Multiple Access System

- TDMA and FDMA require a degree of coordination among users:
  - FDMA users cannot transmit on the same frequency and
  - TDMA users can transmit on the same frequency but not at the same time.
- Capacity in either case can be calculated based on the total bandwidth and power available within the transponder or slice of a transponder.
- CDMA is unique in that multiple users transmit on the same frequency at the same time (and in the same beam or polarization).
- This is allowed because the transmissions use a different code either in terms of high-speed spreading sequence or frequency hopping sequence.

Multiple Access System

- The capacity of a CDMA network is not unlimited, however, because at some point the channel becomes overloaded by self-interference from the multiple users who occupy it.
- Furthermore, power level control is critical because a given CDMA carrier that is elevated in power will raise the noise level for all others carriers by a like amount.

Multiple Access System

- Multiple access is always required in networks that involve two-way communications among multiple Earth stations.
- The selection of the particular method depends heavily on the specific communication requirements, the types of Earth stations employed, and the experience base of the provider of the technology.
- All three methods are now used for digital communications because this is the basis of a majority of satellite networks.

Multiple Access System

- The digital form of a signal is easier to transmit and is less susceptible to the degrading effects of the noise, distortion from amplifiers and filters, and interference.
- Once in digital form, the information can be compressed to reduce the bit rate, and FEC is usually provided to reduce the required carrier power even further.
- The specific details of multiple access, modulation, and coding are often preselected as part of the application system and the equipment available on a commercial off-the-shelf (COTS) basis.

Multiple Access System

- The only significant analog application at this time is the transmission of cable TV and broadcast TV.
- These networks are undergoing a slow conversion to digital as well, which may in fact be complete within a few years.

FDMA

- Nearly every terrestrial or satellite radio communications system employs some form of FDMA to divide up the available spectrum.
- The areas where it has the strongest hold are in single channel per carrier (SCPC), intermediate data rate (IDR) links, voice telephone systems, VSAT data networks, and some video networking schemes.
- Any of these networks can operate alongside other networks within the same transponder.
- Users need only acquire the amount of bandwidth and power that they require to provide the needed connectivity and throughput.
- Also, equipment operation is simplified since no coordination is needed other than assuring that each Earth station remains on its assigned frequency and that power levels are properly regulated.
- However, inter-modulation distortion (IMD) present with multiple carriers in the same amplifier must be assessed and managed as well.

FDMA

- The satellite operator divides up the power and bandwidth of the transponder and sells off the capacity in attractively priced segments.
- Users pay for only the amount that they need. If the requirements increase, additional FDMA channels can be purchased.
- The IMD that FDMA produces within a transponder must be accounted for in the link budget; otherwise, service quality and capacity will degrade rapidly as users attempt to compensate by increasing uplink power further.
- The big advantage, however, is that each Earth station has its own independent frequency on which to operate.
- A bandwidth segment can be assigned to a particular network of users, who subdivide the spectrum further based on individual needs.
- Another feature, is to assign carrier frequencies when they are needed to satisfy a traffic requirement. This is the general class of demand assigned networks, also called demand-assigned multiple access (DAMA).
- In general, DAMA can be applied to all three multiple access schemes previously described; however, the term is most often associated with FDMA.

Time Division Multiple Access and ALOHA

- TDMA is a truly digital technology, requiring that all information be converted into bit streams or data packets before transmission to the satellite. (An analog form of TDMA is technically feasible but never reached the market due to the rapid acceptance of the digital form.)
- Contrary to most other communication technologies, TDMA started out as a high-speed system for large Earth stations.
- Systems that provided a total throughput of 60 to 250 Mbps were developed and fielded over the past 25 years.
- However, it is the low-rate TDMA systems, operating at less than 10 Mbps, which provide the foundation of most VSAT networks.
- As the cost and size of digital electronics came down, it became practical to build a TDMA Earth station into a compact package.

Time Division Multiple Access and ALOHA

- Lower speed means that less power and bandwidth need to be acquired (e.g., a fraction of a transponder will suffice) with the following benefits:
  - The uplink power from small terminals is reduced, saving on the cost of transmitters.
  - The network capacity and quantity of equipment can grow incrementally, as demand grows.

Time Division Multiple Access and ALOHA

- TDMA signals are restricted to assigned time slots and therefore must be transmitted in bursts.
- The time frame is periodic, allowing stations to transfer a continuous stream of information on average.
- Reference timing for start-of-frame is needed to synchronize the network and provide control and coordination information.
- This can be provided either as an initial burst transmitted by a reference Earth station, or on a continuous basis from a central hub.
- The Earth station equipment takes one or more continuous streams of data, stores them in a buffer memory, and then transfers the output toward the satellite in a burst at a higher compression speed.

