Multiplexing and Demultiplexing

Multiplexing

- *Multiplexing* means combining multiple streams of information for transmission over a shared medium.
- *Demultiplexing* performs the reverse function: split a combined stream arriving from a shared medium into the original information streams.

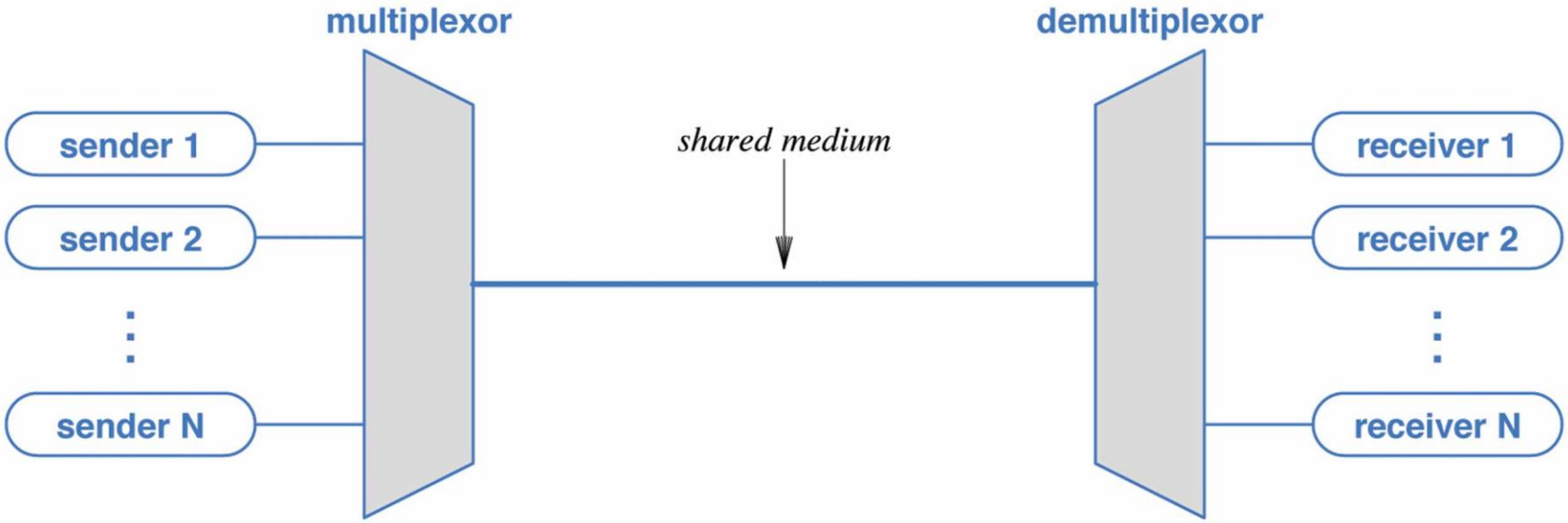

Figure 11.1 The concept of multiplexing in which independent pairs of senders and receivers share a transmission medium.

Types of Multiplexing

- Frequency Division Multiplexing.
- Wavelength Division Multiplexing.
- Time Division Multiplexing.
- Statistical Time Division Multiplexing.
- Code Division Multiplexing.

Frequency Division Multiplexing (FDM)

- It is the basis for broadcast radio.
- Several stations can transmit simultaneously without interfering with each other provided they use separate carrier frequencies (separate channels).
- In data communications FDM is implemented by sending multiple carrier waves over the same copper wire.
- At the receiver's end, demultiplexing is performed by filtering out the frequencies other than the one carrying the expected transmission.
- Any of the modulation methods discussed before can be used to carry bits within a channel.

