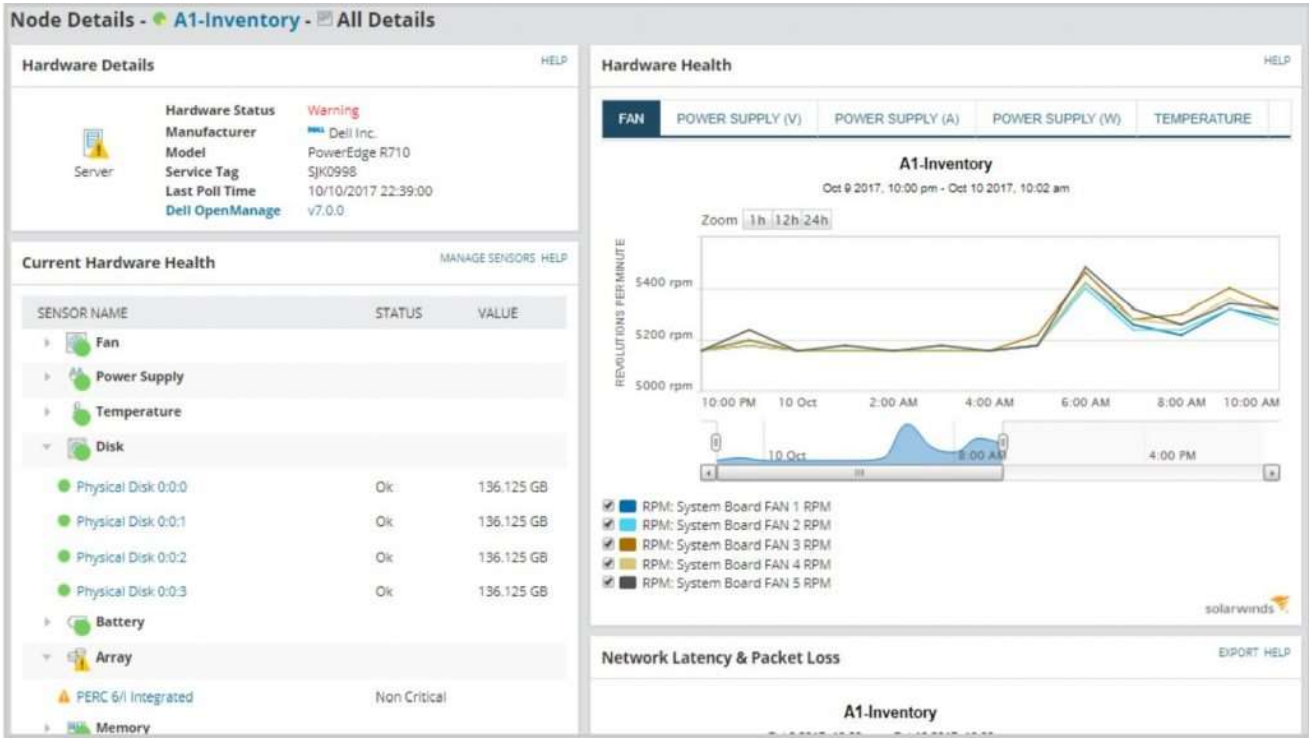
Chapter 6

Bandwidth Utilization



Objective

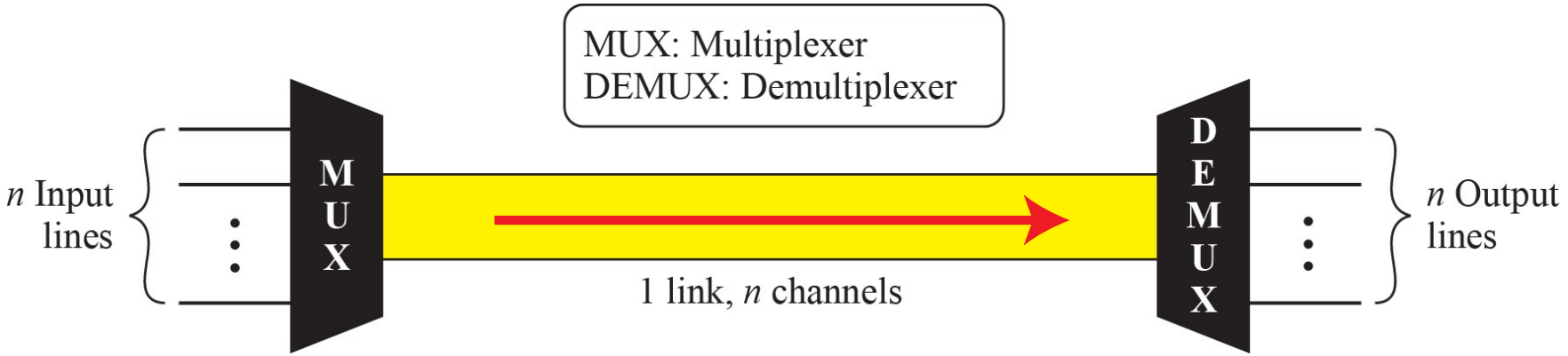
- Frequency-division multiplexing (FDM), Wavelength division multiplexing (WDM), Time-division multiplexing (TDM).

