Telecommunications for the 21st Century: Global Information Super-Highways in the Information Age

Introduction

Just for a moment close your eyes and imagine an international data superhighway. What sort of picture are you imagining? Are you imagining a map of the world with landmasses coloured green, the sea coloured blue and large thick dense brightly coloured red lines spreading across the whole map like a spider's web? That is not the sort of picture I have of super highways. My picture is a very simple one. It is a picture of a small man standing looking towards me and with a slightly bemused expression on his face. He is standing inside a pipe and the pipe diameter is over twice his height. I see this man requiring information and I see him requiring information in a form which can be likened to the way in which he would like to have a cup of water. What he doesn't realise is that the water is coming towards him and its coming towards him from the pipe directly behind him! Accessing information in the information age which is upon us is very much like trying to take a drink of water out of a fire hose. We are in great danger of being totally and utterly swamped by the information which we will be passing through these data super highways. Recently I saw a cartoon, it was a cartoon of an Abbott leaning out of the cloister window of his Abbey. The year is 1394 and he has a thought as he looks towards the sky, his thought is "we do not have a gigabit of information about everything". Quite simply the whole of human knowledge and experience could be easily coded in the year 1394 into one gigabit of information. If the image of that cartoon is now changed to the year 1994, a similar Abbott leans out of exactly the same cloister window, looks at exactly the same sky and wonders, "now we're in the information age, now we have a gigabit of information about absolutely everything". That is the big difference I see in the late 20th century as we rush through the information age, it is not a problem of "how do we move the information", it is a problem of "how do we deal with the information that we are offered".

To get a feel for the amount of information that there is in existence in the world, travel back to the year 400. There was a large library in Alexandria and the library was destroyed by fire. The total amount of stored human information was halved by the loss of one single building. By the year 2,000 we are likely to have millions upon millions of times more information than that. As an example in Europe alone there are over 6 million pictures of stain glass windows from churches in one database. Just accessing that information in a controllable manner is a great problem. Just in this decade the predictions of the amount of information which is already coded and can be easily moved is quite startling. There's going to be a

tenfold increase in ten years. This is something that we now need to be addressing in order to harness the information age of the future.

We are also changing the ways in which we access information, for example, in 1989 only 24% of the households in the United States of America had personal computers, by the year 1993 this was in an excess of 34% and growing very rapidly. We have all seen the new Personal Digital Assistant, like the Apple Newton product. These are small compact hand held computers which we can write on (there's no need to use keyboards any more) and very soon these small devices will be connected into the global digital super highways, to give us information wherever and whenever we desire them. I also see this sort of technology moving forward into the house and the home as well as the office. I no longer see books on shelves. In the future there will be compact disks, optical disks, floppy disks and information terminals both at work and in our homes. The information will be brought to us in a truly mobile form. During the 1980s there was a massive explosion in mobile telephony. With the over lay of the digital GSM systems more and more information will be available in the mobile form. There are also experiments under way using light as the carrying medium rather than radio to make information more and more accessible, especially within buildings and in close proximity to buildings.

The Modern Multimedia Expansion

The latest offering in multimedia from the telecommunications companies is the view phone. Not only can you see someone at the far end but you can also talk to them in a very natural human manner. The latest product to be offered by BT is the VC8000. This allows you to put a full viewphone inside your computer, so now not only can you talk to somebody at the far end and see them in a full moving colour picture, but you also share the whole of your computing experience with somebody at the far end.

If you have a spreadsheet or a word processor they can see what is in your machine, they can see a change as you modify it, even though they don't have those packages on their own machine. It also allows you the opportunity to offer control to the far end of the network so that they can also modify the packages within your machine. A total sharing of communication and computing in one single simple package. And the really magical part about this is that all this information is carried over one pair of copper wires using a single Integrated Subscribers Digital Network telephone line making the cost exactly the same as a simple telephone call. The fact that all this can be carried on one single telephone line is quite magical, but it also has the effect of blocking our vision of the transmission revolution which is already upon us.

