https://drive.google.com/file/d/1Zypkiopu1dY9JmwW-PIh5jvc92rOrQOi/view?usp=sharing

Computer Networks

Data Link Control Protocols (Multiple Access Control Protocols)

(Random Access Protocols: CSMA)

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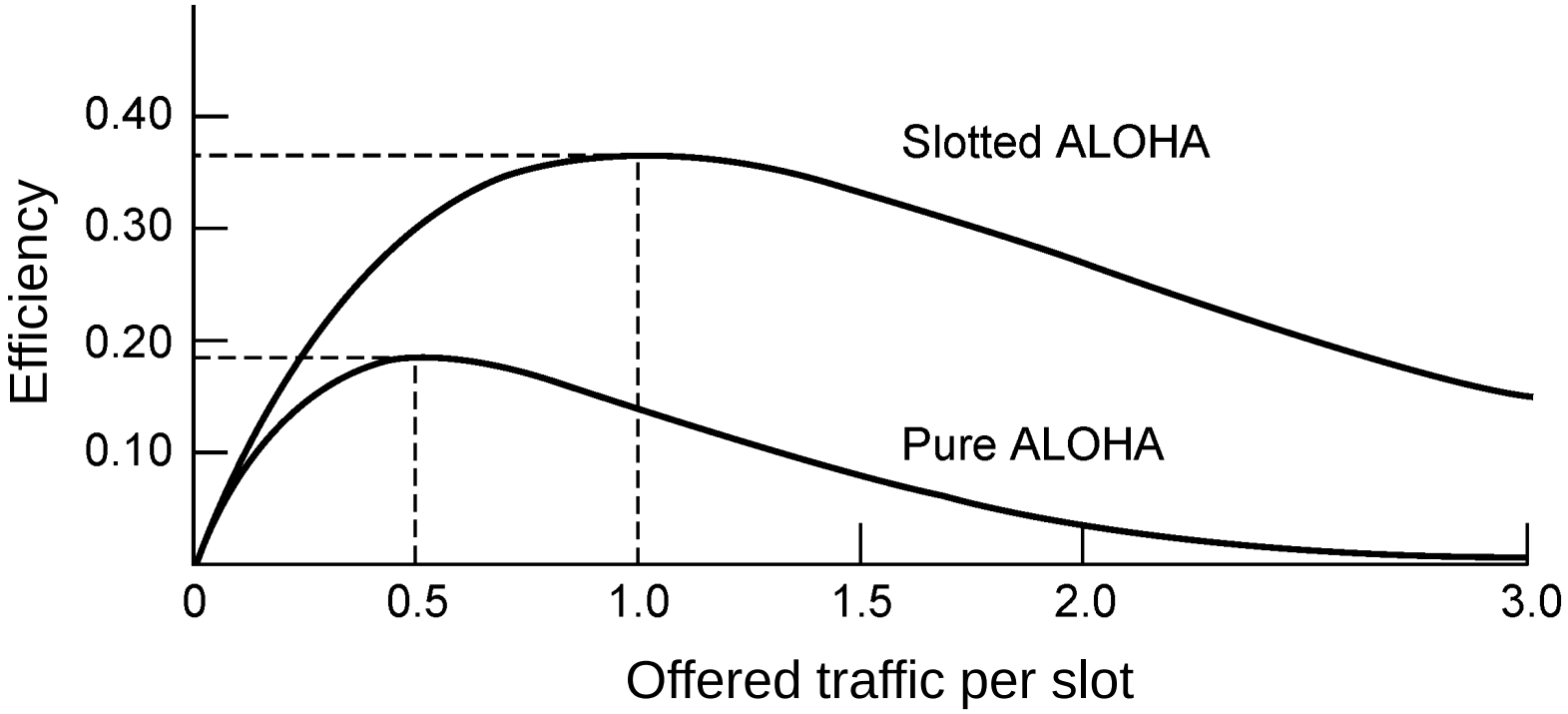
MAC protocols: taxonomy

Three broad classes:

- Channel partitioning
  - Divide channel into smaller “pieces” (time slots, frequency, code)
  - Allocate piece to node for exclusive use
- Taking turns”
  - Nodes take turns, but nodes with more to send can take longer turns
- Random access
  - Use randomization for handling collisions
  - “Recover” from collisions

Pure ALOHA vs Slotted ALOHA



CSMA (carrier sense multiple access)

Simple CSMA: listen before transmit

- If channel sensed idle: transmit entire frame
- If channel sensed busy: defer transmission

- Human analogy: don't interrupt others!

humans at a cocktail party
(shared air, acoustical)

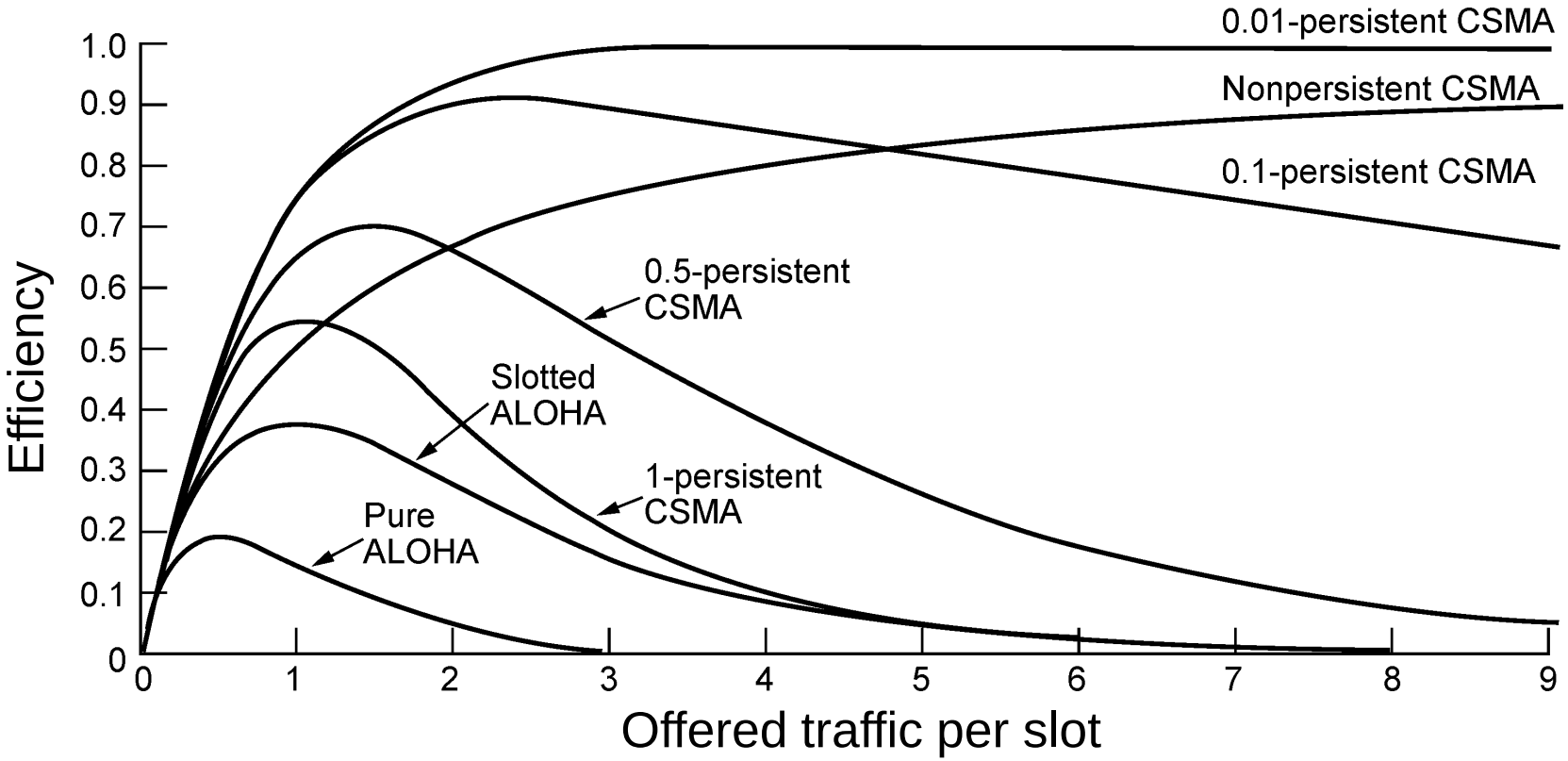
CSMA (carrier sense multiple access)

