Telecommunications Networks: Staying in Control

Speed of Life

Life is something which is getting faster all the time. When you're young it's not that obvious but as you get older it becomes more and more apparent. A few days ago I was talking to an old man who had just celebrated his 92nd birthday, he was as bright as a button and had a very good memory and one of the questions I asked him was what could he remember from his life and what were the biggest changes. His reply was quite surprising, he had, he assured me, seen the first mains powered gas light, the first mains powered electric light, the first car, the first scheduled train service, the first telephone, the first aeroplane, the first world war, the embryonic form of the phonograph, now known as the record player, the first broadcast of radio, the first broadcast of television, the first jet powered aeroplane, the second world war, the first crossing of the Atlantic Ocean by a telephone cable, the first man-made satellite being put in orbit around the world, the first laser, the first microprocessor, the first personal computer, the first colour television set and video tape recorder, the first optical disk, the advent of mobile telephony and more recently the beginning of networking and computers into one transnational and transglobal machine. He had seen that, all in one human lifetime. The staffing effect is that there have been more changes in the last twenty years than there had been in the whole hundred years before that.

For example, let's look at the last twenty years, let's examine what we didn't have twenty years ago. In the home for example, we did not have video tape recorders, compact disks, electronic games machines. Whilst colour television was being broadcast, the majority of homes still only had black and white sets and the automatic washing machine was a strange contraption programmed by pressing squares of plastic into slots in the same way that you would post a letter.

In the scientific world there have also been equivalent changes, twenty years ago we didn't have portable computers, personal computers, CD-ROMs or even pocket calculators. It was in the early 1970s that Clive Sinclair published the first pocket calculator, it had four functions, subtract, addition, multiplication and division, cost in the order of £80 and worked some of the time. In 1970 he wished to programme the computer, it was a mainframe computer that lived in a room all of its own with special air conditioning to keep it cool. Your programme was written by punching holes in pieces of card and then the cards were stacked together and read sequentially into the machine. The output was not a pretty picture of many colours on a monitor that was likely to be typed text on a line printer on a continuous z-fold piece of paper.

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In telecommunications we have also seen dramatic changes over those twenty years, twenty years ago the only means of communicating over the telephone network was by the telephone. This was a large, fairly heavy plastic instrument with a rotary dial on its front surface, to make a call you had to pull the dial round to a fixed position and let it go and as the dial rotated back to its rest position it pulsed out the requisite number of pulses to represent the number you wished to dial. Subscriber trunk dialing which allowed the customer to directly control the call and its connection from one end of the country to the other was still a relatively modern tool and not universally available, leaving some of our telephone calls still being connected by humans sitting at telephone exchanges. In 1970 we didn't have fax machines, we didn't have answer machines, we didn't have mobile telephones and we most certainly did not have video telephones where you could see the person at the far end of the connection. In 1970 telecommunications was all about talking.

Telecommunication as seen in 1970

The scientists and engineers of twenty years ago were very keen to look into the future and wander what telecommunications would be like over the next few years. They predicted the advent of the answering machine which would take a message without human intervention, they predicted the development of the fax machine, in which written and pictorial information could be transmitted to a distance over the telephone network. They predicted that the development of the telephone exchange would become more and more dynamic and allow the customer the capability of controlling the network from the terminal equipment or the telephone. However, there were items which were mis-predicted in 1970 as the engineers looked forward to the year 1990. The first of these was the video phone or view phone, the developments on optical fibres by 1970 were such that the limitless bandwidth and the capability of carrying large amounts of data over circuits were a growing possibility. It was thought by the mid seventies or late seventies at the latest we would all have video phones and be able to see people at the far end of our communication links. This is something that didn't happen, because of the limited bandwidth as we pass through the switches of a telecommunications network. In 1990 however, this is becoming a greater and greater possibility as we will see in a few minutes. The other thing that the engineers of 1970 did not recognise at all, was that of ability. The thought of being able to carry around a telephone with ascending wires and being able to communicate with the rest of the world was thought to be in the realms of science fiction. In fact, a colleague of mine as a student in 1970 during one of the rag stunts took a leather briefcase and walked along the high street of Leeds outside the City Hall. Inside the briefcase he had a plastic telephone, a small battery and a ringer that would make the bell of the telephone ring. A small was concealed in the huddle of the briefcase, as he walked past the City Hall the telephone rang, he put the briefcase down, opened it up and took out the telephone handset with its curly cord and had a conversation, of course, there was nobody at the far end but nobody in the crowd that gathered around him knew of that, at the end of the conversation the student put the telephone back into the briefcase, picked the case up and walked away. Almost instantly the telephone

rang again, he put the case down, opened it up, and way before any of the advertisements, held it out to the nearest man and said 'It's for you', the man was so frightened by this that he ran away. Shortly after this the student in question was arrested for a breach of the peace but that's another story altogether. In 1970 the thought of having a phone that was totally mobile and could make and receive calls was science fiction. Today we take it as a common occurrence, in fact mobile phones are so common these days everybody appears to have one and there are now codes of etiquette for their use in public places.