- Spectrum spreading, in which we first spread the bandwidth of a signal to add redundancy for the purpose of more secure transmission before combining different channels.

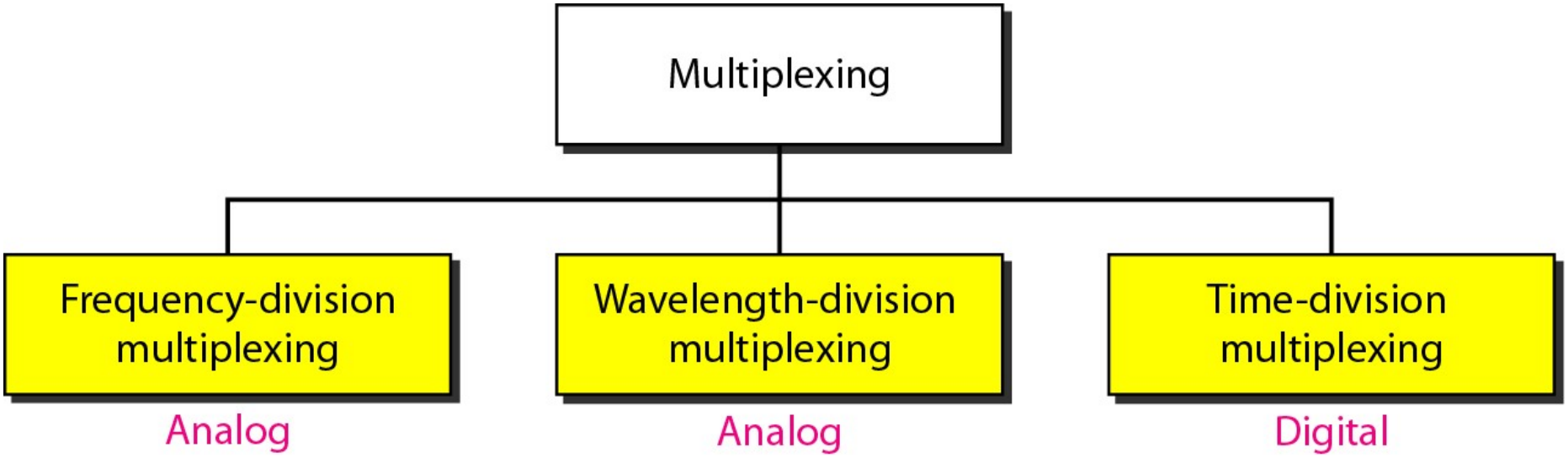
MULTIPLEXING

- Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

- As data and telecommunications use increases, so does traffic. We can accommodate this increase by continuing to add individual links each time a new channel is needed, or we can install higher-bandwidth links and use each to carry multiple signals.



