

SATELLITE TECHNOLOGY PRIMER

SUMMARY

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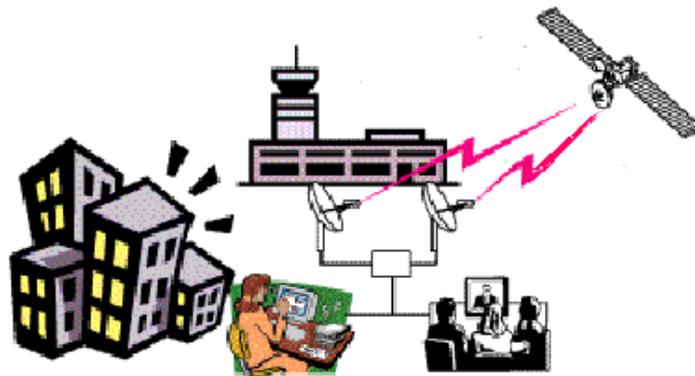
BROADBAND SATELLITE BENEFITS

The following information reviews the benefits of Broadband Satellite Technology.

Step-By-Step

Broadband satellite provides additional benefits over terrestrial access:

- **Ubiquitous coverage:** Unlike other broadband access technologies, satellite-based broadband connectivity provides ubiquitous coverage.
- **Simplicity:** Satellite systems bypass the complex web of landline networks.
- **Bandwidth flexibility:** Configurable satellite systems provide capacity on an as-needed or time-scheduled basis.
- **Rapid deployment:** Quick initiation of broadband satellite service is possible after the installation of the customer premise equipment.
- **Reliability:** Satellites are among the most reliable of all communication technologies.



BROADBAND SATELLITE INTERNET ARCHITECTURE

The following information reviews broadband satellite technology architecture.

Step-By-Step

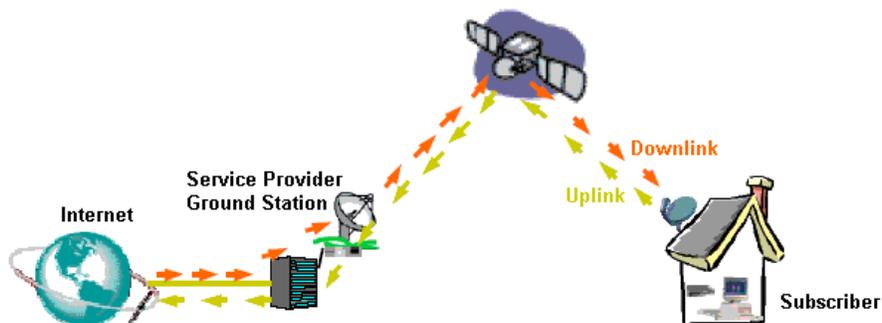
True Broadband Satellite Internet Architecture

With the advent of new satellite technologies, the network architecture has changed, allowing the customer to use satellite transmission for both uplink and downlink. This allowed customers to add high-bandwidth, two-way communication applications, like video conferencing, to their Internet experience. This architecture is the focus of today's marketplace.

To support the new architecture, the first adapters modified existing satellites and customer equipment to provide a Time Division Multi-Access (**TDMA**)-based uplink, while still using standard broadcast technology on the downlink. This method, while workable, has the inherent problems that occur when retrofitting existing hardware to new technology; larger processing overhead and generally slower access than desired.

- Newer true **broadband satellites** and customer equipment use the more efficient TDMA-based technology for both uplink and downlink. They typically provide 1 Mbps downstream and 500 kbps upstream.

Two-Way Satellite Internet Access

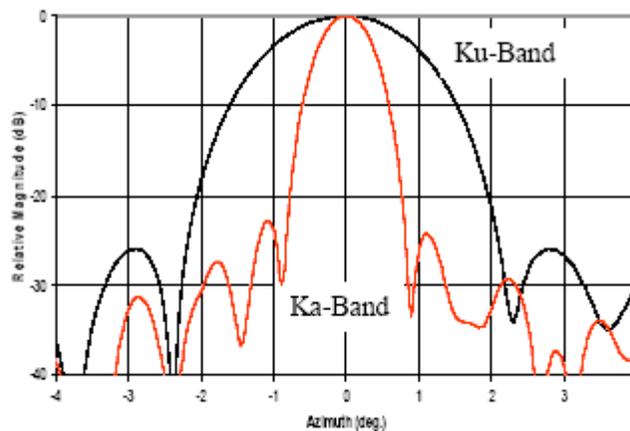


Satellite Frequency Bands

There are several frequency bands available for the satellite marketplace. While each of these frequencies has a place in the market, only the Ka-band frequencies support the robust frequency reuse to efficiently support broadband Internet access. Listed below are two common frequencies and their frequency characteristics and usage:

