PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The Global Picture

Edward Fennessy

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The global picture

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The period from the invention of the telephone in 1876 by Alexander Graham Bell until the late 1950s was characterized by the progressive development of national systems.

Except where these national systems lay within a common continental area there were only very limited means for interworking system to system. In effect any sea separation of more than some 75–150 km presented a barrier that could only be bridged by the limited facilities of radio telephone links.

The successful laying in 1956 of the first intercontinental submarine telephone cable transformed telephone communication between Europe and North America and ushered in a new era of world-wide telephony.

The development of the geostationary communications satellite in 1963 brought an even more dramatic linkage of the telecommunications networks of the world and permitted world-wide telephone and television interchange.

Today some 400 million telephones in over 200 countries are operating on one single global system with a high percentage of automatic dialling. This global system is the most complex machine yet constructed by man. It carries annually a total traffic of 400000 million telephone calls together with a massive flow of telex and data.

It is expanding annually at a rate of over 6% and by the end of this century will consist of 1500 million telephones generating a traffic possibly greater than a million million calls each year.

Later papers in this volume will describe many dramatic technological developments that will permit still further expansion of the capability of the global network. But these developments will not be without problems – problems affecting the nature of the telecommunications manufacturing industry, of handling the rate of change of technology, of choice between the almost embarrassing wealth of new ideas, and problems of reconciliation between old and new technologies in our networks. The resolution of these problems will be a challenging and stimulating task for all of us concerned in the direction of these enterprises.

The social and economic implications of this vast global communication system will be profound.

Today, just over one century since Alexander Graham Bell's invention of the telephone, 60% of the telephones in the United Kingdom have direct dialling facilities to some 300 million telephones throughout the world.

Making an international telephone call has become, for many people, an almost daily event; indeed it may have become essential for the conduct of their business. But as they dial or key their call they are probably unaware of the armoury of advanced technologies they are calling into play. The telephone is such a deceptively simple instrument; yet, at the customer's command, it can select within a few seconds another designated instrument out of the hundreds of millions in the world capable of access by automatic means and provide good speech quality between the two.

Let us imagine a call from London to Sydney, almost half way round the world. When the Sydney number is pulsed out from the telephone, the local exchange recognizes from the early digits that this is not a local but a long distance call and switches it through to a higher-order exchange in the network hierarchy, called a group switching centre. Here, further examination of the first three digits (010) reveals that this is an international call and the next two digits (61) show that the destination is Australia. The call is therefore routed to the London international exchange at Stag Lane in Edgware that handles calls to Australia and is routed to an Australian outlet.

There is more than one way of linking the U.K. to Australia, but the greatest volume of traffic is carried eastabout via the Indian Ocean satellite. It is most likely, therefore, that the call will travel over coaxial cables and microwave radio links to the Post Office satellite Earth station at Goonhilly Downs, Cornwall, where aerial no. 1 carries satellite circuits to the Middle East, the Indian subcontinent, the Far East and Australia.

Goonhilly aerial 1 is directed at the Indian Ocean satellite, an Intelsat IV–A, which of course is carrying not only the traffic to and from the U.K. to the East but also large numbers of connections between the rest of Europe and the East, and between many African, Asian and Australasian Earth stations.

Amongst these is the Australian Earth station at Ceduna from where the call would be transmitted over a long microwave link to the International Switching Centre at Sydney and thence to the called number. However it would not be prudent to rely upon just one route to a destination as important as Australia, so a proportion of U.K.–Australian connections are routed westabout. Some of the outlets from Stag Lane are connected to Widemouth Bay, where they pick up the Cantat 2 submarine cable to Canada. The circuits are then routed over microwave radio links right across Canada to the satellite Earth station at Vancouver and thence via the Pacific Ocean Intelsat IV–A satellite to the Australian Earth station at Moree which, of course, is also connected back to Sydney.

Thus a simple call to Sydney can involve nearly every facet of modern telecommunication technology: complex exchange systems, terrestrial coaxial cables and microwave radio, submarine cables, huge steerable aerials and geostationary communications satellites.

By 1980/1 virtually every telephone in the United Kingdom will have I.D.D. access to some 100 countries throughout the world and some 100 million calls will be made in that year.

This vast global system is expanding annually by about 6%; by the end of this century it may well comprise 1500 million telephones generating traffic possibly greater than a million million calls per year. It could become a system over which streams of complex computer data will link business and scientific centres worldwide; a system which will probably then provide visual communication on a scale which will challenge air transport as a means of conducting face-to-face business negotiations, and which will enable families and friends separated by thousands of miles to meet in intimate discussion at regular intervals at a fraction of the cost involved in global travel.

