WHITE PAPER

INTELSAT®

A Practical Introductory Guide on Using Satellite Technology for Communications

Summary

Satellites can provide global, ubiquitous and multipoint communications. Not surprisingly, satellite technology has become a flexible and cost-effective solution for domestic and international networks, irrespective of the user's geographic location. Wireline and wireless lack this ability to leap across continents and oceans, often linking some of the world's most remote spots.

Satellite technology can thus become a solution for some of the most complicated access problems, connecting cities across a large landmass, where copper or fiber would be cost prohibitive. It brings broadband to the "last mile" of residences and businesses, and overcomes regulatory issues that make alternative carriers dependent on incumbents.

Satellites also have a major role to play in designing, developing and expanding a network. With a satellite and Earth Stations, you can create a network on a permanent or interim basis much more rapidly than "laying cable." An interim station will even let you test a market or provide emergency service prior to a major infrastructure investment. You can also rapidly scale and re-provision a satellite-based network to meet increasing and changing needs.

The benefits of satellite communications have steadily expanded its usage. Today, satellites' diverse purposes encompass wide area network communication, cellular backhaul, Internet trunking, television broadcasting and rural telephony. Satellites are also on the frontiers of such advanced applications as telemedicine, distance learning, Voice over Internet Protocol (VoIP) and video on demand (VOD).

Intelsat has created this Primer to provide an introduction to the technology used in satellite networks. Our intention is help you understand, in general terms, why and how satellite technology might meet your needs. For more information, we invite you to talk to our experts and discuss your specific requirements. We hope this introductory material will be useful to you in meeting the challenges ahead in your network.

Communications Satellites: “Bent Pipes,” Mirrors and Multipoint Broadcasters

A satellite is essentially a space-based receiving and transmitting radio. In other words, it sends electromagnetic waves, carrying information over distances without the use of wires. Since its function is to transmit information from one point on Earth to one or more other points, it actually functions as a “radio-frequency repeater.”

A satellite receives radio-frequency signals, uplinked from a satellite dish on the Earth, known as an Earth Station or Antenna[1]. It then amplifies the signals, changes the frequency and retransmits them on a downlink frequency to one or more Earth Stations.

Satellites are thus often described as a mirror or a “bent pipe” in the sky. The “bent pipe” analogy, however, does not describe one of the main communications advantages of a satellite: its unique ability to support point-to-multipoint communications.

The Satellite’s Orbital Location: Geostationary and Geosynchronous

As you can see, the challenge of “uplinking” and “downlinking” requires a very predictable relationship between the satellite and the Earth Station. The simplest situation is one in which both the spacecraft and terrestrial antenna remain in a fixed position with regard to each other. Otherwise one would necessarily keep the antenna continually moving to keep up with the satellite’s orbit.

That is why most communication satellites in use today are geostationary. The satellite remains stationary over the same spot on the surface of the earth (geo) at all times. It stays fixed in the sky relative to the Earth’s surface.

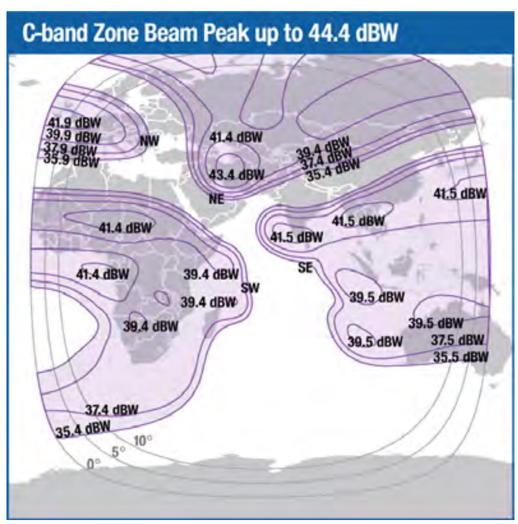
These satellites orbit the earth geosynchronously (i.e. “they move in synch with the Earth’s rotation.”). They orbit over the Earth’s equator at an altitude of approximately 36,000 kilometers or 22,000 miles up. At this height, one complete trip around the Earth (relative to the sun) is basically equivalent to 24 hours on Earth. The precise alignment of longitude, latitude and altitude ensures that the satellite “hovers” in direct line with its Earth Stations at all times. In this orbit, a single geostationary satellite can “see” or “beam to” approximately 40 percent of the Earth’s surface.

