

Physical Layer

Multiplexing and Spread Spectrum

Multiplexing at the Physical Layer

- **Goal:** Get many information flows on a single physical channel.

- **Basic techniques:**
 - For circuit-switched networks:
 - **Frequency Division Multiplexing (FDM)**
 - **Time Division Multiplexing (TDM)**

 - For packet-switched networks:
 - **Statistical Multiplexing**

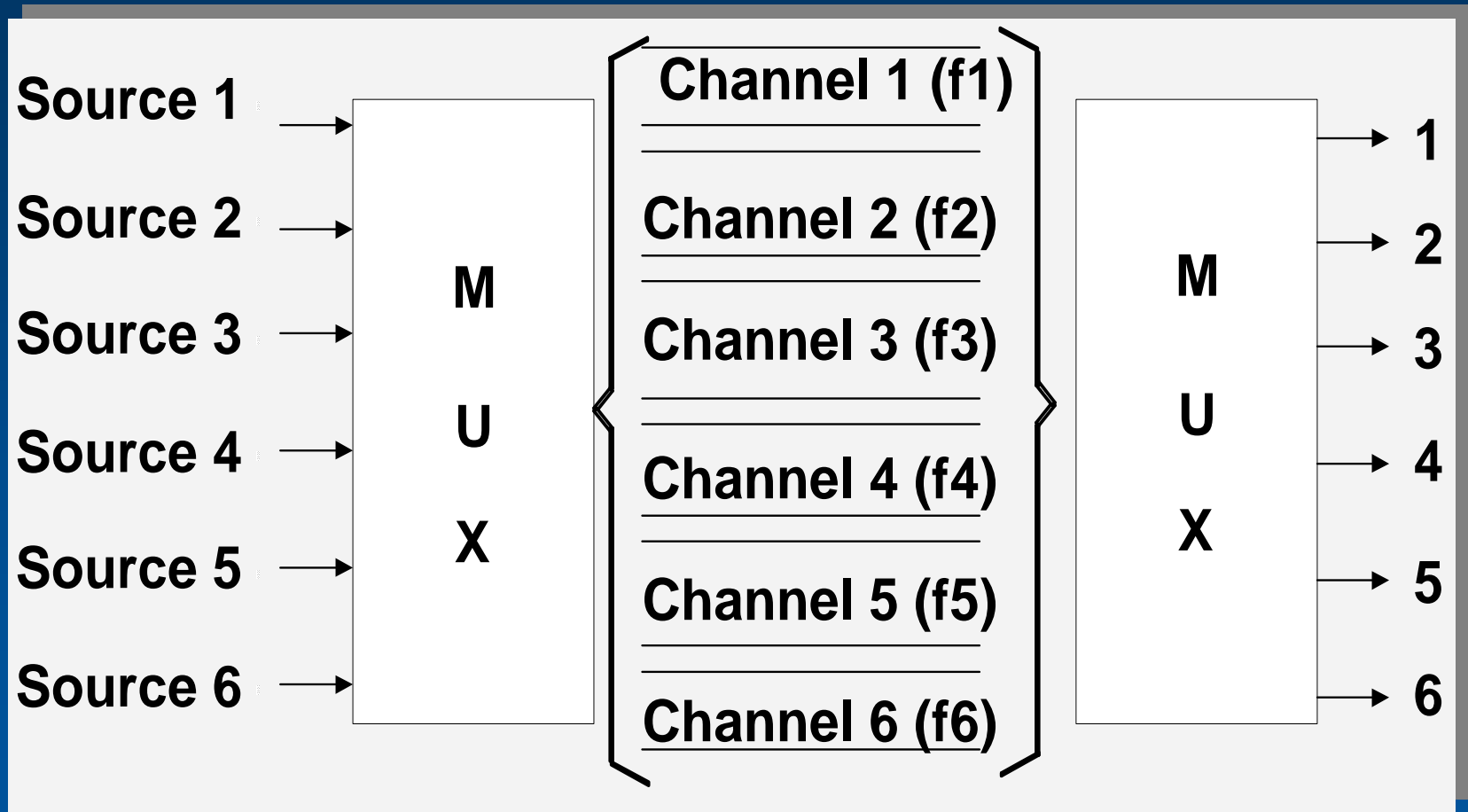
Frequency Division Multiplexing (FDM)

- Used in radio, TV, analog telephone transmission, satellite communication
- **Idea:** Divide the frequency spectrum into logical channels and assign each information flow one logical channel
- **Example:** Voice in (analog) telephone network:

Needed bandwidth:	3000 Hz
Allocated bandwidth:	4000 Hz

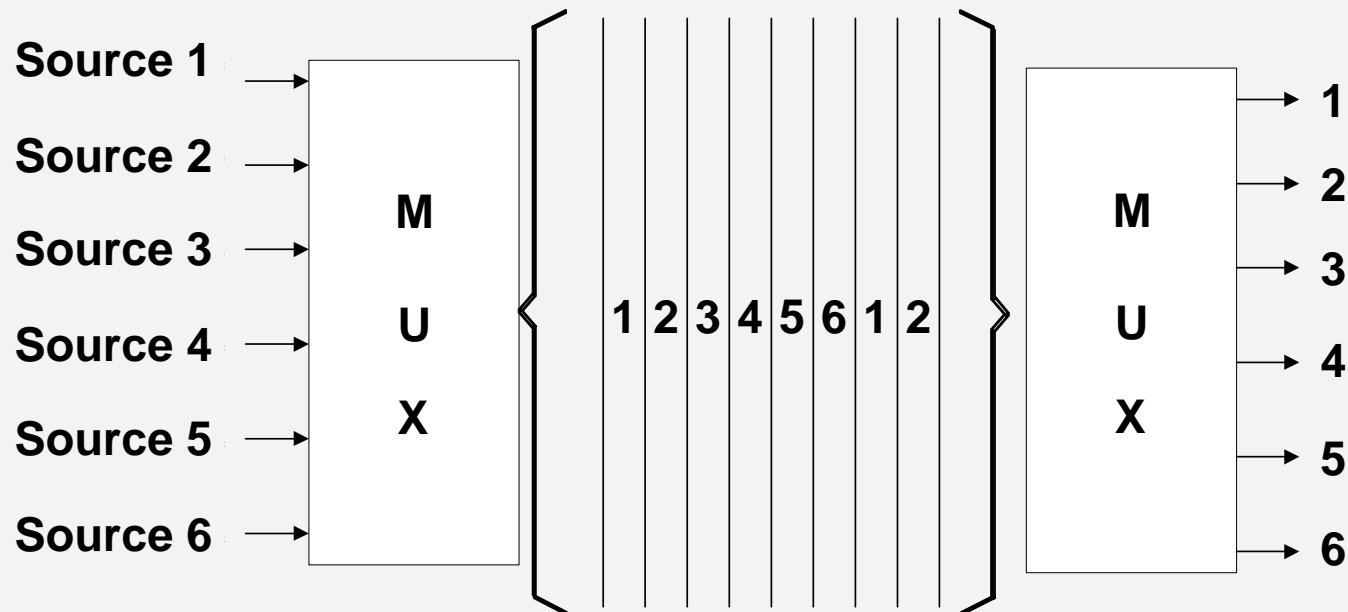
Therefore, a channel with 64 kHz can carry 16 voice conversations

Frequency Division Multiplexing (FDM)



Time Division Multiplexing (TDM)

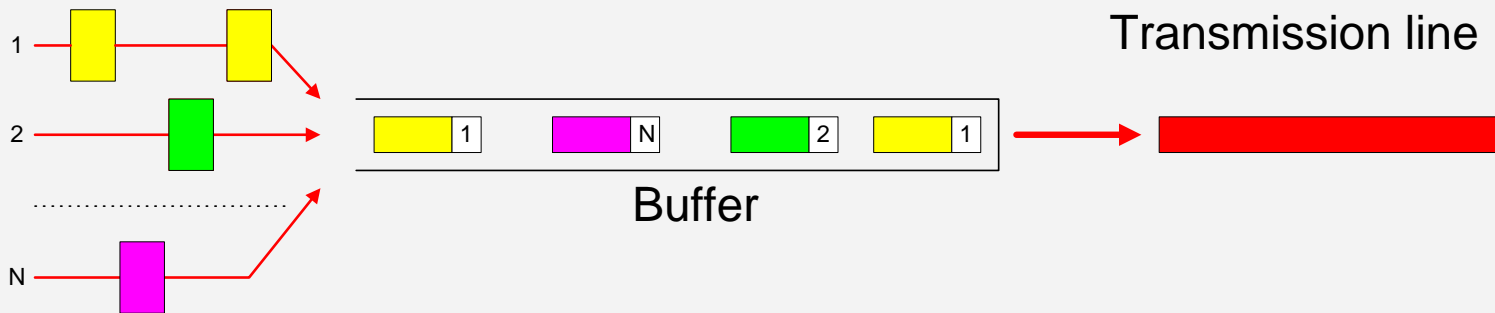
- Used for digital telephone transmission, satellite communication
- **Idea:** Multiple signals can be carried on a single transmission medium by interleaving portions of each signal in time



