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The access network - evolution from separate simple services to a fully flexible environment

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Executive summary

The technology which now enables us all to be part of one large global community is impressive. Fibre optic cables cross oceans, networks of satellites link continents and sophisticated management software keeps it all working. Yet all of this would be wasted without the humble access network. The role and the form of the access network are starting to undergo dramatic changes, driven by the expectations of the users and the availability of new technology.

The aim of this paper is to look at some of the evolutionary trends in how we access our communication networks and at what is driving those trends. It will not present instant answers to the decisions that users and network and service providers have to make, but will allow those decisions to be made in a more informed way.

Trends in the use of communications

A major driver for change has been the widespread adoption of PCs in homes and businesses. This, in itself, would not have been sufficient to cause major changes in the use we make of our networks but the symbiotic relationship with the growth of the internet has completely changed the way many of us communicate and do business. The other main driver for change has been the widespread adoption of mobile phones - in some European countries, there are now more mobile phones than there are fixed phone lines. Broadcast networks (TV and radio) are also changing. They have moved from a passive medium to an interactive medium which allows viewers to select “pay-per-view” programmes, choose from a set of camera angles, call up data about a programme or send e-mails.

One of the major lessons which comes out is that we are now looking at a much richer, more diverse, easy to use set of services than would have been thought possible even just a few years ago. These services place increasing demands on the technology which provides our networks. What the user wants is a network that is versatile, reliable and cheap. What the service or network provider wants is the ability to react quickly and economically to user needs – whatever they may be. They both need either a crystal ball to predict the future, or a “magic box” which will let them use any service on any network.

Trends in access networks

This section in the main body of the report gives an overview of some of the technologies in use now, those which are starting to be used and those which are just appearing over the horizon. It looks at what they are capable of and what the opportunities and problems are which are associated with their use.

Technology which exists widely now

The telephony access network has existed for over 100 years from the earliest days of the telephone and has extended its reach to the vast majority of homes and businesses in Europe. Cable TV networks have also existed for many years and, in some parts of Europe, are very widespread. This means that very large legacy networks exist throughout Europe and any consideration of access network evolution must take this into account.

Technologies in common use include:

- **POTS –** the Plain Old Telephony Service. Originally designed for voice, it now carries voice, fax and internet traffic.
- **ISDN** – the Integrated Services Digital Network. This was the first attempt to optimise the telecommunications networks for services other than voice and is widespread around Europe.
- **Leased lines –** which provide a fixed point-to-point connection for users. They come in many forms and in many bandwidths.
- **Wireless local loop** – which replaces part of the copper network with fixed wireless links. This has advantages in some situations but is not yet universally applicable.
- **GSM** – Global System for Mobile communications. This is the rapidly expanding digital mobile phone network in Europe. It is good for voice and provides limited data (including internet) capabilities.
- **IP** – the Internet Protocol. This was intended for internet communication but is finding wider application. In its present standard form it has limitations which make it difficult to use for some services, notably voice. Enhancements exist which get around some of these problems.

- **ATM –** Asynchronous Transfer Mode. This was the first serious contender for providing broadband multi-service networks and is currently able to handle voice and video better than unenhanced IP can.

Technology which is starting to come into use

New technologies are beginning to be introduced into commercial service which allow much more flexible use of the access network infrastructure. Amongst these are:

- **ADSL –** Asymmetric Digital Subscriber Line - enables a broadband always-on connection to be provided over a copper pair (typically of 2 Mbit/s downstream and 512 kbit/s upstream).
- **Cable modems** - provide a shared broadband interactive link over cable TV networks. This would typically allow a user to have a 2 Mbit/s link.
- **Geostationary satellites and terrestrial broadcasting** - can now provide broadband (asymmetric) interactive capability using the fixed network (eg ISDN) for the upstream path.
- **Powerline.** Some operators have provided services using the electricity distribution network for communications. This has great potential but there are a number of problems to overcome.
- **HSCSD and GPRS -** are enhancements to GSM to provide a mobile service more suited to data.
- **Fixed wireless access –** systems which use radio links to provide connections to customers in fixed locations. It is suitable for broadcast applications as well as broadband telecommunications.
- **Passive Optical Networks** - provide fibre communications without expensive electronics. They are well suited to enhancing existing networks by replacing the copper between the Local Exchange and a flexibility point. A similar approach can be used with CATV networks, for instance in a **Hybrid Fibre Co-ax** system.
- **IP with Quality of Service differentiation –** Differentiated Services, Integrated Services and Multi-Protocol Label Switching are enhancements to IP to handle a range of different services.

Technology which is on the horizon

This is just some of the technology which we can start to see appearing over the next few years.

- **UMTS** – is the 3rd generation of mobile systems and will allow data communications at about 2 Mbit/s.
- **VDSL –** provides very high speed symmetric communication over short copper pairs (or co-ax cable TV) for the last few hundred metres to the user and is used in conjunction with fibre.
- **IPv6** – is an improved form of the Internet Protocol which offers much better addressing and can provide the Quality of Service control needed for services such as voice. It could help to bring about major changes in the way telephony is handled.
- **Ethernet and fibre optics –** the combination of these two technologies would provide an almost unlimited bandwidth to individual users, but the economics are still not clear.
- **Low Earth Orbit satellites and High Altitude Platform Stations –** considerably reduce the problems caused by the transmission time to and from geostationary satellites but have not yet been proven commercially viable.

Problems and opportunities with access network evolution

One characteristic of the access network is that it has almost universal coverage of Europe. To achieve that has required a great deal of investment of time and capital, and any far-reaching changes to the network could also require a major investment in time and capital. As a consequence of that, any change to the infrastructure must be on an evolutionary path which is not a “dead end” but which really does lead to the future.

There are a number of trends that can be seen in the evolution of the access network over the next ten years.

- The continued high growth in demand for internet-based services. Many users will become increasingly unhappy with the slow response times that are achieved using analogue modems over telephone lines and will demand something better.
- An alternative view of evolution for internet access is that many residential customers will not want to buy PCs, especially in poorer communities, but will still willingly pay for TVs. In that view of the future, interactive services via TV will become more important, including the provision of e-mail and e-commerce services.

- As Quality of Service problems are solved there will be increasing use of Voice over IP.
- There will be increasing diversity in the technology used for access networks.
- The increasing pace of change means that there will be overlap between the roll-out of new technologies.
- Mobility will be increasingly important for users. The fixed network will still be the major provider of broadband multi-service facilities. However, we may well see mobile voice telephony become more important than voice telephony over the fixed network.

These trends provide plenty of opportunities for wise service and network providers to take advantage of the new technologies to offer innovative and useful products to their customers. However, they must also be aware of the factors that will influence evolution which are not simply related to the capabilities of technology.

- Changes in the regulatory environment are crucial. For instance, the ability for service providers to have access to the basic copper network once it is unbundled and to put enhanced features (eg ADSL) on that network will create a major change in the communications environment.
- New technology takes a long time to completely replace old technology. Users have invested heavily in devices which interface to the existing access networks and it takes years before they can all be persuaded (or can afford) to change to a newer interface. There will be a need to support existing standards for many years.
- Changes in the access network cannot take place in isolation from other parts of the network. There is no point in providing a super high-bandwidth access network if the capacity of the core network is so limited that it can still only dawdle along at 64 kbit/s.
- Users have fears about new technology, especially about security issues. It will be important to take those fears into account and allay them.

