Networking Concepts and Protocols

1 Multiplexing

Multiplexing is a technique used to combine multiple signals for transmission over a single communication channel or medium. This method maximizes the utilization of available bandwidth by allowing multiple data streams to share the same communication channel.

1.1 Types of Multiplexing

- **Frequency Division Multiplexing (FDM)**: Each signal is assigned a unique frequency within the channel's available bandwidth, allowing multiple signals to be transmitted simultaneously.
- **Time Division Multiplexing (TDM)**: Each signal is assigned a specific time slot within a repeating cycle. Only one signal is transmitted at a time, but by rapidly alternating time slots, it achieves the appearance of simultaneous transmission.
- **Wavelength Division Multiplexing (WDM)**: Commonly used in fiber-optic communication, WDM allows multiple light signals at different wavelengths to be transmitted over the same fiber.
- **Code Division Multiplexing (CDM)**: Each signal is assigned a unique code, allowing multiple signals to occupy the same channel simultaneously by spreading them over a range of frequencies.

1.2 Applications

- **Telecommunications**: Multiplexing enables efficient use of bandwidth in telephone networks, where many calls share a single line.
- **Computer Networks**: TDM is used in packet-switched networks to allow multiple data streams to share the same channel.
- **Broadcasting**: In cable TV, FDM allows multiple channels to be transmitted simultaneously over a single cable.

2 Frequency-Hopping Spread Spectrum (FHSS)

FHSS is a spread spectrum technique where the carrier frequency of the signal rapidly switches or "hops" among multiple frequencies within a designated range. This hopping follows a sequence known only to the transmitter and receiver, adding security and interference resistance to the signal.

2.1 How FHSS Works

- **Frequency Hopping**: The transmitter changes its carrier frequency in a pseudorandom pattern, which the receiver must know in advance to follow and decode the signal.
- **Bandwidth Usage**: By hopping frequencies, the signal spreads over a wider bandwidth than would otherwise be necessary, making it less vulnerable to narrowband interference.

2.2 Advantages

- **Interference Resistance**: If interference occurs on one frequency, the signal can still be received as it rapidly switches to other frequencies.
- **Security**: The pseudorandom hopping pattern makes it difficult for unauthorized receivers to intercept the signal.
- **Multipath Resistance**: FHSS reduces the impact of multipath fading, common in environments with reflective surfaces.

3 Direct Sequence Spread Spectrum (DSSS)

DSSS is a spread spectrum technique in which the data signal is spread by multiplying it with a high-rate pseudorandom code, called a spreading code or chip sequence. This spreads the signal over a wider frequency band than the original data bandwidth.

3.1 How DSSS Works

- **Spreading Code**: Each bit in the data signal is multiplied by a high-rate pseudorandom code.
- **Wideband Signal**: This multiplication process spreads the data signal across a wide frequency band.
- **Demodulation**: The receiver uses the same pseudorandom code to despread the signal, recovering the original data.

4 Automatic Repeat Request (ARQ)

ARQ is a protocol used for error control in data communication. There are three primary versions:

4.1 Types of ARQ

1. **Stop-and-Wait ARQ**
    - Transmits one frame and waits for acknowledgment
    - Inefficient for high-latency networks

2. **Go-Back-N ARQ**
    - Can transmit multiple frames before receiving acknowledgment
    - Limited by window size N
    - Retransmits all frames from error point
3. **Selective Repeat ARQ**
    - Retransmits only erroneous frames
    - More efficient in handling errors
    - Requires complex buffer management

5 Synchronous Time Division Multiplexing (TDM)

Synchronous TDM is a method where multiple data streams are transmitted over a single communication channel by assigning each stream a fixed time slot in a repeating sequence.

5.1 Key Characteristics

- **Time Slots**: Channel divided into fixed time slots
- **Synchronization**: Sender and receiver must be synchronized
- **Fixed Allocation**: Pre-determined slot order

6 Frequency Division Multiplexing (FDM)

FDM allows multiple signals to be transmitted simultaneously over a single channel by assigning each signal a unique frequency within the available bandwidth.

6.1 Key Features

- **Frequency Allocation**: Each signal gets unique carrier frequency
- **Guard Bands**: Prevent interference between adjacent channels
- **Simultaneous Transmission**: All signals transmitted concurrently

7 Sliding-Window Flow Control

A technique for managing data flow between network devices that allows multiple frames to be sent before requiring acknowledgment.

7.1 Advantages over Stop-and-Wait

- **Continuous Data Flow**: Multiple frames in transit simultaneously
- **Better Bandwidth Utilization**: Maximizes channel usage
- **Reduced Delays**: Fewer transmission pauses
- **Higher Efficiency**: Particularly beneficial in high-latency networks