Dividing a link into channels



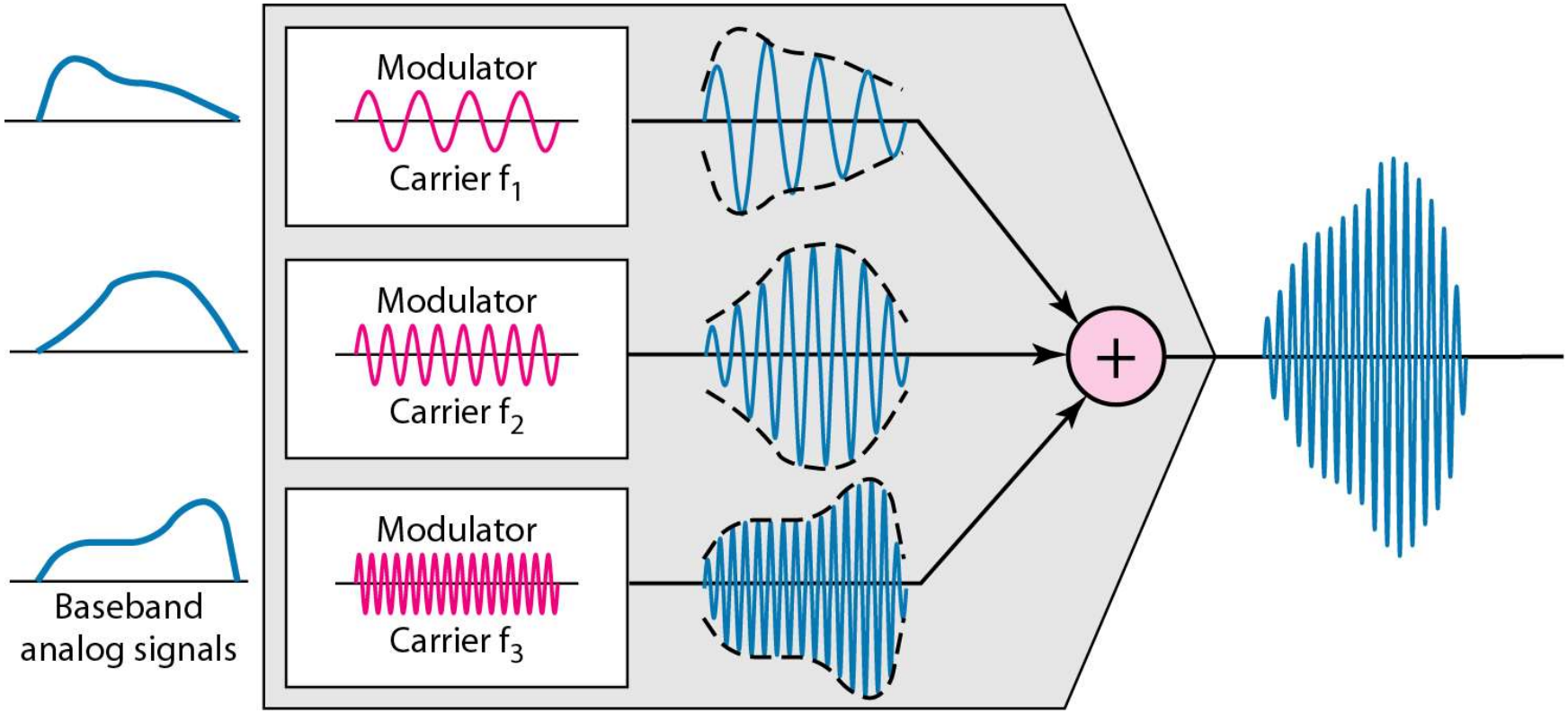
Categories of multiplexing

Frequency-Division Multiplexing

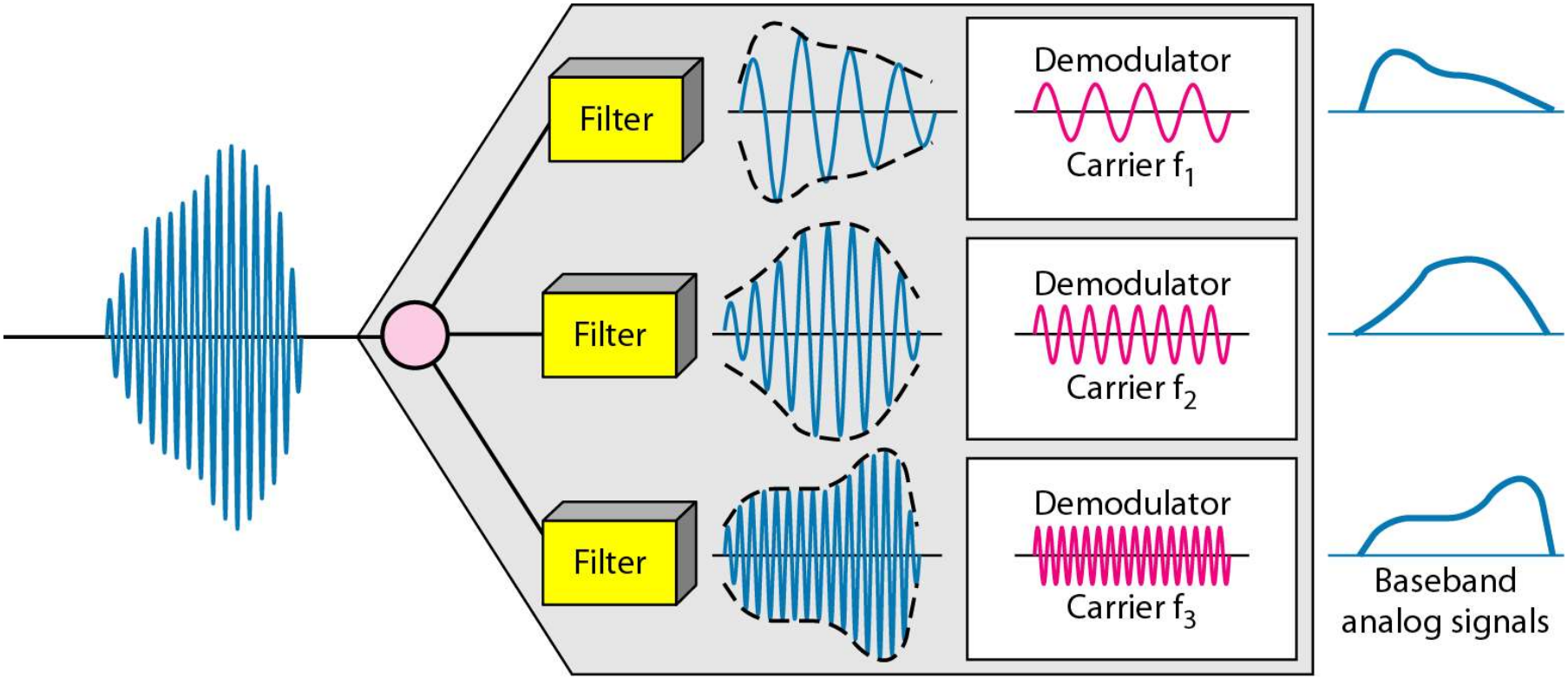
- Frequency-division multiplexing (FDM) is an analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted.

- In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are combined into a single composite signal that can be transported by the link.