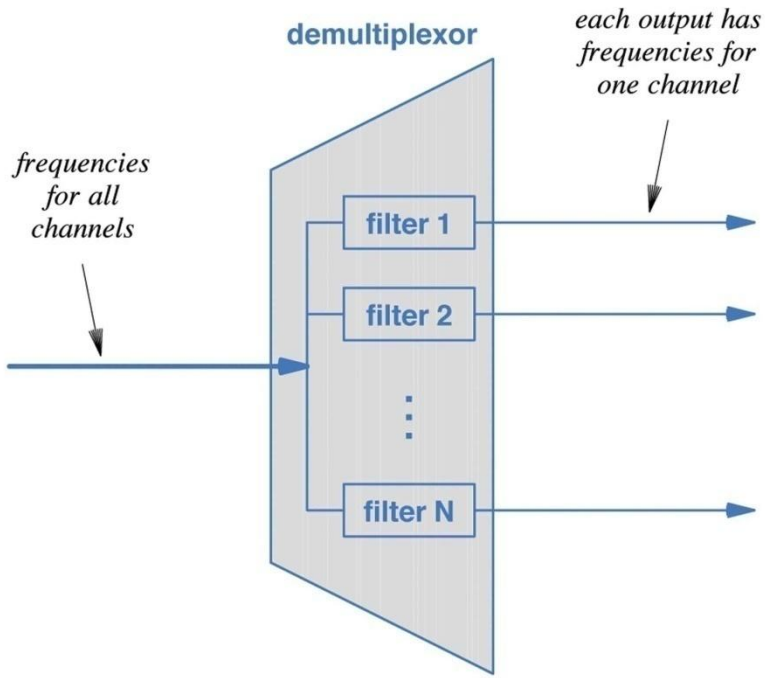

Figure 11.2 Illustration of the basic FDM demultiplexing where a set of filters each selects the frequencies for one channel and suppresses other frequencies.

- Rather than a single frequency, each channel is assigned a contiguous range of frequencies.
- Channels are separated from each other by *guard bands* to make sure there is no interference among the channels.
- Why is a range of frequencies assigned rather than a single frequency?
  - Sender can do FDM within its channel to increase the data rate. For example, it can split its channel into *K* subchannels and transmit 1/*K* of the data over each subchannel. This will result in a K-fold increase of the data rate.
  - *Spread spectrum*: Transmit the same information over *K* separate subchannels. If there is interference in one of the subchannels, the receiver can tune in one of the other subchannels.

Channel	Frequencies Used
1	100 KHz - 300 KHz
2	320 KHz - 520 KHz
3	540 KHz - 740 KHz
4	760 KHz - 960 KHz
5	980 KHz - 1180 KHz
6	1200 KHz - 1400 KHz

Figure 11.4 An example assignment of frequencies to channels with a guard band between adjacent channels.

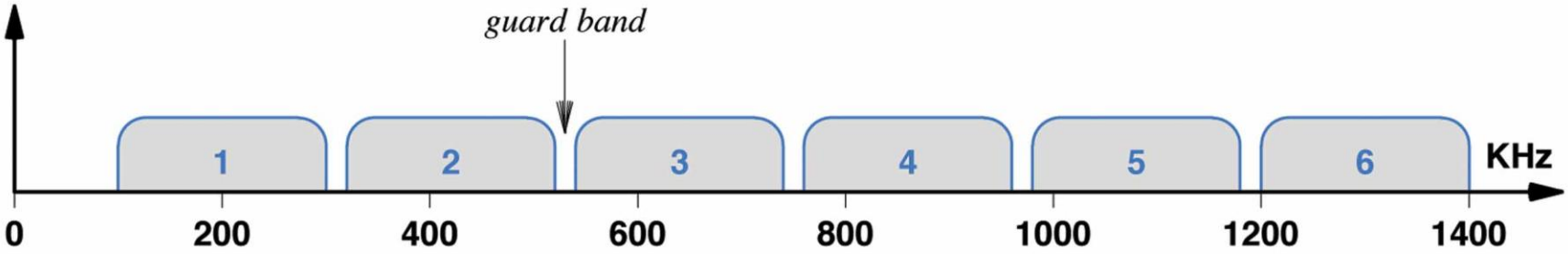

Figure 11.5 A frequency domain plot of the channel allocation from Figure 11.4 with a guard band visible between channels.

Wavelength Division Multiplexing

- In optical transmissions, FDM is known as *Wavelength Division Multiplexing* (WDM).
- With light different frequencies correspond to different colors.
- Several transmissions can be send over the same fiber by using different light colors, and combining into a single light stream.
- Prisms are used as multiplexors and demultiplexors.