- **Ka-band** extends from 27 GHz to 40 GHz and includes the upper part of the Super-High Frequency (**SHF**) band and the lower part of the Extremely High Frequency (**EHF**) range, which extends from 30 to 300 GHz. Broadband satellite systems typically employ the 27.5-30.0 GHz SHF frequency range for uplink transmissions (earth-to-space) and the 17.7-20.2 GHz range for downlink transmissions (space-to-earth). Note that the broadband application actually overlaps a part of the Ku-band in its downlink frequency band. Because the Ka-band frequency is highly concentrated it provides high **gain**, a narrow beam width and the possibility of multiple beams.
- **Ku-band:** Generally considered to extend from 12 to 18 GHz in commercial use this frequency band usually extends to the frequency range from 10.7 GHz to 18.4 GHz. Used by most commercial broadcast TV satellites, this is the most commonly used satellite frequency today.

Because Direct Broadcast Satellites use the Ku-band frequencies, DBS installers are most familiar with aligning antennas to the Ku-band frequencies. The graphic below compares the Ku-band and the Ka-band frequencies. Note that the degree of **azimuth** is considerably smaller in the Ka-band. This translates to a need for more precise customer transmitter/receiver placement.

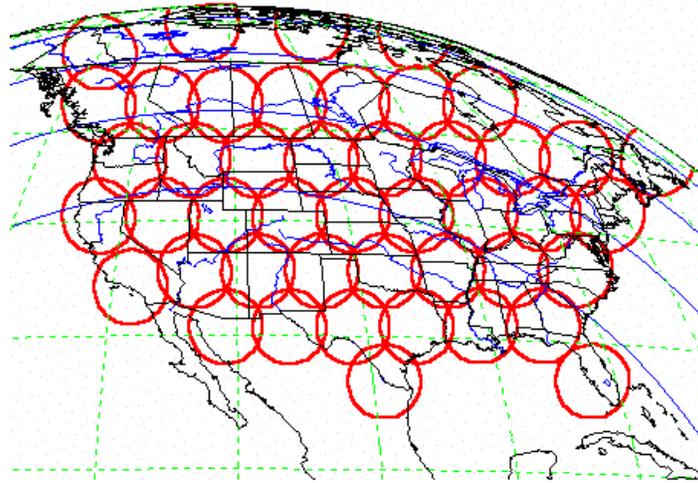


Broadband Satellite Spot Beams

While a conventional satellite using Ku-band will use a single downlink beam to cover a single area on the earth, a broadband satellite, using Ka-band, will use multiple **Spot-beams** to provide the same coverage. Each of the circles in the graphic below is equivalent to a "cell" in a cellular telephone network and allows multiple reuse of the frequency spectrum.

On average, a broadband satellite will provide 35 to 45 subscriber spot-beams and about six Gateway Earth Station spot-beams; about one Gateway spot-beam for every seven or eight subscriber spot-beams. Transmissions in a subscriber spot-beam are to/from the subscriber side terminal. Transmissions in a Gateway spot-beam are to/from a service provider ground station.

The graphic below shows a typical spot-beam layout for the United States from a broadband satellite. Note that a conventional satellite, using Ku-band, would have only one beam for the entire United States.



