Satellite Networking

March 2, 2013

1 Introduction

- Figure 1 illustrates how satellites integrate in the global network infrastructure (GNI).

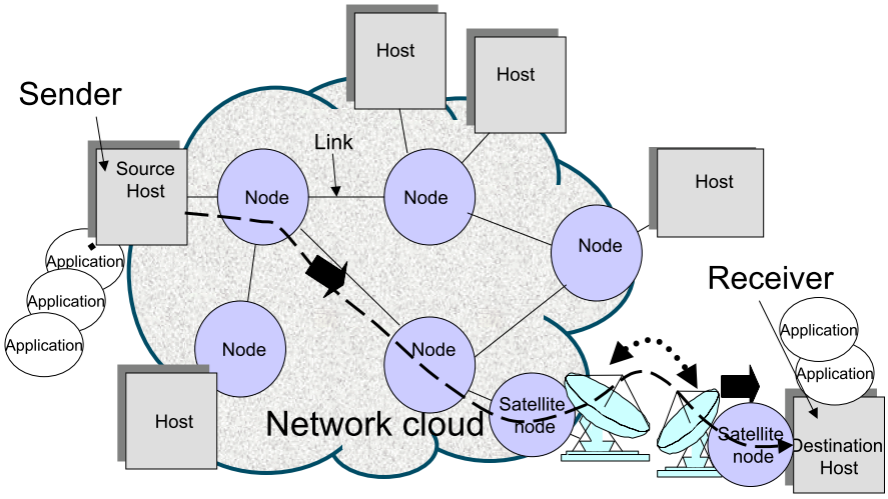


Figure 1: Satellite in the GNI

- Figure 2 shows a general satellite network configuration consisting of

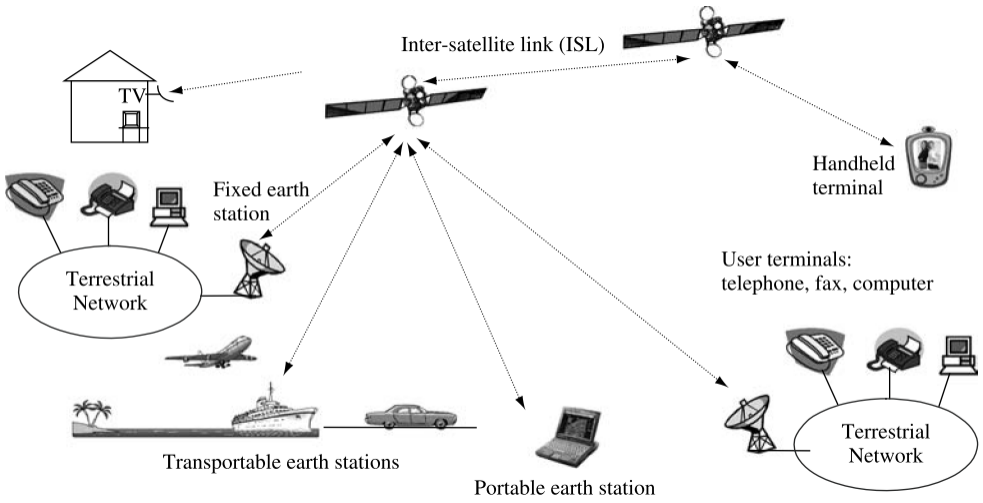


Figure 2: A zoom in Satellite link

  - terrestrial networks
  - satellites with/without inter-satellite links (ISL)
  - Earth Stations
    * based on mobility: can be categorized into fixed earth stations and transportable earth stations
    * based on type of users: can be categorized into user earth station (UES) or gateway earth station (GES)
  - portable and hand-held terminals, and
  - user terminals connecting to satellite links directly or through terrestrial networks.

- Satellite networks share many fundamental concepts with general networking
  - In terms of topology, it can be configured into star or mesh topologies.
  - In terms of transmission technology, it can be set up for point-to-point, point-to-multipoint and multipoint-to-multipoint connections.

