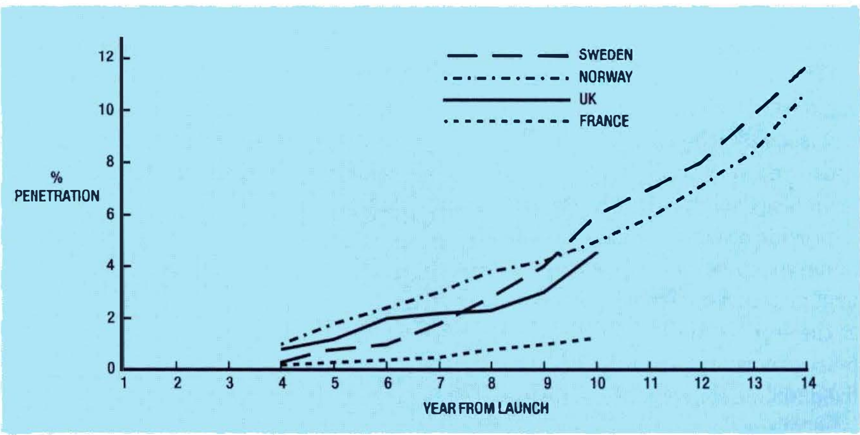
Consumerisation

The UK market penetration for cellphones exceeded 5% in September 1994. This can be compared to France—1·5%, Germany—3%, and Sweden—13%. While the UK compares well with France and Germany, it still has a long way to go to reach Swedish levels of penetration and then a real mass market. However, it is this vision that will put real pressures on operator's costs and quality for this market to be fully addressed. The graph of cellular telephony subscriber growth in Figure 5 shows the bottom end of some important rising 'S' curves, based on years from launch.

Cellular handset design is certainly fundamental to successful consumerisation. Handsets are getting smaller, some are very small. They are also more varied in shape, colour, cost and accessories, and are increasingly targeted at specific market segments. Several brand names such as Sony, Pioneer and Swatch have appeared in the marketplace in the last 2 years.

Additional distribution channels are also a key to releasing the consumer market. Cellnet has led the way to opening up high-street outlets with its Lifetime product. Opening up such markets can be a dramatic experience with 'planned/expected' demand curves being rapidly overtaken by 'actuals'. This is not a new situation in the cellular industry where higher-than-forecast demand seems to have been the norm during the past 10 years. Consumerisation will naturally stimulate new areas of

Figure 5—Cellular subscriber growth



Cellnet network control centre manages the analogue and GSM cellular networks

competition, innovation and better products which in turn will encourage further consumerisation. Projections for market demand will become more difficult and operators will have to be even more skilled at rapidly deploying high-quality cost-effective networks.

Convergence

Traditional boundaries affecting telecommunications are surely and quickly being eroded. Customers' expectations of using services in business, domestic and personal settings will increasingly be met through integrated solutions obtained at 'one shop'. The range of products from the cellphone at one end, to PCN/PCS concepts at the other, will leap across these boundaries and raise expectations for harmonised fixed/mobile services which are even now coming together through numbering, billing and service management initiatives.

The limitations of bandwidth in radio-based systems is, of course, a key issue in achieving full convergence and very creative product and technology solutions will be required to provide or emulate the bandwidth-hungry services now appearing. The next generation of mobile systems is at the start of the standardisation process now and will fully address fixed mobile convergence. A future issue of the *Journal* will discuss this further, particularly the opportunities for broadband services.

A further prompt to convergence has been the change in the UK mobile network operators' licence conditions which enables fixed link services to be provided. This, together with new intelligent network capabilities, is already encouraging important convergent service developments across mobile, private and public networks for corporate and major customers.

Conclusions

The next 5 years will see the 3C trends in different phases across the world, dependent in part on the extent of liberalisation and deregulation. Many of the early challenges of GSM have now been met with the development and launch completed and over 4 million customers. The next challenges lie in how each of the network operators and their industry partners address the trends of competition, consumerisation and convergence—with GSM digital cellular technology as an excellent foundation.

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Biography

Ken Hall
Cellnet

Ken Hall graduated in 1970 from the Woolwich Polytechnic with a B.Sc. Honours Degree in Electrical Engineering. After graduating he worked for several years on the development of submarine telephone systems gaining experience in a manufacturing and major project environment. He moved on to lead an engineering team in the design, development and production of a new range of telephone handsets. He joined BT in 1984 and for the past 8 years at Cellnet he has been responsible for feature and service developments on the TACS analogue and GSM digital networks. During the GSM standardisation period he has worked on several ETSI and GSM-MoU committees and working groups, and was Chairman of the GSM-MoU Services Experts Rapporteurs Group. He is a member of the IEE.

Alastair Brydon

Global System for Mobile Communications

An Introduction to the Architecture

Cellular radio systems are well established as the means of supporting mass market mobile telecommunications. The Global System for Mobile Communications (GSM) is a European cellular system standard offering an extensive array of services, an encrypted digital radio interface, and the facility to roam internationally. This is the state of the art in mobile communications, and in many respects GSM also leads fixed network service and mobility developments.

Introduction

Cellular systems are a spectrally efficient means of providing wide area mobility to a large number of users, and as such are well suited to providing mobile communications to the mass market. A number of analogue cellular system standards were highly successful in paving the way for public mobile communications in the 1980s. However, the launch of the Global System for Mobile Communications (GSM) in the 1990s, opening up the entire European market (and beyond) to a single highly-sophisticated system, sees cellular technology starting to fulfil its true potential.

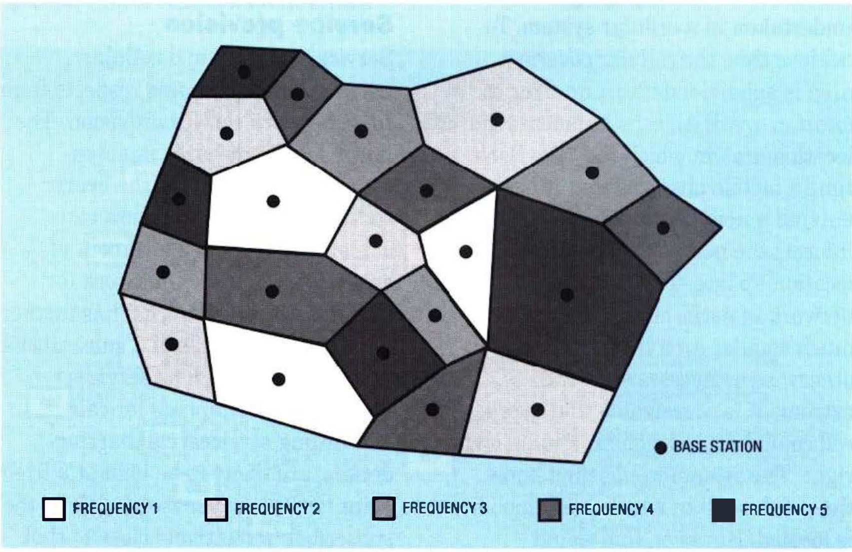
This article is tutorial in nature; it reviews the principles of cellular systems and introduces the architecture, signalling and operation of GSM.

Principles of Cellular Systems

The fundamental principle of cellular systems is that a limited radio bandwidth has the potential to support a large number of users by means of frequency re-use. Each radio frequency is used at a number of sites within the system, sufficiently far apart to avoid interference, as illustrated in Figure 1. It should be noted that such a representation is highly idealised, in that the boundary between cells is not at all distinct in practice (radio waves do not stop suddenly!), and in general there is a diffuse region of overlap between cells.

The support of communications in a cellular system requires a number of special features over and above those found in a simple fixed network. As users move around the

Figure 1—Idealised cellular radio coverage



cellular coverage area, there is a need to find and communicate with them, as and when required; for example, to receive incoming calls. This is achieved by a combination of paging and location updating procedures. There is a further need to maintain reliable communications for the duration of each call, as users move from one cell to another. This is the handover process. The provision of services to cellular users is impacted by their movement, and influences the architecture of the supporting network.

Paging

Paging is a process of broadcasting a message which alerts a specific mobile to take some action; for example, if there is an incoming call to be received. If the system does not know the precise cell in which a mobile is located, it must perform paging in a number of cells. An extreme approach would be to undertake paging throughout the entire coverage area of a cellular system whenever a mobile is to be alerted. However, in anything but the smallest system this would be wasteful of valuable signalling capacity, notably over the radio interface. This problem is addressed by means of location updating.

Location updating

Location updating is used to reduce the area over which paging must be undertaken in a cellular system. To achieve this, the cellular coverage area is subdivided into a number of *location areas*. All cells broadcast the location area in which they lie. Each time a mobile observes that it has entered a new location area, it informs the network by performing a location update. This enables the network to perform paging over a much smaller area than would otherwise be necessary. In the extreme it is conceivable that every cell could be a location area in its own right. The system would then know the precise cell in which every mobile is located. However, this would generate an unacceptable level of location update signalling. As a compromise, location areas are generally defined as groups of cells.

To maintain an up-to-date view of the status of mobiles within its coverage area, the network may request mobiles to perform location updates periodically, thereby confirming that they are still switched on and able to receive calls.

Handover

Handover is the means of maintaining a call when a user moves outside the coverage of the user's serving cell. When this happens, the call must be switched to an alternative cell which is able to provide service. All of this must happen automatically, without loss of the call. Handover is a complex process, requiring close cooperation and synchronisation of events between the mobile terminal and the network. In particular, there is a need to route the call to the new cell before handover can be effected, while maintaining the old connection until the handover is known to have succeeded. Handover is, by its nature, a time-critical process, requiring that action is taken before the existing radio link degrades to such an extent that the call is lost. Furthermore, any interruption to the flow of the call must be kept to an absolute minimum. Handover imposes significant requirements on the network.

Service provision

Service provision in a cellular network differs in some respects from fixed network service provision. The limited radio resource imposes obvious restrictions on the bearer service and teleservice data rates achievable, and the movement of subscribers around a network (or even into other networks) has further implications. Details of a subscriber's service profile, such as services subscribed to, numbers for call forwarding services, call barring details, are likely to be held at a fixed point in the home network. While the subscriber is relatively close to that point, it is no great problem to check the entitlement to use particular services and to retrieve forwarding numbers, call barring details, etc. each time a service is invoked. This becomes more of a problem if the subscriber is at a remote location, and perhaps even in a foreign network. Furthermore, the current status of the subscriber, such as whether the subscriber is engaged in a call, is generally known only by the local network. Hence the provision of some services (for example, call forwarding on busy) requires a combination of subscription information (in this case the forwarding number), and local information (in this case that the subscriber is engaged). This has a profound influence on the architecture of cellular networks (and other networks supporting mobility), leading to the concept of distributing service control between a fixed point in the home network and a (potentially changing) point local to the subscriber.

GSM

GSM represents the state of the art in cellular system design. The system has been (and is being) specified by the European Telecommunications Standards Institute (ETSI) (formerly the CEPT Groupe Spécial Mobile), and by mid-1994 had been adopted by 87 operators in 57 countries, supporting over 3 million customers worldwide. GSM was driven by the need to offer a comprehensive range of high-quality services to a large number of mobile users, at low cost. The ability to use the service when roaming internationally was seen as particularly important (without needing an explicit subscription with the local operator).

GSM takes account of many of the lessons learnt from first-generation cellular systems, and exhibits some notable features:

Digital radio interface

Unlike previous cellular systems, GSM adopts a digital radio interface carrying encrypted and error pro-

SIM card

tected speech and data. Speech is carried at 13 kbit/s (later to be reduced to 7 kbit/s).

Subscriber identity module (SIM)

A GSM user is not tied to specific mobile equipment. Subscribers' identities and other details are carried by smart-card subscriber identity modules (SIMs) which can be transferred between mobiles, any of which can then behave as though dedicated to that subscriber.

Integrated services

Previous cellular systems have focused on the provision of telephony, and while they may often be adaptable to support other services, this may be cumbersome (for example, with the addition of appropriate modems, a speech channel might be used to carry data or fax). In addition to standard telephony, GSM offers a comprehensive range of data, messaging, and supplementary services. Indeed, GSM was designed as the mobile arm of the integrated services digital network (ISDN), and offers largely equivalent services. There are also several GSM-specific services, including a two-way acknowledged messaging service, the short message service (SMS). An overview of the GSM services will be included in the April 1995 issue of the *Journal*. Further information can also be obtained in Reference 1.

Roaming

First-generation cellular systems are predominantly national or regional standards; for example, AMPS in US, TACS in UK, NMT in Scandinavia. As well as restricting the market for each of these systems, this limited users from operating their mobiles outside their home networks. GSM has addressed this problem by detailed standardisation of its radio and network interfaces, rigorous type approval of mobile equipment, and the requirement that GSM operators establish technical and commercial roaming agreements throughout Europe. As a result, subscribers can use the GSM system even when abroad. Providing their home network has a roaming agreement with the local GSM operator, these users will have access to the standard range of GSM services and will receive bills from their home network for any network usage. Callers to GSM subscribers need have no knowledge that they are roaming (and indeed should be given no such indication). They simply dial the usual GSM number.

GSM Network Architecture

In many ways, GSM follows the principles of intelligent networks, by separating control and service provision from the underlying switching fabric. Figure 2 shows the GSM network architecture, identifying each of the elements and the interfaces between them.

Mobile station (MS)

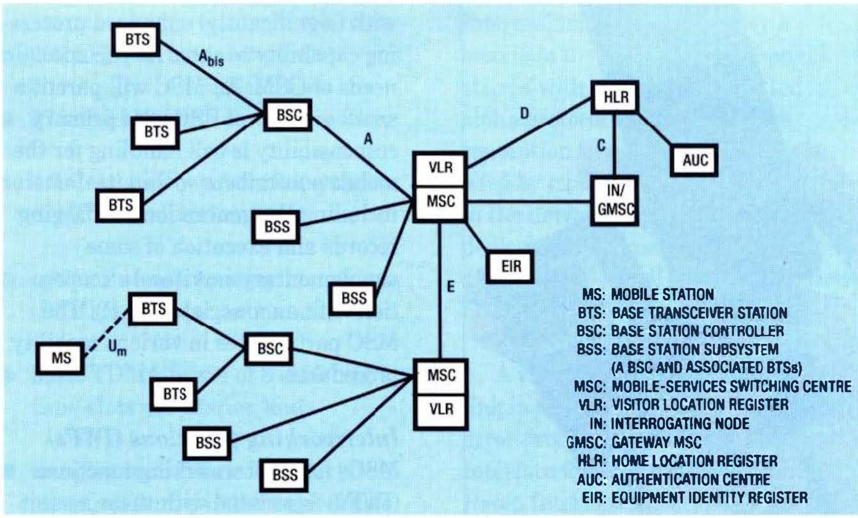
The mobile station (MS) is the physical equipment used by a GSM subscriber. It comprises two distinct parts: a subscriber identity module (SIM) and the mobile equipment (ME).

Subscriber identity module (SIM)

The subscriber identity module (SIM) is a smart card which carries all of the subscriber-specific information needed by an MS. The SIM can be moved between MSs, thereby enabling a GSM user to use any GSM mobile as though it were the user's own; that is, receiving all calls directed to the user's number, and incurring all charges for its usage.

The main functions of the SIM are to identify the current user of an MS,

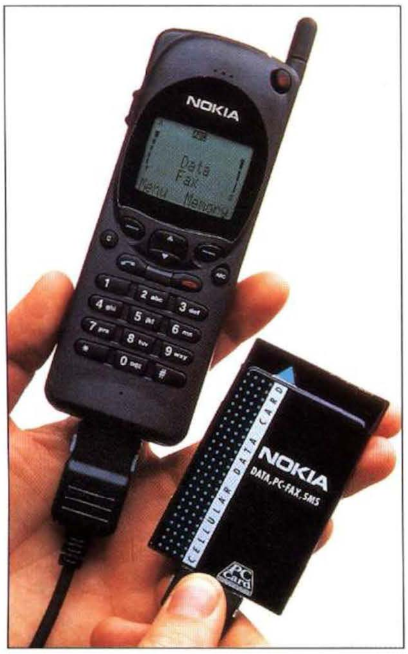
Figure 2—GSM network architecture



and to take part in certain security and confidentiality procedures (subscriber authentication and generation of ciphering keys). The SIM also stores recent location data, and may have the facility to store personal information for the subscriber, such as abbreviated dialling codes, messages received via the short message service, etc.

Mobile equipment (ME)
The mobile equipment (ME) provides the radio and signal processing needed to access the GSM network, plus the man–machine interface (MMI) to enable a user to access services. GSM uses a particularly sophisticated radio interface, including features such as ciphering, slow frequency hopping (SFH), discontinuous transmission (DTX), and the mobile may implement some or all of these. The MMI, encompassing the display and keypad of the ME, is crucially important in enabling users to access the complex GSM service-set intuitively and easily. Depending on the ME's application, it may have interfaces to external terminal equipment such as PCs or fax machines, and may even be integrated with such equipment.

GSM cellular telephone with data card



Base transceiver station (BTS)
The base transceiver station (BTS) provides GSM radio coverage within a cell. It comprises radio transmitting and receiving equipment (including antennas) and associated signal processing. It can be regarded as a sophisticated radio modem.

Base station controller (BSC)
The base station controller (BSC) is effectively a small switch with enhanced processing capability. In terms of traffic, it acts as a local concentrator, and provides local switching to achieve handover between a number of BTSs. In terms of control, the BSC takes a leading role in managing handover, power control, and other radio matters, ensuring that reliable radio links are maintained.

An important feature of the BSC is the transcoding and rate adaptation unit (TRAU), which is responsible for converting between air interface data rates and network data rates; for example, transcoding speech between 13 kbit/s and 64 kbit/s. In practice, the TRAU is often located remotely from the rest of the BSC, at the mobile services switching centre (MSC)/visitor location register (VLR), in order to save transmission costs.

Mobile services switching centre (MSC)
The mobile services switching centre (MSC) is essentially an ISDN switch with (significantly) enhanced processing capability to cater for the special needs of GSM. An MSC will parent a small number of BSCs. Its primary responsibility is call handling for the mobile subscribers within its domain, including the generation of charging records and execution of some supplementary services (in cooperation with an associated VLR). The MSC participates in various mobility procedures.

Interworking functions (IWFs)
MSCs have interworking functions (IWFs) associated with them, to suit particular network and service interconnection requirements; for example, rate adaptation of data services for interworking to data networks/ISDN, modems for supporting data communications across public switched telephone networks (PSTNs), fax adapters to support fax group 3, and protocol conversion. Also, echo cancellers can be switched into speech circuits, to compensate for the codec delays experienced in a GSM network.

In practice, the MSC is invariably implemented with a visitor location register (VLR), forming a single MSC/VLR unit.

Visitor location register (VLR)
The visitor location register (VLR) is an intelligent service control function and database. It stores (on a temporary basis) the information needed to handle calls set up to, or received by, local MSs registered with it. This includes identities, service profiles, and authentication data. The VLR is responsible for undertaking various mobility procedures, and controlling certain services (primarily those associated with outgoing calls).

Interrogating node (IN)
The interrogating node (IN) is the initial target for calls bound for GSM users. It is responsible for determining the location of a called subscriber, and for routing calls accordingly. The IN is commonly combined with an MSC, forming what is known as a *gateway MSC* (GMSC).

Home location register
The home location register (HLR) is an intelligent service control function and database, responsible for the management of mobile subscribers' records, and control of certain services (primarily those associated with incoming calls). It carries subscription details such as the teleservices, bearer services and supplementary services that are to be made available to a subscriber, and location information enabling the

routing of incoming calls towards the relevant MSC/VLR. This information can be accessed by reference to the subscriber's diallable number (mobile subscriber ISDN number (MSISDN)) or the subscriber's system identity (international mobile subscriber identity (IMSI)).

Authentication centre (AUC)
The authentication centre (AUC) is an intelligent database concerned with the regulation of access to the network, ensuring that services can be used only by those who are entitled to do so, and that access is achieved in a secure way. The principle is that the AUC and SIM have a unique key for every subscriber, which is used as the basis for generating a response to a random number generated by the AUC. Only the true SIM will be able to generate the correct response, and thus gain access to the network. The AUC is generally integrated with the HLR.

Equipment identity register (EIR)
The equipment identity register (EIR) is a database carrying information on certain MEs, in order that network operators can identify lost or stolen equipment attempting to access the network. Each ME can be identified by its unique international mobile equipment identity (IMEI).

Alongside the GSM network components described above are various management and administrative entities concerned with issues such as subscriber management, network operations and maintenance. Subscriber management encompasses the control of subscriptions (for example, services subscribed to) and the issuing of bills as required. Network operations includes monitoring the performance of the network, and optimising this by modifying its configuration, while network maintenance includes fault logging and instigation of remedial action. These are crucial aspects of cellular systems, but are outside the scope of this article. For further information, refer to Reference 1.

GSM Interfaces and Protocols

Outside the bounds of the GSM network, most signalling is associated with call control (and supplementary services), but within GSM there is a need to convey information associated with mobility and radio resource management as well as call control, and a number of GSM specific protocols have been developed to achieve this.

Figure 2 shows each of the interfaces of the GSM network. A mixture of call-related and non-call-related signalling is carried across these interfaces, passing between various pairs of entities; for example, call control between MS and MSC, mobility management between MS and VLR, radio resource management between MS and BSC, and so on.

Radio interface

The radio interface (U_m) is entirely GSM specific, and is based on a combination of frequency-division multiple access (FDMA) and time-division multiple access (TDMA). The GSM spectrum allocation and its usage are as follows:

- 890–915 MHz mobile transmit,
- 935–960 MHz base transmit,
- 200 kHz carrier spacing,
- 270·83 kbit/s data rate per carrier,
- 0·3 Gaussian mean shift keying (GMSK) modulation,
- optional slow frequency hopping (SFH) at 10 hops per second,
- basic TDMA frame of 8 (156 bit) time-slots per carrier, and
- complex multiframe TDMA structure on top of the basic frame.

The physical channels provided by this FDMA/TDMA scheme are shared by a set of logical traffic and signalling channels. Details of the multiplexing of these channels on the TDMA structure can be found in Reference 1. Table 1 summaries the usage of these channels, and classifies them as follows:

Dedicated uplink/downlink
Information is passed privately between the network and a mobile on a one-to-one basis. The dedicated mode is adopted, for example, during an active call or when undertaking subscriber-specific signalling; for example, location updating or Short Message transmission. At other times the MS is said to be in the idle state, and periodically monitors the broadcast and common downlink channels.

Broadcast downlink
Information is transmitted by the network to all MSs within the broadcast area. This is used, for example, to give mobiles information related to the local system, such as its location area.

Common downlink
Information is transmitted by the network to a specific MS, on a shared downlink channel (to which other MSs may be listening). This is used, for example, when paging mobiles.

Common uplink
Information is transmitted by a mobile to the network on a channel shared with other MSs. A slotted aloha protocol is used to resolve contention for this channel. This is used by mobiles to gain initial access to the network, typically to request dedicated resources for subsequent actions such as call set-up or location update.

A variant of the ISDN D-channel link layer protocol, $LAPD_m$, provides error protected links on the radio interface for use by GSM-specific Radio Interface Layer-3 (RIL-3)

Table 1 Logical Channels on the GSM Radio Interface

Channel Name	Channel Type	Usage
Traffic channel/full (TCH/F)	Dedicated uplink and downlink	Carries full rate (13 kbit/s) speech, or data at 12, 6 or 3·6 kbit/s
Traffic channel/half (TCH/H)	Dedicated uplink and downlink	Carries half rate (7 kbit/s) speech, or data at 6 or 3·6 kbit/s
Fast associated control channel (FACCH)	Dedicated uplink and downlink	A high-rate signalling channel used during call establishment, subscriber authentication and handover
Slow associated control channel (SACCH)	Dedicated uplink and downlink	A low-rate signalling channel associated with each dedicated channel, used for non-critical signalling such as radio measurement data, and short messages during a call
Standalone dedicated control channel (SDCCH)	Dedicated uplink and downlink	A signalling channel which can be used independently of calls when signalling is required; for example, for location updates, short messages, supplementary services management
Frequency correction channel (FCCH)	Broadcast downlink	Used by mobiles to achieve initial frequency synchronisation with the local BTS
Synchonisation Channel (SCH)	Broadcast downlink	Used by mobiles to achieve initial time synchronisation with the local BTS
Broadcast control channel (BCCH)	Broadcast downlink	Carries a variety of system information used by mobiles in the idle mode; for example, network identity, current location area code, information on surrounding cells
Cell broadcast channel (CBCH)	Broadcast downlink	Carries cell broadcast short messages
Paging channel (PCH)	Common downlink	Carries paging messages to alert mobiles to incoming calls or messages
Access grant channel (AGCH)	Common downlink	Assigns mobiles to specific channels for dedicated operation
Random access channel (RACH)	Common uplink	Used by a mobile to request resources for a subsequent operation; for example, to establish a call or perform a location update

protocols (which in reality extend to the application layer). These are concerned with radio resource management, mobility management, call control, and supplementary services, as captured in Table 2.

BTS–BSC interface

The BTS–BSC interface (A_{bis}) is based on conventional 2 Mbit/s circuits. A slight variant of the ISDN D-channel link layer protocol, LAPD, is used to carry BTS–BSC communications, and to relay protocols between the MS and the BSC, as outlined in Table 2.

BSC–MSC interface

The BSC–MSC interface (A) is based on conventional 2 Mbit/s circuits. Signalling System No. 7 common-channel signalling is used, with the signalling connection control part (SCCP) being used to carry GSM-specific protocols between the MSC and BSC, and to relay messages between the MS and the MSC/VLR.

GSM core network interfaces

The GSM core network interfaces (B–F) are also based on conventional 2 Mbit/s circuits and use Signalling System No. 7 signalling. Call control is conveyed using standard fixed network protocols such as the national user part (NUP) or ISDN user part (ISUP), while mobility and other GSM signalling is carried by a GSM-specific development known as the *mobile application part* (MAP), transported by the Signalling System No. 7 SCCP and transaction capability part (TCAP). The MAP has numerous applications within the GSM core network, carrying a variety of non-circuit-relayed signalling. Table 2 summarises its usage by various pairs of entities.

GSM Operations

The roles of the various GSM network entitles and protocols are best understood by considering their participation in various operations.

Location update

A location update is instigated by an MS when it detects that it has entered a new location area. (Periodic location updates may also be required by the network.) The MS detects that it has entered a new location area by comparing the last known location area (stored on its SIM), with the information broadcast by the local cell. The MS gains access to a radio channel, and requests a location update. If the serving MSC/VLR is unchanged, the network can immediately authenticate the MS (if required by the operator), and take note of the change in location area. If the MS has moved to a new MSC/VLR, further actions are required. The MSC/VLR addresses a message to the MS's HLR (which may be in another network if the subscriber is roaming). This address is provided by the MS's

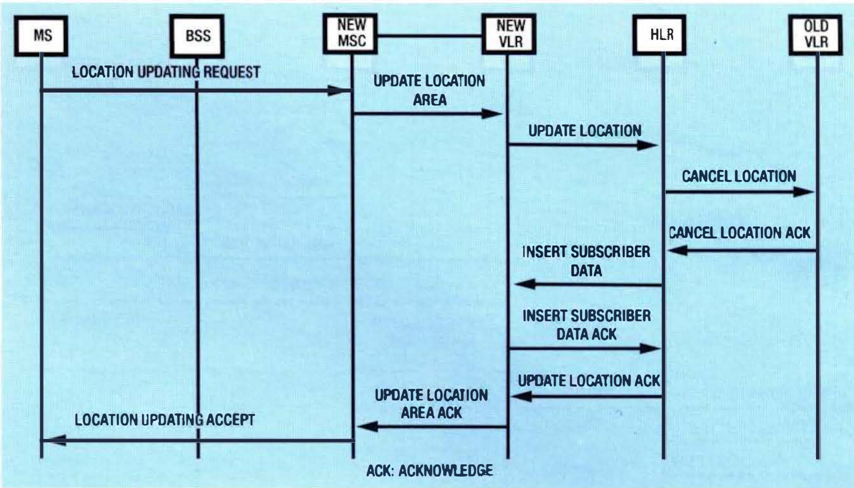


Figure 3—Location update operation

international mobile subscriber identity (IMSI). The HLR takes note of the new location of the mobile and downloads various security parameters, which the MSC/VLR can use to authenticate the mobile and establish ciphering on the radio channel (as required by the operator). The HLR also passes a subset of the MS's service profile to the MSC/VLR, in order that the local network is aware of service entitlements, and various GSM supplementary services can be configured as required. The HLR instructs the old MSC/VLR to delete its record of the MS. Figure 3 shows the information flows associated with successful location updating.

Incoming call

An incoming call for a GSM subscriber is presented initially to a GMSC/IN in the subscriber's home network. From the mobile subscriber ISDN (MSISDN) number dialled by the calling party, the IN is able to identify the HLR which hosts the called subscriber, and it requests routing information from that HLR. The subscriber may have active supplementary services which affect the flow of the call at this stage; for example, call forwarding unconditional. If this is the case, the HLR provides the necessary routing information (the forwarding number in this case) to the GMSC/IN, and the call is routed accordingly. Assuming there are no services active, the HLR must provide the GMSC/IN with information enabling it to route the call towards the MS (which may be roaming in another network). The HLR is aware of the last known MSC/VLR for the called MS (from the most recent location update), and requests from the MSC/VLR a routing number. The MSC/VLR temporarily allocates to the MS a mobile station roaming number (MSRN) from a pool of available numbers. This is passed to the HLR, and on to the GMSC/IN. The MSRN routes the call to the MSC/VLR, which is then able to associate the MSRN with the specific mobile in its

Table 2 GSM protocols

Protocol	Between	Function
Radio Interface Layer 3 —radio resource (RIL3-RR)	MS–BSC	Enables the MS and BSC to cooperate for the management of radio resources
Radio Interface Layer 3 —mobility management (RIL3-MM)	MS–MSC	Enables the MS to communicate with the network for mobility management purposes
Radio Interface Layer 3 —call control (RIL3-CC)	MS–MSC	Enables the MS to communicate with the MSC for call control and supplementary service provision
Radio sub-system management (RSM)	BTS–BSC	Used by the BSC to configure the BTS, for example to control radio interface parameters, and by the BTS to report measurements to the BSC
Base station system mobile application part (BSSMAP)	BSC–MSC	Used for managing resources and connections between the MSC and BSC
Direct transfer application part (DTAP)	BSC–MSC	A relay mechanism between MSC and BSC, enabling communication between an MSC and an MS for call control and mobility management procedures (RIL3-CC and RIL3-MM)
Mobile application part (MAP)	Various	MAP has been developed as a Signalling System No. 7 application protocol, specifically aimed at supporting the special requirements of GSM. It has many different applications according to the pairs of entities using it, as detailed below
MAP	GMSC/IN–HLR	Enables interrogation of the HLR by the GMSC/IN during incoming call set-up, to obtain routing information
MAP	MSC/VLR–HLR	Primarily a mobility management protocol, but also serves to convey call-related information for incoming calls; for example, roaming numbers
MAP	Anchor MSC–relay MSC	Carries exchanges between two adjacent MSCs. It is concerned with all aspects of inter-MSC handover. Acts as a transportation mechanism for messages which must be relayed by an intermediate MSC between an anchor MSC and an MS
MAP	MSC–EIR	A simple request/response protocol for IMEI checking in the EIR
MAP	VLR–VLR	Forwarding of parameters between VLRs
MAP	(MS–HLR)	Supplementary service management

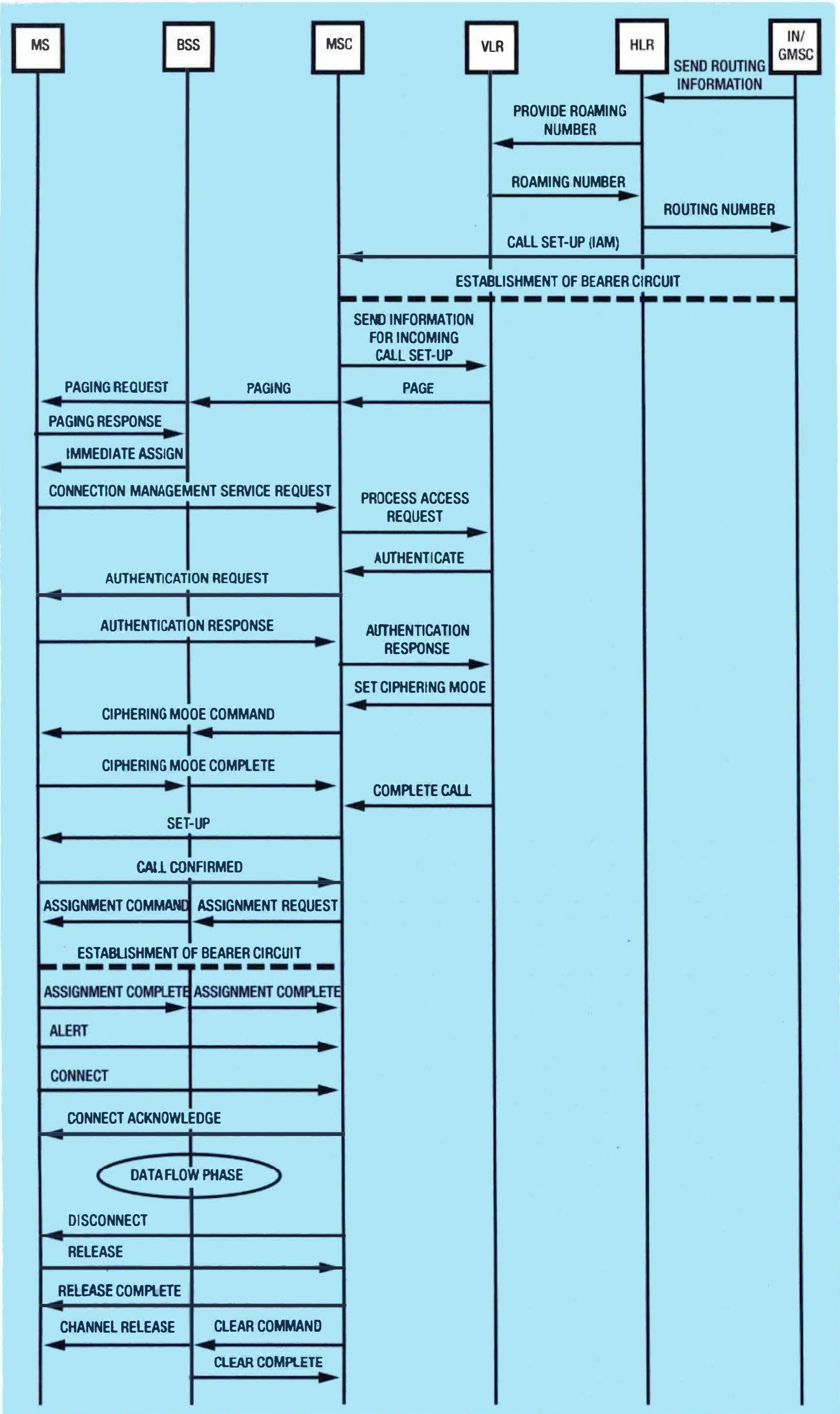


Figure 4—Incoming call set-up

coverage area. The MSRN can then be returned to the pool for subsequent reuse.

At this point, the MSC/VLR attempts to establish contact with the MS by undertaking paging within the last known location area of the mobile. If, for some reasons, the mobile does not respond, for example if it is out of coverage or switched off, then the MSC/VLR may act on its supplementary services. Thus call forwarding on not reachable could route the call to an alternative destination. If the mobile is still within coverage, and switched on, it responds to the paging and requests a radio channel. The MSC/VLR authenticates the MS and establishes ciphering. The radio bearer can now be established, and the alerting signal activated on the mobile. Should there be no answer to this, then once again the MSC/VLR may take follow-on actions as defined by active supplementary services; for example, call forwarding on no reply. If the user answers, the call can be completed. Figure 4 shows the information flows associated with a successful incoming call.

Outgoing call

An outgoing call from a GSM user begins when the user dials a number and presses SEND. The MS requests a radio channel. The local MSC/VLR authenticates the mobile, establishes a ciphered radio channel, and confirms the user's entitlement to service. The MSC/VLR may have supplementary services active, for example, barring of certain numbers, which may then take effect. If these have no bearing, then the call is routed by the MSC/VLR in accordance with the dialled number, and the MSC/VLR maintains charging records accordingly. These can be passed to the home network later. Figure 5 shows the information flows associated with a successful outgoing call.

Conclusions

This paper provides a broad introduction to the GSM network and its operation. By providing a complete and thorough system specification, GSM provides advanced services in the mobile environment with the facility to roam internationally.