The geosynchronous location of the satellite is referred to as the “orbital location” and is normally measured in terms of degrees East (°E) from the Prime Meridian of 0°. For example, Intelsat satellite 906 is currently located at 64°E. The geographic area that the satellite can transmit to, or receive from, is called the satellite’s “footprint”. Customers can review the areas covered by any of Intelsat’s satellites by examining coverage maps available at: www.intelsat.com/fleetmaps/

Satellites have an expected life of 10-15 years. As they reach the end of their planned use, an option is to conserve on the large amount of propellant used to keep the satellite from drifting on its North-South axis. The satellite can then move into “Inclined Orbit” (IO – an orbit “inclined” to the equator rather than fixed above it). Since the satellite remains in its East-West location relative to the Prime Meridian, it will not disturb other orbiting equipment. An IO satellite moves in a figure eight around its nominal slot. This technique helps to conserve fuel and can extend the useful life of a satellite.

Since a satellite in an Inclined Orbit is not in a 24-hour fixed beaming position, it requires tracking equipment at the Earth Station to follow its beam. To compensate for the cost of the tracking equipment, an operator may lower the cost of the less desirable and less efficient fuel capacity. The trade-off in life extension may well make this discounting worthwhile.

Figure 1: Footprint of Intelsat 906 at 64°E



[1] *The terms "Earth Station" and "Antenna" are often used interchangeably in the satellite industry. However, technically, an antenna is part of an Earth Station. An Earth Station may be composed of many antennas.*

The Benefits of Using Satellite

Communications satellites have distinct benefits over terrestrial alternatives:

Ubiquitous Coverage. A small group or constellation of satellites can cover virtually all of the inhabited Earth's surface. Even one satellite can cover a much vaster number of potential subscribers than any terrestrial network.

Consistent Quality of Service (QoS). Essentially, satellites can deliver consistent quality of service to an almost infinite number of locations, regardless of geography. Whereas terrestrial IP networks are often a mixture of different networks and topologies, with different levels of congestion and latency, the predictability of satellite networks provides a constant, uniform QoS. In a terrestrial packet network, variations in the level of congestion and latency can cause problems such as packet "jitter," requiring large equipment buffers to avoid degradation of the voice quality. On the other hand, the predictability of satellite latency levels provides a much more consistent QoS.

Infrastructure Building. Satellite service can be offered in areas where there is no terrestrial infrastructure and the costs of deploying a fiber or microwave network are prohibitive. It can also support services in areas where existing infra-structure is outdated or insufficient.

Cost Predictability. Satellite communication is distance insensitive, thus providing cost predictability.

Traffic Bypass. Satellite can provide additional bandwidth to divert traffic from congested areas, to provide overflow during peak usage periods and to provide redundancy in the case of terrestrial network outages. By being wholly independent of a wireline infrastructure, satellite is the only "truly diverse" communication alternative.

Scalability and Reconfigurability. Satellite connections and Earth Stations are extremely scalable. In contrast to terrestrial alternatives, they can be deployed quickly and inexpensively, enabling rapid network build-out. You can easily reconfigure satellite networks to match changing user demand. Satellite ground equipment also provides un-paralleled flexibility because you can install it on an interim basis, to test new markets or to keep communications going in an emergency.

As demand increases or an emergency stabilizes, you can re-deploy the equipment to another area and, for a new market, replace the satellite network with a permanent terrestrial presence. As an emergency stabilizes, you can re-deploy the equipment to another area.

Temporary Network Solutions. For temporary locations, or mobile applications, such as news gathering, homeland security or military activities, satellite can often provide the only practical solution for getting necessary information out.

Total Network Management. Satellite can provide a single-tier, end-to-end backbone infrastructure. Meanwhile, terrestrial facilities may be managed by multiple organizations. From this perspective, satellites also provide a "truly private" network, entirely under the operator's control.

A Long-Term Solution for the Last Mile. The biggest problem with the last mile is getting the high-bandwidth capabilities available in the long-distance networks to the residence or small business. Network operators "over-built" the long-distance arena (a relatively easy equipment task) without improving capacity for the access arena between central office and home. By being independent of terrestrial equipment factors, satellite can provide cost-effective multipoint access, either to the CO or directly to the home.