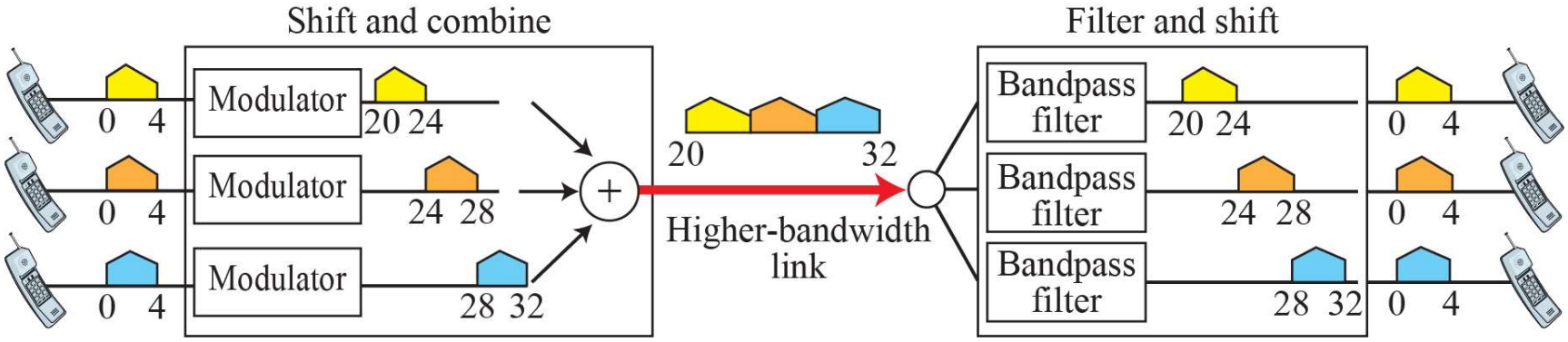
Frequency-division multiplexing


Modulator
Carrier f_1
Modulator
Carrier f_2
Modulator
Carrier f_3
Baseband
analog signals

FDM Process

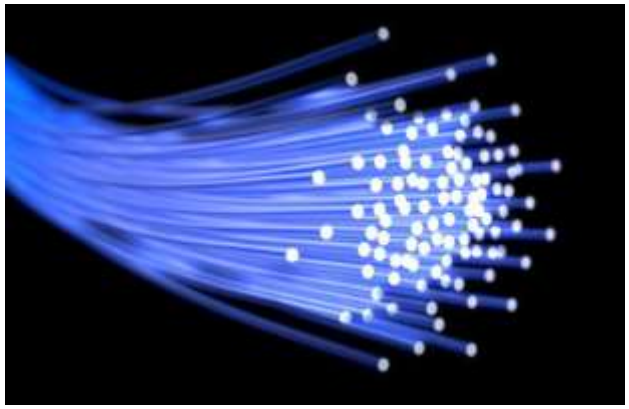


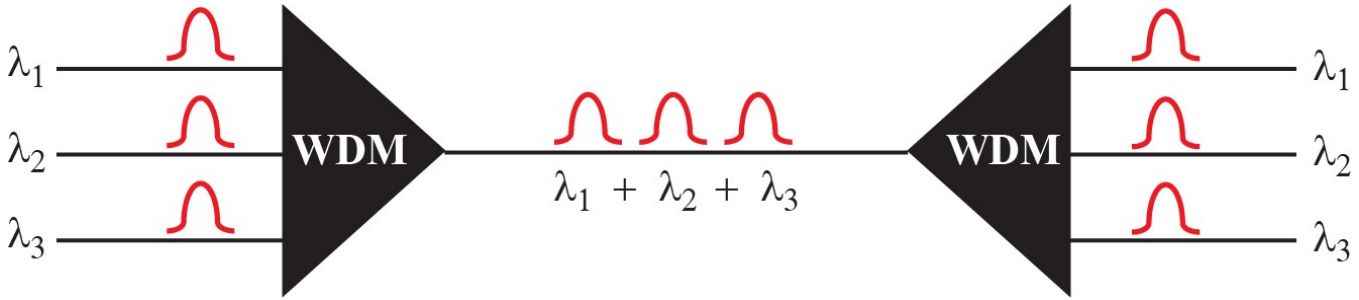
FDM demultiplexing example


Shift and combine
Filter and shift
Modulator
Modulator
Modulator
0 4
0 4
0 4
20 24
24 28
28 32
20
32
Higher-bandwidth
link
Bandpass
filter
Bandpass
filter
Bandpass
filter
20 24
24 28
28 32
0 4
0 4
0 4

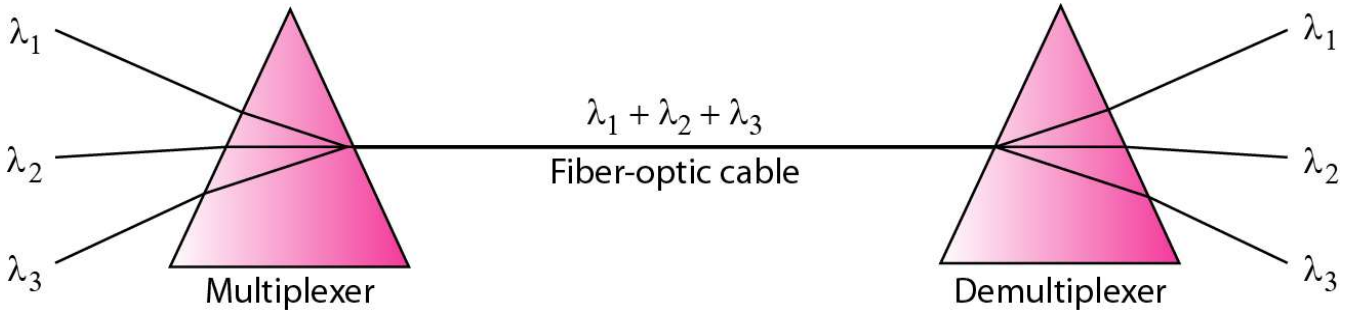
Wavelength-Division Multiplexing

- Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable.
- The optical fiber data rate is higher than the data rate of metallic transmission cable, but using a fiber-optic cable for a single line wastes the available bandwidth.
- Multiplexing allows us to combine several lines into one.