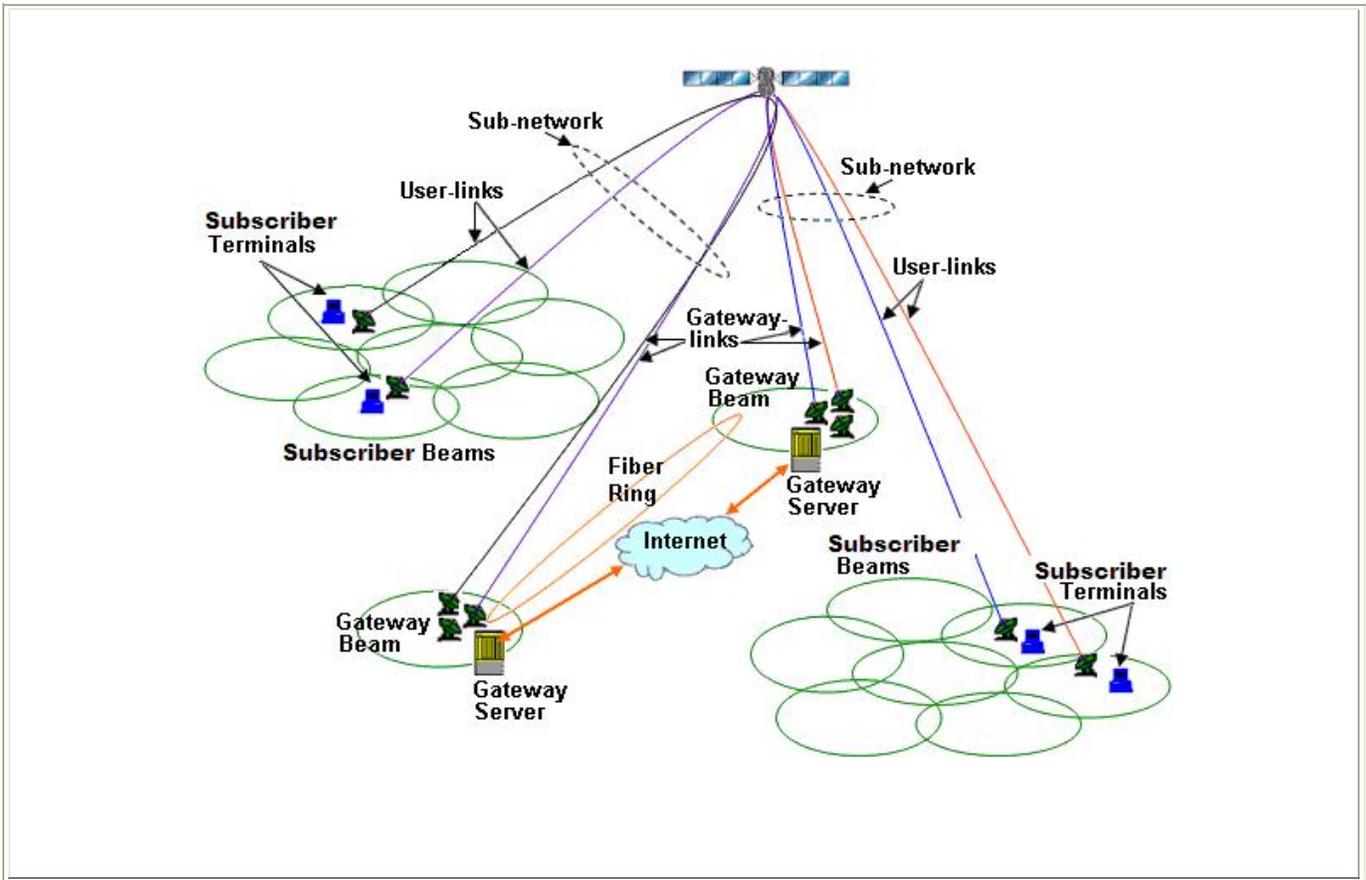
Broadband Satellite Bent-pipe Architecture

Broadband satellites combine spot-beam technology with links that operate on a point-to-point basis. The satellite uses on-board switching to provide two-way data paths between different spot beams and allow for reuse of the Beam Carrier Frequencies.

The bent-pipe architecture allows the satellite processor to concentrate on building the data-paths because the satellite acts as a repeater. In the satellite, the *data-path signal is received, retuned, amplified, and retransmitted* but there is no demodulation, decoding or other type of signal processing.

The satellite divides uplinks and downlinks to **user links**, the up/down links between the subscriber terminal and the satellite, and **feeder-links**, the up/down links between the satellite and Gateway. Bent-pipe technology in the satellite switches a **user uplink** and a **feeder downlink** together to form the **upstream** data path between the customer and the service provider. The same technology switches the downstream **user downlink** and the upstream feeder link together to form the **downstream** data path between the customer and the service provider.

The combination of the upstream and downstream data paths connected to a single Gateway form a **sub-network**. These sub-networks are a part of the larger service provider network, interconnected with **fiber rings**, providing access to the **Internet**. The graphic below shows a portion of a broadband satellite network. Note that user links and Gateway links actually consist of one uplink and one downlink. A single line in the graphic displays an upstream and downstream data path.



SATELLITE ACCESS EQUIPMENT: THE SPACECRAFT

The following information reviews the technology the satellite uses to provide broadband services.

Step-By-Step

At the center of the new Broadband Satellite Networks are high-powered GEO satellites 22,300 miles above the equator operating in **Ka-band** (20-30 GHz) mode.

Current Satellite Internet Access Satellite Capacity



As the demand for satellite capacity has steadily increased, traditional broadcast satellite technology using **Ku-band** (11-14 GHz) frequencies becomes limiting. Because they are built to cover a very large downlink area, traditional broadcast satellites have difficulty supporting the flexible distribution of bandwidth needed for broadband Internet.