The Transmission Revolution

Let us compare three means of moving information around the digital super highway. The first is by a simple twisted pair copper cable. A thousand or more pairs of copper wires, insulated by paper or by plastic bundled together in a cable which is about as thick as your arm. The second method, is a coaxial tube cable, up to 18 coaxial cables, similar to the one that comes out of the back of your television set bundled together into a cable the same size as the copper pair cable. The third method is by using optical fibres. What we must realise is that all the information that could be carried on all one thousand pairs of the twisted copper wires can be carried in one of the coaxial tubes quite easily. All the information that can be carried on all 18 of those coaxial tubes can be carried on one fibre over and over and over again. Each fibre has the theoretical capability of allowing each man, woman and child on the face of the planet to talk at the same-time, twice over. We have almost an infinite optical ether, we have an infinite ability to move information around the planet. Of course we don't use all this capability at the moment, we are currently only using 0.001% of that capability. We are beginning to change questions, no longer is the question how do I move information from Point A to Point B?" The question now is "how do I generate enough information in order to fill the conduit." Within the BT national network, there are already over 3 million kilometres of optical fibre in the ground, with all that extra capacity waiting to be used in the future.

We have seen great changes in the telecommunications industry over the last 100 years. In the late 1880s we had the Morse key and that was rapidly followed by the simple telephone connected by single pair of copper wires. As the technology progressed we started putting amplifiers into the cables so that we could talk to people at a greater and greater distance. In the mid sixties however, there was the revolution which turned our analogue means of transmission into digital transmission and we had re-generators on coaxial cables. The re-generators got closer and closer together as we strived for more and more information transport.

Then with the advent of optical fibres, we moved into a regime whereby the re-generators could be further and further apart. Recently we have moved to a new era, whereby the optical fibre can carry the information to such large distances that we no longer need any regeneration in our network. We have a transparent network end to end. This means that the complexity of the network systems which increased and increased to the middle of the 20th century is now reducing as we take all the complex equipment out of the networks giving us greater and greater reliability. Surely this should be enough, but the engineers and scientists who have been working on the optical transmission systems had head of steam underneath them and they have continued to greater and greater endeavours.

Currently, we are working in the direct detection system. This is where you take a 'glob' of optical energy and push it into a fibre. It's transported along the fibre and at the far end you catch it and say, "Are there enough photons for a one or a zero?" It really is as crude as that. It is as crude as a spark gap transmitter was in radio times at the beginning of this century.

But now we have the opportunity of moving on, we have the opportunity of moving into soliton transmission. Solitons are perfect packages of light energy that transport along the fibre without changing shape. Around the world there are a number of physical manifestations of this type of transmission. For example, the wave that occasionally goes up the River Severn near Bristol in England is a soliton. It demonstrates all the same mathematical equations as we use for the transmission of light along the fibre. As the pulses of light within the fibre do not change shape it means that we can go along distance without any re-generation. The best results so far was in an experiment where 10 Gigabits of information were transmitted over one million kilometres of fibre without any re-generation. What that really means is that if I have a fibre and it starts with me here and it goes off right the way round the world and comes back again I can send you a message. As the message goes whizzing past you, you miss the message! It doesn't matter anymore, the message will go round that loop of fibre (right the way round the world) at least 22 times before it disappears down into the noise. This makes a big difference to the way we start looking at the way we transmit information around the planet. For example, things like hand shaking and parity checking no longer need to be taken into account, because if you missed the message 23 times you didn't really deserve it in the first place! These new types of techniques will allow us to put networks together in a totally different ways. Just imagine an optical network that goes right the way round the globe looking at very much like a hairnet. You could inject information in any node and it transparently would become available at all other nodes. So now I could put small packages of software into that network. These packages could be called "Data Robots" or "Knowledge Sprites". They would go through the network and seek out all sorts of information I want and bring it back to me. These sorts of techniques are going to make a big difference to the way we look at the storage of information in distributed databases, distributed processing of information and the collection of information.

Let's look at the cost of moving information

The cost of a 3 minute transatlantic telephone call in 1920 was about $80, by 1994 that has dropped to less than $1. The cost of moving information is reducing at such a rate that it is very rapidly becoming a commodity that we can use, in just the same way we would use electricity or a water supply. The cost of commissioning systems is also reducing in a similar sort of manner, it now only costs somewhere in the region of £200 million to lay a cable one side of the Atlantic Ocean to the other.