- 1-persistent CSMA:
  - If channel sensed idle: transmit with probability 1
  - If channel sensed busy: continuously sense → transmit immediately when channel becomes idle
  - If collision: wait for a random time, then start sensing

- Nonpersistent CSMA:
  - If channel sensed busy: do no sense continuously → wait for a random amount of time and then sense again
  - Better channel utilization → longer delay than 1-persistant CSMA

- p-persistent CSMA:
  - If channel sensed idle: transmit with probability p

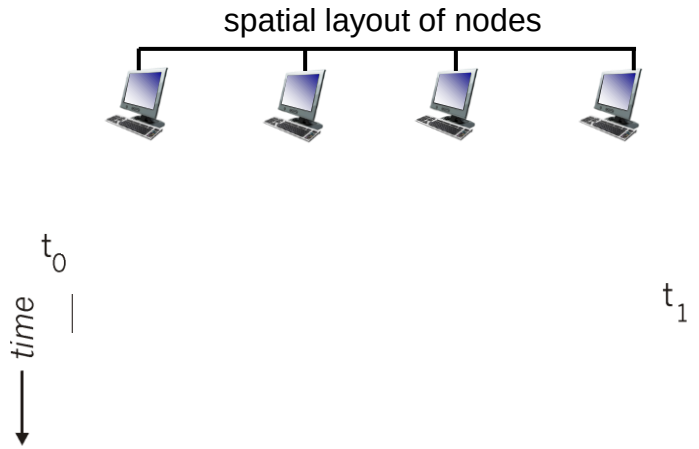
CSMA (carrier sense multiple access)



CSMA: collisions

- Collisions can still occur with carrier sensing:
  - Propagation delay means two nodes may not hear each other's just-started transmission
  - Distance & propagation delay play role in in determining collision probability

- Collision: entire packet transmission time wasted



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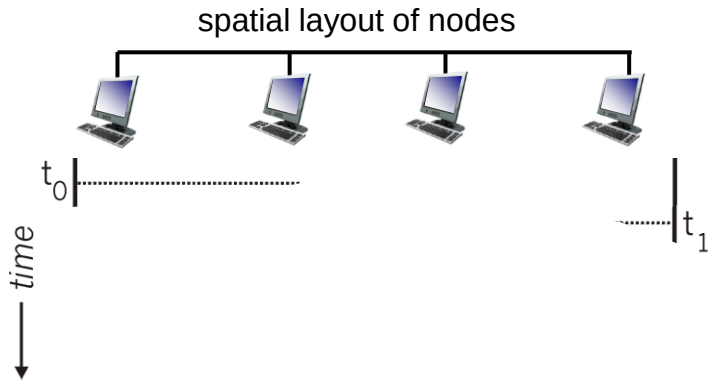
CSMA/CD: CSMA with collision detection

- Collisions detected within short time
- Colliding transmissions aborted, reducing channel wastage
- Collision detection easy in wired, difficult with wireless

- Human analogy: the polite conversation

CSMA/CD

- CSMA/CD reduces the amount of time wasted in collisions
  - Transmission aborted on collision detection



Ethernet CSMA/CD algorithm

1. Ethernet receives datagram from network layer, creates frame
2. If Ethernet senses channel:
   If idle: start frame transmission.
   If busy: wait until channel idle, then transmit
3. If entire frame transmitted without collision - done!
4. If another transmission detected while sending: abort, send jam signal
5. After aborting, enter binary (exponential) backoff:
   - After m-th collision, chooses K at random from {0,1,2, …, 2^m-1}
   - Wait for K slots, return step 2
   - More collisions: longer backoff interval