Acknowledgements

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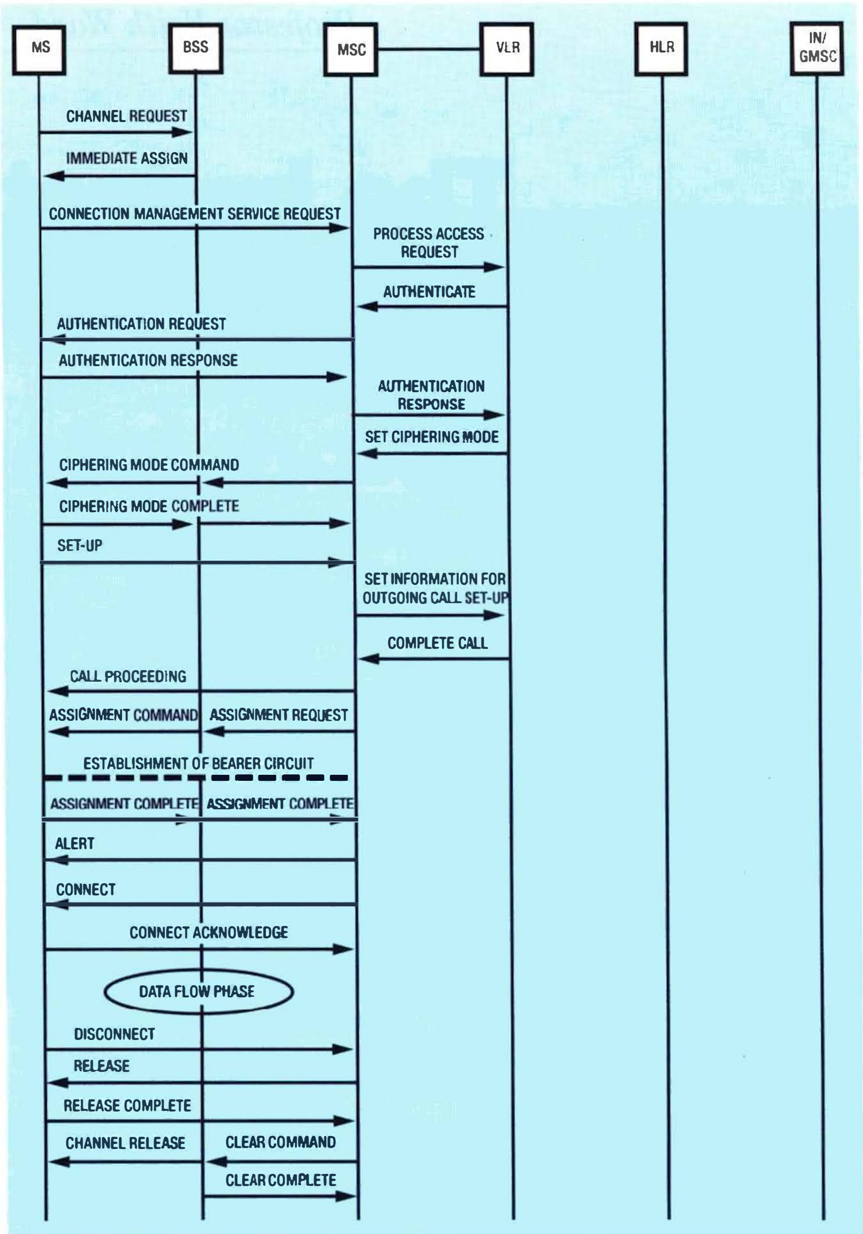


Figure 5—Outgoing call set-up

Biography

Alastair Brydon
BT Development and Procurement

Alastair Brydon is a Senior Engineer in the Cellular Systems Development Unit at BT Laboratories. He joined BT in 1989 following 5 years of lecturing and research at UMIST, leading to the award of a Ph.D. in 1990. While at BT, he has been involved in various aspects of mobile system development, and has worked on GSM, DECT, PMR, TFTS, and UMTS. He recently spent 6 months working with Cellnet on the design of its GSM network.

Glossary

AGCH	Access grant channel
AUC	Authentication centre
BCCH	Broadcast control channel
BSC	Base station controller
BSSMAP	Base station subsystem mobile application part
BTS	Base transceiver station
CBCH	Cell broadcast channel
CEPT	Conférence Européene des Postes et Télécommunications
DTAP	Direct transfer application part
DTX	Discontinuous transmission
EIR	Equipment identity register
ETSI	European Telecommunications Standards Institute
FACCH	Fast associated control channel
FCCH	Frequency correction channel
FDMA	Frequency division multiple access
GMSC	Gateway mobile services switching centre
GMSK	Gaussian mean shift keying
GSM	Groupe Spécial Mobile
GSM	Global System for Mobile Communications
HLR	Home location register
IMEI	International mobile equipment identity
IMSI	International mobile subscriber identity
IN	Interrogating node
ISDN	Integrated services digital network
ISUP	Integrated services user part
IWF	Interworking function
LAC	Location area code
LAPD	Link access protocol (D-channel)
MAP	Mobile application part
ME	Mobile equipment
MS	Mobile station
MSC	Mobile services switching centre
MSISDN	Mobile subscriber ISDN
MSRN	Mobile station roaming number
MTP	Message transfer part
NMT	Nordic Mobile Telephone
NUP	National user part
PC	Personal computer
PCH	Paging channel
PLMN	Public land mobile network
RACH	Random access channel
RIL3-CC	Radio Interface Layer 3 - call control
RIL3-MM	Radio Interface Layer 3 - mobilily management
RIL3-RR	Radio Interface Layer 3 - radio resource
RSM	Radio subsystem management
SACCH	Slow associated control channel
SCCP	Signalling connection control part
SCH	Synchronisation channel
SDCCH	Slow dedicated control channel
SFH	Slow frequency hopping
SIM	Subscriber identity module
SMS	Short message service
SRES	Signed result
TACS	Total Access Communications System
TCAP	Transaction capabilities application part
TCH/F	Traffic channel/full rate
TCH/H	Traffic channel/half rate
TDMA	Time division multiple access
TUP	Telephone user part
VLR	Visitor location register

Professor Keith Ward

The Impact of Network Interconnection on Network Integrity

As telecommunications networks and services become more sophisticated and the control software more complicated, interconnection between different operators' networks has major implications for the integrity of all networks and services. This article analyses the problem and suggests ways of quantifying it.

Introduction

The widespread use of processor-controlled technology in networks with high-capability common-channel signalling and intelligent platforms creates an increasingly unstable equilibrium where comparatively minor perturbations can cause severe network outages. The vulnerability of these new technologies is exemplified by the severity of the signalling-related failures (sometimes known as *brown-outs*) that afflicted several network carriers in the USA during 1990–91.

The risk of breach of network integrity (defined as the 'ability of a network to retain its specified attributes in terms of performance and functionality') is increased when networks are interconnected and this is becoming a major regulatory issue since regulatory policy is allowing many competitive operators and service providers to interconnect to the networks of established telecommunications operators. One example of this is the European Commission's Open Network Provision (ONP) policy. Hence, it is necessary to consider network integrity in the context of network interconnect. The constituent parts of such a scenario are highly interactive and this can be demonstrated by the process model in Figure 1. The process starts with the market demand for value-for-money services needing specialised network platforms to carry and process the signalling and communications information. It is the transport and processing of this information that gives rise to the threat to the network integrity. The assumption is that the integrity problems are fundamentally concerned with network control; that is, the transmission and processing of control information.

Network Interconnect

Given that ONP aims to open the networks of dominant telecommunications organisations (TOs) to new competitors (service providers (SPs) or TOs defined in this article as other licensed operators (OLOs)) to gain access to the TO's customer base or use the resources/services of TOs to offer their competitive services, an environment of extensive interconnected networks and SP equipment could develop. The networks of dominant TOs are interconnected to those of competing or specialised network operators to obtain total connectivity between all customers. Initially, OLOs gain access to the TO's customer base to offer cheap trunk calls, sometimes known as *trunk bypass*, but OLOs are now competing by direct access to customers; for example, cable TV operators. Mobile operators connect to obtain connectivity to customers on fixed networks. Increasingly sophisticated private networks are also interconnected to the public networks.

In the future environment of highly sophisticated intelligent network services, an increasing number of service providers will also require access to fixed and mobile networks to provide specialised services. A complex mesh of networks

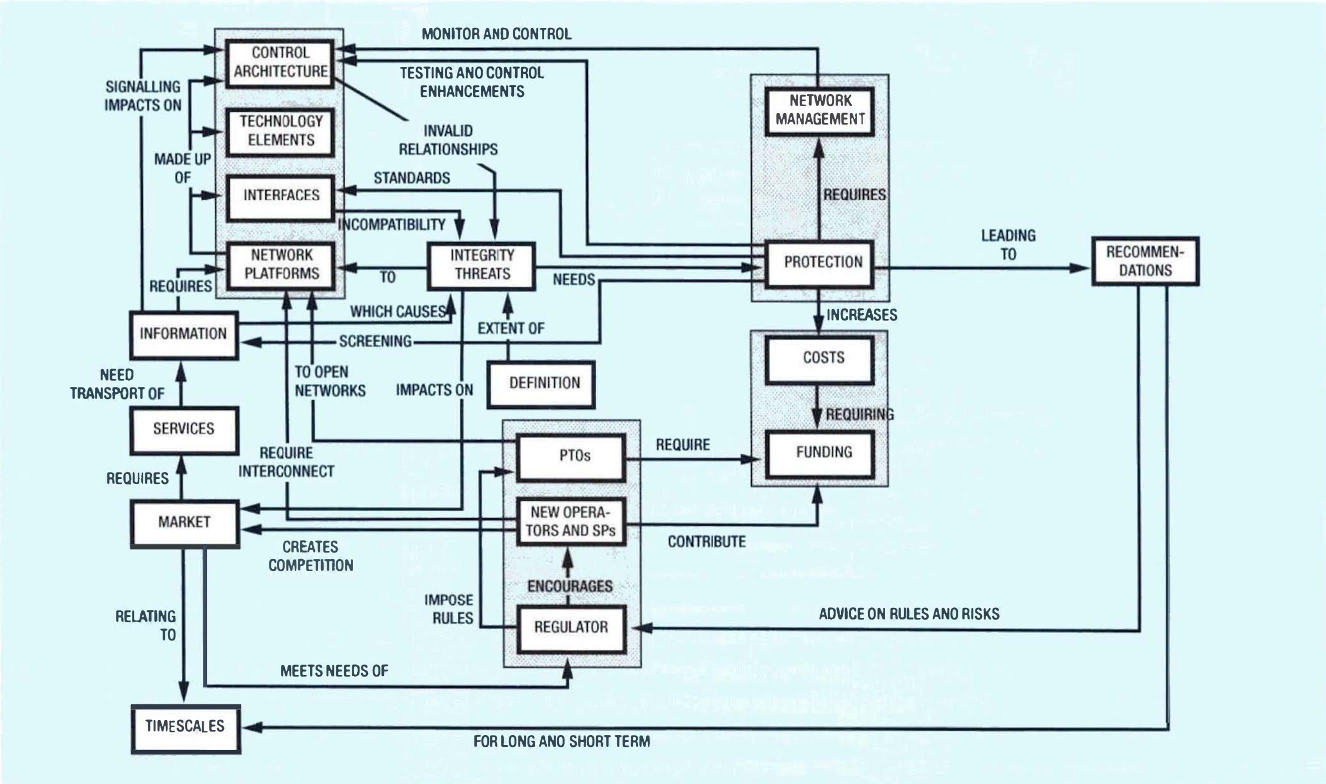


Figure 1—Process model

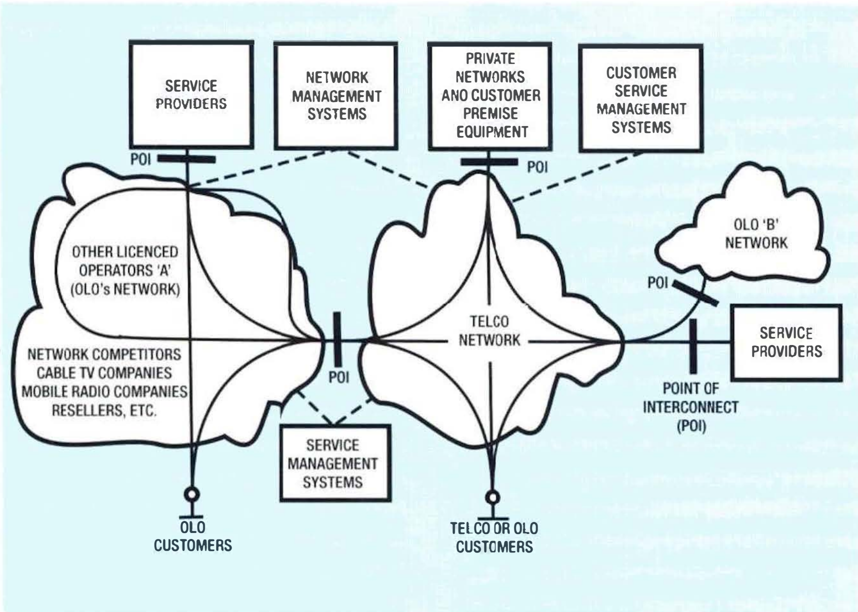


Figure 2—Network interconnect scenario

and management systems will arise (Figure 2).

There are three generic constituent parts of a network (Figure 3); namely, access, core transport and the service platform (together with its management). Traditionally they have formed the monopoly TOs' networks. Combinations of the constituent parts are used to provide the network services. However, with the introduction of competition, new operators entered the market where the cost of entry was lowest, with greatest potential for undercutting the established TO's tariffs. Initially, this was the trunk call market with the new operators providing a core transport network interconnected with the TOs' networks to gain access to their customer bases. Cable TV operators could provide access at marginal cost and compete in the access network connecting with the core transport network of other operators to route calls.

It can be expected that SPs will offer value-added services from their own service platform connected to other operators' transport networks to gain access to customers and to route calls. Independent information providers will supply information services, particularly in the multimedia era. Hence, in an open network environment, customers will be able to gain services from a variety of interconnected constituent parts of the networks and service platforms provided by TOs, OLOs and SPs. The points of interconnect will be determined by a range of technical and economic factors.

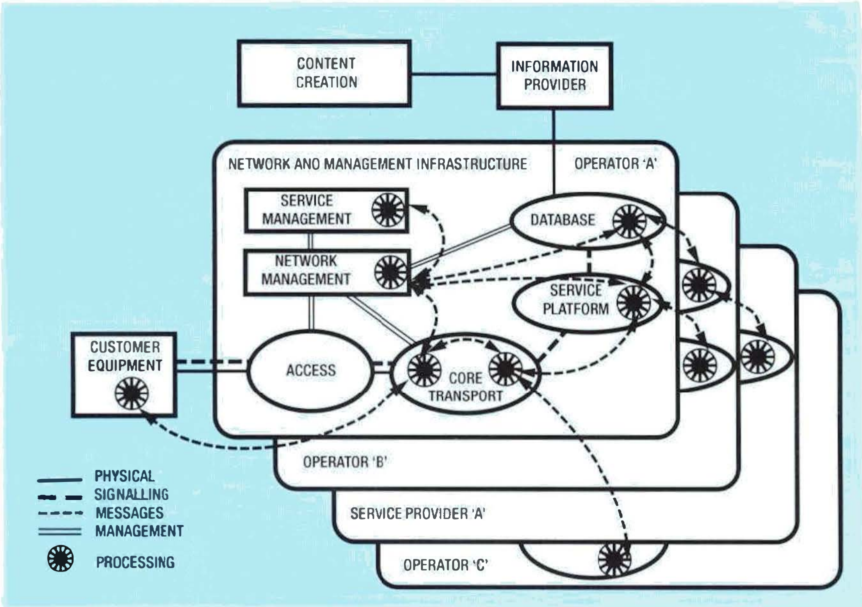


Figure 3—Interaction of constituent parts of networks

Modern networks are software controlled. The services they provide are established by the interaction of application programs, in appropriate network elements, via messaging over the signalling network (Figure 3). Support systems and embedded network intelligence also interact for service and network management purposes. It is increasingly likely that information technology (IT) applications in customer terminal equipment for multimedia services will require heavy interaction with the network control. If invalid messages are exchanged between application programs then misoperation can disrupt the normal operation of the network. In extreme cases, such a malfunction can cause invalid messages to propagate through the network, closing it down. Such problems can be caused by hardware faults, software 'bugs', operational errors, deliberate sabotage or incompatibility in signalling and/or software. The probability of such perturbations rises when the constituent parts of TOs' and SPs' networks are interconnected and the network integrity is threatened. The behaviour of such interconnected software is non-linear and possibly chaotic making it almost impossible to predict. Network integrity is therefore a control engineering problem and is one of the more important aspects of modern performance engineering.

The most common form of interconnect is related to the 'plain old telephone service' (POTS) where the CCITT No.7 signalling is already operating successfully between different public switched telephone networks (PSTNs) and between mobile cellular networks and PSTNs. In the near future, the range of interconnected services will probably be extended to include customer local area signalling services (CLASS) services requiring the transmission of calling line identification (CLI) signals between networks. Other intelligent services will follow as systems evolve.

Network integrity can be compromised by problems migrating between networks and equipment connected to them. Modern networks are made up off numerous 'intelligent' switching and signalling elements interacting in real time. The probability of failure is high because it is virtually impossible to test all possible interaction combinations. The situation is made worse by the interconnection of networks comprising equipment from many different suppliers.

Currently, the most important threat comes with the interconnection of networks with CCITT No.7 signalling. For example, widespread network disruption, sometimes known as *brown-outs*, can be caused by protocol or signal transfer point incompatibilities. Likewise, the interconnection of SDH networks will require particular attention to be paid to control overhead aspects. It is reasonable to predict that future cooperative intelligent services that require network control interworking will be even more sensitive.

There is a broad correlation between the complexity of an interconnect and the degree of risk to network integrity. This will depend on aspects such as the signalling activity and the number and range of network elements that have to be accessed to provide the particular service. For example, POTS would be considered low complexity but intelligent network (IN)-based services require a significant volume of transaction signalling to various databases. This means that decisions on interconnection will be strongly influenced by the risk involved, which reflects the complexity of the systems and services. The more complex services will require more demanding interconnect conditions in terms of, for example, testing and screening. To assist in the assessment of requests for interconnect, it is desirable that a broad measure of complexity is developed for each class of interconnect and internetworked service. One possible measure could be the product of signalling activity (in terms of messages per call) and elements of the network accessed, measured against thresholds to indicate high, medium and low complexity.

Interconnection of Intelligent Networks

In future intelligent networks, service software will be placed in a variety of

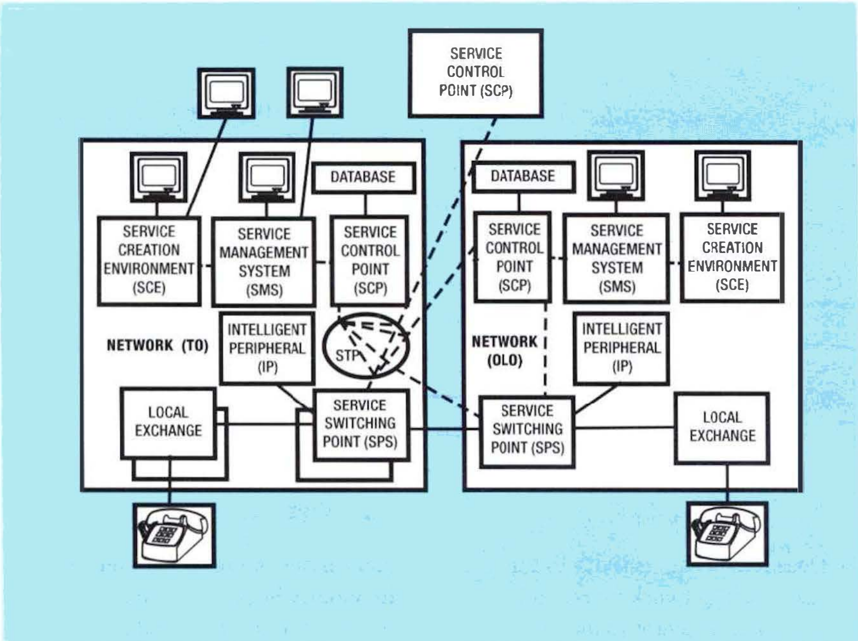


Figure 4—Interconnect possibilities for intelligent networks

elements such as the service control points (SCPs), intelligent peripherals (IPs), adjuncts and even the switches themselves. In addition, some services may be created by assembling a set of, so called, features into a 'feature package', and some features may already be developed and used in other feature packages. Potential interconnect possibilities for intelligent networks are shown in Figure 4.

Feature interaction occurs when the behaviour of one feature is altered in an unexpected and adverse way by another feature preventing customers from obtaining the full benefits of specific services for which they have subscribed. Undesirable interactions can arise from incompatible feature functionality, protocol and logical ambiguities or insufficiency of available data. They may also involve logic on multiple-network and customer premises equipment (CPE) elements in interconnected networks, where implicit conventions may not be observed because the software is developed, deployed and maintained by more than one organisation. Where an undesirable feature interaction occurs on a service that requires network interoperability and it prevents the service being offered between networks or within a network, then network integrity has been breached. In the worst case, feature interaction may cause a catastrophic failure of basic services. For example, repeated execution of one or more features may cause severe signalling overload (feedback loop). As the number of features increase, and there are already hundreds of them, predicting and detecting interactions becomes very complex and the risk of integrity violations increases. Ensuring protocol conformance at each interface is difficult because each developer may specify and interpret aspects of the protocols differently.

The situation can be even more complex under an ONP regime that permits open interfaces to third party service providers. They may be allowed to:

- execute their own service logic on the service creation platform of the network operator (at the application programming interface);
- interconnect to the CCITT No.7 signalling network of the network provider (at the application protocol interface); and
- use their own service control point (SCP), connected to the TO's service switching point (SSP).

Thus, interconnection of intelligent networks for internetworked services presents a high risk of integrity violation due to the increased transaction signalling activity and interface complexity. Such interconnections should be encouraged to stimulate innovative services but sufficient precautions must be taken to prevent violation of integrity. In the USA, extensive testing is being carried out to understand such interconnect and one operating company has already publicly stated its intention to allow SPs to interconnect their own SCPs to its IN platform.

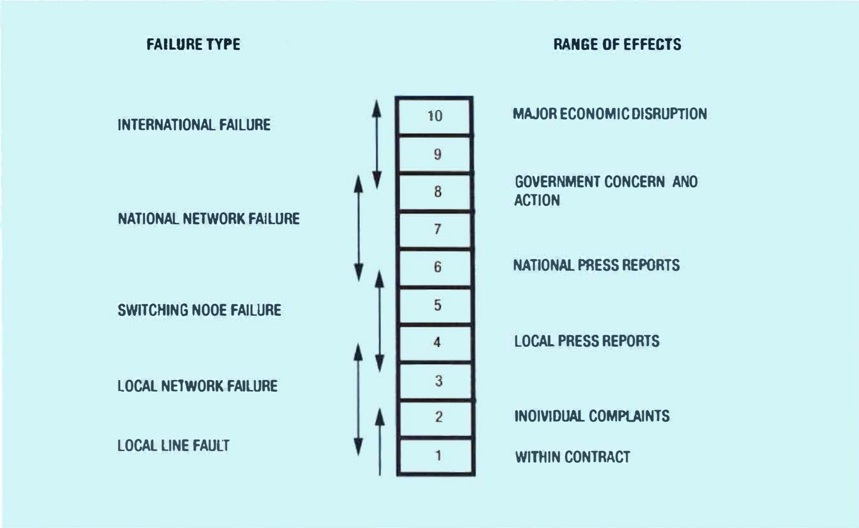
Definition of Network Integrity

Network integrity can be broadly defined as 'the ability of a network to retain its specified attributes in terms of performance and functionality'. Isolated incidents that only impact on a small number of customers should not be classed as a breach of network integrity. It is therefore generally accepted that the definition should focus on major outages or performance degradation affecting a large numbers of customers. The exception is where the loss of an important service is experienced that is used by a relatively small number of major business customers. In the USA, the Federal Communications Commission (FCC) define an outage as 'a significant degradation in the ability of a customer to establish and maintain a channel of communications as a result of failure in a carrier's network'. However, there is a need to define network integrity in a manner that will allow loss of integrity to be identified and, preferably, measured in order to:

- identify when a breach of network integrity has occurred,
- understand the magnitude of the loss of integrity in terms of the impact on network customers, and
- construct meaningful service level agreements or contracts between network operators for network interconnect, or impose regulatory conditions that can be arbitrated in quantitative terms.

In the USA, the Alliance for Telecommunications Industry Solutions (ATIS) T1A1 Working Group on Network Survivability Performance has introduced a general

Figure 6—Network disaster outage scale



framework for quantifying service outage from a user's perspective. The parameters of this framework are:

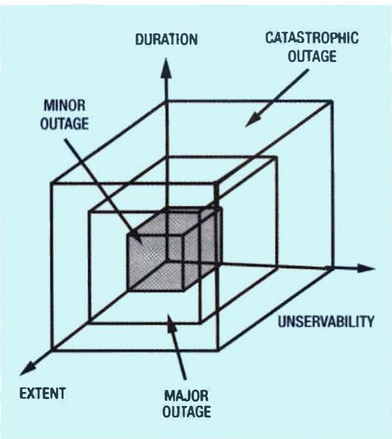
- The *unservability* (U) of some or all of the services effected by the failure, in terms of usage.
- The *duration* (D) for which the outage exists.
- The *extent* (E) in terms of the geographical area, population effected, traffic volumes, and customer traffic patterns, in which the unservability exceeds a given threshold.

The service outage can be categorised by sets of values for which the (U,D,E) triple qualify for particular values of outage. This is illustrated in Figure 5 where the triples are categorised in three regions of minor, major and catastrophic.

The main problem in deriving an index is to quantify the impact on customers connected to the network(s). Questions that need to be addressed include:

- Does a local exchange outage of *x* hours duration affect all customers connected to the exchange, given that only a proportion of them will attempt to make a call during that period?

Figure 5—(U,D,E) qualifying regions



- Does loss of connectivity to the rest of the network merely affect those who attempt to make calls during the outage period and what is the difference between partial and total isolation?
- What is the difference between a total outage and severe degradation of service where, say, loss of network synchronisation causes slip with severe error performance which has a different impact on speech than data?
- Is the impact of loss on business customers greater than that for residential customers?
- What is the impact of loss of interconnect between networks? Is it different for fixed–fixed, fixed–mobile, PSTN–data, etc.?
- How do you determine the impact on customers of different services? Does the tariff reflect the value of the service to the customers?
- How do you equate the difference between a large, highly penetrated network and a small, low penetrated network?
- How can you derive an index with a small numeric range to express the impact of a variety of integrity violations, perhaps illustrated by the 'Cochrane Richter Scale' concept shown in Figure 6.

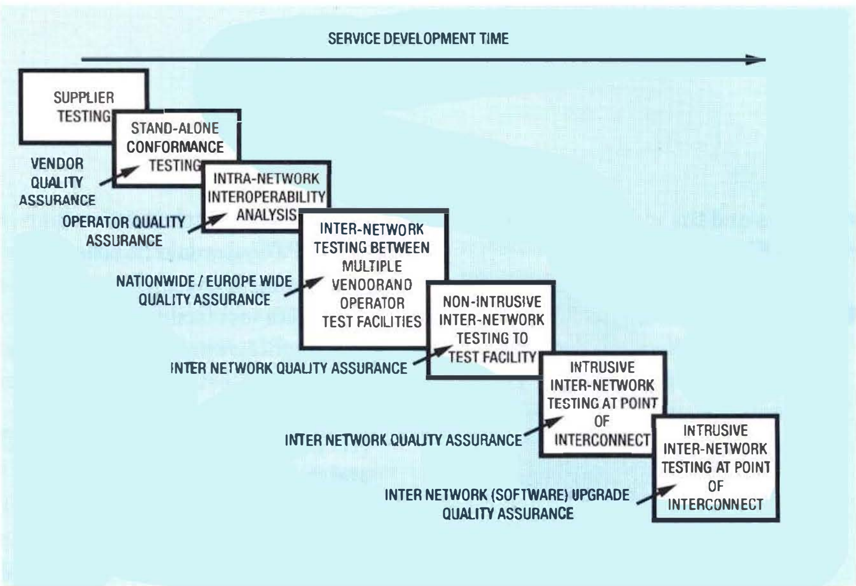
The FCC in its February 1992 Report and Order challenged the telecommunications industry to develop a scientific method for quantifying outages. The Network Reliability Steering Committee passed the remit to the T1 Standards committee. Both are committees of the ATIS.

The T1A1 proposed that the index should be based on a combination of services affected, duration and magnitude (in terms of customers affected). '...In particular it should:

- reflect the relative importance of outages for different services,
- be able to be aggregated to allow comparisons over time, and
- reflect small and large outages similarly to their perception by the public'.

An important objective of the exercise was to enable the summation of individual outage index values, over time periods and related to FCC reporting requirements (<30 minutes, ≥30 000 customers), for comparison purposes. Aggregation should reflect the importance of outages to customers such that the aggregate index for multiple small outages is less than the index for one large outage where its duration or magnitude equals the sum of the small outages. Likewise, the aggregate index for multiple large outages should be greater than the index for one very large outage over the same measurement timescale, for example one year. This index behaviour is captured by an 'S' curve for the duration and magnitude weights allowing aggregates over time periods to be plotted and analysed using statistical trend analysis.

Figure 7—Testing sequence



The index of an outage is the sum of the service outage index values for each service affected. The service outage index of each service affected is the product of:

- service weight (W_s),
- duration weight (W_d), and
- magnitude weight (W_m).

This gives the outage index (O), for an outage O, the following form:

$$I(\mathrm{O}) = \sum_{j=1}^{N} W_s(j)\, W_d(j)\, W_m(j)$$

where $j = 1, \ldots, N$ are the services.

Integrity Risk Definition

The network integrity definition that has been postulated quantifies the extent of the breach of network integrity when an incident occurs. However, further development is necessary but this is difficult to incorporate within the present structure. Once it is possible to quantify network outages, it becomes desirable to quantify the threat of an outage as a consequence of some action. Such an action could be a specific type of interconnect or internetworked service. In fact, this should be regarded as the real definition of integrity.

The definition and development of such a measure of robustness is intimately related to model and interconnect testing development. There are major difficulties in trying to obtain a quantitative measure of a threat to a network. This is in part due to the nebulous nature of the term *threat*, and due to a lack of understanding of network behaviour. Therefore, proposing that a given interconnection process poses a threat to the integrity is no more meaningful than saying that it does not. It would be desirable to be able to say that a given interconnection increases the likelihood of a network failure by a probability of x. Then it would be possible to say that if x was to exceed an agreed threshold value, it would constitute an unacceptable threat.

To achieve such a numerical measure may not be possible; but an indication of the threat within error bounds should be. The development of such measures will be possible only from experimentation, run in conjunction with modelling. This is because the essential process is predictive and hence there has to be some theoretical basis to achieve this.

Ideally, the assessment of risk should be based on a model which would assess the level of risk to integrity and the threshold criteria would determine its acceptability. Such models do not exist, so a more pragmatic and broad-brush methodology must be developed in the short term.

Integrity Protection

There are a number of ways to protect the integrity of networks when they are interconnected. Some of the more common ways are:

- *Gateway screening*—comprising software, usually embedded in gateway exchanges at the points of interconnect which contain a 'mask' of legitimate messages and therefore reject all others as invalid. This is used by many operators for POTS interconnect.
- *Firewalls*—the interconnection of more complex services (employing, for example, transaction signalling) may require more comprehensive protection, such as double firewalls. Typically this may be in the form of a signalling relay point which, in addition to containing a mask of valid messages, can block messages to invalid signalling destinations (point codes), changing signalling routing to avoid network 'hot spots' and act as a fuse when unexpected signalling surges arise to prevent them from propagating into the network.
- *Mediation Devices*—Whereas screening and firewall devices are used for blocking unwanted messages, mediation devices modify the content or structure of messages to achieve compatibility between source and destination. Such devices will probably be required for interworking of complex IN-based services where interconnection is, say, at the SCP level.

In order to achieve seamless service operation with high integrity protection, a sequence of testing programs must be carried out which encompass stand-alone technical analysis and auditing of individual systems, multi-supplier interoperability, as well as inter-network interoperability. The depth of testing will obviously depend on the complexity of the service and interconnect. Responsibility for these tests should be shared between the equipment vendors and the service providers and network operators as shown in Figure 7.

The design for the equipment is usually in accordance with industry standards and the individual specifications of the client operator.

- The first step in the technical analysis is a thorough design review of the specifications. This concentrates on potential weaknesses, such as overload control algorithms, which have been identified previously. It usually becomes prohibitively expensive to correct a fault not detected at the design stage.

- The second stage involves stand-alone conformance testing on each system to verify the correct implementation of the specifications. This includes a check on the generic requirements and SS7 (CCITT No.7) standards, capability and performance, security, hardware and software quality, and, in particular, the feature and service capabilities. Any corrective actions can then be performed prior to product release.

- The third stage of testing considers interoperability necessary within the operator's network, often between multi-vendor systems, for transparent service operation. Such tests are usually carried out within the operator's test facility before intrusive tests are carried out in the network.

- Ideally, if network interconnection is likely for internetworked services, the fourth stage of testing should be cooperative, between the interconnected test facilities of a number of vendors and operators. For such multivendor/operator situations, diversity in the interpretation and implementation of the specifications can lead to operational difficulties. Such testing could take weeks rather than days.

- Stage five arises when an application has been made for a specific interconnect (for example, from a new entrant to an established PTO). If the switch is unfamiliar to the PTO, it would be reasonable to insist on interconnect testing to the PTO's test facility. In addition to straightforward interoperability tests, stress testing would probably be carried out to observe the reaction to such things as overload and fault recovery. Such tests and analysis could take four to five weeks.

- At the time of interconnect, intrusive tests should be carried out at each point of interconnect between the two 'live' networks (stage six). The tests would typically comprise electrical and alarm tests together with test calls and SS7 signalling tests on each type of route with diagnostic testers to check the message sequences. Typically, this could take three to four days for an experienced operator. Such tests may be reduced if similar equipment has been used without problems by other operators interconnecting to the TO.

- A reduced set of intrusive tests should be carried out if a new software generic is introduced; or if additional capacity and/or new routes are added to the interconnect. This would be stage seven.

Interconnecting testing can be time consuming and expensive. Unlike CPE type approval, which is carried out by neutral bodies, interconnect testing is dictated by the dominant PTOs. It is conceivable that PTOs could impose over-elaborate testing that would discourage or delay other operators or SPs from connecting to their networks. In the USA, ATIS has produced standards agreed test scripts but their use is not mandatory.

It is conceivable that internetworked services may require the collaboration of resources in more than two networks. Hence, even though bilateral interconnect testing is satisfactory, the use of three or more networks to provide an internetworked service may give rise to integrity violation in one or more networks.

Software Upgrades

Digital exchanges and signalling transfer points are subject to regular changes in data and upgrades to software design. Hence, interconnected networks are in a state of constant change which may invalidate previous interconnect testing. Furthermore, although standard interfaces may be assumed, in multivendor interconnected networks, each manufacturer may interpret standards differently. Experience in the USA has shown that corruption of data and changes to software are a significant cause of intranetwork outage, particularly for CCITT No.7 signalling networks; it can be assumed that there are similar internetwork risks. Indeed, some operators insist on a reduced test programme being carried out when significant software updates are made at the point of interconnect.

In a multiple-provider-interconnected networks environment, it may be assumed that interconnect interfaces should be defined by standardised protocols, such as CCITT No.7. This implies that the software elements within the networks can be designed by different manufacturers and administered by different network operators. But, conformance to standards can still lead to incompatibility because each manufacturer may interpret protocol aspects differently. The continuous upgrading of software within the interconnected networks means that the compatibility between generic levels of software across the networks becomes difficult to maintain.

Collaborative Network Management

The key role of collaborative network management, in the context of the telecommunications management network (TMN), is to provide mechanisms that enable both the containment of risk and efficient remedial action in the case of network integrity problems.

Today's network management systems are composed of a large set of varied support systems strongly dependent on the state of the art of each managed network. There are several types of management system that are in use in the public environment, namely equipment provided by the manufacturers of network elements and the 'home made' systems of TOs. Few of these can be regarded as 'open systems'. There is a clear predominance of particular systems developed for, and tailored to, specific needs, which results in a poor level of integration among these systems and inconsistencies and overlapping among the management data.

The level of automation of management functions is quite low and there is extensive involvement of human operators in many management aspects. The level of interworking between management systems of the various operators in countries permitting interconnect appears to be quite low, being restricted to accounting management for the management of international circuits. This means there is little opportunity for collaborative network management except by 'manual' means. It is therefore important to establish effective manual procedures to cater for the possible need for rapid restoration of integrity failures between interconnected networks.

The long-term scenario assumes that there is a data communications network between the management systems of TOs and SPs and that the collaboration between the management systems is in a cooperating or joint mode. This is obviously the preferred solution to rapidly overcome integrity problems occurring between networks, but relies on interaction between systems together with the '*x* interface' between operators' systems. Given that the network management systems also interact with the embedded network control, care must be taken to ensure that interaction between the systems and networks does not in itself cause integrity problems.

Conclusions

The level of interconnect between the networks of TOs will inevitably move from being relatively simple and mature, to increasing innovation and complexity with sophisticated internetworked services making use of a variety of network elements provided by TOs and SPs. Thus the risk to network integrity is bound to increase. In essence, it is a problem of control engineering requiring a better understanding of the control architecture of telecommunications networks, if adequate protection methods are to be developed. This article has summarised a study carried out by University College London (UCL) for the European Commission. Further, detailed modelling work is being undertaken by the college.