Conclusions

Those of us who have to deal with access networks are living in interesting times. We are seeing far more opportunities for major change than have ever been possible before. We are seeing far more convergence of previously disparate services than has ever been seen before. And we are seeing far more uncertainty about evolution paths than has ever been seen before.

For those that get their evolution strategy right, they will be rewarded with the ability to deliver services that will keep their customers happy, even as they become increasingly demanding. One way to get the right strategy would be to buy a crystal ball and take lessons in fortune telling. A more successful strategy is to make sure that any changes in the network retain as much flexibility as possible for future enhancement.

The future was defined, slightly cynically, in the Devil’s Dictionary about 100 years ago as “That period of time in which our affairs prosper, our friends are true and our happiness is assured.” By following the right evolution strategy, you can make that definition come true.

Introduction

We survive by communicating. In our daily lives, at work or at leisure, we spend much of our time using communications networks – whether it be a simple phone call, a complex internet transaction, or just watching the television. We expect to be able to contact anywhere in the world immediately and send any form of voice, video or data with just the press of a few buttons.

Things have changed a great deal since the English writer John Ruskin was told that the first cable had been laid connecting England to India, and asked “But what have we to say to India?”.

The technology which now enables us all to be part of one large global community is impressive. Fibre optic cables cross oceans, networks of satellites link continents and sophisticated management software keeps it all working. Yet all of this would be wasted without the humble access network.

The first telephones were connected together using a pair of copper wires, and that is still the technology which is used for by far the majority of the connections from end users to their local telephone exchanges. However, the role and the form of the access network are starting to undergo dramatic changes, driven by the expectations of the users and the availability of new technology.

This presents a challenge for users, who need to understand how these changes will improve the ways in which they can communicate, and for network and service providers, who need to understand how they can give their users the services they want without investing in potentially short-lived technologies.

The aim of this paper is to look at some of the evolutionary trends in how we access our communication networks and at what is driving those trends. It will not present instant answers to the decisions that users and network and service providers have to make, but will allow those decisions to be made in a more informed way.

Note that this paper is based on European communications standards and practice. There are minor differences in standards and practice in other parts of the world.

Trends in the use of communications

The first decades in the life of communications networks saw little change in the way they were used. Anybody used to the telephone in 1920 who picked up a phone in 1960 would only have needed to learn to use a dial and, in a number of places, would have found that they were still connected to a manual exchange and, hence, still needed no dial. What they would have noticed was a major change in how many people they could reach by telephone and how much better the quality was of that connection.

However, anybody used to using the telephone in 1960 would be amazed by the services that are available now. In 1960, the telephone network was almost solely used for voice, with a little bit of data traffic from the more forward thinking companies. Today the telephone network carries voice, data, fax and internet traffic and even residential users use the whole range of these services. In 1960, the nearest thing to mobility was the road-side payphone; today over 60% of the population carry mobile phones in some countries.

A major driver for this change has been the widespread adoption of PCs in homes and businesses. The number of PCs in use in the world has grown by about 15% - 20% per annum in recent years. The versatility of these devices means that they have the potential to carry out a wide range of tasks when connected to a communications network. This, in itself, would not have been sufficient to cause major changes in the use we make of our networks but the symbiotic relationship with the growth of the internet has completely changed the way many of us communicate and do business. The internet started life as a network heavily biased towards those with a technical view of life, ie those that love controlling PCs by typing in complicated strings of characters rather than pointing and clicking. However, the introduction of user-friendly, graphics-based browsers has transformed the internet into a tool that can be used by almost anybody to communicate with almost anybody else for almost any purpose. In recent years, the growth in internet users has been running at about 60% - 70% per annum. In many European countries, the use of e-mail and e-commerce has become a way of life and teleworking has removed the need for daily commuting for many business people.

The other main driver for change has been the widespread adoption of mobile phones. There are many reasons why these have become so popular, including attractive pricing packages (eg “Pay as you go”), the feeling of security that constant contact brings, and fashion. In some European countries, especially in Scandinavia, there are now more mobile phones than there are fixed phone lines. Mobile phones started as basic voice devices, moved to providing short messaging facilities, and now carry a cut-down version of web pages.

Broadcast networks (TV and radio) also changed little in their use for the first few decades of their life. The quality improved remarkably with the advent of colour TV and FM stereo radio, but they were still passive forms of communication (shouting at the TV during a football match does not really count as interaction!). The recent advent of digital TV, however, has acted as a catalyst to change much of that. Broadcasters now sell digital TV packages with an interactive link which allows viewers to select “pay-per-view” programmes, choose from a set of camera angles, call up data about a programme or send e-mails.

One of the major lessons which comes out of looking at the way we use our communications networks is that we are now looking at a much richer, more diverse, easy to use set of services than would have been thought possible even just a few years ago. We can now carry on many of our business activities independently of location, we can buy goods and services without going to shops and we can learn without visiting a college. These are not all new services – we could buy goods from our home by mail order 100 years ago – but they are ways of using services which provide us with a faster response and a greater range of options than have ever been possible before. And we can do all of this in a multi-media way that was never envisaged by the people that put the first copper pairs into the ground.

These services place increasing demands on the technology which provides our networks in terms of the bandwidth needed (which can vary from a few bits per minute for telemetry to megabits per second for video), in transmission delays (which can be minutes for e-mails but only a few milliseconds for conversation) and in terms of mobility (which is zero metres per minute for a cash machine to hundreds of kilometres an hour for a business person on a train). This places a requirement on our access networks for a great deal of flexibility.

The other major factor that we cannot predict is how the use of communications will grow or change even a few years ahead. The internet has been an astounding success, but there are still dramatic commercial failures of internet-based services which once seemed certain to make their owners a fortune. In the mobile world, text messaging was originally just a peripheral extra facility but is now used by some groups (especially the young) far more than voice.

What the user wants is a network that is versatile, reliable and cheap - so he or she can immediately make use of the new services that emerge, or make more versatile use of existing services, and use them at a reasonable cost. What the service or network provider wants is the ability to react quickly and economically to user needs – whatever they may be. They both need either a crystal ball to predict the future, or a “magic box” which will let them use any service on any network.

Trends in access networks

We have become used to seeing network operators pour major investment into upgrading their switches and their core networks. Totally digital networks from Local Exchange to Local Exchange are now common around Europe (although we must always remember that some parts of Europe lag a long way behind others in investment in technology). However, the part of the network which is critical for most users is the connection from their premises to the nearest Local Exchange – the access network.

The access network was originally designed to carry no more than voice at a maximum bandwidth of 3 - 4 kbit/s, and a network of dedicated copper pairs from each phone to the exchange proved more than adequate for that. The cable TV networks which are common in parts of Europe were also only designed to carry analogue broadcast signals and co-axial cable networks were provided which did that job well.