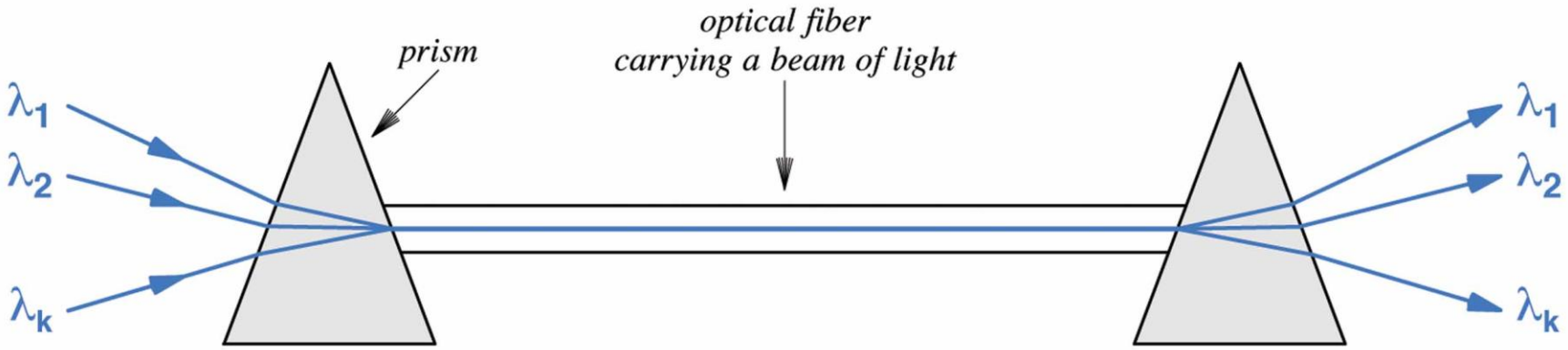

Figure 11.7 Illustration of prisms used to combine and separate wavelengths of light in wavelength division multiplexing technologies.

Time Division Multiplexing (TDM)

- It means dividing the available transmission time into time slots, and allocating a different slot to each transmitter.
- One method for transmitters to take turns is to transmit in *round-robin* order.