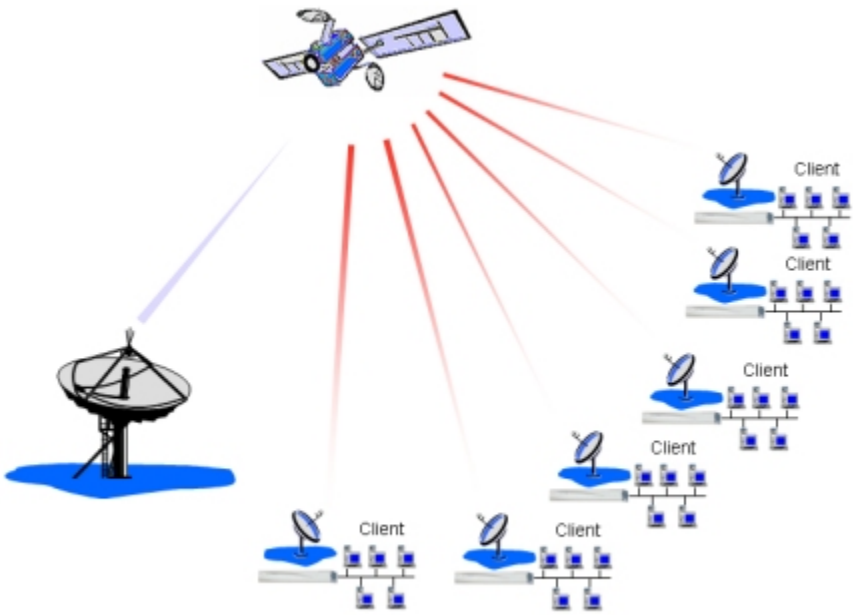


Figure 3: Point to multi-point Topology

  - In terms of interface, we can easily map the satellite network in general network terms such as user network interface (UNI) and network nodes interface (NNI).

1.1 Satellite Network Architecture

- Satellite network architecture can be generally split into two segments, specifically space segment and ground segment as shown in Figure 4.

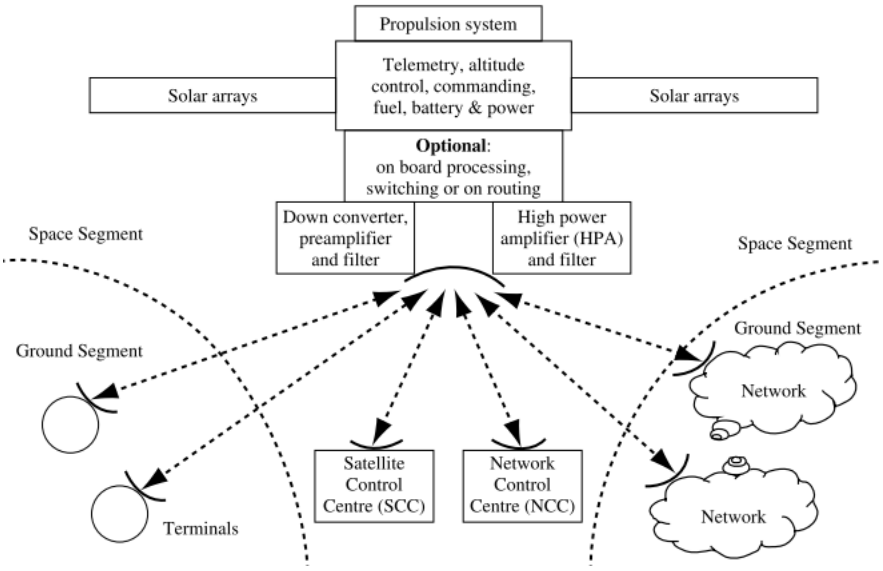


Figure 4: Satellite Network Architecture

1.1.1 Space Segment

- The space segment consists of the satellite, the satellite control center (SCC) and network control center (NCC) (also known as network management center (NMC)). Note that SCC and NCC are located at ground level.

Satellites

- Each satellite consists of a communication subsystem and platform.
- The platform provides the structure support and power supply of the communication subsystems, and also includes altitude control, orbit control, thermal control, tracking, telemetry and telecommand (TT&T) to maintain normal operations of the satellite system.
- The telecommunication subsystems consist of transponders and antenna. The antennas associated with the transponders are specially designed to provide coverage for the satellite network.
- Modern satellites may also have onboard processing (OBP) and onboard switching (OBS).
- There are different types of transponders:
  - ***Transparent transponders*** provide the function of relaying radio signals. They receive transmissions from the earth station and retransmit them to the earth station after amplification and frequency translation. Satellites with transparent transponders are called transparent satellites.

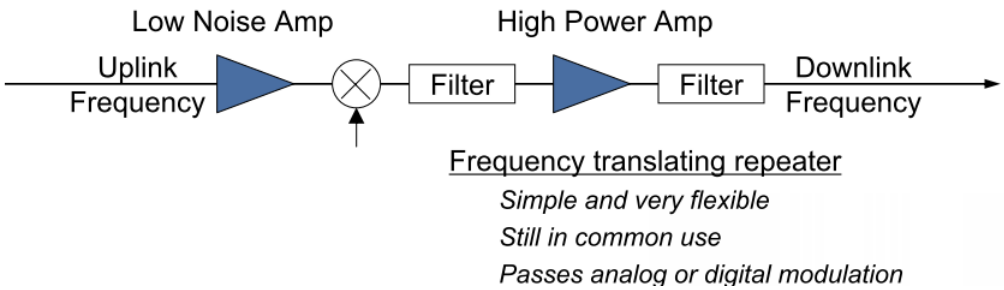


Figure 5: Transparent Transponder

- ***OBP transponders*** provide addition functions including digital signal processing (DSP), regeneration and base band signal processing before retransmitting the signal from satellite to the earth station. Satellites with OBP transponders are called OBP satellites.
- ***OBS transponders*** have additional functions than OBP transponders, providing switching functions. Similarly, satellites with OBS transponders are called OBS satellites. With the rapid development of the Internet, experiments are also in progress to fly onboard routers.