We are now asking our access networks and broadcast networks to carry a far wider and more diverse range of services than the original network designers would ever have thought possible. This section looks at some of the technologies in use now, those which are starting to be used and those which are just appearing over the horizon. It looks at what they are capable of and what the opportunities and problems are which are associated with their use.

Technology in the access network can exist at a number of levels, from the physical transmission medium to the protocols which are used over that medium. So that we can make this survey as comprehensive as possible, we have adopted a wide view of the term “technology”.

Technology which exists widely now

The telephony access network has existed from the earliest days of the telephone and has extended its reach to the vast majority of homes and businesses in Europe. Cable TV networks have also existed for many years and, in some parts of Europe, are very widespread – for instance, in Denmark, over 70% of homes can be reached by cable TV. This means that very large legacy networks exist throughout Europe and any consideration of access network evolution must take this into account. The other factor which must be considered is that not all of Europe is equally developed. The number of lines per 1000 population varies by a factor of about 30 between some eastern European and western European countries.

POTS – Plain Old Telephony Service

This is the phone service that we know and love, and has been around in various forms for over 100 years. Because it has evolved over such a long period of time, the term "POTS" has many meanings. In this paper, we are using the term to refer to the network which supports the provision of basic analogue voice telephony and low speed data services from fixed locations, eg an office. The POTS physical access network largely consists of copper pairs, with a dedicated pair (or set of pairs) running from each user's home or business to the Local Exchange. Flexibility in the allocation of the pairs is provided at a number of "flexibility points" between the user and the Local Exchange. This gives the network more scope to cope with changes in growth patterns than if a continuous cable was run from each user all the way through to the exchange. The distance of users from the exchange can be anywhere between a few hundred metres to tens of kilometres.

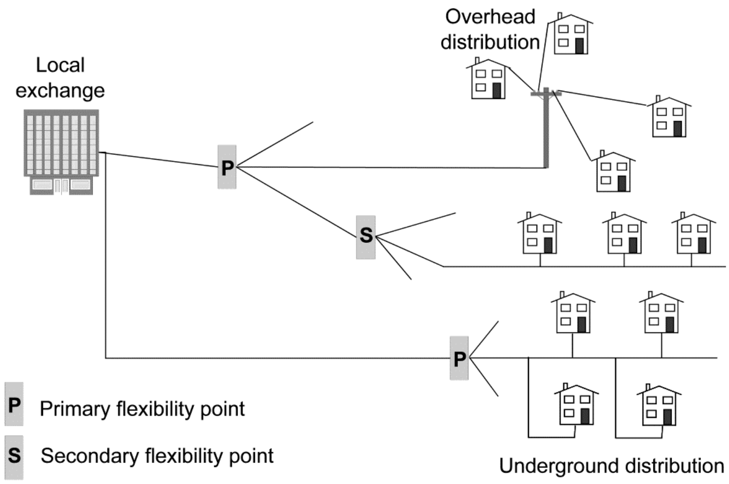

Figure 1 - The POTS access network

Although largely copper, the network is not exclusively so. Aluminium cable enjoyed a brief period of popularity in some places in the 1970's when a world copper shortage was threatened. This is acceptable for voice traffic but it is more liable to failure than copper and causes problems when planning to introduce new technology on the physical network. Pair–sharing technology has been used in some places (eg two channels on one pair) to improve the ability to provide extra circuits at short notice where there is a shortage of physical pairs. Radio links have also been used in places where cabling was impractical, eg to small off-shore islands.

The reliability of the network can be very variable, depending on such factors as the skill of the technicians who made the joints in the cables and how prone to flooding the area is (for underground cables) or how windy it is (for aerial cables). However, in a well built and well maintained network, the failure rate is very low.

The POTS network was originally designed to provide a voice only service, giving a bandwidth of 4 kHz at best. It now also carries fax traffic and supports analogue modems (mainly for internet access). These modems have been developed to the extent where they will provide a throughput of 56 kbit/s under ideal conditions. The actual throughput achieved depends on factors such as the distance from the Local Exchange and the quality of the physical connection and is often nearer to

40 kbit/s than 56 kbit/s. This bandwidth is adequate for many of the current services available on the internet, but is insufficient for downloading large files and only allows real time video to be watched which is of a very jerky, low-resolution nature.

POTS is very widespread in Europe, as in much of the developed world. In western European countries all businesses and most homes have at least one line, and the use of more than one line is becoming more common in many homes, as it has been in businesses for some time. In eastern Europe, the penetration of the phone service is currently much lower.

ISDN – Integrated Services Digital Network

This was the first serious attempt to recognise that telecommunications networks needed to be optimised for services other than voice. It was also an extension of the increasingly digital nature of the core network to the access network. Instead of providing analogue 4 kHz channels, and converting digital data into analogue signals, ISDN is based on 64 kbit/s digital channels. All analogue services, such as voice, are converted into digital signals for transmission over ISDN. This aligns with the way that channels are provided in the core network. ISDN is generally provided over the existing copper access network.

ISDN is offered to users in 2 forms:

- The **basic rate** connection, which provides two 64 kbit/s channels plus a signalling channel. The two 64 kbit/s channels can be combined to provide a 128 kbit/s channel.
- The **primary rate** service, which provides thirty 64 kbit/s channels plus a signalling channel within a 2 Mbit/s connection.

Basic rate connections are the most common and, in effect, give a residential or small business user two high quality connections over their copper pair which can be used for telephony or data. The primary rate connection is more commonly provided to larger users, eg for PBX connection, and will usually be provided over a dedicated fibre or radio link.

At the time that ISDN was launched, it gave a considerable increase in data transfer rates over the contemporary analogue modems. That advantage is not so pronounced now when current modems at 56 kbit/s are compared with an ISDN channel of 64 kbit/s. However, the ease with which two 64 kbit/s channels can be used together (providing that the users at both ends of the connection can accept this) can still give a significant increase in speed. This has, for instance, made dial-up video services a much more attractive proposition.

ISDN has a major advantage over traditional connections in its much reduced call set-up time, as a consequence of the signalling employed. This is of particular benefit for services that need frequent short calls, such as dial-up e-mail.

In general, the advantages of ISDN over an ordinary phone connection can be summarised as faster call set-up, potentially greater bandwidth, and higher quality.

ISDN was first introduced commercially in Europe in the 1980's, but its rate of adoption has varied greatly from country to country, largely influenced by the varying charge for the service in different countries. Even in western Europe there are significant differences between the degree of use of ISDN in, say, Germany and the UK. As ISDN becomes more ubiquitous, it is being challenged by the arrival of other technologies such as ADSL and cable modems that can provide an even more flexible and bandwidth-rich service for residential users and small businesses.

Although European ISDN standards have existed for some years (eg Q.931, I.421), major operators first introduced ISDN with their own national or proprietary versions of these standards. These non-standard interfaces are still offered in some countries, mainly to meet the need to connect to older terminal equipment.

Leased lines

Leased lines give the user a permanent (or semi-permanent) connections between two end-points, for example between a local bank branch and the head office. The major difference between these and other uses of the access network is that no per-call switching is involved once the line reaches the Local Exchange.

Leased lines were originally all analogue, as was the rest of the network. They are now becoming largely digital, in line with the core network. Leased lines vary greatly in their capacity, from a basic permanently wired phone connection between two points to a 155 Mbit/s permanent digital connection.