This paper attempts to set the forthcoming technological revolution in the global context and in particular attempts to identify the new technical opportunities which will present themselves and which will have to be energetically taken up if the full potential of global telecommunications in its widest sense is to be realized.

We have come in just over 100 years from the simple elementary telephone of Graham Bell to the global system of today, a development that might well have astonished Bell himself but would certainly have confounded Mr Culley, the Engineer-in-Chief of the Post Office, who said in 1877, 'My Department is in possession of full knowledge of the details of the invention and the possible use of the telephone is very limited.' Happily Preece who went on to succeed him had a better appreciation of its potential.

But what must impress anyone who studies the matter is man's remarkable desire to communicate. It is as though there is a natural law which states 'Man's need to communicate expands in direct ratio to the availability of the means of communication.' This is well illustrated if we examine the growth of telephone calls between the United Kingdom and North America (figure 1).

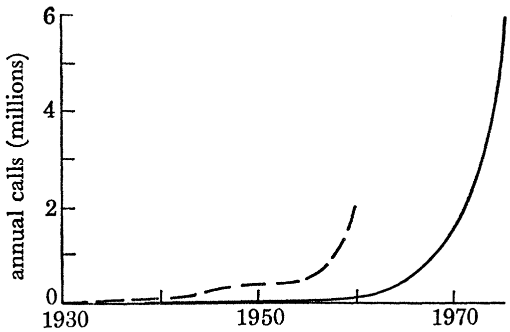


Figure 1. Telephone calls between the U.K. and North America. The broken line represents a tenfold vertical scale enlargement.

On 7 January 1927, just over 50 years ago, the Post Office and A.T. & T. opened the first commercial radio telephone service between the United Kingdom and North America. Calls averaged 2000 per year. Initially there was only one circuit and quality was subject to the uncertainties of radio propagation and the service was inevitably expensive. Limitations of the available frequency spectrum prevented significant increases in channel capacity and, while many devices were introduced to combat fading, the basic instability of the ionosphere prevented high-quality communication being achieved on a consistent basis.

It was not until the submarine repeater had been successfully developed that a submarine telephone cable linking the United Kingdom with North America became possible. Tat 1 was the joint project of the British Post Office, A.T. & T. and C.O.T.C. of Canada, and provided initially 29 telephone circuits between London and New York and 6 between London and Montreal. Tat 1 was brought into service in September 1956 and within one month the number of calls between London and New York had increased by over 50 % and those to Canada by 100 %.

Tat 1 was the first of a family of submarine cables which today link Europe to North America, joined in 1965 by Intelsat 1, the first of the geostationary communication satellites developed under the auspices of Intelsat. Figure 2 shows how a rapid succession of satellites and cables has been needed to keep pace with an annual compound growth rate of 20 %. The cables and satellites themselves are of higher and yet higher capacity to meet what appears to be an insatiable demand for communication between Europe and North America. With such a growth the total system capacity both in gateway exchanges and in cable and satellite circuits must be doubled every few years.

Clearly there will come a point of major decline in this growth curve but it is not yet in sight nor is it likely to be within the next decade or indeed this century. Certainly not if we take account of the increasing demands of data, of the potential needs of facsimile and word processing systems as competitors to the mail service across the Atlantic. More distantly, but most certainly, the massive bandwith requirement of visual communication, when its economics make it acceptable initially to the business community and subsequently to the private citizen, will also make its contribution. However, before considering these issues further let us take a wider global view and consider some of the basic problems that have to be recognized and overcome.

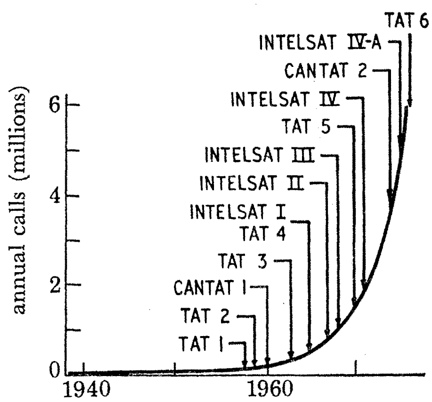


FIGURE 2. Telephone calls between the U.K. and North America, and the introduction of cables and satellites.