So we can see that the technology to create international data super highways is not a problem. The problems that we are going to face are those of the complexity, of the networks and the complexity of the information that comes through them. The art of modern telecommunications is quite simple. The art lies in concealing that complexity. The users of networks should be able to use the facilities and services offered without having to worry about the switches, the nodes, the cables, the connectors. They should be able to use the facility without having to have a PhD in telecommunications or electronic engineering theory.

The Uses of Information Highways

One of things I see progressively increasing in the future is that of distributed production. I see firms having central information stores but distributed remote production facilities. This will reduce the amount of transportation needed for products while giving the customers the maximum amount of access to customised products. Another aspect of the information highway is home working, I see more and more people not having to travel to the office in order to be fully in touch with their colleagues and with their information. There was an experiment recently in BT where 12 of our directory enquiry operators worked from home for a period of time.

We knew the equipment worked, what we were looking at were the social and psychological implications of such work. Modern telecommunications should be able to give you all the information and all the connectivity you need without having to physically transport yourself.

A recent example of a wide bandwidth information super highway is the Superjanet programme within the UK. In 1980 the academic bodies realised that they needed to be able to communicate and set up the Janet (the Joint Academic Network). This allowed academics to communicate with each other by electronic mail. By the year 1990 it was realised that they needed to do more than this. They needed to be able to access university libraries from remote locations, and use one of the strongest attributes the human race has, browsing. You should be able to browse through information at a distance, not just be able to see and interact with text, but be able to see images of the text and pictures and manipulate them. Of course, such access to information at a distance has its problems. For example the police forces of the UK are arranged in 52 separate units.

If one policeman wishes to interrogate a database he currently has to access the local database and then make numerous enquiries of others. In the near future with Wide Area Information Servers, it should be possible to make one enquiry which goes to all the known databases and

brings back all the information at one time, greatly simplifying the human interface into information channels.

One of the greatest difficulties is how are we, as human beings, going to interface with the information that is coming towards us. I, personally, am very disappointed with the small screen on my computer. If I have a word processor text, I can see approximately 15 lines that I can't remember what is at the top or bottom of the page. What I would ideally like would be a large screen so that I can see the information laid out in front of me in a very natural manner, as if it were laid out on a table. For example does your office currently look as though it has been deluged with sheets and sheets of paper. My vision of the office of the future is quite simple I want to bring information over the digital highways to my desk. I want it on large screens so that I can interact with people and information at a distance. We must harness the increasing power of computers and to make them start adapting to us rather than us, as humans, having to adapt to the machine.

Interacting with People at a Distance

I always find the current confravision facilities very limiting and constraining if not embarrassing. What I would like to see in the future are large screens so the people at the far end of the video link appear life-size in a one to one image so you can see all the body language. I would like to see work on acoustic bubbles so that the person on the screen has a voice which appears to come from their physical image rather than an audio speaker which is set at the side of the room. I would also like to have eye to eye contact with the people on the screen. If I talk to somebody in real life I look them in the eye and they trust me, but in the confravision systems today you have the image of the person on the screen and you have the TV camera. I don't look at the TV camera as I address the person I look at their image, and they perceive me as always squinting shiftily over their left shoulder. Would you buy a used car from someone who always squinted over your left shoulder? It is unnatural. It is embarrassing and this is why I believe not many people are prepared to use videoconferencing at the moment. By putting the camera behind the screen and strobing the screen we can get that natural eye to eye communication.

I would also like to see written communications as part of a confravision. I would like to see a whiteboard that I can write on at my end, just as natural as I could write on any other whiteboard but somebody at the far end could walk to their whiteboard (and appear as a shadow on mine) rub out what I have written and write what they want to write. I want to make the whole experience so natural that people want to use it in preference to jumping in cars and driving across the country or jumping into a plane and flying across half the world.

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In our everyday life we have the knowledge, we have the skills, and we have the resources. They all exist but they exist at different locations. What is needed is some way to bring this information together without having to bring the people together. What we really need are digital information super highways.

The CamNet

One of the concepts which have been researched within the BT Labs is that of the CamNet. This is a simple device consisting of a headset which is worn by an operator. There are earphones so one can hear the far end. There is a boom microphone so you can talk to the far end and there is a camera mounted on the headband so that you can send moving colour images of exactly what you are looking at to the far end. Just imagine you are an operator in the field with a problem that you cannot cope with. Do you pack all your tools away, get in your van and drive back to headquarters to look up the information in a book, or do you put something like the CamNet on your head, ring to the head office using a single digital telephone line and point out exactly what your problem is? The controller in the office has all the experience, all the information, all the CD-ROMs, all the manuals and can see exactly what you are looking at. He can also send computer graphics back to a small monitor which is mounted on the far side of the headband.