Biography

Professor Keith Ward
University College London

Keith Ward joined UCL in 1992, as Visiting Professor in Telecommunications Business, when he retired from BT after 44 years service. During this time he became Chief Engineer responsible for the planning and works associated with the BT UK network and established the *BT Telecommunications Masters Programme* that is validated by UCL and who award an M.Sc. in Telecommunications Business to successful delegates. He is a Fellow of the Institution of Electrical Engineers, a Fellow of the City and Guilds of London Institute and a Member of the Institute of Management.

Glossary

ATIS Alliance for Telecommunications Industry Solutions (USA)
CLASS Customer local area signalling services
CLI Calling line identity
CPE Customer premise equipment
FCC Federal Communications Commission (USA)
IN Intelligent network
IP Intelligent peripheral
IT Information technology
OLO Other licensed operator
ONP Open network provision
POTS Plain old telephone service
PSTN Public switched telephone network
SCP Service control point
SDH Synchronous digital hierarchy
SP Service provider
SSP Service switching point
TMN Telecommunications management network
TO Telecommunications organisation
UCL University College London

Kevin Rose and Pat Hughes

The BT Speech Applications Platform

BT's speech applications platform (SAP) has been developed to support BT's future network voice services, the first being Call Minder. This article discusses the design of voice services and gives an overview of a telephone network-based speech system; it goes on to describe the SAP in more detail.

Introduction

Like all companies, BT is looking to increase its range of products and services and offer these at competitive prices. This is particularly true of any new telephone network service. With this in mind, BT Development and Procurement has spent the past four years developing the BT speech applications platform (SAP) for providing BT's future network voice services. The first of these new services—Call Minder, a call answering service—will be launched in early 1995. Although the SAP was primarily designed for network-based voice services, the design philosophy adopted means that it can support non-speech applications (for example, remote meter reading) and operate at the periphery of the main telephone network.

By way of an introduction to the article, the design of voice services is discussed to highlight some of the problems faced by speech system designers. A high-level functional overview of a telephone network-based speech system then follows. The remainder of the article discusses how the SAP has been realised as an operational system within BT's telephone network.

This article is derived from a paper on speech systems that will be published in the April 1995 edition of the *BT Technology Journal*[1].

Designing Voice Services

The perceived quality of the services offered by a telecommunications company, and thereby the perceived quality of that company is, in part, derived from experiences which customers have when using or encountering network and voice services. In particular, such perceptions tend to be based upon the ease of use and naturalness of these

Definitions

For the purpose of this article, the following definitions have been adopted:

Customer: A person who wishes to implement a network service (for example, call diversion) or owns a network voice service (for example, voice mail).

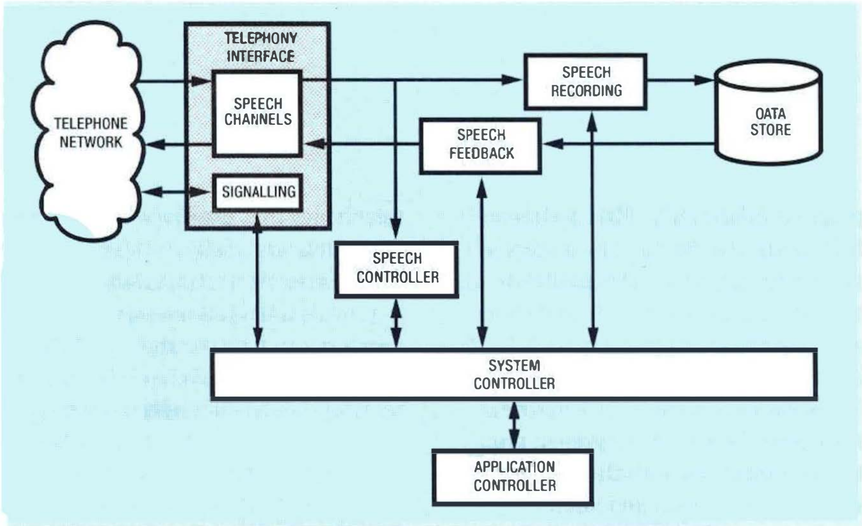
Caller: A person who is met by a network or voice service when making a telephone call.

Telephone: The method by which a customer remotely controls access to a network service via the telephone network. Control is through the use of speech or call 'set-up' signals; that is, loop-disconnect transients or dual-tone multifrequency (DTMF) tones—often referred to as *TouchTone®*.

Network Service: A telephone management service. Such services would include call diversion, message waiting, etc.

Voice Service: Automated customer voice services. Such services would include call answering, voice messaging, etc.

Figure 1—Speech system functional block diagram



services. As such, it is important that voice automation and voice services are used in appropriate circumstances and are designed and structured to improve perceptions rather than lower them.

Managing customers' expectations is a subject that all companies wrestle with on a day-by-day basis; a comprehensive treatment of this subject can be found in Reference 2. However, a brief review of the human factors aspects of telephone network services is presented here to illustrate some of the problems facing designers of speech services.

By way of an example, consider making a telephone call to a mail-order company. In this case, the customer would expect the call to be answered quickly and would wish to be dealt with in a polite and efficient manner. Even if the mail-order company in question cannot provide the requisite service, it would wish to leave the customer with a good impression, so facilitating repeat business. Most companies strive for this goal when dealing with customers on the telephone, whether via human or automated operators. However, in practice, it is clear that the customer's expectation of an interaction with a machine is different to that of interacting with a person. Imposing a badly designed automated service or insisting that callers interact with automated services in inappropriate circumstances can ultimately be damaging to the business. Conversely, appropriate use of well-designed and implemented services can significantly enhance customer and caller perceptions.

In many cases, given the choice of interacting with a person or a machine, callers do not choose to interact with an automated service. An illustration of this is the response which many people have when confronted with an answering machine. In some cases, the caller simply hangs up and does not leave a message. Although the caller may be disappointed at not having made direct contact with the person called, this behaviour is accepted, but is difficult to explain rationally. In addition, the owner of the answering machine has installed the answering machine not only for his/her own convenience but also for that of the caller.

Although this is a simple example, it demonstrates that customers' expectation and attitude on meeting an automated speech system differ considerably from that of a person-to-person interaction. As such, a key problem facing developers of all automated voice services is how to manage the interaction such that callers are positively encouraged to continue the dialogue with the speech system, despite a possibly negative attitude to such interactions. This problem is all-pervading and, at the current time, is relatively independent of the specific technology or architectural approach used to deliver the network or speech service.

Speech Systems—A Functional Overview

A speech system in a telephone network has three principal functions:

- to provide general voice guidance (for example, informing a customer when they have dialled an unrecognisable telephone number);
- to provide customers with automated control of network services (for example, invoking a call-diversion facility); and
- to provide voice services such as call completion, voice messaging, etc.

A speech system can be broken down into key components as shown in Figure 1.

The nature and function of each of these components are discussed below.

Telephony interface

The telephony interface can be divided into two functional areas: the speech interface, and the signalling interface.

In systems with relatively few lines (up to 10, say), the telephony interface is usually an analogue connection. The signalling available from an analogue interface is limited to a small number of call progress tones (for example, equipment busy tone, etc.) which the speech system has to detect automatically in order to manage the call.

When the number of lines becomes large, it is far more economical to use a digital telephony interface. This brings the added benefit of improved speech quality. Signalling over digital connections comes in two forms: channel associated, and common channel. Although channel-associated signalling is easier to handle than analogue signalling, the call management information is essentially the same as for the analogue interface. With this form of digital signalling, the analogue supervisory tones are allocated digital codes which are then embedded within the speech channels and can be detected and interpreted by the speech system.

However, common-channel signalling, where the signalling and speech information are transmitted separately, contains extensive call-related data in addition to basic call-progress information. This additional information can be used by a speech system for improving the quality or ease of an interaction with customers and callers. One example of such information is calling line identity (CLI). This can be used by the speech system to identify the customer, prior to any interaction with the speech service taking place, and allow customer-specific information to be accessed, thus improving the perceived quality of the interaction. For example, the speech system might inform the customer which network facilities were currently invoked on his/her telephone line.

Remote Controller

The purpose of the remote controller is to detect the control signals sent from the customer's telephone. The customer has two methods available for remotely controlling a service using the telephone: the keypad or dial, and the microphone; that is, using speech.

The telephone dial or keypad were designed purely for call set-up and hence signalling from the telephone to the local exchange. With the advent of TouchTone® signalling, it was quickly realised that these tones could be transmitted across an established telephone connection (after call set-up) and reliably recognised at the receiving end. In the UK, however, there are some telephones that use loop-disconnect signalling, especially in the residential market. As a result, and in order to provide a ubiquitous service, it is necessary to consider the use of loop-disconnect transients† as a means of remotely controlling network services; however, the speed of transmission and the accuracy of recognition for loop-disconnect transients is lower than that for TouchTone® signalling.

In operation, the remote controller recognises the signals sent by the customer's telephone and transmits them to the application controller (see later). The number of different signals that can originated by a telephone dial/keypad is limited to twelve—the digits '0–9', '*' and '#'‡—although loop-disconnect telephones usually transmit the digits only.

An alternative approach to providing callers with the ability to control network services from their telephone is to use voice recognition. In this case, the customer speaks appropriate commands into the telephone microphone. Using speech commands in this way has two principal advantages over the keypad/dial:

- there is, in theory, no limit to the size of vocabulary that is available, and
- control of the service can be made to appear more natural and, therefore, easier.

To facilitate this type of control, the speech system must be able to recognise the speech commands spoken by the customer. Until recently, the quality of speech-recognition technology was not perceived as being acceptable for deployment in network services. This perception was reinforced to a degree by an early approach to the use of speech recognition, which was simply to replace TouchTone® key presses with the spoken form (that is, rather than dialling/pressing the digit '1', the customer was invited to say the word 'one'). This particular approach proved to be less than satisfactory for a number of reasons. Not only are the spoken digits notoriously difficult to recognise automatically—they appear to a recogniser to be very similar acoustically—the control of the service was slower than using the keypad/dial. As a result, customers became frustrated with the early voice-driven services.

The utilisation of speech recognition as a form of remote control has, however, progressed substantially in recent years through advances both in the performance of the underlying recognition algorithms and the price/performance of the hardware needed to run these computationally intensive processes. As the technology has advanced, the application of speech recognisers has tended to drift away from being simply 'digit' detectors to that of assisting users to invoke facilities in a more natural fashion. To this end, speech recognition now tends to be used primarily to identify service command words.

An example of where the speech recogniser can be used in this way is in the customer invocation of network services. Currently, a customer invokes a network service, such as call diversion, by entering a unique code made up of TouchTone® digits. However, customers may forget the code for the network service they wish to use. By using a speech recogniser, the customer could simply speak the name of the service required (for example, 'divert'), and the speech system would transmit the appropriate service code to the network. The keypad is used only for entering telephone numbers; for example, destination telephone numbers for diverted calls. If the customer does not have a telephone with TouchTone® signalling, then the speech recogniser can be used for recognising digits, or (but with less reliable results) loop-disconnect transient recognition may be used.

In order to optimise the accuracy of the speech recogniser, the number of words to be recognised at any one time needs to be kept as small as

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† A telephone produces loop-disconnect signals simply by making and breaking the direct current on the local telephone line. During call set-up, these direct pulses are terminated at the local exchange and are not transmitted any further. If these pulses are transmitted once a call is set-up, a series of transients is induced on the line beyond the local exchange and these can be detected at the receiving end of the telephone connection.

‡ There are 16 TouchTone® tones; however, only 12 of these are used by most telephones.

possible and the words themselves need to be easily distinguishable. As such, allowable key words that are used within a service need to be carefully chosen to ensure optimum performance. In the same way, the prompts or guidance messages given to the customer need to be worded carefully to guide the customer, politely and unobtrusively, to use the appropriate words.

Speech feedback

Feedback to the customer can be in the form of supervisory tones or speech (via the telephone loudspeaker), or visual indication (by utilising the display that can be found on some telephones). Supervisory tones are still widely used for feedback to the customer; for example, dial tone, busy tone, etc. However, speech feedback is increasingly being deployed to improve the customer interface; for example, the BT telephone network now plays a message to a customer when it does not recognise a dialled number instead of playing *number unobtainable* tone. Visual feedback is increasingly being used as telephone instruments evolve to include display capability, but this particular form of interaction is relatively new and is not considered further in this article.

The quality of the voice used in speech feedback is an important factor in creating a favourable impression with customers. Quality is both subjective and nebulous; however, a few basic attributes can be identified. The intonation of the voice should create an impression of helpfulness and politeness; however, it should be assertive when required. For example, it may be necessary at some point in the dialogue to instruct the customer to undertake a simple action. The pace of the voice should be such that the customer does not feel rushed. The type of voice selected can also set the perceived 'style' or 'personality' of the company providing the service. For example, a Scottish company may purposely choose a Scottish accented voice for its automated speech services.

Speech recording

Some applications may necessitate the storage of customer information. However, speech requires large amounts of storage; for example, one minute of speech recorded at the standard digital pulse-code modulation (PCM) telephony transmission rate of 64 kbit/s requires 480 kbytes of storage. At this rate, the speech storage soon becomes a limiting factor with respect to cost and the time taken to retrieve the data. As a result, most speech systems employ some form of data compression to reduce the amount of speech storage required. The most common compression rate currently being used in commercial speech systems is 32 kbit/s†; that is, one half of the standard digital telephony transmission rate. Using speech compression also helps reduce the internal data transmission requirements within a speech system, ultimately helping to reduce costs.

Data store

Most applications require the storage of customer information. This information is usually in two forms:

- *Service information*—for example, what services the customer currently has available. This is sometimes referred to as the *customer profile*.
- *Application information*—for example, in a call-answering application a caller may leave a speech message for the customer.

This information is ideally suited to the ordered storage methods offered by standard database structures; for example, relational databases.

† The most common data compression technique used is adaptive differential pulse-code modulation (ADPCM).

System controller

The system controller has two principal functions:

- to provide a simple means of controlling the speech system (for example, on a residential answering machine this would be the control buttons); and
- to undertake housekeeping to ensure that the speech system is functioning optimally.

Application controller

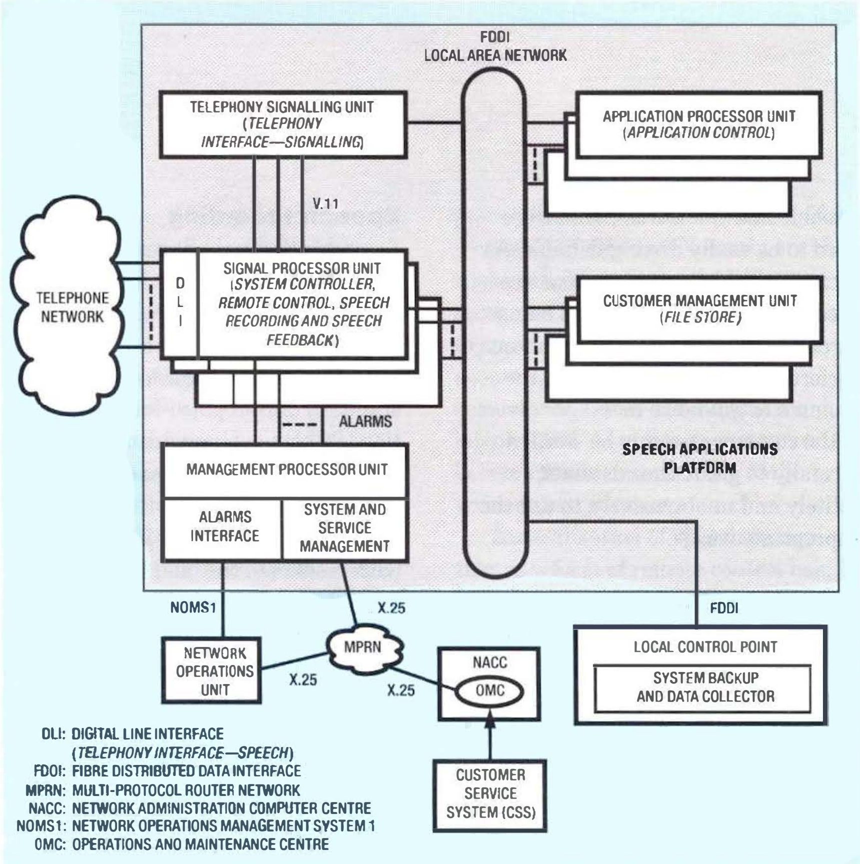
The role of the application controller is to coordinate the elements of the speech system in order to execute a defined transaction, or dialogue, with the customer/caller. All the functions described above (that is, speech feedback, speech recognition, TouchTone® recognition etc.) can potentially be used for interacting with a customer. The only differences between the dialogues for different applications are:

- the order in which the functions are implemented,
- the feedback messages given,
- how the recognised TouchTone® tones/loop-disconnect pulses are interpreted,
- the words to be recognised, and
- the customer profile or caller information that is to be recorded and stored.

The application controller makes requests to the system controller to perform some task; for example, record the customer's voice.

Having reviewed the functional aspects of a speech system, the remainder of this article is dedicated to describing BT's latest network-based speech system, the BT speech applications platform (SAP) and how it fulfils the various functions outlined above.

Figure 2—The BT speech applications platform network element



The BT Speech Applications Platform

The BT SAP consists of six principal units. Figure 2 shows a functional block diagram of a SAP network element for supporting new voice services, such as the BT Call Minder call-answering service, in the BT telephone network. The nomenclature in *italics* in Figure 2 corresponds to the functional units described in the previous sections. This system has been connected into 21 sites in the BT telephone network primarily at digital main switching units (DMSUs). The system is based on the industry standard VME bus which is used for transmitting control information between the various elements within each processing unit. The function of each unit within the SAP is described below:

Telephony signalling unit

(telephony interface—signalling)
All telephony communication, both speech and signalling, is provided by standard 30-channel PCM systems terminated on the digital line interface on the signal processor unit (see later). Each channel provides a 64 kbit/s bearer. Note that the telephony signalling unit handles the signalling functions of the *telephony interface*.

The signalling channels are separated from the speech channels on the digital line interface. The signalling information is then transmitted to the telephony signalling unit (via a V.11 interface). The signalling used is CCITT common-channel Signalling System Number No. 7 (C7). The telephony signalling unit handles levels 2 and 3†—message transfer part (MTP)—of the signalling protocol and extracts the level 4† call processing information—network user part (NUP). The NUP contains the call-processing functionality required to carry out the network service; for example, status of line, CLI etc. The NUP is transmitted to all the signal processor units via the fibre distributed data interface (FDDI) local area network (LAN).

† These C7 signalling levels do not correspond to CCITT Open Systems Interconnection (OSI) layers.

The telephony signalling unit contains three signalling links from separate parent telephone exchanges; this arrangement is sometimes referred to as *triple parenting*. This is to enable alternative network routing in case of traffic congestion or exchange failure.

Application processor

(application control)
The function of the application processor is to run the applications software. As mentioned earlier, each application is a dialogue transaction with the customer/caller.

An application process manages the telephone call via the telephony signalling unit and makes requests to the signal processor unit for signal-processing functions via an object-oriented application programmers interface (API). The API is a library of high-level functions that allow an application to be developed, while at the same time shielding the application developer from the underlying complexity of the SAP system. For example, the application processor could issue the request, 'play stored message No. X to telephone channel No. Y' without any knowledge of the type of telephony interface or the compression rate at which the message was stored.

The application processor can be either located in each of the signal processing units or as a separate central resource that communicates with each signal processing unit via the LAN. For clarity, Figure 2 shows the latter configuration; however, the SAP systems integrated into the BT telephone network have the signal processor units and application processors collocated in the same shelves.

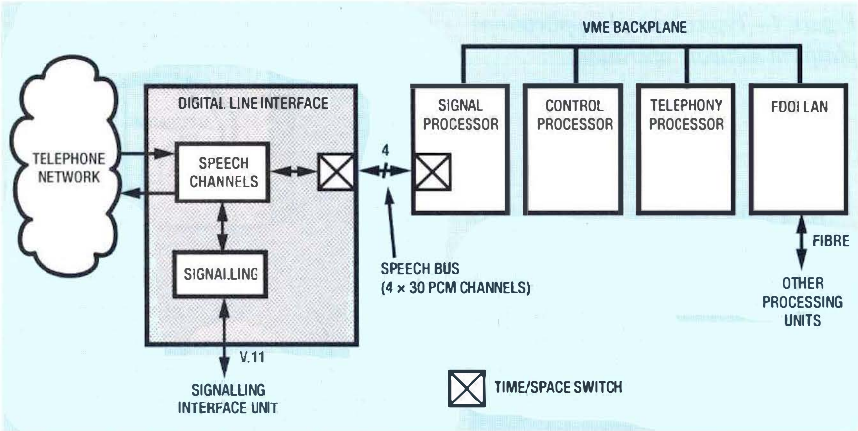
Signal processing unit

The signal processing unit performs the roles of *system controller, remote controller, speech feedback,* and *speech recording*. This unit is shown in Figure 3.

As the system controller this unit is effectively the heart of the SAP and is divided into five main modules:

***Digital line interface** (telephony interface)*
This unit terminates all digital telephony links and separates the signalling information from the

Figure 3—Speech processing unit functional block diagram



speech data. Most of the data channels carry digitised speech signals and are transmitted to the signal processors via the speech bus.

Speech bus

It is possible to transmit speech data over the VME control bus; however, as mentioned earlier, digital speech signals have a high data rate and the available bandwidth on the control bus would quickly be exhausted. This would limit the amount of control information that can be transmitted with the result that less voice services can be supported per system. As such, and like most large voice systems commercially available today, the SAP transmits control information and speech data on separate busses.

As the name suggests the speech bus is used for transmitting the speech data, leaving the VME bus for control information only. The speech bus has four 30-channel PCM highways that are used for transferring speech data between the digital line interface and the signal processors. Connection to the speech bus is via time-space switches located on the digital line interface and signal processor units. This provides the capability for the speech data to be switched internally within the SAP and creates the infrastructure required for dynamically allocating the speech resources (see later).

Telephony processor

The telephony processor processes the C7 signalling NUP call-processing information from the telephony signalling unit and converts this information into a form that can be manipulated via the API.

Control processor

The control processor has two primary tasks: to manage the signal processing resources when requested by an application (via the API), and housekeeping. On receipt of an API request (for example, RECORD SPEECH), the control processor schedules the speech processing resources to undertake the task. This will include switching the speech data from the digital line interface to the appropriate signal processor resource via the speech bus. As housekeeper, the control processor continually monitors the state of all modules to ensure that they are functioning correctly.

Signal processors

The signal processors execute the various signal processing functions (for example, speech recognition, speech recording, speech playback, etc.) requested by the control processors.

Customer management units

(data store)

These units are the mass storage systems that contain the customer profiles and customer speech data for different applications. An open interface standard has been adopted for these units so that the appropriate technology can be utilised to meet the service requirements. In the case of the BT telephone network implementation, Winchester disk technology has been used with each individual disk having a 'shadow' for resilience. The customer management units are shared between all the other units and the data is managed by using a relational database management system.

Management processor

This unit is the interface between the SAP system management and BT's network management systems. It has three principal functions:

- To raise alarms to the network operations unit (NOU) via the BT network operations management system (NOMS) interface.
- Undertake system management commands requested by the network engineer in the NOU. For example, the engineer may interrogate the status of a particular SAP unit if an alarm is raised. These commands are transmitted from the engineer's system console in the NOU via the BT X.25 multi-protocol router network (MPRN)†. Statistical information, such as the number of calls handled is also provided upon request from the network engineer.
- Update customer information; for example, add a new customer. This information would be transmitted from the customer service system (CSS) and collected by the operations and maintenance centre (OMC) software in a network administration computer centre (NACC) and transmitted onto the SAP via the MPRN.

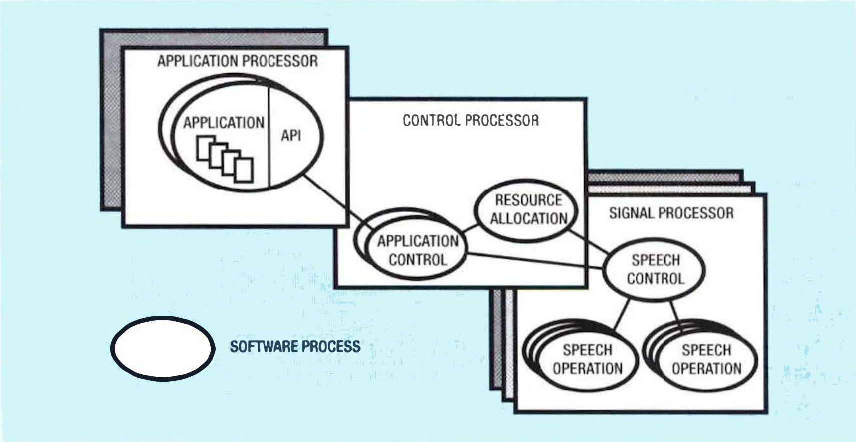
All the SAP processor units can send and receive operational information, such as statistics, alarms etc., to and from the management processor, which then converts this information into the format required by BT's network management systems.

System backup and data collector

As the name suggests, this unit has two roles. As the system backup unit, it holds an up-to-date software image of the whole SAP system together with the applications software. Periodic backups are undertaken such that in the case of failure the system can be restored to the known state at the time of the last backup. The backup is stored on a magnetic tape cartridge.

† Until recently, this X.25 network was known as the administration data packet network (ADPN)

Figure 4—Typical speech applications platform software operation



As a data collector, the unit can be programmed to monitor and record transactions undertaken on the SAP. For example, if the performance of the speech recogniser for a particular application needs to be assessed, then all invocations of this application are recorded by the data collector. This information is then stored on some form of bulk removable storage media, such as optical disks, and removed for analysis. The system backup and data collector is usually located in the same place as the telephone exchange backup tapes; for example, local control point (LCP).

Local area network

All the above units communicate via an FDDI optical-fibre LAN, although for smaller installations, an Ethernet LAN is used.

Software overview

From a software perspective, the SAP is a collection of independent software components each providing an integral part of the speech system. From a technical perspective, these units have considerably different constraints placed upon them and the approach to software design reflects this difference. In line with the design philosophy, either open and/or industry standards were adopted as appropriate.

A full description of the SAP software would warrant an article in its own right; however, to give a flavour of the software operation, a single API command process is described.

Figure 4 shows a diagrammatic representation of the software processes involved in the execution of a typical API command.

For example, assume the application program issues the API command, RECOGNISE_TOUCHTONE®_KEYPRESS. The API passes this command to the application control process (that runs on the control processor), which in turn requests the resource for this function from the resource allocation process.

The resource allocation process reviews the current state of the signal processes (running on the signal processor unit) in the available pool and decides which of these should execute the TouchTone® recognition—this is the heart of the dynamic resource allocation process adopted on the SAP. Several factors are taken into consideration when making this decision; for example, is a signal process resource available that has just executed a TouchTone® recognition so that it can be reused and therefore avoid having to reconfigure another resource?

Once the resource has been identified, the resource allocation process informs the speech control process (that runs on the signal processor) of which process to run, on which resource to run the process, on which speech bus channel (not shown in Figure 4) to expect the incoming tone, and to which application process the recognised tone should be returned.

The TouchTone® recognition is then performed (speech operation). Note that, in practice, many speech operations are being undertaken simultaneously. Once the process has been executed, the result (the recognised TouchTone® digit) is passed to the speech control process and then onto the application control process. The speech control process also informs the resource allocation process that the signal processing resource used for the TouchTone® recognition is now available.

Finally, the application control process returns the result of the TouchTone® recognition to the application program via the API. The system operation is very complex owing to the large number of concurrent processes; however, it is this concurrent operation that provides the most optimal use of the available resources.

The optimal method by which the SAP utilises its resources is known as *dynamic resource allocation*; this is one of the features that distinguishes the SAP from other speech systems currently available.

SAP Signal Processing Functionality

The following processing functionality is currently available on the SAPs installed into BT's telephone network.

- *TouchTone® recognition*—recognition of TouchTone® digits transmitted from the customer/caller.
- *Loop-disconnect transient recognition*—recognition of loop-disconnect signals transmitted from the customer/caller.
- *TouchTone® generation*—use of TouchTone® digits to control remotely other items of telephony equipment; for example, pagers.
- *Speaker-independent speech recognition*—the recognition of up to about 30 words spoken by any person. This type of recognition would be used for the command words of a network service. The smallest vocabulary would consist of the words 'yes' and 'no' which would be used for very simple control of voice services such as Call Minder.
- *Speaker-dependent speech recognition*—the recognition of up to about 30 words spoken by a particular person. This type of recognition would be used when a

customer has chosen specific words for a particular application; for example, repertory dialling.

- *Speech recording and playback at 64 kbit/s*—speech data is recorded and played back at the standard telephony PCM rate. This facility is used when speech storage requirements are minimal.
- *Speech recording and playback at 8 kbit/s*—the speech is recorded at one eighth of the standard telephony PCM rate (64 kbit/s), which offers a major saving in data storage over other commercially available speech systems. The quality of the reproduced speech is (subjectively) as least as good as the speech produced by telephone answering machines.
- *Silence detection*—this is used to detect when customers/callers have stopped speaking when recording speech.
- *Call progress tone detection / generation*—used for signalling on analogue telephony circuits.
- *Modems*—used in applications that require data transmission; for example, remote meter reading.

It is planned to upgrade the SAP to include a number of new and advanced functions. These new functions will considerably expand the range of services which the SAP can support and further enhance its usefulness to BT.

SAP Tools

Several tools have been developed to assist in using the SAP and are outside the scope of this article. However, the Visage application generation tool[3] should be mentioned in that it significantly benefits the developer of network services. Visage is a PC-based tool with a graphical user interface that assists with designing voice services. The tool imposes a set of design criteria upon the designer to ensure that services developed meet a set of criteria defined in a style guide[4]. By using the tool it can be ensured that each service has the same 'look and feel'. Once the service has been designed, it can be loaded directly onto the SAP application processor via the FDDI LAN. Therefore, the time taken to develop and test new services is dramatically reduced.

Conclusions

Network-based voice services are predicted to increase significantly over the next decade. The deployment of the SAP into the BT telephone network has provided an infrastructure which can be used to support these services. It is hoped that the next few years will see more services supported by the SAP with consequential benefits to BT. In the meantime, further development work will be undertaken to make the SAP even more cost-effective with further increases in functionality.

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Biographies

Kevin Rose
BT Development and Procurement

Kevin Rose joined BT Laboratories (BTL) as an apprentice in 1973. After graduating from Essex University with a B.Sc. in Computer Systems and an M.Sc. in Telecommunications Systems in 1983, he joined the newly established Speech Division in BTL. He has remained in the field of speech technology except for a short period in BT's Switching System Business Unit. In 1990, he became responsible for the development of the BT SAP and has managed its development from feasibility through to implementation into BT's telephone network. This has included managing the launch of the Call Minder pilot service. He recently became manager of the development of BT's range of video-telephony products, as well as the application of the SAP in advanced voice trials.

Pat Hughes
BT Development and Procurement

Pat Hughes graduated from Liverpool University with a B.Eng. in Electronic Engineering in 1978 and went on to study for a Ph.D. Some six years later, having completed his doctorate in digital signal processing and spending three years as a lecturer, he joined BTL, working on speech analysis and synthesis. He became involved in the development of speech platforms, working initially with network-based message announcement systems. Later he worked on the development of the SAP and is named on the patent documentation as one of the co-inventors of the SAP. He is currently still actively connected with the SAP, coordinating its onward development.

Ian Pearson and Peter Cochrane

200 Futures for 2020

Articles in this series have been considering possible future developments in telecommunications into the 21st century. These can be considered against a wider backdrop of future changes in technology and society. Bringing together views from a wide range of organisations, including BT Laboratories, this article lists technologies, events and trends that may be key features in our society in the next 25 years.

Predicting the Future

Twenty-five years ago, there were no personal computers, laptop machines, liquid crystal displays, digital wristwatches or pocket calculators. Most households didn't have a telephone or a colour television set, and tape recorders still used open reels. Washing machines, cars and other domestic appliances contained no intelligence and there were no camcorders or VHS players. However, man had been to the moon and the space race, plus the cold war, had promoted the creation of integrated circuit technology. Since that time, our electronic-based industries and society have seen a doubling in capability every one or two years across a broad range of technologies. Today, most people in the first world have a telephone, at least one colour television, a VHS player, camcorder, personal computer and any other item they desire. All of these have become consumer items.

The intelligence now available in a fairly average car is greater than that embedded in the first lunar lander! In fact, there are now wristwatches that have more computing capability than some mainframe computers of 25 years ago. Given this rate of progress, we can expect to see somewhere between a thousand- and a million-fold increase in electronic capability in the next 25 years. That is, the personal computer on your desk (or its derivatives) will be about a million times more powerful in 25 years. Moreover, this raw electronic capability will become more pervasive as we see mechatronics (the combination of mechanical and electronic engineering) realise a range of new devices ranging from internal body parts for humans through to robotic and cybernetic entities.

> 'Our plan is to lead the public with new products rather than ask them what kind of products they want. The public does not know what is possible, but we do. So instead of doing a lot of market research, we refine our thinking on a product and its use and try to create a market for it by educating and communicating with the public.'
>
> *Akio Morita*
> *Sony Corporation*

> 'Prediction is difficult, especially of the future.'
>
> *Neils Bohr*

Looking back over history, it is plain that predicting the future is extremely difficult and, while Ph.Ds in hindsight are in great supply, Ph.Ds in foresight are extremely rare! Futurologists currently use a combination of projection, extrapolation and pure 'guessology' to create their visions of technology and society in the decades ahead. In this brief article, we have used the same techniques augmented by a survey of reports and publications from organisations across the globe. The listing that follows therefore represents the combined wisdom and guesses of a multitude of organisations and people. We have also taken the insights and projections of our own team to temper and shape the listing of 200 technologies, events and trends we predict to be key features of our society and individual lives by the year 2020. In most cases, the single-phrase descriptors are self-evident and sufficient, but we have chosen to amplify some items to add further depth and explanation.

Our purpose in compiling this list was to create a concise and, hopefully, visionary document that condenses a wide range of views from a large number of organisations. It is intended to act as a catalyst to thought and discussion for others pursuing a future vision. Experience of compiling, debating and presenting the material that follows has been fun—we hope that you enjoy a similar experience as you read and contemplate our efforts.

A brief technology calendar is included to illustrate more graphically the progress of some of these technologies.

Biotechnology, Health and Medicine

1 Effective management of the organic environment. We will know the genomes of most plant and animal groups so will be able to manage gene pools effectively, and control their populations.
2 New engineered organisms used to produce chemicals. Organisms will be designed for production of commodities medicines and complex chemicals, and for waste disposal, agricultural processing and environmental management.
3 Widespread genetic intervention programmes for animals and plants. Many genetic enhancement techniques will be applied to wild and domestic organisms, including pets.
4 Many new forms of plants and animals from genetic engineering.
5 Custom foods for particular medical conditions will exist.
6 Genetic links of all diseases identified. The important biochemical mechanisms and interactions with the environment will also be known for most diseases.
7 Genetic screening widely used.
8 Genetic programmes to enhance human well-being. Beyond curing disease, we will see the enhancement of physical and mental abilities.
9 Genetic, chemical and physiological bases of human behaviour understood. This will allow control of mental disorders. Brain and mind manipulation will allow control of emotions, learning, senses, memory and other psychological phenomena.
10 Full personal medical records stored on smart card. Records will be highly comprehensive, with videos of operations, audiovisual interview records—complete life history on a smart-card-size device.
11 Individual's genome part of their medical record.
12 More people will live into their 80s in good health.
13 Many synthetic body parts available.
14 Home (health) diagnostic systems, daily/real-time check-up via radio.
15 Home artificial-intelligence-based elderly and handicapped support devices.
16 Devices roaming within blood vessels under their own power.
17 Sensors directly connected to human sensory nerves. Also artificial nerves.
18 Artificial senses, sensors directly stimulating nerves.
19 Direct pleasure production.
20 Prevention of cancer.
21 Artificial ears, eyes, legs, lungs, hearts, pancreas, liver, kidneys, blood.
22 Fine particle beam gene engineering.

Business

23 Global electronic currency in use.
24 Paper and coins largely replaced by electronic cash.
25 Paper cash used mainly for black market.
26 Virtual companies dominant.
27 Artificial-intelligence models used extensively in business management.
28 Purely electronic companies exist—minimal human involvement.
29 Universal monitoring of business transactions.