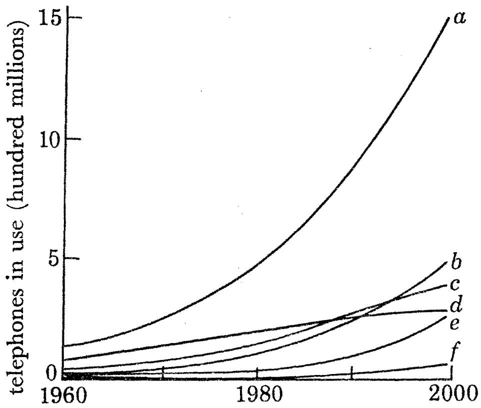


FIGURE 3. Forecast growth in the number of telephones in use: (*a*) the world; (*b*) Asia and Oceania; (*c*) Europe; (*d*) North America; (*e*) Central and South America; (*f*) Africa.

We know that there are now about 400 million telephones in the world and that this figure is growing by around 6% per annum. What this represents in investment in plant is difficult to determine but by extrapolation it is probable that the total investment is around $250000 M, and that new plant is being installed at about $30000 M per year. Total revenue is perhaps of the order of $90000 M per year.

Penetration expressed in terms of telephones per 100 of population varies from 70 for the U.S.A. with nearly 150 for Washington down to less than unity for some African and Asian countries. Growth rates range from a high of 10–12% per annum with a world average that fluctuates at around 6%. The growth of national telephone systems have followed the classical growth curve, and if it is assumed that this too will be the pattern of global growth then world growth is likely to be as shown in figure 3. Naturally such forecasts are highly speculative but it is a fascinating thought that Asia and Africa, at present having very low telephone penetration, could well dominate the world telephone market towards the end of this century.

To expand a modern telecommunications system to meet public demand at growth rates of 6–8% calls for very substantial sums of money. In the United Kingdom, with an annual investment running at about £1000 M per year, we are employing about 0.8% of the national g.d.p. and this figure would seem typical for Europe.

Looking forward over the next twenty years of growth of this global system, there can be no doubt that the problem of finance on the scale envisaged, involving such very substantial sums of money, will present perhaps the most formidable barrier to progress. Investment must be planned to match demand, but demand is dependent on the cost to the public of the service and upon the economic conditions prevailing at the time. But because of the lead times involved, buildings must be erected and equipment ordered several years in advance of the equipment being required in service. Such massive programmes cannot be readily trimmed to match changes in demand arising from arbitrary political or regulatory decision on tariffs, or as they are called in America 'rates'. Such tariffs must be carefully planned in advance in phase with the investment programme if the assets in which the investment is made are to be utilized cost effectively. This is rarely achieved in practice because the determination of tariffs resides in the ultimate with authorities external to the administrations who themselves carry the responsibility for planning. Short term arbitrary decisions on pricing far too frequently result in demand and supply being in antiphase resulting in inefficient use of assets representing vast sums of money. Not only does this result in inefficiency in the telephone service itself but it has a most damaging impact on the efficiency of the equipment supply industry.

While telephone penetration varies country by country from less than one up to 70, so too is there a wide variety in the types of equipment that comprise each national system, not in basic principles and not to any great extent in performance standards, but to a significant degree in important details that give to most major national systems technical characteristics that have to be recognized in planning their ongoing development. Failure to take proper account of such differences can result in substantial operational problems. The nature and scale of these national characteristics in the telephonic sense constitute a significant constraint in the development of most major systems. They represent vast investment in assets which, if they were to be replaced in the short term, would impose a very heavy financial burden. Thus in the U.K. the replacement value of the Strowger equipment to be displaced by modern equipment is some £2500 M and for logistic and financial reasons will take 20 years to accomplish. The forward development of any system must therefore be evolutionary with the new equipment designed to interwork effectively with the old, and the new itself designed as far as possible in a way that will impose minimum constraint on future developments as yet but broadly envisaged.

Just as Graham Bell was not content that communications should be limited to the constraints of the telegraphic code, the telecommunications engineer of today sees the challenge and opportunities of the many extensions of the basic telephone service that modern technology is now making possible. The ability of the system to provide data links between computer centres and between remote inputs and central computers; the potential of Viewdata, of fascimile and of word processing, and further ahead the ability to bring people together with visual communication of such quality, that something approaching the total communication achieved in actually meeting becomes possible; all these are areas of major potential growth. The ultimate challenge to the telecommunications engineer must be the question, 'is it necessary to physically transport people to achieve effective communication?' This is a challenge which will almost certainly be answered within the next 25 years.