New Ka Band Multiple-Beam Antennas (**MBA**) have become key components in broadband satellite communication systems because they enable frequency reuse. MBA technology maximizes bandwidth capacity while minimizing required frequency allocation. To use

the MBA technology efficiently, broadband satellites use the Ka-band frequencies, multiple pencil-like **spot-beams** and **bent-pipe** technology.

SATELLITE ACCESS EQUIPMENT: CUSTOMER SITE

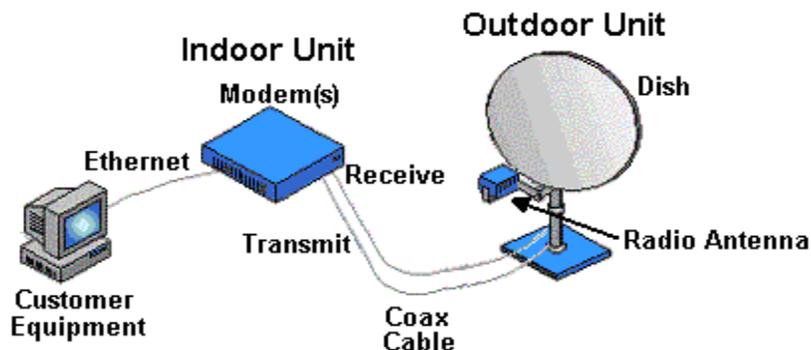
The following information reviews both the equipment needed by the customer and that provided by WildBlue.

Step-By-Step

For the **Customer Provided Equipment** (i.e. PC, router) to access the broadband satellite network, the customer must have additional physical components installed:

- **Outdoor Unit (ODU)**
 - A small (2-3 foot diameter), low-cost dish-type radio antenna with transmit and receive components placed at the focal point of the antenna
 - Receives/sends data from/to the satellite in two-way systems
 - In the Continental United States, the antenna must face the southern sky for proper transmission
- **Indoor Unit (IDU)**
 - The **Satellite Modem** serves as an interface between the outdoor unit and customer provided equipment (i.e. PC, router) and controls satellite transmission. It provides two types of connectivity:
 - **Coaxial cable (COAX)** connectivity to the satellite antenna
 - **Ethernet** connectivity to the computer
- **COAX** cable must support the **Intermediate Frequency** present in the connection between the indoor unit and outdoor unit:
 - Up to 150 MHz on RX data path
 - Up to 2225 MHz (Ka-band)

The graphic below shows a generic system.





Antenna Line-Of-Site (L-O-S):

To access the satellite the antenna must be aligned to the satellite’s location in the sky. *Traditional Ku-band antennas have four characteristics that affect the placement of the outdoor unit, while the Ka-band antenna has five.*

Setting these characteristics properly makes uplink and downlink communication with the broadband satellite possible.

The characteristic settings used by both Ku-band and Ka-band are the **Azimuth**, **Elevation**, **Polarization**, and **Skew**. The combination of these settings gives the outdoor unit a **Line-Of-Sight (L-O-S)** to the chosen satellite. *In Ka-band transmissions, combining the L-O-S characteristic settings with the **beam assignment** characteristic setting makes data transmission possible.*

SATELLITE ACCESS EQUIPMENT: SERVICE PROVIDER GATEWAY

The following information reviews the [Satellite Modem Termination System – Network-Side Interface \(SMTS-NSI\)](#)

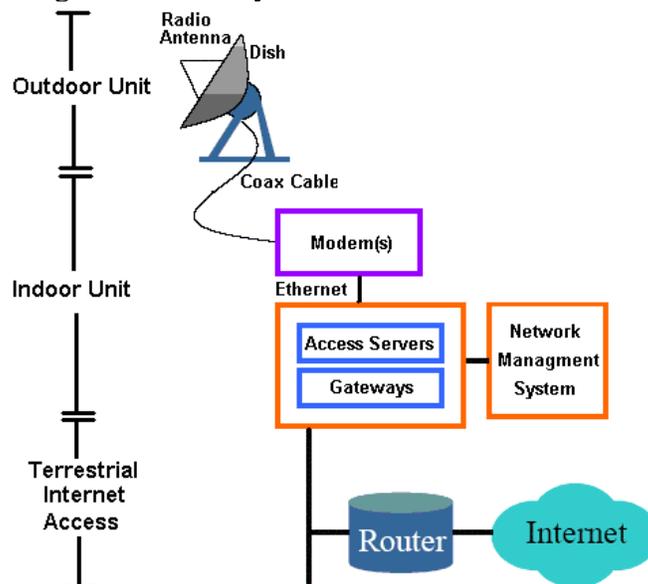
Step-By-Step

Once the **Modem** successfully connects to the WildBlue network, the broadband satellite redirects the data path to the appropriate Gateway.