Using this type of technique we have a two way audio and visual communication. But it is also a totally unambiguous two way audio and visual communication. When the controller suggests that an action is taken he sees your hands go out and the action being completed. It's almost as if he is there with you. It is a way of transporting the intellect and the knowledge to a distance without physically having to travel there yourself.

One application that we have recently undertaken is in the medical field. Apparently when an endoscope is being used for examination of a bowel the surgeon experiences great difficulty knowing exactly where the endoscope is. All the films that we see are usually of the examination of the oesophagus or trachea, large cartilage tubes into which the endoscope can be inserted easily. The bowel on the other hand is a big floppy organ and the surgeon has no idea of the exact track of the endoscope within the human frame, and it does matter whether it looped to the right or to the left because the intubation of the endoscope is a very mechanical process and can cause damage to the patient. Currently, the only way of knowing where the endoscope is to use a fluoroscope, an x-ray technique which is quite harmful to the patient in large doses. One of my colleagues who underwent such an examination was sufficiently encouraged to develop a new technique of working out where the endoscope was. A small magnetic resonance device can be placed underneath the bed and the track of the endoscope can be displayed on a computer screen in the same two-dimensional form as the fluoroscope equivalent. However, colour can be used on this data set to show the third dimension. So

now the surgeon knows exactly the track of the endoscope and exactly the path of the intricate loops of the bowel. On offering this device to the medical profession they were greatly excited but our question was quite simple 'what else do they need?' What, for example, do they do should they intubate an endoscope and see something that they have never experienced before. That, apparently, is quite easy, a photograph is taken through the endoscope, the endoscope removed and the patient sent home. The photograph is then sent using the postal services. Why, were we asked, did they not ring the expert at the far end and discuss it? Primarily this is not done because the expert needs to see the information. Using the techniques of the CamNet of extending the image and the audio information to the far end, we now have doctors regularly diagnosing using a telecommunications link.

These sorts of techniques are not limited only to the medical profession. Just imagine if I had a pair of spectacles with two very small shirt sized TV cameras, placed on each side along with two small microphones. All the visual & audio information I could transmit to you at the far end of a link. These days there are some very small head mounted television sets - it is now quite possible to walk down the road watching television, (what a boom to mankind). If I could take the information from my TV cameras and my microphones and place them into your eyes and your ears I could effectively take the whole of your awareness and place it inside my head.
Everything I experience you would now experience. It would be like being there without having to travel. These techniques are already being used by surgeons and maintenance operators.

The Interaction with Information

When was the last time that you asked for information and it landed on your desk in the form of four and half inches of computer printout with a dull sickening thud. It is totally rational to expect a human being to be able to relate to and understand the information printed in such a manner. We are researching the possibility of turning large data sets into simple moving coloured pictures. We as human beings inter-relate with moving images throughout the whole of our waking existence and quite a number of our sleeping moments as well. We are very good at being able to analyse and relate to moving coloured pictures. What we need is the techniques of transporting gigabits of information into a pictorial form.

One example which we have undertaken, is to investigate the correlation between lightening strikes and transient errors within telecommunications networks. Everybody who has ever worked in the network knows that if you have lightening strikes anywhere near telecoms equipment, there are transient errors. These are not errors that disconnect your telephone, these are errors that change the digital code and require a re-modification of a code before it is handed back to the customer. No matter how much computational work was done using

the largest computers available no correlation could be found between the instance of lightning strikes and the transient errors. Within the BT Labs, a project was commissioned to draw a simple coloured picture of complex data sets. The information of lightning strikes was collected and turned into a three dimensional chart representing a given geographical area in the UK. The transient error information was also turned into a similar three dimensional chart to represent exactly the same geographical area. The two parts were stacked on a simple computer screen one above the other. With the information in the still picture form there is still not a lot of evidence of correlation between the data sets. But if the data is chopped into 5 minute intervals throughout the day and run as a real time moving video image the information suddenly becomes very apparent. There is almost 100% correlation between one data set and the other. This is apparent to most people without any training what so ever.