However, these exciting developments of telecommunications will only be achieved if they are themselves economic and cost effective in the service they render and, since telecommunications is entirely concerned with the transmission of information, the preoccupation of the telecommunications engineer must be to reduce the cost of transmitting and directing this information so that it is conveyed from sender to recipient with acceptably low distortion in the most economic manner. This is the objective that has been pursued by the telecommunications engineer over the past 100 years. It was the reason for the invention of the phantom circuit, it was the driving force in the concept of carrier telephony, and it is why today we are planning the transatlantic cable Tat 7, and why the communications satellite Intelsat V will succeed Intelsat IV–A.

The dramatic fall over the years in the costs of transmission is illustrated in figure 4. But while transmission costs have fallen and will continue to fall, the cost of switching the millions of individual calls that flow through a telecommunications system has remained stubbornly constant over many years. Crossbar succeeding Strowger has given more reliable and flexible

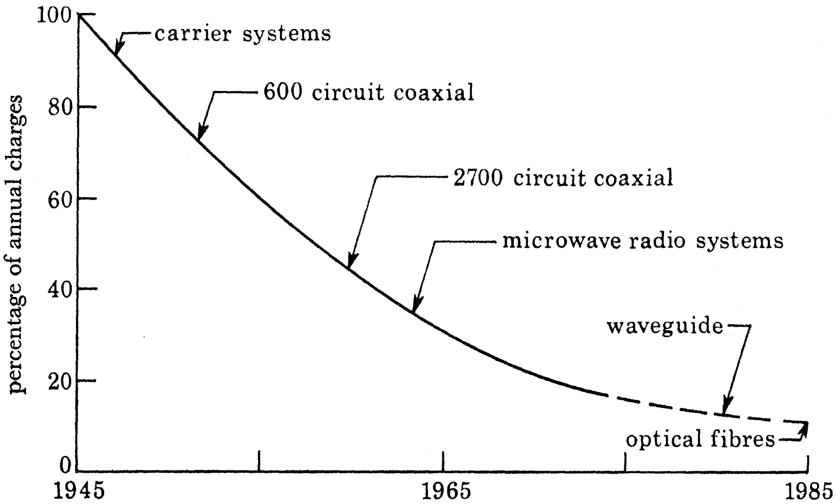


Figure 4. Relative costs of transmission.

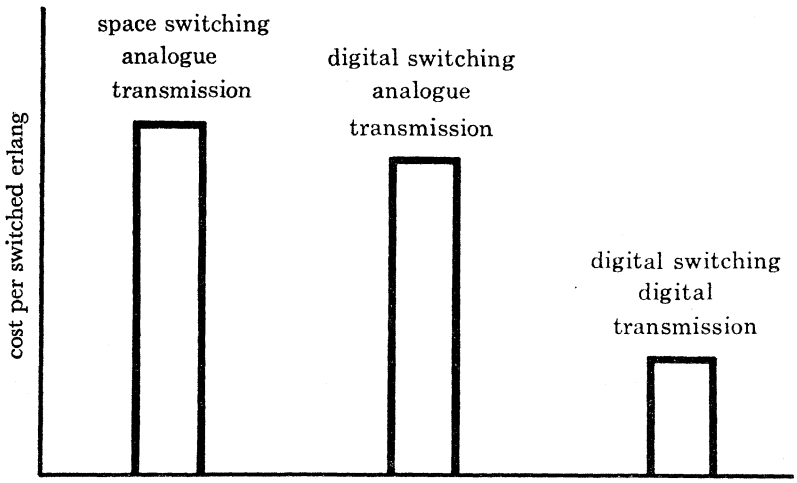


Figure 5. Telephone switching costs.

switching but it has not basically reduced the capital cost of the equipment. Semi-electronic exchanges now coming into extensive service have not made any significant impact on the problem and, bearing in mind that switching equipment represents a very substantial percentage of the cost of a telecommunications system, it is a problem of the greatest importance to every administration.

It is for this reason that telecommunications engineers worldwide are now well advanced in the development of digital switching which, in an analogue transmission environment, offers cost advantages but which when associated, as it will be, with digital transmission represents a very substantial advantage in both capital and operating cost, as figure 5 shows.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

To meet worldwide growth there exists an immense market for equipment but the investment required represents a major demand on the economy of every nation, probably representing in many cases 1 % or more of the g.d.p. It is for this reason above all others that attention must therefore focus on the possibilities for reduction in both capital and operating costs presented by new methods and processes which are now well advanced in development. The potential of digital technology in the field of transmission combined with the broadband capability of modern coaxial cable systems, of the millimetric waveguide and perhaps most significant of all, in respect of the future, the optical fibre. The latter is a development which in my judgement is likely to have a profound impact on the design of telecommunication systems over the next 20 years.