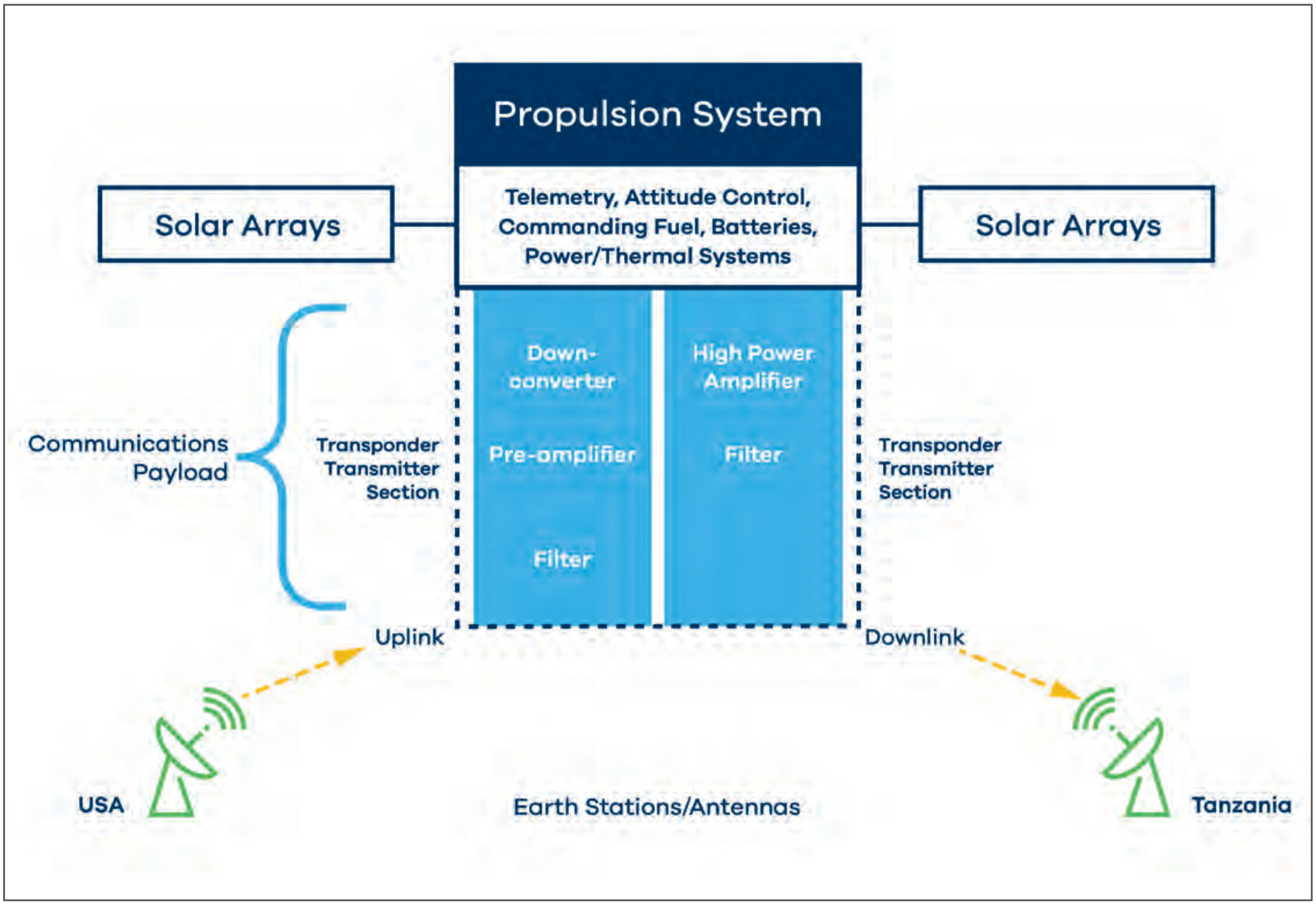
Rapid Provisioning of New Services. Since satellite solutions can be set up quickly, you can be fast-to-market with new services. For the most part, you can re-point or expand services electronically without the customary "truck rolls" of traditional terrestrial networks. As a result, you can decrease capital expenditures while realizing revenues earlier.

Of course, all communications satellite networks are not alike. To realize these general advantages, it is helpful to know the elements of satellite architecture. While the structure of a communications satellite remains the same, its capacity and frequency bands will vary according to your needs.

Satellite Architecture

Communications data passes through the satellite using a signal path known as a "transponder." Typically satellites have between 24 and 72 transponders. Transponders may be shared between many customers, in a "demand access" environment, or segments of capacity may be dedicated to individual customers, depending on the customer application. A single transponder is capable of handling up to 155 million bits of information per second. With this immense capacity, today's communication satellites are an ideal medium for transmitting and receiving almost any kind of content, from simple voice or data to the most complex and bandwidth-intensive video, audio and Internet content.

Figure 2: Diagrammatic Representation of a Satellite



Bands and Beams

Satellites transmit information within "frequency bands." The primary commercial frequency bands currently in use are C-band and Ku-band, although Ka-band is also in use. Over the next several years, the use of a new frequency band known as Ka-band is expected to increase. Generally C-band operates in the 4-6 GHz range and is mostly used for fixed services such as PSN, Internet Trunking and mobile feeder links.

Ku-band operates in the 11-14 GHz range and is generally used for fixed services such as Very Small Aperture Terminal (VSAT), a network, serving corporate networks and small businesses, that uses a small transceiver directly linked to a satellite in a Star topology. Ku-band serves Internet trunking and video distribution applications, as well as mobility applications for aeronautical, ground and maritime services. Ka-band operates in the 18-30 GHz range largely for broadband applications[2].