When this information in a pictorial form is offered to the network engineers they are then able to start vacuuming vast amounts of information from the data sets. Thus, it can be seen that there are great benefits from turning the large data files into simple colour pictures making it easy for a human operator to inter-relate with all that data.

Virtual Reality and its use in Business

The new virtual reality games machines of today are quite magnificent. It is possible to immerse yourself in a three dimensional computer generated image and fly advanced modern fighter aircraft. The machines, however, are not that applicable to a business use. Can you really imagine yourself sitting in one of these big machines, wearing one of the large virtual reality helmets in your office? It is too invasive and will never ever be used. What we are looking at is the ability to use the capability of virtual reality but in a business situation. I cannot imagine the large virtual reality helmets being used in an office environment, for one thing they tend to be very heavy and when worn for long periods of time the muscles of the neck become very tired and the whole process is very uncomfortable. In the future I do see the invention of very light weight non-invasive spectacle size displays that can be worn in comfort. Until that time, I see most of the work of virtual reality in the office using a computer monitor to give a window on a computer generated three dimension world through which we can navigate.

One example we have done within the BT Labs in Ipswich is to model the BT network. The BT telecommunications network is one of the biggest machines that has ever been built, it stretches from one side of the land to the other. The BT network carries, for example, 2 million million telephone calls every year, that's nearly 2 million every second of every day. If you requested all the information of the BT network at one time it would completely swamp you.

As an example, when I first started working in networks I asked if I could see a map of the BT network, my colleagues laughed and in a few minutes presented me with sheet of white paper with the outline of the UK drawn and completely blacked in. That is what the information would look like if you tried to draw it on a single map, it is too cumbersome, too large and completely unintelligible. In a project we have modeled the BT network in a three dimensional world, a virtual world. We have modeled the land and coloured it green, modeled the sea and coloured it blue. This is to tell you which way 'down' is because in virtual reality there is no gravity and consequently 'down' has no meaning. Having given you an emotional 'down' we then create the layers of the BT network above the land. A network controller can now fly through the three dimensional world and investigate that world as he navigates through. An error in the network, for example, could be depicted by flashing red. You can fly down towards that node, fly into that node and if the error was in a piece of equipment you could see the rack of equipment flashing red. You could fly towards the rack and see the card, fly to the card and see the component. Your ability to see the information is limited only by your ability to collect the information and turn it into a simple coloured moving picture and the latter is now being automated.

It is also possible to depict routings through the network by a simple three dimensional representation. No longer do you have to pour over sheets and sheets of paper with multiple digit circuit numbers on them, having to remember the interconnectivity between them. The information is brought to you in a very simple way that a human being can relate to.

This is not only telecommunications networks that virtual reality could be applied to. Just imagine the amount of information which is handled and processed in the dealing rooms, dealing with currency or stocks and shares.

Being able to create a simple picture of that sort of information makes the process easier, simpler and more reliable. But that is no reason to limit ourselves to just the business community. Why can't we have virtual reality in our homes? Why can't we go shopping in virtual reality? Instead of driving to the local shopping arcade, why can we not bring this into our homes? We could see the shopping arcade in virtual reality. We could walk down it, look at the shops, we could walk into the shops and see the merchandise on the shelves, and we could browse through the shelves and the merchandise. We could gain information about the products before we decided to buy them. The process becomes not only simpler and more convenient but it also could be done at a time of our choosing rather than just at the times when the shops themselves are open for business.

The Problems of Super Highways

As we make more and more information more and more readily available there is a problem with security. What we need to do is to look at how we can make access to our information over the super highways as secure as possible.

Currently, we use devices like pin numbers and security codes. These rely on the human being being disciplined enough to apply them and also to use them to block other people's access. Why can't we use biometrics? Something which we all carry around all the time to make the systems secure. We could use finger prints but those are frequently associated with criminal activities and people have emotional objections to them. We could use scans of our facial features, our retina is a good example of an excellent signature of the body. Unfortunately, it is rather difficult to get to and, should you wear contact lenses like I do, you can completely destroy the data set. But the iris, the coloured part of the eye, is also an excellent signature. The structure of the iris, (i.e., the bars that you can see) does not change through your life, the colour may change slightly as you age but the bars themselves are unchanging. I see in the near future an intelligent desk. A desk at which I sit down it scans my eyes it recognises who I am and with that knowledge it configures the computing system to be the form I want. It arranges for all my phone calls to be brought to my desk, all my faxes to be brought to my desk, all my electronic mail will be brought to my desk and I will have secure access to my information.