Time Division Multiple Access and ALOHA

- At the receiving Earth station, bursts from Earth stations are received in sequence, selected for recovery if addressed for this station, and then spread back out in time in an output expansion buffer.
- It is vital that all bursts be synchronized to prevent overlap at the satellite; this is accomplished either with the synchronization burst (as shown) or externally using a separate carrier.
- Individual time slots may be pre-assigned to particular stations or provided as a reservation, with both actions under control by a master station.
- For traffic that requires consistent or constant timing (e.g., voice and TV), the time slots repeat at a constant rate.

Time Division Multiple Access and ALOHA

- Computer data and other forms of packetized information can use dynamic assignment of bursts in a scheme much like a DAMA network.
- There is an adaptation for data, called ALOHA, that uses burst transmission but eliminates the assignment function of a master control.
- ALOHA is a powerful technique for low cost data networks that need minimum response time. Throughput must be less than 20% if the bursts come from stations that are completely uncoordinated because there is the potential for time overlap (called a collision).

Time Division Multiple Access and ALOHA

- The most common implementation of ALOHA employs a hub station that receives all of these bursts and provides a positive acknowledgement to the sender if the particular burst is good.
- If the sending station does not receive acknowledgment within a set “time window,” the packet is re-sent after a randomly selected period is added to prevent another collision.
- This combined process of the window plus added random wait introduces time delay, but only in the case of a collision.
- Throughput greater than 20% brings a high percentage of collisions and resulting retransmissions, introducing delay that is unacceptable to the application.

Time Division Multiple Access and ALOHA

- An optimally and fully loaded TDMA network can achieve 90% throughput, the only reductions required for guard time between bursts and other burst overhead for synchronization and network management.
- The corresponding time delay is approximately equal to one-half of the frame time, which is proportional to the number of stations sharing the same channel.
- This is because each station must wait its turn to use the shared channel.
- ALOHA, on the other hand, allows stations to transmit immediately upon need. Time delay is minimum, except when you consider the effect of collisions and the resulting retransmission times.

Time Division Multiple Access and ALOHA

- TDMA is a good fit for all forms of digital communications and should be considered as one option during the design of a satellite application.
- The complexity of maintaining synchronization and control has been overcome through miniaturization of the electronics and by way of improvements in network management systems.
- With the rapid introduction of TDMA in terrestrial radio networks like the GSM standard, we will see greater economies of scale and corresponding price reductions in satellite TDMA equipment.

Code Division Multiple Access

- CDMA, also called spread spectrum communication, differs from FDMA and TDMA because it allows users to literally transmit on top of each other.
- This feature has allowed CDMA to gain attention in commercial satellite communication.
- It was originally developed for use in military satellite communication where its inherent anti-jam and security features are highly desirable.
- CDMA was adopted in cellular mobile telephone as an interference-tolerant communication technology that increases capacity above analog systems.

Code Division Multiple Access

- It has not been proven that CDMA is universally superior as this depends on the specific requirements.
- For example, an effective CDMA system requires contiguous bandwidth equal to at least the spread bandwidth.
- Two forms of CDMA are applied in practice:
  (1) direct sequence spread spectrum (DSSS) and
  (2) frequency hopping spread spectrum (FHSS).
- FHSS has been used by the OmniTracs and Eutel-Tracs mobile messaging systems for more than 10 years now, and only recently has it been applied in the consumer's commercial world in the form of the Bluetooth wireless LAN standard. However, most CDMA applications over commercial satellites employ DSSS (as do the cellular networks developed by Qualcomm).

Code Division Multiple Access

- Consider the following summary of the features of spread spectrum technology (whether DSSS or FHSS):
  - Simplified multiple access: no requirement for coordination among users;
  - Selective addressing capability if each station has a unique chip code sequence—provides authentication: alternatively, a common code may still perform the CDMA function adequately since the probability of stations happening to be in synch is approximately $1/n$;
  - Relative security from eavesdroppers: the low spread power and relatively fast direct sequence modulation by the pseudorandom code make detection difficult;
  - Interference rejection: the spread-spectrum receiver treats the other DSSS signals as thermal noise and suppresses narrowband interference.

Code Division Multiple Access

- A typical CDMA receiver must carry out the following functions in order to acquire the signal, maintain synchronization, and reliably recover the data:
  - Synchronization with the incoming code through the technique of correlation detection;
  - De-spreading of the carrier;
  - Tracking the spreading signal to maintain synchronization;
  - Demodulation of the basic data stream;
  - Timing and bit detection;
  - Forward error correction to reduce the effective error rate;

Code Division Multiple Access

- The first three functions are needed to extract the signal from the clutter of noise and other signals.
- The processes of demodulation, bit timing and detection, and FEC are standard for a digital receiver, regardless of the multiple access method.