ECF 5233 Satellite Communication

Lecture 16.

Multiplexing and Multiple Access in satellite systems.

* Satellites are expensive
  + Hardware costs
  + Launch cost
  + Operation cost
  + Spectrum cost

  To make the system viable from a commercial standpoint,
  the satellite systems need to be designed/operated in
  an efficient manner so shared between many users.

* Two basic concepts that allow efficient use of satellite systems

  1. Multiplexing.
  2. Multiple Access.

1. Multiplexing - aggregation of ground signals before it is sent over a satellite link.

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geographical region 1
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Reverse process of multiplexing is de-multiplexing.
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geographical region 2
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Contemporary networks most common multiplexing scheme is Time Division Multiplexing (TDM).

Three standards:
- North American (T-1 hierarchy)
- European (E-1 hierarchy)
- Japanese (T-1 hierarchy)

Basic unit: 64 kbps corresponds to a single voice channel.

\[
\begin{align*}
4 \times DS0 &= T1 (or DS1) & \text{First level multiplex: } & 1.544 \text{ Mbps} \\
2 \times DS1 &= DS3c & \text{Intermediate layer: } & 5.152 \text{ Mbps} \\
4 \times DS1 &= DS2 (or T2) & \text{Second level multiplexing: } & 6.312 \text{ Mbps} \\
7 \times DS2 &= DS4 (or T3) & \text{Third level multiplexing: } & 44.736 \text{ Mbps} \\
6 \times DS4 &= DS3 (or T4) & \text{Fourth level multiplexing: } & 274.176 \text{ Mbps}
\end{align*}
\]

Multiplexing may be:

a) Channelized - respects the standard TDM organization

b) Non-channelized - treats given level of multiplex as a "pipe" that can be filled in a manner that gives best resource utilization. This leads to fractional channel assignments on lower end or fractional channel aggregation on upper end.
Multiple Access - Methods that allow multiple users to access the satellite

There are 3 basic access schemes used in satellite systems.

1) Frequency division multiple access (FDMA)
2) Time division multiple access (TDMA)
3) Code division multiple access (CDMA)

Typically, systems combine multiplexing and access. For example, satellites may be

1) FDMA-FDMA: Frequency division multiplexing + Frequency division access
2) TDMA-FDMA: Time division multiplexing + Frequency division access

1) FDMA - overview

![Diagram](image)

Users are co-time, but they are separated in frequency domain. This is the most common access scheme in satellite links since it requires no time synchronization between the users and it is somewhat tolerant to differences between their received powers. (more known: CDMA)
Users are separated in time domain. The user look times (i.e. operate in
five time slots) in utilizing the entire bandwidth of the transponder. This
scheme is sensitive to timing synchronization between the users and it is
appropriate for LEO and MEO non GEO satellites. It is robust with respect
to power differences of individual users since they do not utilize the transponder
simultaneously.

* Users are co-time and co-frequency but the signals are encoded with orthogonal
spreading codes. The spreading codes allow receiver to separate individual signals.
CDMA is quite sensitive to power differences between the users and requires tight power control. It is more appropriate for LEO users.

**Frequency Division Multiple Access.**

There are two approaches for implementing FDMA in satellite networks:

1) One carrier per link
2) Single Connectors per Carrier.

1) Illustration of one carrier per link

- Possible links:
  - A→B
  - A→C
  - B→A
  - B→C
  - C→A
  - C→B

- Transponder bandwidth

* For three stations there are six links. In general, for N earth stations, there will be \( N(N-1) \) links — this leads to overcrowding of spectrum and loss of tracking efficiency, especially in Rx assignment. Even each earth station could demodulate only path of satellite signal directed to its consumption (see above figure).
Single Connection Per Carrier (SCPC)

In this case all traffic from a single earth station is aggregated on a single carrier.

The SCPC is more efficient from the spectrum use standpoint. It allows traffic balancing between different links. In the case of N earth stations there are only N links which makes segmentation of spectrum and loss of efficiency due to guard bands.

Each ES demodulates all the traffic (except its own) and then performs the selection of relevant one while discarding the rest.

Outline of a SCPC Earth Station block diagram

TX Channels  →  Modulator  →  TX

Demux  →  Channel Select  →  Demux

Communication from B to C is demodulated but is discarded. Error signal is never at the station A.
There are 2 types of assignment:

1) Fixed assignment - spectrum of the carrier is preassigned to each station.
2) Assignment on the demand - spectrum is assigned in a flexible manner depending on the traffic needs of a given ES.

Most contemporary systems implement TDM-SCPC-FDMA with either fixed or flexible assignment.

**FDMA-Adjacent Channel Interference / IH products**

A provides limits on how close the signal may be in frequency domain.
B provides limits on how different signal power levels may be.

**Adjacent Channel Interference (ACI)**

![Adjacent Channel Interference Diagram]

ACI - Interference between adjacent satellite signals. It depends on the following factors:

1) Type of modulation schemes used for signals
2) Power levels of individual signals
3) Amount of spectrum allocated for the guardbands
4) Filtering capabilities of the ES receivers
The ACI is unavoidable part of the satellite communication FDMA. It originates at the transponder RX regardless of transponder amplifier nonlinearities. In other words, it is not caused by intermodulation products. To mitigate its effects, the following steps are taken:

1) Choose modulation schemes with small sidelobes. This is achieved through either short phase horizons between modulation symbols or through signal filtering at the ES transmitter. Most of these techniques are used.

2) Guard bands are selected based on type of modulation used.

3) The signal power is managed so that the signals arrive at the satellite transponder at approximately same power levels.