The telecommunications networks of today are very very different animals to those of 1970. They offer very more facilities and many more services, and the way that these services and facilities are provided make great demands on the network over which they are carried, and the way that we as humans interact with them. Let us have a look at some of the services which we might see over the next few years.

The Control of Services

Over the last few years we have seen a coming together of both the communications and computing aspects of our life, over the next twenty years a differentiation between communications and computing is going to become ever less distinct.

Introduction

As we approach the mid 1990s we are going to be surrounded by information and means of moving that information. We are going to be surrounded by data super highways these are highways that you can't see, link everybody and they go everywhere. There will be information, entertainment, work and even companionship on tap over these massive information highways. There are dangers, however, and I see two main dangers. The first is, that we need to keep control of the interconnection and the networks on which these highways sit. The second one, is that we need to be able to keep control of the information. How are we as human beings going to manage to deal with all the information that comes from these high bandwidth super highways from our large powerful computers of the future? I can liken the accessing of information in these large super highways to trying to take a drink of water from a fire hose. Let us now investigate the sorts of services and the sorts of networks that we will be seeing in these new digital super highways.

Video on Demand

As you will see from the press recently, there are new services arriving in the telecommunications network arena, one of these is video on demand. Just imagine the possibility of sitting at home and instead of just watching the broadcast channels of BBC and ITV and Channel 4 you had access to a complete digital super highway. By pressing one button on your remote control you can access the services on demand and video on demand channel. You can ask for any facility which is available, for example films, by pressing the

simple icon for films, you are offered a choice, do you want the top ten films, comedy films, horror films, war films, old films, weepy films, the list is almost endless. But as this is an information channel you can also choose by different methods, for example, if you were uncertain about what you wanted to watch as a film, maybe you would like to see a Spielberg film, it is quite possible to navigate your way through the menu using the directors name. But what if you can't even choose using this sort of idea, it would be quite simple to create a desert island disk type menu where certain famous people list their preferences in films and you can look through their sort of film, it would be quite possible to choose from a list of films, for example, that Angela Rippon would choose to watch.

But we are not limited to only entertainment and films, we could have shopping facilities, we could have information programmes on travel, for instance, where you could experience a travel log type programme and have buried in it adverts for and details of how to purchase different types of travel and holiday functions. The whole video on demand and services on demand scenario allows you a simple convenient access to an enormous database which encompasses education, information and entertainment, and it does all this by providing the connection over a pair of cooper wires which already comes to your home to service your telephone. The truly magical part about all this is that while accessing all this information you still have the facilities of that telephone.

The Age of Information

We are all aware that the industrial revolution which happened at the end of the 18th century was a very massive change for mankind. The thing that set it apart from all other changes that happened to that date was the ability to harness energy sources and by so doing allowed the physical movement of people and materials around both the country and the planet. We are now embarking upon the age of information, this is equally signified by the ability to move things but this time we are not moving physical things but we are moving information, we are creating networks and structures which will allow us simply to move, over large distances, enormous amounts of information. Currently, we have the digital phone network throughout the UK, it incorporates over 3 million kilometers of optical fibre, nearly 90% of all telephone calls made within Great Britain today are carried optically over the fibre network. It is interesting to compare the information carrying capacity of different types of telecommunications cable. For example, if we compare the old twisted copper pair cables where you'd have a thousand pairs of copper wires twisted together, insulated by paper or plastic and bundled together in a large cable about as thick as your arm with a coaxial cable which is the same size but contains anything up to 18 coaxial tubes just like the one that comes out of the back of your television set and an optical fibre. There is a simple comparison between these three media, it is this, all the information that can be carried on all 1,000 pairs of the twisted pair of copper cable can be carried quite simply in one of the tubes of the coaxial tube cable and all the information that can be carried on all 18 of the tubes of the coaxial cable can be carried very simply on the optical fibre over and over and over, I