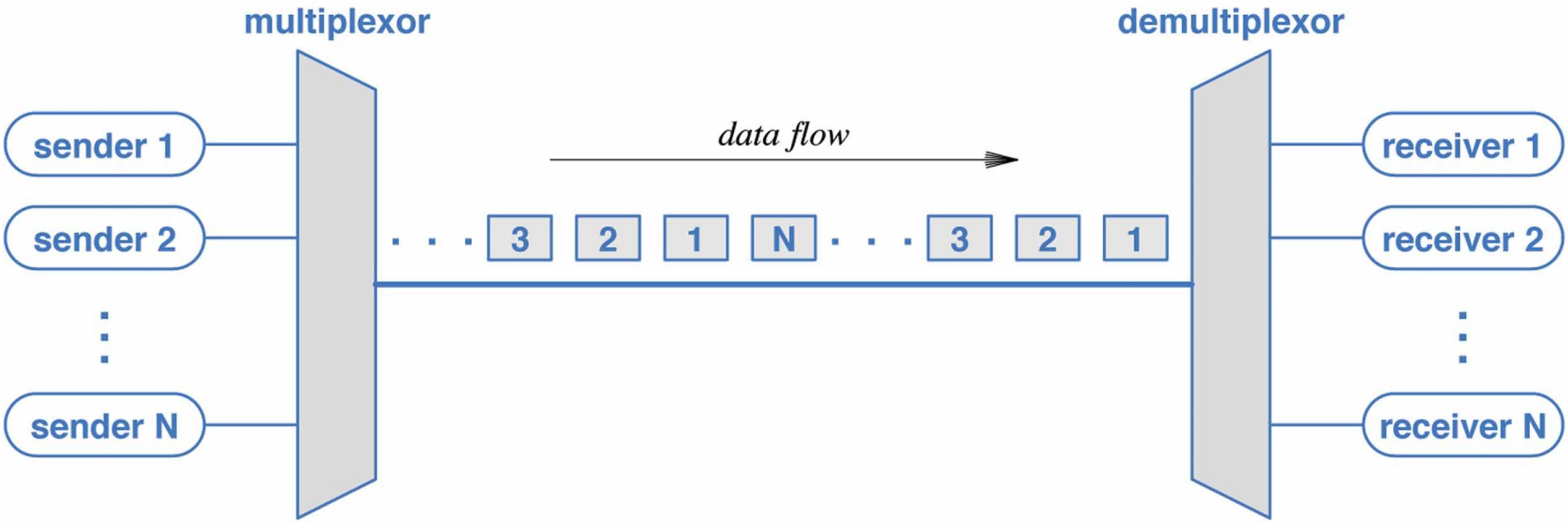

Figure 11.8 Illustration of the Time Division Multiplexing (TDM) concept with items from multiple sources sent over a shared medium.

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Synchronous TDM

- No gaps between items.
- Uses round-robin.

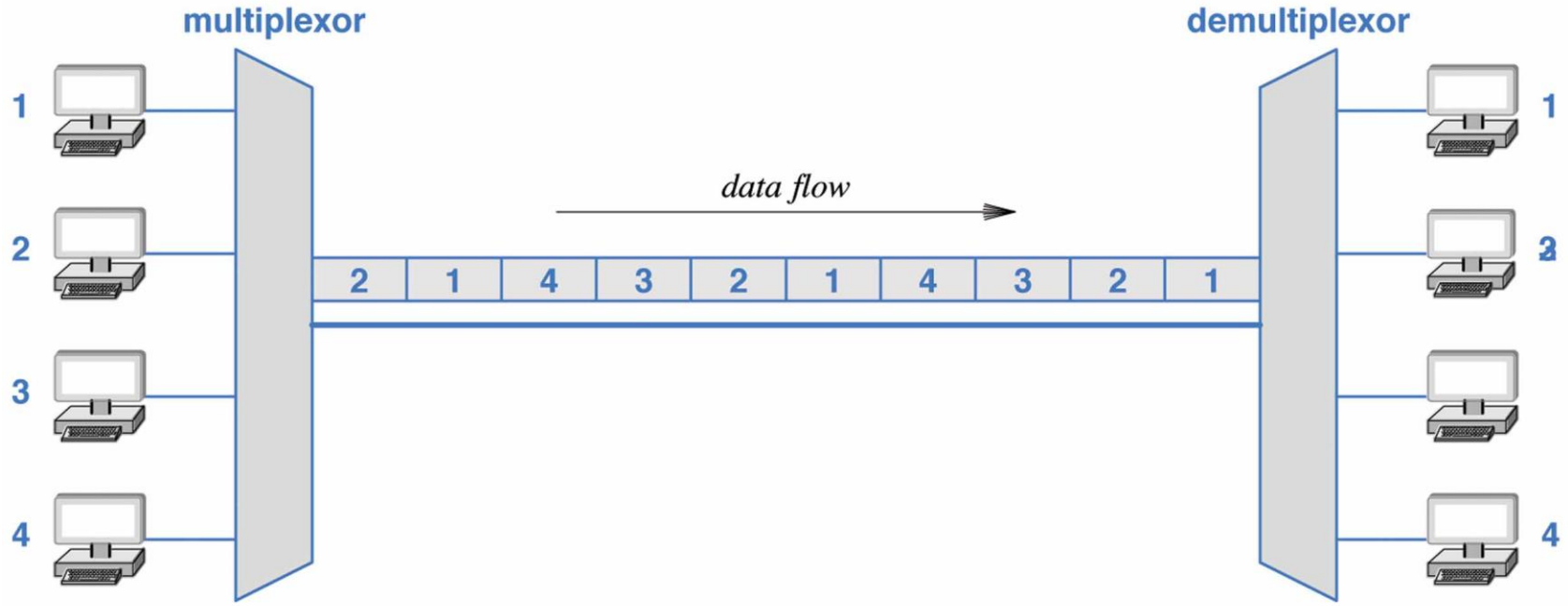

Figure 11.9 Illustration of a Synchronous Time Division Multiplexing system with four senders.

TDM in the telephone system

- An extra bit is inserted at the beginning of each frame. The extra bit alternated between zero and one.
- Used by the demultiplexor to detect a synchronization error.

