Satellite Communication: Overview and Application

by Doug McLean

Commercial use of satellite links(or space segments) is a rather old technology by computer industry standards. TELSTAR I, the first commercial satellite was launched in 1962. INTELLSAT has been providing international satellite communication services since 1965. Recently the cost of earth stations and transponder time has dropped, making satellite communication feasible for HP 3000 users. The purpose of this paper is to look at the state-of-the-art of satellite data communication and to review an example of how it has been used at HP to lower data communication costs.

I. Satellite Communication Terminology

Before proceeding with a discussion of the satellite communication industry, it will be helpful to review some of the "buzz words" typically used in the industry.

The Hardware

A satellite link or "space segment" is made up of three parts: the satellite(or bird), the antenna(or dish), and the attendant signal processing equipment which transforms the data from the computer into a form the satellite can handle. The dish and attendant signal processing equipment collectively make up the earth station.

To the Stars and Back

When the earth station broadcasts to a satellite, it does so on a circuit known as the up-link at a frequency of approximately 6 GigaHertz(GHz). When the signal reaches the satellite, it is processed by a piece of hardware known as a transponder. The transponder does three things to the signal. First, it amplifies it so it can be received more easily(and accurately) by the receiving earth station. Second, it changes the frequency of the signal to approximately 4 GHz. Finally, the transponder broadcasts the signal back to the receiving earth station on the down-link. Because of the frequency shift performed by the transponder, a single earth station can transmit and receive simultaneously at very high data rates.

Satellites

There are currently 27 communication satellites in orbit serving the northern half of the western hemisphere. In addition there are fourteen INTELSAT satellites doing international communication world wide. All of these satellites are 22,300 miles from the equator in geostationary orbit. This means that their position relative to the earth never changes. Because it is in geostationary orbit a satellite is available 24 hours per day, 365 days per year with the exception of outages due to solar eclipse. These outages are generally quite brief(averaging 7 minutes) and occur once per day for a week in the spring and fall. The outages do not generally present any operating problems as they are extremely predictable. One of the more heavily used domestic communication satellites is Western Union's WESTAR IV. WESTAR IV has twelve transponders on board of which two are used as back-up in the event one of the other ten fails. Each transponder has a total bandwidth capacity of 36 MHz, which means that each transponder may be used to carry:

-One color television broadcast
or
-1200 voice channels
or
-A data channel of 50 Mbps

Clearly, with this much bandwidth, very few users need to own a transponder. Consequently, a number of companies have purchased one or more transponders on WESTAR IV and resell the transponder time on an occasional use basis. These companies include Vitalink, AMSAT and Equatorial Communication.

Propagation Delay

Because communication satellites are stationed 22,300 miles above the earth, it takes 135 milliseconds for a signal to travel from the ground to the satellite. Thus, when one bit of data leaves a computer in San Francisco, it is at least 270 milliseconds later that it is received by an earth station in Boston. Therefore, a full round trip delay of approximately one-half second is normal in a satellite network. Fortunately, the earth stations are programmed to allow for this "propagation delay", so no data is lost. The delay can, however, be a nuisance in a highly interactive application. Good satellite applications tend to trans- mit large blocks of data to minimize some of the effects of propagation delay.

II. Satellite Industry Structure

Participants in the satellite industry fall into 4 broad categories:

Common Carriers: Those companies that lease transponder time. Signals are transmitted and received by dishes owned by the carrier and generally situated on the carrier's premises. While some common carriers have their own satellites, others have leased or purchased individual transponders from other common carriers. AMSAT, COMSAT, SBS, INTELLSAT and Western Union are all satellite common carriers.

Satellite and Antenna Construction: Electronics firms whose primary business is the design and fabrication of the hardware involved in satellite communication. Hughes Aircraft Company is currently the most popular satellite contractor and Scientific Atlanta and Harris Communications the most popular dish vendors.

Leased Private Network: Several firms such as RCA have purchased transponders from a common carrier and will lease "on-premises" equipment to users. The networking company also resells the transponder time it has available on a monthly or occasional basis. AMSAT, COMSAT AND RCA (under the brand name CYLIX) all offer private leased networks.

Owned Private Network: A few firms sell earth stations and network management services so a user can own his network. Only Vitalink offers the antenna, network management and the transponder time.

III. Network Design

As with any network, the topology chosen should be a function of the application. The purpose of this section is to review some of the more common topologies and how the currently available satellite technology can be used to implement them.

Public vs. Private

The first decision to be made in implementing a satellite network is whether or not to own the earth stations. For the very occasional user or the user whose nodes are all in major metropolitan areas, using the satellite common carrier's facilities can be quite economic. In many large cities (New York in particular) there are very few microwave rights of way left. As the microwave frequency spectrum overlaps the satellite C band(4/6 GHz) putting a private satellite network in such cities is often not possible. In these cases, it is generally easier and less expensive to interface the computers to the common carrier's equipment via high speed data line. Conversely, if a user needs to transfer large batches of data fairly frequently amongst sites which are rural or suburban, a private network can be extremely cost effective. A hybrid network which uses owned earth stations for receiving and the common carrier's facilities for transmitting should also be considered. Both of these alternatives are discussed below.