could go on for days and days, over and over again. Each optical fibre has the ability to allow every man, woman, child on the face of this planet to talk at the same time, twice over. It is almost an infinite optical ether. We are starting to change the questions, no longer is the question how do we move the information from point A to point B, the questions we are now starting to ask are how are we going to generate enough information to fill the pipe which is available. Of course at the moment, we don't use all that capability in fact we are using only about .001% of the capability of those optical fibres which are already in the ground and already part of the network. One of the reasons for not using all that bandwidth is it is incredibly difficult to totally fill an optical fibre and as the material costs are so low it is not necessary to completely stuff every fibre to its complete maximum. The other thing which causes us to under use a fibre are the switches which we have in our network. Currently we switch 64 kilobits of digital speech from one line to another using our System X and similar exchanges. These exchanges are capable of switching up to 2 megabits per second. In the near future there are new generations of switches arriving, the transfer mode switch which allows packages of information to be despatched and travel via different routes to be recombined at the far end will allow the switching of variable bandwidths and we'll be able to start using the re-source of the enormous capability that the fibre optical networks offer us.

So we can see as we rush towards the information age, it is not an inability to move the information which will be a problem to us because using the wide bandwidth systems and the wide bandwidth switches we have the ability to move all the information we want. The difficulty is, how we as human beings are going to be able to inter-relate and interact and analysis all the information which is coming towards us over these wide bandwidth systems. I saw a cartoon recently of an Abbott leaning out of the cloister windows of his Abbey, he was looking up towards the sky and the caption underneath the cartoon read as follows 'These are the dark ages, we don't have a gigabit of information about everything, however, adjacent to this cartoon there was another one showing the same Abbott leaning out of the same cloister window of the same Abbey, the difference now is as he looks towards the sky the date is not 1300 and something but 19 hundred and 90 something. He looks towards the sky and says, 'This is now the age of information, we now having a gigabit about everything', and this is the big difference as we move into the information age. In the year 1312 all of mankind's knowledge could be easily coded within a gigabit of information, by the end of the 1990s we are likely to be able to generate a gigabit of information about any topic no matter how specialised that topic is, we are likely to be able to store it and we are likely to be able to move it at will from any point of the network to any other point in the network.

At a recent conference, I asked all the delegates to close their eyes and imagine in the mind's eye what an international data super highway would look like. I did not bother going into the detailed observations of their images but suffice to say the vast majority of them saw the world map laid out before them and large red lines data wiring certain parts of the globe to other parts. I have a very different view of digital super highways, my image is quite simple it is a man looking slightly bemused facing towards me and he is stood in the entry to a large

pipe, the diameter of the pipe being more than twice his own height and the difficulty of this picture is that the man standing there requires a drink of water. What he is unaware of is the water coming towards him and its coming down this enormous pipe. Dealing with information as we go into the information age is going to be like trying to take a drink of water from a fire hose. In order to be able to cope with all this information, we as humans, are going to require assistance. I see assistance coming in a number of different ways.

Virtual Reality

I don't know how many of you have been lucky enough to see virtual reality machines let alone be able to play on them. They are quite magical, they allow you to be transported into a computer generated world to navigate yourself around that world to explore that world and gain information about it. In the games arcade there are large machines, they have a computer as a central information engine and it requires the operator to wear a bulky heavy head mounted helmet, to have joysticks to control the environment and frequently in the sit-on machines have motors and vibrators in the seat to give you that real feeling of being involved in the world. For example, on one games machine where you are flying a harrier jump jet you really do feel the g-force pulling as you go around corners, quite magical in the arcade games but hardly a tool which we can use in business to navigate round our real world of information. At the BT Labs at Ipswich, we have teams looking at virtual reality and how it can be incorporated into the business world and we have, of course, to make certain changes to the machines which are used in arcade games. For example, the helmet is partly intrusive can you imagine sitting in an office at a desk with a large helmet strapped to your head. First it precludes you reacting from your real world, if somebody walks into your office you would have to unstrap the helmet before you can find out who has just walked into your real world. This is not an acceptable practice in the business world and the other problem with the helmets is that they are very large and very heavy. Can you imagine sitting in your office with a helmet which basically has four kilograms of weight hanging on the front of your face. After a bout ten minutes the muscles down the back of your neck completely give up and your chin slumps down onto your chest, but not to worry some mechanical engineers came in with a solution, they added another four kilograms of weight on the back of your head to balance it all out. Unfortunately now we are in a situation where after fifteen minutes the whole of your neck gives up and your head power drives down into your chest. It is uncomfortable, it is hot and it is totally unmanageable. What we really need is another way of interacting with a three dimensional worlds of virtual reality. This can be done by using a window on the three dimensional world using the standard computer monitor we can view the three dimensional world and navigate our way through it. One of the examples we have used to demonstrate the versatility of the virtual reality machines is to build a model of the BT network. The BT network is one of the biggest machines ever built it spreads from one end of the country to the other it carries over two million million phone calls a year, that's over two million every second of every day. It is incredibly complicated and incredibly powerful, and to control this we require a control centre which is housed in