Devices

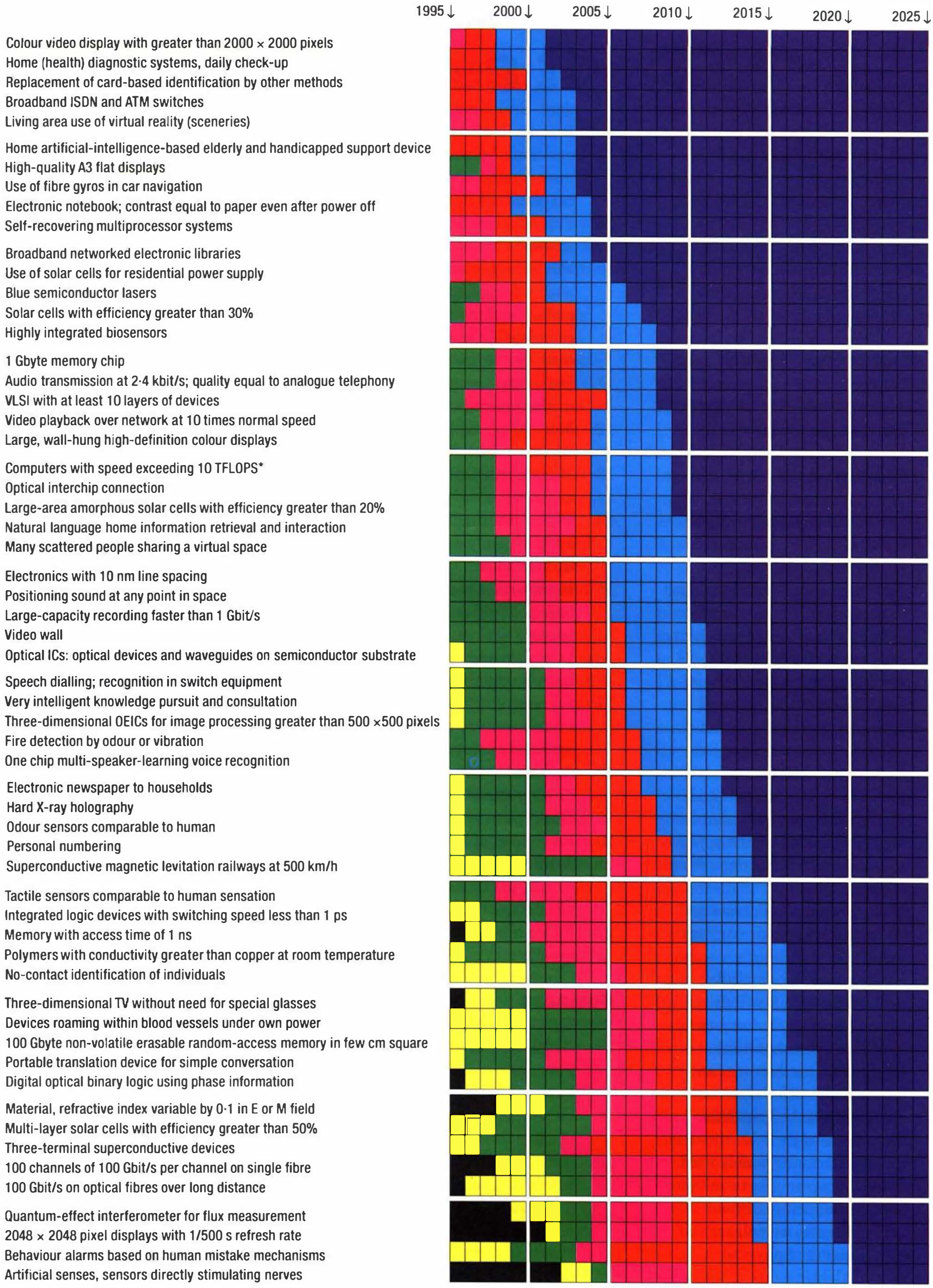
30 Self-recovering multiprocessor systems.
31 Blue semiconductor lasers.
32 Three-dimensional very-large-scale integration with at least 10 layers of devices.
33 Optical inter-chip connection.
34 Electronics with less than 10 nm line spacing.
35 Optical integrated circuits: optical devices and waveguides on semiconductor substrate.
36 Integrated logic devices with switching speed less than 1 ps.
37 Digital optical binary logic using phase information.
38 Three-terminal superconductive devices.
39 Quantum-effect interferometer for flux measurement.
40 High-performance non-linear optical third-order devices.
41 Super-lattice two-dimensional or three-dimensional controlled semiconductor devices.
42 X-ray free electron lasers with few dozen angstroms wavelength.
43 Self-organising adaptive integrated circuits.
44 Continuous-sheet production of large-scale-integrated semiconductor substrate.

Education and Knowledge Pursuit

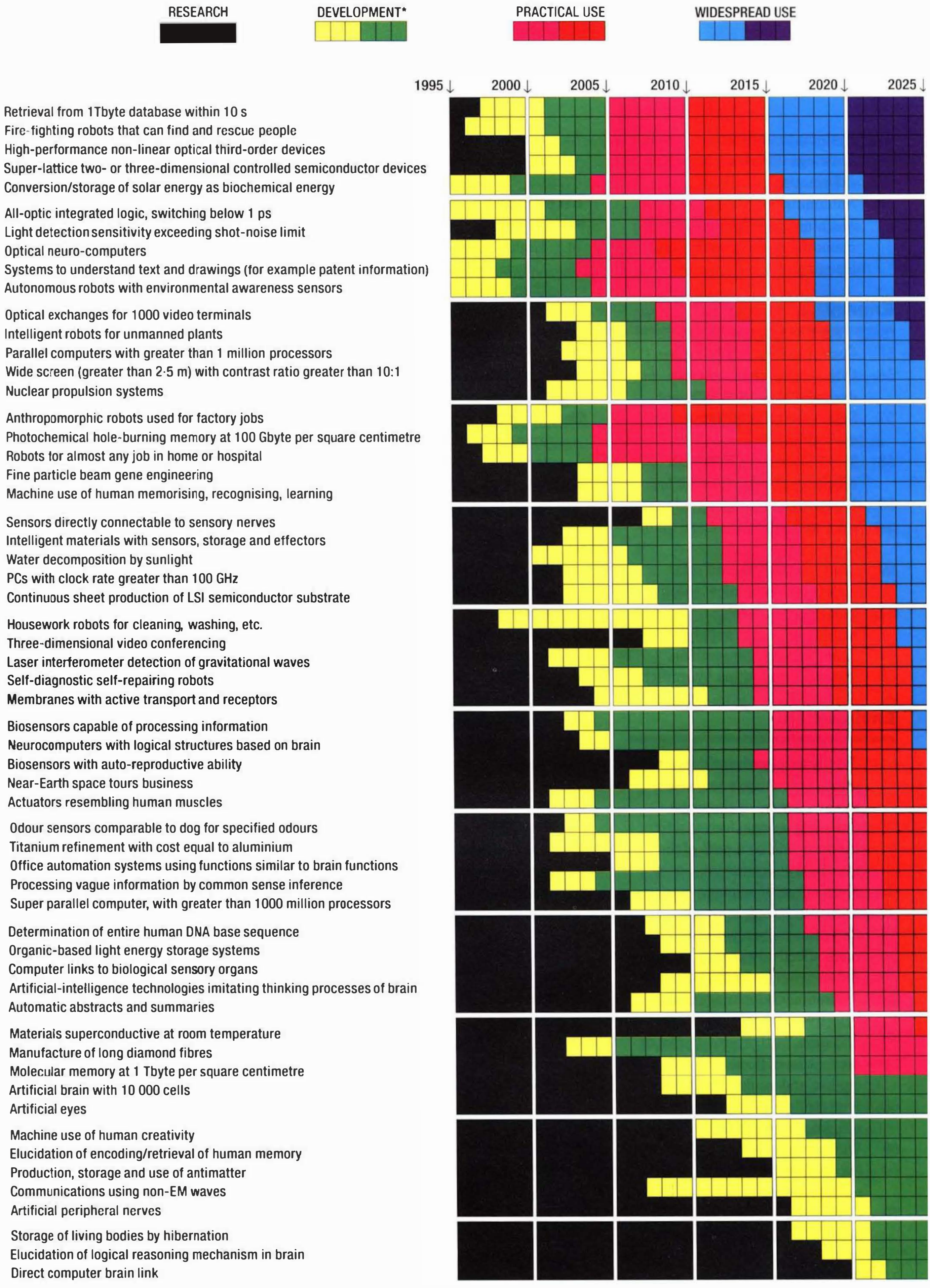
45 Life-long learning is the norm.
46 Distance learning widespread—virtual universities.
47 Expert systems surpass human learning and logic abilities.
48 Real-time language translation for print and voice.
49 Broadband networked electronic libraries.
50 Natural language home information retrieval and interaction.
51 Very intelligent knowledge pursuit and consultation.

List continued on p. 316

Technology Calendar



*1 TFLOPS = 10^{12} floating point operations per second
OEIC: Optoelectronic integrated circuit



* Development: achievement of goal/first prototype

52 Systems to understand text and drawings (for example, patent information).
53 Subliminal learning.
54 Machine use of human memorising, recognising, and learning.

Energy

55 Cost of energy will be higher.
56 Cities and accommodation designed to be more efficient.
57 Solar cells with efficiency of more than 30%.
58 Multi-layer solar cells with efficiency of more than 50%.
59 Large-area amorphous solar cells with efficiency more than 20%.
60 Conversion/storage of solar energy as biochemical energy.
61 Common use of solar cells for residential power supply.
62 Space solar power stations.
63 Water decomposition by sunlight.

Environment

64 Totally managed world environment. Extensive large-scale environmental engineering, including oceans, forests, etc. Industry will be a part of the managed environment.
65 More-effective resource management. Recycling, re-engineering and resource recovery will be more effectively used.
66 Extensive remote sensing use in environmental management.
67 Effective intervention in natural disasters. Mitigation, control or prevention of floods, earthquakes and landslides.
68 Worldwide NIMBY problem for refugees, waste etc.
69 Widespread contamination (worse than Chernobyl) by a nuclear device.
70 Carbon dioxide fixation technologies for environment protection.
71 Deep underground cities.
72 Artificial precipitation induction.
73 Global environmental management corporations.

Interfaces

74 High-quality A3 flat displays.
75 Colour video display with more than 2000 × 2000 pixels.
76 Large, wall-hung high-definition colour displays.
77 Wide screen (more than 2·5 m) with contrast ratio of greater than 100:1.
78 Video walls, including living area use of virtual reality (scenes).
79 Electronic notebook, contrast equal to paper even after power off.
80 Video playback over network at 10 times normal speed.
81 Many people sharing a virtual space.
82 Positioning sound at any point in space.
83 Three-dimensional television without need for special glasses.
84 Personal audiovisual interfaces well developed.
85 Three-dimensional videoconferencing.
86 Computer link to biological sensory organs.
87 Use of cheap holograms to convey three-dimensional images.
88 Full integration of processing, audio and video equipment.

IT Literacy

89 Everyone in advanced nations computer literate.
90 IT literacy essential for any employment.
91 Widespread virtual reality use for recreation and training.

Machine Input

92 Highly integrated biosensors.
93 Speech dialling, with recognition in switch equipment.
94 Single-chip multi-speaker-learning voice recognition.
95 Odour and flavour sensors comparable to human.
96 Tactile sensors comparable to human sensation.
97 No-contact identification of individuals.
98 Portable translation device for simple conversation.
99 Machine recognition of body language and gestures.
100 Hands-in-screen interface.
101 Biosensors capable of processing information.

Materials

102 Atomic customisation of materials.
103 Polymers with conductivity greater than copper at room temperature.
104 Material, refractive index variable by 0·1 in electric or magnetic field.
105 Intelligent materials with sensors, storage and effectors.
106 Smart skin for intelligent clothing and direct human repair.
107 Manufacture of long diamond fibres.
108 Use of polymer gels for muscles, bioreactors, information processing.
109 Membranes with active transport and receptors.

Memory and Storage

110 1 Tbyte memory chip.
111 Large-capacity recording faster than 1 Gbit/s.
112 Hard X-ray holography.
113 Memory with access time of 1 ns.
114 100 Gbyte nonvolatile erasable random-access memory in few square centimetres.
115 Molecular memory with density of 1 Tbyte/cm^2.
116 Retrieval from 1 Tbyte database within 10 seconds.
117 Optical storage media will be static; for example, optical card.
118 Single storage medium usable for all forms of data.
119 Memory/storage density still a bottleneck for some applications.
120 Photochemical hole burning memory at 100 Gbyte/cm^2.

Processing

121 Very widespread embedded intelligence. Everything will use processors, sensors and smart materials sensitive to heat, light, sound and electromagnetic fields where appropriate.
122 Computers with speed exceeding 10 TFLOPS (1 TFLOPS = 10^{12} floating-point operations per second).
123 Three-dimensional opto-electronic integrated circuits for image processing greater than 500 × 500 pixels.
124 Behaviour alarms based on human mistake mechanisms.
125 Extensive use of analogue and neural processing.
126 Artificial-intelligence technology imitating thinking processes of the brain.
127 Optical neuro-computers.
128 Parallel computer with 1000 million processors.
129 PCs with clock rate greater than 100 GHz.
130 Computers will write much of their own software.
131 Processing speed still a bottle-neck for some applications

Robotics

132 Robots will be commonplace. In home, factories, agriculture, building and construction, undersea, space, mining, hospitals and streets for repair, construction, maintenance, security, entertainment, companionship, care.
133 Domestic robots will be small, specialised and attractive; for example, cuddly.
134 Robotised space vehicles and facilities.
135 Totally automated factories commonplace.
136 Autonomous robots with environmental awareness sensors.
137 Intelligent robots for unmanned plants.
138 Anthropomorphic robots used for factory jobs.
139 Robots for almost any job in home or hospital.
140 Housework robots for cleaning, washing, etc.
141 Artificial brains with ten thousand or more cells.
142 Robots for guiding blind people.
143 Self-diagnostic self-repairing robots.

Security

144 Universal identification cards. May include nationality, medical history, education, employment record, credit status, social security, affiliations, passport, life history, etc.
145 Crime and terrorism will mainly be computer based.
146 Viruses based on advanced artificial intelligence will evolve and adapt.
147 Replacement of card-based identification by other methods.
148 Almost all transmissions will be encrypted.
149 Fire detection by odour or vibration.
150 Fire-fighting robots that can find and rescue people.

Social

151 Products of all kinds will be customised.
152 Infrastructures will be self-monitoring, using smart materials and sensors.
153 Factory manufactured housing will be the norm.
154 English still the global language.
155 Numerous worldwide virtual communities.
156 Worldwide popular culture, regardless of government intervention.
157 On-line voting.
158 Electronic shopping for many products will be the norm.
159 National decisions influenced by electronic referenda.
160 World population greater than 7·5 billion.
161 Average age in advanced nations will be 41.
162 Migration regulated by international law.
163 State pensions on a need-only basis.
164 More recreation and leisure time.
165 Still mass starvation in third world.
166 Rise of secular substitutes for religion, such as network-based groups.
167 Electronic newspaper to households.
168 Various forms of electronic addiction will be a big problem.
169 Replacement of people leads to anti-technology subculture.
170 Power will be held more by corporations than by countries.
171 Some cybernations will exist which have significant economic muscle.
172 Many people will have nationality of both geonation and cybernation.
173 Third-world technology highly vulnerable to first-world hackers.

Space

174 Orbiting space station well developed.
175 Regular manned missions to Mars.
176 Start of manned Mars laboratory construction.
177 Space planes in practical use.
178 Space factories for commercial production.
179 Moon base the size of a small village.

Switching

180 Electronic asynchronous transfer mode (ATM) switches largely obsolete and replaced by photonic versions.
181 Unified personal numbering for everything and everybody.
182 All-optic integrated logic, switching below 1 ps.
183 Optical switches for 10 000 interactive video calls (three-dimensional and virtual reality terminals).

Transmission

184 Global broadband fibre-based network.
185 Audio transmission at 2·4 kbit/s; quality equal to analogue telephony.
186 Multiple channels of greater than 100 Gbit/s on single fibre.
187 Tbit/s on optical fibres over long distance.
188 Light detection sensitivity exceeding shot-noise limit.
189 Network will still be a significant bottleneck for some services.
190 New mechanisms for communication discovered.
191 Laser interferometer detection of gravitational waves.

Transport

192 Interactive vehicle highway systems.
193 Use of fibre gyros in car navigation.
194 Various traffic information systems in use. These will help with navigation, traffic control, estimated time of arrival, dynamic routing, monitoring, taxation and crime prevention/ detection.
195 Energy provided by hydrogen fuel cells and/or solar power.
196 Nuclear propulsion systems for various transport types.
197 Ships with superconductive electromagnetic thrust.
198 Fully automatic ships able to navigate and dock automatically.
199 Passenger planes with speed beyond Mach four and greater than 300 capacity.
200 Superconductive magnetic levitation railways at 500 km/h.

Biographies

Ian Pearson
BT Development and Procurement

Ian Pearson graduated in 1981 from Queens University, Belfast, with a B.Sc. joint honours degree in Applied Mathematics and Theoretical Physics. After four years at Shorts in Belfast working on missile design, he joined the Performance Engineering Division at BT Laboratories studying data networks and protocols. He has since worked in several divisions, advising on the communication impact of technology developments, especially in computing and information technology. Inventions along the way include a free-format ATM derivative, various novel computer interfaces such as the active contact lens, and many other service and technology concepts. Since 1991, he has worked in the Systems Research Division investigating various aspects of future networks, while keeping a view of developments within IT.

Peter Cochrane
BT Development and Procurement

Peter Cochrane graduated from Trent Polytechnic with a B.Sc. Honours degree in Electrical Engineering in 1973 and gained an M.Sc., Ph.D. and D.Sc. in Telecommunications Systems from the University of Essex in 1976, 1979 and 1993 respectively. He is a fellow of both the IEE, IEEE and Royal Academy, a visiting professor to Essex and Southampton Universities and an honorary professor at Kent. He joined BT Laboratories in 1973 and has worked on both analogue and digital systems. He has been a consultant to numerous international companies on projects concerned with systems, networks and test equipment. In 1978 he became manager of the Long Lines Division and received the Queen's Award for Technology in 1990 for the production of optical receivers for TAT-8 and PTAT-1 undersea cable systems. In 1991, he was appointed to head the Systems Research Division at BT Laboratories which is concerned with future advanced media, computing and communications developments. During 1993 he was promoted to head the Research Department at BT Laboratories with 620 staff dedicated to the study of future technologies, systems, networks and services. He is also the Development and Procurement board member for technology.

José-Luis Fernández-Villacañas Martín

Artificial Life for IT

Systems that evolve and become self-maintaining could make the future information world more robust and easier to manage. This article reviews computational systems that evolve to become quicker, fitter and less-expensive solutions compared to those created solely by human programmers. The article highlights some of the current advantages and limitations of genetic algorithms and artificial life, and goes on to forecast progress towards the end of the millennium. The trade-offs between open-endedness and fitness for a specific task are discussed and the current state of the art is evaluated.

Introduction

When we face a new problem our first inclination is to look for an existing analogue for which a solution has already been found. For highly-complex technical problems with many possible solutions, what better analogy than life itself? Evolution and natural selection are very successful at creating, through mutation, different life forms that survive because they are fit for purpose and better match their environment than competitors. The question is: can we apply such well-established and proven principles to solve different problems? Just as giraffes mutated to have long necks and survived because they could feed from tall trees, can we expect the same behaviour from computer programs? The obvious answer seems to be yes, but we might anticipate that the biological analogy may need extension to create a more optimal process.

First is the question of replication; can programs have sex? In itself replication is nothing special as programs possessing this property date back to the 1950s. For instance, Von Neumann[1] created an automaton in a cellular space that was able to build a copy of itself and then set the copy to work independently. Further pioneering work in this field was completed by Codd[2], Myhill[3], and Penrose[4] who built a mechanical system with a limited ability to reproduce.

Second is natural selection; what is the force that decides whether a program lives or dies? Generally programs are immersed in an electronic and software soup that plays the part of the ecosystem: biological creatures use light (energy) to organise matter; programs use central processing unit (CPU) time to organise memory. Because these resources are limited, programs fight for a share, and if one dominates, it stops others running and brings them nearer to death. What should decide how programs share CPU and memory and consequently the ability to replicate? The answer leads to two different schools of thought for looking at, and solving the problem: the *genetic algorithm* (GA) and *artificial life* (AL).

Genetic Algorithm versus Artificial Life

The concept of evolving systems experienced a rebirth of interest with the publication by Holland[5] of a method of searching for function optimisation modelled on Darwinian evolution: the 'genetic algorithm'.

At a basic level, programs are strings of 1s and 0s similar to the nucleotide sequences in DNA that constitute the genetic code for living organisms. We might therefore expect them to be inherently capable of evolving in a similar way. Within a collection of computer programs, some are less efficient than others at a certain task. After completing the task, each program is given a *fitness* value that depends on its effectiveness. The worst programs are discarded and only the best are kept for sexual procreation. In this process, two programs exchange sub-strings of bits to create a new program with a mixture of information from both parents[1]. With a certain recurrence, mutations of single bits happen and change the offspring further. The new-born programs are then evaluated (their fitness value calculated) and the discarding process started again. The result is a population of programs that are progressively more effective.

GAs do not have any special requirements for the computer language in which they are constructed. They need a *simulator* that handles all operations including the evaluation of the fitness function and a *classifier system*. The latter consists of a series of outputs as a response to different inputs and is a way of representing the program so that any change in its genotype (the bit strings) leads to a meaningful change in its phenotype (what the program does).

What happens when the predicted output of the system is unknown? In this case, it is impossible to build a classifier system. Furthermore, if the output behaviours cannot be 'priced', it is not possible to write a fitness function. This situation occurs in many systems in real life. Fortunately, this type of problem is one nature has learned to deal with. It is called an *open-ended* problem and the new-born science that deals with such problems is artificial life.

If we have a long, complicated program, must we check every possible level of input and output, every single possible error? How do we test it? Writing the fitness function is very difficult and tedious.

Artificial life systems overcome this problem through an ecosystem characterised by computer resources (CPU and memory) and interactions with other programs. These decide when to replicate, although there are some restrictions imposed by the simulator (computer resources are finite). An explicit fitness function is a global description of the desired result that presupposes how an efficient program is going to behave. This could lead it to ignore programs that unexpectedly perform better than others, and have not been considered explicitly, or have survival strategies that change with time. In AL, the explicit fitness function is replaced by an implicit definition of fitness which is an emergent property of the system. In this way, the system can cope with a wide variety of behaviours.

Advantages and limitations of GAs

GAs are suited to applications where the best option among many is being sought. They have been used to evolve good solutions for problems like sorting, finding the shortest path and scheduling. Sometimes GAs are used to enhance a solution that has been obtained by a conventional method. For example; GAs have been used to develop services and software which improve credit and portfolio management. The GAs predict credit-worthiness and profits based on incorporated cost and revenue figures for different possible outcomes.

The applications in industry are many and varied, including improved aircraft design and optimised manufacturing. Improvements of 25% in the life span of combat aircraft with only six hours of GA computing time that would have taken engineers days to achieve with all their knowledge and physical insight into the problems. It can be argued that these automated optimisation methods sometimes lack the flair of the talented individual designer, but time demands are always important and engineers can be freed from the mundane to be creative.

GAs have also been used to model food-foraging and trail-following behaviour in ants and wall-following behaviour for robots. One of the better known examples is the *John Muir Trail*† (Jefferson *et al.*[9]). A 32 × 32 grid is bred with programs traversing a certain fixed trail within a time limit. These programs are 'artificial ants' (in the form of finite-state automatons). Each ant has a position and a direction on the grid. All ants 'sense' the colour of the cell they are pointing to (food) and can take one of four different actions: forward, turn left, turn right or do nothing. The system starts with a population of 65,536 which are ranked on how far they can follow the trail in 200 time steps. The best are selected for procreation. Jefferson ran this system for 10 hours on a connection machine and after 200 generations reported one ant reaching the final stage.

No assumption on the structure of programs that compete in a GA system has been made so far; however, we know from biology that information is crossed over in blocks (or cells) of genetic material. It is inadequate to see programs merely as successions of bits without structure. This idea was taken up by John Koza[10] who used a GA to breed a population of LISP-like programs. These are collections of building blocks (functions and terminal sets) that form a tree-like structure.

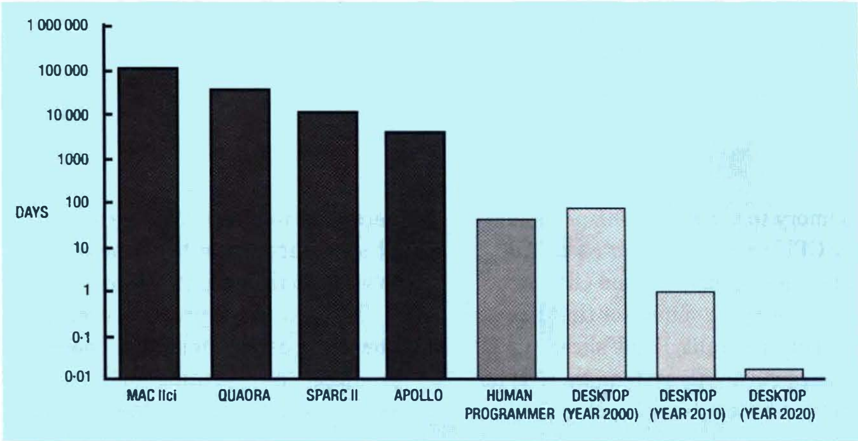
LISP expressions have also solved a number of different problems: block stacking, discovery of trigonometric identities and solving differential equations. They have even demonstrated the emergence of collective behaviour in ant colonies with the mission to find food and take it to the nest leaving a scent, or *pheromone*, to tell other ants where it is. Being a GA-based method, the ants' actions (the set of functions and terminals) and the expected emergent behaviour must be know in advance.

Inman Harvey[11] from the University of Sussex has also overcome the fixed bit string limitation of classical GAs by extending Holland's Schema Theorem[5] to include variable length genotypes. This changes the search space from predefined with a finite number of dimensions to potentially infinite dimensions. In his model, genotypes can increase in length (very early human ancestors had genotypes shorter than now) on a slow time scale. The changes in genotype length propagate keeping a high degree of uniformity (any change spreads through the whole population before the next variation occurs). One of the main limitations of this method is that it **still** needs a classifier system.

Although GAs seem to provide solutions to many practical problems they have limitations. Fitness

† A 200-mile long hiking trail that travels north-south through the Sierra Nevada mountains in California. John Muir was a 19th-century naturalist who hiked and wrote about these mountains.

Figure 1—Comparative predicted performance of evolving software



functions must be well defined and specified for every single input and output behaviour. Not knowing one of the components (or its evolution) in advance, can result in the system not finding a stable solution. When a stable solution is found, the system stays in that optimum position. If an unexpected event takes place (for instance the advent of parasites), the system is unable to evolve so the programs eventually die. In summary, GA methods are not robust, not flexible, not adaptable and doomed when dealing with open-ended problems.

AL advantages and limitations

The telecommunications network is a good example of an open-ended problem: the future state, configuration and loading, the variety of different sub-systems connected and the services that will be derived are all unknown. Every application requires a different piece of software (or even hardware) which introduces inflexibility. This may limit future developments and/or even current capabilities. Sophisticated equipment has to be renewed or upgraded: control software is increasingly larger, more complicated and more difficult to write and test. In addition, current systems fail when there are minor errors in the code (brittle software) or hardware. AL systems respond to all of these deficiencies: they mimic the behaviour of biological organisms and are thus able to survive in complex environments where the best strategy changes with time and the emphasis is on adaptability, robustness and flexibility.

David Hillis[13] has studied evolution with the aid of parasites and proved that systems evolve faster to escape from the parasites themselves. This sort of behaviour could not have been predicted when the fitness function was written. GA systems tend to freeze in local optima and are very resistant to move when the strategy changes. Parasites force the system 'to get down from the hill top' and continue searching in other directions. Hillis applied this idea to a sorting network with 16 elements. By using a traditional GA method, 65 exchanges were needed, but using test cases that classed flaws in the network as parasites, and using co-evolving networks and test cases, a sorting network evolved needing only 61 exchanges. However, in other cases, parasites could have the opposite effect on evolution. When a system is complex, it normally opens up for 'cheating' programs that use the code of others. It could be argued that parasites slow down the evolution of a certain task because 'normal' programs must first find a way to conquer and defeat the cheaters.

Again this story of success has some drawbacks. AL systems are characterised by *emergent behaviour* which means that the solution to a problem is not generally programmed directly but should emerge from a large number of local interactions among agents (programs, creatures). System behaviour is not, therefore, explicitly formulated: agents behave autonomously and a solution evolves when they communicate and compete for system resources. This means that there is an important trade-off between evolvability and programmability. If the system is left to evolve on its own and there are no restrictions to the possible solutions, it gets increasingly difficult to instruct the system to carry out a certain task. This can be looked upon as open-endedness versus a well-defined fitness function for the particular problem. The system is informed of a series of desired outputs and left to evolve an acceptable solution, but with the controlling restriction of memory and CPU allocation. This is the crucial point concerning AL: creatures must be taught how to do simple things like eating, fighting, flying away in the same way that they know how to reproduce. How is this done? All behaviour must be expressed in terms of system resources, that is, going back to basics, which allows more complex creatures to evolve.

If progress in AL keeps pace with hardware development, machines capable of generating code should be generally available by the year 2000 for the price of today's desktop computer[14] (see Figure 1).

Results

Tierra[6] and C-zoo[7] are AL systems which aim to model evolution and synthesise life. Both suites of programs were obtained from the original author (Thomas Ray and Jakob Skipper, respectively) and modified to fit a series of different requirements. Originally, the main goal for the programs living in the 'soup' was the completion of a single, useful task: the programs had to survive in order to procreate. They did this by competing against other programs for the system resources (CPU and memory).

The fundamental question is: *How can programs in these ecosystems evolve to do something useful other than procreation, consuming resources and surviving?*

Tierra

Tierran creatures are small programs (20–200 instructions) in a virtual pseudo-assembler language. The code itself is written in C. Each program contains only a reproduction loop varying in complexity and a number of instructions. Programs compete for memory to place their offspring and for CPU to execute their code. The allocation of memory and CPU is controlled by a simulator that has 'reaper' (mortality) and 'slicer' (CPU) queues. As an AL system, there is no implicit fitness function: it is the interaction among the programs and system resources that causes some programs to survive and others to die[6].

Different Tierra simulations have proved that programs can optimise their reproduction algorithms by a factor of six in a few hours. They have also been able to find techniques like 'unrolling the loop' in which redundant instructions are ignored. Tierra appears to be a good tool for the optimisation and generation of application programs, and may be particularly useful for the programming of massively parallel machines. The question is: *can Tierran programs do something else apart from reproducing?*

After an initial period of trial runs and code modifications to increase speed, Tierra was set a practical problem to see what the creatures would evolve into. A modified instruction set was used to allow the programs to write and read data from input and output buffers. This kind of communication allows programs to write into the buffers of other creatures or for users to establish an external link and give programs input values and get output results.

A series of questions remain: What can be inputs and outputs? How are the best programs valued? Are the programs going to grow in size to incorporate the software needed for the task? The first problem Tierra attempted was a mesh network of 16 nodes arranged in a 4 × 4 array with vertical and horizontal interconnections. When the algorithm is exited, the ancestor gets on with reproduction. When mutations occur in successive offspring, natural selection favours programs that get out of the algorithm quickly. When programs are created, those same constants are written into the input buffer. It is not necessary to create an external fitness function nor have the ability to write to the output buffer.

Tierra controls program execution flow in by using templates. These are groups of 'no operating instructions' 1s and 0s. When a template is found, execution is resumed at the point where the complementary template is found. A mutation in a template can cause the program to start executing the wrong part of its code. If mutation occurs in the template that calculates the size (in number of instructions) of the offspring, the new program's length will change. Currently, the results are quite disappointing as programs tend to ignore the new algorithm and get on with the reproduction loop. This is achieved by mutating one of the templates that govern flow in the loop to remove the algorithm as not relevant compared to the need to procreate.

C-zoo

C-zoo is an AL system based on the same principles as Tierra, but with a somewhat different handling and mapping of the available memory. Programs are collections of data and code cells. Each cell contains a maximum of 16 instructions and two jumping templates through which the succession of events is controlled. This allows sensing and communication to happen among programs because one cell's emitted template can start the execution of another cell in the same or another program. Programs are displayed in a two dimensional grid with the allocable memory either mapped into this surface or taken from a central pool.

C-zoo provides a different way of handling the memory from Tierra: The operating system allocates a block of memory that is quickly occupied as soon as programs start reproducing and filling the 'soup'. When a program wants to reproduce, it searches for free memory space to allocate. Programs that do not find memory wander around and are eventually killed by the simulator. When these 'ants' die, they deposit their memory back into the simulator. This memory can be dumped into a central pool or can be left exactly where the ant died. If another ant in search of food finds the memory, it can allocate it and start replicating.

Different experiments showed the simulations to be very short-lived with a consequently limited evolution. Normally the ants do not die quickly enough and the simulator starts killing them when they do not find food. This problem was solved in two different ways: more memory was artificially introduced in selected points of the grid by increasing system resources. This normally provoked an increase in the population numbers; and the 'kill' instruction was introduced randomly into cells so that when a program found and executed this instruction, it died. The probability of insertion and location of these 'dead' cells were controlled during the simulation.

This work led to a re-think about the use of system resources in AL systems: the only parameters that could be controlled were the system resources. When the simulation happened in a computer, these resources were CPU and memory. Memory had become analogous to food which could be placed anywhere and the ants forced to find it (if they didn't die). Thus an analogy of 'eating' and 'moving' had been created by simply using the memory resource.

This analogy was simulated with C-zoo where the remote collection of data (ants can have sex with other ants and perform cross-over), the insertion of 'kill' venom with a fixed probability (to have a steady supply of dead ants) and the positionings of the dead cells in the middle of the screen were introduced. The results were quite surprising: ants started to multiply until they consumed all the system allocated memory and filled the screen. When food was scarce, ants started to die and deposit their dead cells in the middle; when ants passed through this point by chance and found this food they began self-organising in several radial directions

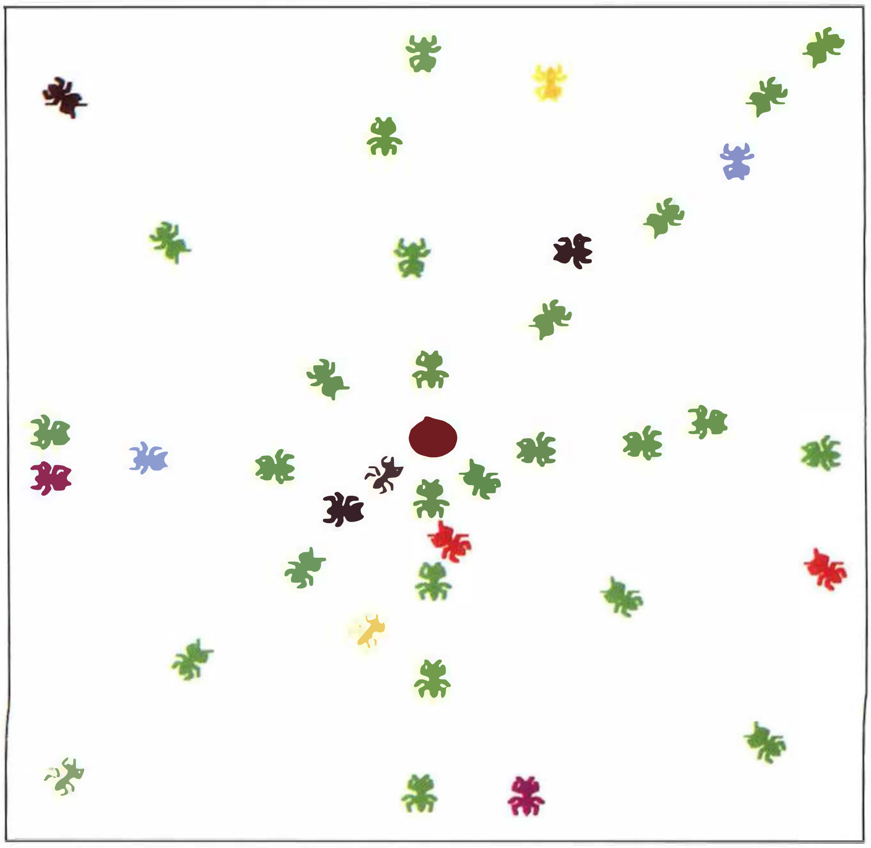


Figure 2—Self-organised ant system finding food. Each colour corresponds to a different species reached by mutation and evolution

taking the food and returned for more (Figure 2).

When mutation was introduced into their codes, different colours of ants (corresponding to mutated species) were created. New species self-organised and displaced the old species as the dominant population. Some 'clever' ants found that the best way to get a lot of food with the minimum effort was to mutate their movement instructions and, instead of going away and coming back for food, stay in small closed circles around the middle of the screen. This was, of course, an evolutionary improvement: these ants needed less CPU cycles to get food and consequently they replicated faster and dominated the whole population. Furthermore, when the position of the dumped memory cells (either from dead ants or artificially introduced) was changed, the ants did not take very long to find the new position and self-organise again, proving the system to be adaptable.

One of the problems of AL systems is that it is difficult to choose a parameter as an indicator of how fit a species is getting at a fixed task while GAs can have a numerical value given by the fitness function. In C-zoo, the number of dominator programs at each point of the simulation was selected as a measure of evolution. If through mutation and cross-over, a species of ant develops some qualities that make it a better food-tracer than the rest, it is normal that its numbers increase as it competes with less-efficient ants for the dead cells. If a system evolves to something useful it is expected that the number of dominators will increase during the simulation.