Wavelength-division multiplexing



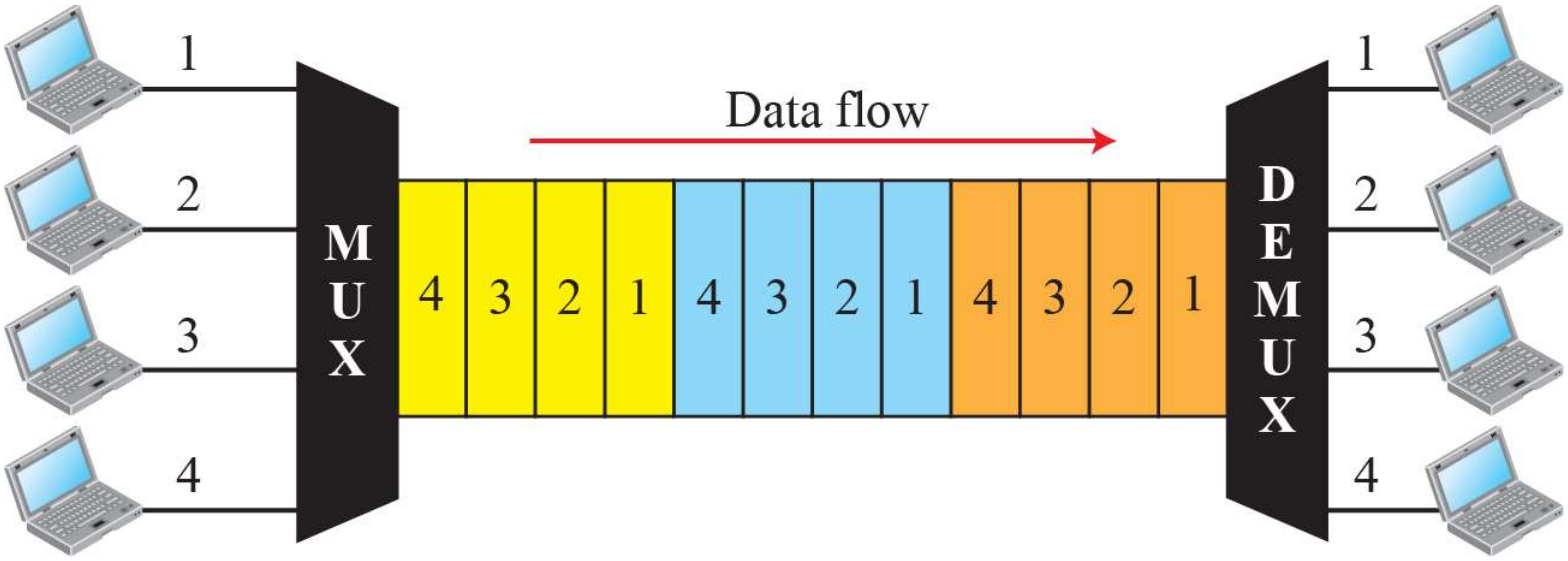
Prisms in wave-length division multiplexing