The equipment in the Gateway is very similar to the customer site equipment except on a much larger scale. *It is this equipment that connects the customer's data path to the terrestrial Internet.* Typical equipment would be:

- **Outdoor Unit (ODU)**
 - This is a large dish antenna (15-36 feet) with transmit and receive components placed at the focal point of the antenna
 - Receives/sends data from/to the satellite similar to customer terminals
 - Needs to face the southern sky for proper transmission
- **Indoor Unit (IDU)**
 - Satellite modem(or modems) demodulates an incoming signal from the Outdoor Unit to IP packets and sends the packets to the local network
 - Can be separate transmit and receive modems
 - Can be integrated transmit and receive modem
 - Access server/gateways manage traffic transported to the Internet
 - Network Management System (NMS) manages the server activity and controls satellite transmission

The graphic below depicts a generic Gateway.



ANTENNA POSITIONING

The following information reviews the technology used to position the antenna to receive satellite transmissions.

Step-By-Step

Azimuth: **Azimuth** is the horizontal angle from the **True North** point on the horizon to the point where the satellite intersects the horizon. **Magnetic Declination** defines the offset angle between True North and Magnetic North at a particular location on earth. Modifying the azimuth reading, based on True North, by the Magnetic Declination will provide the correct magnetic compass reading for pointing an ODU transceiver.*

**NOTE: WildBlue service orders provide the azimuth reading not True North.*

Elevation: The satellites that are in geostationary orbit are at a right angle (90-degrees) to the earth's axis. Only at the equator will the **GEO Arch**, the portion of the geostationary belt viewable from a position on earth, have a 90-degree **elevation**. All other earth locations use a calculation of angles formed from the relationship between the ODU and satellite locations, along with a calculated line to the center of the earth.

Polarization: **Polarization** is the orientation of a signal wave produced by an antenna on a stationary plane defined by the direction of propagation (transmission) and the associated magnetic and electric fields. WildBlue uses circular polarization. A corkscrew best visualizes the circular transmission. The wave rotates as it travels along the direction of propagation. If the rotation is counter-clockwise as seen looking in the direction of the propagation, it is **Left-hand Circular Polarization (LHCP)**. If the rotation is clockwise as seen looking in the direction of propagation, it is **Right-hand Circular Polarization (RHCP)**.*

**NOTE: The position of the TRIA feed horn, a part of the Feed horn Assembly (FAS), determines if the antenna is LHCP or RHCP.*

NOTE: The receive sides of the antenna are opposite polarization. Therefore, an RHCP antenna will use RHCP to transmit and LHCP to receive. Use either two RHCP antennas or two LHCP antennas in a transmission circuit. FCC regulations require American broadband satellite communications use circular polarization.

Circular Polarized Antenna Skew: Because the broadband satellite's ODU dish is **elliptical**, the skew is used to align the antenna horizontally with the GEO Arch. This adjustment compensates for slight variations in angle between identical senses of polarity generated by two or more satellites. Therefore, the antenna only needs a skew adjustment if it obtains signals from more than one satellite on the GEO Arch or if the antenna needs to exclude transmission or reception from competing signals. Circular polarization combined with an elliptical ODU dish allows a precisely positioned antenna to receive the greatest antenna **gain** and ignore competing signals, therefore reducing the **Carrier-to-Interference Ratio (CIR)** and the **Carrier-to-Noise Ratio (CNR)**.

BEAM ASSIGNMENT

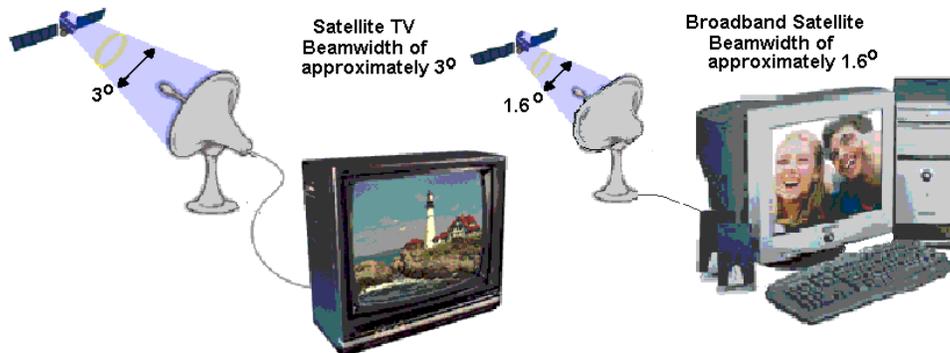
The following information reviews Spot-beam technology.