The data corresponding to the number of dominators was used to make contour plots of fitness (number of dominator programs) versus time (in million of instructions executed). The contour curves indicate the probability of the program having a certain fitness value at a given time, so very close contours show a high likelihood of programs being there.

Ten specific cases of evolution were studied. The first eight were permutations of three parameters: remote collection of data (sex), broadcast of events and remote execution. Broadcast of events happens when a program has executed one of its cells and looks within a fixed radius (called the *Hamming* distance) for occurrences of complementary templates. When it finds them, the simulator starts executing those cells. As in biology, there is a strong redundancy in the sense that not all the bits of the template are used to match (normally around 5 from a total of 32). This can be considered to be a way of sensing or communication among programs. Remote execution happens when a cell uses broadcast events to benefit from the execution of other programs' code. This is the case of parasites: they do not posses the code to replicate but they execute the hosts' by sending the complementary template to the reproduction loop of the parasited program.

Contour plots of each simulation gave positive evolution results only in the case of the absence of the three parameters, that is, no sex, no broadcast of events, no parasitism; that is, no communication among creatures (Figure 3). The rest of the simulations showed contour plots parallel to the time axis without any sign of improvement in fitness.

Fitness is represented by the number of dominator programs while time has been scanned in 49 channels from 0 to 13·41 million instructions executed (6 minutes of real time).

The remaining simulations were cases of flock formation and presence of predators[7]. In both cases, the fitness seems to have spurious peaks (Figure 4) that correspond to the arrival of parasites. When these appear, they replicate very quickly and, with the aid of the hosts, dominate the population in large numbers. When the hosts learn how to cope with parasites (or they die out), the parasites' population falls as quickly as it increased. This is not a clear positive case of evolution compared to Figure 3; there is no net permanent gain in fitness.

It would not be daring to affirm that when communication was introduced among programs, there was no evolutionary improvement in carrying out a specific task. The fitness function has an implicit component that results from the interactions and an external term that is imposed by forcing the system to do something useful. When communication takes place, the implicit fitness dominates the

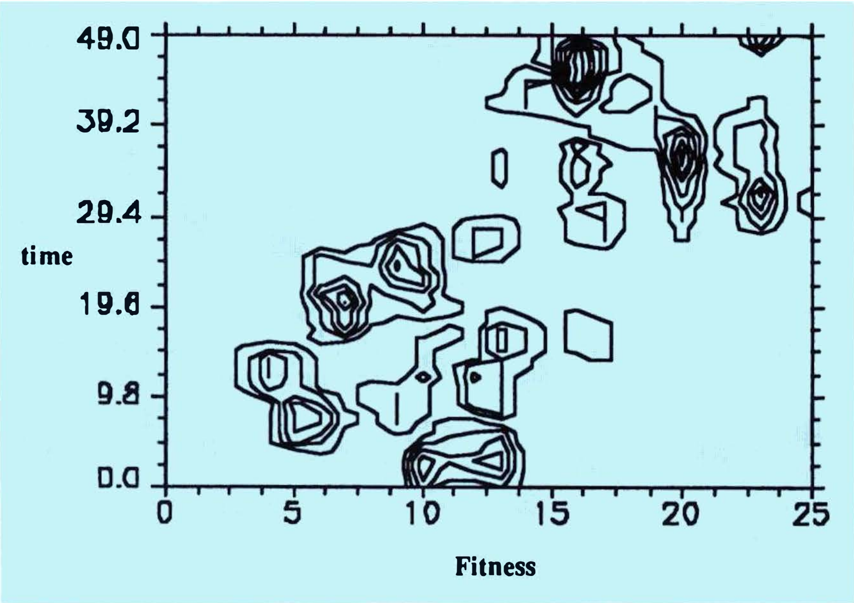


Figure 3—Contour plot for 'non-communication' evolution

external counterpart. It is only when all 'collective' features are removed that programs can be seen to be getting fitter at the task.

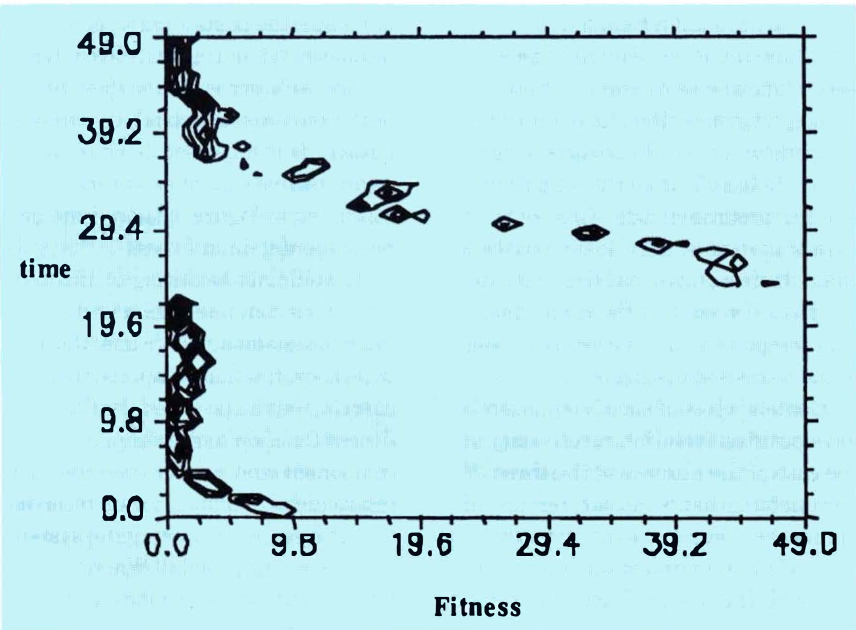
Where Are We Going?

At present, AL systems cannot be used to get software to do something useful unless CPU and memory are cleverly converted to be external fitness parameters: they only produce diversity and solve very simple and basic tasks like reproduction. C-zoo produced a self-organising mutating colony of ants searching for food and eating it at different places in a display grid. Only this case demonstrated evolutionary improvement in AL systems. Intensive research in this field will bring many new and useful developments, but the time scale for these is unknown and difficult to predict.

In contrast, GA systems currently provide solutions to practical complex problems. Their main disadvantage is that they are unable to adapt when new unexpected behaviours appear. They are not good at dealing with social behaviours like parasitism and other sorts of communication or interaction among programs living in a closed ecosystem. Currently, Koza's LISP expressions seem to be the best way to tackle complex problems where the programs must complete a useful task. They overcome some of the limitations of classical GA methods and offer comparatively faster tree-structured solutions.

A further discussion of some of the evolving software techniques quoted above can be found in[15].

Figure 4—Contour plot for 'parasitic' evolution



A Practical Application

Telecommunications networks grow every day in terms of traffic, customer activity and physical complexity. Mobile systems and information libraries in particular will soon grow (exponentially) to a point where traditional control and management methods, based on today's software techniques, will not be suitable owing to their brittleness and lack of adaptability. Evolving software provides a flexible, adaptable and robust solution to this complex problem. Following this direction, we are looking at incorporating mobile agents into the complex software currently used to control telecommunications networks, services and applications. These agents, could help to guarantee network reliability levels and future adaptability.

The properties of mobile agents have also been compared to the behaviour of ants. Ants are interesting because, although they are apparently very simple creatures, they appear to do very complicated things. It is essential to look into translating what it is that gives them their simplicity and robustness into computer programs.

Benign forms of mobile agents, capable for example of searching databases and looking for certain patterns of statistics, could be in widespread use in the near future. More powerful agents, which can carry out network control functions, will need to be tested extensively before they can be released. However, their presence in telecommunication and computer networks would further enhance reliability and avoid a simple code error causing a network to crash.

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Biography

José-Luis Fernández-Villacañas Martin
BT Development and Procurement

José-Luis Fernández-Villacañas Martín graduated in Physics from Madrid University in 1984. He obtained an M.Sc. and a Ph. D. in Astrophysics for his work on nucleosynthesis of heavy elements in the atmospheres of cool supergiant stars. In 1989, he became a member of staff in the Theoretical Physics Department, Oxford University, where he worked on plasma physics and radiation transfer in stars. He joined the Systems Research Division in January 1992 to research on artificial life systems. Currently, he is involved in optimisation problems and biological models for market and navigation systems in the network.

Ian Hawker and Peter Cochrane

The 'Really Intelligent Network'

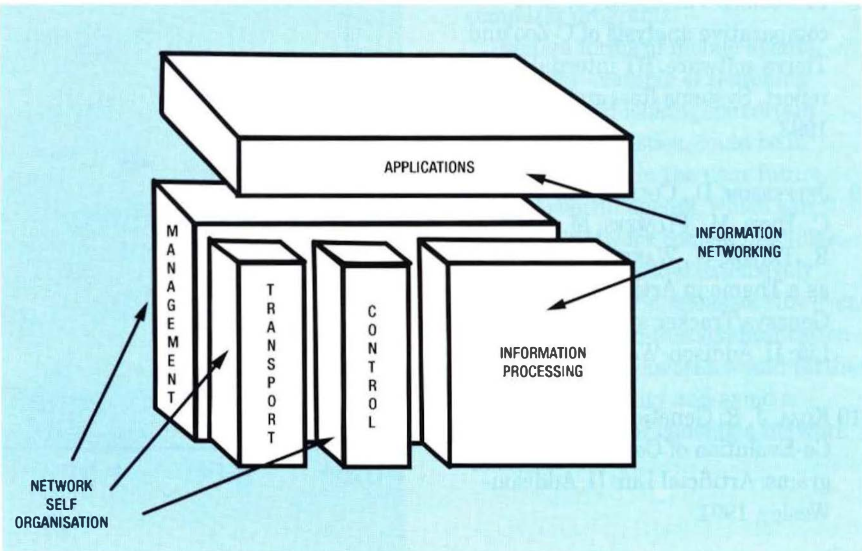
The convergence of computing and telecommunications technologies has provided the opportunity to create information networks greatly enhancing the range, quantity and usability of services available to customers. In addition, embedding a small amount of intelligence into network elements can make networks self restoring within seconds following major service failures such as cable breaks and node failures. Such networks are necessary to meet the accelerating demand for ever increasing volumes of information and services with very high reliability.

Introduction

As we enter the 'information age' telecommunications networks must provide increasing volumes of information on demand anywhere on the planet, in a form suitable for users at reasonable cost. This implies integrated transportation, processing and storage of data, and the provision of a very wide range of information services over a cost-effective network. The 'really intelligent network' (RIN) needed to do this in the most effective and economic manner is not the product of incremental change (based on our telephonic past), but is the result of a new approach requiring new thinking and a new architecture. Here we address fundamental questions and issues related to the realisation of the RIN:

- The current intelligent networks (INs) are targeted at providing network-based speech services with later upgrades to support mobile users and customer-based speech applications. But what form of network intelligence is needed to support the whole range of future information services such as data searching, mobile broadband and advanced multi-media?
- Given the accelerating migration of computer power, artificial intelligence (AI) and service creation software from within the network to customer sites, what is the future role of centralised network intelligence?
- What form of network management is required to maintain high reliability and quality of service (QoS) while continuing to be responsive to changing customer needs? Can the network itself become self-organising so that it

Figure 1—Really intelligent network architecture



can autonomously manage its resources to maximise QoS and reliability while minimising costs?

- How should we change current networks and systems to meet these needs?

The two main constituents of the RIN are concerned with revenue generation and cost reduction. Revenue generation is principally realised through the provision of a range of services to customers (including support of customer-generated applications) described, in this article, by the term *information networking*. Services include communications, marketing, brokering and entertainment.

Network costs may ultimately be reduced through optical networks offering bandwidth transparency[1, 2] and embedding rules and algorithms within network elements[3-10] to reduce the software burden of network management systems. The latter is referred to as *network self-organisation*, which can play a complementary role to conventional artificial intelligence.

Figure 1 illustrates an architecture for a future RIN showing the roles of information networking and network self-organisation. Information networking comprises primarily information processing and applications to represent how the future telecommunications network will store and process information to support both network services and customer applications. Self-organisation is contained mainly within the control, transport and management layers.

Information Networking

The convergence (since about 1985) of computing, telecommunications and user equipment (Figure 2) has created the new science of information technology (IT), greatly enhancing the range, quantity and usability of services available to customers. This has led to the vision of an information network enabling interaction to take place between anybody, anything, anywhere in an intuitive fashion, without concern for the underlying technology. Users should be able to send or receive information easily, regardless of ownership, location and format (Figure 3).

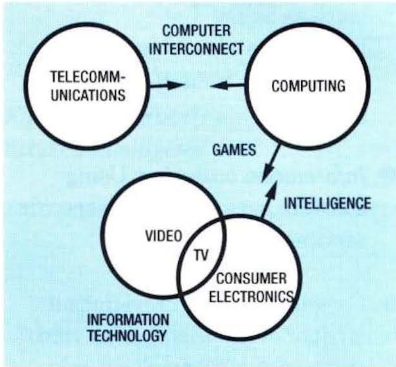
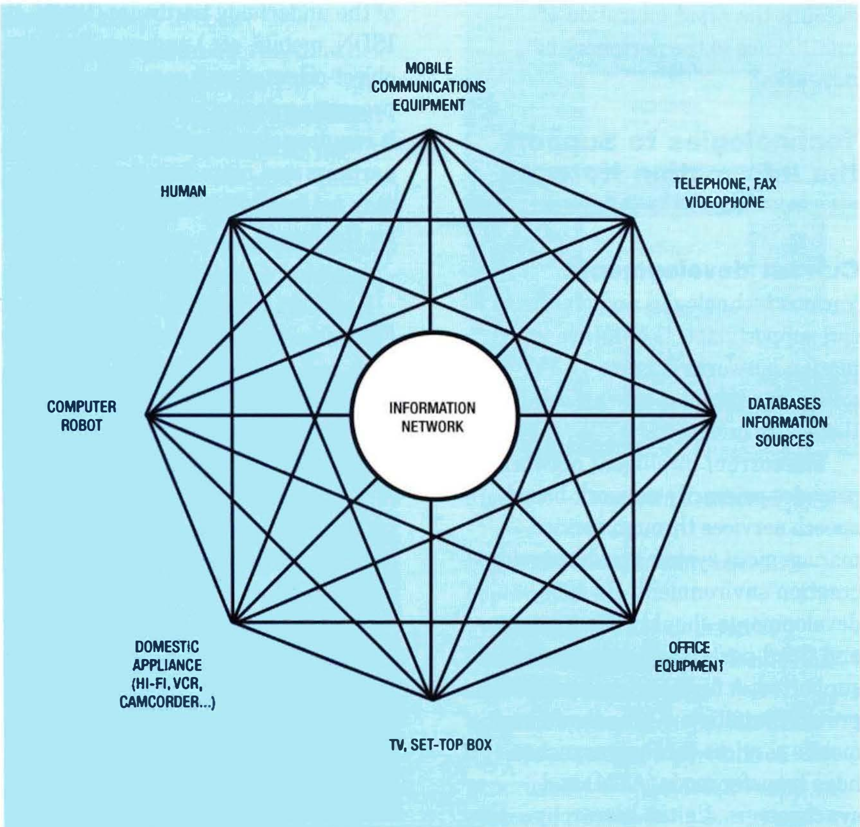


Figure 2—Convergence of computing, telecommunications and users' equipment

It is interesting to examine what information networking means from the perspectives of different types of user.

Figure 3—Interactions between anyone and anything



Business customers

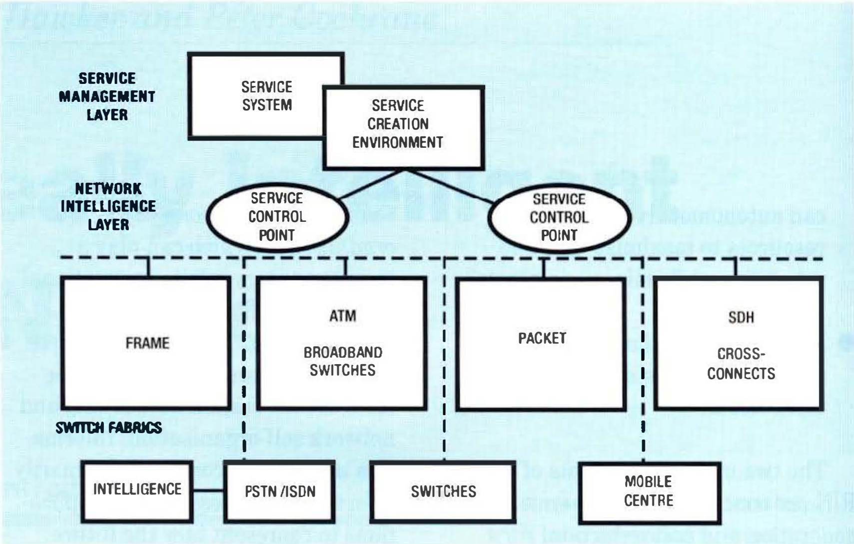
The information network should be the natural medium that enables businesses to interact with their customers and suppliers. The business customer should be able to use the information network to improve traditional business processes such as:

- *Marketing*: Achieve access to virtual market-places available to other business and residential users. This is an important step towards mass customisation of products and services.

- *Distribution*: Rapid access to the latest information will allow 'just in time' manufacturing and distribution and reduce the need to maintain large stocks.

- *Advertising*: The creation of intelligent multimedia services

Figure 5—Developments in switching and intelligence



(such as Yellow Pages, travel brochures and catalogues) targeted on the basis of customer profiles.

- *Information brokering*: Using software agents to supply specific services.
- *Communications*: Providing all manner of services such as videoconferencing, teleworking, telepresence and coordination.

Residential customers

The information network will be a natural medium for social or business interaction between residential users. The take-up of information services will be strongly dependent upon user-friendly interfaces that overcome the reluctance of most users to experiment with new technologies. The residential user should be able to use the information network for:

- *Communications and entertainment*: reducing the need to travel and bring together individuals in virtual meeting places.
- *Information gathering and purchasing*: to access and browse information services such as home shopping, libaries and museums. Users will benefit from the assistance of intelligent software agents for searching, negotiating, purchasing and monitoring the customers' domain of interest.
- *Information smallholding*: everyone can be an information supplier, advertising and selling products and providing new services and facilities.

Network operators

The information network will provide the infrastructure and associated platforms to support services and applications that enable interactions between anybody, anything, anywhere in an intuitive fashion.

This will involve:

- the distribution of computer processing capability, and
- the use of software agents roaming through the network seeking management information and locating network problems.

It is clear from all three perspectives that the information network has many advantages over the conventional intelligent network. The question remains: Which technologies are available to implement such an approach economically, taking into account the rapid migration of intelligence to the periphery of networks?

Technologies to Support the Information Network

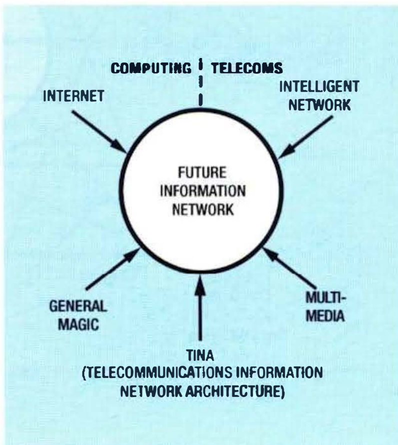
Current developments

Various technologies and platforms can support aspects of future information networks (Figure 4). The following examples give an insight to the issues involved.

The current intelligent network provides primarily network-based speech services through service management systems and a service creation environment. By 1996, developments should allow customer and third-party applications to be supported. A further development to provide 'intelligent' broadband and mobile services through asynchronous transfer mode (ATM) and synchronous digital hierarchy (SDH) technology is also likely (Figure 5). These developments are firmly network based, with the network operator providing public services, substantially contrasting with the trend of intelligence migrating to the periphery of the network.

Similarly, telecommunications information network architecture (TINA) is a major initiative by public network operators (Bellcore, BT et al) to produce a platform for information services built on ideas from computing and telecommunications. It will support the migration of functions to the network periphery, is independent of the underlying hardware (ISDN, B-ISDN, mobile, etc.) and uses flexible object-oriented and open distributed processing design methods. However, it requires close agreement between partners and manufacturers and it may not be the most flexible solution for the future.

Figure 4—Current information options



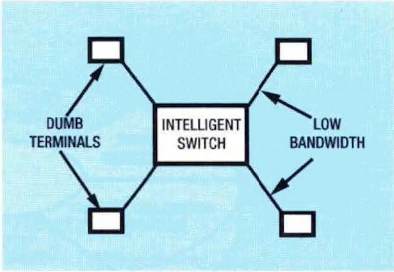


Figure 6(a)—Traditional location of network intelligence

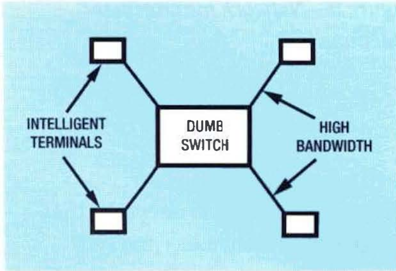


Figure 6(b)—Future location of network intelligence

More radical approaches

In traditional telecommunication networks, intelligence and functionality reside at the switch (usually the local exchange) with dumb terminals such as telephones at the periphery (Figure 6(a)). In the next few years the power of personal computers will be comparable to switches, so applications can be readily generated by users supported by network services. The picture will more closely resemble Figure 6(b). Major issues now emerge:

- Should the platform for information networks be based within the network or at the periphery (or both)?
- How do the functions associated with network management fit into this picture?

The growth in the Internet gives some evidence of a major direction of change in telecommunications: linking millions of computer users throughout the world (Figure 7). It provides electronic mail (e-mail) services, access to book shops, magazines, bulletin boards, libraries and other novel facilities. The Internet concept is cheap and robust although bandwidth, security and billing are major issues and limitations. But perhaps the most detrimental features are delay and organisational chaos. It is fundamentally incapable of providing interactive services of any kind. It is slow, ponderous and disorganised, but it is a great experiment and pathfinder for the future of IT.

Clearly computer manufacturers see the opportunity to generate additional revenue by providing information services over computer networks. A number of companies are developing a range of software products that will allow customers to generate applications on their personal computers using simple languages such as TELESCRIPT. In this scenario the public operator provides the network infrastructure but is restricted in new revenue opportunities.

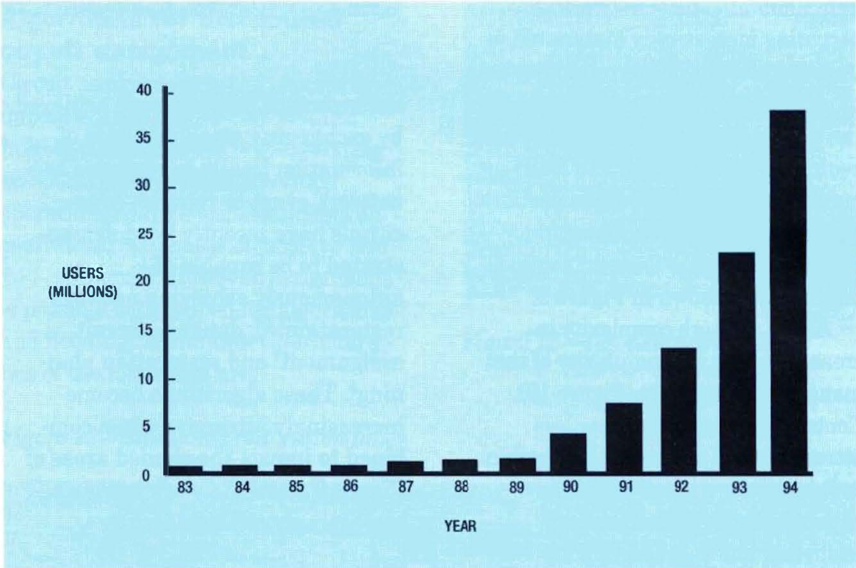


Figure 7—Growth of Internet

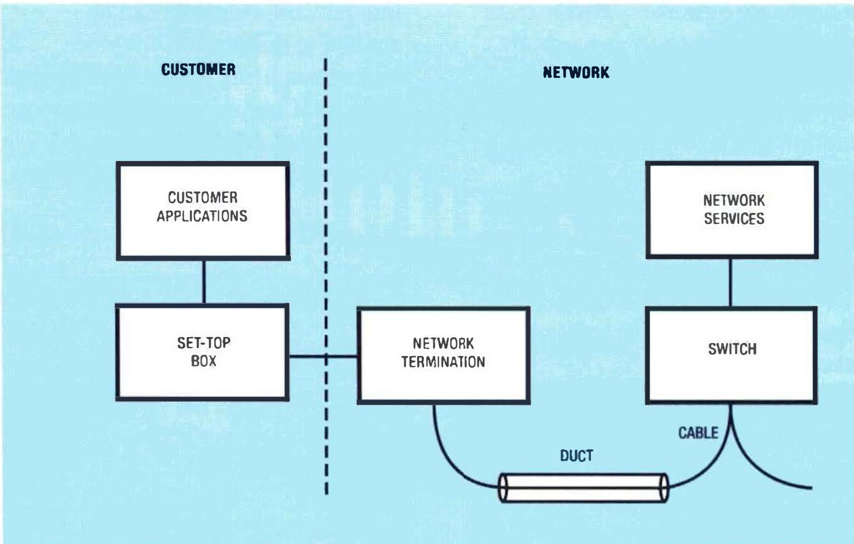
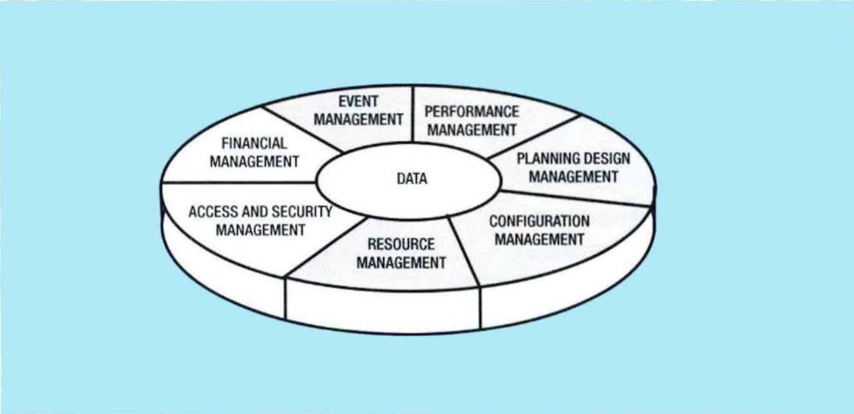


Figure 8—Supporting customer applications

Given these developments, network operators must decide how best to generate revenue from information services. Possibilities include providing a portfolio of generic network services to support customer applications providing security, bandwidth on demand, service building blocks and billing, for example (Figure 8).

There are clearly a number of developments which could potentially support the future information network. An issue of equal importance in the RIN is increased automation of network management functions,

Figure 9—Network management functions



eventually leading to networks that are largely autonomous and self-organising.

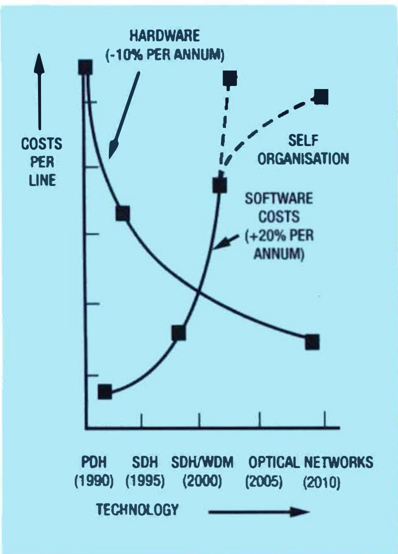
Network Self-Organisation

Telecommunications networks are becoming increasingly automated to improve perceived QoS/reliability and to provide integrated management of the growing number of transport and switching technologies. The management of telecommunications networks can be segmented into major functional areas with a focus on common databases as shown in Figure 9.

As the network complexity increases so does the complexity of the management software (Figure 10). Centralised control becomes less attractive (and ulitmately impossible) as it increases response times to network events, reduces overall resilience, and encourages a top-level approach to development of network management applications. Figure 10 indicates how the current dominance of hardware costs over software costs will change completely as hardware costs fall (for example, with the increasing use of wavelength division multiplexing (WDM)) and software costs continue to rise.

An alternative is to embed rules/algorithms within network elements (switches and cross-connects) so that management processes are achieved by exchanging small amounts of information locally in response to a network event or request. Algorithms have recently been demonstrated to be capable of autonomously achieving network restoration[4,5,6], dynamic circuit assignment[7] and restoration planning[3]. These algorithms become increasingly attractive when combined to impact the shaded areas of Figure 9 as the network becomes increasingly self-organising.

Figure 10—The growing software mountain

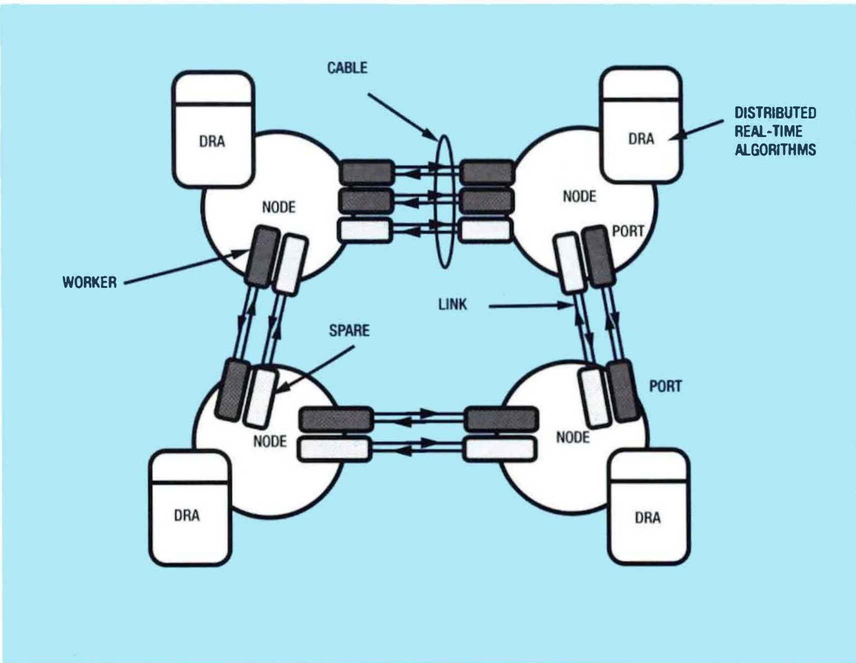


Algorithms for distributed restoration

Distributed algorithms embedded into network elements can be applied to distributed link/node restoration using software controlled SDH/ATM techno-logy. For example, a simple but efficient flood search[7] can be employed to identify alternative routes quickly, following a failure. There is no need for a totally centralised network database or control software as the network is its own database. Any line system or node added to the network is automatically protected since there are no protection plans to modify. Each node knows only its unique identity and contains a simple set of rules that tell it how to react when it sees an alarm or message from a neighbouring node. Figure 11 shows the individual elements used in the restoration process where the block DRA refers to the distributed restoration algorithm.

Simulation results have been obtained for link and node restoration based on a hypothetical SDH transport network[6]. Protection links were added to the network using a heuristic algorithm[2] to enable restoration of any single link failure. The basic topology of

Figure 11—Elements of the restoration process



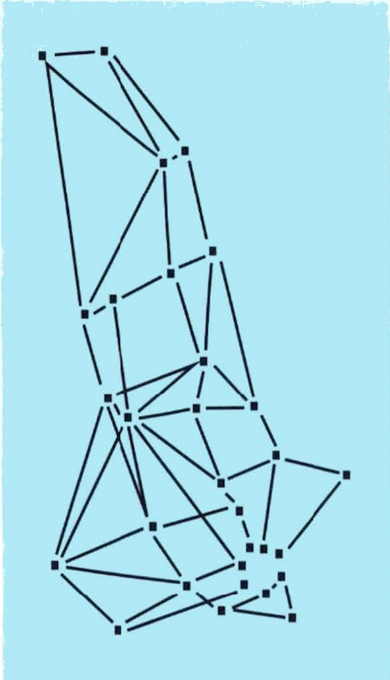


Figure 12—Test network topology

the network (Figure 12) comprises 30 nodes and 57 spans with a total of 332 working links. The results (Figure 13) indicate that distributed span restoration in an SDH network is feasible in around 500 ms, offering restoration within the call drop-out threshold of exchanges to provide customers with an uninterrupted service. A processing time of 5 ms and a cross-connect time of 20 ms were used, representing modest modifications to current cross-connect specifications[8].

Given that advanced transmission systems are designed to realise a high mean time between failures (MTBF), it is sensible to utilise the processing power and time available during operational periods to minimise system 'panic' when failure occurs. Pre-planned distributed restoration offers advantages over real-time stochastic restoration with regard to speed, although it cannot guarantee 100% restoration should plans become outdated. Ideally, pre-planned restoration should be augmented by a real-time technique leading to multi-layer restoration strategies[4].

Summary of reliability enhancements

A summary chart is given in Figure 14 comparing the performance of various restoration strategies in core telecommunications networks. It can be seen that link protection and centralised network protection improve circuit availability by reducing down times. However, DRAs are also able to restore service within the call dropout time for switches and thereby reduce the number of faults seen by customers, greatly increasing the perceived MTBF. Only very rare multiple failure events will affect service to the customer.

'End-to-end' path protection is equally fast as using DRAs but is much more expensive in standby hardware, since DRAs allow protection capacity to be shared across the network, thus considerably reducing the redundancy necessary for a given restorability.

Distributed restoration can be used to uplift the reliability of all network services with additional 1+1 protection applied when justified. In reality, network migration from fully centralised to distributed restoration is most likely to be an evolutionary process.

Algorithms for distributed circuit assignment

Circuit assignment is the process of implementing 'end-to-end' circuits linking customers via routings based on operational availability. Such operational data is generally held on centralised databases of massive size and complexity. However, assignment is possible with embedded algorithms and flooding techniques. Characteristics of the algorithm are:

Figure 13—Simulated restoration times

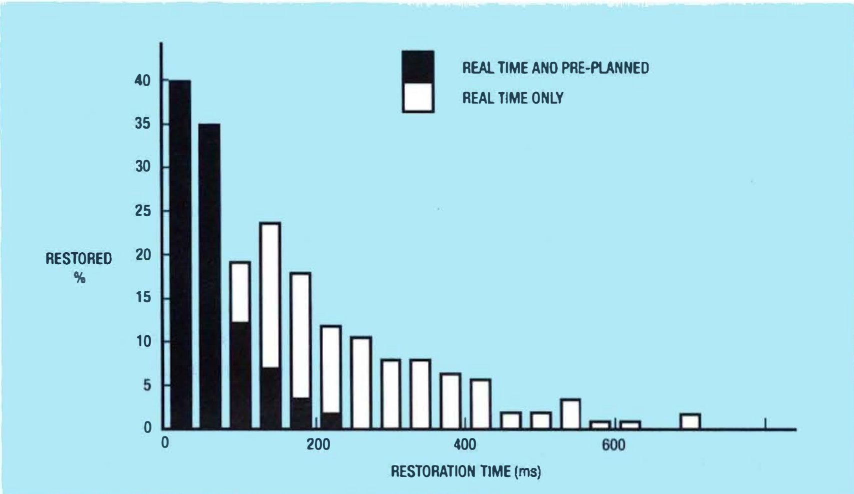
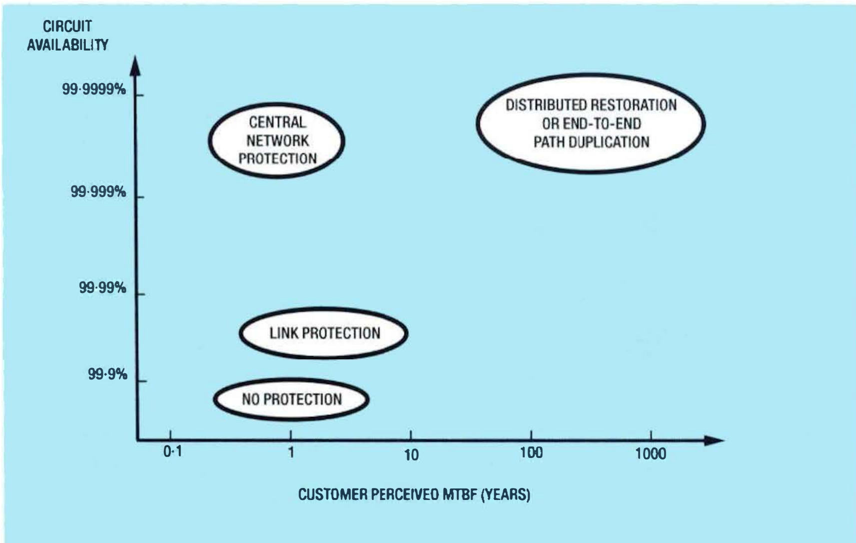


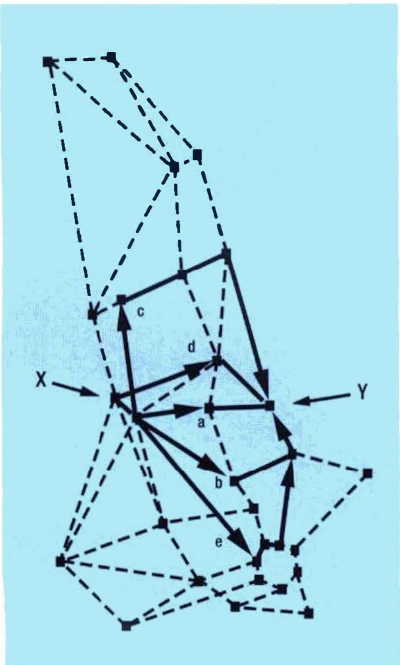
Figure 14—Comparison of core network restoration strategies



- no centralised management,
- sub-second operation,
- no databases of pre-planned solutions,
- action based on instantaneous network configuration,
- (optionally) disjoint assignment paths, and
- optimum path selection (node hops, span balancing, etc.).