There is also the added advantage that should I leave the desk for any time and somebody else sits in the chair it will recognise them and bar their access to information which is pertinent to me. Complete security in a passive form, it no longer requires that I take specific action in order to safeguard the information which is in my super highway.

But it is not only the security of the information in the super highway that we need to be worried about. We also need to be worried about the security of the interconnection of the highway.

The Problems of Network Control

One of the biggest problems we have in operating a very large national data highway is that of controlling them. The control at the moment is done by software and the software is very large and very complex and currently, it is written as millions upon millions of lines of deterministic code. If we do a comparison between software and hardware we see some interesting trends.

First, hardware has been around a long time, we understand it, we can create mathematical models of it, we can shape it and we can test it. This is not the case with software. Software has not been around at all long. We cannot create determinalistic models of it and we most certainly can't test it. To give you an example, if you take all the software from one of our large System X telephone exchanges and you printed it on computer z-fold paper and measured the length of the paper it would measure over 4.6 kilometres in length. No one person can be expected to understand and to know that amount of code. To put it into context, if you put that 4.6 kilometres of print-out and stacked it in z-fold manner, the pile of paper that you would create would be over 1.5 metres high.

It would be equivalent of the encyclopaedia Britannica. Just imagine if I gave you 34 volumes of the encyclopaedia Britannica and told you that there was an error in there, one character had been printed in red ink instead of black ink, could you find it?

The answer is, yes, of course you could find it but it would probably take forever, but now if we change this error slightly and say that somebody had typed the letter '6' instead of the letter 'd', could you find it now?

The answer is probably not because now you would have to read every page and see every word, understand every word and understand every word in its current environment of meaning. Even if you did find the fault, the chances are there might be another elsewhere. That is what we are asking our software engineers to do, not only to relate to software programmes which are so huge no one person can see it but also seek out, isolate and correct errors that might be in that code. If software is put into telecoms a network which has bugs in it the result could be absolutely disastrous. They are called Brownouts. There have been evidences in recent years of parts or even whole networks being rendered in-operative because somebody has made a simple mistake, for example, like typing the number '6' instead of the letter 'd'.

In the BT Labs we are looking at new ways in which we can construct software programmes. In the next ten years it is suggested that we will have software which will be able to write other software. Until that time we are looking at the possibilities of writing small packages of software and associating those packages together so that the combination does something far more complex than any one package could do on its own. This has the advantages that the packages are small enough so one person has the ability to totally understand, to own , to control and to check the software within that package.

You might well have seen in the press recently, headlines which say, 'BT Researches Ants'. This is quite true, we are not looking at ants per say, we have no interest in the animals but we have used them as a metaphor for small agents that can be modeled using simple software

codes. For example, in the ant's case, food gathering, the code could be written in four simple rules.

One is, if you find food, take a bite and take it back to the nest leaving the pheromone trail. The second rule is, if you cross a pheromone trail and you are not carrying food follow it to the food, take a bite and take it back to the nest. The third rule is that, if you arrive at the nest carrying food, put it down and go back up the vapour trail you have just left and the fourth rule (and this is the one that is total novel in software engineering) is, if none of the above apply just walk around randomly and see what happens. With these four rules we can create a computer model of an ant's nest which operates in exactly the way we would expect an ant's nest to operate in your back garden. Writing software in this way removes our ability to have deterministic programmes. For example, there is no queen ant in the middle of the nest with an intelligent look-up table, directing four ants to this piece of food and twenty-seven ants to that piece of food over there. The system self generates and self organises. However, the main gain is robustness. As you will know if you have ever tried to kill an ant's nest, you can kill half the ants and the others instantly reform and continue with the task in hand. This is the same way with software coded ants nest. Killing half the ants and scattering the others instantly results in the remaining ants reforming into a self organising network and continuing with the task in hand because they have no need to resource back to a central intelligence control within the network.