Step-By-Step

Broadband satellites use **Spot-beam** technology. Since the spot-beam Ka-band frequency is much smaller than the traditional broadcast TV beam frequency, a precisely pointed antenna is a necessity. The frequency defines a beam's width.

After acquiring the satellite signal by aligning the antenna to the satellite using the correct azimuth, elevation, and polarization, the **satellite modem** will still need to lock on to the correct beam frequencies. These frequencies must be within the correct beam width.

In comparison, an 18-inch satellite TV dish will have a beam width of approximately 3° , while a 28-inch broadband satellite dish will have a beam width of approximately 1.6° . This means that positioning the satellite TV antenna within the three degrees of the Line-Of-Sight and positioning the broadband satellite antenna within the 1.6° of the Line-Of-Sight maximizes the sensitivity of the antenna and the greatest antenna signal power (antenna **gain**).

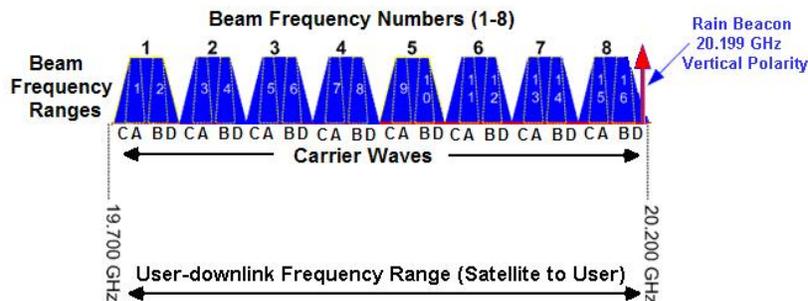


Spot-beam Usage:

Every customer has a **User uplink** and a **User downlink**. Using **Bent-pipe** technology the broadband satellite combines the user links with the corresponding **feeder links** providing the customer with upstream and downstream data paths to the terrestrial Internet.

The customer **Beam Assignment** L-O-S characteristic, expressed in a **Beam Frequency Number** that defines a frequency range, allows the **Customer Provided Equipment (i.e. PC, router)** to connect to the appropriate sub-network.

- **User downlinks** use frequencies within the 19.700 GHz to 20.200 GHz range. Each **spot-beam** will use one of eight frequency ranges for its user downlinks. Each customer's **satellite modem**, within a spot-beam, uses one of the two **carrier waves** within the beam for a static RX data path. Each customer satellite modem assignment includes the **Beam Frequency Number**. To align the Outdoor Unit antenna to the satellite requires the use of the Beam Frequency Number (see Graphic below).



- **User uplinks** use frequencies within the 29.500 GHz to 30.000 GHz range. Each customer's **satellite modem** dynamically uses a **carrier wave** within one of the twelve frequency ranges for its user uplink. The **user downlink** frequencies used in the customer's beam determines the range of available user uplink frequencies in that beam. Therefore, the satellite modem uses the **Beam Frequency Number** to lock on to the appropriate frequency range (see Graphic below).



BROADBAND SATELLITE PROTOCOLS

The following information reviews the transmission and transport protocols used in Broadband Satellite transmissions. WildBlue allows the end-systems to see only TCP/IP protocols and traffic; virtually any TCP/IP device can use the broadband satellite network.

Step-By-Step

Subscriber Segment:

The part of the interface connected to the customer's PC uses standard **TCP/IP Ethernet protocol**. The terminal can send several **packets** in each time slot. While the format of the packets can use several protocols, one of the most common is *Data-Over-Cable System Interface Specification (DOCSIS)*. This protocol provides compatibility with cable modem standards, in terms of bandwidth and packet structure.

Satellite Segment:

The Satellite Modem connects to the TRIA on the outdoor unit that transmits to the satellite. The satellite uses onboard processing and Carrier Frequency reuse to develop the up/downstream data paths. The satellite data path signal is amplified and retransmitted but there is no demodulation, decoding or other type of signal processing.