Deployment of such algorithms would enable a network operator or customer to establish a circuit immediately without route planning. If it were embedded in a network at the 2 Mbit/s level, it would effectively provide 'MegaStream on demand' as illustrated in Figure 15 showing five paths identified between nodes X and Y. The choice of path depends on metrics such as distances and utilisation which can be evaluated automatically in real time.

Figure 15—Results of distributed circuit assignment



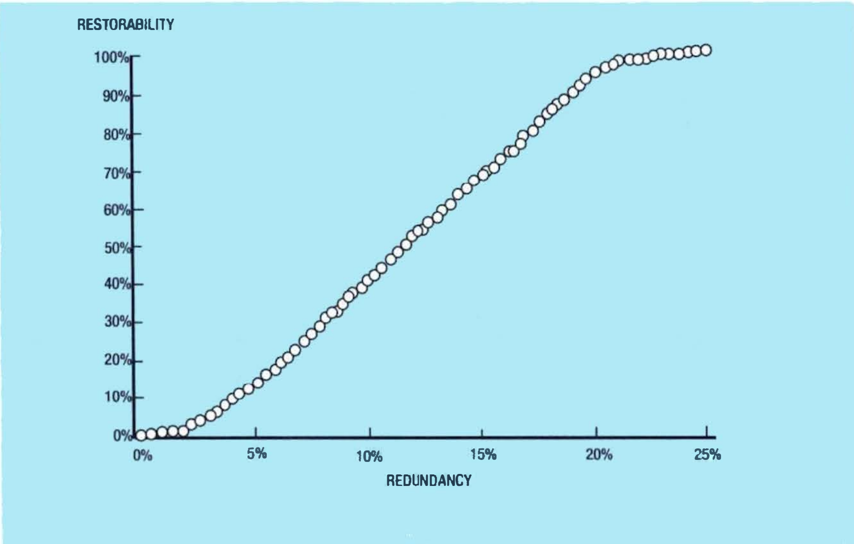


Figure 16—Restorability versus redundancy plot for a test network

Algorithms for restoration planning

The restoration planning process can also be automated with heuristic algorithms[3] optimising network cost to protect against multiple span and node failures for either distributed or centralised restoration. The algorithm:

- designs new protection networks or finds optimum places to add protection to existing networks;
- runs in a time which scales polynomially, not exponentially, with network size; and
- produces graphs showing the effects of adding and removing protection systems.

Figure 16 shows the restorability versus redundancy for the test network in Figure 12. The algorithm adds capacity to individual spans throughout the network calculating the restorability at each stage until 100% restorability is achieved. It then goes through a 'tightening' phase removing surplus links that may have been added early in the process but have been superseded as the optimisation becomes more global. If the initial network design is reasonably optimal (avoiding reliability bottlenecks) then restorability increases approximately linearly as further redundancy is added.

Integration of network algorithms

The concept of network self-organisation is that the telecommunications network manages its resources to maximise QoS/reliability while minimising costs. Maximum benefit is derived by allowing algorithms to interwork and reusing protocols to minimise network response time to events and requests. This also realises a considerable reduction of the 'software mountain' since network management procedures are achieved automatically using rules and algorithms embedded within the network elements.

An example is shown in Figure 17 where the algorithms are combined in a common framework with feedback from network perceived QoS/reliability used to maintain the entire network in an optimal state. Resource management is also automated as the network can request resources as required in real time.

Relationship to artificial intelligence

The traditional AI approach to distributed network control uses fixed

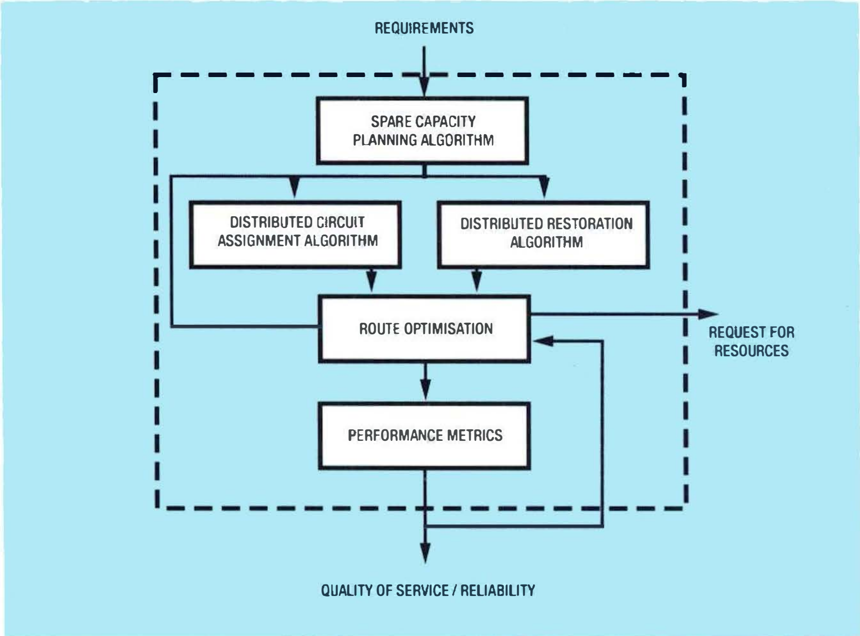
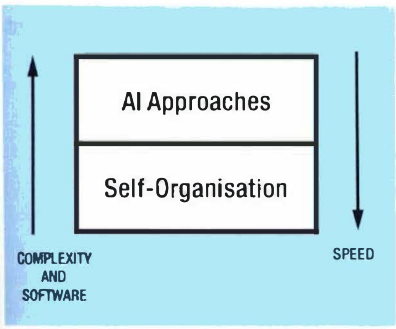


Figure 17—Combining network algorithms

agents communicating with each other and the management centre to carry out functions such as diagnostics. A derivative is to use mobile agents, containing only a few simple processes, which move around a network gathering information and acting when required[10]. These are much simpler than fixed agents since inter-agent coordination is not needed. However, the algorithmic approach described here makes use of even simpler processes at the network element level to carry out specific functions, and is especially useful when rapid response such as disaster recovery is needed.

In practice, a hierarchy of self-organising/AI methodologies will be necessary to meet future network needs (Figure 18) as they evolve from electronically to photonically dense solutions. It may even become necessary to introduce a degree of biological evolution so networks can learn and adapt in real time as the configuration, hardware, applications and services change with the technological migration. For example, recognising a pattern in a sequence of events in traffic activity or fault statistics can steer network responses in a more effective way. This is an area of current research, principally using neural networks, which can be integrated into the self-organising concepts outlined.

Figure 18—Network self-organisation and artificial intelligence



Summary

The two major components of the future RIN are information networking and self-organisation. The first provides a platform for revenue generation by rapid delivery of information services (including entertainment) on demand to users. The second reduces operating costs to provide network management automation by embedding simple rules into network elements (and eliminating the software mountain).

Now we can address the questions raised at the beginning of this article.

- *Information network of the future:* There are several possibilities taken from the worlds of telecommunications and computing. It is important that the chosen platform is sufficiently flexible to support as yet undefined services and revenue sources.
- *Impact of migrating intelligence to the network periphery:* Clearly intelligence retained within the network for service creation must interwork with intelligence in customers' equipment to support customer applications. The main issues concern, for example, definition and interworking of service objects using proprietary technologies.
- *Network management in the future:* Overall management complexity (both centralised and distributed) grows as the mix of network technologies increases. Hopefully the new management architectures such as the telecommunications managed network will minimise the growing complexity and allow flexible interworking between systems and networks. However, there is also the opportunity for new approaches such as embedded algorithms to simplify management applications and thus avoid the ever growing software mountains.
- *Evolution to the RIN:* The capability to provide networks that support information and entertainment services will emerge within the next decade. They will generate new revenues in one of the fastest growing markets. However, network self-organisation, as a means of improving QoS/reliability and reducing the software dependence may proceed at a slower pace allowing the capabilities to be fully developed and understood.

In conclusion, the telecommunications operator will gain considerable benefit in revenue generation, operating cost reduction and flexible service provision through the 'really intelligent network' of the future. However, we will be dealing with the ever faster moving target of technology, service and customer habits–a combination of evolution and revolution.

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Biographies

Ian Hawker
BT Development andProcurement

Ian Hawker received B.Sc. and Ph.D. degrees from Leicester University in 1973 and 1976. He joined BT Laboratories in 1976 where he worked on the design of high-speed integrated circuits for TAT-8 submarine systems and for inland 565 Mbit/s transmission systems. He then undertook studies in design, control and quality-of-service issues for synchronous digital hierarchy (SDH) networks. He currently leads a team researching into future telecommunications networks including advanced network management issues and techno-economic modelling for SDH, ATM and optical networks.

Peter Cochrane
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Peter Cochrane graduated from Trent Polytechnic with a B.Sc. Honours degree in Electrical Engineering in 1973 and gained an M.Sc., Ph.D. and D.Sc. in Telecommunications Systems from the University of Essex in 1976, 1979 and 1993 respectively. He is a fellow of the IEE, IEEE and Royal Academy, a visiting professor to Essex and Southampton Universities and an honorary professor at Kent. He joined BT Laboratories in 1973 and has worked on both analogue and digital systems. He has been a consultant to numerous international companies on projects concerned with systems, networks and test equipment. In 1978 he became manager of the Long Lines Division and received the Queen's Award for Technology in 1990 for the production of optical receivers for TAT-8 and PTAT-1 undersea cable systems. In 1991, he was appointed to head the Systems Research Division at BT Laboratories which is concerned with future advanced media, computing and communications developments. During 1993 he was promoted to head the Research Department at BT Laboratories with 620 staff dedicated to the study of future technologies, systems, networks and services. He is also the Development & Procurement board member for technology.

Nicola Millard

Requirements Elicitation in the Global Marketplace

Multinational companies must consider the needs of the global marketplace, including factors associated with the development, design and marketing of products and services to suit a variety of cultures. Talking to customers to find out what they want requires a high level of interpersonal skill—including a sensitivity to the issues peculiar to each culture involved. These issues are reviewed and their implications for people involved in determining product requirements explored.

Introduction

Many companies are striving to succeed in the global marketplace by differentiating on quality and service—and seeking to satisfy local requirements (Figure 1). However, it is not generally possible to bolt on internationalisation at the end of the development process. Consideration of issues such as target languages and cultures throughout the life cycle is more cost effective than trying to retrofit a product to a new user population (Figure 2).

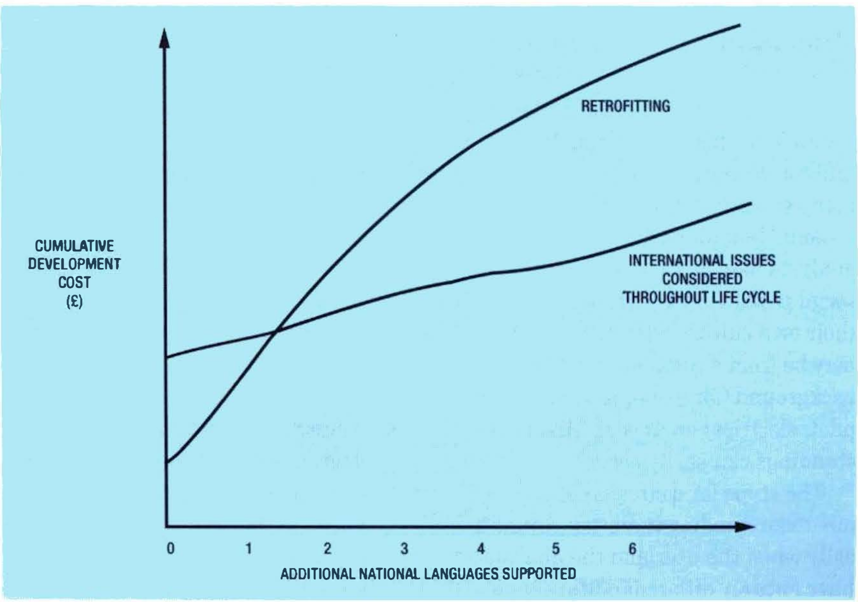
Product designers and marketing managers need to be aware of the target cultures at all levels. Figure 3 shows a categorisation of these levels and the associated issues.

Product Design

The team responsible for the product should address cross-cultural issues early in the life cycle so mechanisms for cultural flexibility can be built in. Figure 4 shows an idealised development life cycle in which requirements analysis, design and implementation follow on in a neat sequence. In practice, the process is often more complex with multiple iterations supported by rapid prototypes and parallel activities. In either case, requirements capture and analysis, being at the beginning of the life cycle is **the** critical task in capturing

Figure 1—International product requirements

Figure 2—The cost of retrofitting extra languages to a new service



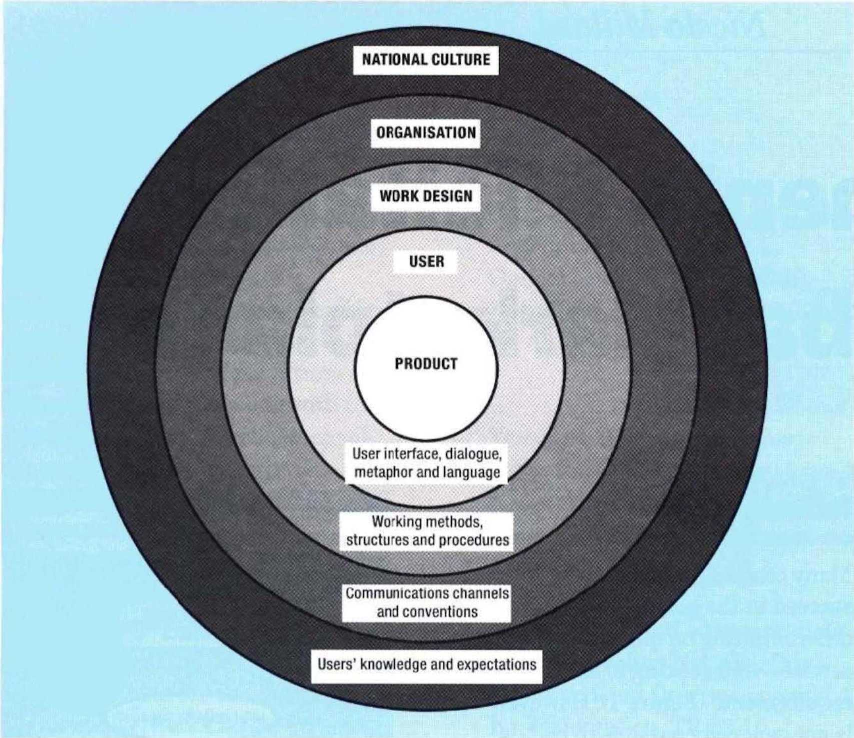


Figure 3—Factors influencing global product design

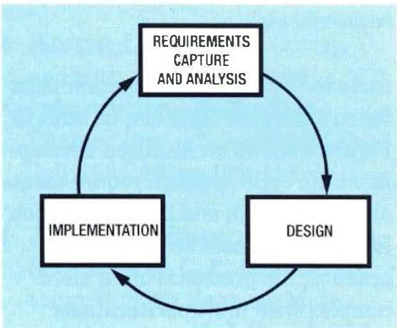


Figure 4—The design life cycle

cultural issues relevant to a particular product. However, the most effective way of capturing requirements itself varies from culture to culture.

Cross-Cultural Dimensions

Cultural concerns are not limited to interactions between people from different countries. There may be many cultures within a single national boundary. For example, analysts may be from a computing or social psychology background with their own culture and jargon; users may be from a completely different background (for example, accountant, pilot, electrical engineer). Misunderstandings can easily occur!

The scope for confusion and misunderstanding increases dramatically when the user and the analyst have entirely different cultural and linguistic backgrounds. In a survey of IT managers[1], 49% considered language to be a significant barrier to success, 42% thought differences in national work practices were an obstacle, 36% thought that national differences *per se* were problematic and 31% cited intercultural rivalry as a barrier.

We have a wealth of knowledge about other cultures, including well known—though often misleading—stereotypes, masses of survey data and thoughtful distillations of national and cultural characteristics. The following dimensions have been identified[2, 3, 4] as a useful basis for cross-cultural comparison.

- *Universalist vs. Particularist* This distinguishes between being governed by strict sets of universal rules and guidelines and being driven by relationships and situations.

- *Individualist vs. Collectivist* This is the degree to which a culture is 'I' centred or individual versus 'We' centred or group oriented.

- *Neutral vs. Emotional* This is the degree to which people find expressing thoughts and emotions, either verbally or non verbally, acceptable in social and business situations.

- *Achieved vs. Ascribed* This relates to the way in which respect for superiors is gained. Respect for superiors, irrespective of their performance, is seen as a measure of commitment to an organisation and its mission in an achieved society. In an ascribed society, respect for superiors is based on their knowledge level and how effectively they perform their job.

- *Time perception* Time perception includes the emphasis a society puts on the past, present or future and whether the culture is sequential (does one activity at a time) or synchronic (multi-tasking).

- *Low Context and High Context* Low-context cultures speak in a literal way, making it clear what they mean, whereas high context cultures are indirect, using understatement, hints and body language to put across their message.

- *Masculine vs. Feminine* A masculine society has clearly differentiated sex roles, is highly materialistic and competitive. A feminine society has more fluidity in its sex roles, is people and service driven.

- *Individual vs. Group Leadership* This is the extent to which decisions are made autocratically or democratically.

From evidence obtained from earlier research[2, 3, 4], a selection of countries were compared against these dimensions (Table 1). It should be noted that the matrix is geographically based and does not distinguish between cultural differences within countries. An analysis at this level provides pointers to the main differences between national cultures and serves as a starting point for an exploration of the issues that need to be considered when planning any critical interpersonal or communications activity.

Table 1 Countries versus Cultural Dimension

	UK	US	Japan	France	Germany	Italy	Spain
Universalist vs. Particularist	Universalist. Rule based. Resist change	Universalist. Rule based. Resist change	Particularist. Relationships important	Particularist. Relationships important. Follow rules when appropriate	Universalist. Very rule based. Resist change	Particularist. Relationships important. Follow rules when appropriate	Particularist. Relationships important. Follow rules when appropriate
Individual vs. Collective	Individual	Individual	Collective	Collective	Individual	Collective	Individual
Neutral vs. Emotional	Neutral	Emotional	Neutral	Emotional	Neutral	Emotional	Emotional
Achieved vs. Ascribed	Achieved	Achieved	Ascribed	Ascribed	Achieved	Ascribed	Ascribed
Time perception	Sequential. Strong link to the past but present and future more important	Sequential. Efficiency. Individual can affect future. Last achievement most important	Synchronic	Synchronic. Past used as a context to understand present. Not concerned with planning to achieve ends	Sequential. Efficiency. Present and future strongly interreleted	Synchronic. Goals important, paths not. Present oriented	Synchronic. Present oriented. Past important
Low vs. high context	Low. Explicit messages. Verbal and written communication important	Low	High. Less messages in words, more in context/position. Word is bond, less legal paperwork	High. Rate telephone communication as untrustworthy	Low	High	High
Masculine vs. Feminine	Masculine	Masculine	Masculine	Feminine	Masculine	Masculine	Feminine
Leadership	Group	Individual	Group	Individual	Individual	Group	Individual

Implications for Requirements Elicitation

The best approach for determining customer requirements depends on:

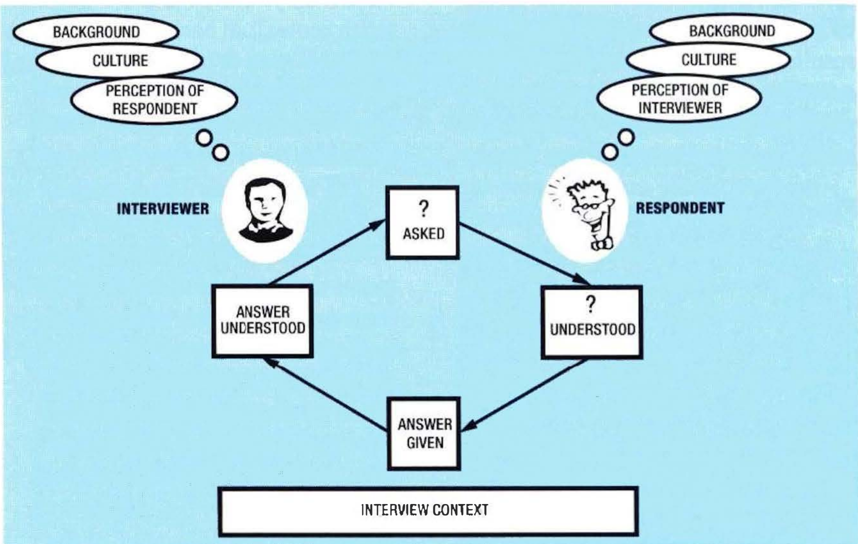
- organisational context,
- situation/environment,
- role/status/knowledge/personalities of the people involved,
- type/scope of project,
- type of target application,
- information required,
- number of people involved, and
- time constraints.

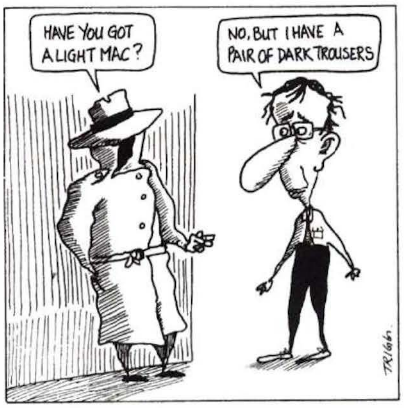
Of these, the effects of context, situation and role are culturally dependent. Let us consider some of the elicitation techniques used by information systems analysts to see how cultural issues affect their application.

Interviewing and Questionnaires

The most obvious method of finding out what customers want is to ask them. This can be done using either an interview or a questionnaire, although considerable experience and skill are needed to do either well; as Alan Davies[5] observed, 'the problem is not asking the right questions but asking the questions in the right way'. The interviewer needs considerable sensitivity to ensure that the characteristics, traditions, customs and norms of the target culture[6] are taken into account during the interview (Figure 5).

Figure 5—The cross-cultural interview





The cartoon, by Trigg, is from the Culture Shock by Esther Wanning, published by Kuperard (London) Ltd. Reproduced with permission.

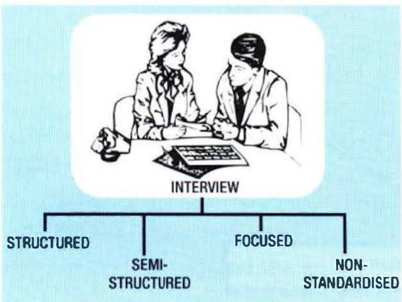
Interviewing is an almost universally recognised practice. However, the acceptability is likely to be influenced by the degree of formality and structure implicit within the culture. Interview techniques vary according to the degree to which the interviewer varies the content and order of the questions[7] (Figure 6).

Structured interviewing rigorously follows an interview schedule. Semi-structured interviews have a skeleton framework around which to weave questions. Focused interviews have even less structure but retain some element of control. Non-standardised interviews rely on a set of information objectives to be achieved through no particular question plan.

Structured interviewing is more appropriate to cultures that are strongly sequential, universalist or specific. They are less appropriate to those cultures who do not think sequentially (synchronic), are more relationship driven (particularist) or like to spend time exploring other avenues of thought (diffuse). In more hierarchical cultures, it may be politic to interview throughout the organisational hierarchy. Interviewing individuals in a group oriented culture may be regarded with suspicion, especially if decision-making is usually carried out by a cooperative group.

The development of cross-cultural interview plans or questionnaires can be problematic, especially if the results are to be compared statistically. This must be done by carefully piloting the interview or questionnaire to ensure that questions are culturally specific enough to be understood but sufficiently equivalent to allow valid comparisons.

Figure 6—The interview hierarchy



Misunderstandings can easily occur when communicating with people from other cultures or in a second language. For example, a French person may say that they 'demand' something. What that person means is 'ask', but in French '*demander*' means 'to ask'. English is widely used as the language for international business. However, English speakers must remember that their counterparts may not be as familiar with the language as they are—even though they may be reluctant to admit this. They may pretend to understand, when they do not, in order to avoid losing face. On the other hand, they may be misunderstood—for example saying 'Yes' may mean 'I am listening' or even 'No' if it is spoken in a hesitant manner. High-context communicators do not always say what they mean and the interviewer must be prepared to 'read between the lines' and pay close attention to non-verbal cues.

The relative strength of the context dimension determines if a person from one culture appears too forthright or brash (low context) or vague and evasive (high context) to someone from another culture. This has important implications for interviewing. To communicate effectively you need to know how much contextual background you can expect or need to give. When dealing with low-context countries, an interviewer should ask more direct questions than usual.

The interviewer's background can be a highly influential factor. Aspects such as gender, age, race, culture, biases and attitude should influence the manner in which the interview is conducted and the way that questions are posed. The respondent's background is similarly influential but there is the additional dimension of their ease and ability to answer the questions (possibly due to language difficulties). The perception of the respondent is all-important so that the dress of the interviewer can influence the amount of information forthcoming more than the interviewer's actual status[8].

Scenario building/discourse analysis

The ascribed and synchronic nature of many Asian and Eastern cultures makes storytelling a natural mode of communication. It may be appropriate, when eliciting requirements for future products in these cultures, to involve the subject in a scenario and allow the subject to communicate ideas through the development of a story. This approach may be allied with prototyping as a way of solidifying existing requirements and eliciting new ones.

Workshops and brainstorming

Workshops and brainstorming are commonly used Western techniques of teasing out requirements. However, brainstorming can be threatening by its egalitarianism to hierarchical cultures and to ascribed cultures where people may fear that their behaviour could cause loss of face. An alternative technique, where participants write comments that are aggregated into anonymous collections of ideas, may be more productive in these cultures.

Observation

In cultures that are sensitive to intrusion, low-profile observational techniques such as video analysis and ethnographic methods may be required. An extreme example of this non-intrusive approach to determining what customers want is to put an early version of a product on the market and use customer reaction to guide subsequent development and marketing activities.

Requirements visualisation

The expression of requirements can be stimulated and captured through the medium of pictures, animations and prototypes. These are often more effective than written specifications, particularly in high-context cultures such as Japan. However, this approach is less appropriate in low-context cultures where text-based specifications are more likely to be acceptable.

Concluding Comments

The complexity of working across cultures makes it difficult for an analyst from one country to elicit customer requirements in another. However, we need to address a global marketplace—with all the cultural diversity that implies. Just as good design is often carried out on a local basis to a high-level brief controlled centrally, the most effective strategy for requirements elicitation may be for local people to capture the requirements and feed them into a central unit for coordination. This approach involves cross-cultural teams who can negotiate and coordinate requirements centrally after capture. It is critical in this situation to use a common and effective mechanism for coordinating the requirements to ensure that they can be weighed and managed effectively.

The cross-cultural matrix can be used by requirements analysts, marketing people and designers to plan how to deal effectively with a target culture and thereby help multinational companies establish, develop and market products globally. The dimensions themselves are cultural stereotypes and do not take individual differences into account. Desmond Morris[9] has stated that 'there are far more similarities across cultures than people think. We always dwell on the differences but they are superficial. The human play is acted out with the same script and story line but different actors, sets and languages.'

Finally, it should be noted that telecommunications, media and travel are driving a process of cultural convergence. Long-term exposure to another culture inevitably leads to some mutual cultural accommodation and merging. This may ultimately mean that similar products and services will be demanded and similar methods to produce them will be effective[10]. However, peoples across the globe will continue to be complex and mysterious. Finding out just what they want will remain an area of potential misunderstanding and uncertainty. The framework of cultural issues and their implications discussed here is offered as a guide to minimise the difficulties.

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Biography

Nicola Millard
BT Development and Procurement

Nicola Millard graduated from Bournemouth University in 1990, gaining a B.A. (Honours) degree in Information Systems and Communication. She joined the Human Factors Unit at BT Laboratories shortly afterwards. She has worked as a requirements analyst on a wide variety of projects encompassing areas such as service management, decision support and customer handling. For the past two years, Nicola has been involved with a project looking at cross-cultural issues and their influence on product and service design, management and organisation. This, and her interest in innovative methods for requirements elicitation, inspired an (ongoing) investigation of the socio-technical and cultural factors involved in cross-cultural requirements elicitation for products and services.

Steve Fox and Alan Snowball

The Global Managed Platform

The global managed platform (GMP) provides the basic managed transport network infrastructure to support BT non-correspondent services. The primary driver for the GMP is the provision of a resilient transmission network that minimises costs through economies of scale. This article describes the background to the formation of the GMP, gives an overview of its current structure and outlines possible future developments.

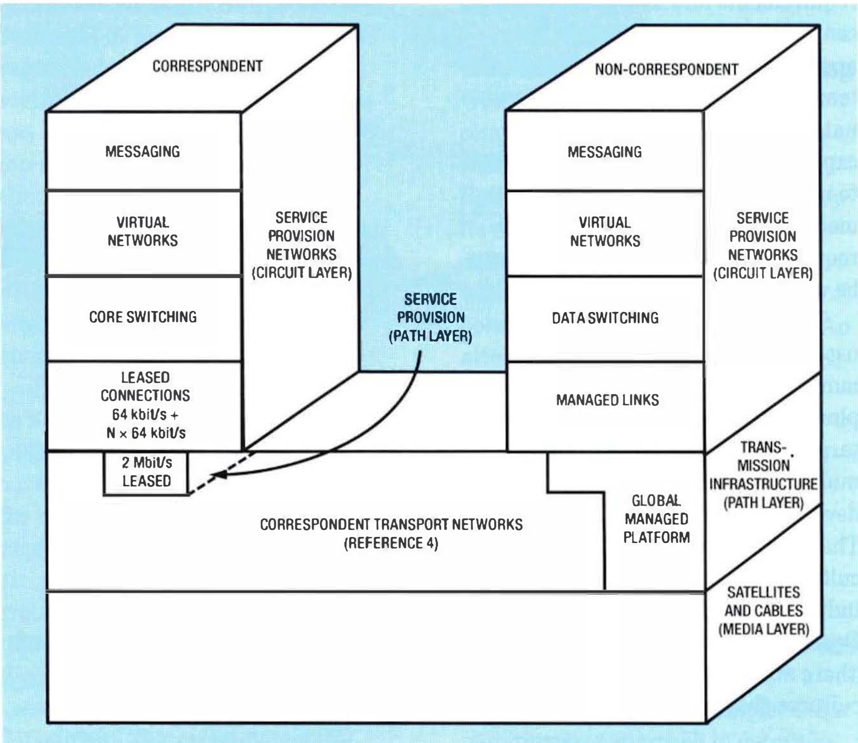
Introduction

The global managed platform (GMP) provides a unified, managed transport network infrastructure that will support all of the global services for the new BT/MCI joint venture company—Concert Communications. This global transmission network was not created directly as a result of the establishment of Concert, but has been developing over a number of years. It has been adapted as necessary to meet the changing needs of BT's global services. Today it is designed to support the full range of Concert services, including Concert Virtual Network Services (CVNS), Concert Managed Bandwidth Services (CMBS), Concert Frame Relay Services (CFRS), Concert Packet Services (CPS) (formerly Global Network Services (GNS)) and Syncordia outsourcing services.

Background

After the reorganisation of BT as a result of Project Sovereign, proposals were made for an international network services platform (INSP) to support BT non-correspondent international services. Conceptually, this platform would act as the carrier's carrier, providing interconnected *netports* throughout the world. This concept was then developed further within the Policy, Planning and Performance (PPP) and Global Networks (GN) directorates of BT Worldwide Networks to identify an architecture that defined the relationship between correspondent and non-correspondent services and the infrastructure to support them[1]. (See Figure 1.) Backbone (GBN) and circuit/access (GCN) networks were defined to clarify interfaces and identify optimum scope to achieve economies of scale.

Figure 1—Transport architecture



In parallel with these activities, Syncordia was developing its network to support outsourcing services, and BT had also acquired from McDonald-Douglas Corporation the Tymnet global data network which eventually came under the control of BT North America.

Syncordia

In order to address the needs of large multinational companies, BT launched Syncordia in September 1991. Its key objective was to provide international outsourced network solutions by managing and operating all or some of a customer's telecommunications service requirements[2]. To deliver this objective, a new network was established, interconnecting the 70 major industrial, financial and commercial centres in the world. This network was composed of Integrated Digital Network Exchange (IDNX) equipment manufactured by NET (Network Equipment Technologies Inc.) and connected by numerous diverse-routed digital links. This network was monitored and controlled by an integrated Global Network Management Centre (GNMC), based in Atlanta, USA. The GNMC can remotely supervise the performance and operation of the network and initiate action, as necessary, to maintain and provide customer service.

Establishment of the GMP

To address and support the individual demands of the different global services, a programme to establish a global managed transport network, called the *global managed platform* (GMP), was approved by the BT Investment Committee in September 1992. This programme proposed the establishment of a global backbone network (GBN) consisting of digital cross-connect equipment (Tellabs/Ericsson DXCs) at a number of key sites. These nodes, referred to as *netports*, would be interconnected by high-capacity E3/T3 (up to 34/45 Mbit/s) digital links. The whole network would be managed from a network management centre based in Atlanta. The aim of the GMP was to aggregate the global transmission capacity requirements of all the individual global services, thereby achieving reductions in the cost of transmission capacity as well as improvements in the flexibility of assignment of bandwidth, network resilience, speed of provision and manageability. The installation of the DXCs commenced in September 1993.

Once this network had been established, the individual separate transmission networks supporting the emerging global services would migrate onto the GBN with the Syncordia IDNX network becoming a 'concentrator' network feeding the relatively-low-rate customer capacity onto the high-capacity GBN links. In this way, the object of the GMP to provide economies of scale would be realised.

Additionally, rationalisation of the BT North America IDNX network and the Syncordia IDNX network was also included in the approved GMP programme. This integration was seen as a vital step in creating the GMP and when completed would form a single cost-effective network, sometimes referred to as the *global circuit network* (GCN), servicing the needs of Syncordia, frame relay, packet and flexible bandwidth services.

Concert Communications

In September 1993, BT and MCI announced the formation of a joint venture company (initially referred to as *NewCo*) to manage BT's and MCI's global services to multinational companies; the joint venture company was formally launched in June 1994 as Concert Communications. The importance of the GMP in the support of Concert objectives was quickly realised; analysis of the structure of the NewCo/Concert services and the way in which they would be managed confirmed the need for the GMP as the transmission infrastructure for the new company.

At a joint BT/MCI/NewCo network design workshop held in October 1993, a major change to the design of the GBN was proposed. In summary, the proposal was to provide all of the GMP functionality using only NET IDNX technology until the widescale availability of synchronous digital hierarchy (SDH) and synchronous optical network (SONET) international cable facilities. The BT GMP programme team undertook extensive analysis of this proposal, which resulted in a GMP reapproval paper, supporting this change, being endorsed by the BT Investment Committee in February 1994. The new GMP programme now focused on the deployment of IDNX 90 equipment at 15 key sites worldwide as the basis for the GMP core network. The deployment of this new equipment commenced in 1993 with planned completion during 1994.

The GMP Today

The GMP currently comprises over 170 nodes interconnected with more than 400 000 Mbit.km of optical-fibre transmission capacity to provide a global reach covering the UK, USA, Europe, Asia/Pacific, Americas and the rest of the world (see Table 1). This network provides both the core/backbone trans-border bandwidth for Concert services and access/egress circuits to customers. In time, access/egress will migrate to 'in-country' networks as and when they are developed. US rationalisation is already underway to maximise the benefits accruing from the strategic relationship with MCI. Similarly, advantage will also be derived in Europe, from activities such as the Banco Santander joint venture, and opportunities in the Asia/Pacific region.

The GMP network is designed with a high degree of resiliency provided through diversely-routed trunks and is managed by a proprietary network management system. Circuit and trunk attributes are software defined and prioritised to meet specific service and customer requirements. Network design tools such as NetMaker are used to optimise the network topology, minimise bandwidth requirements and maximise utilisation consistent with the necessary design rules to ensure provision of a high-quality network. Transmission costs for the GMP are minimised through aggregating bandwidth demands for the various service platforms to derive economies of scale in the purchase of bandwidth.

The challenge for the network designer is to balance the dilemma between maximising utilisation while reducing unit costs and providing the necessary resiliency/diversity within the network. Unit cost reductions are achieved through economies of scale in the purchase of bandwidth; for example, a 1920 kbit/s circuit is more cost effective than 2 × 768 kbit/s circuits. Network capacity comprises bandwidth for:

- in use revenue earning traffic;
- resiliency;
- network management and other overheads;
- pre-provided/planned circuits;
- spare.