There is a trade-off between the size of the geographic area in which signals can be transmitted or received and the amount of power that can be used to send or receive the signal. Therefore, modern satellites support a variety of "beam" types to allow the satellite to focus its power at different levels to particular locations. Use of beams other than global also allows satellites to employ frequency reuse to increase capacity.

Intelsat offers Services with the following beam types:

- C-Band Global
- C-Band Hemi
- C-Band Zone
- Ku-Band Spot

Figure 3: Satellite Frequency Bands

Band	Intelsat's Uplink Frequency	Intelsat's Down-link Frequency	Comments
C-Band	5850 to 6650 MHz	3400 to 4200 MHz	Transmissions are immune to atmospheric conditions such as snow and rain. However, C-band transmissions have low power, so Earth Stations must be rather large to compensate, typically 4.5 to 18 meters in diameter. Applications include public switched networks and Internet trunking.
Ku-Band	13.74 to 14.5 GHz	10.95 to 12.75 GHz	The Ku-spectrum has higher power than C-band, allowing for smaller Earth Stations to be used (4 meters in diameter or less). However the higher frequency of Ku-band makes it more susceptible to adverse weather conditions than C-band. Ku-band is generally offered in "Spot" beams (see below). Applications include VSAT, rural telephony, satellite news gathering, mobility, videoconferencing and multimedia services.
Ka-Band	TBD	TBD	Ka-band has a higher power frequency than Ku-band and therefore will be used for high-bandwidth interactive services such as high-speed Internet, videoconferencing and multimedia applications. Ka-band transmissions are even more sensitive to poor weather conditions than Ku-band.

[2] *The letters used to name frequency bands do not mean anything; they are used as code names by the US Military; frequency ranges are approximate and not agreed to by everyone.*

A "global" beam essentially means that the radiated power of the satellite beam is directed at the equator and spreads outward. The global beam provides widespread coverage. However it provides less power than a concentrated beam. This means that a larger antenna must be used with a global beam. For this reason, global beams tend to be used by carriers who require coverage not available with other beams, or require multiple points within a large coverage area, and have access to a large antenna, either via their own facilities or via a shared hub. Intelsat offers the option for higher-powered global beams on some satellites that can support smaller antennas; small antennas are generally lower cost and require less physical space.

In contrast, some satellite beams direct the satellite's power to specific areas. These are called "Hemi," "Zone" and "Spot" beams. Hemi and Zone beams essentially offer approximately one half and one quarter of the coverage of a global beam, respectively. A larger antenna will be needed when using a global beam than a Hemi or Zone beam, to achieve the same level of quality, because the antenna must compensate for the reduced power through its increased receive signal gain. The main benefit of Ku Spot beams is that they provide more power and, therefore, very small, low-cost antennas can be used. This makes it an excellent solution for corporate network and mobility applications.

Bandwidth and Power

Satellite capacity is the combination of bandwidth and power, and is measured in units of Hertz (cycles per second). Since large bandwidths are required it is more common to use MegaHertz (MHz) or kiloHertz (kHz). Since terrestrial capacity is leased in Megabits per second, or multiples thereof, Intelsat often makes the conversion to MHz which will support the required information rate.

There is a relationship between the amount of bandwidth and the amount of power available from the satellite. Each transponder has a maximum amount of power and a maximum amount of bandwidth available to it. Therefore, if a customer has a small antenna, he may use all of the power available to him before he has used all of the bandwidth. Conversely a customer with a large antenna may use all of the bandwidth available but still have power available. For this reason, Intelsat will work with their customers to help design a "Transmission Plan" that will optimize the amount of power and bandwidth required.

Shared and Dedicated Capacity

As in terrestrial networks, satellite capacity can be shared among multiple users or can be dedicated to individual customers. There are several methods of increasing capacity. In Demand Assigned Multiple Access (DAMA), a caller's demand to the "satellite switchboard" determines a temporary allocation of frequency. Frequency Division Multiple Access divides the available spectrum into channels like radio stations, tuned to different frequency. Time Division Multiple Access (TDMA) increases the traffic a slot can handle by dividing it into units of time. Generally shared capacity is suitable for low-volume telephony applications, which are supported using technologies, such as Demand Assigned Multiple Access (DAMA), Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA).

For higher volume or more bandwidth-intensive applications, such as video distribution, dedicated capacity ensures a consistent quality of service. Most capacity in use on the Intelsat system is assigned as Frequency Division Multiple Access (FDMA).