Time-Division Multiplexing

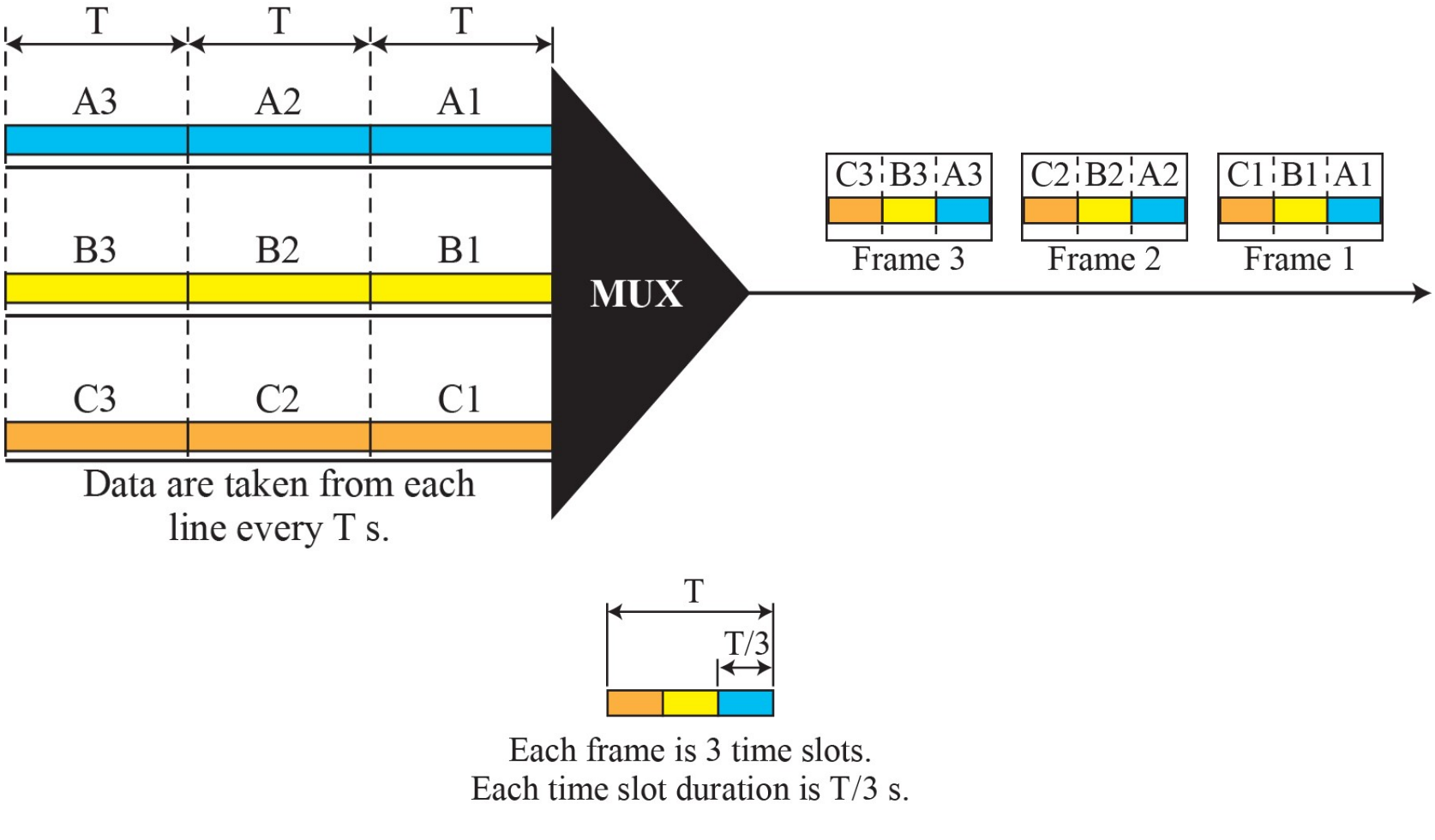
- Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link; Time is shared.

- Each connection occupies a portion of time in the link. Note that the same link is used as in FDM; here, however, the link is shown sectioned by time rather than by frequency.

- In the next figure, portions of signals 1, 2, 3, and 4 occupy the link sequentially.