Gateway segment:

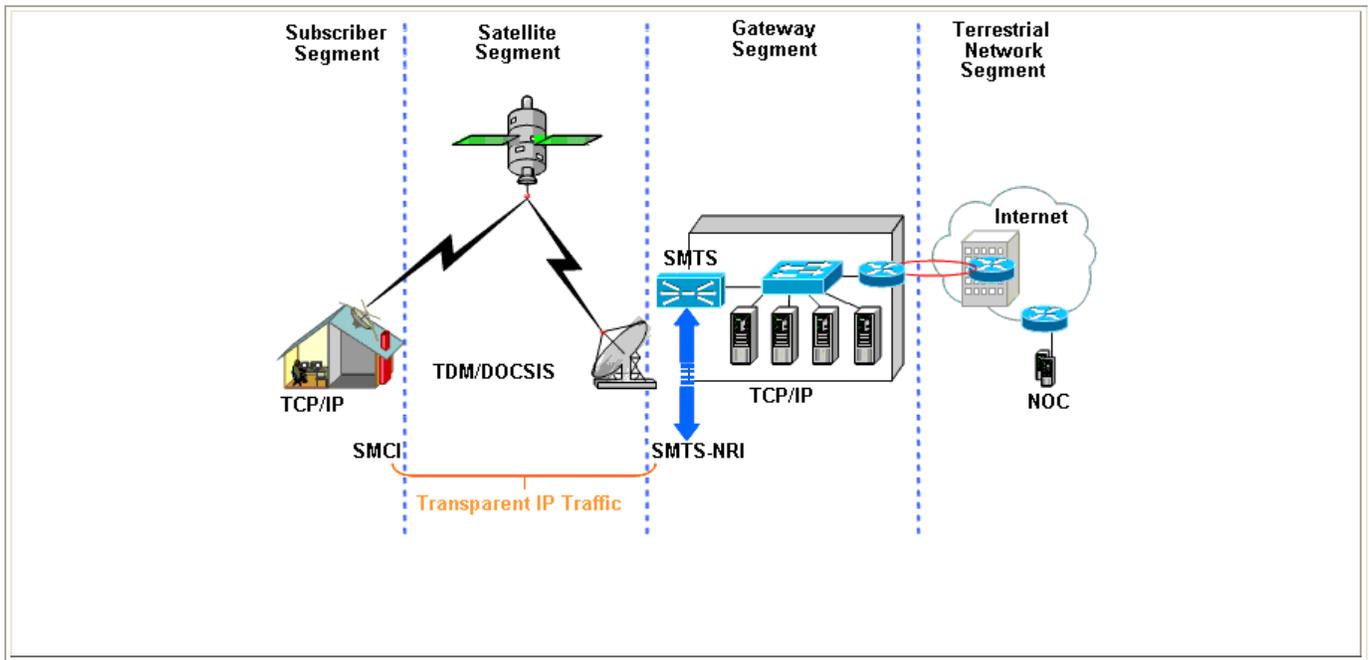
The service provider ground station provides the Satellite Modem Termination System - Network-Side Interface (**SMTS-NSI**). Like the SMCI, the SMTS-NSI uses TDMA protocols and DOCSIS packets to communicate with the satellite. The gateway SMTS houses multiple SMTS-NRI. Each interface connects to the Gateway server using standard TCP/IP Ethernet protocol.

Terrestrial Network Segment:

This segment works like any service provider network using terrestrial network and standard TCP/IP Ethernet protocols.

The traffic includes, but is not limited to, **DHCP** and **datagrams**, along with **ICMP** to allow the Network Operations Center (**NOC**) to receive error messages from the subscriber's modem.

The graphic below shows the relationship between the various protocols.

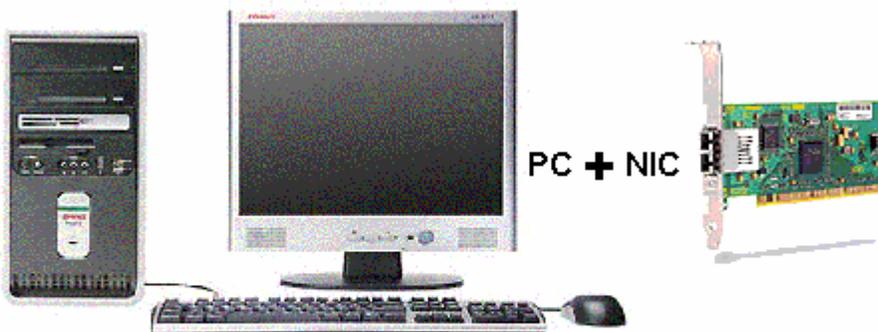


NETWORK ADDRESSES

The following information reviews network-addressing computers and **Internet Ready Devices (IRD)** used to communicate on computer networks.

Step-By-Step

MAC Address



A computer, or **Internet Ready Device (IRD)**, needs a **Network Interface Card (NIC)** to access a **computer**. This card supplies the physical connection and contains a hardware-embedded **Medium Access Control (MAC) address**.

