

Tutorial 2: MAC layer

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Computer Networks 2025-2026



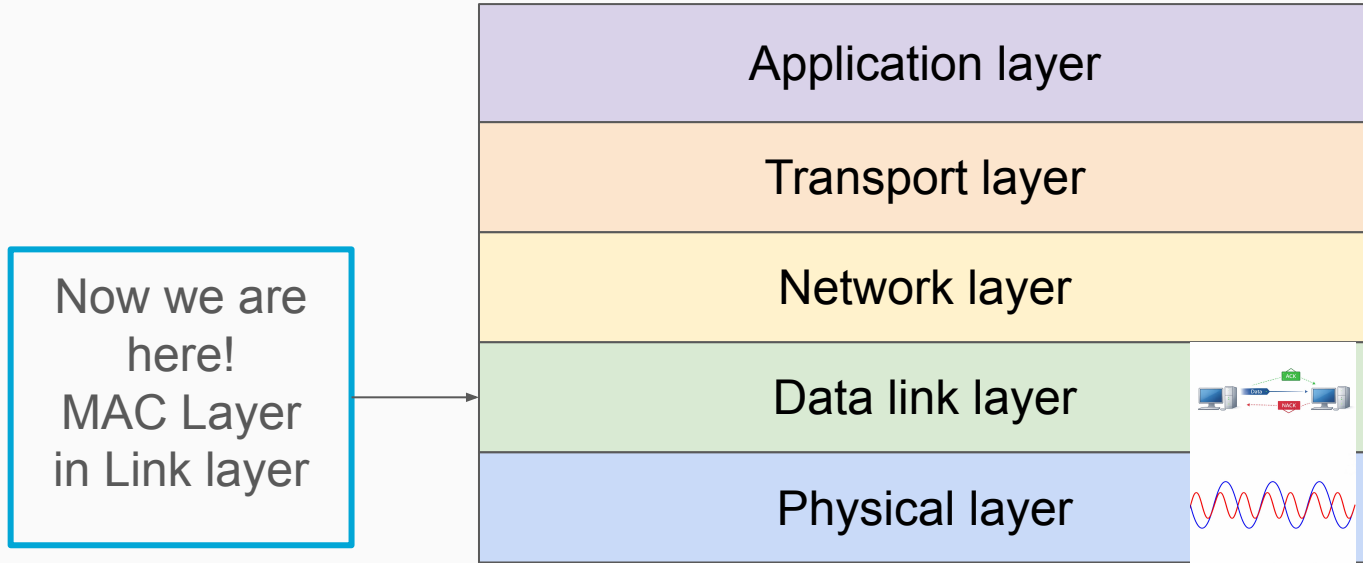
Mandatory Lab 1 & 2

- 21 april (Tuesday lab)
- 24 april (Friday lab)

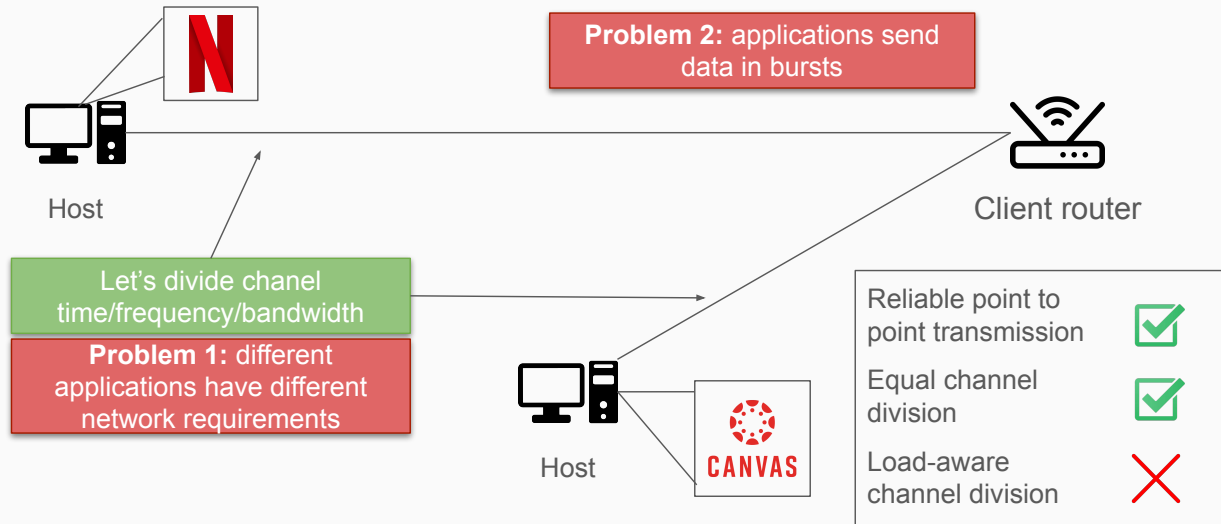
Self Study part 1

- 24 april, 23:59

Recap: Layers



Controls who can send their data, but ...
Didn't we already have this in the physical layer?



Menu of The Day

MAC Layer (Medium Access control)

Recap

Wireless & Wired

1. CSMA/CD algorithms

Wireless

2. Exposed and hidden terminals

Wired

3. Ethernet
 - a. Frame size
 - b. Switching

Error Correction

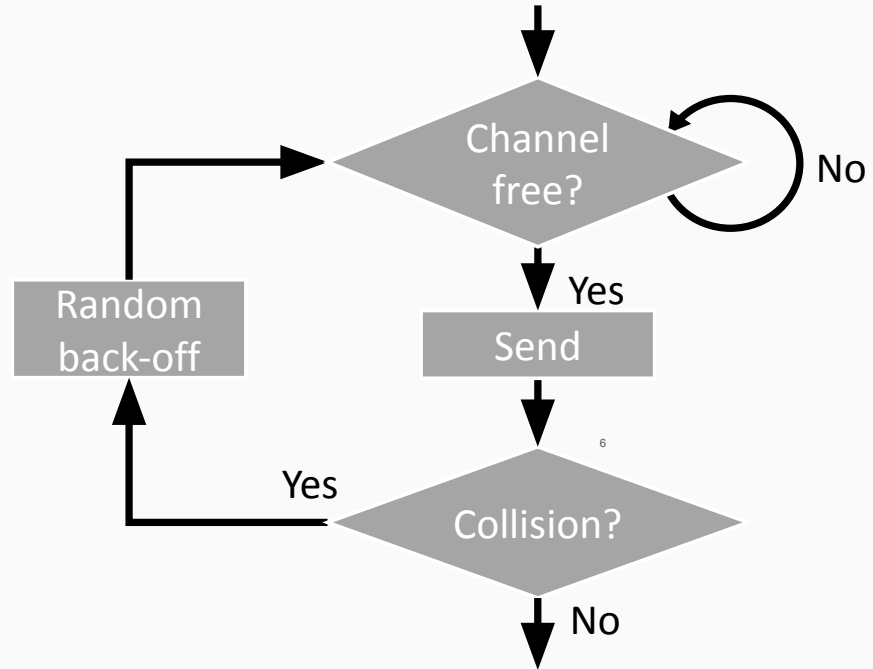
4. Hamming codes



CSMA: Carrier-Sense Multiple Access, Contend or Coordinate?

What is CD?

First: 1 persistent CSMA/CD



Exercise 1

Stations A, B, and C use 1-CN-persistent CSMA/CD to share a single channel. This protocol is identical to 1-persistent CSMA/CD, except station **A** always backs off **1 time unit**, **B** backs off **2 time units**, and **C** backs off **3 time units**.

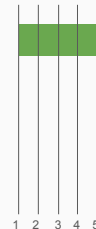
Assume that the stations have a frame to send at the following points in time:

A: $t=1$ and $t=10$, **B**: $t=2$ and $t=12$, **C**: $t=6$

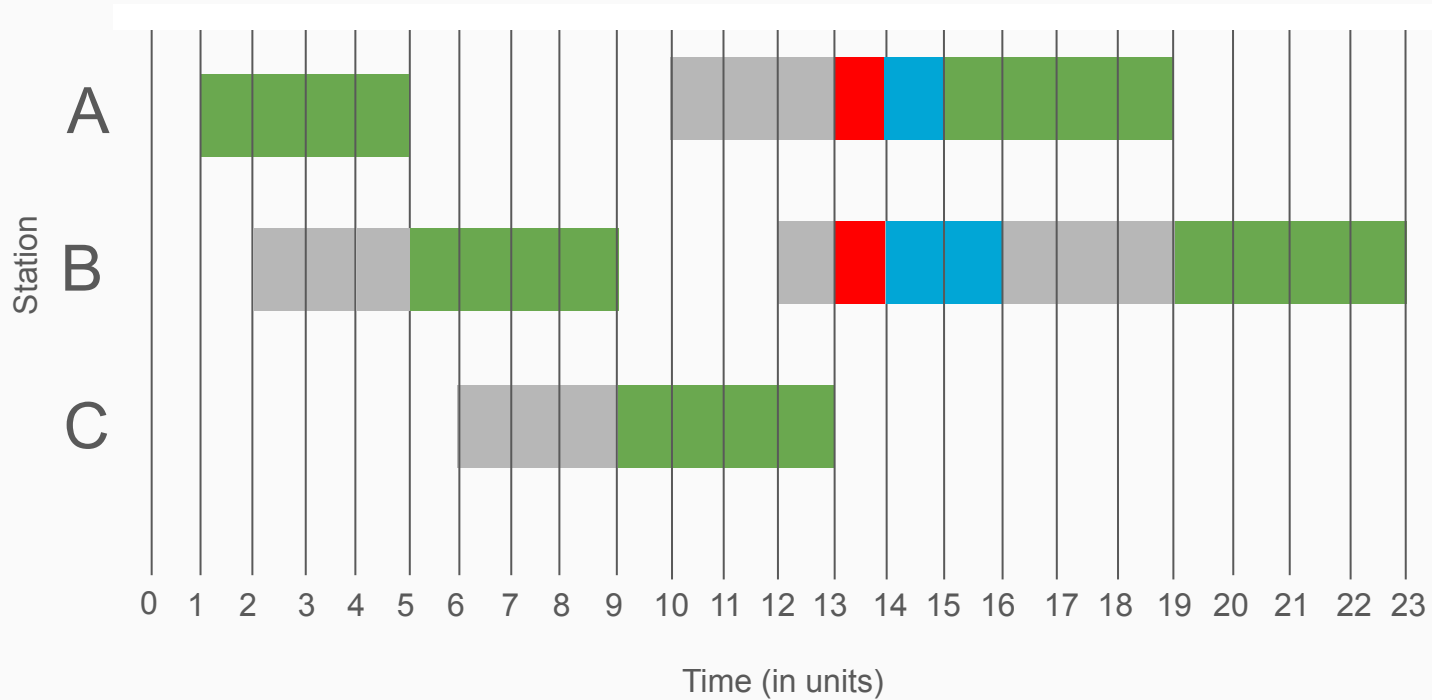
Assume that sending a **frame** always takes **4 time units**, and that it takes one time unit to detect a collision and stop transmitting.

Simulate and visualize the correct order of events (wait, transmit, collide, back-off), starting at $t=0$. Question: what is the time unit at which station B finishes the transmission?

Note: sending
frame at $t = 1$



Answer exercise 1

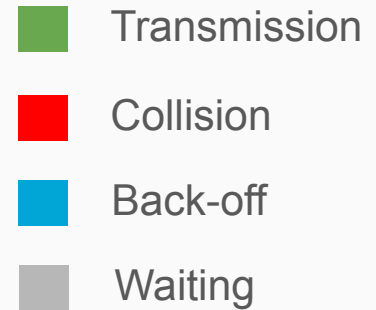


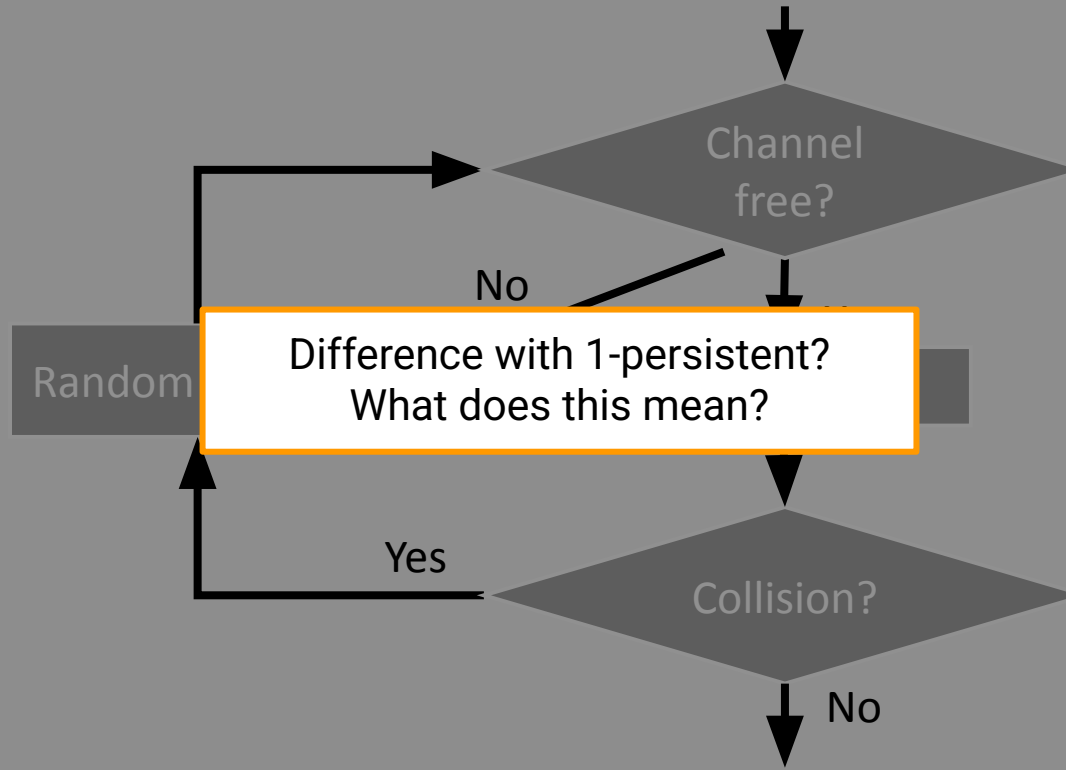
Transmission - 4
time units

A: at $t=1$ and $t=10$.
Backoff - 1

B: at $t=2$ and $t=12$.
Backoff - 2

C: at $t = 6$. Backoff
- 3





Exercise 2: Non-persistent CSMA/CD

Stations A, B, and C use non-CN-persistent CSMA/CD to share a single channel. This protocol is identical to nonpersistent CSMA/CD, except station **A** always backs off **1 time unit**, **B** backs off **2 time units**, and **C** backs off **3 time units**.

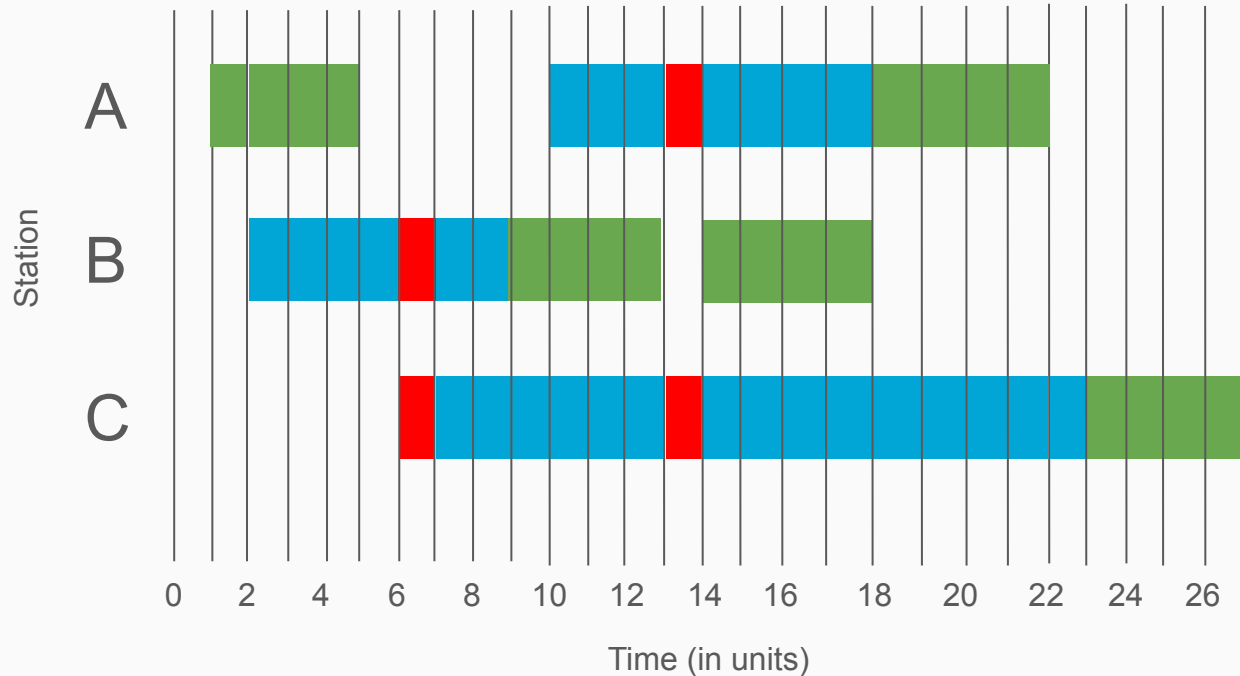
Assume that the stations have a frame to send at the following points in time:

A: $t=1$ and $t=10$, **B**: $t=2$ and $t=14$, **C**: $t=6$

Assume that sending a **frame** always takes **4 time units**, and that it takes one time unit to detect a collision and stop transmitting.

Simulate and visualize the correct order of events (wait, transmit, collide, back-off), starting at $t=0$. Question: what is the time unit at which **station C** finishes the transmission?

Answer for Non-persistent CSMA/CD



Transmission - 4 time units

A: at $t=1$ and $t=10$.
Backoff - 1

B: at $t=2$ and $t=14$.
Backoff - 2

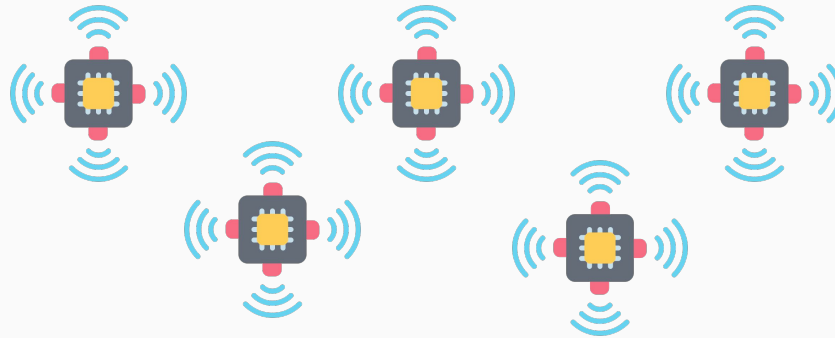
C: at $t=6$. Backoff - 3

Transmission

Collision

Back-off

Offers a trade-off between collision count and a latency



Example use: Low-powered IoT devices

Menu of The Day

MAC Layer (Medium Access control)

Wireless & Wired

~~1. GSM/CD algorithms~~

Wireless

2. Exposed and hidden terminals

Wired

3. Ethernet
 - a. Frame size
 - b. Switching

Error Correction

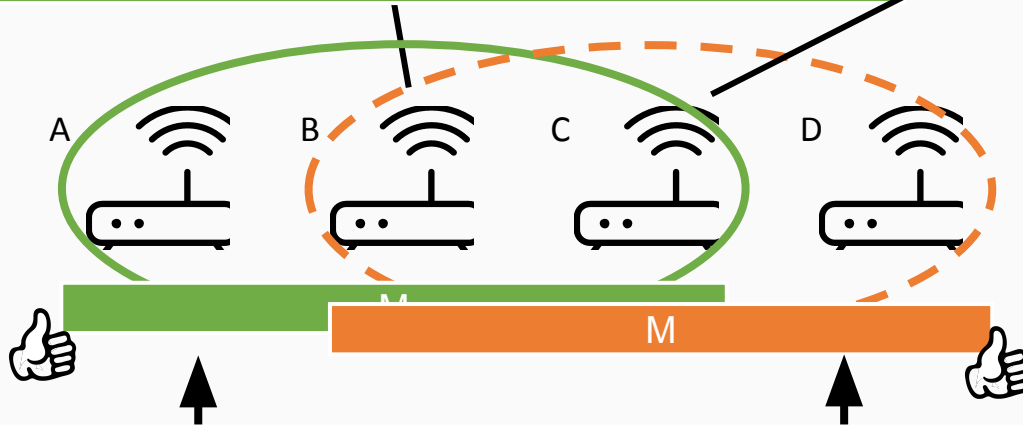
4. Hamming codes



Exposed Terminals

Channel is free, I can send my frame to A

Channel is in use,
I **cannot** send my frame to D



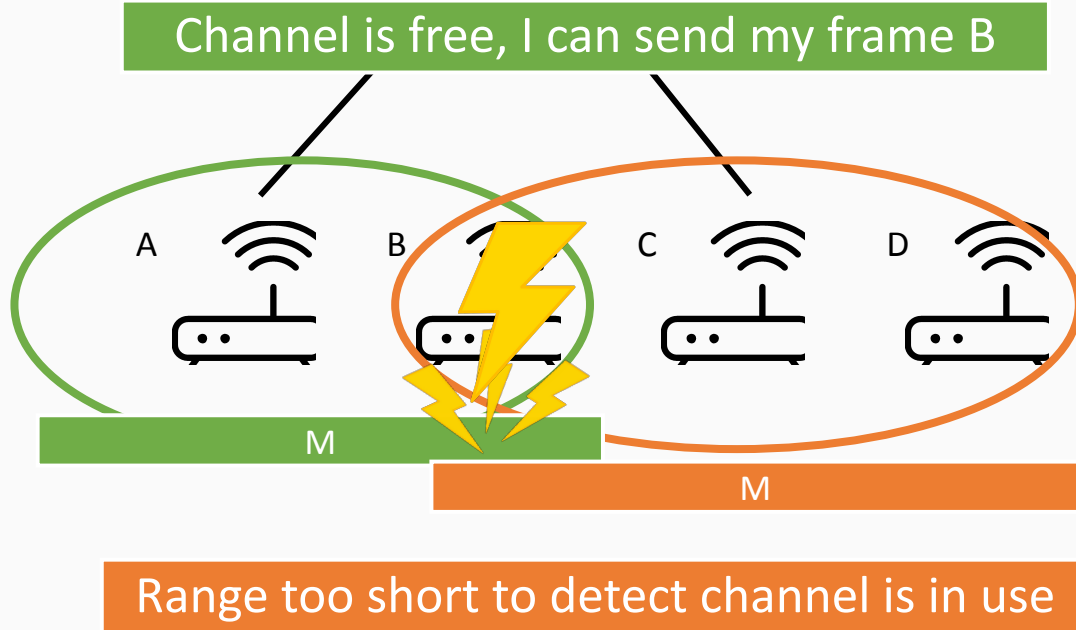
There would be no collision at recipients

B starts transmission to A and then C wants to transmit to D

Assume a station has a range only to a neighbouring stations

Wasted bandwidth!

Hidden Terminals



A transmits to B and then C transmits to B

Collision at B!

Exercise exposed and hidden terminals

There are 4 stations A, B, C, D with the **transmission range** as specified **on the diagram**. Find all the hidden and exposed terminals if:

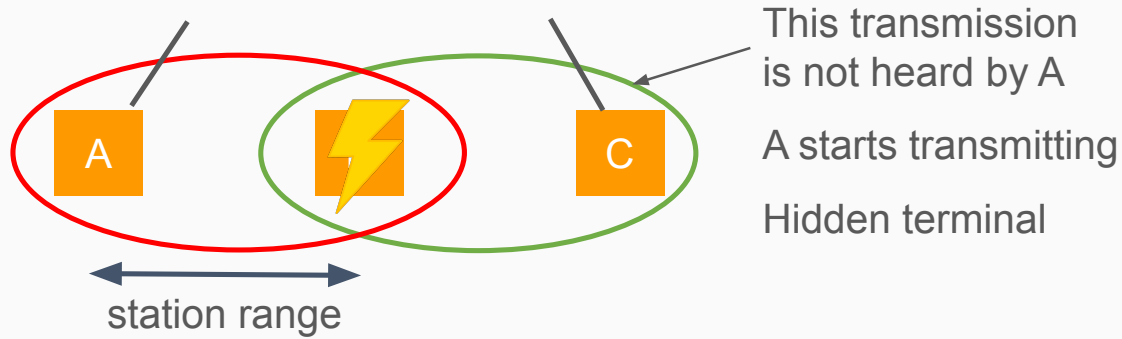
1. A wants to send to B while C is sending to B?
2. A wants to send to B while D is sending to C?
3. B wants to send to A while C is sending to D?

List whether a situation involves hidden (H), exposed (E) terminals or none of those (N). Write down your answer in a form as EHN

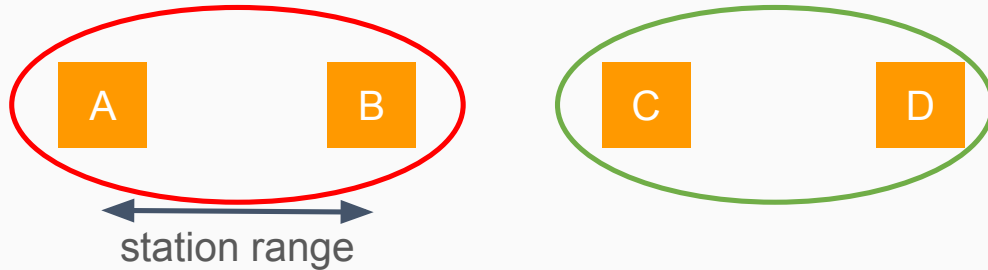


Answers question 1 and 2

A wants to send to B while C is sending to B?

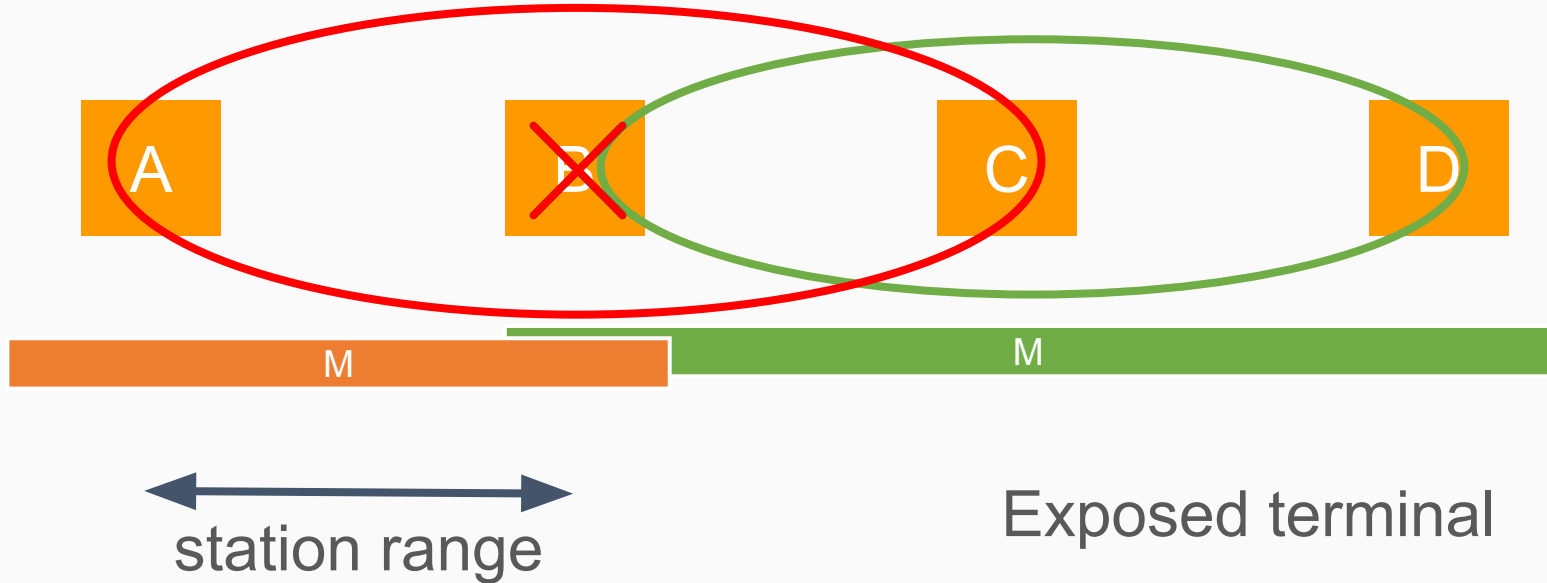


A wants to send to B while D is sending to C



Answer question 3

B wants to send to A while C is sending to D



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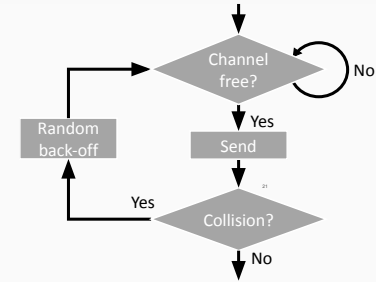
4. Hamming codes



BREAK

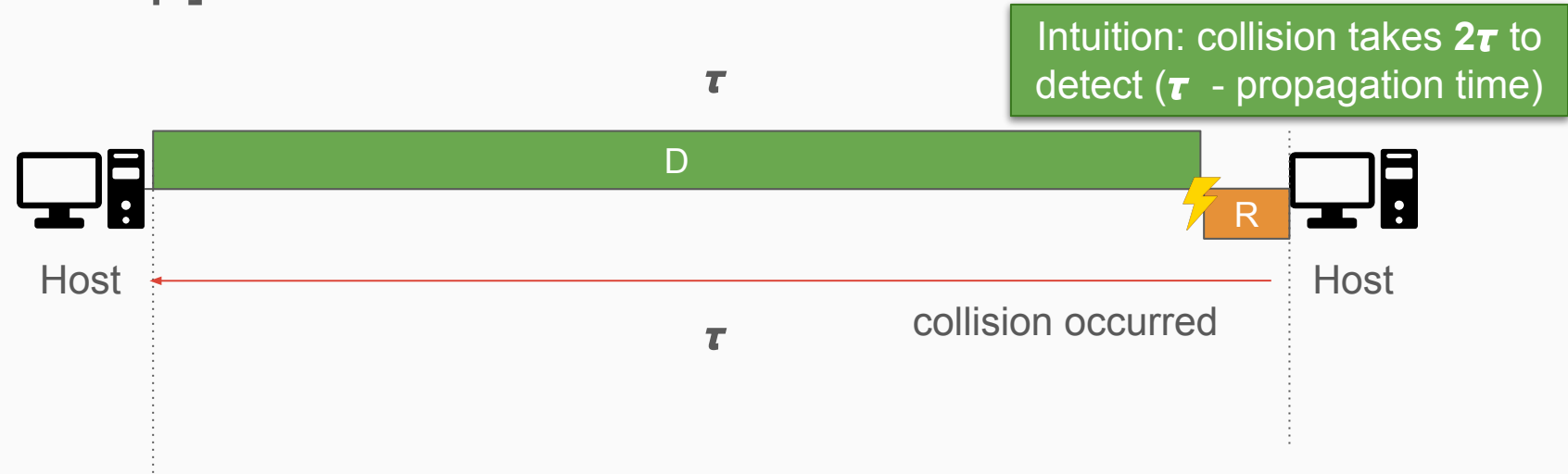
MAC and CSMA/CD for Ethernet

- CD (Collision detection)
- 1-persite CSMA/CD



Failed Attempts	Maximum Delay	Random Delay Range
0	$2^0 - 1 = 0$	$w \in [0,0]$
1	$2^1 - 1 = 1$	$w \in [0,1]$
2	$2^2 - 1 = 3$	$w \in [0,3]$
3	$2^3 - 1 = 7$	$w \in [0,7]$
4	$2^4 - 1 = 15$	$w \in [0,15]$
...

[Recap] Minimal transmission time



We need to keep transmitting to detect a collision. Why?

Minimal packet size:
bandwidth $\times 2\tau$

Ethernet cable has maximum length of **100 meters**. Propagation speed for copper wires is **200,000,000 m/s**. What is the minimum packet size for **10 MB/s**, **100 MB/s** and **1 GB/s** ethernet?

Pre-gigabit Ethernet standard defined minimal packet size **64 bytes**. If distance is kept the same, what would be the maximum supported transmission speed?

Minimal packet size:
bandwidth \times 2τ

Minimum Packet Size

Propagation delay: $100 \div (200,000,000) = 0.5 \mu\text{s}$

$10 \text{ MB/s} \times 2(0.5 \mu\text{s}) = \mathbf{10 \text{ bytes}}$

$100 \text{ MB/s} \times 2(0.5 \mu\text{s}) = \mathbf{100 \text{ bytes}}$

$1 \text{ GB/s} \times 2(0.5 \mu\text{s}) = \mathbf{1000 \text{ bytes}}$

Transmission Speed

Bandwidth = $64 \div 2t$

$= 64 \div 2(0.5 \mu\text{s})$

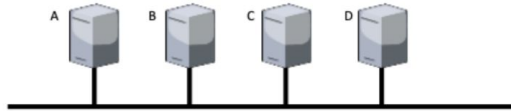
$= 64 \div 1 \mu\text{s} = \mathbf{64 \text{ MB/s}}$

Ethernet Switching

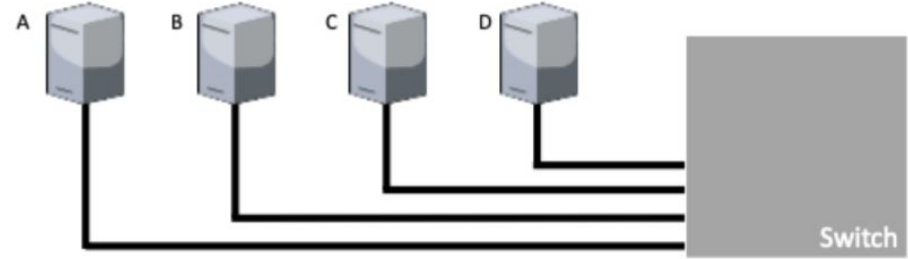
Classic Ethernet

Maximum data rate: 3 to 10 Mbps

Remember?

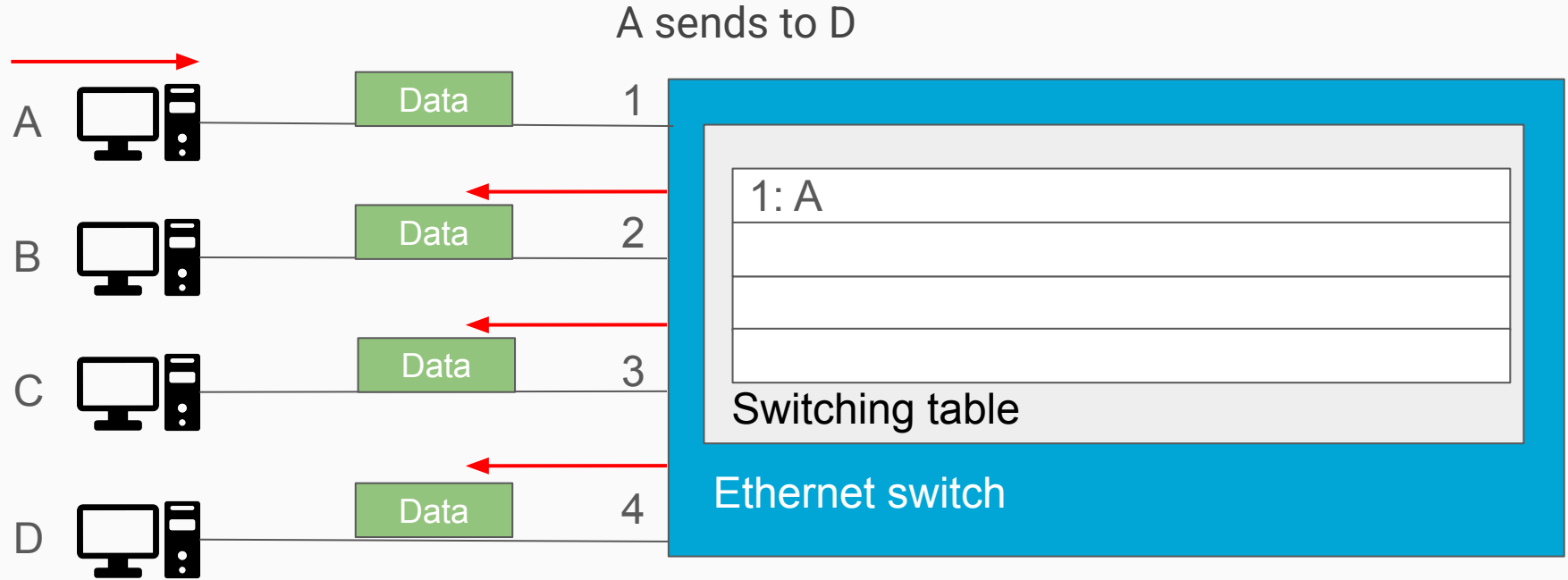


File preview

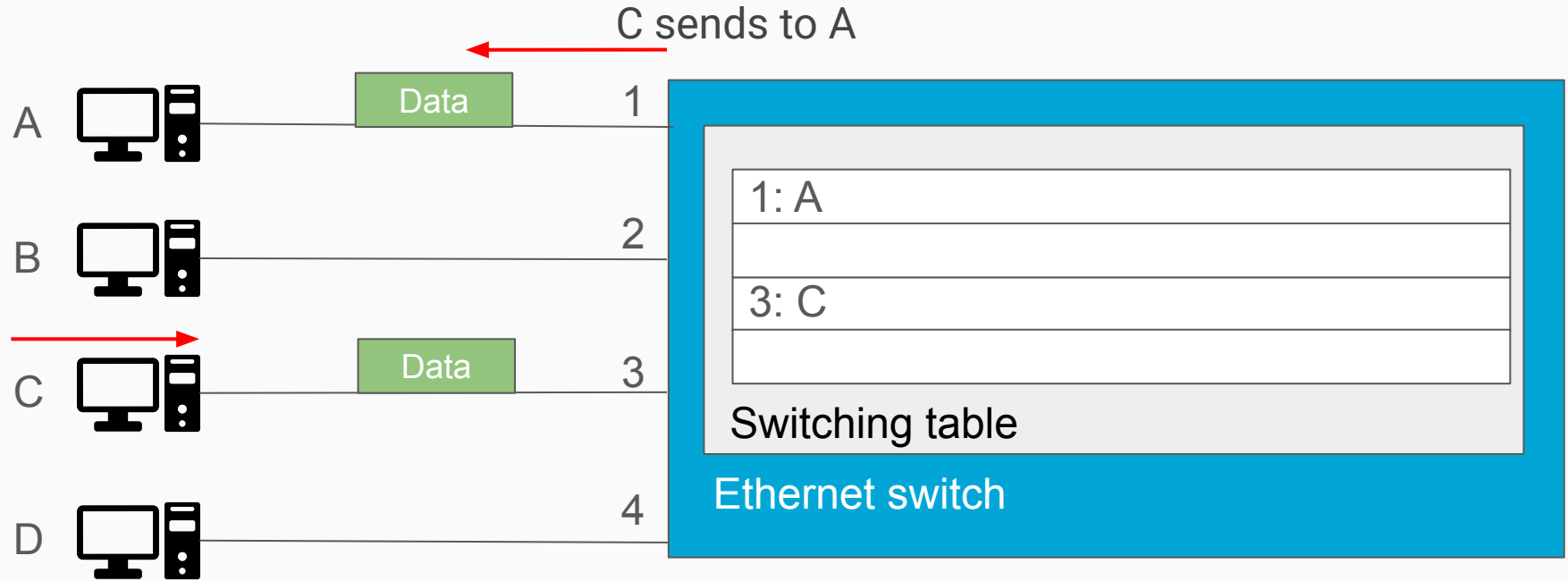


Do we still need the MAC layer?

Ethernet Switching Example



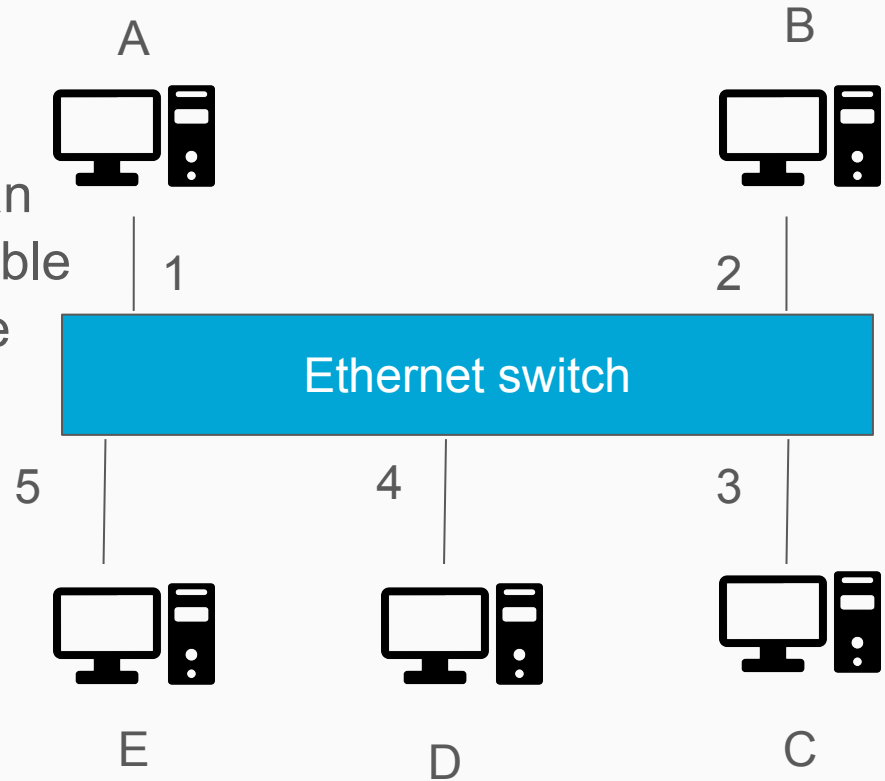
Ethernet Switching Example



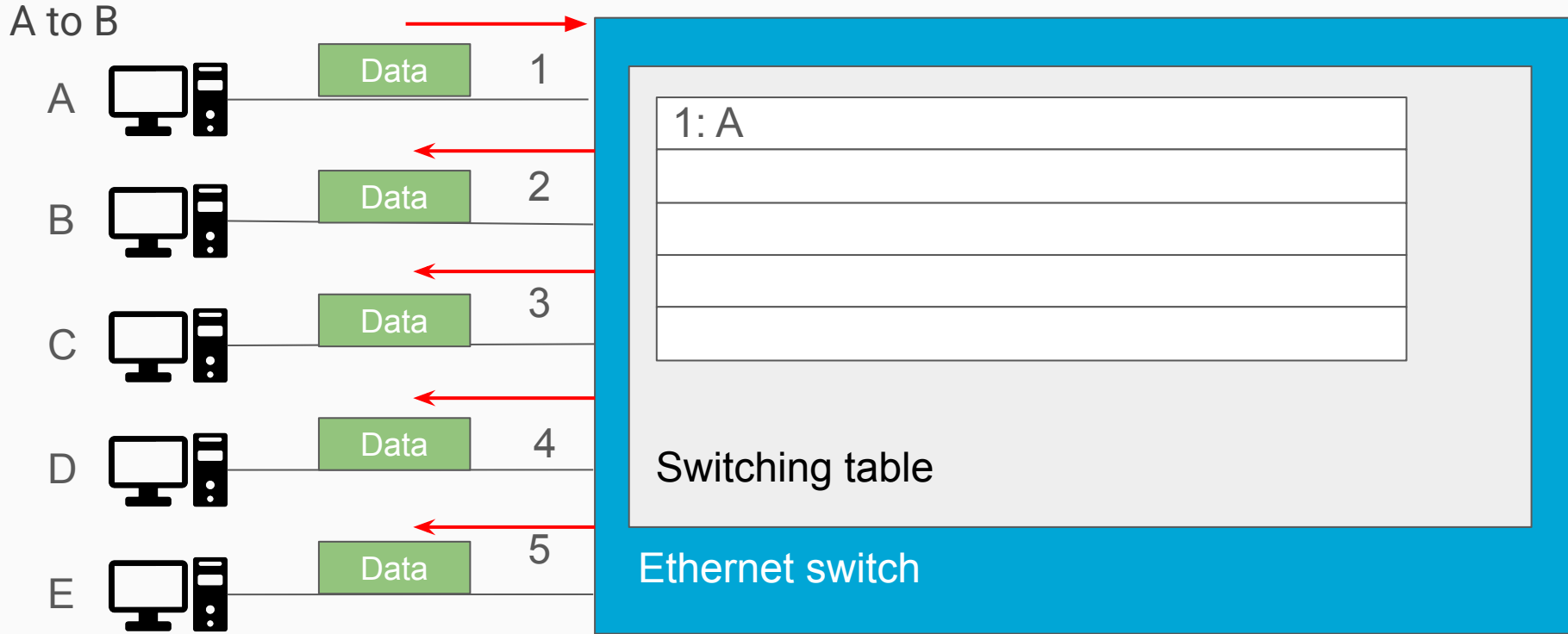
Ethernet switching exercise

There are five stations connected to an ethernet switch. Assume the switch table is empty. What is the state of the table after the following events:

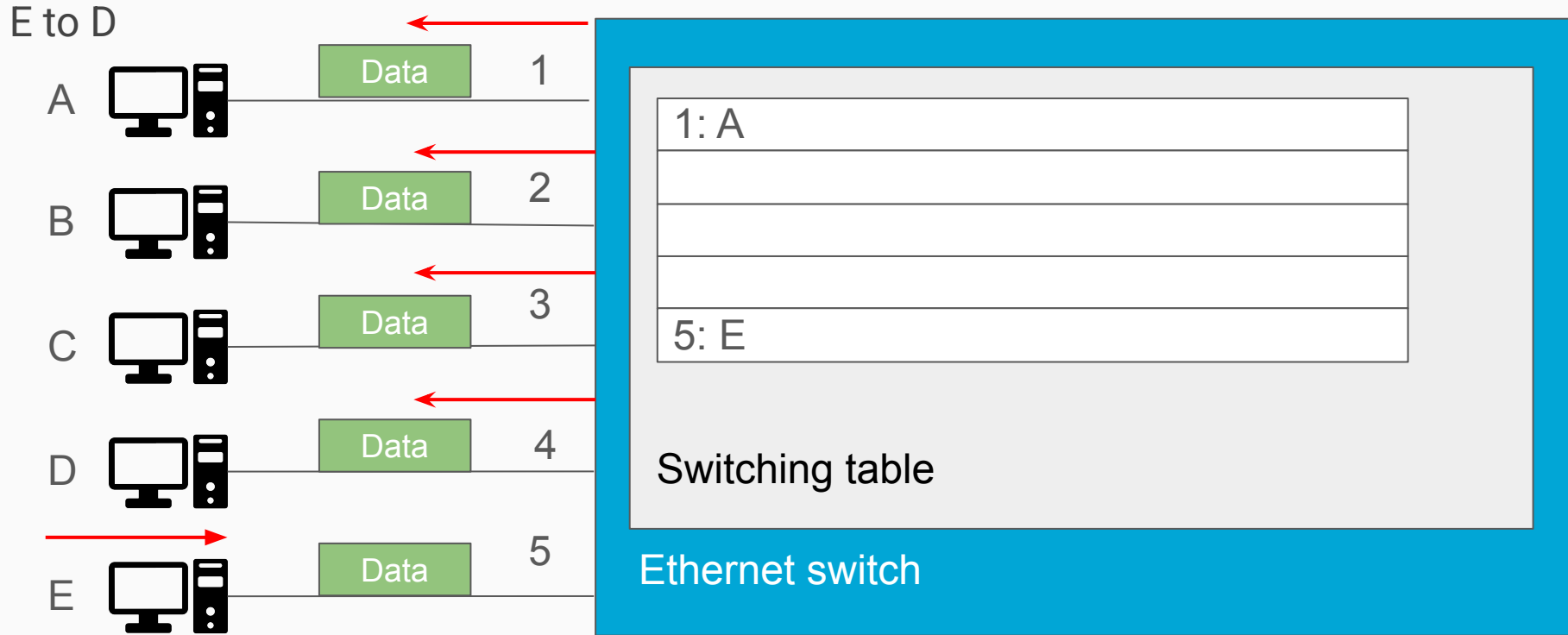
1. A transmits to B
2. E transmits to D
3. D transmits to A
4. C transmits to D
5. B transmits to C



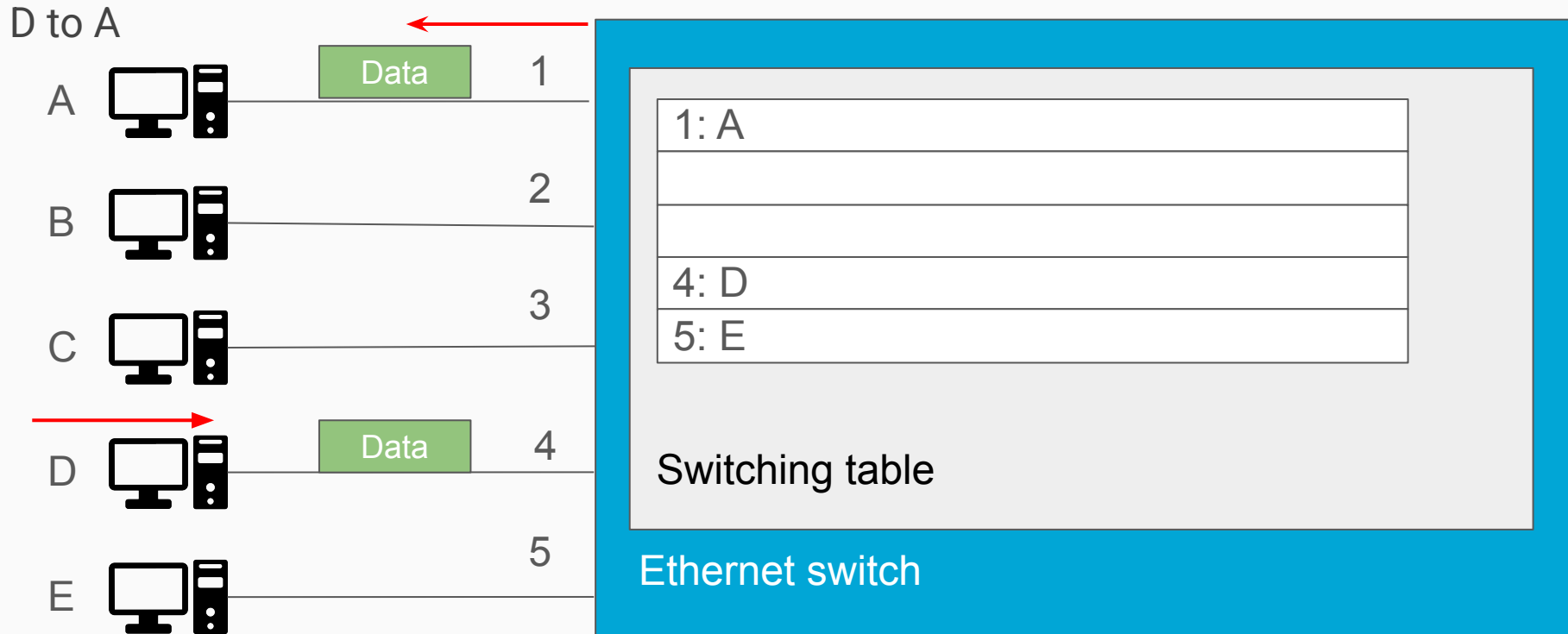
Ethernet Switching solution



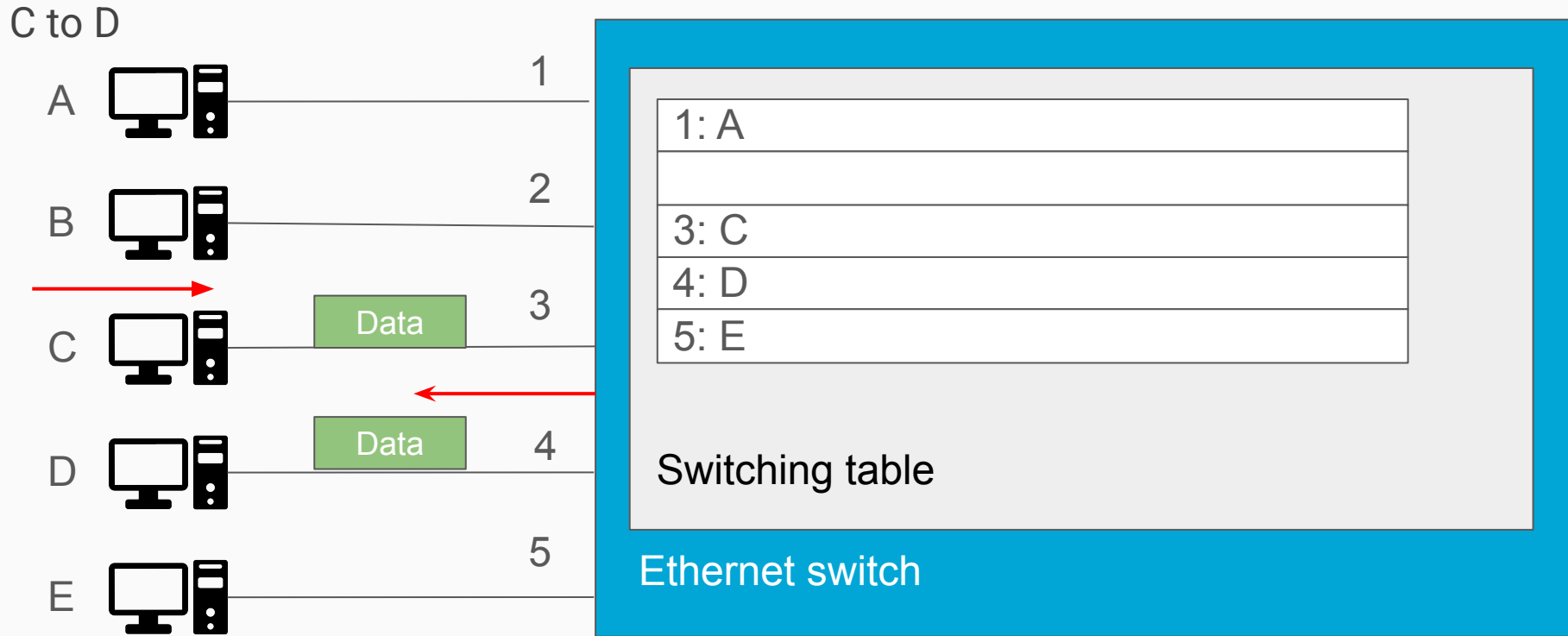
Ethernet Switching Solution



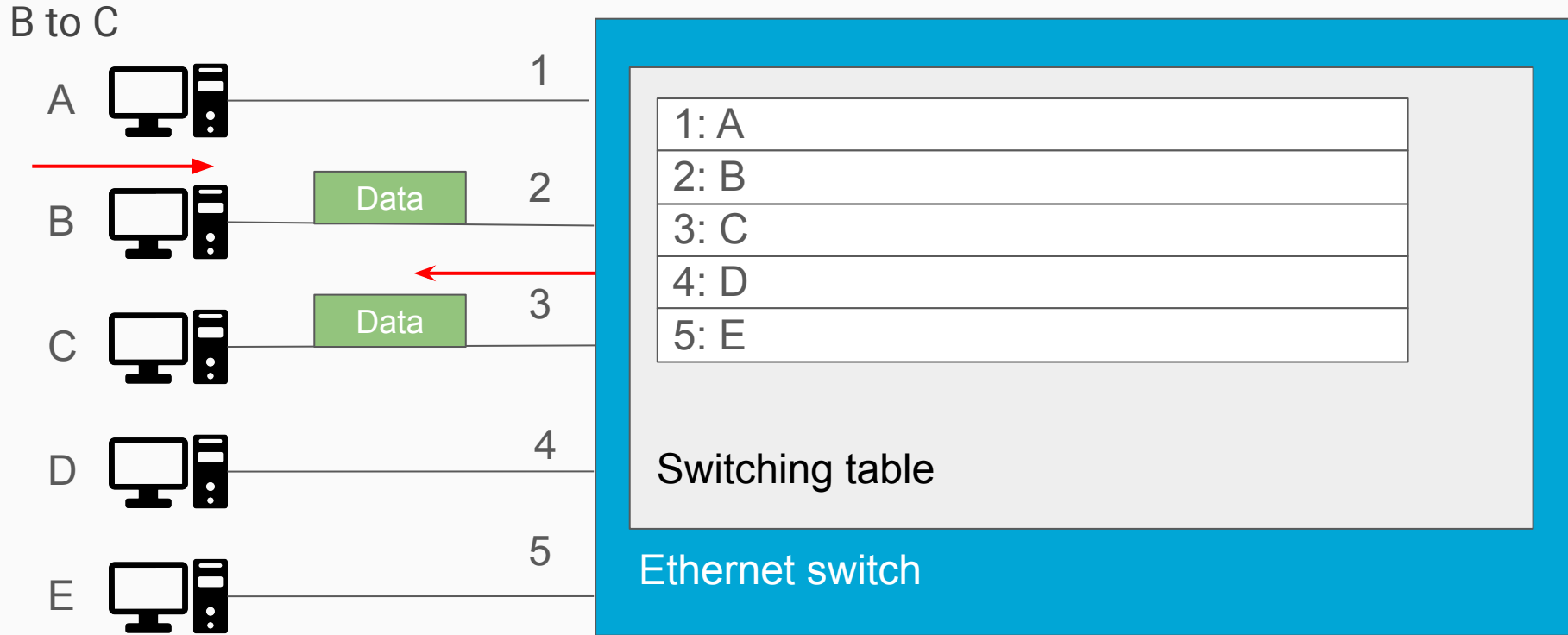
Ethernet Switching Solution



Ethernet Switching Solution



Ethernet Switching Solution



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Wireless & Wired

~~1. GSM/GD algorithms~~

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- ~~3. Ethernet~~
- ~~a. Frame size~~
 - ~~b. Switching~~

Error Correction

4. Hamming codes



Hamming Codes

Error Correction!

- Parity
- Hamming codes

For check bit 1:

message: 1 101 0101
codeword: **1** **101** **0101**
positions: **1**23456789...

	1	2	3	4	5	6	7	8
	0001	0010	0011	0100	0101	0110	0111	1000
1	x		x		x		x	
2		x	x			x	x	
4				x	x	x	x	
8								x

Exercise Hamming codes

You want to send the data bits 1000 0001.

You use a Hamming code to enable the receiver to *correct* a single bit error in the data.

What is the code word that you transmit?

	1	2	3	4	5	6	7	8
	0001	0010	0011	0100	0101	0110	0111	1000
1	x		x		x		x	
2		x	x			x	x	
4				x	x	x	x	
8								x

Exercise Hamming codes answers

Transmitted bits - 1 000 0001

Check bit 1 - 1 000 0001

Check bit 2 - 1 1 000 0001

Check bit 4 - 111 1000 0001

Check bit 8 - 1111000 10001

	1	2	3	4	5	6	7	8
	0001	0010	0011	0100	0101	0110	0111	1000
1	x		x		x		x	
2		x	x			x	x	
4				x	x	x	x	
8								x

Answer - 111100010001

Golden Exercise

Check 1: 1111 1000 0101 : 1

Check 2: 1111 1000 0101 : 1

Check 4: 1111 1000 0101 : 1

Check 8: 1111 1000 0101 : 0

Position: 0111 = ? = 7

Answer: 1111 1010 0101

Question 3 Consider a protocol that uses a (8,12) Hamming code for error correction. This protocol detects an error in the code word 1111 1000 0101 (spaces added to improve readability). What is the corrected code word?

- 1110 1000 0101
- 1011 1000 0101
- 1111 1010 0101
- 1111 1001 0101

What have we done

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1. CSMA/CD algorithms

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Error Correction

4. Hamming codes



QUIZ TIME!