Oswestry near the Welsh borders, which looks like the NASA space control centre and is technologically every bit as complex. What we have done is we have modelled the BT network within the virtual reality machine which allows the network control manager to navigate through the three dimensional world of the model. He is not in-undated with all the information all the time but can seek out information of the nodes and the connections which are closest to him in the model at the time.

He can see where faults have developed as nodes flash red and can fly towards them and investigate the problem, he can fly to a node, he can fly inside the node and if there is a fault condition he can see the equipment room with one of the racks flashing red, you can fly to the rack and see the card and fly to the card and see the component, the ability to access and manipulate information is limited only by your ability to collect the information and turn into a simple moving coloured picture, because we as humans are so good at relating to and analysing coloured moving pictures. After all we do it every single waking moment of our lives and quite a number of our sleeping moments as well. Bringing information to a human in this sort of form allows the human to make maximum use of the information in a way which also allows the human to be very comfortable navigating through large datasets.

It's all a bit like looking at a watch, how often have you seen somebody look at their watch and then look away again and you've asked them 'what time is it?' And they do not know this is because when they looked at their watch they asked a very specific question of it and it is unlikely to be what is the time now but it is more likely to be how long is it before the train leaves, how long is it until lunch? They would then look back at their watch and inform you that the time is 3.30pm; this is how humans relate to information and how we make best use of it. Another example of turning large amounts of information into simple moving pictures is a project called 'visualisation of data'. In this project we have been able to turn all the information on all the calls made throughout the whole of the UK over an eighteen month period into simple coloured pictures. We can plot the information in a three dimensional manner using time of day on one axis, day of month on another axis and a parameter on the third. We can ask the information questions, questions like how many calls were generated? What were the average holding times for these calls? The BT network is sufficiently large and sufficiently complex to generate nearly two gigabits of information every single day. If this was printed out as numbers in columns on computer printout paper it would be impossible for anybody to see any patterns or receive any information about the collected data by turning it into a picture you can look at the picture and very simply analyse the trends and the aspects of that picture. We as humans are so good in being able to identify visual information. Unexpected things happen, for example, we all know that the electricity boards can tell when the adverts have been transmitted in television programmes because everybody goes into the kitchen and switches on the kettle. We are now seeing some of the trends within the telephone network, we can tell when the television programmes and schedules change as the calling patterns are shifted within the pictorial information brought out of these

large databases, this is a way that allows a human to mine down into large amounts of data in a way that the human being can accept the information, analyse it and make use of it.

Voice Recognition

Getting information out of the system is only part of the problem, the other part of the problem is putting information into the system, the vast amount of information input assessed these days entered in using keyboards, the QWERTY keyboard. This is a device that was designed over one hundred years ago it was not designed to be convenient it was designed to slow the typists of the day down because the mechanical machines if operated too quickly would lock together. The greatest claim to fame for the QWERTY keyboard is that is hat been slowing us down quite consistently for over one hundred years. Go into any office anywhere in the UK and you will see QWERTY keyboards on every single desk. There has got to be better ways of putting information into our new systems as we move into the information age.

One of the ways of inputting information is the natural way that humans have of eating, the great difficulty is that over the years we have not been able to build machines that could understand human speech. In 1970 a lot of work was being done in that area but great barriers were being perceived. However, it was thought that as computers got more complicated and more powerful there would be a way forward as the large number crunching capability was achieved.

By 1990, however, computers had advanced many folds, the long awaited breakthrough had not happened. Recently, however, there have been big strides forward in the technology of the human speech recognition.