The greater the utilisation, the greater the efficiency of the network in principle. However, economies of scale enable reductions in unit costs from the purchase of high-bandwidth pipes; this in turn reduces the apparent network utilisation owing to the availability of 'spare' capacity. The need to maintain separation/diversity within the network to assure a high degree of resiliency also militates against achieving theoretically-high utilisation factors. The solution to this dilemma has been through the cost-effective provision of virtual pipes; for example, T1, E1, E3 and T3 as appropriate.

Table 1 Concert Network Deployment

Europe	Americas	Asia/Pacific	Rest of World
Austria	Argentina	Australia	China
Belgium	Brazil	Hong Kong	India
Cyprus	Canada	Japan	Israel
Denmark	Chile	Malaysia	Kenya
Finland	Columbia	New Zealand	Saudi Arabia
France	Costa Rica	Singapore	South Africa
Germany	Mexico	South Korea	
Greece	Panama	Taiwan	
Ireland	Puerto Rico	Thailand	
Italy	USA		
Luxembourg	Venezuela		
Netherlands			
Norway			
Portugal			
Spain			
Sweden			
Switzerland			
Turkey			
UK			

Note: Deployment is dependent on regulatory constraints and market demand

Concert currently operates as an *international resale* operator with capacity being acquired on a lease basis in international cable facilities and on correspondent transport networks[3]. At first sight there is an apparent contradiction between the use of correspondent transport networks and facilities[4]; however, the value add that Concert is able to provide through leverage of such networks demonstrates that benefits accrue to BT non-correspondent business as a result of cooperation with its correpondents.

Using these leased correspondent facilities, the GMP has been established on an NET IDNX platform for the reasons described previously. This platform currently, and for the foreseeable future, offers the 'best-of-breed' solution to providing the GMP.

IDNX Network

The IDNX platform (see Figure 2) provides flexibility to meet both the high-bandwidth needs of the core network, together with cost-efficient network access to smaller sites. The product family supports trunk interfaces compatible with both European and North American plesiochronous digital hierarchies (PDHs), ranging from 56 kbit/s to 45 Mbit/s. Applications interfaces include analogue and digital voice, digitised video, asynchronous and synchronous data, local area network (LAN) and frame relay interconnections.

The platform provides a resilient managed network that can minimise the effects of outages of PTT facilities to assist in maintaining uninterrupted circuit connectivity. Distributed intelligence and network control are inherent attributes of the platform, with every IDNX node maintaining an updated view of the network's topology; that is, the status of the nodes and links. The proprietary management capability enables the IDNX nodes to use this information to perform fast routing and re-routing of circuits to preserve end-to-end connectivity independently of the need for a centralised network management system, including the ability to automatically re-route around network failures. This self-

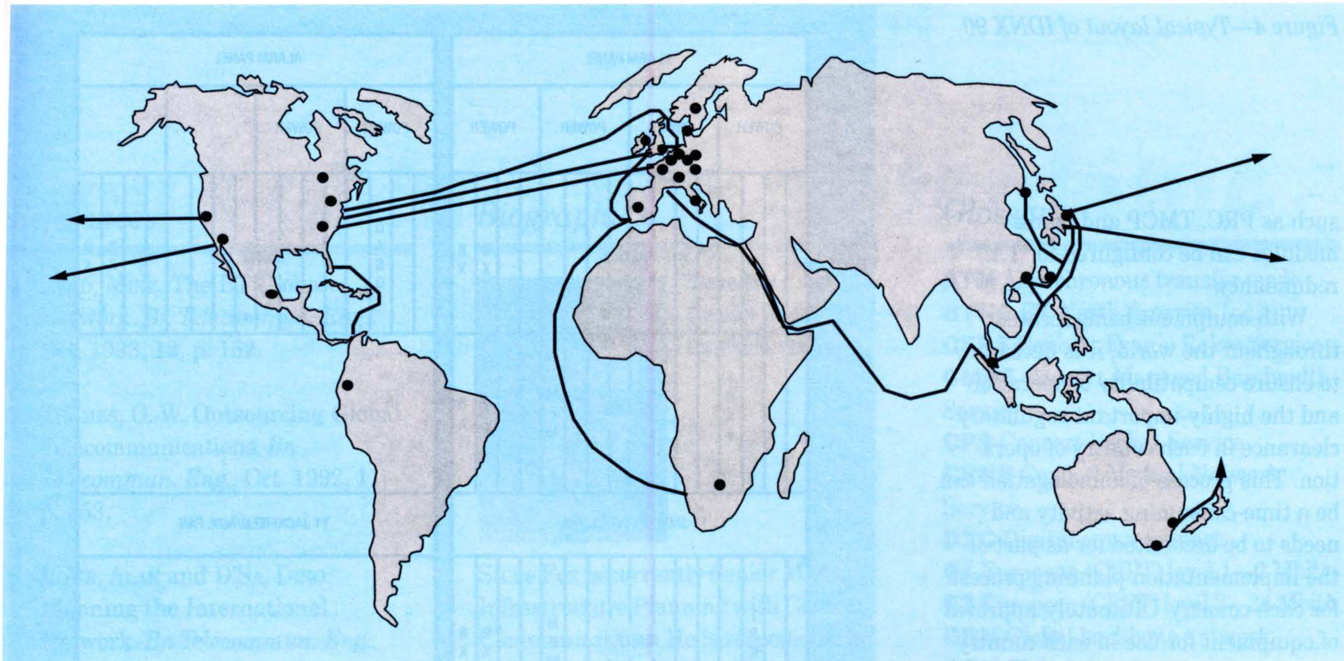


Figure 2—Key IDNX deployment 1994/95

healing feature ensures that the network's most critical applications are not disrupted by network faults. Circuits on the network are assigned appropriate priority according to their needs. The IDNX then dynamically determines the optimum path, given any specific routing requirements. This feature enables the network to operate with maximum efficiency and flexibility.

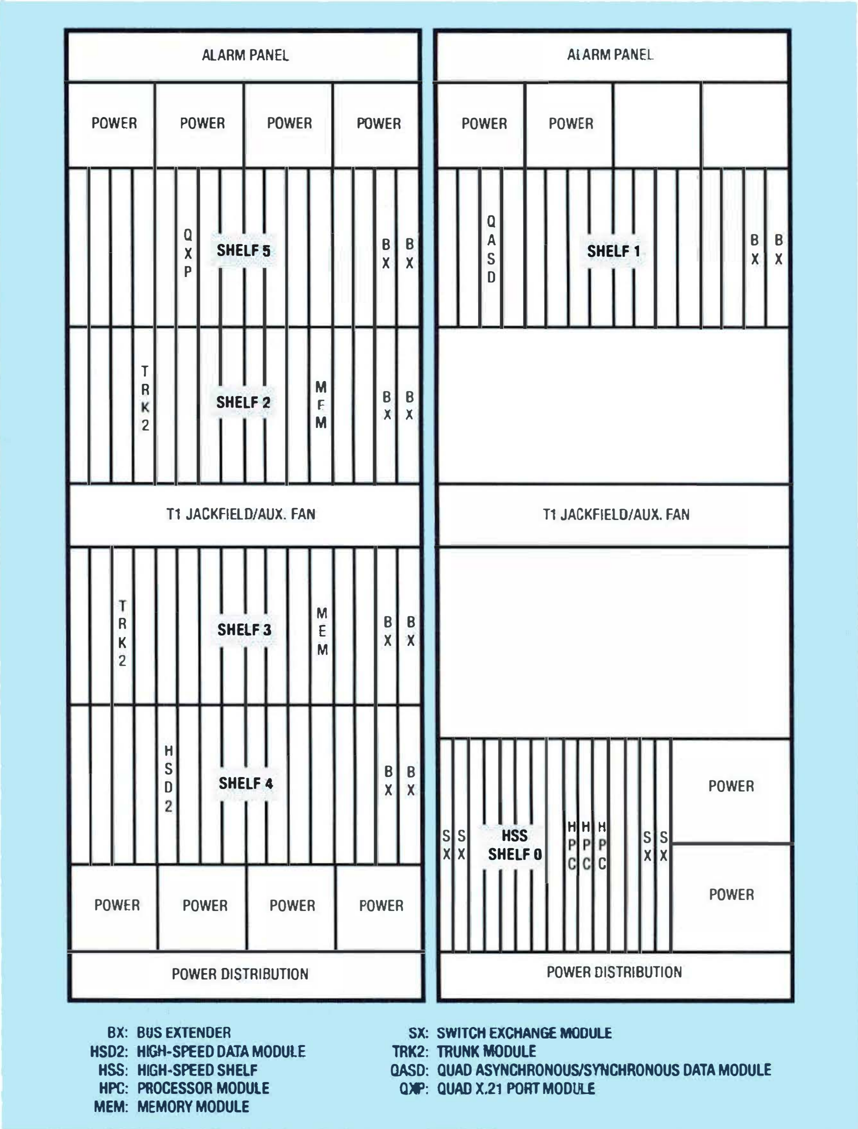
Internodal signalling is a fundamental component of the resilient network architecture. The sophisticated NET proprietary signalling system is based on ITU-TS standards for Signalling System No. 7. Embedded in each IDNX internodal trunk is a communications channel which enables network topology, diagnostic, routing/re-routing and maintenance information to be transmitted throughout the network without affecting network traffic. The communications channel provides protection against signalling errors and allows control of the entire network from the GNMC.

The network management capabilities inherent in the operating system software of every node enables the IDNX network to be self-managing and self-maintaining, in addition to being self-healing. The network management functions provide control, real-time monitoring and status reporting. This includes bandwidth utilisation reports, comprehensive event and alarm logs and full reporting status for all network components and resources.

The IDNX product family covers a range of intelligent multiplex equipment from the IDNX 90, which supports high-speed, high-bandwidth networking of trunks up to E3/T3, through the IDNX 70, which acts as a network concentrator and medium-capacity node capable of handling T1/E1 trunks, to the IDNX 20, which provides a cost-effective solution to low-volume and customer access applications. (See Figures 3 and 4.) IDNX design provides a high degree of reliability through hardware and software redundancy. Equipment can be configured easily for system redundancy; power supplies, common equipment and applications modules

Figure 3—NET equipment at Baynard House

Figure 4—Typical layout of IDNX 90



such as PRC, TMCP and trunk modules can be configured for 1:1 redundancy.

With equipment being located throughout the world, it is necessary to ensure compatibility of operation and the highly-important regulatory clearance in each country of operation. This process of homologation can be a time-consuming activity and needs to be accounted for as part of the implementation planning process for each country. Ultimately, approval of equipment for use in each country rests with the vendor but this does not remove the necessity from Concert to ensure that the regulatory clearances have been obtained. Operational compatibility in the Concert network is also confirmed through reference model testing at Martlesham Heath.

Evolution of the GMP

Evolution of the GMP will be driven by market demands to accommodate growth, global expansion and technological innovations. In addition to market demand, the development of the GMP will also be dependent on unit-cost reductions and regulatory clearances.

The development of Concert services is currently in the initial stages, being at the start of the conventional S growth curve, with the GMP presently encompassing nearly 50 countries. Expansion of Concert services and the development of distributors' 'in-country' networks will result in the need to extend the global reach of the GMP and rationalisation of access/egress arrangements with 'in-country' network developments. It is anticipated that over a 5 year time frame the network will grow to a be a $1 billion business.

The extent of growth and expansion on a global basis will depend on changes in the regulatory environment. This will impact both in terms of the services that can be offered and on the unit costs for transmission capacity. Concert currently operates in the UK and elsewhere on the basis of an international resale licence; that is, capacity is leased at tariff for resale of Concert products.

On the technology front, SDH and SONET 'islands' are already beginning to be interconnected by international cable facilities such as CANTAT-3. The advent of TAT-12/13[5] in the Atlantic ocean and TPC-5 in the Pacific will provide opportunities to take advantage of SDH technology[6]. It is anticipated that the GMP will evolve to an SDH platform to benefit from enhanced transmission management facilities and enable SDH service offerings. In parallel with migration to SDH facilities, the platform evolution will also address the gains that can be achieved from asynchronous transfer mode (ATM) technology.

Upgrades will also be provided to the GMP network management capabilities to accommodate growth in the size of the network and further enhance the management facilities currently available. The introduction of telecommunications network management (TMN)[7], and particularly the exchange of information over the X-interface, will also provided major operational benefits when such interfaces are fully defined by the standards bodies and can be implemented.

Summary

The GMP has been created to provide a managed transport network and to derive economies of scale in bandwidth purchases for the various Concert service platforms. Global reach is already established by the GMP to the world's major business and industrial centres to enable the provision of a unified-look-and-feel product set. Evolution of the GMP is anticipated to see expansion to address market needs and gain benefit from opportunities provided by technological innovation.

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Biographies

Steve Fox
Concert Communications

Steve Fox is currently Senior Manager Infrastructure Planning with Concert Communications. He is responsible for both the GMP and the associated Concert infrastructure and for service planning aspects of the CMBS product. During a varied career in BT and the PO, Steve has been responsible for the development and introduction of optical-fibre cable systems in both the BT core and global networks. More recently, he has been responsible for planning correspondent transport networks including GEN, GNP and METRAN. He is a Chartered Electrical Engineer and a Member of the Institute of Managers.

Alan Snowball
Concert Communications

Alan Snowball joined the International Executive of the then Post Office in 1974 and since then has undertaken a number of responsibilities in BT including network interconnect planning with Mercury Communications Ltd (MCL) and mobile networks as well as planning and provision of BT's international correspondent networks in Europe and Middle East. At present, Alan is a manager in Concert Infrastructure Planning with responsibility for GMP IDNX roll-out and Concert's node accommodation and data communications network.

Glossary

ATM Asynchronous transfer mode
BTNA BT North America Inc.
CFRS Concert Frame Relay Service
CMBS Concert Managed Bandwidth Service
CPS Concert Packet Service
CVNS Concert Virtual Network Service
DXC Digital cross-connect
E1 European (CEPT) level 1—2 Mbit/s
E3 European (CEPT) level 3—34 Mbit/s
GBN Global backbone network
GCN Global circuit network
GMP Global managed platform
GNMC Global Network Management Centre (Atlanta)
GNS Global Network Service (now CPS)
IDNX Integrated Digital Network Exchange
INSP International network services platform
ITU-TS International Telecommunication Union—Technical Standard
LAN local area network
NET Network Equipment Technologies Inc.
PDH Plesiochronous digital hierarchy
PRC Primary-rate card
SDH Synchronous digital hierarchy
SONET Synchronous optical network
T1 North American (ANSI-T1) level 1—1·5 Mbit/s
T3 North American (ANSI-T1) level 3—45 Mbit/s
TMCP 2 Mbit/s channelised port module
TMN Telecommunications management network

Barry Manning and Paul Warren

Automating the End-to-End Customer Network Design Process

One of the fastest growing and potentially most profitable areas in telecommunications today is that of the global customer network. The differentiator between the key players is customer service, and responsiveness. Building on available network design tools is the concept of the network design centre, the 'one-stop shop' of network design.

Introduction

This article follows on from a previous article 'Ensuring Quality in Design of Customer Networks'[1], which described network design processes and tools within BT at the present time. This article details how Global Networks (part of BT Worldwide Networks) plans to combine these discrete components into a single entity with the intention of automating the end-to-end design process.

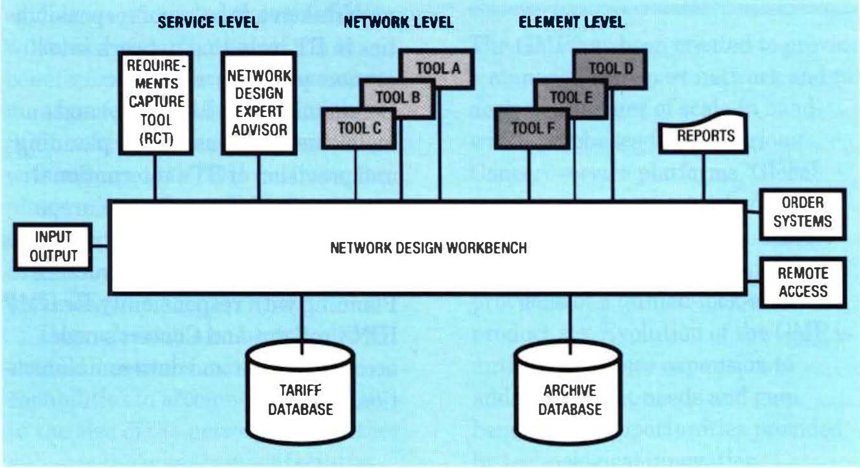
The complex area of network design relies upon highly skilled people providing the solutions to customers' networking problems. It is often carried out in a highly pressurised environment, to tight timescales and with resources which are becoming increasingly limited. In the spirit of continuous improvement and increased quality for Global Networks' customers, the network design centre (NDC) has been conceived.

Network Design Centre

The NDC (see Figure 1) will enable designers to access a range of software tools to provide costing, modelling, and design of networks; these will help the designer to make structured decisions on technology, cost and performance of the network.

The use of discrete tools in a network design environment can lead to inefficiencies in the design process as there is often a need to enter the same data into a number of tools. This results in a high proportion of time being expended in the rekeying of data into different tools at various stages of the design process. There is also the risk of errors during this manual transcription stage.

Figure 1—Network design centre



The NDC concept works to minimise this repeated effort. At the front end is a requirements capture tool (RCT) which enables capture of the customer's requirements. This tool can also be configured to capture specific customer service requirements; for example, frame relay.

The NDC is not just a collection of tools connected together. At the heart of the NDC is the network design workbench (NDW). As Figure 1 depicts, the NDW provides the 'glue' for the interworking of tools and databases; an input/output facility enables the user to be connected to the available entities. At the front end of the process, the requirements capture tool enables all necessary customer information to be captured. This information is passed, via the workbench, to the network design expert advisor (NDEA) to enable a technical solution to be identified; this will provide guidance to the network designer on the possible solutions available to fit the customer's requirements.

Design levels

Of interest are three 'levels' of network design:

- The *service* level is generally concerned with systems engineers and account managers liaising with the customer to identify their needs from a service point of view. For example, a customer may want to transmit voice and/or data between sites; the customer is not concerned with how the calls are routed, or what equipment is used.

- The *network* level identifies the possible solution to the customer's problem in the form of a network design and costing. It will specify the technology and topology used, link sizes, resilience, etc.

- The *element* level design provides the ability to model and optimise networks down to individual card or item level in terms of configuration and routing; at this level, detailed parts lists can be produced, which in turn allows detailed costings.

The RCT and NDEA both reside at the service level, the objective being to provide formatting of requirements, platform selection and definition of the operational support systems.

Referring to the network level of design in Figure 1, tools A, B, and C provide topology design, connectivity, dimensioning of links, network interconnections, cost of support and network management, circuit costings, network configuration, bandwidth requirements and network performance.

Element level design tools D, E and F provide configuration information, parts list, software build, cost of hardware and performance modelling to a much greater degree than can be obtained at the network level. (The corollary of this greater accuracy is that modelling may take longer and, because the tool is vendor- and probably module-specific, its scope of use is narrower.)

Scope of the network design centre

Globally, the number of organisations that need to model their own networks is small; a growing number of companies are choosing to outsource design and maintenance. This is precisely the reason why there is a growing market which BT is attacking. In general, smaller companies have smaller networks which are less likely to have a need for design tools.

Even those companies which model their own networks automatically may not need the sophistication of tools such as those detailed later in this article; they can use a cheaper tool giving approximations, safe in the knowledge that where their calculations are a little rule of thumb, the 'slack' can be taken up by overflow to the public networks, and the only losers will be themselves; if they run into trouble, they can ask one of the 'experts' for help. However, organisations such as BT whose main purpose is to provide design capability cannot provide 'half a solution'; if the design is lacking, the customer will rightly complain.

These factors mean that there is a limitation on the number of tools of quality which a vendor can expect to sell; consequently, the tools are expensive. In order to gain advantage of economies of scale and discounted bulk licences, the maximum number of users must be allowed access. The actual mechanism for providing access to multiple users must take into account situations such as:

- several designers working on their own copy of the same network without each having to enter starting parameters, and each being able to save their altered network back to the common space without affecting other users; and

- several users who may each want access, but not necessarily simultaneously.

The NDC will enable users to meet their design needs in the following areas by enabling users to access various tools, either simultaneously or individually, with the tools interworking to provide an end-to-end process eliminating the need for duplicate data entry. Another useful possibility is the automatic iteration of a design so that the output of an end-of-process tool could be fed back to a tool earlier in the process.

- Requirements capture.
- Platform specification.
- Topology design.
- Network design.
- Network costing.
- Element design.
- Element configuration.

- Network management centre design.
- Storage and filing of bid/requirements information.
- Version control of network design iterations and bid phase requirement changes.
- Process management of the design project, from start to implementation handover. The process should also necessarily include a post-implementation review.
- Network security.

Tools in the NDC

Some tools have already been mentioned. Others of interest have been described in some depth in Reference 1, but a brief résumé of the main ones is given here.

Worldplan

Worldplan is a proprietary tool which runs on a PC platform and is used for designing and costing voice networks. It has access to intra-country tariffs for many parts of the world, and has a menu interface which is an extension of that used in Micronap (see below). Worldplan has a powerful 24-hour feature which allows design of networks across time zones; to facilitate this, the tool can accept traffic data profiles with local zone times, and automatically accounts for the slippage. Profiles can be input manually or directly from call loggers. 'What-if' modelling and comprehensive report generators are included.

Micronap

This is a tool from the same supplier as Worldplan. It is specifically for in-country use; although there is a limited range of countries for which tariffs and geographic data is available, this range can be enhanced. Many of the design features of Worldplan are available in Micronap, and the interfaces and menus are similar.

NetMaker

Make is a US company which is internationally known for its network design tools. NetMaker is one of the company's products which allows design and costing of networks built from various suppliers' equipment. NetMaker XA is the latest version of the tool offering even more functionality. The tool is modular, consisting of core software, around which the user can put other modules depending on the application. Device libraries which contain details of manufacturers' router or multiplexer equipment is available to suit the users' requirements; libraries for Timeplex, Cisco, NET are among those offered. Netmaker must be run on a RISC (reduced instruction set computing) based platform running UNIX.

NetMod

NetMod is a BT-developed tool widely used to design and configure Timeplex multiplexer networks. It can automatically upload and download configuration data directly from the network, allowing a complete sequence of upload, modelling, reconfiguration, and download back to the network to be done without rekeying data. Although NetMod has performed admirably for several years, the pace of technology and its inability to handle other manufacturers' equipment without major overhaul have recently led to the decision to withdraw the tool and replace it, probably with NetMaker XA. NetMod has been used successfully to design and maintain networks not only for several major UK customers, but also for BT's own internal data network, the IBTN, run by Global Networks for use by BT worldwide with over 200 nodes in the UK, USA, Far East, Australia, and Europe. NetMod must be run on a RISC-based platform running UNIX.

Site audit tool

The site audit tool is a hand-held terminal with a bar code reader. It is used to store details of equipment in situations such as outsourcing communications management. An inventory can be carried out in a fraction of the time taken to implement a paper-based audit. This ensures that the most common errors which occur, such as equipment being missed or double-counted because it has physically moved during the audit, are avoided. Also, since the data is electronically uploaded to a host computer, there are no transcription errors due to mistyping. Future visits to site can result in a quick comparison between current and past equipment.

ACD modelling tools

Global Networks has responsibility for the largest networked automatic call distributor (ACD) system in the world. The network consists of about 60 Northern Telecom (NT) Meridian ACDs; real-time resource management and longer-term statistics are provided by individual management information systems and a higher-level network administration centre (NAC) system which looks at the network figures. However, the NAC has a limitation in that it can only service about 20 fully-interconnected ACDs. Although several NACs can ensure complete coverage of the network, a complete network picture cannot be obtained. To allow modelling of ACD networks to determine resourcing levels and optimum configurations, an ACD modelling tool has been developed by BT.

Northern Telecom itself has also recently developed a tool which is intended to perform a similar function. This is currently being evaluated to determine its suitability in fulfilling BT's ACD design needs.

Admin ToolSet

The Admin ToolSet (ATS) is a PC-DOS based tool which is effectively an inventory system. It was developed specifically for storing customer information relating to the New South Wales Government (NSWG) project, a contract won by BT to design and implement customer networks on behalf of NSWG departments; however, it is finding use in other Europe and Asia/Pacific projects. ATS is a PC-based tool which stores data on customers at a top level (where, for example, the customers for NSWG would be government departments such as Justice, Traffic, etc.), and under these, sites, works orders, services, links, cards, and time-slots are some of the database tables. Comprehensive reports are available, and search and browse features maximise the tool's use.

Geographical information systems

A geographical information system (GIS) is basically a database with an associated graphical system. An example might be a map of a town on which could be overlaid the positions of all the manholes, telephone poles, and duct which comprise the telecommunications infrastructure. By mouse-clicking on one of these items, an underlying database entry is displayed which details the information associated with that item; the format of the display may vary according to the item, so that for a pole the displayed information might be the height, date last safety-checked, etc, whereas for a duct, the data could consist of a record of all the circuits carried therein.

As well as having obvious stand-alone use in many situations, GIS is seen as an important part of the NDC because it can give a common graphical front-end to many tools which do not use graphics (such as ATS). This enhances their usefulness by aiding understanding of the networks; it is also a powerful tool which can demonstrate to customers that their network is (for example) resilient or routed in a sensible manner.

Network design workbench

In Figure 1, the NDW is shown connecting the tools and databases. The NDW has been a major component of the NDC architecture since it was recognised that no single system was available, or could be developed within business constraints, that would support all the goals of the NDC concept. However, it was considered that a feasible approach would be to provide a system which could integrate current and future network design tools and support systems. This system became known as the NDW. Additional value is given to existing network design tools by providing features within the NDW not available within the individual tools but necessary if the full potential of the NDC concept is to be exploited. These features include support for:

- transfer of data between individual network design systems to avoid rekeying data available in one system but required in another,
- cooperating NDCs working on common network designs,
- access and version management of data across a network of NDCs,
- access to tools and databases at local or remote locations,
- work structure organisation, and
- notification of events; for example completion of an activity, up-issue of data.

A prototype NDW system has already been developed for use by Worldwide Networks in the Asia/Pacific Region in support of the New South Wales Government project. This system was developed on a PC platform to provide compatibility with existing computing and communications infrastructure. It is now operational at Worldwide Networks sites in York and Sydney. From this development exercise and subsequent NDC projects, additional requirements have been identified and further development is being arranged to deliver these capabilities.

The NDW will provide mechanisms for transferring information between autonomous network design systems. Each network design system supported will have its own data store. The NDW will provide front ends for these systems to enable the transfer of data between systems. For example, a user may want to extract a subset of sites and links from the data store of a requirements capture tool for use in building a network model within a network design tool. A task would be created on the NDW's graphical user interface (GUI) that would:

- invoke the front-end for the requirements capture tool with parameters to extract the desired subset of site and link information from its data store; and
- invoke the front-end of the network design tool with parameters to insert the extracted data into the design tools internal data store.

As individual network design systems are identified as requiring NDW integration, front-ends will be developed to support this mechanism of data transfer. Systems used for network design and potentially requiring data transfer range from simple documents and spreadsheets to complex stand-alone network modelling tools. The essential feature of this capability is that the rekeying of data from one system to another is minimised.

A library system will be provided within the NDW for the storage of network design data. Essentially any piece of data can be stored in the library. Data could include spreadsheets, documents, data extracted from network management systems and the storage of data used by proprietary network design systems. The only constraint is that the data can be packaged as a file within the operating system of the NDW. This capability will provide improved control of the data used during the network design process.

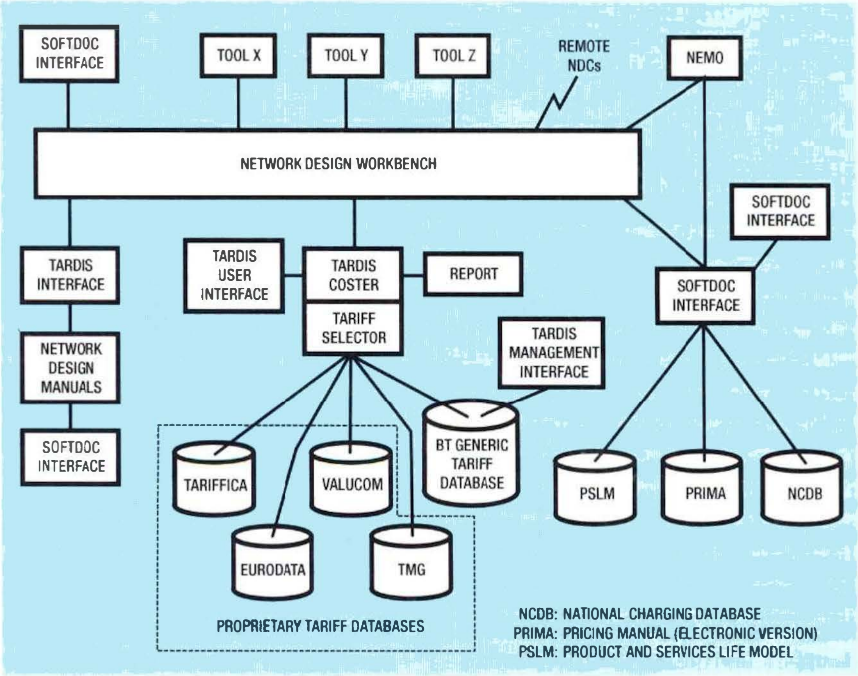


Figure 2—TARDIS system

Tools and data available on an NDC's local NDW will be accessible to users at other NDCs. This will allow:

- network people at different NDCs to work on common network designs in a controlled manner,
- sharing of network design tools,
- bureau services to be set up for specific network design skills at NDCs, and
- data to be extracted from centralised databases and systems for use locally.

Remote access will be provided to network design systems that are capable of this mode of operation. The system to be accessed will be selected from a list of available systems displayed at the remote NDW terminals. The NDW will then make the connection to the system and start the appropriate terminal emulation to provide user access. Front-ends will be developed for specific systems to provide greater integration with the NDW.

The proposed solution, which is based on a client/server application architecture, has a number of components, some of which are commercially available products while others are in-house developments. The philosophy of the NDW development is to integrate commercial products wherever possible to meet the requirements and thus minimise the amount of in-house work required.

The solution is based on providing users access to NDW functionality via a Microsoft® Windows™ user interface running on a desktop PC. Core NDW services will be provided on a Sun SPARC UNIX machine. The Distributed Computing Environment (DCE), which is an operating environment, will be used to provide many of the NDW's low-level networking and control capabilities. These include security, access control, file replication, remote procedure calls, and network-wide time synchronisation. The user-interface component of the NDW will provide the Microsoft Windows front-end through which NDW's own capabilities will be accessible (for example, library system, event management) and through which the access to NDW integrated systems will be achieved.

Global tariff database

An integral part of the network design process is the ability to cost and compare various solutions. Cost comparison has several uses; for example:

- to produce a range of costed solutions for a given design,
- to predict the cost of a customer running the network, and
- to determine the price a competitor would quote (competitive bid situation).

Necessarily, if BT is to win business and profitably support that business, then network designers require access to accurate, up-to-date, validated tariff information, both for BT's own and BT's suppliers and competitors services.

A tariff database information system known as *TARDIS* will provide access to tariffing information to enable the designer to cost circuits and networks. Figure 2 illustrates the TARDIS system.

The TARDIS system will provide the ability to select tariff information from a number of sources. There are various tariff data providers on the market, three of the market leaders being Valucom, Tariffica and Eurodata; each of these provides tariff information in various parts of the globe. TARDIS allows BT designers to select the database that serves them best in the part of the world which is of current interest. The tariff selector can be programmed to select the best supplier of tariff information to meet the designer's specific needs.

Alongside the proprietary databases, TARDIS will have BT and custom databases; the first will hold specialised BT tariffs such as discount structures peculiar to specific projects, or unpublished data such as costs which BT incurs in dealings with foreign PTTs and carriers. Custom databases will allow users to hold their own 'personalised' data; one use for this could be to determine costs if tariffs were to change; that is, 'what-if' testing on financial, rather than technical scenarios.

A system known as *softdocs* enables the user to view any textual information on tariffs via the same interface as the TARDIS system. Figure 3 shows how the TARDIS system and NDCs are networked. The BT-specific data source will be maintained in-house by BT and the

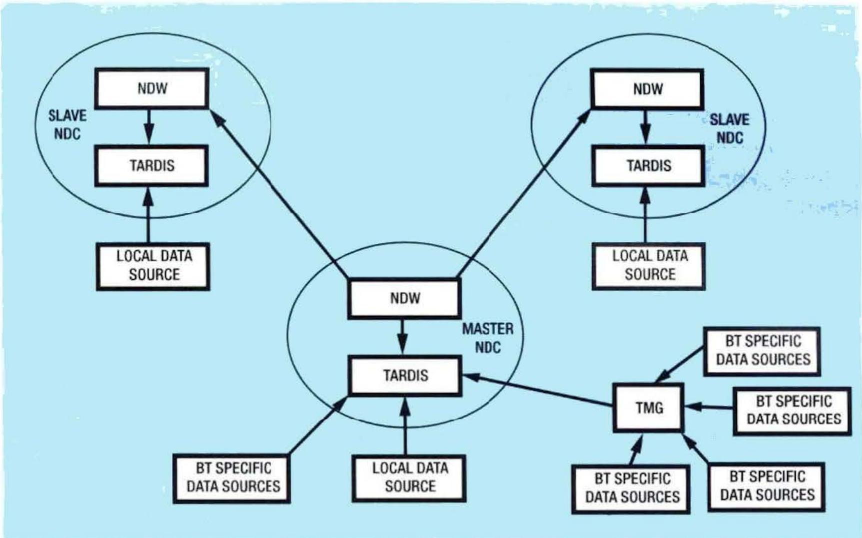


Figure 3—Networking NDCs

proprietary data sources will be maintained to BT standards by an external company, Telecommunications Management Group (TMG) Ltd., under contract.

The main TARDIS system will receive quarterly updates from BT-maintained tariff data and from the externally-maintained information.

The main TARDIS will then update all slave systems on line.

Conclusion

The network design centre provides BT with the technology to design global customer networks with minimum re-keying of information, and with maximum automation of the processes which govern which service to use. The tools that sit upon the workbench provide powerful and fast solutions to customer requirements.

While there will always be a need for skilled network designers, this and future developments will enable them to use their creative abilities to concentrate on producing network designs rather than performing administrative tasks. With the NDC concept, where quality is assured, BT can now concentrate on quantity, and target new global markets.

Acknowledgements

Acknowledgement is given to Nigel Fletton and Paul Payne of BT Development and Procurement for their input to the text and figures in this article.

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Biographies

Barry Manning
BT Worldwide Networks

Barry Manning joined the British Post Office in 1973. He worked in the Suffolk area on installation of business systems. After a period of involvement in business systems planning, he moved into the customer service systems (CSS) implementation team, based at Colchester, where his responsibilities included training and system implementation support. He transferred into the commercial training team serving the (then) Home Counties District where project management on the National Job Recording (NJR electronic time sheets) was a year-long responsibility. His present position is as an implementation manager on design tools within Global Networks.

Paul Warren
BT Worldwide Networks

Paul Warren joined the Post Office as an apprentice in 1966. After graduating from Loughborough University of Technology in 1974, he worked in several areas of PO and BT Headquarters, including analysis of fault statistics on TXE4 exchanges, Monarch PABX development, and testing and validation of computer systems. More recently, he has been involved in the evolution and strategy of internal networks and now works in Global Networks, where he is responsible for the identification and provision of automated tools for use in network design, especially in the global customer arena.

Glossary

ACD Automatic call distributor
ATS Admin ToolSet
CSS Customer service systems
GIS Geographical information system
GUI Graphical user interface
NAC Network administration centre
NDC Network design centre
NDEA Network design expert adviser
NDW Network design workbench
NEMO A BT-developed network modelling tool
NSWG New South Wales Government
RCT Requirements capture tool
TARDIS Tariff database information system
TMG Telecommunications Management Group Ltd

BT and VIAG Join Forces

BT and German industrial group VIAG announced that they have reached agreement in principle to form an alliance to offer telecommunications services in Germany, the largest telecommunications market in Europe. Both parties will have 37·5 per cent of the new venture with the remaining 25 per cent to be taken up by other German partners.

The alliance, to be known as VIAG InterKom KG, will be headquartered in Munich. It is planning to offer services from April for national and international business customers. These will include international voice and advanced data services currently offered by Concert—the BT and MCI global network company—and will be quickly followed by domestic services aimed at medium sized multi-site companies.

This is the first phase of the strategic plan for the alliance company that will seek a licence in Germany to offer a full range of telecommunications services, including public voice.

Investment by the alliance will be several hundred million pounds over 10 years, with a considerable increase should the alliance receive a full licence to provide services. In its first year, the alliance will have 350 employees which will increase to 1000 in the medium term.

BT Chairman, Sir Iain Vallance said: 'We are delighted to have reached this agreement with VIAG. We now view the whole of Europe as our home market and this represents BT's single largest investment there outside the UK. This is a major step in our plans to become a leading alternative to selected incumbent European operators such as Deutsche Telekom.'