Analogue leased lines are increasingly being used solely for a simple 2-wire or 4-wire permanent connection between two points. Digital leased lines can offer bandwidths from, typically, 2.4 kbit/s upwards and match the PDH or SDH hierarchy at the higher bandwidths (eg 2 Mbit/s, 34 Mbit/s, 140 Mbit/s). The use of higher bandwidth leased lines requires the use of dedicated fibres, co-ax cables or microwave links in the access network.

Leased lines represent an important market for network operators. For example, BT currently gets about 6% of its revenue from leased lines (ie about €1900M per annum). The prices for leased lines vary greatly across Europe, differing by a factor of over 2 for a 30 km line in different countries.

Wireless Local Loop

Instead of copper cables (or fibres), wireless can be used to link users to the Local Exchange, either for the complete link or just for the last part of the fixed link. This is known as the Wireless Local Loop. At present, it is largely used instead of an ordinary telephone or ISDN connection, although broadband systems are starting to appear (see Fixed Wireless Access on page 14). High capacity microwave links are also often used to connect large users to their Local Exchange.

The technology has been available for about 10 years and has found its greatest application in sparsely populated areas, or by new entrant operators. It has the advantage that it is relatively quick to add new customers, once a base station has been constructed, and does not require much in the way of civil engineering.

At present, WLL suffers from high equipment costs, compared to copper cables, and from the normal problems associated with radio such as limited spectrum and shadows caused by high buildings. It is estimated that 80% of the cost of a cable system is in the installation and 20% is in the equipment. For a radio system, 20% of the cost is in installation and 80% in equipment. The cost of radio equipment is expected to fall rapidly, while it is difficult to lower the cost of installing cable to any great extent. For this reason, WLL is expected to become a more attractive proposition for network operators.

GSM[1]

This is the technology used for the majority of the mobile phones in Europe, although analogue systems do still exist. Mobile networks are often largely separate from the fixed network, being owned and operated by different companies – although all of the major fixed network operators either own or part-own a mobile operator. The GSM technology was originally used to provide a good quality voice service and is a significant improvement on the analogue service which preceded it. One major area of improvement was in security – it is very easy to eavesdrop on a conversation on an analogue mobile phone but it is much more difficult to listen in to a GSM conversation.

GSM added the ability to send short text messages of about 140 characters. This has now become a major form of communication in some markets, especially amongst younger users, and has led to the development of information services to give, for example, weather reports.

Internet and data access has always been possible over GSM, although the data speed of 9.6 kbit/s is unacceptably slow for regular use. Enhancements to GSM will improve this and are described in “Technology which is starting to come into use”. The Wireless Access Protocol (WAP) is now becoming available on most GSM networks. This allows access to the internet, albeit in a much simplified form with very limited graphics. Again, the slow speed of response is an issue as is the limited WAP content currently available.

GSM is a major access technology and has overtaken fixed lines in some parts of Europe for telephone services used by residential customers. However, it still has severe limitations for anything other than voice or very basic information services. It also suffers from the usual radio problems of a finite spectrum and reception dead areas.

[1] Global System for Mobile communications; originally : French : “Groupe Speciale Mobile”

IP

The Internet Protocol (IP) is not really an access technology, but its use within the access network (and throughout communication networks) is so widespread that it is having a major impact on network evolution.

IP, as its name suggests, started life as the protocol which was used for communication over the internet. As such, it was optimised for data services and is packet based, rather than circuit switched. Data services are characterised by being relatively insensitive to delay and are thus well suited to packet switching, where individual packets can take different times to travel through the network. IP is also well suited to streamed audio and video broadcast, where buffering at the receiver can be used to smooth out jitter in the arrival of the packets. The main limitation in the use of these services is the bandwidth that the physical access network can supply. As a consequence of this, IP is not yet a serious contender for delivering broadcast TV to the home – but that will come as access technologies improve.

The growth in internet users of around 60% - 70% per annum, compared to 6% - 7% growth in phone lines, has led to IP being an extremely widely used protocol. Most users only pay the price of a local call for access to the internet[2] and this has led to pressure to provide telephony over the internet – since anybody could then make international voice calls for the price of a local call. A number of service providers have set up Voice over IP (VoIP) services, but they all suffer to some degree from the fact that Quality of Service cannot generally be guaranteed over the internet since all services are treated to the same “best effort” approach. New IP standards are proposing ways of differentiating between different services and of providing the appropriate Quality of Service. (See “IP with Quality of Service” on page 16 and “IPv6” on page 17)

The growth in IP-based traffic will put new demands on the access network in terms of changing traffic patterns (eg always-on connections as opposed to dial-up services), in terms of higher demand for bandwidth, and in terms of differentiated Quality of Service for different services over the same network. It is also changing the architecture of communications networks as network operators strive to create national IP-based networks (including broadband core networks) to separate this traffic from circuit-switched traffic.

ATM

Asynchronous Transfer Mode (ATM) is again not really an access technology. It was probably the first serious contender for providing broadband multi-service networks (ISDN is essentially narrowband) and was first being seriously trialled by major network operators about 8 years ago, followed within a short period by the introduction of public services. It is a packet based system, using fixed length packets, and is designed to support a wide range of services such as voice, video and frame relay. It has an advantage over IP in that it can provide differentiation between different types of service (eg voice and data). LAN interconnection is one application which was very much in mind when the service was developed. It is possible to run IP over ATM and this is, in practice, quite common within core networks.

ATM was intended to be the panacea to all broadband problems. That role has probably now been taken over by IP but ATM still has a significant role to play until IP has full Quality of Service features.

Technology which is starting to come into use

New technologies are beginning to be introduced into commercial service which allow much more flexible use of the access network infrastructure - generally by offering an always-on, high bandwidth connection to the user with a lower bandwidth return path from the user. This asymmetry is based on the premise that most users need to download large amount of information (eg a video clip) whilst only needing to send relatively small amounts of information (eg e-mails).

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[2] There is considerable pressure within Europe for unmetered access to the internet to be provided for a flat monthly fee. This is slowly being introduced, hampered slightly by the uncertainty about the business model for service providers that supports this. The pace of introduction of unmetered services is likely to accelerate dramatically once a few major Internet Service Providers successfully provide unmetered access.

One factor which must be taken into account with all of these technologies is that they do not all have universal application. For instance, those that rely on the cable TV infrastructure will probably not be usable in industrial areas - where very little cable TV infrastructure exists.

ADSL

Asymmetric Digital Subscriber Line (or Loop) - ADSL - is a technology which was first developed about 10 years ago to enable a broadband always-on connection to be provided over a copper pair, whilst maintaining the telephone service for that user. As the name suggests, it is asymmetric and provides a greater downstream capacity (ie towards the customer) than the upstream capacity.

Because each ADSL customer has a connection to their Local Exchange over a copper pair, there is no sharing of the medium in the access network. This means that the bandwidth available to any one customer will not be affected by the number of other customers using the access network at the same time. However, all networks are dimensioned on the basis that not all of the customers will be using their maximum bandwidth all of the time. Thus, at the Local Exchange, the connections into the core (IP) network work on a contention ratio - ie the total ADSL bandwidth available in the access network for a group of customers compared to the total core network bandwidth available to that same group. This would typically be 50:1 for residential customers or 20:1 for business customers.