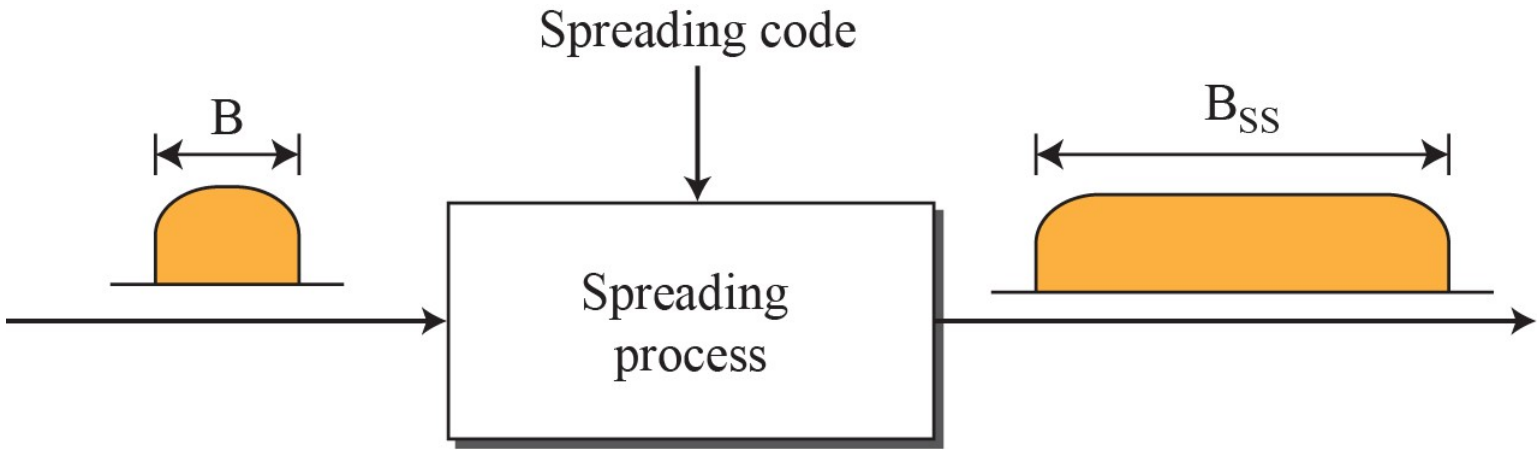
TDM



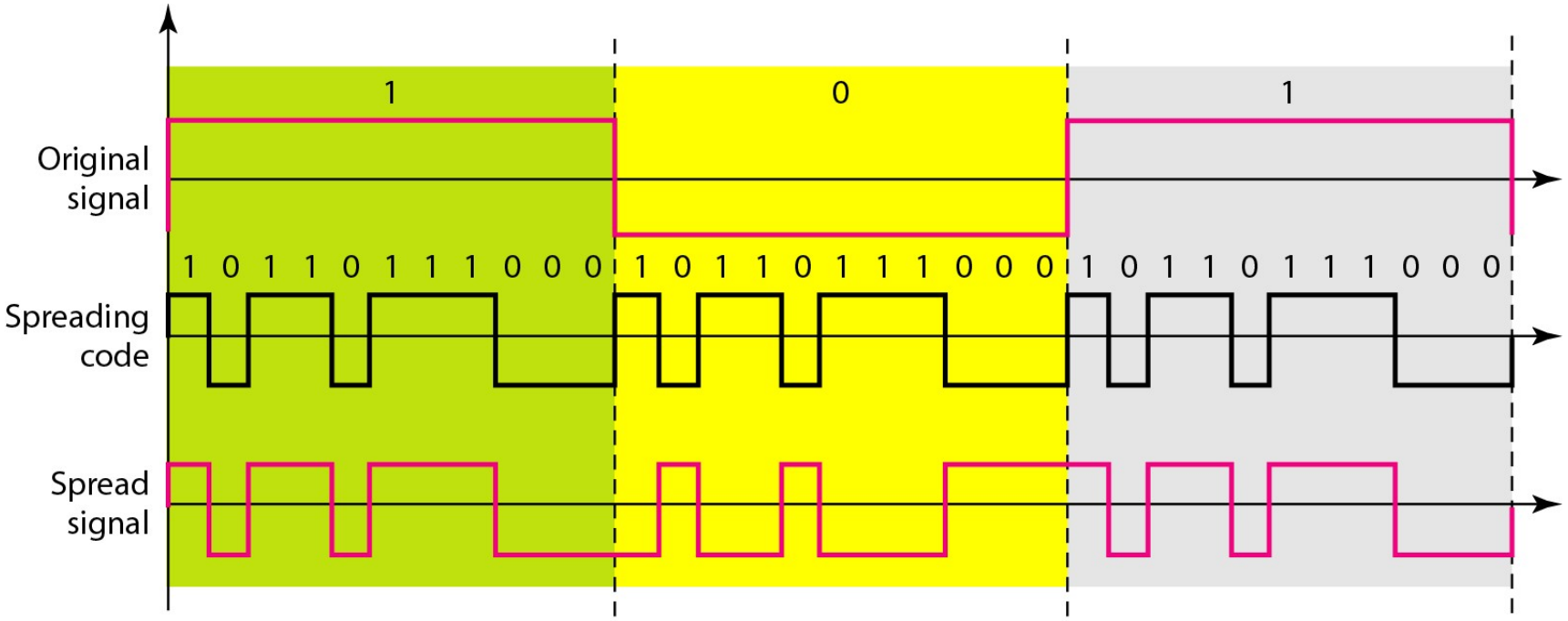
Synchronous time-division multiplexing

SPREAD SPECTRUM

- In some applications, we have some concerns that outweigh bandwidth efficiency.
- In wireless applications, stations must be able to share this medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder
- To achieve these goals, spread spectrum techniques add redundancy;