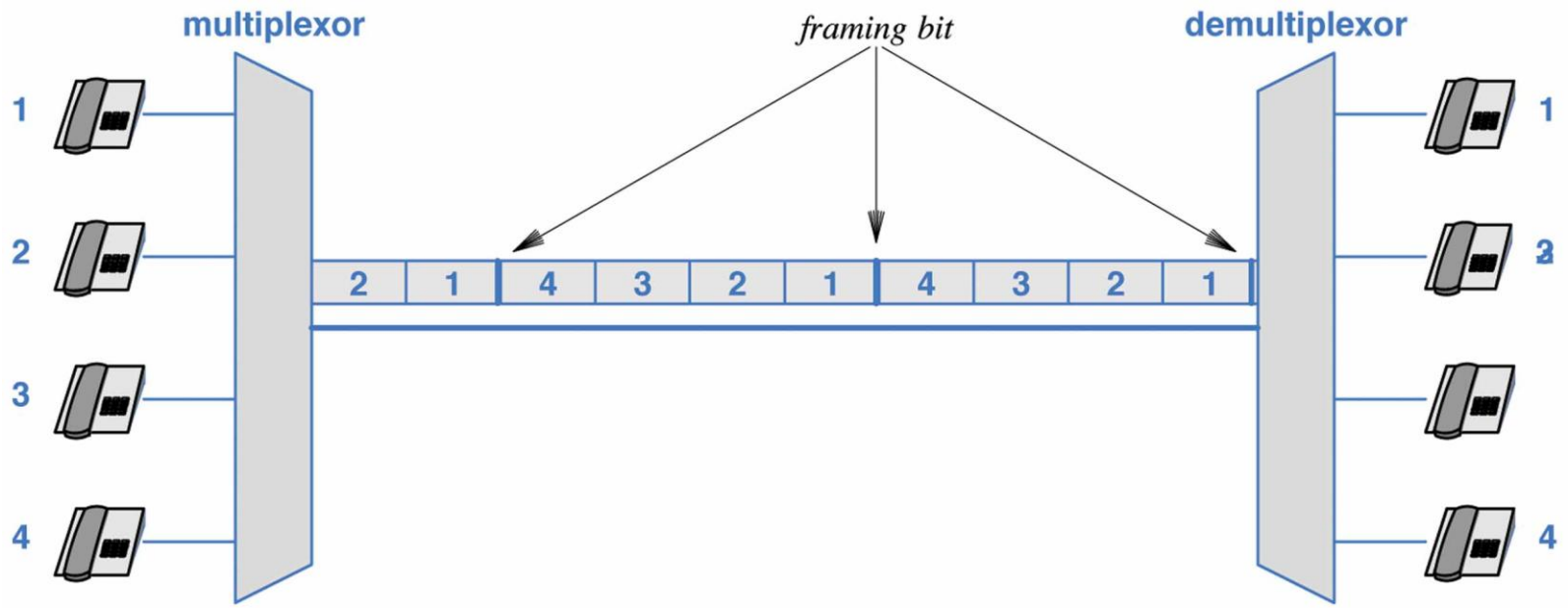

Figure 11.10 Illustration of the synchronous TDM system used by the telephone system in which a framing bit precedes each round of slots.

Hierarchical TDM.

- A DS-1 (or T1) phone channel can transmit 24 conversation simultaneously. Data rate = 1.544Mbps.
- A DS-2 (or T2) channel multiplexes 4 DS-1 channels. Data rate = 6.312 Mbps.
- A DS-3 (or T3) channel multiplexes 7 DS-2 channels. Data rate = 44.736 Mbps.
- A DS-4 (or T4) channel multiplexes 6 DS-3 channels. Data rate = 274.176 Mbps.