The Ground Installation

All satellite communications are sent to and received from the satellite using an Earth Station or Antenna; sometimes referred to as a "dish." Earth Stations may either be fixed and installed at a specific installation, or mobile, for uses such as Satellite News Gathering (SNG) or mobility applications. There are various sizes of antenna, depending on the customer application and the type of beam being used on the satellite. Antennas range in size from large telecommunications carrier dishes of 4.5 to 15 meters in diameter, to VSATs of less than one meter in diameter, which are designed to support services such as Direct to Home TV (DTH) and rural telephony. Intelsat uses the following definitions to classify dish sizes and types:

Antennas below 1.2m for Ku-band and 1.8m for C-band may be approved for use with the Intelsat system under certain circumstances — these are included in the "G" standard.

Earth Stations may incorporate sophisticated technology to ensure that the link between the satellite and the Earth Station is optimized. As mentioned above, some antennas may use tracking equipment to follow the movement of an Inclined Orbit satellite. In other situations where the Earth Station itself is likely to move, such as in mobility applications, special stabilization equipment is used to compensate for the movement.

Figure 4: Intelsat Approved Antenna Sizes

Standard	Approximate Antenna Size (Meters)	Frequency Band
A	18	C
B	11	C
C	16	Ku
E1	2.4-4.5	Ku
E2	4.5-7	Ku
E3	6-9	Ku
F1	3.7-4.5 (typical)	C
F2	5.5-7.5	C
F3	7.3-9	C
G	Up to 4.5	C & Ku
H 1, 2 & 3	1.8-3.7	C
K 1, 2 & 3	1.2-1.8	Ku

The antenna itself will generally be connected to an Indoor Unit (IDU), which then connects either to the actual communications devices being used, to a Local Area Network (LAN), or to additional terrestrial network infrastructure.

Network Topologies

Satellite communication supports a number of different network topologies, depending on the application. At its simplest, satellite can support a simplex (one direction) or duplex (two directions) link between two Earth Stations. More complex networks can be fashioned to support "Star" or "Mesh" topologies, especially in corporate VSAT applications. In a Star topology there will be a "hub" Earth Station, at the center of the network. Content originates at the hub, which features a large antenna. The hub can control the network through a Network Management System (NMS), which allows the network operator to monitor and control all components of the network. Outbound information from the hub is sent up to the satellite, which receives it, amplifies it and beams it back to earth for reception by the remote Earth Station(s). The remote locations send information inbound to the hub. In a Mesh topology, remote Earth Stations can also communicate with each other via the satellite, but without information being sent through the hub. This is common for international voice and data traffic via satellite. This is also referred to as a community of Earth Stations.

The examples on the following pages show some of the options available to customers for configuring their satellite networks.

Figure 5: Simplex Transmission

Applications for simplex services include:

- Broadcast transmissions such as TV, video and radio services

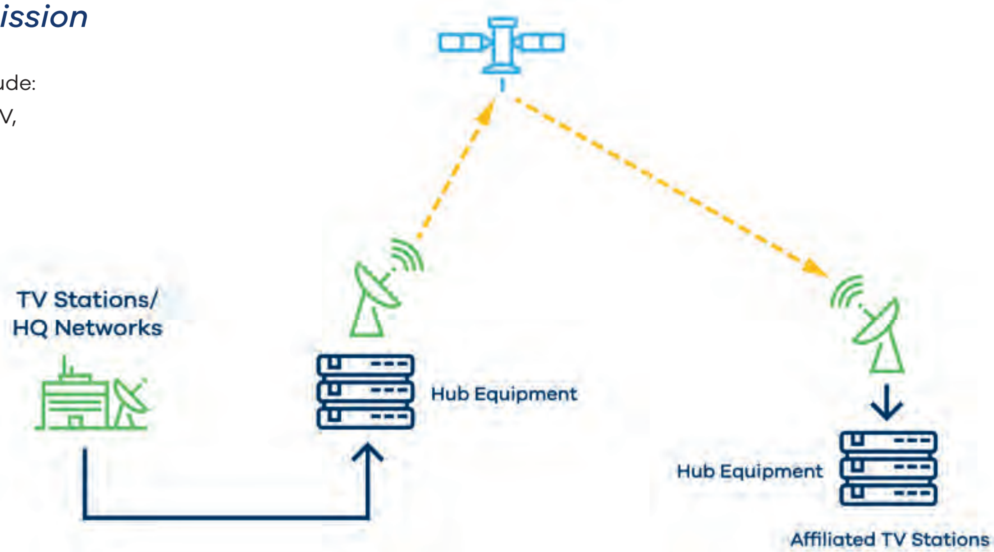


Figure 6: Point-to-Point Duplex Transmission

Applications for duplex services include:

- Voice telephony transport
- Data and IP transport (especially in asymmetric configurations)
- Corporate networks
- TV and broadcast program contribution and distribution

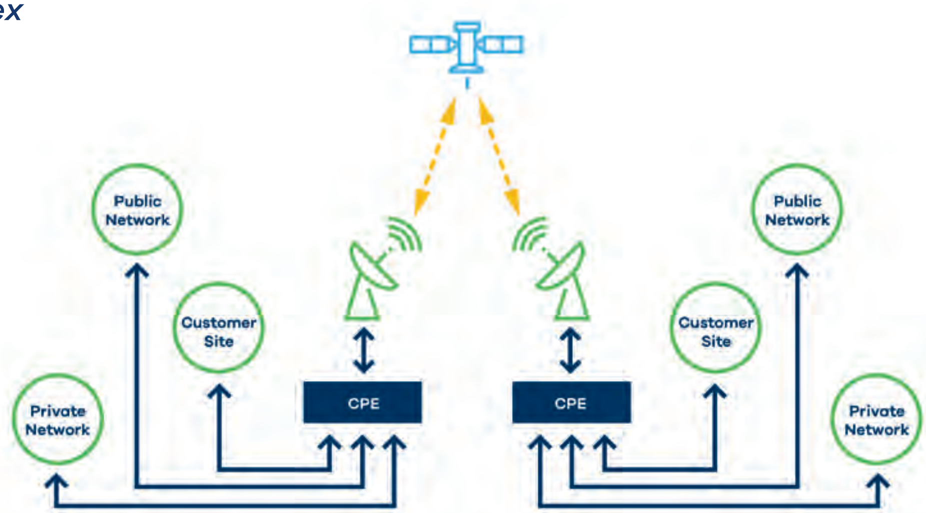


Figure 7: Point-to-Multipoint Transmission

(May be simplex or duplex, symmetric or asymmetric)

Applications for point-to-multipoint services include:

- Corporate networks, including VSAT services and business television
- Video and broadcast distribution, including Direct-to-Home Internet services

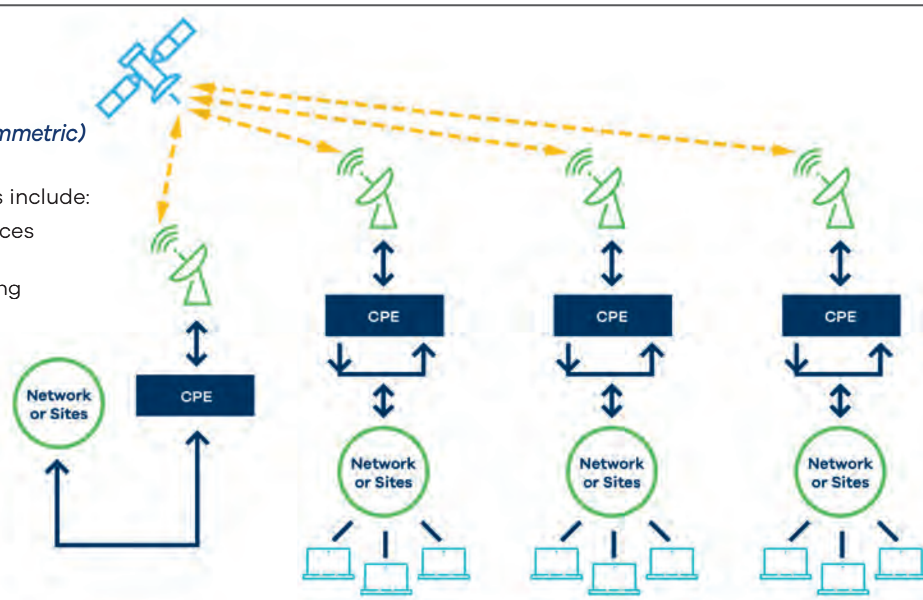


Figure 8: Mobile Antenna Service

Applications for mobile antenna services include:

- Satellite news gathering
- Special event backhaul and broadcasting
- Mobility services