The implementation of ADSL can cause practical problems. Because the copper pairs in the cables are being asked to carry much higher bandwidth signals than they were originally designed for, there is a slight danger of interference between pairs in the same cable. This will be more difficult to manage once the local loop is unbundled and several operators are using the same cable. Because access networks have grown over many decades, network operators rarely have good records of the electrical characteristics of each pair. Before ADSL can be provided to a customer, tests have to be carried out on his existing connection and some pair re-arrangement may be needed.

ADSL is now being marketed in most major European countries, although the spread within each country is not yet very great and it will take 2 – 3 years before it is generally available. ADSL services being commercially offered in Europe can provide a bandwidth of up to 6 Mbit/s downstream and 512 kbit/s upstream, although a maximum downstream speed of 2 Mbit/s is more common. (In the USA a wider range of 128 kbit/s to around 7 Mbit/s is available). The degree of asymmetry being offered in Europe ranges from 10:1 to 2:1. (In the USA, there are even ratios of 1:1 on offer – these are really DSL rather than *A*DSL services.) The bandwidth that can be offered depends on the distance of the customer from the Local Exchange, since ADSL is sensitive to the electrical characteristics of the copper network. In a typical European country such as Denmark, it has been estimated that 50 – 60% of customers could be reached by 2 Mbit/s ADSL whilst 90 – 95% could be reached by lower speed ADSL (eg 256 kbit/s downstream).

Prices currently being charged in Europe range from €60 per month to €3750 per month. Although there is not a direct correlation between price and bandwidth, because different providers have adopted different pricing models, the price generally increases steeply for the higher bandwidth services (ie 2 Mbit/s and above).

Cable modems

Cable TV networks were originally co-axial cable networks, although hybrid fibre – co-ax systems are more common in recent networks, and were built to distribute TV and radio broadcasts. Because of this, they were essential one way networks. However, networks have recently begun to be converted to bi-directional working by using part of the available bandwidth for upstream transmission. If there is sufficient bandwidth available in the cable system, then one TV channel can be allocated for carrying downstream data to cable modems and another channel can be allocated for the upstream data. The user is connected to the cable TV network by a cable modem which is then connected to his PC, and receives an always-on service. Internet protocol will be run over this connection.

Cable modem networks are essentially a shared medium so that, for example, a group of users in an area (eg 200) would share the available bandwidth. This means that the bandwidth for an individual user can vary considerably in theory but, in practice, is likely to be less variable. The total bandwidth available on the channel will be of the order of 40 Mbit/s. In theory, a single user on the network could use all of this but most network operators restrict the maximum speed available to individual users to, typically, 2 Mbit/s. It is also important to realise that the bandwidth is not allocated in fixed size segments to users but that they only seize network resources when they send or receive data, and this tends to be in short bursts.

The availability of cable TV systems is very varied throughout Europe, being very widespread in some countries and relatively uncommon in others. Cable TV systems are unlikely to cover areas which cannot be reached by ADSL or mainly industrial areas. However, they do give an alternative access network to the copper telephony network with similar standards of reliability and bandwidth.

The use of cable modems is very widespread in the USA, being available to about 40 million homes with 3 million cable modem subscribers. The take-up of this service in Europe is currently much lower than in the USA, possibly because of price differences, but the use of cable modems in Europe is expected to grow significantly in the next few years.

Geostationary satellite interaction

Communications satellites have been a common method of broadcasting TV and radio to Europe, and other parts of the world, for some years now. Their use has opened up many opportunities for broadcasters to reach new audiences and for viewers to see new programmes. They have also opened up many new legal and regulatory problems – for example, what is illegal to broadcast in one country can now be broadcast to anywhere in Europe via satellite from a country where that content is not illegal.

Communications satellites are also used by many companies for closed user group broadcast within the company, such as advertising material for use in a chain of department stores.

With the advent of digital TV broadcasts, and their potential for carrying more channels and data to the end user, interactive services have started which use the satellite as part of the access network. At present, almost all of these services use the fixed telephone network as the return path and the satellite as the route for downloading material. So, for instance, high quality moving images of a holiday resort can be requested from a travel agent's web page (over the fixed network return path) and downloaded to your TV from the satellite link. Typically, a commercial service would offer a download speed (via the satellite) of about 500 kbit/s and a return path of 33.6 kbit/s. Full internet services via satellite are available in many countries around Europe but are not yet widely used. E-mail and interactive TV services (eg choose from a set of camera angles) are being actively promoted.

Larger companies may also use the satellite for the return path, but this is not generally thought economic for smaller users. However, consumer-based services are being launched by a few companies.

Terrestrial broadcast interaction

As with satellites, the terrestrial broadcast network was originally set up to distribute radio and TV programmes, mainly to residential sites. Whilst the analogue services were the only ones available, this remained the only use of this network apart from the text pages broadcast by teletext. The introduction of digital broadcast services (DVB and DAB[3]) has opened up new opportunities for interactivity. Many broadcasters are now offering services which use the digital terrestrial broadcast system for downstream transmission and use a connection through the telephone network for the upstream connection. There are limitations with this system, such as the need to share the downstream bandwidth between a large number of users. The services which can be offered are very similar to those provided by satellite.

This is a relatively new technology (ie interactive digital broadcasting) and its use is therefore in its infancy. We can expect to see more proposals for better use of this medium in the next few years.

Powerline

The electricity supply network is even more ubiquitous in Europe than the telephone network. The network of cables reaching nearly every building has seemed like an attractive carrier for communications services for some time. However, there are considerable technical, regulatory and commercial obstacles to over come.

A major trial was launched by a company (NorWeb) in the UK but, in 1999, the company ceased operations because it could not see a good business case for this technology. However, suppliers and operators across Europe and North America still believe that this technology has potential and are

[3] DVB is digital video broadcast and DAB is digital audio broadcast.

carrying out trials – for example in Germany and Finland. They aim to provide a data rate of about 3 Mbit/s to end users in the first commercial realisations of the service.

One major advantage of Powerline access over other methods is that the power network extends to most rooms in buildings and it therefore provides the potential for communication within the building as well as to a Local Exchange.

The main technical issues that have to be solved involve the frequencies to be used for data transmission. The frequencies needed to allow broadband working are in the same part of the spectrum as the frequencies allocated to police and air traffic control. Power lines are inherently very bad for leaking electromagnetic radiation and the use of these frequencies for broadband transmission could cause serious disturbance to radio services. There are also technical problems to be overcome with the fact that power lines are an inherently very noisy electrical environment.

However, the companies involved in the trials, and the standards organisations, are confident that these problems can be overcome and that it will be possible to introduce commercial services around Europe in 2001.

