THE ADVANTAGES OF SATELLITES OVER TERRESTRIAL FACILITIES FOR PUBLIC TELECOMMUNICATIONS.

Paper by A G Reed*

Why use Satellites for Commercial Telecommunications?

As has been well demonstrated operationally, both cable and satellite transmissions systems can be engineered to convey public telecommunications signals to CCITT quality standards. Hence, leaving aside safety and security purposes there are three principal answers to this question;

a) for certain services, satellites are the only practical and/or economic way of providing the communications capacity required,

b) under certain circumstances the cost per unit of capacity can be lower for satellite than terrestrial facilities,

c) In certain cases there are political reasons, usually associated with stimulating national or regional industrial concerns - this reason is not discussed further here.

The degree to which the first two reasons are applicable for each type of service tends to change with technology advances in both satellite and terrestrial fields. For intercontinental, point-to-point, trunk telephony links, for example, in the last two decades satellites have proved the more cost effect medium, whereas in the forseeable future fibre-optic submarine cables are likely to involve the cheaper per circuit costs.

Various advantages of satellites over cables have been cited - eg flexibility, wide bandwidth,multipoint capability, etc, but in most cases similar facilities can be provided on the ground if the customers will pay the necessary prices, so in the author's view these are only valid advantages if it is cheaper to provide the facilities via satellite, and they are therefore only different ways of expressing reason (b).

Costs have to be taken into account in deciding whether or not to provide a satellite service even when there is no practical alternative means of implementation, simply because such large investments are involved. For a typical satellite of about 1700kg mass at launch (half-ARIANE class) development costs are currently of the order of £60M, with recurring costs of about £50M per satellite and launch costs of about £33M per satellite. In-orbit control and administrative costs run out at about £2M per year for a 2 operational +1 spare satellite system. Insurance, or provision for satellite failures at launch or in orbit adds about 20% to the space sector costs. The costs of the earth sector depend more strongly on the type of service being provided, and on whether or not earth stations already exist,

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but can easily add millions to the overall cost. Thus the capital investment in setting up a new satellite system is typically several hundreds of millions of pounds, and it would appear unwise to undertake such large commitments unless the likelihood of adequate returns is reasonably high.

Because the cost of a satellite circuit is independent of the distance on the Earth between the two ends, whilst the cost of a terrestrial circuit is approximately directly proportional to that distance, the concept of a "breakeven" distance where the costs are equal has been used to determine where services should be routed via satellite. This break-even distance varies according to the size of the route, growth rate, and any special networking requirements.

During the establishment of the Eutelsat system this distance was estimated to be 800km, but in recent years the differing developments in cable and satellite technology have increased the figure substantially. By the mid 1990's fibre-optic techniques will have multiplied the capacity of a cable by a factor of about 8 compared to that in 1987, whereas the capacity of a satellite of given mass, by exploitation of multiple switched spot beams and/or the 20/30 GHz bands, will optimistically have increased by a factor of about 4 during the same period. In consequence the terrestrial cost per circuit will have reduced to a considerably greater extent than that of the satellite cost per circuit. In the longer term, there is a limit to improvements in satellite mass efficiency at conventional frequencies and propagation attenuation seems likely to inhibit the operation of earth-space links at optical frequencies, so it is difficult to envisage satellites regaining economic competitiveness with cables for point-to-point trunk services in Regional systems. For intercontinental systems also cables are likely to become the cheaper mode of operation for such services.

For these reasons it is the author's view that future applications of satellites should concentrate on exploiting their primary advantage - that of broad geographical coverage - rather than on the public switched telephone network, which except for the local tails comprises point-to-point trunk links.

Services to Mobiles

There are three categories of mobile unit to which communications are desirable, namely ships, aircraft and land mobiles (trains, lorries, cars). For the first two, radio is the only practicable means, and for the ocean regions (ie beyond line of sight) only frequencies below about 30 MHz are possible using terrestrial means, which places a low limit on capacity. Satellites are the only means of accessing ships and aircraft with the number of circuits needed now and in the future, and thus reason (a) above applies strongly in these cases. Experience has shown that customers are willing to pay the relatively high call charges necessarily involved, when the alternative is either no service or substantial delays in establishing calls.