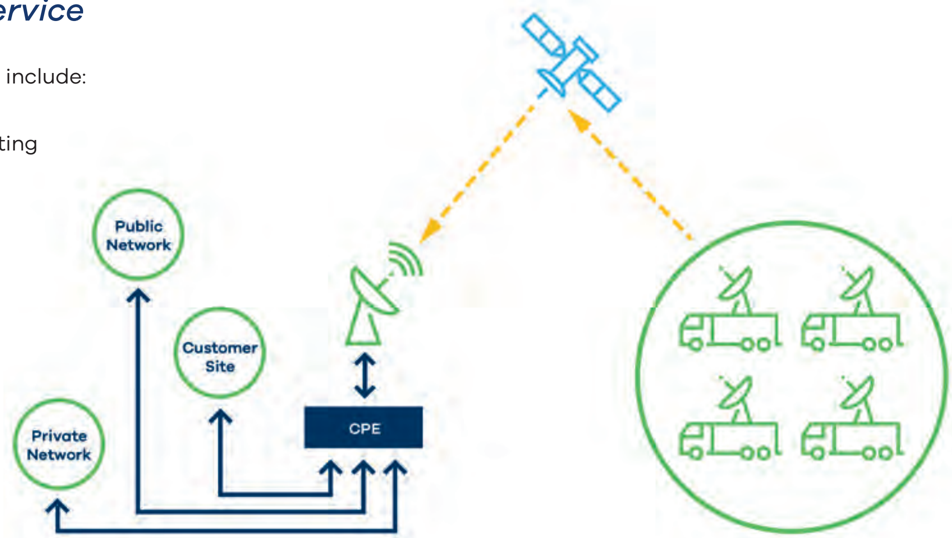


Figure 9: Star Network

Applications for Star networks include:

- Corporate networks
- Distance learning

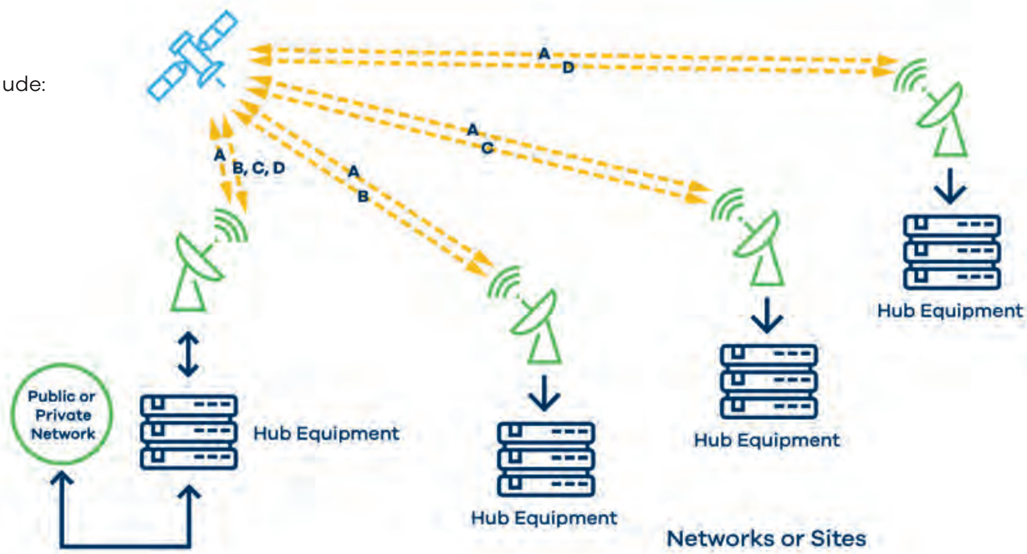
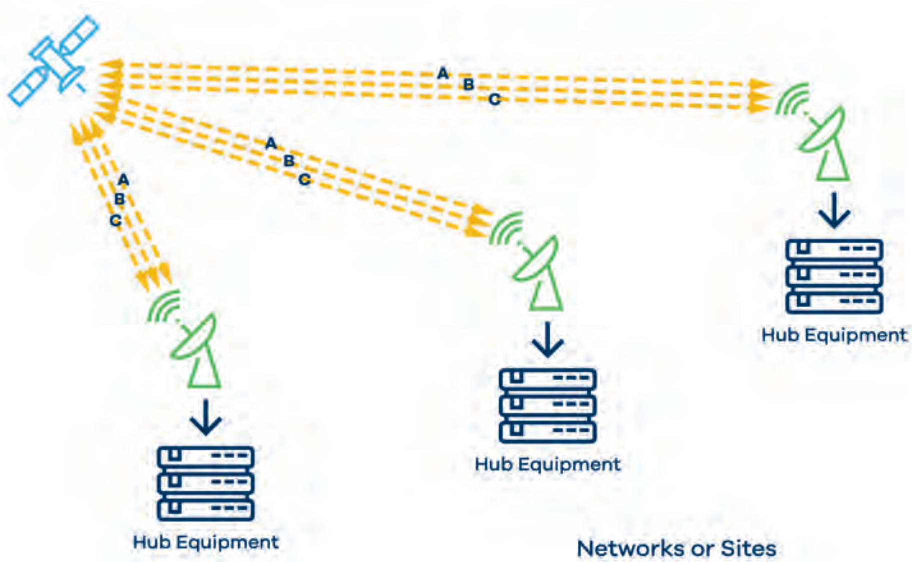