HSCSD, GPRS

This paper has already described the GSM cellular radio system and explained that the data rate available (9.6 kbit/s) is too low for most serious applications. The 3rd Generation (or UMTS) networks that are being planned around Europe are expected to make cellular data communication (eg internet access) a practical reality. (See UMTS on page 16)

In the meantime, operators are introducing interim solutions. One such is High Speed Circuit Switched Data which will allow data rates of up to between about 20 kbit/s and 60 kbit/s. This service is still circuit switched and thus makes relatively inefficient (ie expensive) use of the network for data. It has not been widely offered around Europe.

An alternative solution is the General Packet Radio System (GPRS) which is now being introduced by some European operators. This is packet-based, rather than circuit switched, and can offer data rates up to a theoretical maximum of 171.2 kbit/s – although practical maximum rates will be significantly lower at first. Because it is packet-based it makes much more efficient use of the cellular radio network for services such as internet access, and is therefore expected to be cheaper than HSCSD. For the user, the main advantages are the increased data speed and the fact that it is an always-on service.

GPRS services were launched in Europe at the end of 1999 and most major mobile operators have plans to offer the service in the near future.

It must be borne in mind that this data rate is still below that which can be offered by services such as ADSL. It will make internet access a much more sensible proposition for the mobile user but will still not provide good multi-service access.

Fixed Wireless Access

This is a generic term to cover systems which use radio links to provide connections between customers in fixed locations and telecommunications networks. It covers systems such as LMDS (Local Microwave Distribution System), MVDS (Microwave Video Distribution Systems) and MWS (Multimedia Wireless Systems). They mostly work in the 25 GHz or 40 GHz area of the radio spectrum.

These systems are well suited to broadcast and multi-cast applications but also provide broadband data links to and from the customer. Typical figures for a LMDS system would be 36 Mbit/s (shared) downstream and 8 Mbit/s upstream. Compared to a satellite, individual FWA systems have a much smaller coverage area (eg a radius of 5 km) and this means that their radio spectrum can be reused many times across a geographical area. For domestic users, IP would normally be used over the system, but ATM connections may be offered to some business users.

FWA should provide a similar level of reliability to ADSL systems, but does need line of sight communication. It has the advantage common to most wireless systems of requiring little civil engineering to provide service to a customer once the base station is built. Trials of systems using FWA were carried out under the EU's ACTS programme and licences have now been issued in many countries for services to start.

Passive Optical Networks

One of the limitations inherent in any broadband system which is based on the copper network is the trade-off between bandwidth and distance - ie the further from the Local Exchange the customer is, the lower the bandwidth it is possible to supply to them. An optical fibre connection does not have such serious limitations, but it is very expensive to supply a fibre to every customer.

Passive Optical Networks (PONs) take advantage of the fact that it is possible to split off wavelengths out of a fibre without the use of expensive electronics. (A very simple analogy would be the way that a prism can split light into different colours.) This means that a much greater bandwidth can be taken closer to the customer at a reasonable cost. The only points where active electronics are needed are where the optical signals are converted into electrical signals at either end of the PON. Because PONs can be configured in a robust architecture (eg a ring), they can also be made less prone to failure than many other forms of network.

It is possible to use a PON out as far as individual customers, but they are also very useful for extending the capabilities of copper or radio networks. They can also be used in conjunction with cable TV networks (see Hybrid-fibre co-ax networks below). By using a PON to take the fibre to a cabinet, to the kerb or to a large building (eg an apartment block), the only copper needed is from the cabinet (or kerb or within the apartment block) to the customer. Since this will typically only be a few hundred metres, much higher bandwidths can be carried than if the entire route to the exchange was copper. This strategy also means that much of the existing copper in the ground and in buildings can be reused and the amount of civil engineering is reduced. In a similar way, PONs can be used to serve local broadband radio base stations, with the broadband radio link being used for the final drop to the customer.

The use of PONs provides a good migration route, since the fibre network can gradually be extended to go past the cabinet, to the kerb and then to the building. Where the services which need to be supplied justify it, PONs can also be taken direct to the customer. ATM is commonly provided over such systems (known as APONs).

Hybrid-fibre co-ax

In the same way as copper telephony networks can be enhanced by the addition of fibre, co-axial cable TV systems can also have their capabilities extended by the addition of fibre in part of the network. Hybrid fibre co-ax (HFC) systems replace most of the co-axial cable between the cable TV head-end and the customer with fibre. Only the last part of the drop still uses co-axial cable. Existing CATV systems are already being upgraded in this way with fibre to reduce noise and the number of amplifiers needed in the network. The telecommunications network can also be connected to the same system (see Figure 2) and part of the bandwidth available (typically between 5 and 35 MHz) can be allocated to telephony and interactive services.

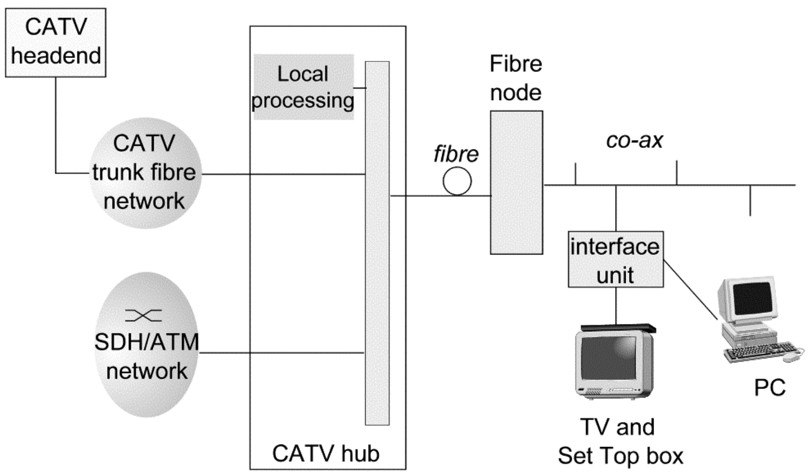

Figure 2 - HFC architecture

In an HFC network, the interactive bandwidth is shared between the users connected to each fibre node. Thus, as the demand for bandwidth-hungry services increases, the number of customers served from each node can be decreased (by increasing the number of nodes) so making more bandwidth per user available. The use of PONs for the fibre network of HFCs is one way of providing the links to the nodes in a robust, flexible, cost-effective way.

HFC systems have been intensively trialled around Europe for several years, especially in countries such as Germany, Netherlands and Switzerland. Commercial networks using HFC are now available in many major European areas.

IP with Quality of Service

As described earlier in this paper, IP traffic is rapidly growing. However, a true multi-service network has to be able to carry traffic with a wide range of network requirements – or Quality of Service (QoS) requirements. IP in its current form (IPv4) has very limited capabilities for differentiating between services. A new version of IP (IPv6) is to be introduced which should overcome many of these limitations (see IPv6 on page 17) but there are also other enhancements to IP which are becoming available sooner to add QoS support.

Integrated Services (known as IntServ) allows a client application to request specific performance criteria (eg bandwidth) to a particular destination. Every routing point along the path to the destination is then interrogated to check if it has enough bandwidth to meet the requested performance and, in effect, sets up a virtual circuit. A major criticism of IntServ is that this method requires the storage of a large amount of information and so it may not scale well for major networks.