Mesh Topology

Perhaps the most flexible topology in

common use is the mesh topology. Mesh allows any node on the network to communicate directly with any other node. Each earth station sends data directly to the satellite. The satellite in turn broadcasts the data to all of the earth stations in the network. Each earth station then either processes the data or ignores, it depending on whether the data packet is addressed to it. A mesh topology is most appropriate for users with a need to move large volumes of data amongst a limited number of sites. Financially, a mesh satellite network become very attractive for sites more than 800 miles apart with a bandwidth requirement in excess of 56 Kbps. There are a number of ways for HP 3000 users to implement a mesh network. Companies like AMSAT lease on-premises dishes and profide end-to-end network management. Alternatively, users can implement a private satellite network by purchasing earth station equipment from one of a number of vendors (eg. Scientific-Atlanta). The problem with implementing a network this way is that a user then has to contract for transponder time with one of the common carriers. One earth station vendor, however, offers both earth stations and transpon- der time. Vitalink Communications Corporation purchased two transponders on WESTAR IV and resells the time to its customers on an occasional use or contract basis. Vitalink also provides network management services.

Broadcast Star Topology

For users who have a need to move large amounts of data from a central site to many remote sites and do not need response from the remote sites the broadcast star topology is more appropriate. Using this technique, data is collected and/or processed at a single site and then transmitted to a vendor's earth station. The data is then transmitted to the satellite and broadcast to the receiving earth stations. There are two variations on the broadcast star network. The most common method of implementation involves leasing a high speed terrestrial data link from the central data processing center to the vendor's earth station. Increasingly, however, users are purchasing their own transmitting earth station for transmission to the vendor's facility or directly to the receiving earth station. Depending on the type of broadcast protocols used, the receiving earth stations can be as small as two feet in diameter. The major problem with the broadcast star topology is that the transmitting station has no way of verifying whether or not the data has been accurately received. In applications where data accuracy must be verified an inexpensive, low speed terrestrial link back to the trans- mitting earth station can be used. RCA and Equatorial Communications both offer broadcast star networks for private use.

Economics of Satellite Communication

It is no great secret that earth stations are expensive. A small, low speed transmit and receive earth station costs approximately $50,000. A large, high speed station can cost upwards of a quarter million dollars. The payoff, of course, is that the relative operating costs are low compared to high speed terrestrial circuits. If a user needs to transmit large amounts of data, a satellite network, once installed, is extremely cost effective. Very few applications, however, require constant or even frequent use of a 56 Kbps data link. Justifying a satellite network often depends on calculating the aggregate data rate amongst the potential sites. A satellite network is capable of carrying data, voice, and video signals simultaneously. By multiplexing together a number of 9.6 Kbps or slower channels on a satellite network, a user can reduce her telephone, TYMNET and air travel bills. The next section contains a discussion of how Hewlett-Packard intends to do this internally. For those users who can not cost justify their own satellite network and do not want to use common carrier's facilities, the possibility of sharing earth station facilities may provide a viable alternative. By putting the earth station at a central location in a small to medium sized city and running high speed data links to the owners' facilities, a number of small users can realize the cost savings of an owned satellite network while sharing the start-up and operating expenses. Sharing earth station facilities is also becoming popular in large cities, as evidenced by New York's Teleport project. The New York City Port Authority in conjunction with Merrill-Lynch and Western Union have begun construction of a "dish farm" on Staten Island. The dishes will be connected to users in Manhatten via high speed fiber. As microwave rights of way are filled in other major cities we may see other Teleports appear.

IV. Case Study: The Hewlett-Packard Satellite Network

Like most other large companies, HP is extremely interested in finding ways to control its communication costs. With the A.T.&T. divestiture almost complete it seems certain that minimizing communication expenditures will be a more difficult task in the future. After investigating a number of alternatives, HP concluded that a three node network connecting its Cupertino, Boise and Fort Collins facilities had the potential to lower both communication and(with the advent of video teleconferencing) transportation costs. The network consists of three earth stations purchased from Vitalink Communication Corporation. Each earth station is 9.2 meters in diameter and has a maximum bandwidth of 3 Mbps. The earth stations are connected to HP 3000's via high speed V.35 interface. The

Vitalink earth station is fully redundant, providing an extremely high level of reliability. By using both sides of the earth station to communicate with one other node on the network, HP 3000 users can achieve data rates up to 56 Kbps at bit error rates better than one in ten to the seventh. Should a problem develop on one side of the earth station, the other functional side will take control and continue transmitting with no loss of data. Alternatively, HP can use one side of the Cupertino earth station to communicate with Boise and the other side to simultâneously communicate with Fort Collins. By similarly dividing up the Boise and Fort Collins stations, HP can implement a three node mesh network without the need for any multiplexing. When HP adds more nodes the Vitalink Codamux will handle the necessary multiplexing tasks. HP is currently using their satellite network to transmit engineering, manufacturing and financial data amongst the three sites. We have found that this significantly reduces the development cycle of new products as it normally takes a day or two to send a board or chip design from one site to another via U.S. Mail or rather expensive courier packs. By using the satellite network, HP can move gigabytes of data between sites in a few minutes. We will also be able to shorten the financial reporting cycle as sales and shipment data are available in Cupertino the same day they are transmitted from Boise and Fort Collins. All data is, of course, encrypted prior to transmission to prevent interception. In the future, HP will be will be implementing full motion video teleconferencing amongst the three sites. Using compression equipment from Compression Labs Inc.(CLI), HP will be able to send color video, voice and data simultaneously between specially built conference rooms. HP currently spends a great deal of money moving its people between sites on both commercial and private aircraft. By using video teleconferencing we will be able to limit such travel to those instances where a face to face meeting is absolutely necessary, saving time and wear and tear on our people. HP firmly believes that satellite communication is a cost effective method of controlling communication and transportation costs. In the future we will continue to expand our use of the network as the teleconferencing and Direct Broadcast Satellite technologies mature.

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