However, transmission is but part of the total problem of telecommunications. The extraordinarily complex task of ensuring that any one telephone in the hundreds of millions of telephones that constitute the global system is capable, within seconds, of being connected to the other unique telephone with which communication is required presents signalling and switching problems of a challenging magnitude. As I have already indicated it is in this area that much more remains to be achieved by way of cost reduction. The application of digital technology in the whole field of switching and signalling is therefore of dominating significance.

Furthermore, there are the questions, 'what will be the economic and social consequences that flow from the growth of this great global system with almost unlimited ability to transfer information, be it speech, data or vision, to any part of the globe virtually instantaneously? How will this affect the development of world business and what impact will it have on the social habits of people?'

We now have within our laboratories all the necessary fundamental knowledge to ensure that the telecommunications networks of the many countries that constitute the global system can be developed in a way which makes the maximum use of digital technology and of the new methods of transmission. In all these developments the use of the silicon integrated circuit will have a profound effect on reduction in equipment volume and cost, while software will become as important an element as hardware. It will of course place challenging demands on the engineering design teams, and it will present particular problems to the manufacturing industry, the nature of whose products will over the next decade undergo a very fundamental change. These changes will involve dramatic modifications in the nature of production processes and will inevitably lead to increasing rationalization of production facilities on a national and worldwide scale. All this will call for much imagination, sound planning and determination and very substantial financial resources.

However, these developments will lead to yet further demands for international circuits linking all the nations of the world in one global system. Fifty years ago there were a few uncertain radio links across the Atlantic; today the globe is interlinked by a great network of submarine cables and satellites. There are now eight major submarine telephone cables across the North Atlantic. In the 20 years since the inauguration of Tat 1 the capacity of cables has increased more than 100-fold from the 36 circuits of Tat 1 to the 4000 of Tat 6, as figure 6 illustrates.

At the heart of this astonishing development has been the submerged repeater. Built with transistors having a reliability target such that not more than 1 in 4000 will fail in 20 years, this complex electronic package is incorporated in the submarine cable before laying.

One might ask why it is necessary to continue to increase the bandwidth, and hence the

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

traffic-carrying capacity, of submarine cables. On the transatlantic route there are not more than two models of any one design: would it not have been better to have eased the maintenance, spares holdings and other related considerations, by staying with one standard design? The answer lies in the huge growth in demand for long-distance communications. In the 20 years separating Tat 1 from Tat 6 about 7500 circuits have been provided in submarine cables across the Atlantic. If the design had been standardized at Tat 1 then about 200 cables would have had to be laid, an average of one every 5 weeks, but since the demand has increased exponentially over the period the laying rate would have had to be appreciably greater in the last few years than in the earlier period. To have provided the equivalent of Tat 6, 100 Tat 1 cables would have had to be provided simultaneously, requiring a vast fleet of cable ships.

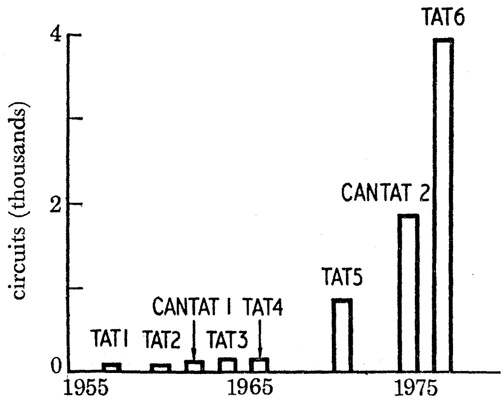
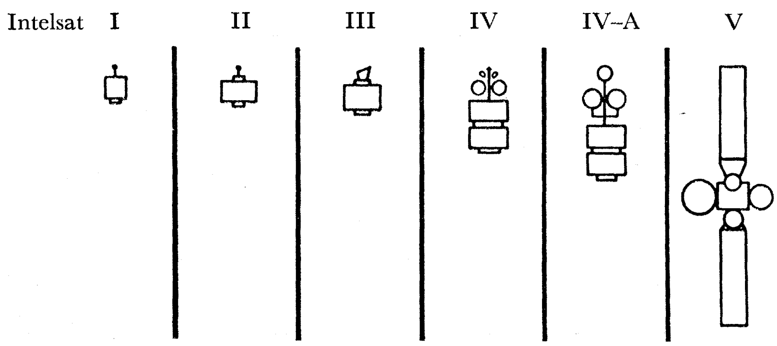


FIGURE 6. Transatlantic submarine cable capacity.