Differentiated Services (DiffServ) addresses the scaling problem by combining multiple flows with similar behaviour and then dealing only with these combined flows. Packets are assigned to the appropriate combined flow on a per-hop basis. Since the routing nodes only need to maintain information about a relatively small number of combined flows, rather than many paths or virtual circuits, scalability is much improved. The major disadvantage of DiffServ is that it cannot give such an absolute guarantee of QoS as IntServ can, but the statistical probability of an adequate QoS is very high.

The other approach which can enhance QoS is multi-protocol label switching (MPLS). MPLS offers a way to create virtual circuits, called "label switched paths", through the otherwise connectionless IP network. This is a useful tool for managing the network, especially in conjunction with IntServ and DiffServ.

Technology which is on the horizon

The technology which we now have, or which is starting to appear, will give a good start in providing a broadband multi-service environment. However, the demands we place on our networks, and the technology needed to meet those demands, do not stand still.

Within Europe, the European Commission has an ongoing series of research programmes which look at new communications technologies and their applications. The Advanced Communications Technologies and Services programme finished at the end of 1999 and the results of this programme can be found at http://www.actsline.org. The current Information Society Technologies programme is described at http://www.cordis.lu/ist/overv-1.htm.

This section highlights just some of the technology which we can start to see appearing over the next few years. It is not a comprehensive list and it must be borne in mind that many of the advances will be an evolutionary improvement of the existing technology rather than revolutionary technology. We can also expect to see an increasing number of tools appearing to allow us to make better use of the technology which already exists in the access network.

UMTS

Mobile communications is a rapidly growing sector. However, it has a major problem at present with providing the bandwidth needed for anything other than voice. Standards for a 3rd generation of mobile technologies have been developed, primarily in Europe. These are know as 3G (3rd Generation) or UMTS (Universal Mobile Telecommunications System). UMTS will allow data communications at around 2 Mbit/s. The standard has now been adopted world-wide although more regional variants have been allowed in the standard than would be ideal from an implementation perspective. European governments are now allocating licences to operators and commercial services are likely within the next year or so. There is some concern about the cost of these new services, as the amounts that operators have paid for some of the licences far exceeded expectations.

UMTS will give much better and faster data (eg internet) services to mobile users, but these will still not match the bandwidth available in the fixed network.

VDSL

ADSL is already being installed around Europe to provide faster access to the internet for residential and small business users. Typically, it provides 2 Mbit/s downstream and 512 kbit/s upstream. There is likely to be a growing need for speeds which are faster than this and are symmetric, eg to support collaborative working between a number of small sites.

In theory, a copper cable can carry up to around 50 Mbit/s but it can only do that for short distances – eg 300m for 26 Mbit/s. VDSL (Very high speed Digital Subscriber Line) technologies and architectures are being developed to make this possible. These will make use of optical fibres for the majority of the access network from the Local Exchange, with copper pairs (or co-ax cable TV) being used for the last few hundred metres. This is described in more detail in the section on Passive Optical Networks on page 15. The high bandwidth of VDSL and its flexible allocation will also allow different services to be mixed on the same link, eg data, video and voice.

There are still a number of technical problems to be solved before VDSL becomes a practical solution for widespread application. These are mainly associated with cross-talk with other pairs in the same cable and with radio frequency interference.

IPv6

The protocol which runs over the access network to allow users to interwork with the internet is called the Internet Protocol. In its most common form, it is known as IPv4. This has a number of shortcomings, mainly associated with addressing, security and Quality of Service – for example, IPv4 provides a “best effort” connection which cannot guarantee adequate QoS for Voice over IP. Extensions to IPv4 exist to partially tackle these problems, as do some proprietary solutions, but the longer term solution is a new version of the internet protocol, known as IPv6.

IPv6 provides a much better structured, more flexible and larger addressing system than IPv4. This should allow better management of routing through the backbone network of the internet. IPv6 also has enhanced security. For example, it is inherently able to supply information that will enable the source of a message to be checked, something which is not always easy with IPv4.

For many service providers, the most interesting feature of IPv6 is likely to be its ability to convey information across the network about the type of traffic it is carrying. This will enable the internet to treat voice (which can only tolerate delays of a few milliseconds) in a different way to e-mails (which can tolerate delays of several minutes) and make voice and video communication a more attractive reality.

Ethernet and fibre optics

DSL has inherent problems with cross-talk and with radiation, and with the testing of the copper network needed to find a copper pair with acceptable electrical behaviour. Cable TV does not suffer from these problems, but does suffer from the need to share the available bandwidth between a number of households.

It is possible that DSL and cable modems may be superseded by a combination of Ethernet and fibre optics in the future. Ethernet is a well-established computer networking technology which is widely used to connect computers in offices. Ethernet networks can have links of up to about 50 km and have been shown, in trials, to be capable of working at 10 000 Mbit/s – although speeds of 10 Mbit/s or 100 Mbit/s or more commonly used.

Fibre optic cables can carry a vast amount of traffic in a small physical space. For instance, a single fibre can easily carry 10 Gbit/s[4] and a single cable can contain 1000 fibres. By installing a fibre to every home or business, and running fast Ethernet over these, the potential bottlenecks in the access network would be eliminated for the foreseeable future.

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[4] 10 Gbit/s = 10 Giga bit/s = 10 000 000 000 bit/s

There is still debate about the economics of doing this, and whether such a high bandwidth is needed at present, but the viability of this approach is increasing as costs fall and demand for bandwidth increases. It is also being made more attractive in those countries where the incumbent network operator must allow competitors to install cable in their right of way. This can drastically reduce cable installation costs, which make up the bulk of the costs in cable-based access networks.

Low earth orbit (LEO) satellites

Communications satellites have until recently been mainly geostationary, ie they appear to hover above a fixed point on the earth. This has the major advantage that the antenna used to connect the ground station to the satellite does not have to track the path of the satellite across the sky and calls do not have to be handed over from one satellite to the next as the first satellite flies below the horizon.

The major disadvantage of a geostationary satellite is that it has to be at around 36 000 km above the earth. This means that the signal being received from the satellite is not very strong (and that any transmitter from the ground to the satellite has to provide a strong signal) and that the transmission time to and from the satellite is high. Anybody who has made a phone call via a satellite will be aware of the slightly disconcerting effects of this. This delay can also affect protocols which assume failure if they don't receive a rapid response.

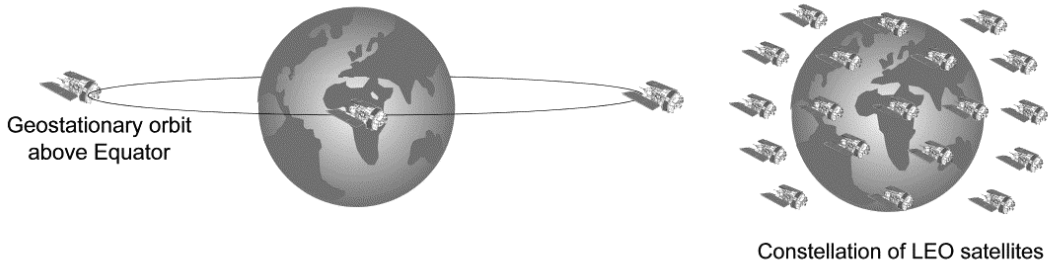

Figure 3 - Geostationary & LEO satellites

One solution is to provide satellites in a much lower orbit of around 1 000 km (See Figure 3). These have the advantage of a much lower delay and the reduced power needed means it is much easier to design aerials for bi-directional communication. By using LEO satellites it is possible to provide users with a high bandwidth for download and upload. The main disadvantage of LEO systems is that a large number of satellites (between 50 and 300) are needed for good coverage of the world.

