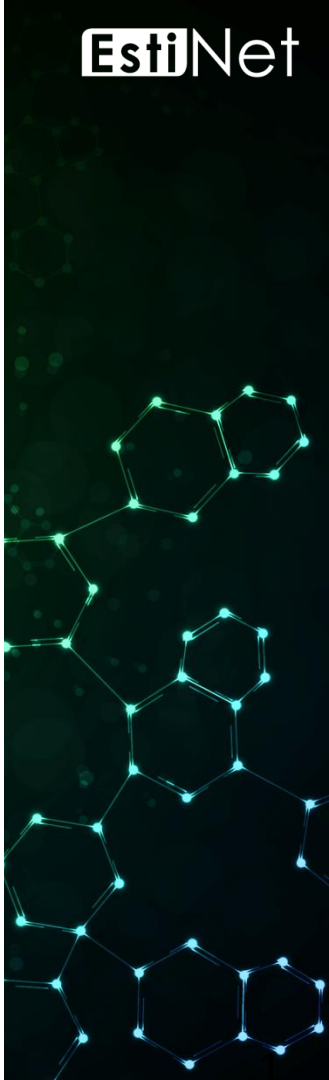
Physical Layer



Outline

- Signal Propagation Media
- The Calculation of Signal Delivery Time
- The Evaluation of End-to-end Delay
- Signal Encoding and Modulation
- Wired Signal's Encoding, Decoding and Decoding Error
- Wired Signal's Propagation
- Wireless Signal's Modulation, Demodulation and Demodulation Error
- Wireless Signal's Propagation
- Summary

Signal Propagation Media

Media for Delivering Signals

- Wired Media
  - Copper wire for delivering electrical signal
  - Optical fiber for delivering optical wave
  - etc.
- Wireless Media
  - Air for delivering electromagnetic wave
  - Air for delivering optical wave
  - etc.

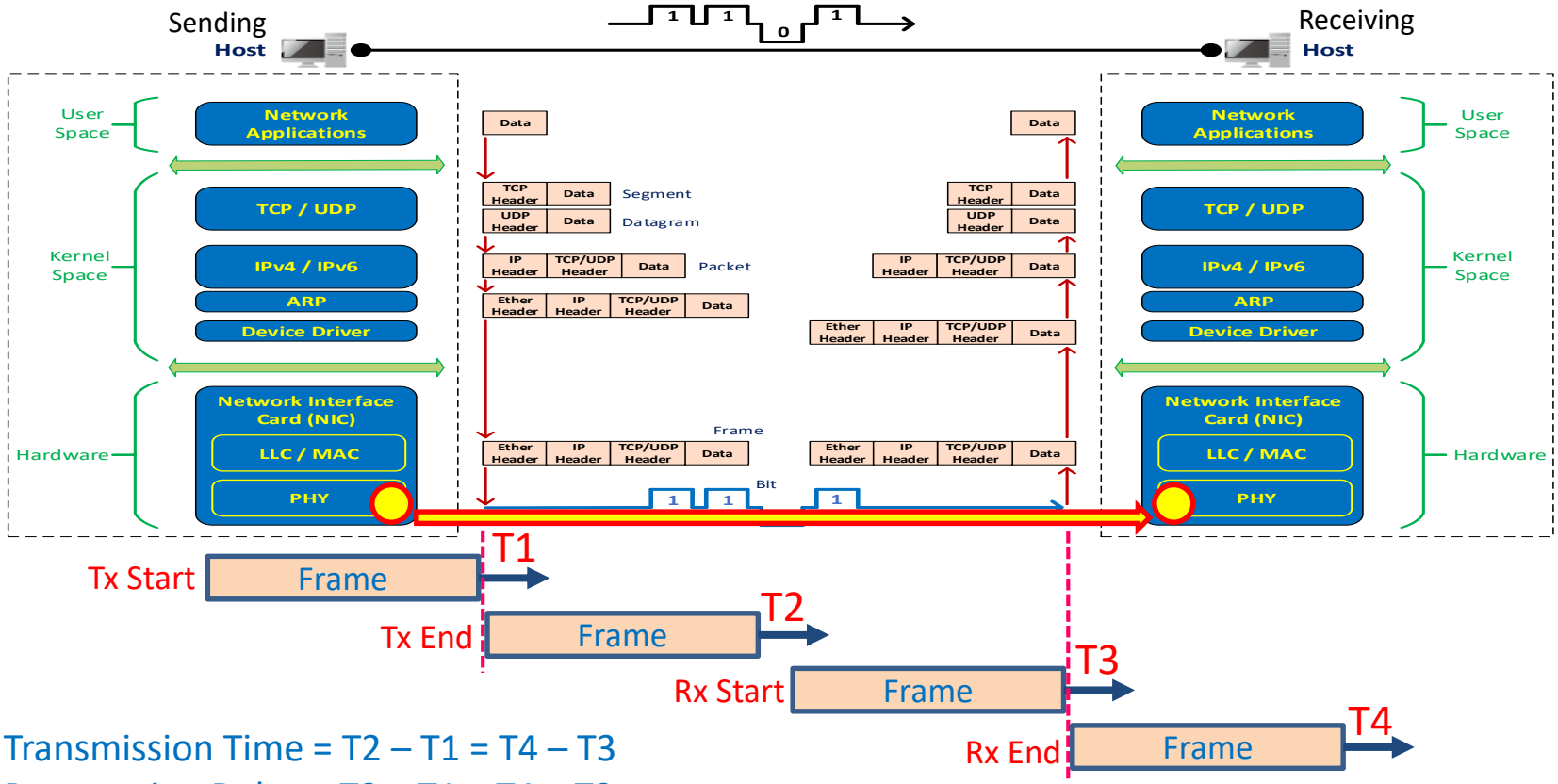
The Calculation of Signal Delivery Time

< Simulation Case >

trans_time_and_prop_delay.xtpl

trans_time_and_prop_delay_comparison.xtpl

Transmission Time & Propagation Delay

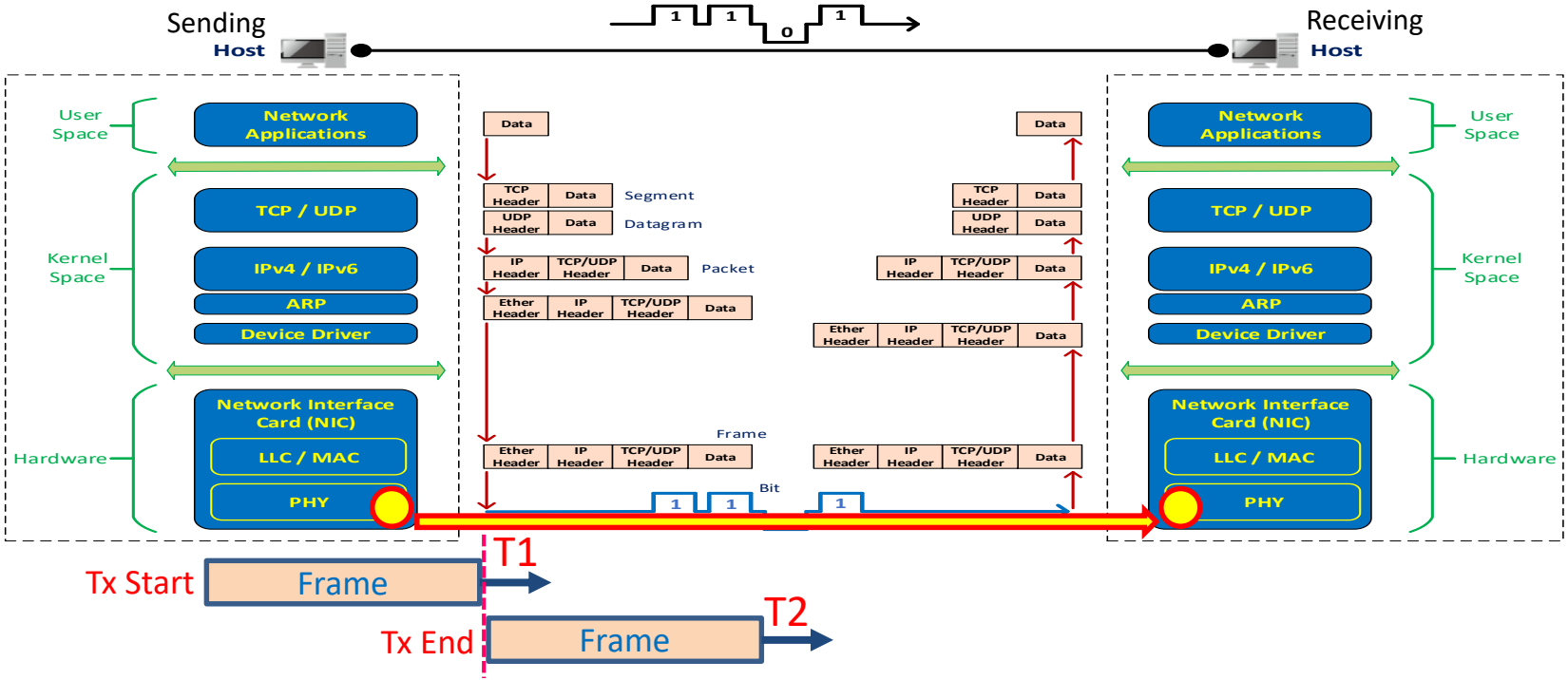


Transmission Time = T2 – T1 = T4 – T3

Propagation Delay = T3 – T1 = T4 – T2

Frame Delivery Time = Rx End – Tx Start = T4 – T1 = Transmission Time + Propagation Delay

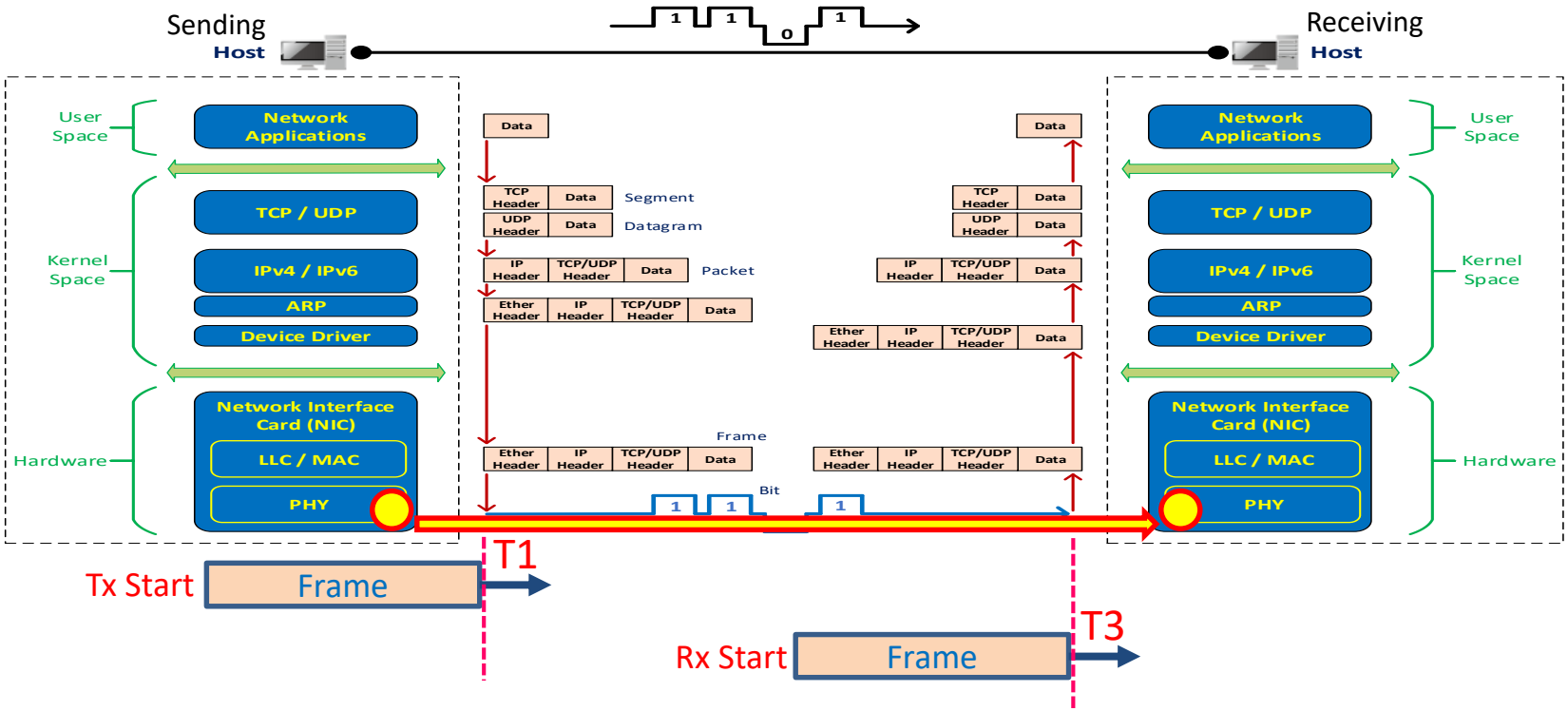
The Calculation of Transmission Time



Sending Host's Interface Data Rate = X Mbps = (X * 10^6) bps
Frame Size = Y bytes = (8 * Y) bits
Transmission Time = T2 – T1 = (8*Y)/(X * 10^6) sec

E.g.,
If X = 10 and Y = 1000,
Transmission Time = (8*1000)/(10 * 10^6)
= 0.0008 sec

The Calculation of Propagation Delay



Signal Speed over the Medium = S meter/sec

Distance between Sending Host and Receiving Host = D meters

Propagation Delay = T3 – T1 = D/S sec

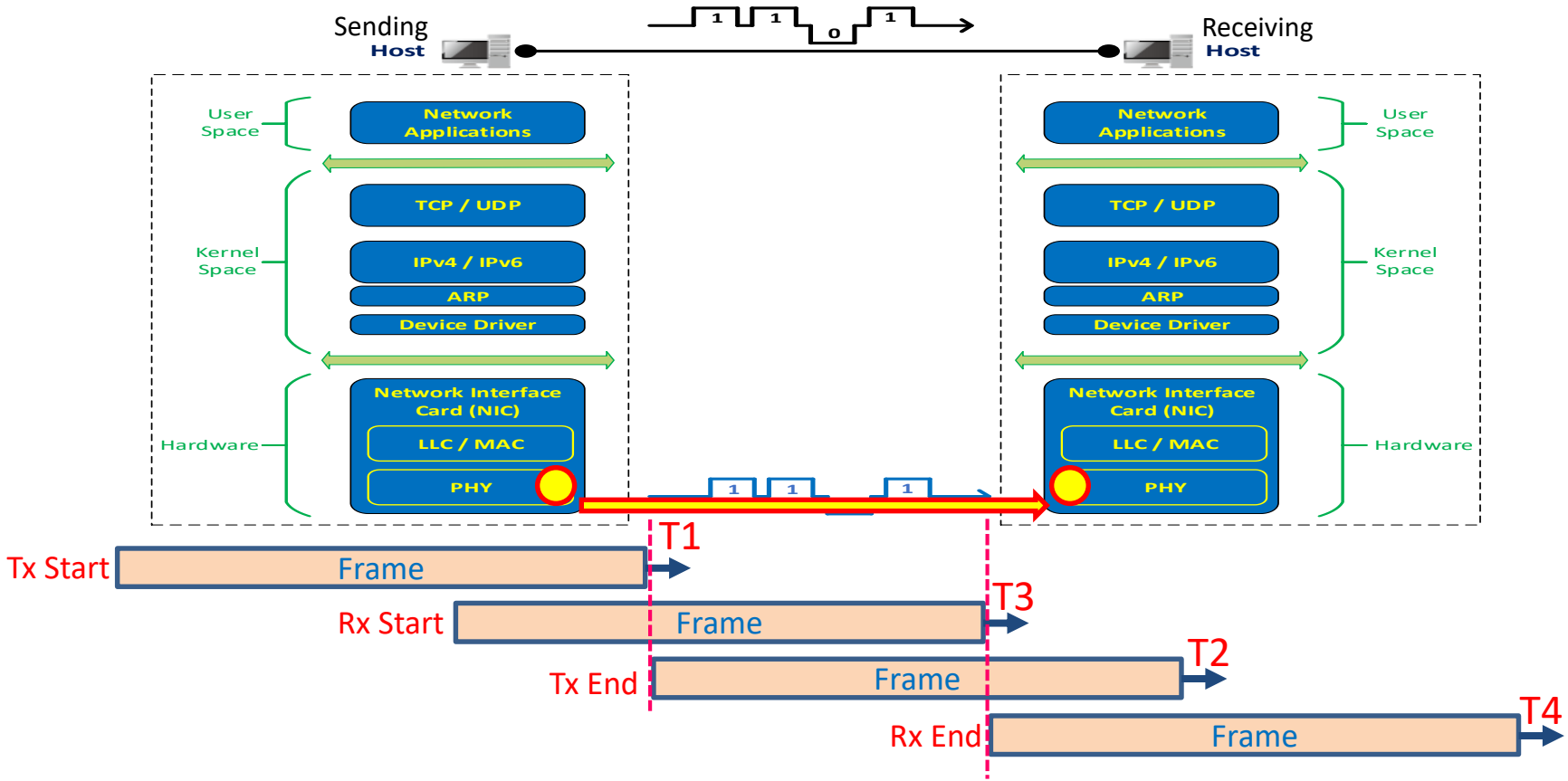
E.g.,

If S = (2 * 10^8) and D = 200,

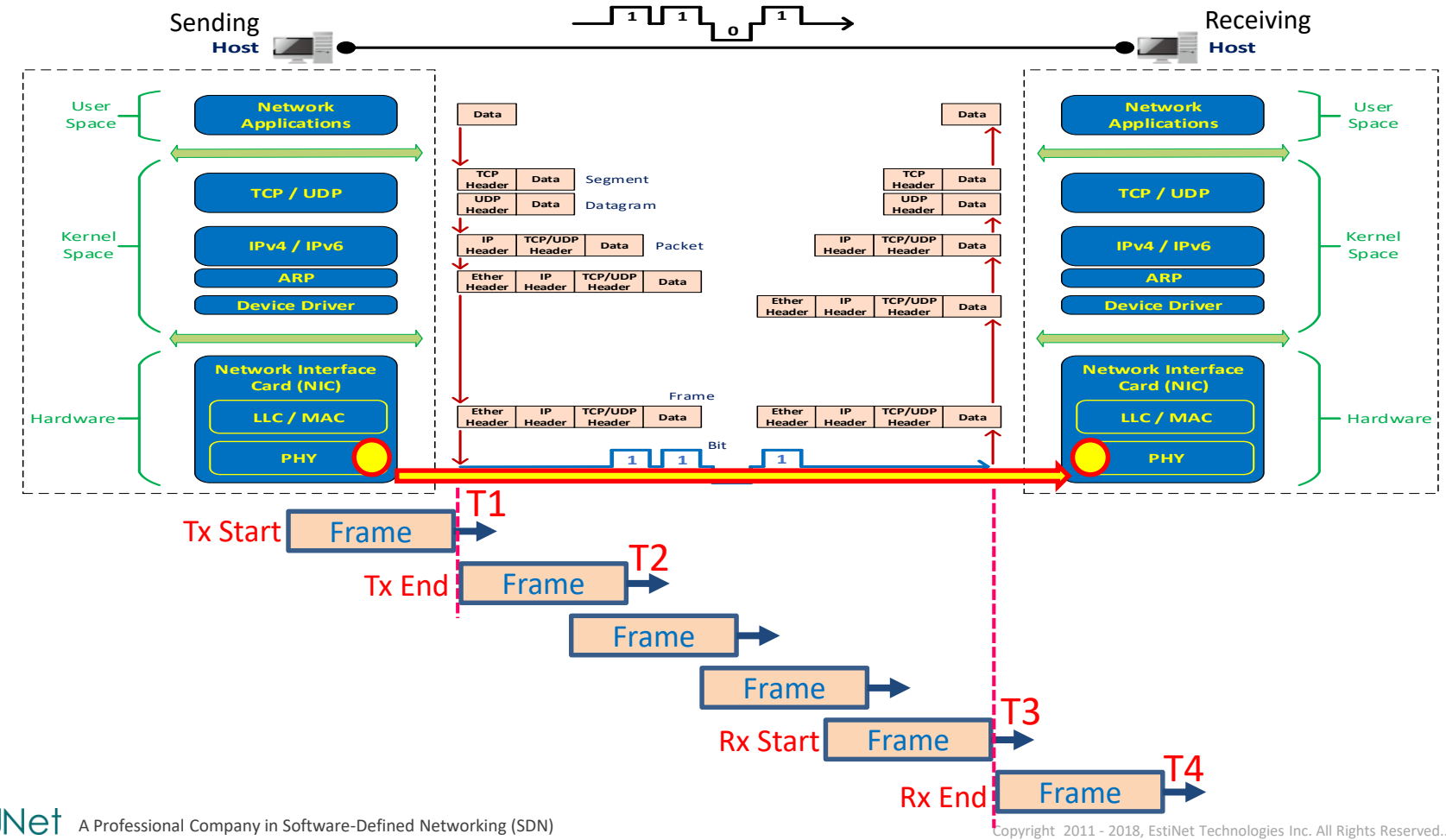
Propagation Delay = (200)/(2 * 10^8)

= 0.000001 sec

Transmission Time > Propagation Delay



Transmission Time < Propagation Delay



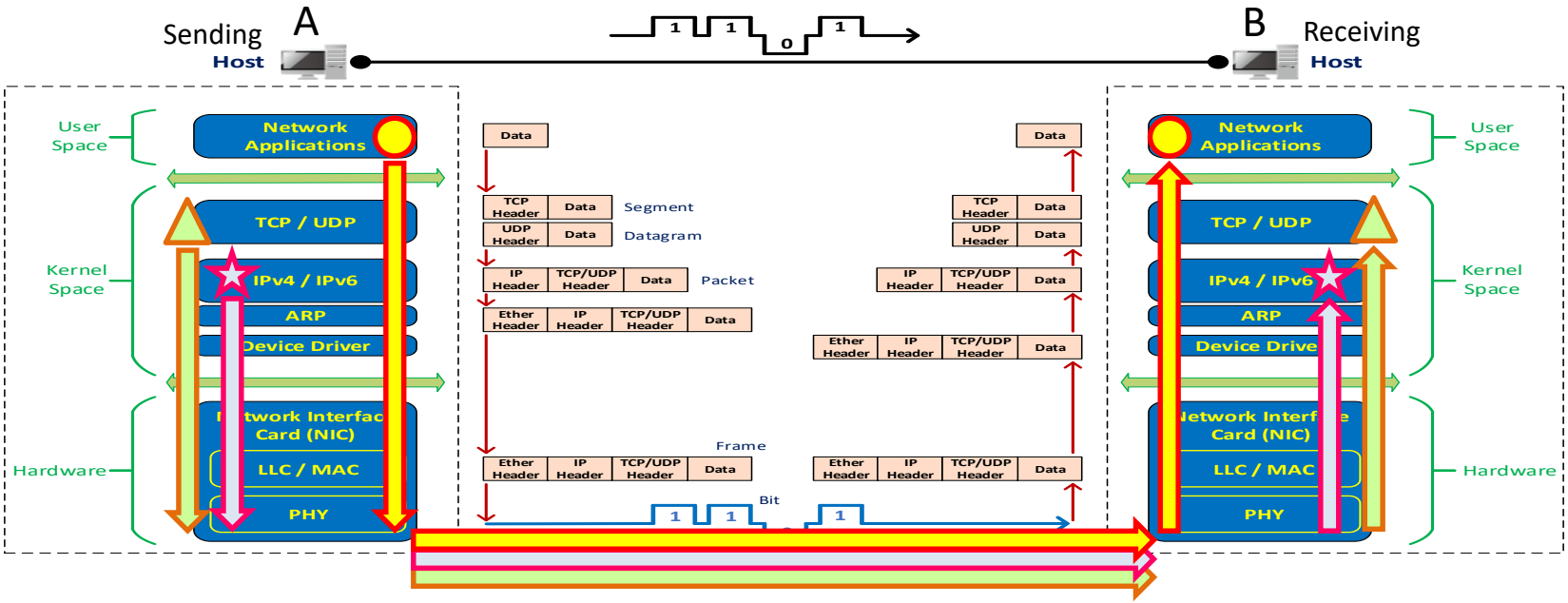
The Evaluation of End-to-end Delay

< Simulation Case >

end_to_end_delay.xtpl

end_to_end_delay_trans_time_dominates.xtpl

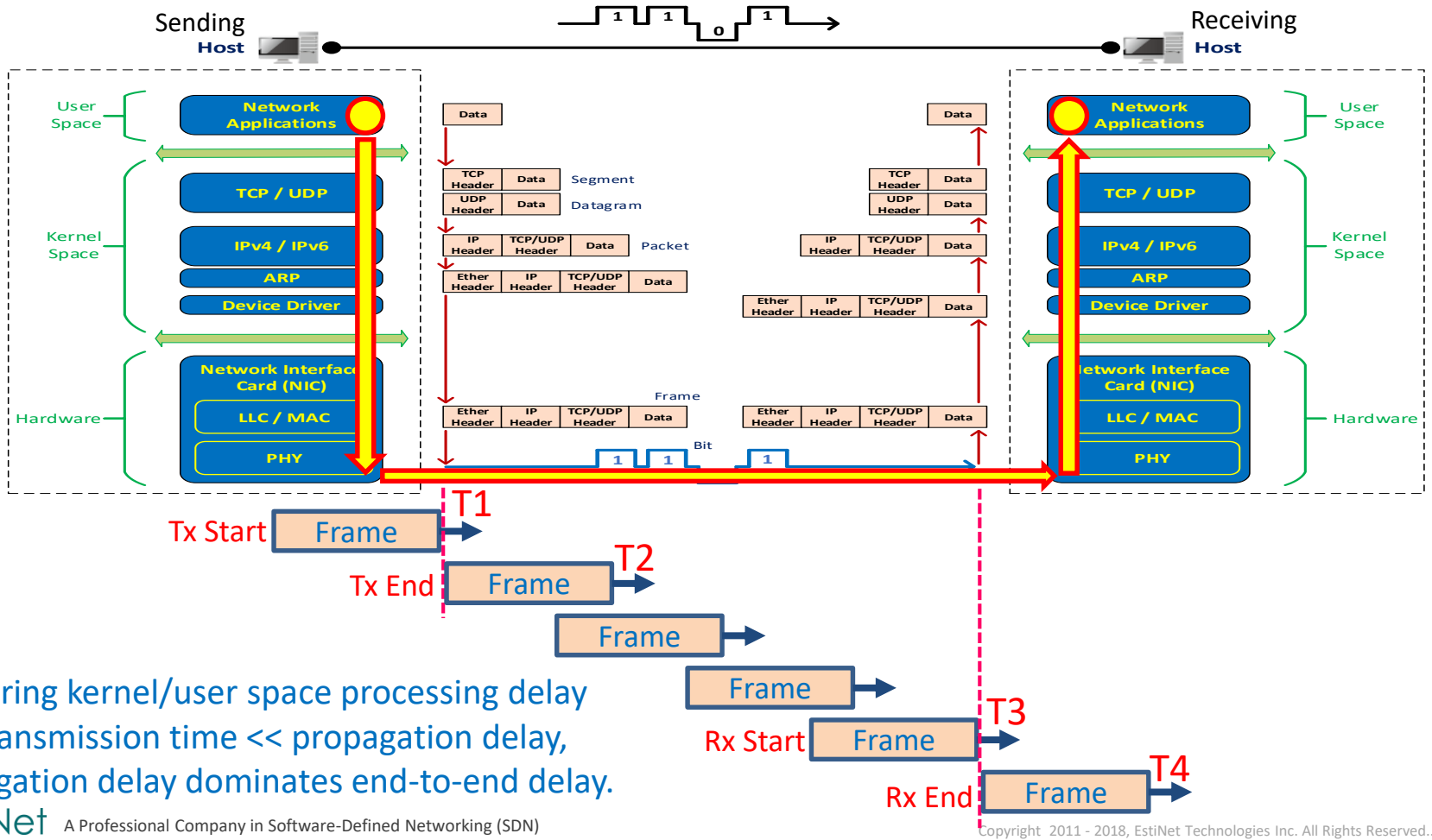
End-to-end Delay



End-to-end Delay = Sending Host's Kernel/User Space Processing Delay (e.g., **Protocol, Scheduling,** Queuing, etc.)
+ Transmission Time + Propagation Delay
+ Receiving Host's Kernel/User Space Processing Delay (e.g., **Protocol, Queuing,** etc.)

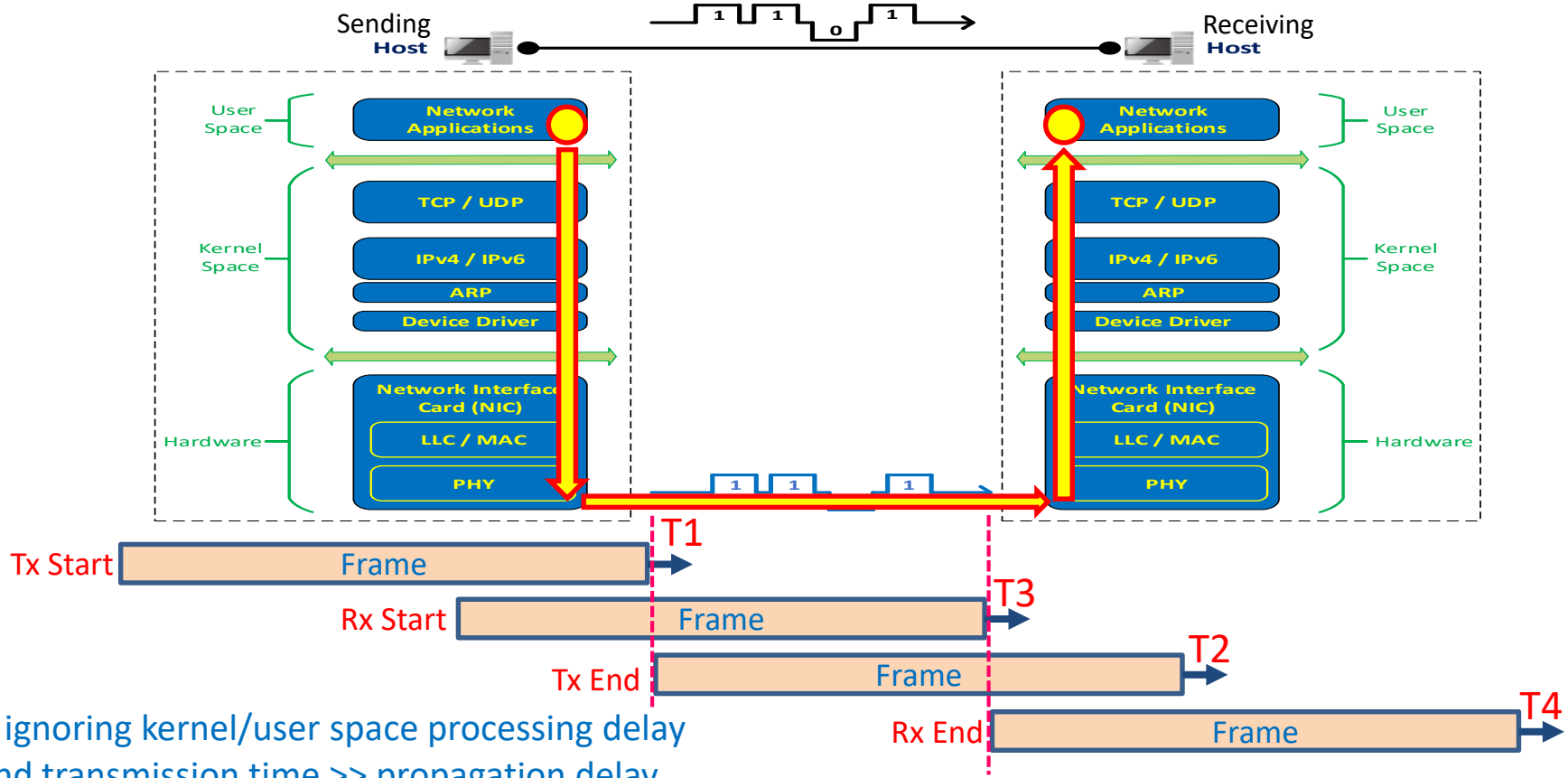
Round Trip Time (RTT) = End-to-end Delay from Host A to Host B
+ End-to-end Delay from Host B to Host A

Transmission Time < Propagation Delay



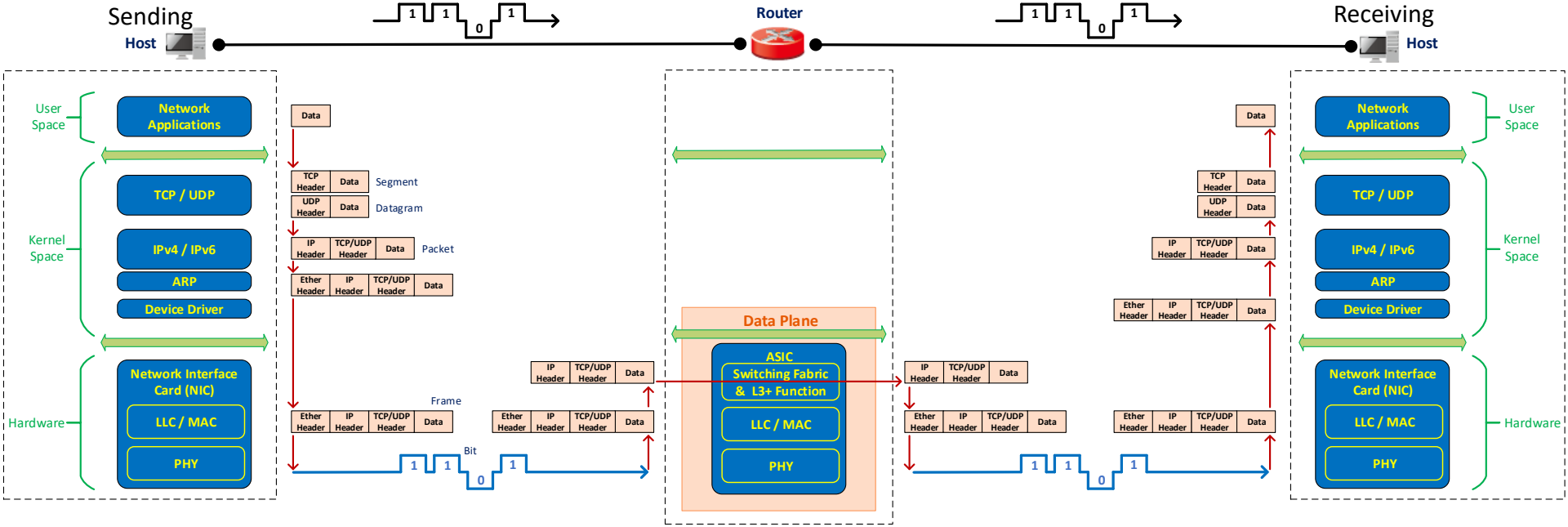
If ignoring kernel/user space processing delay and transmission time << propagation delay, propagation delay dominates end-to-end delay.

Transmission Time > Propagation Delay



If ignoring kernel/user space processing delay and transmission time >> propagation delay, transmission time dominates end-to-end delay.

End-to-end Delay across Other Network Devices



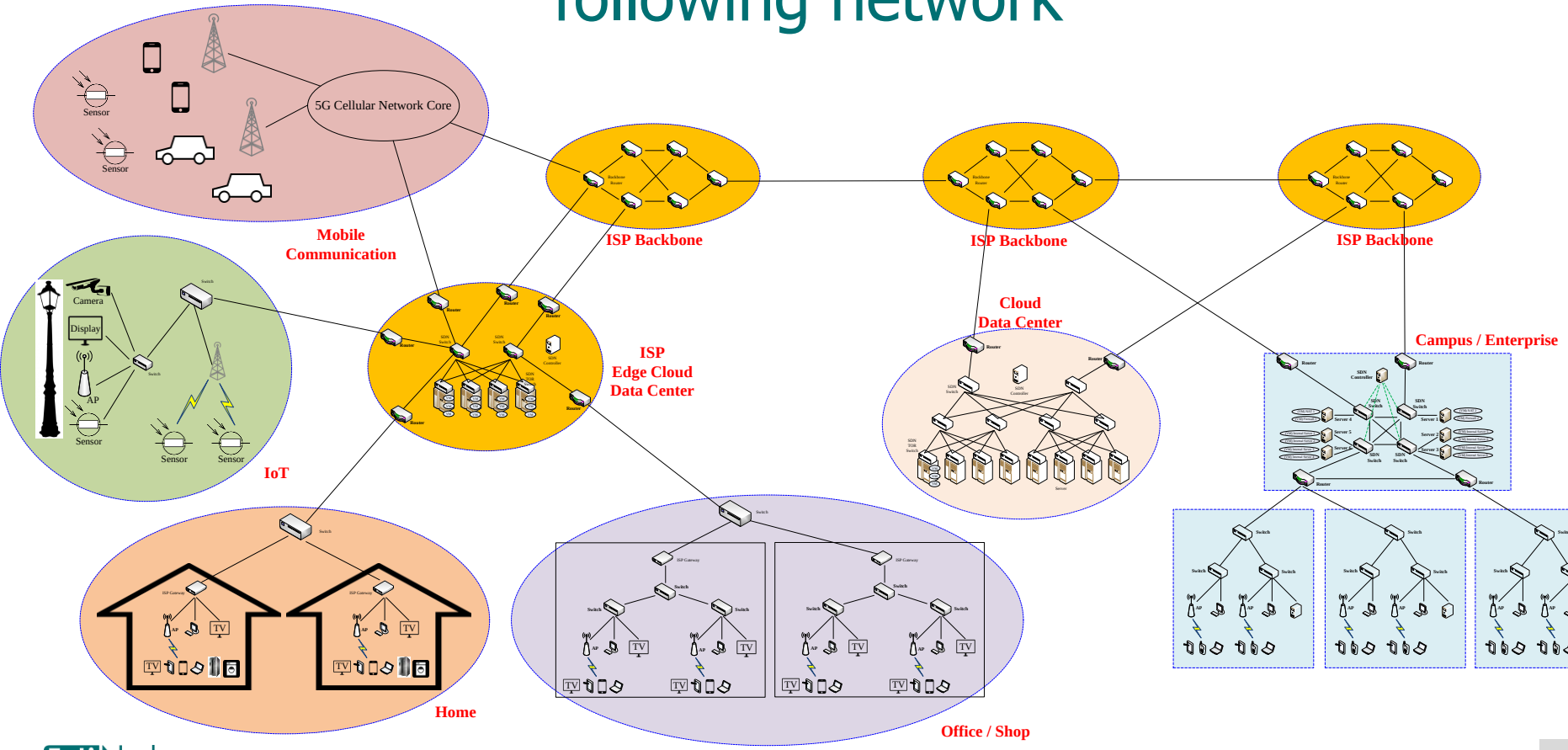
End-to-end Delay from Sending Host to Receiving Host

= Point-to-point Delay from Sending Host to Router

+ Router's Forwarding Delay

+ Point-to-point Delay from Router to Receiving Host

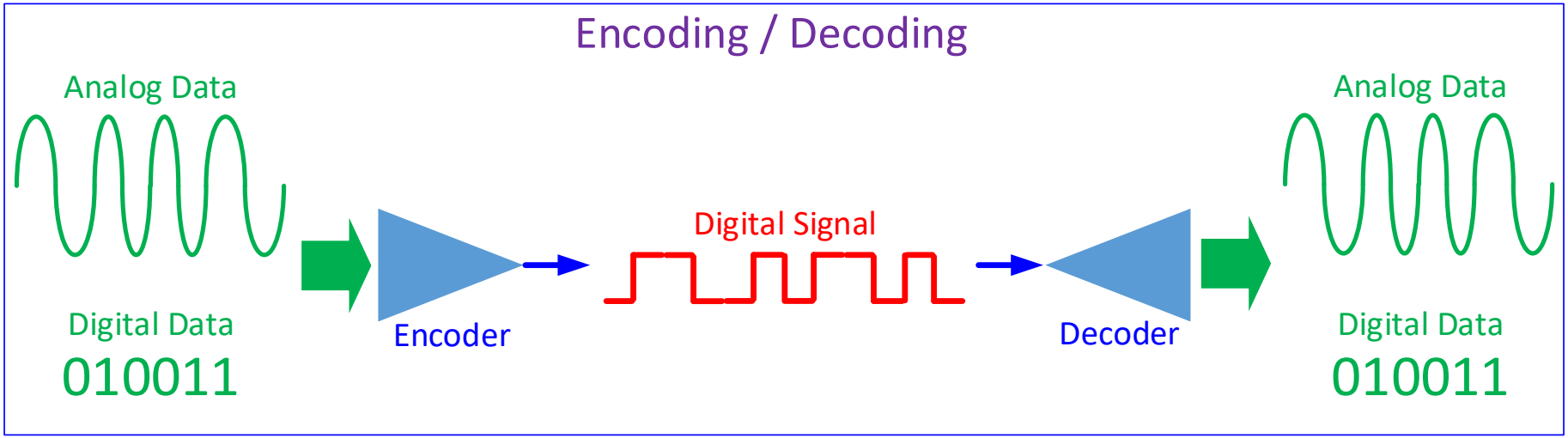
Think about different end-to-end delays in the following network



Signal Encoding and Modulation

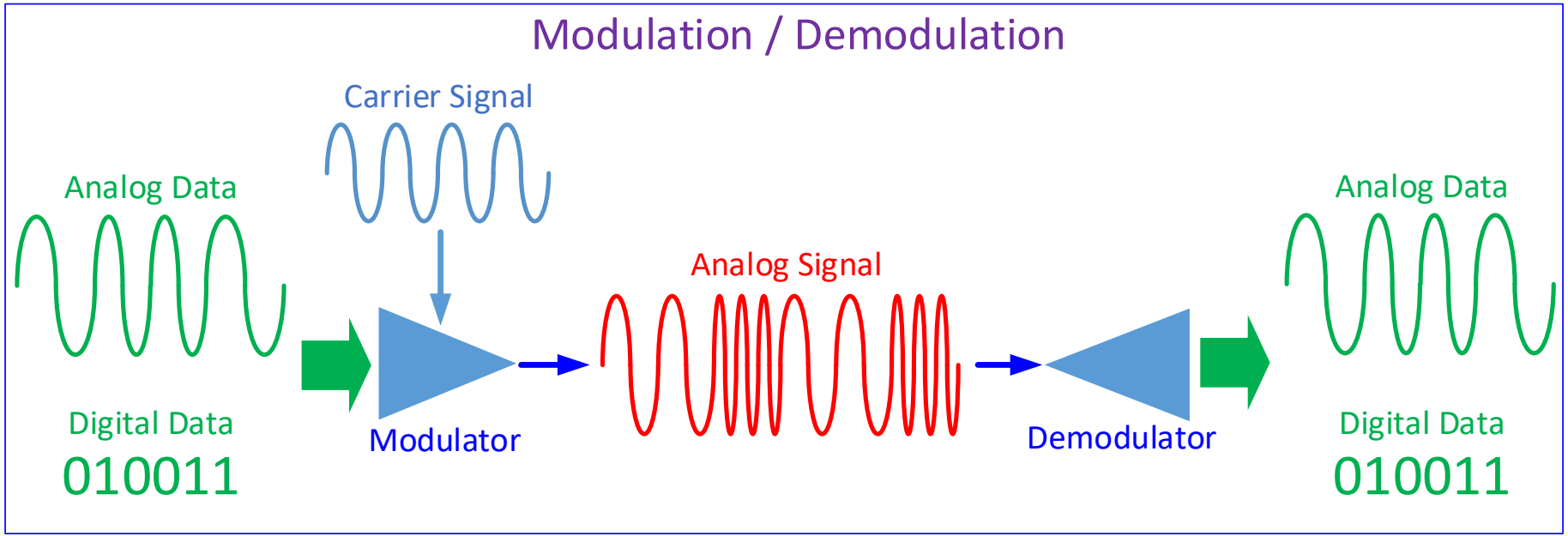
Encoding and Decoding

- If some data (analog or digital) have to be transmitted in the form of digital signal, the data have to be encoded into digital signals at the sender site.
- At the receiver site, the received digital signals are decoded to retrieve the original data (analog or digital).



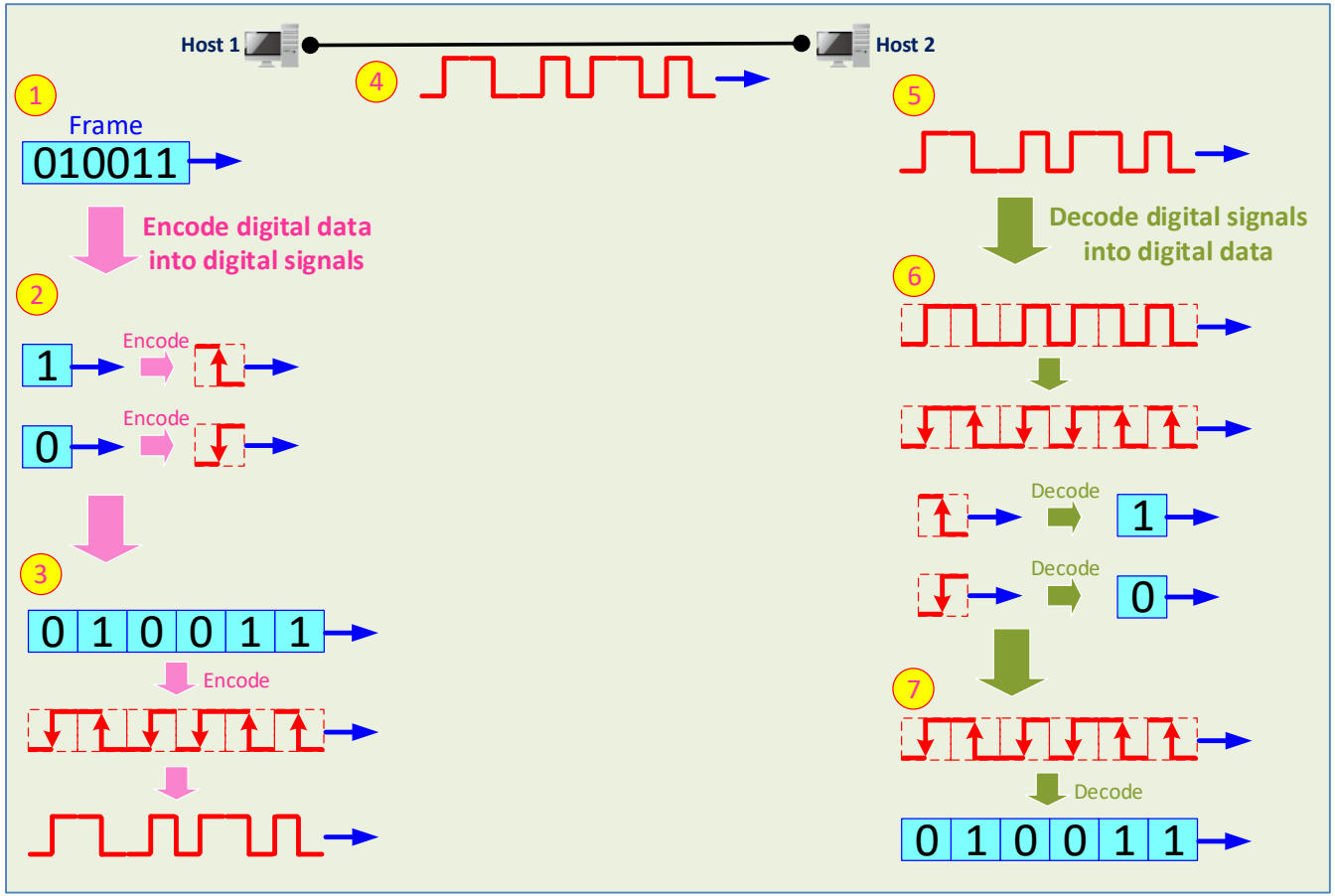
Modulation & Demodulation

- If some data (analog or digital) have to be transmitted in the form of analog signal, the data have to be modulated into analog signals at the sender site.
- At the receiver site, the received analog signals are demodulated to retrieve the original data (analog or digital).

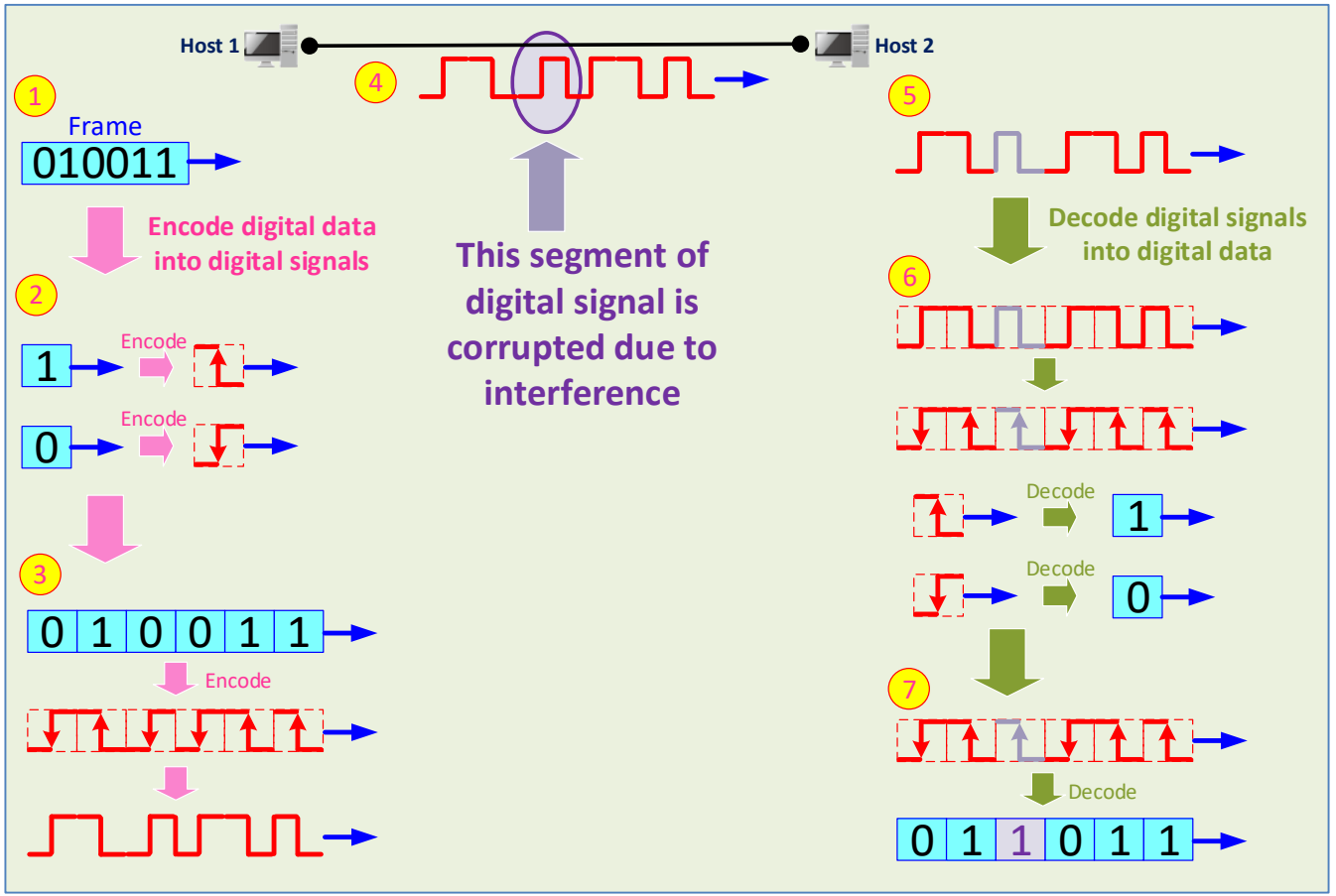


Wired Signal's Encoding, Decoding and Decoding Error

Wired Signal's Encoding and Decoding

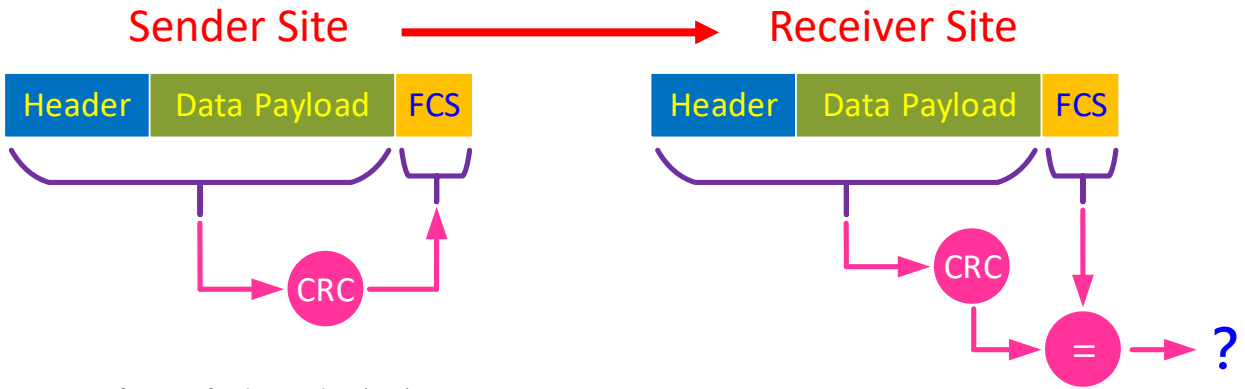


Wired Signal's Decoding Error



How to check if the decoded data are corrupted?

- A frame is usually composed of header field, data payload field, and frame check sequence (FCS) field.
- The value filled in the FCS field is calculated by the Cyclic Redundancy Check (CRC) algorithm. The input data for the algorithm are the contents of header field and data payload field.
- Before a frame is transmitted at the sender site, a CRC value is calculated and filled in the FCS field.
- When the frame is received at the receiver site, another CRC calculation is done and the new CRC value is used to compare with the value of the FCS field. If the two values are different, the received data are considered corrupted.



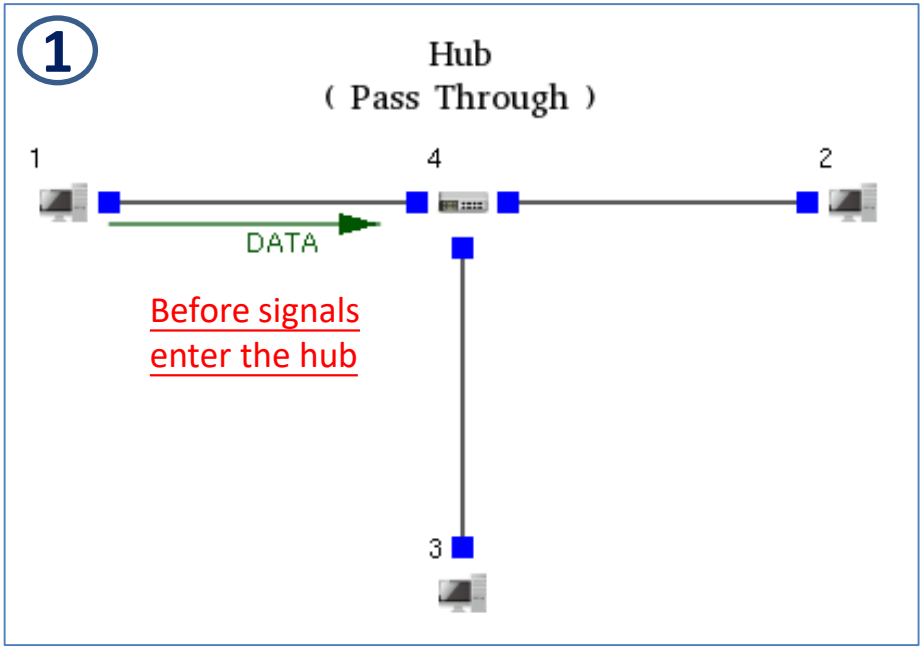
Wired Signal's Propagation

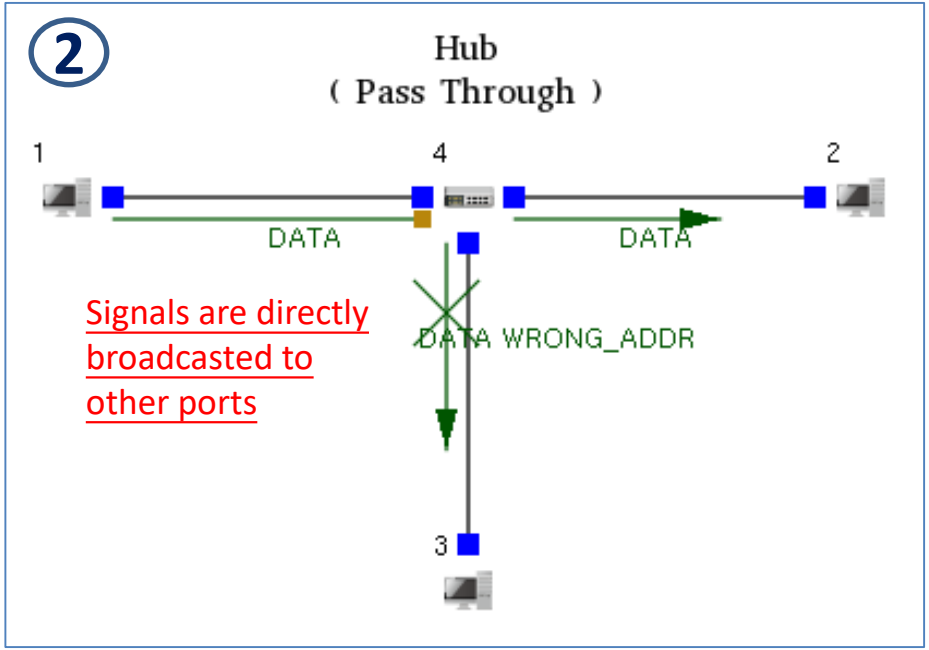
< Simulation Case >

pass_through_and_store_and_forward.xtpl

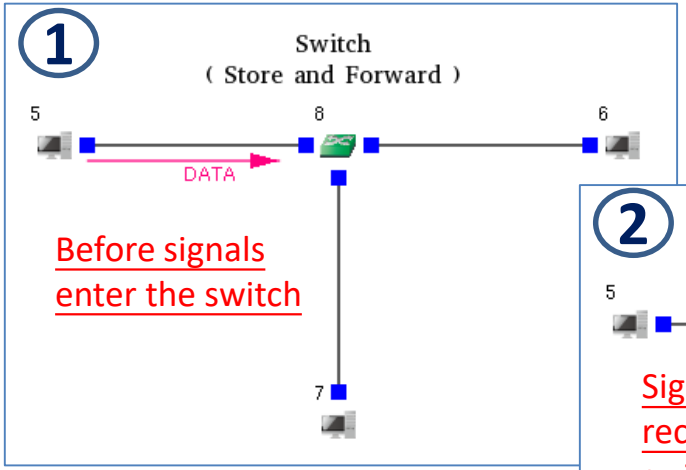
wired_signal_collision.xtpl

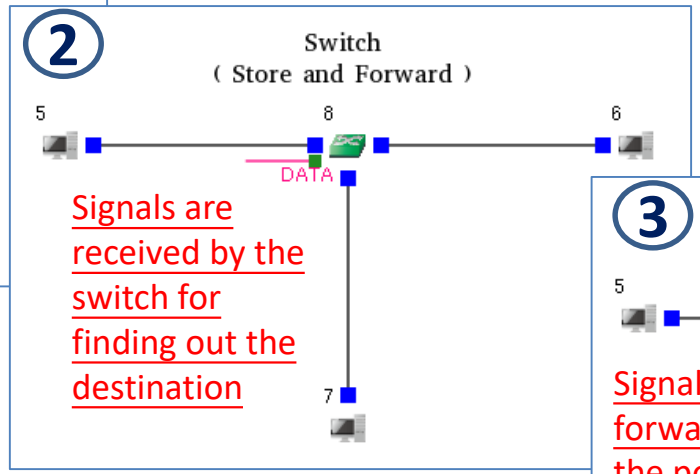
When wired signals enter a network device like hub or repeater, the signals directly pass through the device without experiencing signal decoding.

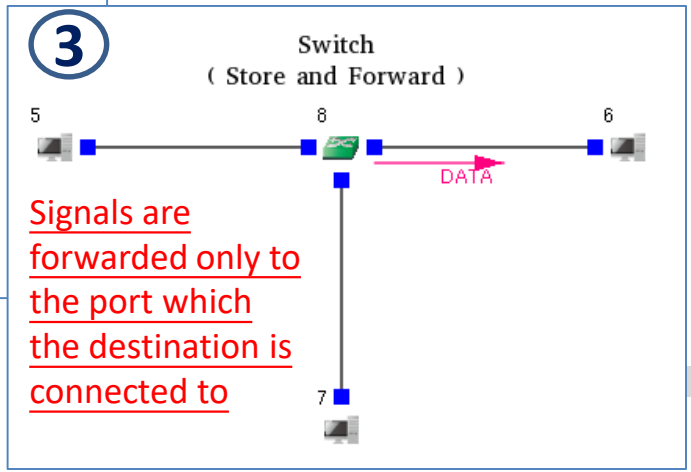




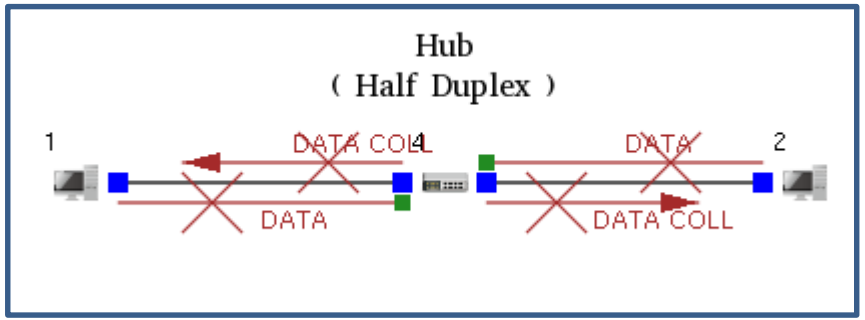
When wired signals enter a network device like switch or router, the signals have to experience signal decoding and the decoded data have to be stored and processed for determining the outgoing interface/port.

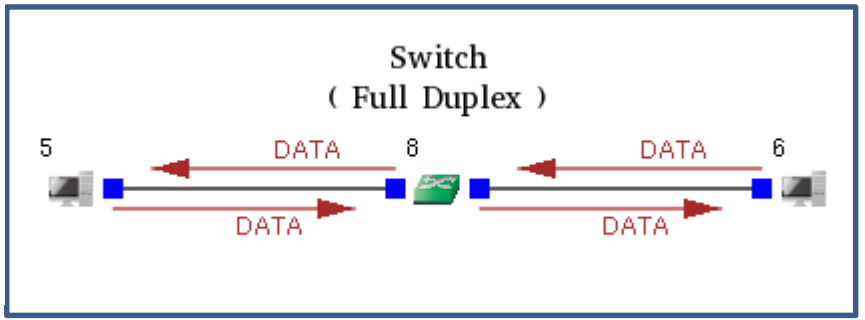






Wired signals could collide with other signals while being transmitted on a wire.



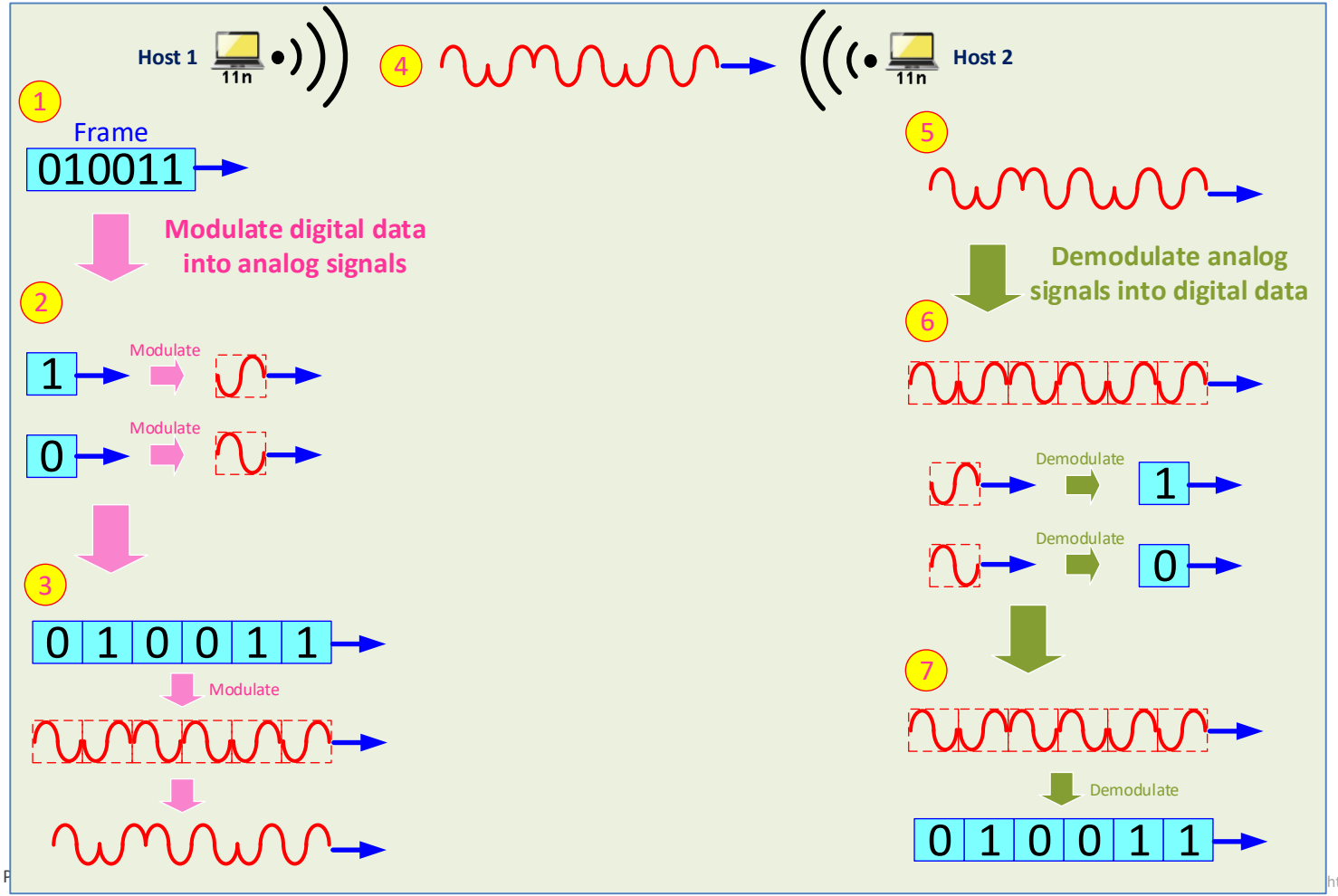


- If, on a wire, only one direction is allowed to transmit signals simultaneously, it is called half duplex.
- If signals are transmitted from both directions simultaneously, a signal collision occurs and that results in no successful signal reception.

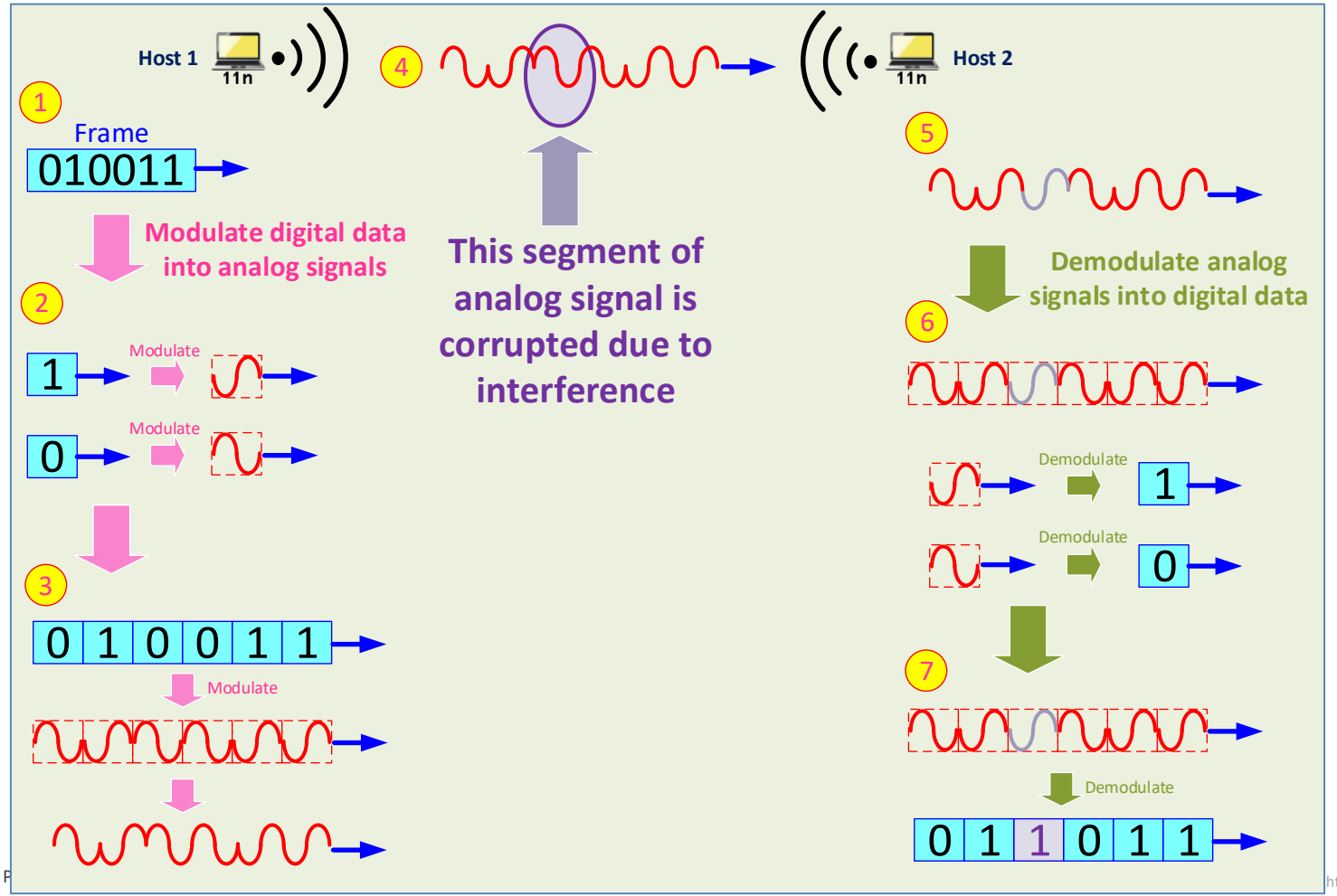
- If, on a wire, both directions are allowed to transmit signals simultaneously, it is called full duplex.
- No collision occurs on a full-duplex wire.

Wireless Signal's Modulation, Demodulation and Demodulation Error

Wireless Signal's Modulation and Demodulation



Wireless Signal's Demodulation Error



How to check if the demodulated data are corrupted?

- A frame is usually composed of header field, data payload field, and frame check sequence (FCS) field.
- The value filled in the FCS field is calculated by the Cyclic Redundancy Check (CRC) algorithm. The input data for the algorithm are the contents of header field and data payload field.
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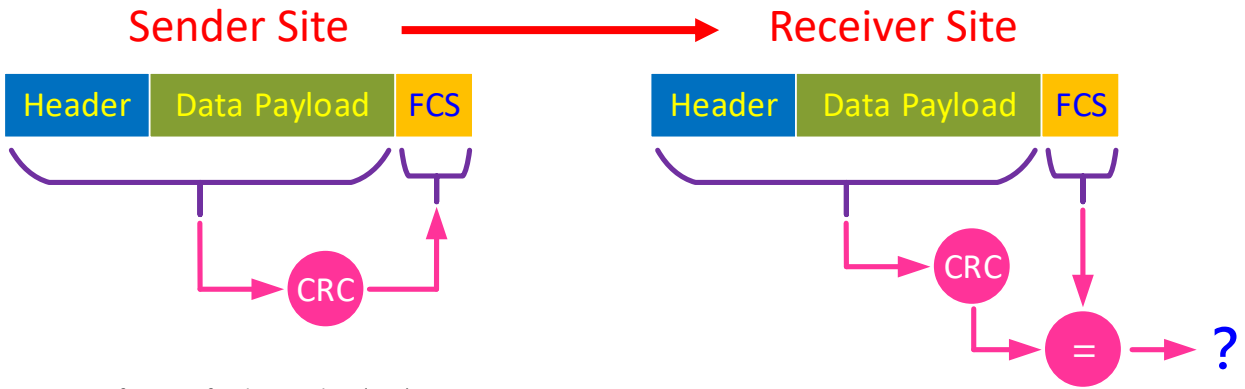


Wireless Signal's Propagation

< Simulation Case >

antenna_gain_pattern.xtpl

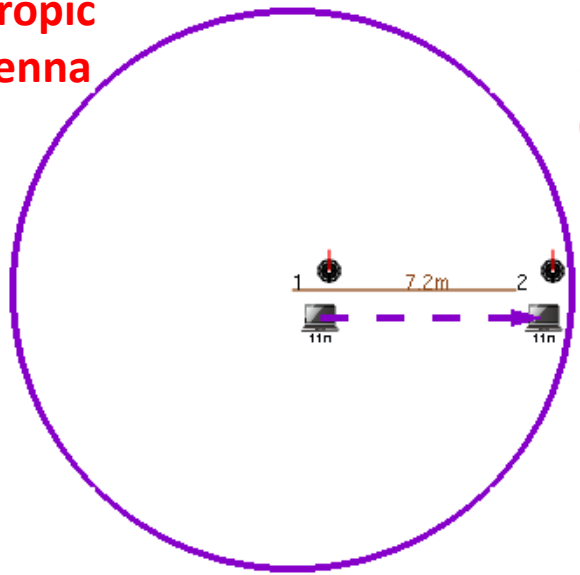
wireless_link_recv_sensitivity.xtpl

wireless_signal_collision.xtpl

Factors to determine the transmission range of wireless signals:

1. Antenna gain patterns of both sender site and receiver site
2. Signal transmission power on sender site
3. Signal receiving sensitivity on receiver site
4. Signal frequency and environmental parameters (e.g., terrain, surface object, weather, interference, etc.)

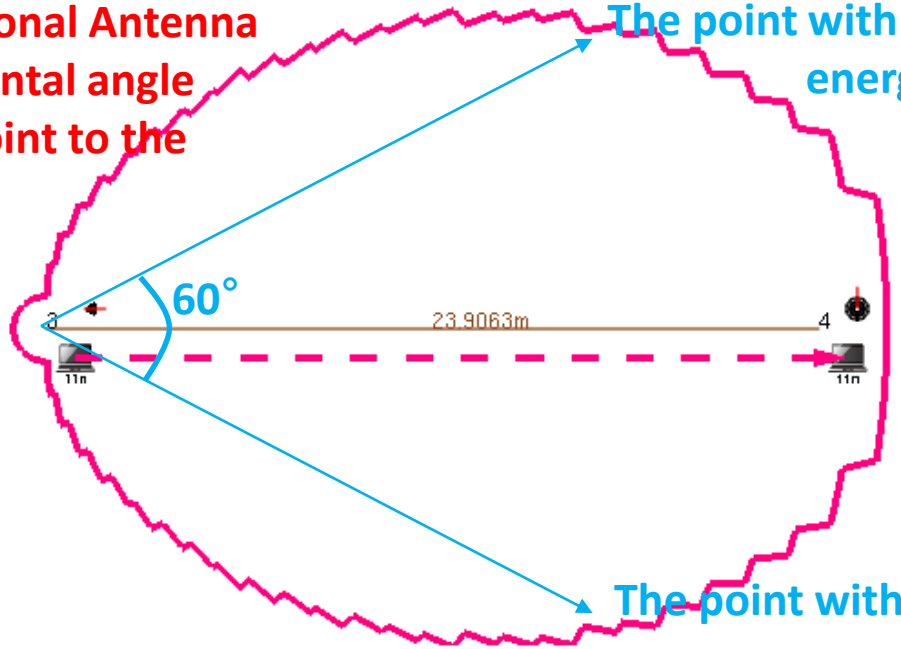
Isotropic Antenna



Tx Power = -17 dbm

Isotropic Antenna

Directional Antenna (horizontal angle 60°, point to the right)



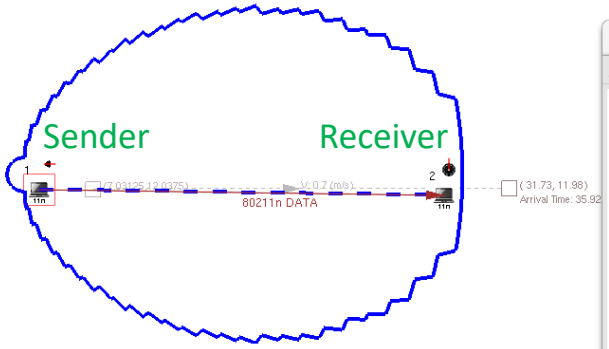
The point with half the energy (-3dB)

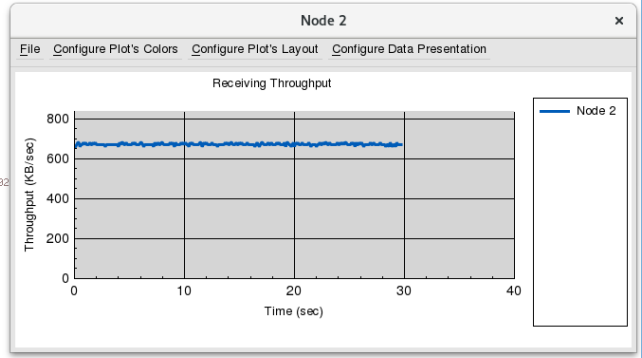
The point with half the energy (-3dB)

Tx Power = -17 dbm

(Antenna Gain Pattern) 3 dB Beamwidth 60 degrees

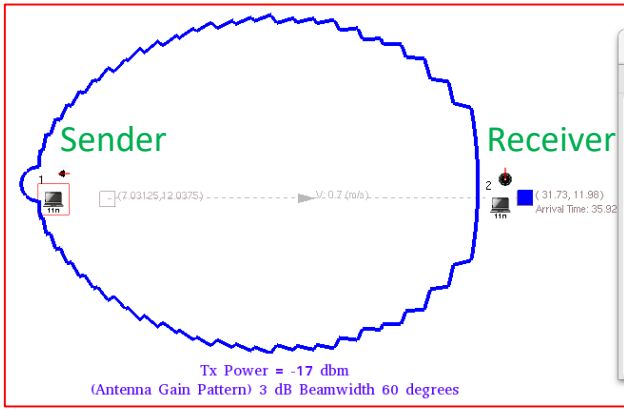
The transmission power of signal is gradually attenuated along with the signal emission path. When the power is lower than the receiving sensitivity of a receiver, no signal is received.



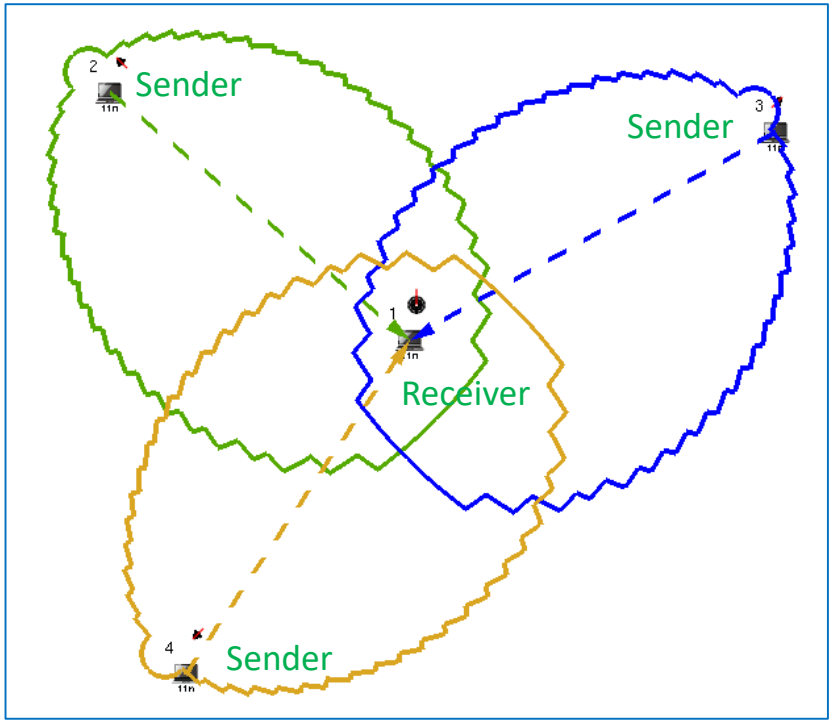


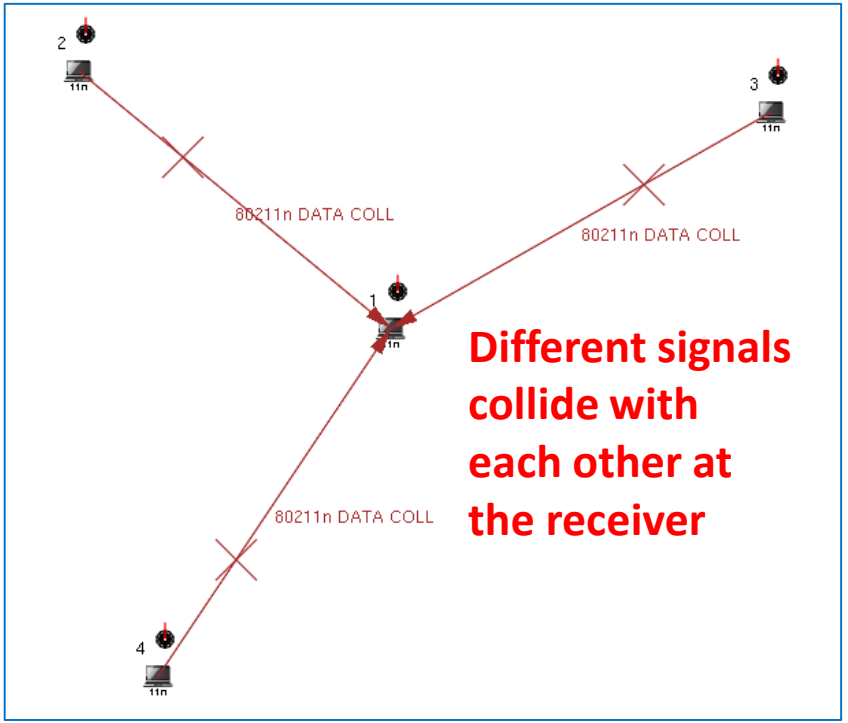
The receiver is moving within the coverage of transmitted signals, it receives the signals successfully.

Once the receiver moves beyond the coverage of the transmitted signal, no signal is received.



When wireless signals are transmitted on the air, collisions could occur among different signals.





Summary

Review of Points

- In terms of signal delivery time, what is transmission time? And what is propagation delay?
- What are the factors to determine the end-to-end delay?
- What are the procedures of signal encoding/decoding and modulation/demodulation? Why are there errors during the procedures of signal decoding and demodulation?
- What are the characteristics of wired signal propagation?
- What are the characteristics of wireless signal propagation?