There are two aspects to speech recognition, there is the machine to which you can talk it can understand everything and take it into processable text form. The voice activated word processor, for this you need a very large lexicon usually amounting to twenty or thirty thousand words, in order to access that number of words you have to train the operator and train the operators voice to the machine and more and more these days the machines are learning over a period of time from the operators. However, we have a completely different aspect there is the aspect which allows a very limited lexicon to be used by all people as operators without any training. Telebanking is an example of this type of operation you only need a few words the numbers 0 through 9, words like account, transfer, balance and we do require to be able to recognise these words spoken by all of the English speaking population, in respective of age, sex, racial background, regional accent, etc, it is in this later area that we have made the great advances in recent years. It is now not only possible to recognise voices but to also create the lexicon of words very quickly, this has been done by breaking each of the natural words down into small phonemes and then being able to reconstruct the words using the small packages of sound energy. In the near future we will increasing see systems allowing us to enter information into machines and networks in a very natural human way.

Natural Language

Just imagine if we could build a machine that could manipulate textural information, in the BT Labs we have built just a machine, it can read an article, for example, an article from a newspaper, you can read it, you can understand it and you can ask it to précis the article but keep all the meaning. You could ask for an abridgement of say 5% or 1% of the original article. So that you as a human don't have to read the whole article you can see a short abstract and if you're interest is captured by the shortened version you then have the ability to data mine back down into the longer version. We have such a machine, of course, it does not understand anything about what is in the article. All it has are the rules and syntax of the English language and soon we hope to extend it to other languages such as French and German. What we have found is that within about a 5% abridgement we can keep the vast majority of the meaning of an article. So the first question to ask is why do we write the other 95%, in most cases, it's quite simple, we were just showing off. Though that technique is very powerful as a simple article abridger it also has other implications for the information ache.

Just imagine you have a library every week the library receives articles from magazines and journals and a list is compiled of all these and distributed to all the people that use your library. In the old days this would arrive on each desk as a bulk printed on paper these days it arrives as an electronic mail file. Imagine if you had an agent that could help you read this long file, as you look through the first copy you can indicate that you quite like this article and this article and this article, but not that article or not this one. The agent can then learn your preferences and be able to read through the whole list of all the articles using the natural language techniques. It could then re-rank all the articles, putting the ones you definitely want at the top and those you don't want at the bottom and rank all the others between the two extremes. So basically it could offer you articles that you had not said you wanted but are of a similar meaning. This could take a lot of the pain away from the human being as we process more and more information. The bonus of this is that the agent would then remember and on the next issue of the library circular it would be able to pre-read it for you and have it pre-ranked for you before you need to look at it at all and you can add more preferences and subtract others. In this way the agent will grow in its intelligence.

It is not a large step from having your own personal agent working within your office to having agents that you can send out through the networks of the information super highway. These agents would know the information that you were wanting to gather and would go out through the network and seek that information and bring it back to you. With the advent of artificial intelligence the agents could be given the apparent properties of being able to think and to reason and to negotiate with each other and the sources of the information at the far end of the network, the possibilities are almost endless.

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Network Control

As I mentioned before, our Network Control Centre at Oswestry is large, its display screen fills a whole wall which is 5 metres high and 28 metres wide. It looks at every node and every connecting cable, every minute of every day throughout the year. It also monitors all our connections into the international networks. The numbers involved in the data streams from this network control are so huge they require far comprehension by the human mind. However, we expect human operators to sit and the desks and terminals and ensure that the whole of the network runs smoothly and reliably. To give you an example of the types of things they have to deal with, there was one soft drinks company who ran a competition, they said they required the purchasers of their product to take the numbers printed below the supermarket checkout and laser bar lines and dial the number as a telephone number, the first hundred successful competition entries would be awarded free tickets to a rock concert. Neither BT nor the BT network controllers knew anything of this and suddenly at 6 o'clock one evening the whole of the network around Bristol on the large video display wall started flashing bright red. The network managers traced through the network to find out where the congestion was happening and found one small telephone exchange with only a thousand lines being in-undated with millions of calls every minute. The office in question, however, only had 10 telephone lines so the other 990 customers on that telephone exchange had no service at all. The network controllers quickly established network blocks elsewhere throughout the whole of the national network to stop their concentration of calls on to the small telephone exchange. The operators of the competition were offered far more calls than they could cope with but we also managed to establish service to the rest of our customers both on that switch and throughout the rest of the national network.

Services and the Control of Services

Twenty years ago we had computers and they were large boxes. We had a telephone network and it was mainly composed of mechanical switches and telephones, and we had television, which was a box that sat in the corner of your lounge that wasn't connected to anything other than the mains electricity and an aerial. As we approach the mid 1990s we are going to see a coming together of communications, computing, television and entertainment. The concurrence of all these technologies is frequently referred to as the multimedia. Multimedia is a difficult term to define, it basically is the combination of information in the form of text, sound, pictures and moving pictures. Frequently it is thought that you need to have all these elements in order to be multimedia, my definition of multimedia is that you should have the ability to be able to use each, or all of these in any combination that you wish to use.