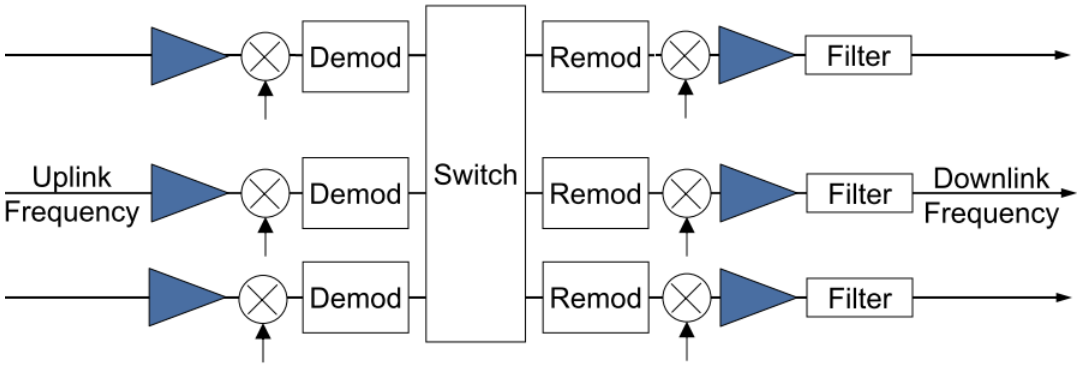


Figure 6: Onboard Operations

SCC

- SCC is the on-ground system responsible for the operation of the satellite.
- SCC monitors the status of the different satellite subsystems through telemetry links, controls the satellite on its nominal orbit through telecommand links.
- SCC communicates with the satellite using dedicated links, which are different from the communication links.
- SCC normally consists of typically one earth station and GEO or non-GEO satellite systems.
- SCC receives telemetry from the satellites and sends telecommands to the satellites.
- Typically, a backup SCC is built at a different location to improve reliability and availability.

NCC

- NCC is in charge of managing the access and bandwidth allocation
- NCC it typically located in a major earth station but it may be located onboard for modern satellites.

1.1.2 Ground Segment

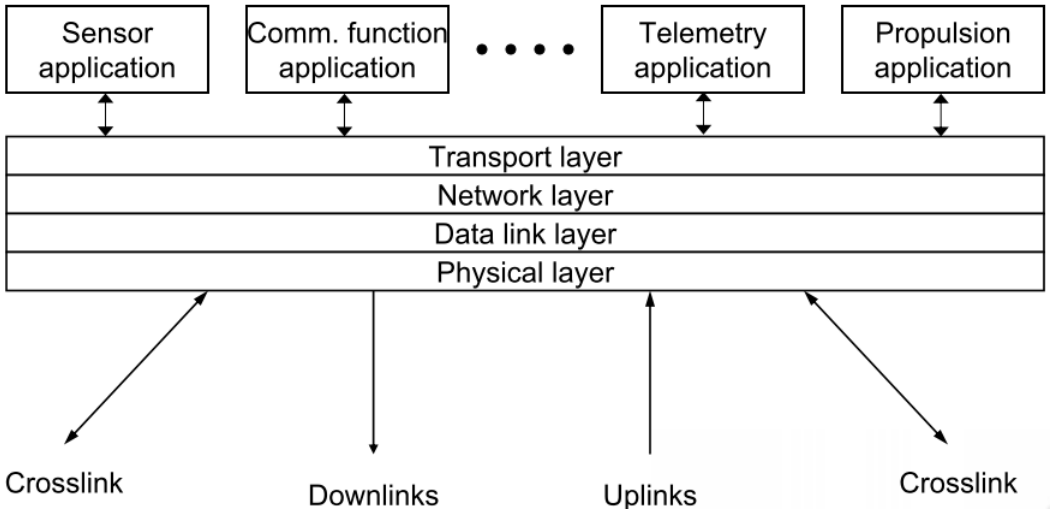
- The earth station is the main element in the ground segment.
- Each earth station transmits and receives traffic signals to and from satellites and provides interfaces to terrestrial networks or to user terminals directly.
- The earth station may consist of the following parts:
  - The transmitting and receiving antenna (ranging from below 0.5 metres to 16 metres and above) are the most visible parts of the earth station.
  - Low noise amplifier of the receiver system with noise temperature ranging from about 30 Kelvin to a few hundred Kelvin.
  - High performance amplifier (HPA) of the transmitter with power from a few watts to a few thousands kilowatts depending on capacity.
  - Modulation, demodulation and frequency translation.
  - Signal processing.
  - Interfaces to terrestrial networks or user terminals.