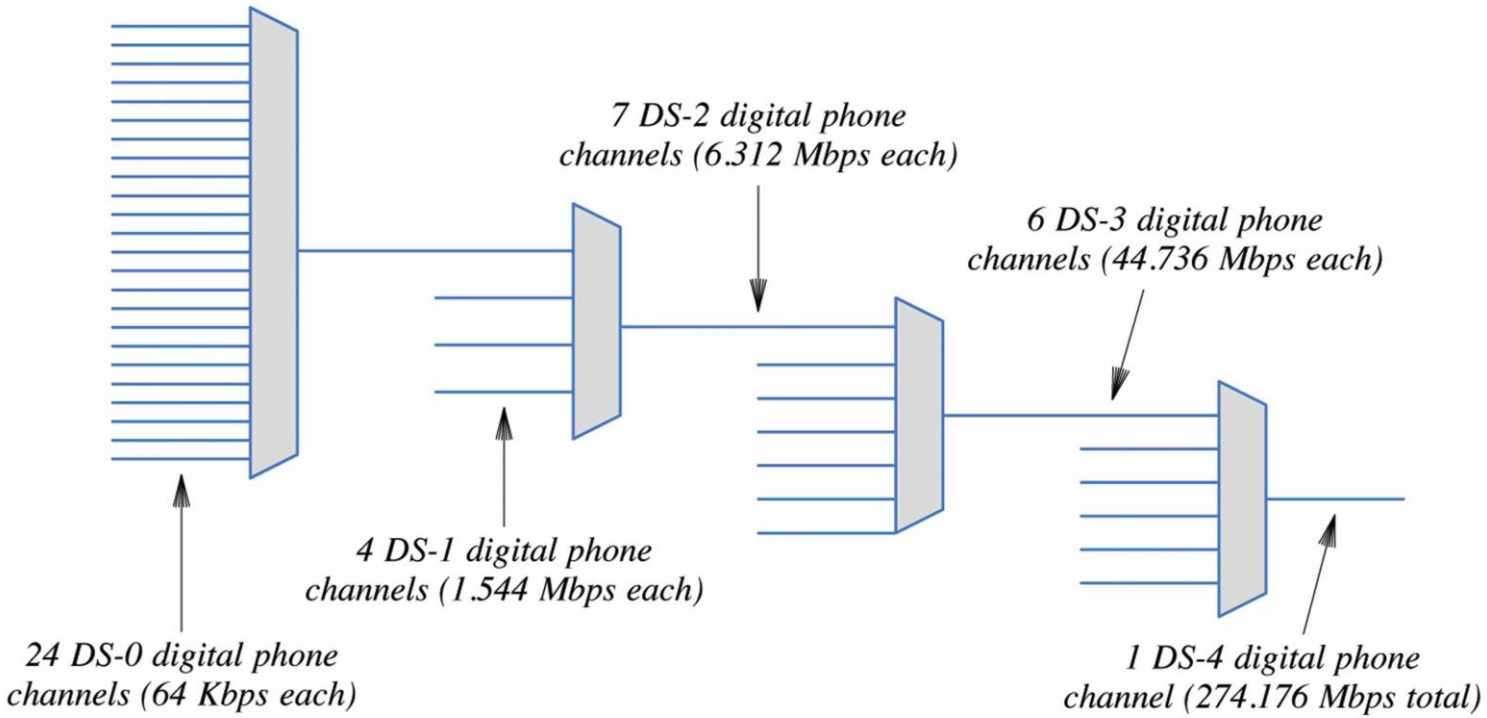

Figure 11.11 Illustration of the TDM hierarchy used in the telephone system.

Unfilled slots in TDM

- In TDM every possible sender has a reserved time slot, whether it needs it or not.
- This may lead to underutilization of the transmission channel.