The first multimedia product offered in telecommunications is the VC, standing for Visual Communications 8000. This is the device developed jointly between the BT and IBM Labs to put a video telephone inside a computer. Not only can you see the person at the far end of the telephone link and talk to them but you can share the whole of your computing experience

with them. For example, if you have a spreadsheet on your computer they are allowed to see the spreadsheet, as you change the numbers they see the numbers change and they see the graphs change.

If you have a word processor they can see you changing the text within the word processor in real time as you change it. It does not matter that on their computer they don't have that particular spreadsheet or word processor package, they can see the image of the word processor and you are in a position of sharing your computing environment with somebody at a distance, and the really magical part about the product is that, with your permission, you can extend the use of your machine to the far end keyboard so they can even change the numbers in your package while you both sit in the same shared computing environment. All of this happens using one ISDN digital telephone line and the cost is exactly the same for any other simple telephone call.

An example of multimedia and the moving of information is as graphically shown in the Super Janet Project, in the early 1980s the universities of Great Britain decided that they required the ability to communicate with each other. This was done over the Janet network, the joint academic network. Using this network which worked up to speeds of two megabits per second, people at the different node universities were able to send electronic mail messages to each other. By 1990, however, the academic bodies that just sending electronic mail messages was quite restrictive and they wished to go further. This was the time when the Super Janet Network was put into place, this is a network, a switched network, which works at currently 34 megabits per second and is upgrade able as technology progresses to 155 megabits per second, 655 megabits per second and with time, into gigabits per second. Using this network the aim is to be able to supply information from any part of the country to any other part of the country. For example, it will be quite possible for an operation to be happening in an operating theatre in London and the whole picture of the operation in all its technicolour visual detail could be distributed to all the medical students in all the universities on the Super Janet Network, not only that it will be quite possible for each of the students to ask questions about the operation they are viewing on the screen. Personally, I would prefer that if I was on the operating table that they were asking questions of a commentating surgeon somewhere in the operating theatre than the man who was actually yielding the knife above me, but that is a personal matter. But the Super Janet Network has other benefits, we have created many universities recently by re-naming polytechnics, unfortunately there are not the resources to provide for university library facilities at all of the old polytechnic sites.

Consequently we need an ability to be able to access information from the known sources of university libraries. Using the facilities of the Super Janet Network, it is possible to log on at any node, and to browse information at any far node, and it is important that we have the ability to browse. The human ability to browse is one of the special facilities we have as a species. How many times have you gone into a library looking for very specific information and very rapidly collected vast quantities of other information that at the time you didn't

realise that you needed. Using the wide bandwidth switch circuit of the Super Janet Network we can not only access information from the far end in both text and image form but we can also browse through that information in a very natural human way.

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 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 because if software is put into telecoms networks which has bugs in it the result could be absolutely disastrous. They are called brown oats, 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 that 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, a headline which says, 'BT Research's Ant's'. 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 and 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 vapor trail you have just left and the fourth rule and this is the one that is total novel in software engineering, the fourth rule is, if none of the above apply just walk around randomly. 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 the piece of food over there, the system self generates and self organises. However, the main gain from all this is that of robustness, as you will know if you have ever tried to kill an ants nest, you can kill have 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 because the agent is an inverse of the ant where the ant took separated food and concentrated together what we want to look at is nodes which are over loaded with a concentration of calls and be able to spread 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 all evasive 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 dialing the digits. Each digit would rest 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 look and 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, 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 have to make between their offices using standard method of dialing 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 would dial a four digit number to access another worker within the same building dialing 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 the network.

Conclusions

So you can see as we move forward into the 'information age' there are many exciting challenges. The first challenge is to be able to create and control the national and

international digital data super highways. The technology we already have and the technology which we are researching for the future should make this an achievable, if not a trivial task. I see the biggest challenges for the future are not in the technology but in our personal interactions with the information. We must be able to control the input of information to systems and make it an easy process for the human to generate that information and we must also spend time and effort looking at how we can take information from these systems and make it accessible to a human in a very natural sort of way that allows the human to develop, to analyse and make use of the information which is being carried upon these large networks. The real challenge for the future is staying in control of information.

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