Of course, BT is not interested in ants but what we are interested in is the concept of intelligent control agents. Just imagine the BT network with small agents migrating along the network path, looking at the nodes. The agent is an inverse of the ant. Where the ant took separated food and concentrated together, the agent looks at the nodes which are over loaded with a concentration of calls and spreads out those calls with minor changes to routing tables. In this way if one agent gets lost the functionality of the whole is not impaired and if there is too much work and not enough agents it is quite possible for the agents to re-generate themselves in order to attend to the task in hand. Using this type of concept we are looking towards a system of stable network control which is pervasive throughout the network and is totally resilient to errors.

Intelligent Networks

20 years ago telephone exchanges were mechanical and looked like clockwork. The customer controlled the path of connection through the network by dialling the digits. Each digit would progress the call one stage forward in a sequential way from one end of the network to the other. Using this type of technology there is absolutely no way in which we can have any central control of the network facilities.

Today, however, telephone exchanges look more like computers, they have the processing power of computers and they have the 'intelligence' of computers. This allows the set-up process of a communications call to be modified during the process of that set-up. The early digital telephone switches, the processing power was held within the switch and its aim was to control the working of that switch.

As the power of computing has increased, we have now been able to take the processing power away from the switch control and we can create a new layer of intelligence outside the main switching path. This is used, for example, in the 0800 calls. The customer no longer needs to know the destination of the call but can dial a simple easily remembered number. On seeing the 0800 number a telephone switch can make a request to a remote computer and ask for the requisite routing for that call. The routing information received from the external computers system is likely to be far more complex than you could ever expect any of our customers to dial. It might even change with time. For example, if there is a Bank Holiday in Scotland the routing for that day could put those calls through to an office in England or a customer might well want to call into one office during the week and another office during the evening or night or at weekends.

But it is not only simple calls that can use an intelligent network structure.

For example, imagine company A that has three offices within the UK using the old fashioned un-intelligent network, they would be using, between their offices, the standard method of dialling that would be used by yourselves and myself using an intelligent network, however, the three offices can be brought together in one virtual telephone network.

A worker in one office could dial a four digit number to access another worker within the same building. Dialling a similar four digit number they could access workers in the other offices, the intelligent network would realise that the call was not intended for delivery locally and would go to the intelligent layer within the network for instruction of how to route the call to the far end. This type of inter-working offers great benefits to the company concerned.

It is possible to go even further because now it is possible to manipulate the destination of call by accessing an intelligent layer within the network. It is possible to bring the telephone service which is normally housed within a small switch within a company into the main national telephone network. As far as the customer is concerned the prescribed area of the national network still looks and feels and operates as if it is a privately owned switch but they get the advantages of being part of a large network.

They still have all the capability of virtual networking but they have also got the resilience of being part of a bigger network and can also take advantage of the scale for extension, expansion and modification of their network within the bigger network.

We also need to be aware in these new digital super highways of the differing demands that will be made on them. It is not just one system that is going to cover all our needs and aspirations. For example, there is a great difference between the steady traffic which is needed for composite imaging or interactive visualisation or video conferencing and the bursty type images which will be used in distributed computing and image transfer and multimedia database access, multimedia mail or electronic mail. We have a wide range of networks it is not one simple tube.

Conclusions

Global digital information highways offer the opportunity to be able to move information easily and conveniently over large distances. They will allow us to extend our intellect our information and our experience to distances. They will allow us to interact with other humans in the most convenient manner. Whilst this is very exciting I am reminded of a cartoon which apparently appeared in the 'Punch' magazine in the year 1842. It shows mother and father operating the Eddison Telephonoscope. This is a device which allows audio communication to the far end and over the mantel shelf there is a large screen with a picture of their daughter who is in Ceylon and the caption underneath relates the conversation they're having.

The type of conversation they're having obviously shows that the cost of the communication is incredibly minimal because they're prepared to wait until the end of a tennis match in order to continue the conversation with one of the players. There is nothing new in our expectations of technology, all we're managing at the moment is to harness that technology and bring the functionality towards us so we can use it in our everyday life.

The advent of digital super highways will allow us to move information and manipulate information very easily. I see them as being tools which will open the door of our human imagination. Putting these systems in place is not the end it is only the beginning. It is what we, as a human species, can manage to do with the information that we transport over these highways which is important.

What we must realise for today, however, is a simple statement, that as far as moving information over telecommunications systems is concerned the "Time for just Talking is Over".