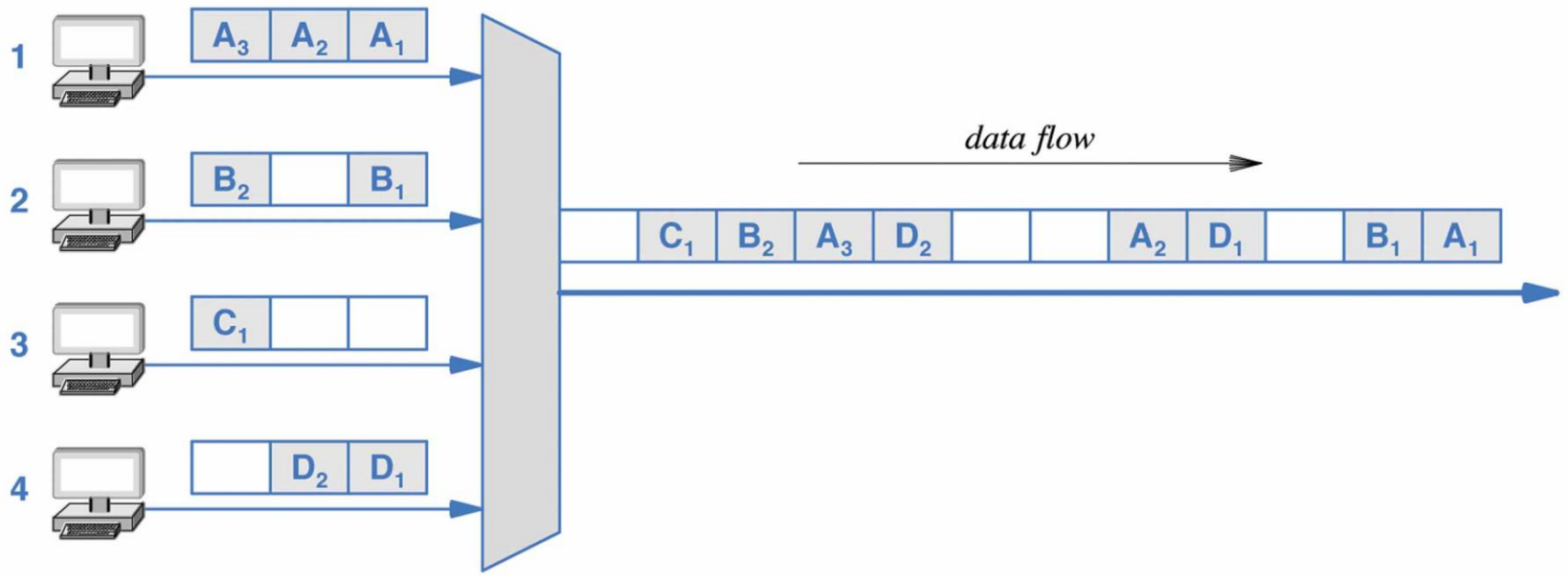

Figure 11.12 Illustration of a synchronous TDM system leaving slots unfilled when a source does not have a data item ready in time.

The solution to unfilled slots: Statistical TDM

- Select items for transmission in round-robin order.
- But if a sender's data is not ready, skip that sender and move to the next one.
- All slots will be filled as long as some sender has some data ready to send.
- But now each slot must also contains an identifier to indicate who is the receiver.