The case of land mobile services is rather different. Here terrestrial cellular networks are being developed both nationally and internationally (eg the system being pioneered under the aegis of the CEPT committee GSM) and these have some major advantages over equivalent satellite systems. First, for medium coverage areas the costs of providing the cell nodes are approaching an order of magnitude lower than those of an equivalent satellite network, and second the costs can be met gradually, starting with the dense traffic areas (eg cities, motorways). This means that satellites will probably be serious contenders only for the outlying districts, and then only to complement the terrestrial systems. Further, it seems unlikely that a satellite system dedicated to land mobile communications will be an economically viable service proposition in the foreseeable future, and that such services should therefore be provided only on the basis of a modest share of a satellite payload developed primarily for other services.

TV and Sound Distribution and Broadcasting Services

In these cases the terrestrial alternatives have significant disadvantages relative to satellites. First, television signals require reception at many points over a wide area, so cable implementation involves many duplicate paths and is therefore relatively expensive, and there are also connectivity problems. Second, television signals have relatively wide bandwidths (eg 6.5 MHz basebandwidth); terrestrial radio, based on a network of large "cells", is the cheapest method, but frequencies are limited to VHF and UHF (in higher bands atmospheric fading is a problem) and cannot cope with the demand for more channels. That satellites overcome both disadvantages at acceptable prices is evidenced by the rapid growth in the number of commercial transponders carrying TV in recent years. Over Europe alone there are currently more than 30 low power (43 dBW) TV distribution channels in the FSS bands, and this number promises to increase significantly with the advent of the Astra and Eutelsat II medium power (50 dBW) satellites. Furthermore, several Direct Broadcasting Satellites, each with 3 or 4 high power (60 dBW) transponders, are scheduled for launch during the next couple of years (TVSAT, TDF, BSB, TELE X).

Fixed Satellite Services (FSS)

Satellite communications in the FSS frequency bands were initially developed in order to provide transmission links between the public switched telephone networks (pstn's) of different countries, first intercontinentally and then regionally (eg the Intelsat and Eutelsat systems respectively); subsequently attention has been paid to the possibility of extending this role by integrating satellites more extensively into the national switched telephone networks. Thus, satellites have been seen as increasingly assuming a role similar to that of the terrestrial trunk transmission facilities (cable and microwave radio). However, for the reasons stated in Section 1 the author believes that, for satellites to survive in these bands, efforts should be concentrated on exploiting other roles for which the terrestrial network is less well suited. TV distribution is the obvious such role, and this has been addressed in Section 3. The rest of this paper outlines additional roles which fall into this category.

Owing to the wide geographical coverage available using a satellite it is possible to employ a single transponder to convey information between different pairs of points on the ground successively, and thus replace several terrestrial routes. Exploitation of this principle enables expenditure on one satellite link to facilitate savings on a number of earthbound links, and in appropriate circumstances the savings can outweigh the costs, making satellites economically attractive. The time sharing of the satellite connection can be short term or long term, and the following roles 1 to 6 exploit this principle in one form or the other. The rest of the roles make use of either the satellite's multipoint capability, or its ability to avoid current shortcomings in the pstn.

1 Demand - Assigned coverage of low traffic areas

By using small-dish business satellite networks (eg INTELSAT IBS, EUTELSAT SMS), which by-pass the terrestrial network, it is possible to provide new and existing services to remote and/or low traffic areas. Although the costs per satellite channel are relatively high, demand assignment facilities associated with such networks enable space sector costs to be shared and the networks are designed for relatively low earth sector costs. Conversely, in areas where traffic requirements are modest the cost of provisioning fibre-optic cable systems will probably remain difficult to justify for some years.

2 Coverage of different time zones

Satellites have the potential to cope successively with busy hour overloads on routes in different time zones via a single satellite traffic pool. Each individual terrestrial link has to be dimensioned to meet its peak traffic demand, taking into account the average diurnal and longer term variations in load. Temporarily unused capacity on a link in which the demand is currently not at its peak cannot be deployed to cater for overload on another link where the peak demand is occurring. Satellite capacity however, is inherently capable of being redeployed in this way. Studies have shown that in Europe, where clock times vary by no more than an hour, daily peaks tend to coincide in different countries so it is only the seasonal peaks from which this advantage might be gained. For coverage involving large East-West spans, (eg "global" and USA wide coverages), the economic benefit can be reaped daily.