Ethernet: unreliable, connectionless

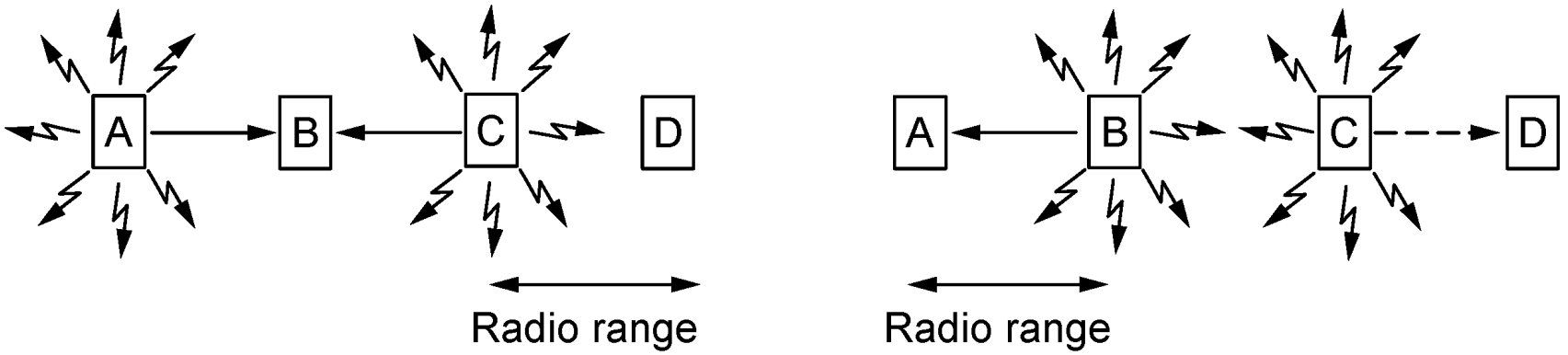
- Connectionless: No handshaking between sending and receiving NICs
- Unreliable: Receiving NIC doesn't send ACKs or NAKs to sending NIC
  - Data in dropped frames may be recovered by the higher layer protocols (e.g., TCP), otherwise dropped data lost
- Ethernet's MAC protocol: 1-persistant CSMA/CD with binary backoff

Wireless ≠CSMA/CD

- Transmitter cannot send/listen concurrently

Wireless ≠CSMA/CD

- Nodes have different coverage areas
  - Hidden terminal problem and Exposed terminal problem



CSMA/CA: MACA → IEEE 802.11

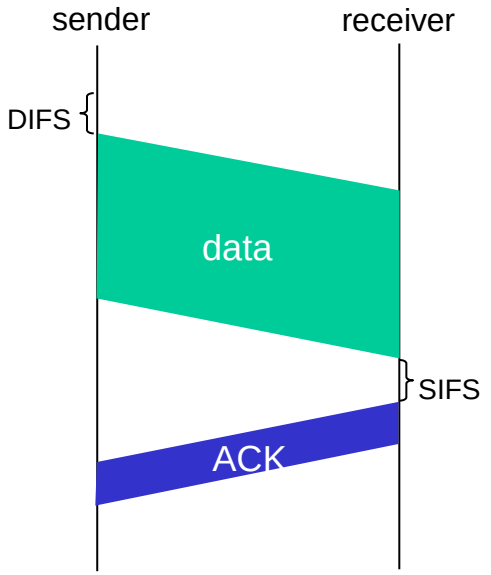
- MACA: Sender and receiver uses a short handshake before transmitting
  - IEEE 802.11 uses a refinement of MACA
- 802.11: CSMA - sense before transmitting
- 802.11: no collision detection!
  - Goal: avoid collisions: CSMA/CollisionAvoidance
  - Hidden and exposed station problems are alleviated using RTS/CTS exchanges
  - In 802.11 RTS/CTS is optional