Intelsat	I	II	III	IV	IV–A	V
year of first launch	1965	1967	1968	1971	1975	1979
mass in orbit/kg	38	86	152	700	790	967
capacity (telephone circuits)	240	240	1200	4000	6000	12000

FIGURE 7. Development of satellites.

Dramatic as the development of submarine cables has been, the satellite story is even more so. As figure 7 shows, there has been a 50-fold increase in capacity during the 16 years separating Intelsat I and Intelsat V.

It is this great global complex of cables and satellites that has created the global telephone system linked by some 50000 circuits with an annual income probably exceeding $1000 M.

What then is the future of this great global network? Will the present explosive growth of intercontinental traffic continue and, perhaps even more importantly, what will the impact

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

of new services be on the total bandwidth requirements and what technical advances will enable such requirements to be met?

A number of different international telecommunication bodies such as Intelsat and the joint U.S./Europe North Atlantic Study Group, as well as individual telecommunication administrations, are deeply concerned with such questions and various forecasts have been made. In figure 8 these forecasts have been related to the total volume of intercontinental calls that may have to be handled by the U.K. gateway exchanges. The most optimistic show the total volume of intercontinental traffic (Europe–North America) growing at 22 % per year for the remaining few years of this decade and declining to 18.5 % thereafter. Other forecasts perhaps more realistically assume 20 % per year until 1980 and a slow decline in growth rate to about 10 % by the end of the century.

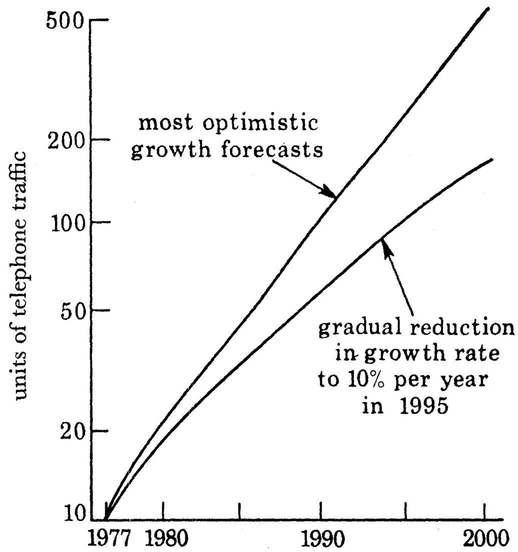


FIGURE 8. Intercontinental traffic forecasts: telephone calls from the U.K.

On the basis that most forecasts of international traffic growth have so far been pessimistic in the out-turn, let us suppose that the most 'expansionist' forecast is correct and that the demand for intercontinental telephone calls continues to grow at 18.5 % per year until the end of the century. By 1980 there will be about 12000 circuits, by satellite and cable, in operation between Europe and North America. If the 18.5 % per year growth rate continues there will be a demand for about 240000 circuits by the year 2000 and more than half of these must be added in the last five years. Can we expect the advances in technology to keep pace with this formidable demand, a demand which takes no account of what other services may by then be requiring?

Over the past 20 years there have been 8 transatlantic cables and in the 15 years between Intelsat I and Intelsat V there will have been 10 satellites in use over the Atlantic region. This is just about as many projects as the planners, designers, international organizations and the manufacturers can effectively handle. In the last 5 years of the century, if this rate of provision is maintained, it would therefore be reasonable for two cables and four satellites to be added to the North Atlantic capacity and the requirement is that together they would add about 125000 circuits. We are therefore looking for capacities in these individual facilities of about 20000–30000 circuits each, i.e. about 5 times the capacity of current systems. The rate of expansion of circuit-carrying capacity of both cables and satellites has been much greater than this in the past but we cannot assume that this will continue without considering the possible limitations.

The present generation of submarine cables has a capacity in the range 4000–5000 circuits and these cables will continue to fulfil transatlantic and shorter-haul needs until the mid-1980s. The succeeding generation will probably be the last to employ analogue transmission over coaxial tubes and will have capacities three to four times as great as the most advanced systems in use today, say 13000–15000 circuits.

By the early 1990s we could well see a complete change in submarine cable technology. Optical fibres will by then have penetrated the inland networks and the development of reliable light sources – lasers or light-emitting diodes – will be well advanced. It will be possible to enclose a large number of optical fibres into a cable capable of being easily handled on board a cable ship, but the practical limitation to the cable circuit capacity will probably be the number, size and reliability of the regenerators that must be contained in the repeater housings.