3 Savings from terrestrial investment delays

It is potentially possible to successively delay investments in the expansions of various terrestrial links by the use of a single satellite traffic pool. For each terrestrial link there will be a need to expand the capacity from time to time. Sometimes this will simply mean adding terminal equipment, but occasionally the installation of additional cables or even new duct lines will be needed. If the commencement of a given expansion could be delayed by, say, 6 months, a financial saving (in accountancy terms) would accrue to the operating organisation provided an alternative means was available for routing the additional traffic. The traffic demands would not grow sufficiently in this relatively short period to impact significantly on the size (and hence cost) of the expansion.

In principle a few satellite transponders could be used to delay the expansions of a number of geographically separate terrestrial links, one-by-one, thus facilitating a corresponding number of investment savings. If the expansion plans of an administration were drawn up to fit in with such a policy, the aggregate saving could exceed the cost of providing and maintaining the necessary satellite capacity. Whether it is practicable for a number of administrations to coordinate their expansion plans to extend this advantage internationally is an open question, but in a recent study[1] calculations suggest that an excess in terrestrial savings over satellite costs of about £4M per year is possible for Europe.

4 Common diversity provision

It is possible to provide in one satellite traffic pool diversity for a number of geographically separate terrestrial routes for service security purposes. It is common for main terrestrial trunks to be protected by standby facilities often on a 1 for 1 basis. This is especially true of routes carrying international traffic. Although such "protection channels" are occasionally used for pre-emptible services such as ad hoc TV distribution, they represent a necessary but significant cost overhead in the provision of transmission facilities. Since the probability of geographically remote terrestrial trunks suffering simultaneous breakdowns is small, it is feasible to employ a single block of satellite capacity to provide protection for N separate terrestrial links. This is likely to be a cost-effective option, the more so because the wide coverage of a satellite greatly increases the potential to gain revenue from ad hoc pre-emptible use while the capacity is not needed to cover main route breakdowns.

Clearly the cost-effectiveness of this role for satellites depends on the number and length of the terrestrial routes protected. The study mentioned above [1] derived an approximate potential economy totalling about £6.7M per annum from the application of the principle to the main European international links on a 1 for 9 basis.

5 Catering for special events

Events such as major sport competitions (eg Olympic Games, World Football Cup) and high level political meetings (eg Summit conferences) create abnormal telecommunications demands at different times and in different parts of a region. It would not be cost-effective to over-dimension the whole of the European terrestrial network, for example, to provide a margin of capacity for such short term needs, but the reservation of a single block of satellite capacity for successive use in different parts of that continent may well prove economically viable. The wide coverage of satellite systems makes it feasible to make long term plans on this basis, even though the nature and locations of the specific events to be covered may not be known at the planning stage.

6 Exploitation of "Erlang" advantage

As a development of the theme outlined in 1 above it is possible to derive Erlang advantage by having a large pool of satellite circuits shared between divers small routes even though the busy hours of those routes may be coincident (see 2). In a small way this advantage - ie the need for less satellite capacity than the aggregrate capacity required if all the routes were provided terrestrially - has already been exploited in satellite small-dish business systems with voice activated demand - assignment facilities (eg "SPADE", TELECOM 1 TDMA). The referenced study[1] has shown that it is theoretically possible to derive the advantage more extensively on international connections in the main trunk network.

Taking Europe as an example, in the great majority of cases international voice channels are handled by facilities (cables, ducts, repeater stations, etc) provided mainly for the much greater local national traffic. On the links which include international channels the Erlang advantage from concentrating many individual calls via common transmission paths has been largely taken up - but mainly for the national traffic. The international traffic actually comprises relatively small "bundles" of channels carried via many, geographically separate terrestrial routes. If many of these bundles could be concentrated via a single satellite an additional Erlang economy could be made. By making reasonable assumptions for the terrestrial and satellite system cost elements a computer model of the European network has shown that it could be cost-effective to route via satellite in the mid 1990's a considerably greater proportion of international calls than currently envisaged. Potential savings of the order of £60M a year are theoretically possible for Europe as a whole.