Statistical Multiplexing (TDM)

- Assumes that data is organized in “packets”. Packets are stored in a buffer before they are transmitted
- Advantage over TDM: Statistical multiplexing utilizes the available bandwidth more efficiently
- Note: Statistical multiplexing is sometimes referred to as statistical TDM

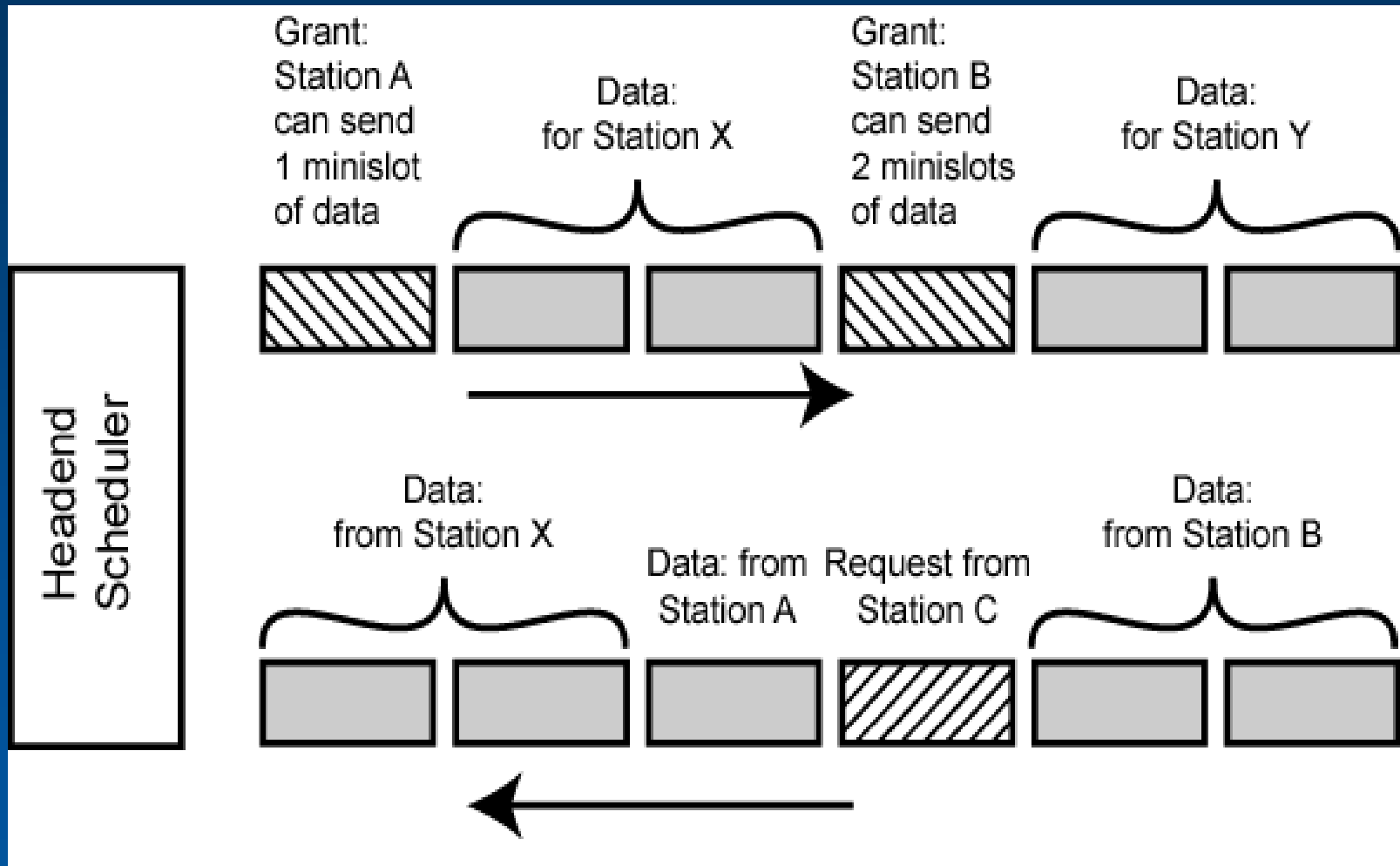
Packets from different streams



Cable Modem

- Two channels from cable TV provider dedicated to data transfer
 - One in each direction
- Each channel shared by number of subscribers
 - Scheme needed to allocate capacity
 - Statistical TDM
- Downstream
 - Cable scheduler delivers data in small packets
 - If more than one subscriber active, each gets fraction of downstream capacity
 - May get 500kbps to 1.5Mbps
 - Also used to allocate upstream time slots to subscribers
- Upstream
 - User requests timeslots on shared upstream channel
 - Dedicated slots for this
 - Headend scheduler sends back assignment of future time slots to subscriber