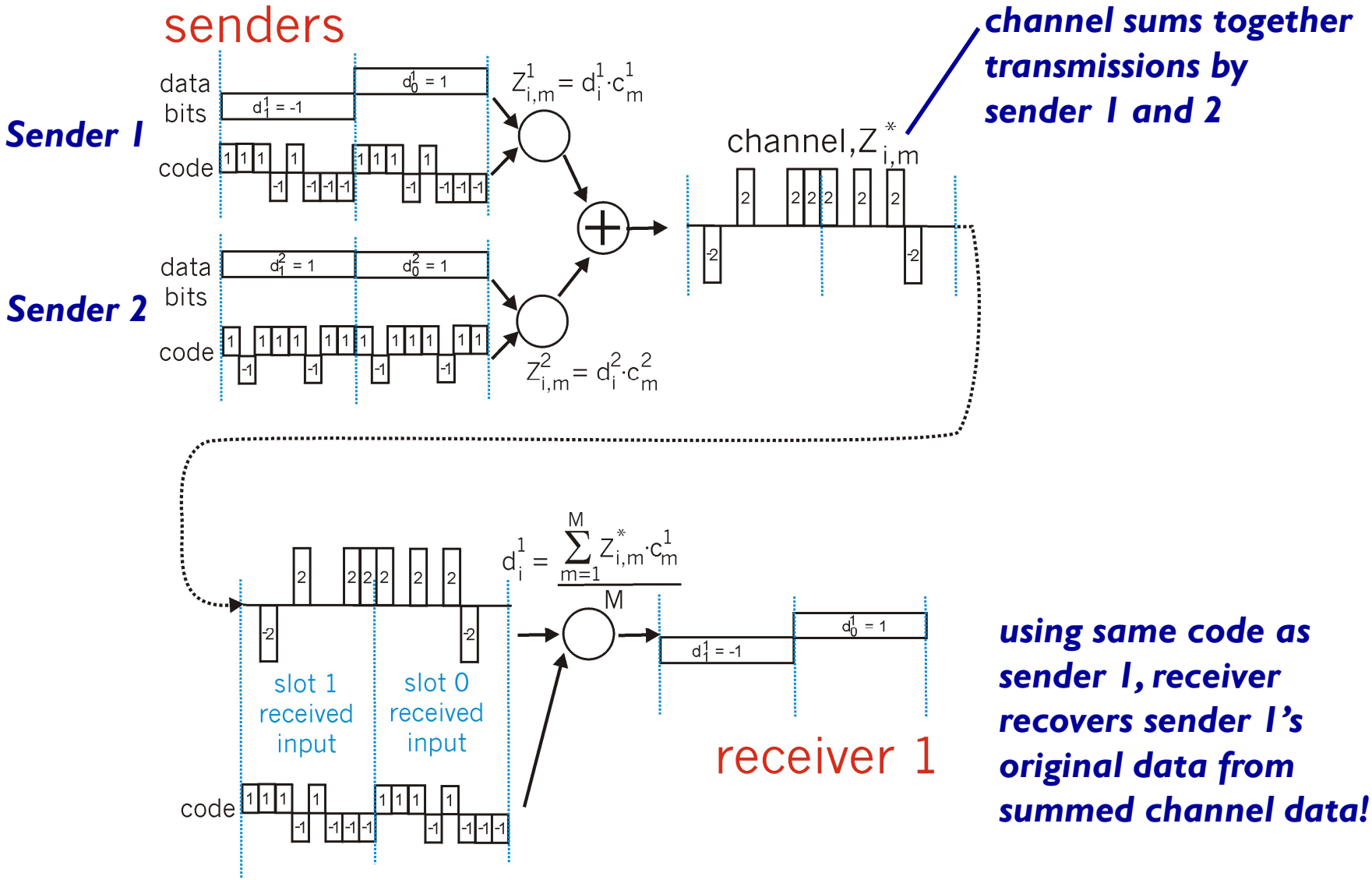


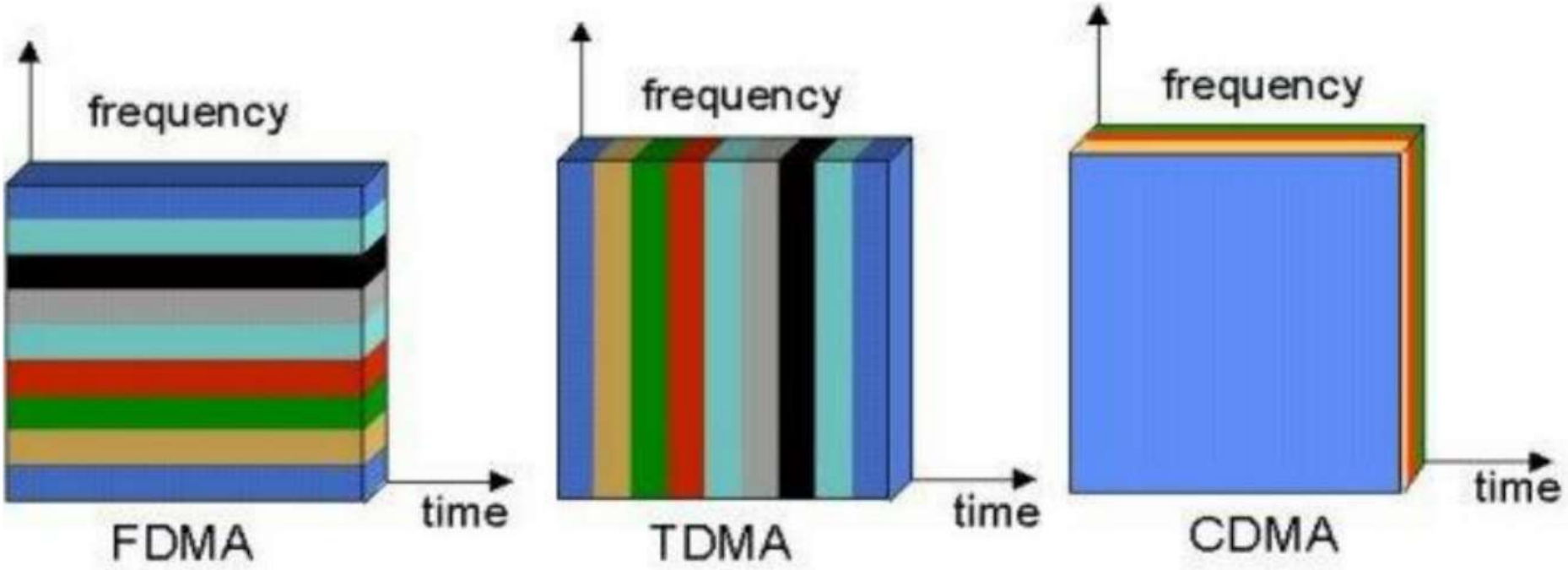
Spread spectrum



CDMA example

CDMA: two-sender interference




frequency
time
FDMA
frequency
time
TDMA
frequency
time
CDMA

Spread singnal