There are very many practical problems to be overcome before such a system comes into service but progress may be sufficiently swift to permit shallow water short-haul systems to come into service in about 1990 with trans-oceanic systems following a few years later. If the repeater problems can be overcome we can envisage a cable containing five optical fibre circuits operating at 560 Mbit/s combining to meet our target of about 25000 circuits, and this capacity could be increased by more fibres per cable.

If we turn now to satellites we find that the number of satellites being launched into the geostationary orbit is increasing every year, and they are not evenly spaced around the equator but are clustered over certain areas. Already it is necessary to pay careful attention to inter-satellite interference possibilities when choosing the location for a new satellite operating in the 4 and 6 GHz bands. The time is fast approaching when new geostationary satellites will be constrained as to their location and technical parameters if they are not to cause unacceptable interference to satellites already in service. There is therefore a resource barrier upon the horizon – but this time it is a natural resource.

With the advent of the space shuttle, serious thought is already being given to the design of satellites that can be repaired in space. In this concept the satellite consists, in essence, of an open rectangular framework into which standard modules are plugged for such units as transponders, batteries, command and telemetry and so on. Should any of these fail, standby units in the satellite will automatically take over their functions but the faulty unit will then be replaced from a stock carried by the orbiter element of the space shuttle. The tug unit separates from the orbiter, moves up into geostationary orbit, docks with the satellite and then unplugs the faulty unit and replaces it by a new one.

The next step could be the commercial use of the spacelab concept, so that very large satellites could be assembled in space and then drifted into synchronous orbit. We can then imagine the limitations of the natural resource I mentioned earlier – orbital positions × usable frequency bands – being overcome in two ways. First, the satellite could carry a battery of steerable aerials automatically directed towards individual Earth stations or clusters of Earth stations, thus giving a large degree of frequency reuse; and second, the power available in the satellite – perhaps by using enormous solar-cell paddles, or nuclear generators – could be increased to such an extent that very high frequency bands, at present considered unusable because of atmospheric attenuation, could be employed.

Obviously, either of these development programmes, cable or satellite, could be held up by practical problems. It could be, for instance, that the development of highly reliable light sources for the optical fibre cable could take many years to perfect, or that congestion of the geostationary orbit reaches serious proportions before the large satellite is available to overcome the problem. But provided both technologies are vigorously developed there is a good chance that one medium or other will be available to meet the demand; and success in one will spur the other to even greater achievements.

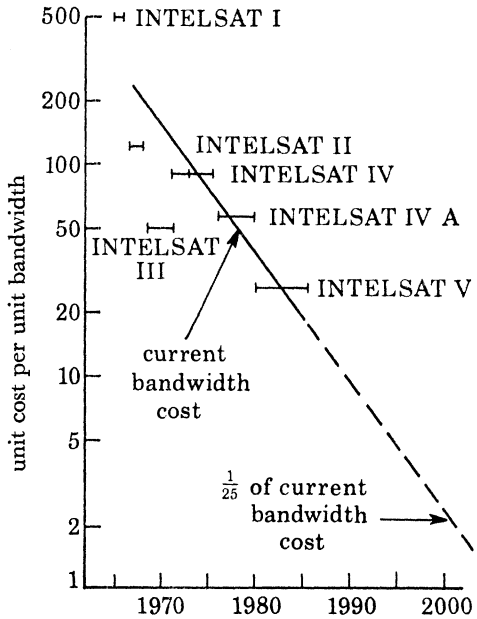


FIGURE 9. Satellite bandwidth cost trends.

At this stage it is interesting to speculate on satellite transmission cost trends in the future. Figure 9 shows how the cost of a unit of bandwidth provided by satellite has fallen since the days of Intelsat I; the costs include the cost of launching the satellite and are adjusted to constant 1977 prices. I make no claims for the precise accuracy of the trend line shown but at least it indicates how the cost of satellite bandwidth is rapidly falling. The value of this trend to the user will, however, be diminished if the contribution made by Earth station costs does not fall correspondingly.