Cable Modem

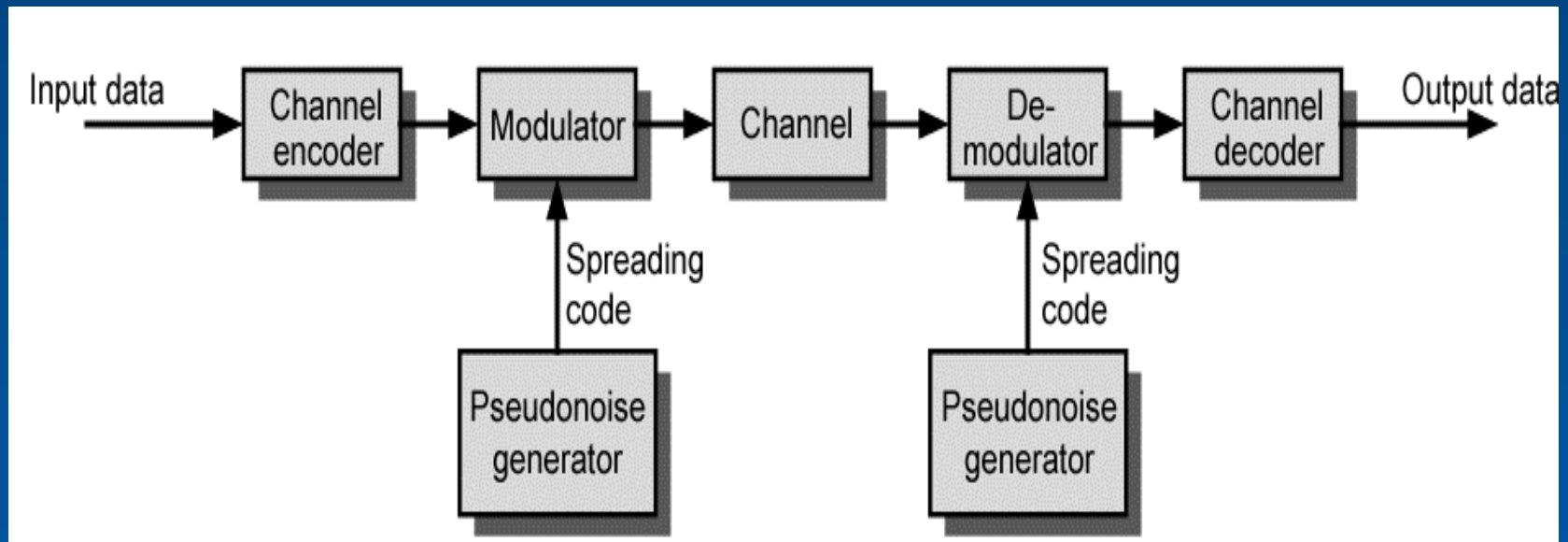


DSL

- Provide high-speed digital transmission of the subscriber line.
- The most important schemes:
 - ADSL
Asymmetric mode, analog signaling
 - HDSL
Attractive for replacing T1 line. Requires two twisted pair.
 - SDSL
Provides same type of service as HDSL over a single twisted pair.
 - VDSL
Similar to ADSL at a higher rate but shorter distance.

Spread Spectrum

- Analog or digital data
- Analog signal
- Spread data over wide bandwidth
- Makes jamming and interception harder



Spread Spectrum

- Frequency hopping
 - Signal broadcast over seemingly random series of frequencies.
- Direct Sequence
 - Each bit is represented by multiple bits in transmitted signal.
 - Chipping code
- Code division multiple access (CDMA)
 - Enable multiple users to independently use the same bandwidth with very little interference.
 - Used in cellular telephony applications.