The MAC address consists of six hexadecimal numbers separated by colons, and is unique to every card manufactured. The first numbers of the MAC address identifies the manufacturer of the card. A MAC address looks like this:

00:A0:BC:01:AB:48

The MAC address is usually used:

- To send messages between local devices on a **Local Area Network (LAN)**
- For device identification

IP Address Format

The TCP/IP Address, commonly called the IP Address, is used to identify **Internet Ready Devices (IRD)** (i.e. PCs) on both private and public networks. This address is a four-field number, displayed in the following format.

Field 1	Field 2	Field 3	Field 4
212	58	240	110

IP Address Assignment

- **Static IP Address:** A Static IP address requires manual modification of a network device (i.e. subscriber's computer) configuration file. *The IP address is stored permanently in the device and rarely changes.*
- **Dynamic IP Address:** A Dynamic IP address is not stored permanently in the network device. This is a common assignment method for personal computers. When the computer is set up to use Dynamic IP addressing, it requests a new IP address every time it connects to the LAN. The Dynamic Host Configuration Protocol (**DHCP**) server responds to this request. This server resides on the LAN. It is responsible for tracking and assigning all IP addresses on the LAN. *A PC may have a different IP address every day.* WildBlue only assigns IPs dynamically.

Public and Private IP Addresses

In order to simplify network administration and to conserve IP addresses certain blocks from each address class have been set aside for private network use.

- **Private IP Addresses:** The Internet Assigned Numbers Authority (**IANA**) has reserved the following three blocks of the IP address space for private networks:

- ***Private IP Addresses:***

10.0.0.0 - 10.255.255.255 (10/8 prefix)

172.16.0.0 - 172.31.255.255 (172.16/12 prefix)

192.168.0.0 - 192.168.255.255 (192.168/16 prefix)

The addresses in these blocks are used by many networks and are only unique within each LAN. Internet routers consider these private addresses as un-routable, and therefore they do not forward IP packets with these addresses in the header to the Internet. In addition, ISP routers filter out routing information about private networks.

- **Public IP Addresses:** All other IP addresses are public and have a globally unique network ID.

WHAT ALL COMPUTERS SHOULD KNOW

The following information outlines the general configuration settings that all computers need to communicate properly with the network.

Step-By-Step

TCP/IP protocols allow the subscriber's PC to communicate with the network. From the standpoint of the PC, four items define network access:

1. The **MAC address** is the "physical" address of the PC's NIC card. The card has this address or "number" built into it.
2. The **IP address** defines the PC's network address and IP class. The PC's network configuration defines the IP address or, if the PC network configuration uses DHCP, it requests an IP address when connecting to the network.
3. The **Subnet Mask** defines the Network ID and the Host ID within the IP address. The PC's network configuration defines the Subnet Mask or, if the PC's network configuration uses DHCP, the DHCP server provides a Subnet Mask when the PC requests an IP address.
4. The **Default Gateway** is the router port attached to the LAN where the PC resides. The PC's network configuration defines the default Gateway or, if the PC's network configuration uses DHCP, the DHCP server provides a default Gateway when the PC requests an IP address.

PC APPLICATIONS USED TO ACCESS THE INTERNET

- The following information provides general information about the Internet and the Worldwide Web (WWW), along with an overview of the Web-based tools; the Browser and the Email client.

Step By Step

Internet: The **Internet** is a network of networks, linking computers to computers. This worldwide network uses a common set of **TCP/IP protocols** to transport messages between computers.

WWW: The Internet supports the **World Wide Web (WWW)**. The WWW is a universe of **hypertext (HTTP)** servers, often called Web servers, which allow PC users access to information resources using Web-based tools.

The two basic Web-based PC application tools used to navigate the Internet and access Web pages are:

Browser applications: The PC **Browser** application is a Web-based tool that allows the PC user to view WWW documents, called **Web pages**, which reside on Web servers. While the Internet provides access to the Web servers, the browser allows the PC user to view the Web page information by translating **HyperText Markup Language (HTML)** code.

***NOTE:** The HTML code embedded in the Web-page contains commands read by the browser. These commands tell the browsers how to display the Web page on the PC monitor.

In addition, the browser can help speed up the PC internet connection. This function requires the use of a **Proxy Server** within the Internet, usually provided by the **Internet Service Provider (ISP)**.

Mozilla Firefox and Microsoft Internet Explorer are examples of Browser software applications.

Email Client applications: The **Email client** PC application is the Web-based tool that enables the PC to create, read, and organize Email messages residing on the PC. Based on client-server architecture it can only generate requests to send or receive Email messages. It must rely on a specific Email-server residing on the Internet to actually send and receive Email messages to or from other PC users. The customer's **Internet Service Provider (ISP)** provides the Email server.

WildBlue Service supported Email Clients:

- Outlook
- Outlook Express
- Netscape Mail
- MacMail