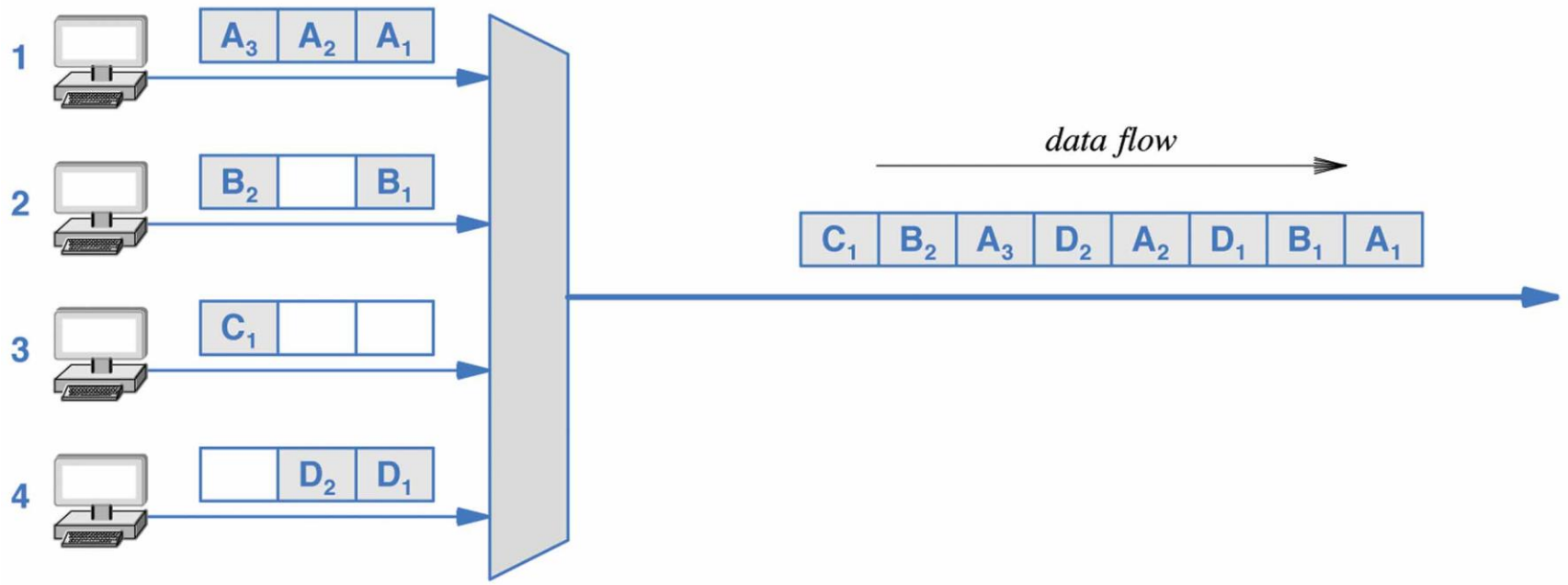

Figure 11.13 Illustration that shows how statistical multiplexing avoids unfilled slots and takes less time to send data.

Inverse multiplexing

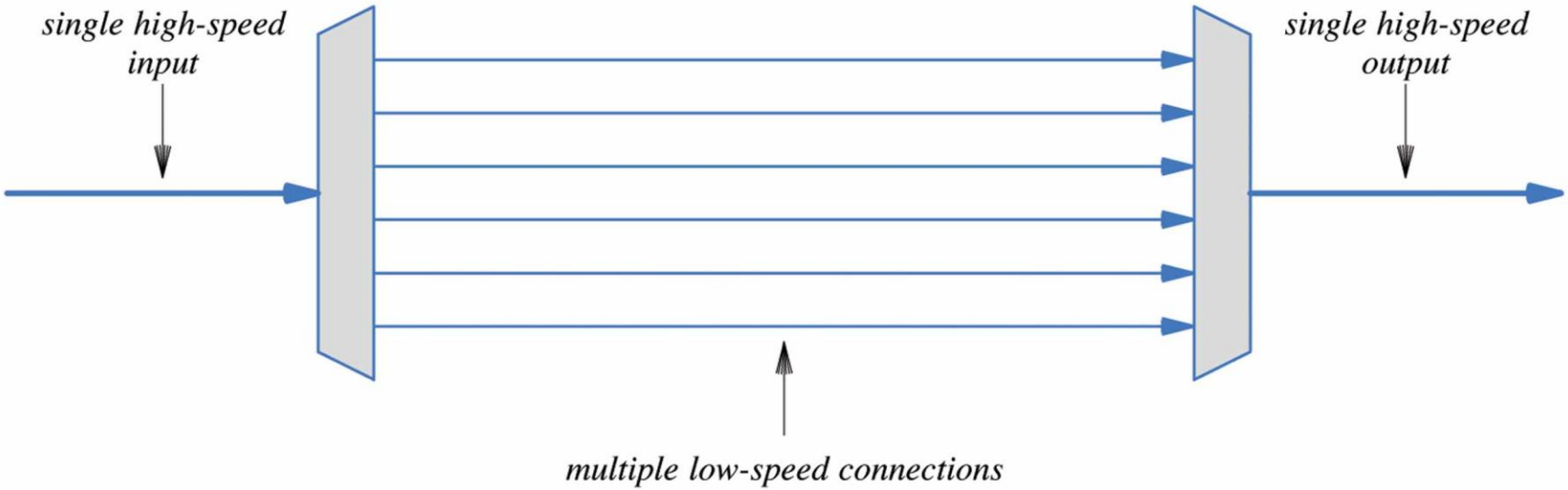

Figure 11.14 Illustration of inverse multiplexing in which a single high-speed digital input is distributed over lower-speed connections for transmission and then recombined to form a copy of the input.

Code division multiplexing (CDM)

- Used in the cellular phone system and in some satellite communications.
- Each sender is assigned a unique binary code: its *chip sequence* (with -1 representing 0).
- Chip sequences for different senders are *orthogonal* vectors.
- A one is sent as a chip sequence. A zero is send as the oposite of the chip sequence.
- Lower delay than TDM in high utilization networks.