CSMA/CA: IEEE 802.11

802.11 sender

distributed inter frame space

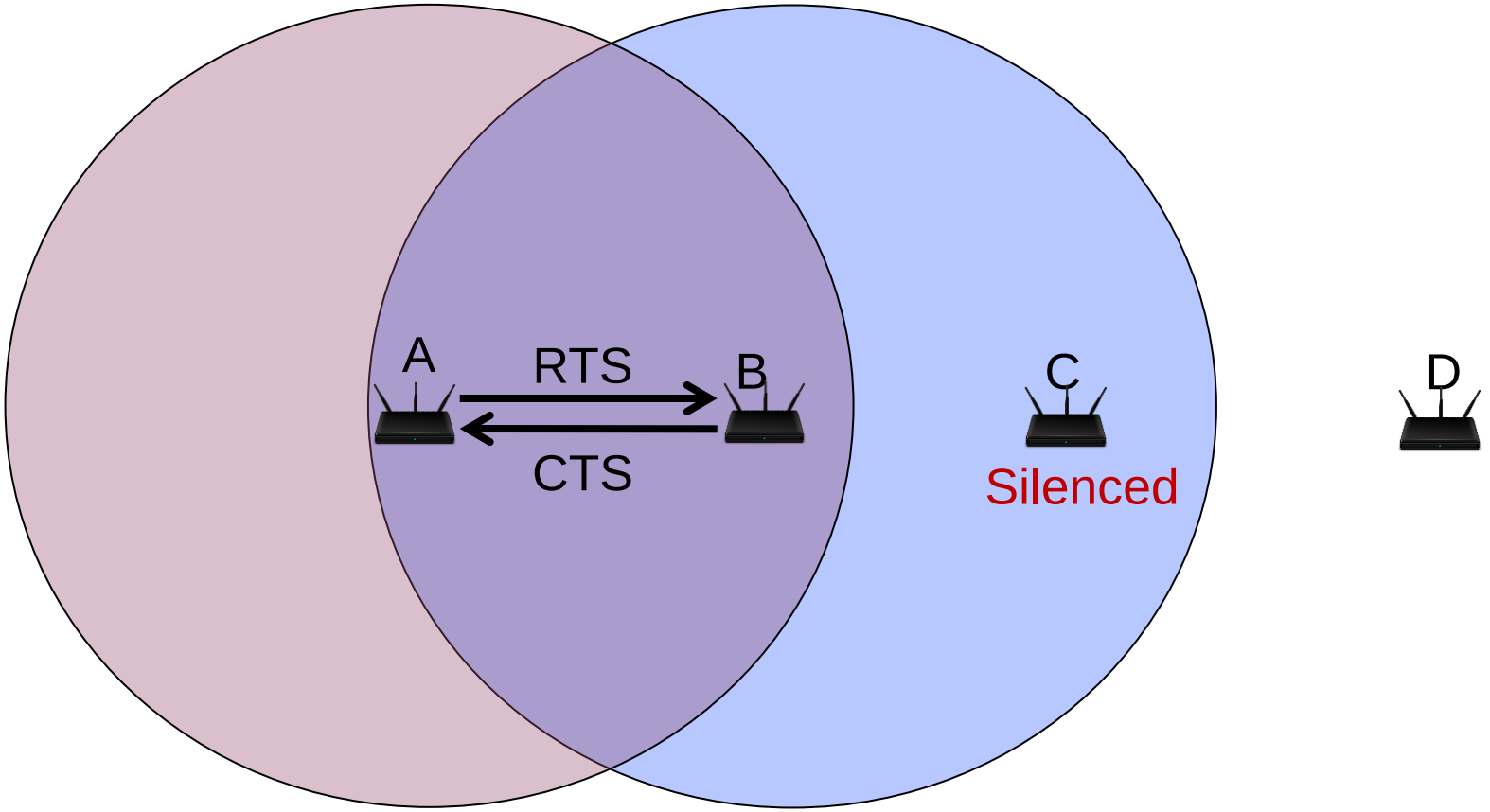
1. If sense channel idle for **DIFS** then
   transmit entire frame (no CD)
2. If sense channel busy then
   start random backoff time in range (0, w-1), w = CW_{min}
   timer counts down while channel idle
   transmit when timer expires
   if no ACK, increase random backoff interval (double w upto CW_{max}), repeat 2



802.11 receiver

If frame received OK
return ACK after **SIFS** (ACK needed due to hidden terminal problem)