1.1.3 Satellite Network Interfaces

- Technically, there exist three different interfaces in satellite networks
  - UES-User terminal interface
  - GES-Teresstrial network interface
  - ISL interface

2 Satellite Broadband Networks

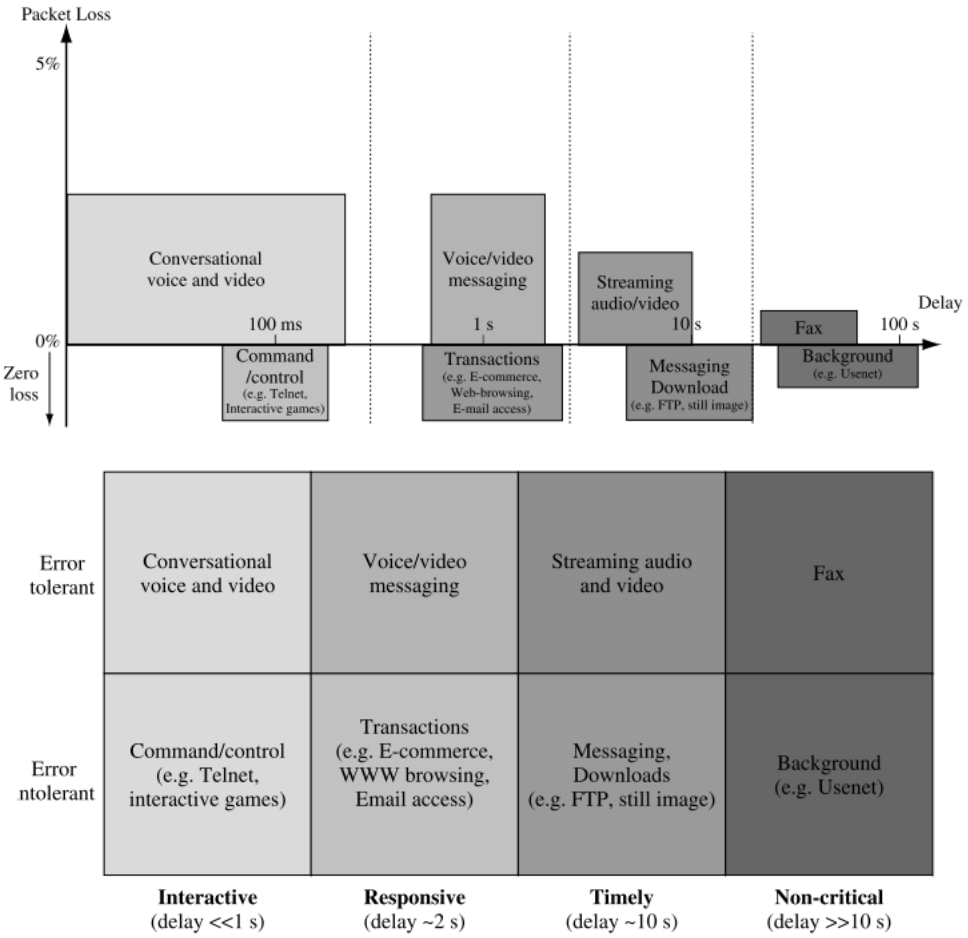
- Our focus in the rest of this lecture series would be satellite broadband services.



- Clearly, many applications may share a satellite link. These applications have different requirements (bandwidth, delay, error limit) and operating constraints.
- In the sequel, we highlight these requirements for the most common applications. Additionally, we present well-known general frameworks for providing these requirements.

2.1 Application Quality of Service (QoS)

- The most commonly used QoS metrics include
  - packet error rate, defined as the ratio between the erroneous packets to the total transmitted packets.
  - packet delay, defined as the difference between the the packet availability at the sender until it is received at its intended destination.
  - system throughput, defined as the amount of transmitted data over unit time.
- The sensitivity of different applications to error and delay are shown in the following figures.



- In order to provide these QoS requirements, many changes may be introduced to the standard protocol stack to improve the performance. In this following lectures, we will introduce some of these changes
  - Application layer improvements (pipelining, caching, admission control, bundling)
  - TCP improvements (split connection, selective acknowledgment, window size, ...)
  - link management (dynamic resource allocation, traffic classification, packet scheduling, ..)
- Many of these functions are typically implemented in the last node connected to the satellite modem. This node is commonly knows as performance enhancing proxy (PEP)

References

[1] Zhili Sun, "Satellite Networking: Principles and Protocols," John Wiley & Sons Ltd, 2005