Figure 10: Mesh Network

Applications for Mesh networks include:

- National and international telephony and data networks
- Rural telephony



Reference Books:

The following sources are recommended for additional information:

1. ITU Handbook of Satellite Communications, Pub: John Wiley & Sons
2. Satellite Communications & Broadcasting Markets Study — Worldwide Prospects to 2010; Pub: Euroconsult, January 2002
3. Satellite Communications Systems, by G. Maval & M. Bousquet, (Paperback), Pub: John Wiley & Sons
4. Introduction to Satellite Communication, 1987, by Bruce R. Elbert, Pub: Artech House
5. Communications Satellite Handbook, 1989, by Walter L. Morgan & Gary D. Gordon, Pub: Wiley Interscience, John Wiley & Sons
6. The Satellite Communications Applications Handbook, 1997, by Bruce R. Elbert, Pub: Artech House

Glossary of Terms

Antenna: A device for transmitting and receiving signals. An antenna is part of an Earth Station.

C-Band: A frequency band in the 4-6 GHz range.

DAMA: Demand Assigned Multiple Access. A way of sharing a channel by assigning capacity on demand.

Downlink: The link from the satellite down to the Earth Station.

Duplex Simultaneous: Two-way transmission over a satellite or terrestrial link.

Earth Station: A device for transmitting and receiving signals.

FDMA: Frequency Division Multiple Access. A way of sharing a channel by assigning different frequencies to different users.

Footprint: The area of the Earth's surface from which an Earth Station can transmit to or receive from a particular satellite.

Frequency Band: A defined portion of the electromagnetic spectrum.

Geosynchronous Orbit: A satellite orbit 22,300 miles over the equator with an orbit time of exactly 24 hours.

Global Beam: A satellite beam with wide geographic coverage of 40 percent of the Earth's surface, as seen from the satellite.

Hemi Beam: A satellite beam with approximately half the geographic coverage of a global beam.

Hertz: A measurement of satellite capacity based on cycles per second.

IDU: Indoor Unit. Comprises equipment not mounted on the antenna system.

Inclined Orbit: Any non-Equatorial orbit of a satellite. In order to conserve fuel, the satellite is allowed to move in a figure eight pattern over its nominal orbital location. May also be used for photography and to reach extreme North and South latitudes that cannot be seen from the Equator.

Ka-Band: A frequency band in the 18-30 GHz frequency range, nominally.

kHz: KiloHertz. One KiloHertz is the equivalent of one thousand Hertz, or one thousand cycles per second, to measure frequency and bandwidth.

Ku-Band: A frequency band in the 11-14 GHz range.

LAN: Local Area Network. A geographically localized network.

Mesh Network: A network topology where all terminals are connected to each other without the need for a hub.

MHz: MegaHertz. One MegaHertz is the equivalent of one million Hertz, or one million cycles per second. Used to measure frequency and bandwidth.

NMS: Network Management System. Equipment and software used to monitor, manage and change elements and devices in a network.

Orbital Location: The location of a satellite over the Equator, measured in degrees from the Prime Meridian of 0°.

Simplex: Transmission that flows in only one direction over a channel.

SNG: Satellite News Gathering: Use of a mobile antenna to transmit news stories.

Spot Beam: A satellite beam with concentrated geographic coverage.

Star Network: A network topology where all terminals are connected via a central hub, and can only communicate with each other via the hub.

TDMA: Time Division Multiple Access. A way of sharing a channel by assigning different time slots to different users.

Tracking Equipment: Equipment installed on an Earth Station that allows the Earth Station to track the position of a satellite.

Transmission Plan: A design showing the configuration and capacity (power and bandwidth) resources required for a particular customer application.

Uplink: The link from the Earth Station up to the satellite.

VSAT: Very Small Aperture Terminal. A very small satellite antenna, usually 1.2-3.0 meters in diameter.

Zone Beam: A satellite beam with approximately one quarter of the geographic coverage over a global beam.

Determining Which Service to Use, Contact Intelsat

Every satellite network is unique. The design you choose chiefly depends on three factors:

- The specific application
- The geography of the network
- The volume of traffic required

Intelsat has a team of experts who can understand your specific requirements and help you to make the right decisions. After deployment, they will continue to help you optimize your investment.

About Intelsat

As the foundational architects of satellite technology, Intelsat operates the largest, most advanced satellite fleet and connectivity infrastructure in the world. We apply our unparalleled expertise and global scale to reliably and seamlessly connect people, devices and networks in even the most challenging and remote locations. Transformation happens when businesses, governments and communities build a ubiquitous connected future through Intelsat's next-generation global network and simplified managed services.

At Intelsat, we turn possibilities into reality. Imagine Here, with us, at Intelsat.com.

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