Recent years have seen several schemes launched to provide LEO services for voice or multi-service broadband communication. A number of these have been commercially unsuccessful and this looks like a technology that might be ahead of the market need.

High Altitude Platform Stations

LEO satellites have the disadvantage that they move relative to the earth. This means that they will spend a percentage of their time over parts of the earth's surface where there is little demand for them and, conversely, a large number of satellites is needed to provide constant service to any one location.

An alternative approach which is being considered is High Altitude Platform Stations. There are a number of variations of these being proposed, but a typical scheme is proposing a balloon based platform about the size of a football field at a height of 21 km. They plan to launch these over large cities starting in 2002. These would offer broadband communication similar to that which is possible from satellite, with simpler aerial design and transmission times similar to the terrestrial network. The main problems that have to be resolved for HAPS are with the physical platform rather than with the communications equipment.

Problems and opportunities with access network evolution

The preceding sections have described some of the many technologies which are available, or are becoming available, for access networks. The end user rarely cares about the technology that they are supported by. All they want is to be able to use a wide range of services in the easiest, safest and cheapest way possible. However, that often means that the service provider has to be able to take advantage of any improvements in access network technology as rapidly and cheaply as possible.

One characteristic of the access network is that it has almost universal coverage of Europe. To achieve that has required a great deal of investment of time and capital, and any far-reaching changes to the network could also require a major investment in time and capital. As a consequence of that, any change to the infrastructure must be on an evolutionary path which is not a “dead end” but which really does lead to the future.

There are a number of trends that can be seen in the evolution of the access network over the next ten years.

- The first one is the continued high growth in demand for internet-based services. For the next few years at least, this is expected to continue to grow at the same high rate as it has done recently. Many users will become increasingly unhappy with the slow response times that are achieved using analogue modems over telephone lines and will demand something better. For most residential and small business users, that is likely to be provided by ADSL or cable modems. However, there will still be users who are perfectly happy with the service provided by 64 or 128 kbit/s ISDN, or even 56 kbit/s analogue, and will not abandon this technology. One of the main factors affecting the spread of ADSL and cable modems will be pricing. Most telephone companies still apply usage based charges to internet access via POTS or ISDN (eg €0.05 per minute), whereas cable modems and ADSL are charged on a flat fee (monthly service charge) basis. For a heavy user, that makes those technologies much more attractive. The usage based charges are likely to be abandoned by many telephone companies in the near future and it will be much easier for users to decide if the cost of ADSL (or cable modems) is justified by their extra benefits in terms of bandwidth and always-on connectivity.
- An alternative view of evolution for internet access is that many residential customers will not want to buy PCs, especially in poorer communities, but will still willingly pay for TVs. In that view of the future, interactive services via TV will become more important, including the provision of e-mail and e-commerce services. The evolution of the satellite, cable and terrestrial broadcast access networks will play a key role in taking the information society to all sectors of Europe. The ability of these networks to interwork with telecommunications networks (for the return path) will be crucial, at least in the early stages.
- The internet will start to take over part of the role of the traditional telephony network as we see improved Quality of Service control in the internet leading to increasing use of Voice over IP. This will lead to access networks becoming true multi-service networks. However, the POTS network will still exist for many years as the number of users who do not have, or need, internet access will remain significant.
- There will be increasing diversity in the technology used for access networks. Until recent years, the choice was largely between copper cable for telecommunications and radio, satellite or co-ax cable for broadcasting. Now, anybody wanting to set up or extend an access network for telecommunications or broadcasting has a choice of copper cable[5], fibre, radio, co-ax cable, satellite or combinations of these. Some of these technologies (eg wireless local loop) require relatively little capital investment and are quick to install, thus being especially suited to new entrant operators trying to gain a foothold in the market.
- The increasing pace of change means that there will be overlap between the roll-out of new technologies. As an example, in the UK, BT only started to aggressively market ISDN to domestic and small business users about a year ago. It is now starting to market ADSL which is targeted on much the same market segment. That isn’t an ideal strategy from the point of view of BT, but it is driven by pressure from its competitors and from the UK telecommunications regulator.
- Mobility will be increasingly important for users. The growth in mobile phones has already outstripped the growth in fixed communications and is likely to continue to do so over the next few years. Mobile phones and networks are also becoming more capable and can already offer basic information services and e-mails over the internet. With the advent of GPRS and, later, UMTS they will become much better at handling data-based traffic, such as internet access. However, the radio spectrum available is always going to be much more limited than the bandwidth that is

[5] For broadcasting, this is really only suitable for low quality web-casts.

available over land lines. This means that the fixed network is always going to be able to provide a much higher bandwidth service than mobile networks. The majority of users will also still do their daily work in one fixed location and will spend much of their leisure time at fixed locations. For those reasons, the fixed network will still be the major provider of broadband multi-service facilities. However, we may well see mobile voice telephony become more important than voice telephony over the fixed network.

These trends provide plenty of opportunities for wise service and network providers to take advantage of the new technologies to offer innovative and useful products to their customers. However, they must also be aware of the factors that will influence evolution which are not simply related to the capabilities of technology.

- Changes in the regulatory environment are crucial. The unbundling of the local loop is being actively planned throughout Europe. The ability for service providers to have access to the basic copper network and put enhanced features (eg ADSL) on that network will create a major change in the communications environment.
- New technology takes a long time to completely replace old technology. Users have invested heavily in devices which interface to the existing access networks and it takes years before they can all be persuaded (or can afford) to change to a newer interface. There will be a need to support existing standards for many years.
- Changes in the access network cannot take place in isolation from other parts of the network. There is no point in providing a super high-bandwidth access network if the capacity of the core network is so limited that it can still only dawdle along at 64 kbit/s. Synchronising the capabilities of the various networks is more of a challenge in the environment of increasingly fragmented network ownership.
- Users have fears about new technology, especially about security issues. There is a natural fear that a shared medium such as cable or wireless is less secure than a dedicated pair of wires. It will be important to take those fears into account and allay them.

Conclusions

Those of us who have to deal with access networks are living in interesting times. We are seeing far more opportunities for major change than have ever been possible before. We are seeing far more convergence of previously disparate services than has ever been seen before. And we are seeing far more uncertainty about evolution paths than has ever been seen before.

For those that get their evolution strategy right, they will be rewarded with the ability to deliver services that will keep their customers happy, even as they become increasingly demanding. One way to get the right strategy would be to buy a crystal ball and take lessons in fortune telling. A more successful strategy is to make sure that any changes in the network retain as much flexibility as possible for future enhancement.

The future was defined, slightly cynically, in the Devil’s Dictionary about 100 years ago as “That period of time in which our affairs prosper, our friends are true and our happiness is assured.” By following the right evolution strategy, you can make that definition come true.