CSMA/CA: IEEE 802.11



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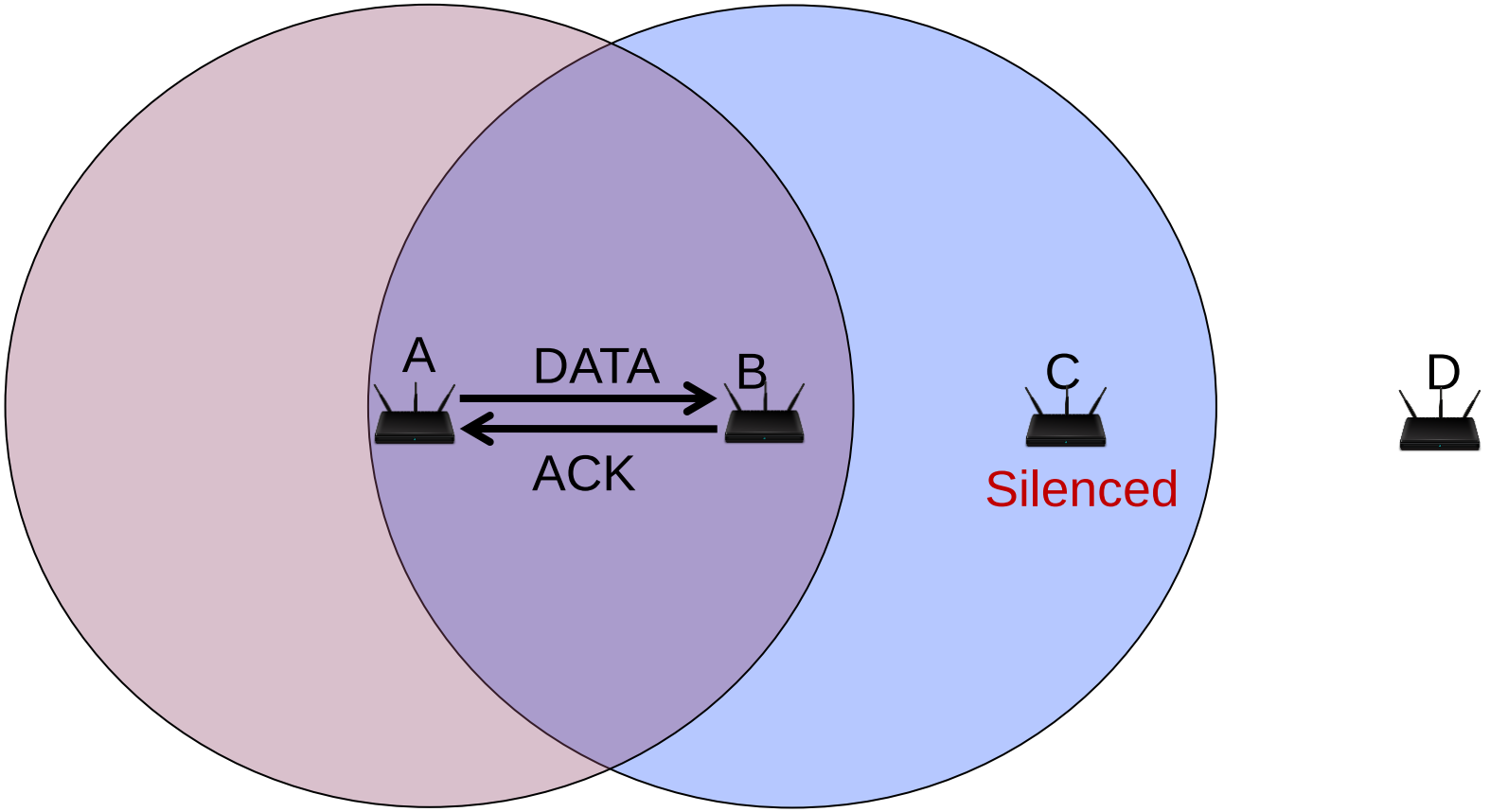
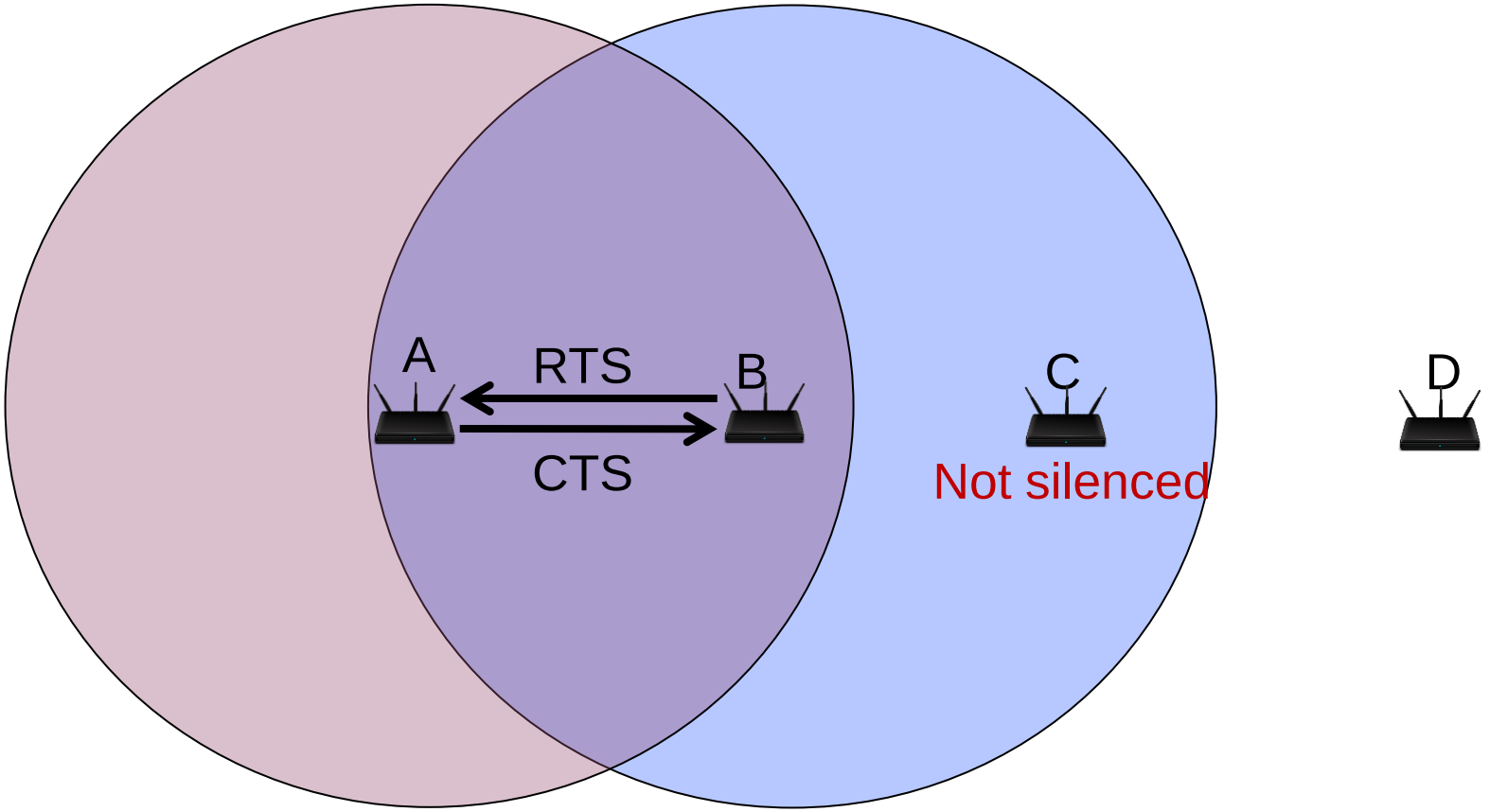