The cost of the present generation of Earth stations is made up of a fixed element, arising from the aerial and its control system, the low-noise amplifier and the power supplies, and a variable element related to the number of channels being carried; the latter element will depend on whether the Earth station is using a few carrier frequencies efficiently bearing large numbers of channels, or a large number of small route carriers inefficiently bearing small numbers of channels. If we look to the future we can expect to see two forces at work; the creation of the large satellite with high gain aerials will alter the balance of contributions made by satellite and Earth station to the overall gain of the system, so the size of the Earth station aerial and hence the fixed cost element of the Earth station should come down; and with the advent of all-digital working, both heavy and light traffic streams will be handled equally efficiently so the cost dependence on traffic volume should also be reduced. In short, we can expect to see the cost of bandwidth in both the space and Earth sectors falling dramatically by the end of the century.

Now let us consider what new services would be made feasible by such cost reductions and concentrate on conference-by-television, or Confravision as we call it in the Post Office. Let us suppose that of the 12000 or so passengers who currently cross the Atlantic every day, 10% would be happy to conduct their business conferences by television, rather than waste time shuttling backwards and forwards over the Atlantic, if only they could have a high quality television link for, say, 5 times the cost of a telephone call. Taking three members per delegation we would have to handle about 400 conferences a day. Let us also assume that bandwidth-reduction techniques will in the future enable a high quality television picture to be transmitted by 8 Mbit/s, i.e. 125 times the 64 kbit/s requires for a digitalized voice channel. We are therefore looking for a bandwidth cost reduction factor of 25:1. If we examine how the cost of satellite bandwidth has reduced from Intelsat I to Intelsat V and assume it continues with the same trend line in the future, we see that this reduction is achieved in the mid-1990s. This, again, is a very broad-brush approach for I am not only assuming that satellite bandwidth costs will continue to fall as they have in the past but that Earth station cost reductions will be in step.

If our 400 conferences a day are attracted by this cost reduction we must now consider what this means in traffic volume terms. If all the conferences are in session simultaneously then the total requirement would be about 6500 Mbit/s which would be comparable with, or even more than, the satellite element of the voice channels required across the Atlantic in 1995.

Based on these somewhat sweeping assumptions, it can be argued that by the year 2000 we shall need at least as much satellite bandwidth capacity across the Atlantic for Confravision purposes as for normal telephony. Reduction on this requirement should be achieved by endeavouring to persuade customers to hold their conferences outside the Atlantic telephony peak traffic period, 16h00–20h00 G.M.T. This could be done if the business man would accept a 12h00–15h00 G.M.T. slot for conferences but as this spans the British business lunch period such a sell would not be easy – nor indeed would his American counterpart relish in general a 07h00 E.S.T. start.

So the likely outcome may well be very stretching demands on the technology of both the optical fibre submarine cable and the space satellite.

The creation of this immense capacity of bandwidth across the Atlantic will pose another problem. As the effective occupancy will be during the peak traffic period 16h00–20h00 G.M.T., what can be done to use the vast communication capacity on a 24 h basis and thereby greatly improve the economics of the system? Data and telex will undoubtedly be avid users of such capacity but they are not great consumers of bandwidth. To find another communication need that can utilize such a great surplus we must look to the intercontinental traffic in letters and documents.

In 1976 the number of airmail letters sent from the U.K. to North America was 104 million and the number of outgoing phone calls was 6 million. The postal growth rate is less than the telephone growth rate; nevertheless, in the early 1980s, the dawn of the digital transmission age in the international field, the postal service will still account for about 80–90% of messages on these routes. Now let us assume that a letter will, by a facsimile process, take the same time

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

and bandwidth to transmit as a telephone call. The busy period for transatlantic telephone calls extends from 16h00–20h00 G.M.T. – just 4 h – and outside these hours traffic falls to about 20 % of peak levels. By the early eighties there will exist a transmission capability that could carry well over 50 % of all transatlantic postal traffic without any additional investment in intercontinental circuits or switching. This, of course, is a very general approach. Nevertheless, as the demand for telephony continues to gain on the mail service, as economic means are devised for transmitting writing efficiently and as international communication links become digital, it can be foreseen that it will be possible to transmit the bulk of international mail by submarine cable and satellite without its needs predominating over the capacity required for the existing telecommunication services.

That particular example points the way to perhaps one of the most interesting and richest fields of development that lie ahead in telecommunications, namely the development of a wide range of customer apparatus that will utilize the vast communication potential of the global system without demanding further investment except in the user equipment; enabling the vast investment in the global system to be effectively loaded with traffic throughout the day with a profound effect on the economics of global telecommunications.

It has often been remarked that the only thing certain about long range forecasts is that they will be wrong. However, although the future may not follow my speculation in every detail I am certain that the demand for global communications will continue to grow in scale and variety and that the next 20 years will bring an ever increasing power to communicate to the peoples of the world

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES