Revision Notes: Carrier Sense Multiple Access Protocols

1. Carrier Sense Multiple Access (CSMA)

CSMA is a **Random Access Protocol** used in the MAC layer where multiple nodes share a common medium/channel.

Concept	Definition/Principle	Analogy / Explanation	Citation
Principle	**Sense before Transmit** (or Listen before Talk). A station must check the channel status before sending data.	The shared medium is like a common road; check if a vehicle (data) is moving before pulling out your car.	
Sensing Limit	Sensing checks only the node's local connection point, not the entire medium.	You only check traffic directly in front of your house, not the whole street.	
Collision Cause	Collision still exists due to **propagation delay**. A station senses idle because the first bit sent by another station has not yet arrived.	The data is "on the way," but your station senses it as free because the signal hasn't reached your point yet.	

CSMA Persistent Methods

Type	When Channel is IDLE	When Channel is BUSY	Analogy/Behavior	Citation
1-Persistent	**Immediately** transmits data (Probability P=1).	**Continuously senses** the medium until it becomes idle.	Highly persistent, utilizes resources continuously. **Worst case:** High chance of collision when multiple stations immediately transmit once the channel clears.	
Non-Persistent (0-Persistent)	Immediately transmits data.	**Does not continually sense**. Waits for a **random period of time** (backoff time) and then repeats the algorithm.	Collision is reduced because stations wait different random times. **Drawback:** Can cause longer transmission delays.	
P-Persistent	Does **not** transmit immediately. Transmits with probability **P** (where $0 < P < 1$).	**Continuously senses** (like 1-Persistent).	A hybrid approach, often used in slotted channels. Utilizes an intermediate probability value. Used conceptually by **Wi-Fi**.	

2. CSMA/CD (Collision Detection)

Topic	Concept / Definition	Application / Use	Key Steps & Requirements	Citation
CSMA/CD	Carrier Sense Multiple Access with **Collision Detection**. The transmitting node can detect collision.	Widely used in **Wired LAN Technology (Ethernet)**.	**Detection Principle:** Stop transmitting immediately when collision is detected to save bandwidth. No acknowledgement system is used as it would increase collisions.	
Detection Rule	Collision is detected **only** if the station receives the collision signal **while it is still**	If transmission finishes *before* the collision signal returns, the station cannot reliably judge if its own data collided.		

	transmitting.	
Worst Case Timing	To ensure detection, the transmission time must be sufficient for the collision signal to return from the farthest point.	**Scenario:** A transmits, B senses idle just before A's bit arrives and transmits, collision occurs immediately at B, collision signal returns to A.
Key Formulas	Transmission Time (TT) must be greater than or equal to the Round Trip Time (RTT).	**1. TT $\geq 2 \times$ Propagation Delay (PD)**. **2. Length of message $\geq 2 \times$ PD $\times$ Bandwidth**.
Efficiency	The efficiency of CSMA/CD.	Efficiency $= 1 / (1 + 6.44a)$, where $a = \text{Propagation Time} / \text{Transmission Time}$.

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3. CSMA/CA (Collision Avoidance)

Topic	Concept / Definition	Application / Use	Strategy / Why Avoidance?	Citation
CSMA/CA	Carrier Sense Multiple Access with **Collision Avoidance**. The goal is to ensure collision does not happen.	Used in **Wireless LAN (Wi-Fi / IEEE 802.11)**.	**Why Avoidance?** Collision detection is not possible in wireless networks because signals lose energy; the sender cannot reliably receive the required "double energy" signal.	
Primary Method	Achieved through a strategy of forcing the sender to wait repeatedly.	**RTS/CTS Exchange:** Used to solve problems like the Hidden Terminal problem. RTS (Ready To Send) and CTS (Clear To Send) signals are exchanged.		

Key Avoidance Steps (Flow)

Step	Action	Explanation / Detail	Citation
1. Sense Carrier	Node senses the channel status. (If busy, senses again).	This is the basic CSMA step.	
2. Wait DIFS	Wait for Distributed Coordination Function Inter Frame Space (DIFS/IFS).	This delay occurs even if the channel seems idle, to check if another station may have started transmitting.	
3. Contention	Choose a random waiting time (R) from the range 0 to $2^K - 1$, where K is the number of attempts.	This exponential backoff mechanism makes stations wait different amounts of time, minimizing simultaneous transmission.	
4. Send RTS	Transmit a Ready To Send signal to the hub/modem.	Signals readiness but not the actual data.	
5. Wait SIFS	Wait for Short IFS.	A small mandatory wait.	
6. Receive CTS	Wait for the Clear To Send signal from the receiver/modem.	If CTS is received before timeout, the transmission can proceed.	
7. Transmit Data	Transmit the data frame.	This step is executed only after all prior waiting and confirmation steps.	

8. Check ACK	Wait for Acknowledgement (ACK).	If ACK is received, success. If ACK times out (not received), a collision occurred, K increases, and the process repeats.