However, in order to derive this economy two fundamental actions would be required:-

i) installation of earth stations at or near many more network switching nodes than the 17 ISC's currently associated with Eutelsat earth stations (48 if all ISC's were to be connected and up to 800 if all Level 2 nodes were to be connected), and

ii) coordinated agreement by all the major PTT's to change the way in which network expansion plans are carried out, in order to ensure that the necessary terrestrial savings were really made.

In the author's view the certainty of the large investments implied in (i), when set against the uncertainty of making the savings in (ii), makes it unlikely that integration of international satellites at Level 2 switching nodes will take place in the forseeable future. However, extension of satellite integration at more of the Level 1 (ISC) nodes shows promise of being practical, as well as economically advantageous, and should be studied further.

7 High speed digital services

National and international developments of the ISDN are proceeding apace, and by the mid-1990's geographical penetration of facilities capable of switching 64 kbit/s digital signals will be well advanced, at least in the developed parts of the world. Implementation of switches capable of handling higher bit rates is likely to proceed much more slowly, however, and the CCITT has yet to establish the appropriate standards. Satellite business systems are able to by-pass the pstn, and to provide signal bandwidths capable of handling up to 45 Mbit/s today. There is therefore a window of opportunity for satellites to facilitate high speed digital services during probably the next decade.

8 Point-to-multipoint services

Clearly the length dependancy of terrestrial connections makes it expensive to route the same signal to a variety of dispersed destinations. In a satellite system the cost of providing a multi-destination (or multi-origin) service is only marginally greater than the cost of single-destination provision. Television distribution has already been covered, but there are many data distribution and collection applications - eg stock control, news gathering - which require economic multipoint transmission facilities.

9 Rapid provision of new services

By the installation of small dish terminals at customers' premises the practicability of setting up new services - eg electronic document distribution - within a few days of the decision to do so has been demonstrated. If the customers concerned already possess such terminals for earlier services, the setting up time can be further reduced. The need to establish permanent connections at many telephone exchanges makes it impractical to match these set up times in the case of most long distance terrestrial private wires.

Conclusion

This brief survey leads the author to the view that for commercial telecommunications applications, satellites have some significant advantages over earth bound transmission facilities, but that despite these their role in the public switched telephone network will diminish. For the main trunk routes optical fibre cables may be expected to cater for an increasing proportion of traffic. The volume of regular PSTN traffic handled by satellite is foreseen to grow, but at a much slower rate than the total traffic volume, and in some areas it may actually fall. In the European network the number of satellite connection points seems likely to expand, but not generally to below ISC level.

The principal advantages of satellites are all attributable, directly or indirectly, to their wide geographical coverage capability. They will continue to enjoy superiority over terrestrial facilities for services to ships and aircraft, and for TV broadcasting and distribution. In the FSS bands their advantages for multipoint services, and for applications where time sharing of transponders can effect multiple terrestrial savings, should be exploited to a greater extent than has been done hitherto. Such roles as 1 for N service security provision, catering for special events, and enabling successive terrestrial investment delays have been under-exploited up to now, and it is felt that provision of satellite capacity for them should be considered even if the appropriate international planning agreements have to be anticipated. "Transparent" transponders would appear more suitable for this role than those using signal processing.

If future developments concentrate on these advantages it is considered that satellites will continue to play a valuable role in public telecommunications for many years, complementary to the terrestrial network and catering overall for a relatively small proportion of the traffic. This paper has referred to Europe in several cases because of the author's familiarity with the European telecommunications scene. However, it should not be overlooked that there are more than 90 countries elsewhere in the world where, because of their remoteness or the lack of terrestrial network development, satellites will remain the only economic way for the UK to communicate with them.

Reference 1

ESCO study for ESA, 1986/87,, "Study of the Integration of advanced satellite systems and terrestrial networks". The kind permission of the European Space Agency to quote from the results of this study is greatfully acknowledged.