Dr. Alfred Pfeiffer, Chairman of the VIAG Management Board, added: 'VIAG now regards telecommunications as becoming an increasingly important part of its activity and we look forward to it becoming a core element of our business. The impending liberalisation of the German market, currently worth about £29 billion and set to grow at six per cent annually, offers considerable opportunities.'

The new company will have access to BT's wide range of communications technology and have the advantage of BT's 10 year experience operating in one of the world's most competitive environments. It will also have access, when regulation permits, to 4000 km of optical fibre through Bayernwork, the Bavarian energy company. This is one of German's largest private fibre grids.

The current activities of TB&D and BT Deutschland will be merged into the alliance.

BT—Past and Future Technological Developments

In the ten years since BT was privatised, the world of telecommunications has changed dramatically. To meet the new challenges, BT has introduced a number of world-beating technological developments including optical-fibre cable and digital exchanges, giving customers clearer lines, faster connections and a significant reduction in call charges.

But these products and services have not been developed purely for technology's sake. Every concept has been developed to meet specific customer requirements—the company's significant research and development effort is very much customer and service driven.

Since 1984, BT has spent £20 billion producing the world's most advanced network—that is more than £70 for every second of the decade.

The last ten years have been a decade of improvement. The company has concentrated on the development of new and improved telecommunications services, particularly in the areas of speech applications, mobile (cellular) products and video telephony. Cost reductions and an improved quality of service have been achieved through the building of a superior network infrastructure.

The benefits of such technological improvements are significant.

- In 1984 there were 20 million BT lines. Today, thre are 26 million—an increase of 30%—all of which allow higher quality line clarity and increased service reliability.

- Today, more than 93% of BT's customer lines are served by digital or modern analogue exchanges.

- BT has installed more than 30 500 000 kilometres of optical fibre in the network, resulting in faster, clearer connections with fewer errors.

- The mobile telephony market has experienced explosive growth. BT has more than one million mobile customers and offers them greater communications flexibility, convenience and personal safety.

BT is a company with a commitment to the future. BT Laboratories has the largest centre of telecommunications research and development in the United Kingdom. Across the company, BT spends in the region of £250 million each year on research and development projects.

With the foundations of 10 years in place, BT is now poised to introduce a wave of new products and services which will take telecommunications into a new era.

Concepts in the pipeline include:

- A broadband network, with a global reach, which is accessible both from fixed and mobile locations,

- An increasingly flexible personalised network, with easy user interfaces, such as voice control of telephony services,

- A range of multimedia services which support things like home shopping, entertainment and education, and

- A range of services that businesses are going to need for efficient and rapid communications across international boundaries, such as collaborative working and desktop videoconferencing.

In 1984, the technology developed by BT was in its infancy. Today it is part of all our every day lives. BT has grown from being just a telephone company to one of the largest and most successful telecommunications companies in the world.

10 Years of Technological Milestones for BT

- 1984 Digital video conference multi-point system demonstrated, and product launched.
- 1985 Operational switched-star cable TV network.
- 1986 Largest integrated customer handling system installed.
- 1987 Video on demand trial in Westminster.
- 1988 Derived services network introduced.
- 1989 Narrow-MAC, a bandwidth efficient means for distributing TV signals demonstrated.
- 1990 Concert unified network management system developed.
- 1991 100% Integrated services digital network (ISDN) availability for all UK customers.
- 1992 Video phones for the deaf with full motion video over the public switched telephone network (PSTN).
- 1993 Virtual reality technology deployed for network management applications.
- 1994 Interactive video on demand service launched.

Experimental Link is Technology 'First'

Recently, for the first time in the UK, a telecommunications link between BT Laboratories (BTL) Ipswich Hospital allowed endoscopic examinations to be carried out by an expert in a remote location on three adult patients, with their prior agreement.

Two of the country's top endoscopists were involved. Dr Duncan Bell was with the patients at Ipswich Hospital, while Dr Brian Saunders of St Mark's Hospital in London offered verbal and visual guidance from BTL.

BTL's Dr David Heatley, who helped develop the system, said, 'This technology makes it possible for endoscopists and other medical specialists to literally dial up additional expertise to assist in patient examinations and treatments. Because the ISDN network is global, these experts could be called in from almost anywhere in the world. Any hospital or medic can be linked to any other. Distance does not matter.'

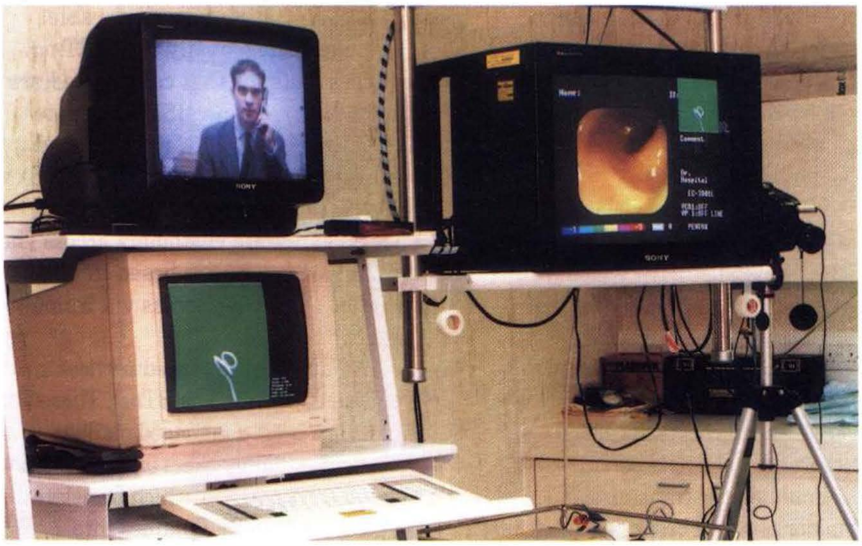
The link also offers an excellent opportunity for medical education. Ipswich Hospital's Dr Duncan Bell said, 'The ability to dial up and observe ongoing patient examinations will become common place and provide an important training supplement to hands-on experience.'

The telecommunications link between the two locations was provided by BT's all-digital ISDN telephone network. Commercially available confravision terminals at both locations were used to convey sound and vision in both directions over a single ISDN telephone line. An adequate sound and picture quality for this application was achieved over this one telephone line, indicating that this technique involves minimal cost and is suited to widespread use.

The images conveyed to the remote expert included not only the conventional view from the colonscope but also the path of the instrument inside the patient's body (Figure 1). This image is produced by a revolutionary system, developed jointly by BT Laboratories, Mr John Blaydon of Sheffield University and Ipswich Hospital. It avoids the need for X-rays and produces a real-time 3 dimensional display. This aspect of the link-up is a world first, as only Ipswich hospital has the new imaging system and patients attending the Endoscopy Unit are the first in the world to benefit from this new system. A third image relayed to the expert was a view of the patients and attending medics at Ipswich hospital. They in turn had a head and shoulders view of the expert.

Professor Peter Cochrane, head of Advanced Applications and Technologies Department at BTL, said, 'This work shows a vision of the future that is being realised today. This is but a glimpse of what ISDN can ultimately offer medicine and education.'

Figure 1—Remote-viewing endoscopy equipment



100 Gbit/s All-Optical Switch Using a Semiconductor Laser Amplifier

Results from BT Laboratories (BTL) have shown that semiconductor laser amplifiers can be operated at higher speeds than were previously thought possible. By using them as all-optical switches, they can be operated at approximately 100 Gbit/s.

According to BTL's Bob Manning, who has developed this technology, the advantage of this approach is that these devices operate over a broad wavelength range which, depending on the device, can cover the first, second or third telecommunications window.

The speed of the device is also controllable. Because of the semiconductor technology, these devices are very small—approximately 500 micrometres long—this means that it could be possible to perform the key optical processing functions of telecommunications on an integrated chip, running at 100 Gbit/s or faster.

It is possible to achieve these bit rates by using an optical beam to speed up the response of the amplifier. For all-optical switching applications, these very small devices are used as a non-linear element in an interferometric arrangement, where a phase shift of 180 degrees (π) is needed to change the switch from 'off' to 'on'. It is possible to perform this switching operation approximately every 10 ps, with reasonable switching energies. This corresponds to a switching rate of up to approximately 100 Gbit/s.

Fast Flying Fax Service Launched by BT

BT announced the availability of the world's first 4·8 kbit/s airborne fax and data service for airlines and business jet operators. The new service, operating at twice the speed of existing airborne facilities, means passengers on long-haul flights or on business jets can send and receive faxes much faster and more efficiently.

The new BT facility will initially be offered in the Atlantic Ocean region through the satellite consortium, Skyphone. Airborne fax traffic will be delivered to its destination by BT's ground earth station facility at Goonhilly in Cornwall.

The new software needed to support the faster transmission speed is being installed at Skyphone's other ground earth stations in Singapore and Norway. Covering Inmarsat's other two global zones, they are expected to come on line shortly, completing the first fully global 4·8 kbit/s airborne fax and data services.

Doubling the transmission speed is a major network breakthrough for BT and its Skyphone consortium partners. The 2·4 kbit/s rate—up until now the only satellite transmission rate available from any service provider—is relatively slow for airborne fax and data services. Some innovative long-haul airlines have offered these services right from their launch in 1993 and are now looking to upgrade them. Added to that, the industry as a whole is now looking to standardise at the new, faster and more price-efficient 4·8 kbit/s rate. BT is the first organisation to be able to satisfy that need.

The lack of a faster fax and data facility has held some operators back from opting to install on board passenger communications and the introduction of the 4·8 kbit/s fax will help convince those airlines who are still debating the issue.

BT Launches Internet Service for Business

BT officially launched BT*net* in November 1994, the most comprehensive connection service available to Internet—the world's largest growing data network.

BT*net*, comprising the widest range of direct connections offered to date, includes everything from dial-up to high-speed broadband communications. As a result, businesses are given improved choice and a cost-effective way of extending their corporate networks to include internal departments, trading partners and customers.

BT's connections to Internet are now in place and UK-based customers with existing corporate networks and potential customers are able communicate globally using BT*net*. Access methods that can be used are the public network, ISDN, private circuits, frame relay and switched multi-megabit data service (SMDS). By early 1995, BT will offer UK-based corporate customers access via X.25, and customers based in mainland Europe access via frame relay and X.25.

A number of enhanced services are offered as standard on BT*net*. These include e-mail, a managed mailbox service for dial-up users and a domain name service (DNS), which translates user-friendly e-mail names into numerical Internet addresses. Also available are file transfer protocol (FTP), which allows customers to connect to another computer and transfer, copy and list files on a directory, and a Usenet feed, a network of conference and interest groups.

Two-Way Text Messaging with BT Reply Master

BT has announced a new mobile service aimed at field service engineers, logistics and distribution companies and any other mobile people who need cost-effective two-way communication with a central despatch centre. Called the *BT Reply Master*, the system uses a Windows based software package to transmit text direct from the customer's PC-based despatch centre to individual hand-held mobile units, the Reply Masters.

A key benefit of the system is that the mobile units contain a selection of up to 128 pre-set messages, each one being customised for the user's particular business, enabling field staff to report their status simply and easily to their despatch centre. The central despatch unit will get rapid, automatic confirmation that the message has been received by the mobile unit. In addition the mobile unit can reply with one of the messages stored in the unit.

There has been a gap between paging and fully integrated mobile data solutions that two-way messaging will fill.

At the heart of the system is a Windows-based software package, linked to the Reply Master units by a radio modem. The software automatically tracks messages and records replies, giving the facility of a full audit trail.

Error-free transmission and reception ensures that messages are received in full and, if the Reply Master is switched off or is out of reach, messages are automatically stored and forwarded when the unit is back in service.

BT to Trial Interactive Television

BT has announced that it is to start consumer trials of BT Interactive TV—which includes video-on-demand—in the middle of 1995 with 2500 households in Colchester and Ipswich.

Interactive TV brings together the telephone and the television to enable customers to choose a range of services from a menu on an ordinary television set. The material is then transmitted from a central database over the telephone network to the television, not affecting the normal telephone line.

BT aims to offer, during the market trial, shopping on demand, a range of educational programming for homes and schools, movies and television programming (video-on-demand), a home banking service, a magazine service and community link (a local information service). Additional services will be introduced during the course of the trial.

BT will be using asymmetric digital subscriber loop (ADSL) along with fibre in the ratio of about four copper to one fibre. In the earlier technical trial BT used discrete multitone (DMT), but will be using carrierless amplitude and phase modulation (CAP) ADSL in this trial as it is available earlier and in more integrated and cost-effective form.

BT Introduces Voice Messaging for Small Businesses

Small businesses can reduce the amount of time incoming callers wait to be answered by installing BT's new digital interactive voice messaging system, StarTalk Mini. The system is compatible with BT's Meridian Norstar Compact and Modular switches. It helps businesses improve customer service and business efficiency by answering calls and taking messages.

The StarTalk Mini system is connected to an extension port on the Meridian Norstar. The auto-attendant function answers calls and, using pre-recorded messages and customer call routing, gives customers the option to dial an extension, obtain pre-recorded information or leave a message on one of the system's 32 mailboxes. Each of these mailboxes can be accessed remotely or programmed to forward messages to pagers, mobile phones or fixed phones. They also filter out standard enquiries with pre-recorded information that can be accessed without speaking to an operator.

The system can be used to answer calls during busy periods without increasing the number of staff needed, and can give 24 hour access to a company.

Steve Roberts, marketing specialist for BT's Business Switching Services, said:'The introduction of this voice messaging system will help small businesses maximise their staff resources by using the system to answer some of their calls. It can help portray a professional image and increase the standard of service to customers.'

BT Expands Visual Communications Portfolio with Two New Launches

The UK's first ISDN desktop videophone, Presence (Figure 2), is one of two new additions to BT's visual communications portfolio. It combines a telephone with full-motion, full-colour video enabling users to turn a telephone conversation into a more

Field Focus Articles

Are you aware of a local BT project that would make the subject of an interesting article in the Journal's Field Focus section? For example, novel solutions to field problems could make the bases of very interesting items.

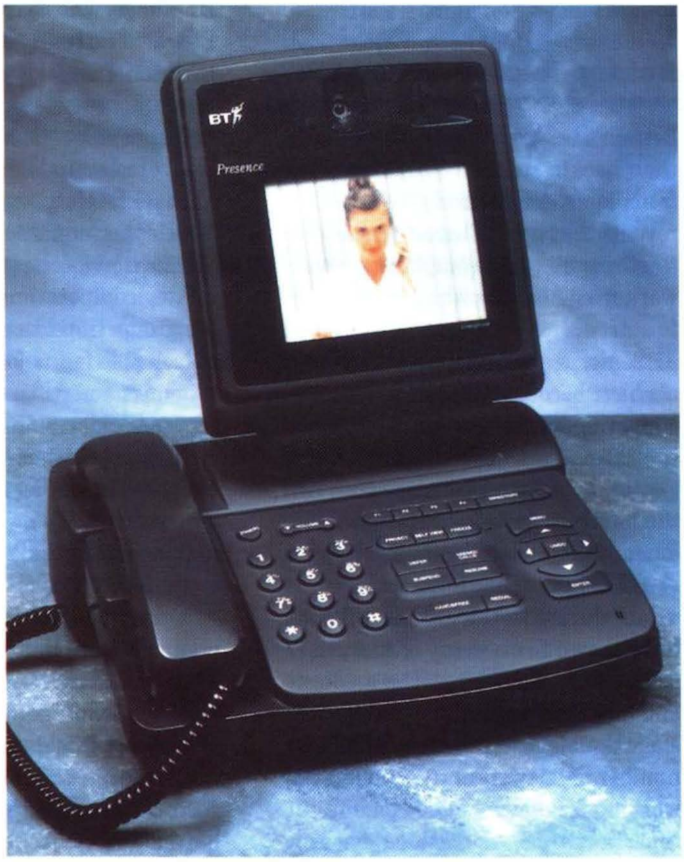
If you feel that you would like to contribute an article, then please contact:

The Managing Editor,
British Telecommunications Engineering,
Post Point G012,
2–12 Gresham Street,
London EC2V 7AG
Tel: (0171) 356 8022
Fax: (0171) 356 7942

Alternatively you can contact your local IBTE Centre (details inside the back cover).

You do not need to be a skilled author to produce an article. Simply provide the details of the project (and some colour photographs, perhaps) and we can produce the article on your behalf.

Figure 2—Presence: ISDN desktop videophone



productive meeting. The videophone incorporates the benefits of video-conferencing and an ordinary telephone.

Presence includes features such as missed call log, answering message, calls directory, handsfree and on-screen menus. The video-phone will be available at the end of February 1995.

The second addition is the VC6000, a new high-quality low-cost roll-about videoconferencing system offering a flexible format. It provides excellent picture quality on a large screen, making it ideal for interactive group discussions and larger meetings. It includes features such as picture-in-picture, an on-screen menu system and a large number store directory.

The portfolio includes the newly released VC5000 series 3 for larger groups of people in a dedicated conference environment and the compact VC7000 for the open plan office or desktop; and the newly available PC Videophone, which converts a PC into a multimedia terminal enabling users in different locations to share images, graphs, text, files and spreadsheets in a face-to-face meeting.

Bosses Back Teleworking

Britain's bosses have finally given their backing to their people working from home. A new study for BT reveals that nearly three in every ten firms now have employees who work from home or who are planning to start soon.

Senior managers and professionals have become the most ardent supporters of teleworking for themselves and their people. Bosses are expecting to see an increase both in the number of teleworkers and the amount they telework themselves.

BT believes that teleworking 'trials' during the 1994 rail strike have shown firms many of the benefits of teleworking. The media and business consultancy industries show the biggest growth in the number of teleworkers—people working from home either on a full-time, part-time or occasional basis using faxes, telephones and computers to stay in touch with the office and with clients.

One in three of those employed in the media (33 per cent) and a further third employed in business consultancy (31 per cent) now telework, many having started in the last six months. One in five of these new teleworkers plans to increase the amount of time spent working at home.

Over the last six months there has also been significant growth in the areas of finance (22 per cent), manufacturing (18 per cent) and freight and distribution (19 per cent). But the government is the biggest employer of potential teleworkers. More than a third of all government employees (35 per cent) are currently increasing the amount of time they spend working from home.

BT Announces Senior Appointments and Organisational Changes

On 13 January 1995, BT announced the appointment of Dr. Alan Rudge as Deputy Group Managing Director. Dr. Rudge, who is a member of BT's Board, is currently Managing Director of Development and Procurement.

In his new role, he will continue to report to Group Managing Director Michael Hepher, and will support Mr. Hepher and Chairman Sir Iain Vallance on a range of issues of strategic importance to the future of the group. In particular, he will be responsible for major group programmes and will continue as BT's top spokesman on technology issues.

Michael Hepher said: 'I am delighted that Alan is taking up this appointment. He brings to the role a unique blend of skills, technical expertise and vision.'

Other senior management and organisational changes will take effect from April.

Mike Armitage, Managing Director of Worldwide Networks, will retire on 30 April, after 36 years with BT. Michael Hepher said: 'Mike has made a major contribution to BT and its predecessors, for which the Board is enormously grateful. We wish him a long and happy retirement.'

A new role of Managing Director Networks and Systems will combine the management of BT's networks and its development and procurement activities. This will be taken up by Chris Earnshaw, currently Chief Executive Concert, BT's joint venture with MCI, based in Reston, Virginia, USA.

Alfred Mockett, Managing Director BT Global Communications, will become accountable for Concert. He already represents BT on the Board of MCI and on the Concert Board. Peter Erskine, Director of BT Mobile, will be acting Chief Executive on a temporary basis, and will report to Mr. Mockett.

Stafford Taylor, Managing Director Personal Communications, will assume responsibility for BT's multimedia and mobile activities, and oversight of Cellnet where he was Managing Director before the current MD, Howard Ford.

OFTEL Document on Future

Public meetings are now being held around the country to discuss OFTEL's 'Framework for Effective Competition', a consultative document on the future of interconnection and related issues which was published in December.

The document seeks to build on the industry's achievements over the last decade, and establish how a competitive market-place from which detailed regulation can be draw. Among the issues it raises are:

- the current price control cap of RPI–7·5 per cent, which it says will stay until 1997;
- options for the reform of interconnect charges;
- provisions on anti-competitive behaviour;
- pricing flexibility for large customers;
- residential customers and the Universal Service Obligation;
- service providers (the impact of the licensing regime on the development of new services and how OFTEL could encourage their development); and
- alternatives to pence per minute charging for interconnect services. (OFTEL is taking this forward by asking pairs of operators, including BT and Mercury, to experiment with capacity charging arrangements.)

Be Bold, Says Sir Iain

On the eve of the publication of OFTEL's document 'A Framework for Effective Competition', BT Chairman Sir Iain Vallance encouraged OFTEL to use its consultation process to set 'a bold vision of a deregulated future.'

Speaking at a *Financial Times* conference in London, he urged OFTEL to:

- commit to deregulate all retail activity from 1997;
- set time limits to market entry support; and
- set out an explicit and stable regime for interconnection charges, applicable to all licensed network operators.

Sir Iain said: 'A major challenge confronts our regulator. The UK can, once more, exercise regulatory leadership by taking the next bold step towards a fully competitive market.'

He argued that regulation had succeeded in bringing choice and investment to the UK, although market entry mechanisms were beginning to outlive their usefulness. Sir Iain also re-emphasised the need for investors to have confidence that their long-term investment would be rewarded appropriately, and stressed that his proposals were aligned with the Government's commitment in the 1991 White Paper to move away from competition managed by the regulator, towards open competition.

Yellow Pages Launches Local Touch

Yellow Pages has launched 'The Local Touch', a unique touch screen information system, as part of its ongoing new product development programme.

Developed for consumer use, the new touch screen terminal has been placed at a leading shopping centre in Bromley, Kent. The Local Touch will enable a wide range of information to be accessed on the local area including leisure facilities, community information, restaurants, in-town shopping and public transport. The data held on the system has been based on the content of a new local directory published by Yellow Pages for the Bromley region, The Bromley Local, and can be updated on a regular basis. The Local Touch will also offer vouchers for retail outlets within the shopping centre enabling consumers to take advantage of discounts on goods and services.

The terminal is the first of its kind for Yellow Pages and its usage will be carefully monitored prior to extending the touch screen programme to other areas.

The Local Touch has been custom designed to meet requirements Yellow Pages has identified through its multimedia publishing activities in the UK over the last 15 years. In particular, experience of screen-based information delivery has been gained from work with the Electronic Yellow Pages service. The changing information needs of consumers have also been highlighted by developments in the directories and the national Talking Pages service.

INMARSAT-P Funding Rolls In

INMARSAT has announced that it received formal indications of intent to invest in its affiliated company, being formed to implement a global handheld satellite telephone service, exceeding $1 billion.

Authorised initial investors, from more than 40 countries covering six continents, have filed intent-to-invest forms with INMARSAT. The investors are INMARSAT signatories or their subsidiaries and comprise many of the world's leading telecommunications operators, a number of whom are key players in the provision of mobile services. A meeting of the investors is being held to formalise the new venture.

The new company's intermediate circular orbit satellite system will cost approximately $2·6 billion and will provide worldwide service to handheld terminals for digital telephone, fax, data and paging. It is expected to begin service in 1999 and be fully operational by 2000. A typical INMARSAT-P user in the year 2000 will carry a pocket telephone virtually indistinguishable from a normal cellular telephone.

More Direct Access Waivers

Don Cruickshank, Director General of OFTEL, has given 19 companies payment waivers until 31 March 1996 of payments they would otherwise have made to BT. These follow waivers granted to eight companies in July 1994.

Under the present regulatory regime, when a competing operator's customer uses BT's local network to make a call, that operator is required to make a payment called an *access deficit contribution* (ADC) to BT.

BT's access deficit for the year 1992/3 was £1·45 billion. The Director General's powers to waive the payment of ADCs is limited to 15 per cent of each of the domestic and international markets. Currently the maximum value of waivers would be approximately £150 million per annum.

MCI Becomes Major Internet Carrier

Following its selection by some of the major regional Internet providers in the USA, MCI will become one of the world's largest carriers of Internet traffic on the information superhighway.

A full Internet provider, MCI offers a wide range of access options from switched local and dedicated access to more advanced switched services such as ISDN, frame relay and, soon, SMDS and ATM.

The company recently announced 'Internet MCI', a portfolio of services including a new secure electronic shopping mall, a user-friendly software package for easy Internet access and high-speed network connections.

IEE Develops Internet Information Services

The Institution of Electrical Engineers (IEE) is developing Internet Worldwide Web and gopher services covering a range of information including Institution news, events, membership and library services, and in particular, details of the IEE Publishing and Information Services. Full details of all publications are included—books, journals, conference publications, distance learning material and INSPEC services. Additional information, such as new publications and services, advertising rates, guides to authors and the text of INSPEC Matters is also available. All of this will be updated regularly and can be accessed on the Internet via the Web or gopher server.

The servers are still in the pilot phase, and future improvements proposed include links to other relevant Web and gopher servers and FTP access to demonstration software such as for Electronic Letters Online.

EUTELSAT Simulcasting of Digital and Analogue Television

EUTELSAT has been successfully demonstrating, since April 1994, the possibility of simulcasting analogue and digital television signals in a single 36 MHz EUTELSAT transponder, at no extra cost to the broadcaster in terms of the transponder lease.

This opens up new possibilities for broadcasters, such as simulcasting the same service in order to facilitate a gradual transfer from analogue to digital technology, or simulcasting two different television services in analogue and digital for different target audiences. These new options have created considerable interest in the marketplace, to the extent that a number of television broadcasters have indicated they will simulcast from the satellite at 13 degrees east.

On the receiver side, a number of hardware companies are now manufacturing decoders either for simulcast reception or for reception of a package of digital television channels.

OFTEL Faces up to Numbering

OFTEL has published a consultative document on numbering for pan-European telecommunications services, an issue seen as critical to the growth of new services for customers. The document seeks comments on a report by the European Committee for Telecommunications Regulatory Affairs, which identifies and analyses various strategic options for European numbering, including the introduction of European Telephony Numbering Space for special pan-European services.

OFTEL believes its document gives the UK an important opportunity to influence European developments.

Cellnet Buys Racal Antennas

Cellnet is buying £1·5 million worth of base station antennas from Racal Antennas. They will be used to expand and improve Cellnet's already comprehensive coverage for both the analogue network and the future growth of the digital Global System for Mobile Communications (GSM).

Racal has already delivered several thousand of its ETACS/GSM cellular panel base station antennas, with further deliveries scheduled to meet Cellnet's stringent roll-out programme.

Racal says that its products were chosen for their 'improved electrical performance, visually discrete profile coupled with cost-effectiveness and lifetime reliability.'

EC Drive for Universal Service

The Commission of the European Communities made another move towards liberalising Europe's telecommunications monopolies with the adoption, in November, of a Communication on the development of a universal service. The Commission says that the provision of a service for all at an affordable price is the cornerstone of the Community telecommunications policy, which aims for liberalisation by 1 January 1998. But it says that, at the moment, as much as 16 billion ECU each year are transferred from profitable long-distance and international telephone calls to cover losses made on local services.

Standard Software on the Increase

There is a strong trend in the more developed European information technology (IT) markets away from customised software towards standard software packages, as already seen in the USA, according to a new report from consultants Datamonitor.

There is also strong growth in new markets such as local area networks (LANs) due to the effects of client server computing and downsizing in the software market, which increased the amount of package software sold and increased revenues. Distributed computer architectures require increasingly complex datacommunications systems, fuelling the growth of sectors such as LAN management, electronic mail and groupware.

Manufacturers in Europe's standard software market, are spending even more on research and development, sales and marketing. These activities now account for over half of the leading personal computer applications software companies' revenues.

book reviews

Telecommunications Engineering

by J. Dunlop and D. G. Smith

The last few years have seen changes in telecommunications taking place at a fantastic rate and many text books have been left behind in the rush. Thus it is very welcome to see effort being put into updating long standing books like this one.

The third edition of this text has added sections on the more advanced techniques of audio coding, including techniques for lessening the impact of errors as encountered in mobile systems.

The sections on television and mobile communications have been thoroughly modernised. These are in addition to the previous content which covers the conventional subjects of signals, channels, modulation, noise, traffic, switching and signalling. Transmission by metallic pairs, radio, optical fibres and waveguides is covered to a depth that is entirely adequate for the average student, or someone who is trying to update themselves, or remind themselves of something forgotten.

A short section covers the techniques used in local area networks (LANs) and metropolitan area networks (MANs). The inclusion of asynchronous transfer mode (ATM) and synchronous digital hierarchy (SDH) is very useful. One particular feature of the style that I particularly like is the way that, when it is necessary to get mathematical, the authors do not just leave you with pages of equations but intersperse them with bits of text to relate the progress of the derivation to the real world. Thus they have successfully managed to cover properly Shannon's evaluation of channel capacity—an area which is usually glossed over in other text books. This is particularly important in the present day where signal processing technology is so advanced that Shannon's limit is more likely to put a bound on performance rather than instrumentation limitations.

One area which could use some attention is the references to other books for those who need more information; although many references are given, they are generally to older books which may well be out of print and certainly will not contain up-to-date information. At the other extreme, the section on plesiochronous digital hierarchy (PDH) has been severely cut back, presumably to make more room for SDH and ATM. I feel that this is premature as the vast majority of digital links are still PDH.

Despite these minor comments, this is a very useful text and reference which I will regard as a major source of basic information.

Published by Chapman & Hall.
£22·95. xxii + 589 pp.
ISBN 0-412-56270-7

Reviewed by John Griffiths,
Queen Mary and Westfield College, University of London

Microwave Electronic Devices

by Theo G. Van De Roer

The stated objective of this book is to cover the complete field of microwave electronics, and it is successful in plugging a gap by providing an overview of all relevant devices in one book. It covers vacuum tubes, semiconductor diodes, bipolar transistors, field-effect transistors and high-electron-mobility transistors. It is an ideal companion to a course on the subject, which is indeed the origin of the book. It is not a book to pick up and read from cover to cover for an introduction to, or an overview of, the subject as each chapter tends to commence with a review of the necessary basic theoretical principles. An accompanying commentary is required and could have been usefully provided by a summary and a better introduction within each chapter.

It is certainly impressive in its breadth of coverage—even extending beyond the devices themselves and skimming the surface of measurements and circuit applications. A book so wide ranging could not include the practical performance and circuit examples that would make it more interesting, as there would be so many.

For the student, it is an excellent single reference to accompany a course on microwave device technology. Included are problems to test understanding, but there are no answers or worked examples. For an engineer new to the field, it is a useful collection of concepts, formulae, and sources of reference. However a practising microwave device or circuit designer will probably find the book's treatment rather too superficial.

Published by Chapman & Hall.
£19·99. xiii + 340 pp.
ISBN 0-412-48200-2

Reviewed by Phil Wilson

Fundamentals of Telecommunication Networks

by Tarek N. Saadawi and Mostafa H. Ammar with Ahmed El Hakeem

Written by a team of academics from the USA, this book explores the fundamentals of telecommunication networks. The title is slightly misleading, as the content of the book is restricted mainly to the fundamental concepts and mechanisms associated with telecommunications, while the title of the book gives the impression it will explore all aspects associated with a tele-communications network.

The book successfully focuses on the fundamental design and operation of telecommunications networks. It is well structured, allowing easy referencing of information and the diagrams are concise and effectively complement the text. Each chapter identifies additional reading material and poses challenging questions that aid the understanding of the basic concepts and mechanisms used in network design.

The first section of the book gives a comprehensive history of major technological advances in the telecommunications industry and combines this effectively with the advances in the computing industry, highlighting the increasing convergence between these two industries. The book does lack information on future trends within these industries and how asynchronous transfer mode (ATM) and intelligent network technologies will further enhance these links.

While the book is effective in describing the technical developments within telecommunications, it does not balance that with a consideration of the telecommunications industry's commercial drivers. Therefore, little or no reference is made to the current technologies, such as intelligent networks, network management, mobility and broadband integrated services digital network (B-ISDN) that are all major ingredients of a telecommunications network of the future.

It is surprising that a current publication makes no reference to the evolving intelligent network architecture and signalling systems required to support the more sophisticated services currently available. The book therefore fails to recognise any advancements relating to the processing, transmission and switching of information that need to be made to ensure the success of modern networks.

The preface states that the book is designed to meet the needs of a variety of audiences from students in electrical engineering to practising engineers and managers, who are dealing with telecommunications networks and systems. I would agree it adequately meets the needs of the student engineer. However, people already working in the area may feel it simply confirms their knowledge rather than substantially adds to it.

The technical concepts and mechanisms are explained effectively throughout the book. It does, however, lack a certain business perspective relating to the future of telecommunications networks. Therefore, based upon the technical concepts and mechanisms, I have no hesitation in recommending it to student engineers and managers new to the telecommunication industry.

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ISBN 0-471-51582-5

Reviewed by Amer Herian

Coherent Lightwave Technology

edited by Sadakuni Shimada

Although this book is entitled *Coherent Lightwave Technology*, which is its major theme, much of the material is also applicable more widely to multichannel optical transmission systems in general. The scope of the book is from the basic theory of coherent communications through to practical engineered systems and their design.

The early chapters set the scene with a historical perspective on coherent communications and the potential applications for the technology in a lightwave transmission system. This is followed by a clear theoretical treatment of the potential sensitivity obtainable from a coherent receiver using amplitude, frequency or phase coding. There then follows a discussion of the basic technology options for the required active and passive components, such as narrow linewidth lasers, modulators and filters, together with the limitations imposed by the transmission medium caused by dispersion and nonlinearities.

The particular problems of optical frequency-division multiplexed systems are covered next, including stabilisation techniques for multichannel systems, the role of fibre nonlinearities in determining limits to the number of channels and their power, and the design of selective receivers, using both coherent and incoherent detection techniques. The following chapter describes the application of optical amplifiers to a coherent transmission system and includes details of both semiconductor and fibre amplifiers. Finally, the application of coherent techniques to long haul transmission and optical networks is presented, together with related engineering issues.

Overall, the book achieves its aims of describing the possibilities of coherent technology and its application reasonably well. However, the multi-author nature of the work inevitably leads to style variations and some minor duplications and inconsistencies from topic to topic. It should also be noted that the most recent reference in this book is from 1992. Although this does not detract from the validity of the work presented, it does mean that more recent progress is not included, particularly with respect to amplified multi-wavelength optical networks.

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Reviewed by Richard Wyatt

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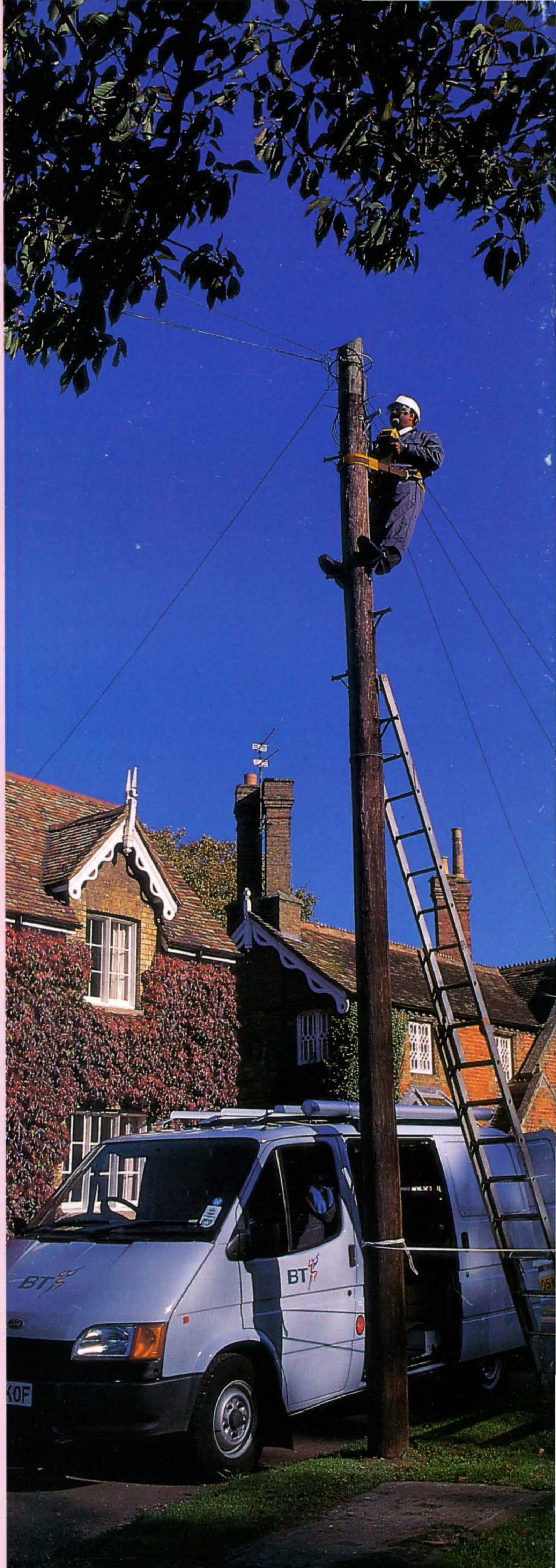

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