CSMA/CA: IEEE 802.11



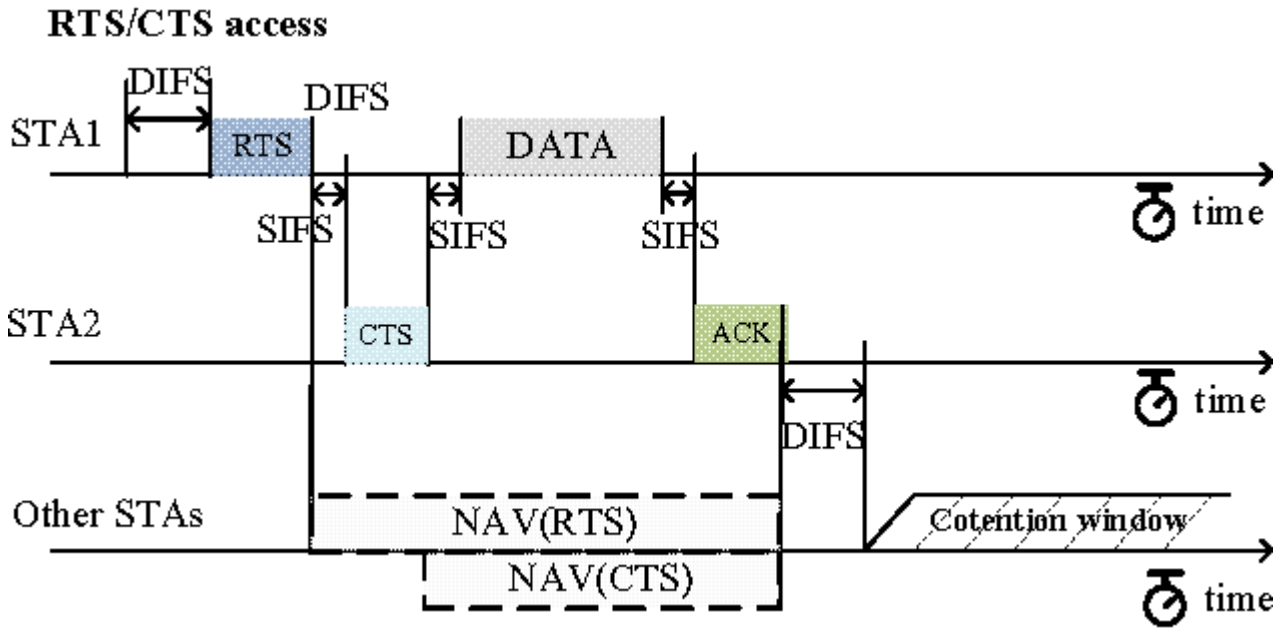
CSMA/CA: IEEE 802.11

- Sender first transmits small request-to-send (RTS) packet to the receiver
- Receiver replies with clear-to-send CTS in response to RTS
- Sender transmits data frame
- Nodes receiving CTS defer transmissions

- Nodes receiving RTS → defer one CTS time
- Nodes receiving RTS but not CTS, free to send

- RTS/CTS may still collide, but less likely (as they're short)
  - RTS/CTS exchange does not entirely solve the hidden and exposed station problem

CSMA/CA: IEEE 802.11



Src:https://www.researchgate.net/publication/26429569_Autonomous_Power_Control_MAC_Protocol_for_Mobile_Ad_Hoc_Networks/figures?lo=1

IEEE 802.11 Wireless LAN

Standard	Frequency	Maximum Speed	Backwards compatibility
802.11	2.4 GHz	2 Mbps	-
802.11a	5 GHz	54 Mbps	-
802.11b	2.4 GHz	11 Mbps	-
802.11g	2.4 GHz	54 Mbps	802.11b
802.11n	2.4 and 5 GHz	600 Mbps	802.11a/b/g
802.11ac	5 GHz	1300 Mbps	802.11a/n
802.11ad	2.4 GHz, 5 GHz and 60 GHz	7 Gbps	802.11a/b/g/n/ac

Src: https://networkustad.com/2019/11/16/ieee-802-11-standards/

MAC protocols: Comparison

Three broad classes:

- Channel partitioning
  - Share channel efficiently and fairly at high load
  - Inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node!
- Taking turns
  - Look for best of both worlds
  - Single point of failure
- Random access
  - Efficient at low load: single node can fully utilize channel
  - High load: collision overhead

Summary

- Random access based MAC protocols:
  - CSMA
  - CSMA/CD
  - CSMA/CA

- Comparison of the MAC protocols