CSC8004

The Data Link Layer in Broadcast Networks

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Next

- Multiple access protocols
  - ALOHA
  - Carrier Sense Multiple Access protocols
  - Collision-free protocols
  - Limited-contention protocols
- Ethernet
- Wireless LANs
- Bluetooth

Multiple access protocols

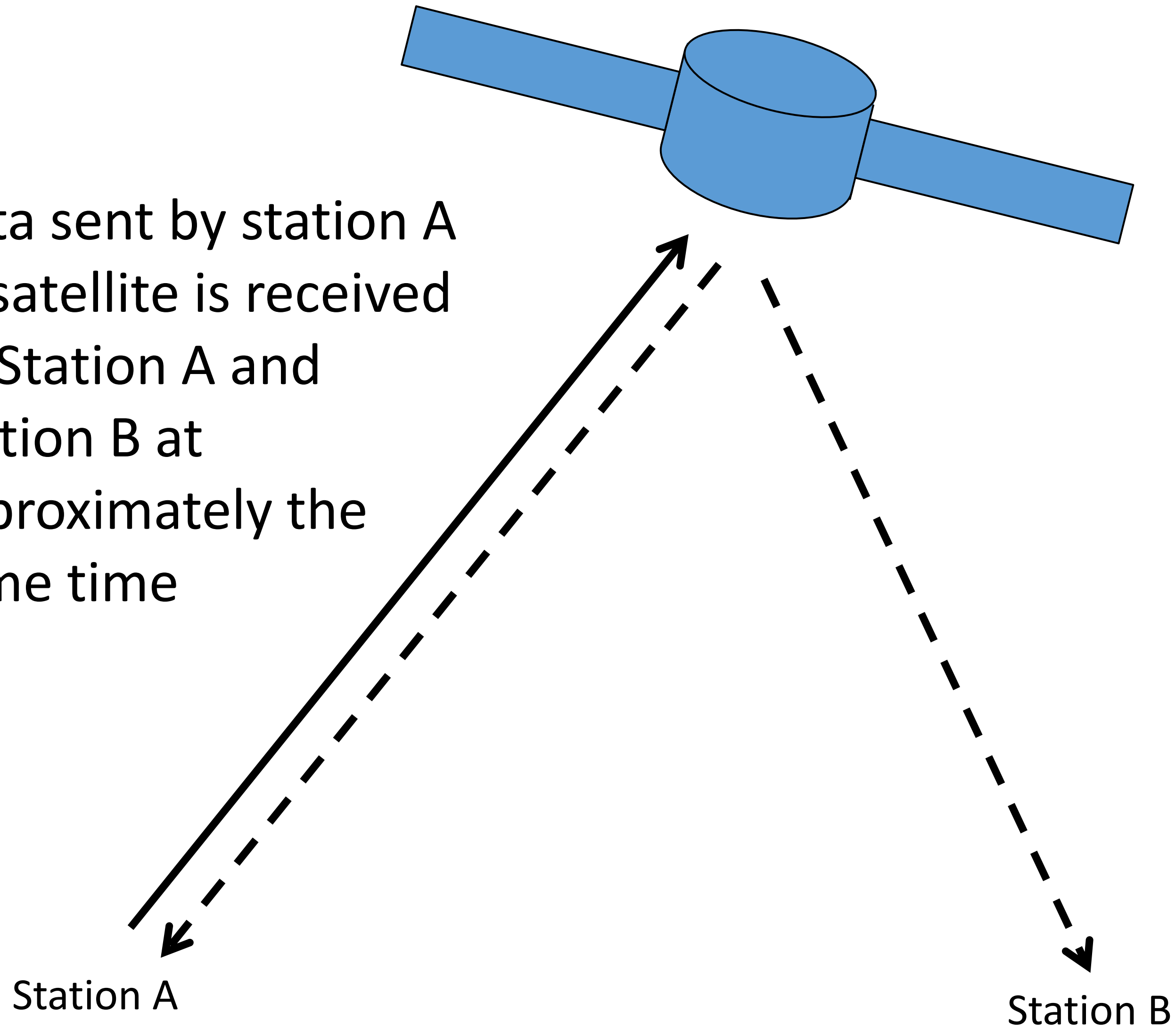
- There is a single shared transmission medium called the channel.
- Each frame sent is received by all hosts, including the sender.
- Hosts have to contend for the use of the channel.
- Channel users are completely uncoordinated (usually).
- If two hosts send more or less simultaneously, the two packets will collide. Both will be damaged (in data terms – electrically, the medium can cope).
- Because the sender can check whether the packet was damaged, it can retransmit if necessary. So there is no need for ACKs or NAKs.
- Adding new hosts to the network is very easy.
- Main problem is how to share the channel efficiently among the hosts.

Multiple access protocols (2)

- There are two basic types of broadcast networks:
- Satellite networks. These have a very long delay (about 270 msec). The protocols used on satellite channels are called Aloha. There are, of course, several variations.
- Local area networks (LAN). These have a very short delay. Protocols are called CSMA, again with several variations.

A Satellite Network

Data sent by station A to satellite is received by Station A and Station B at approximately the same time

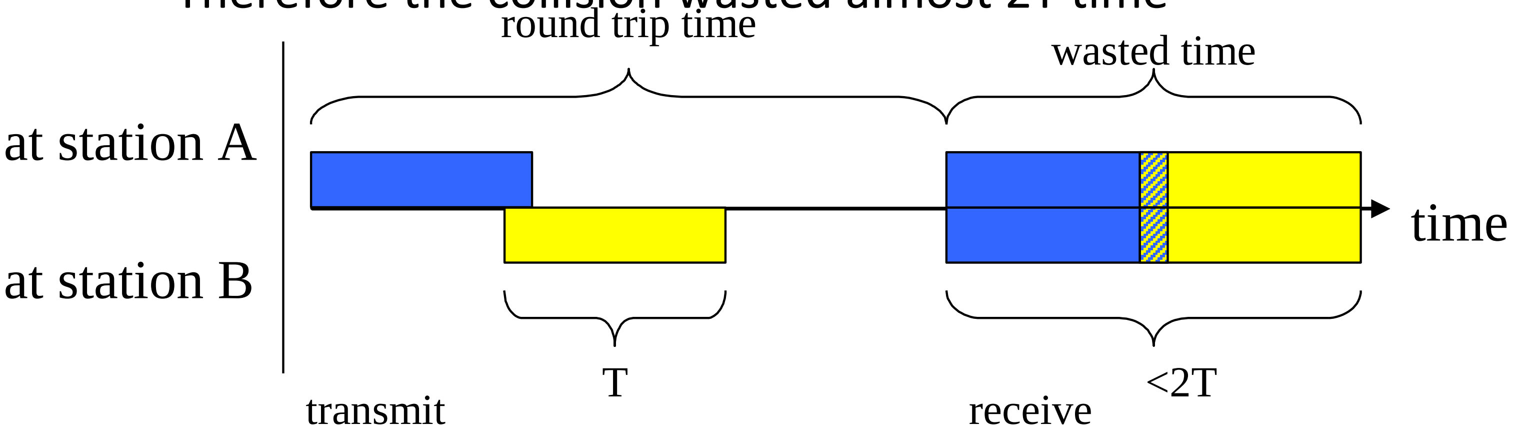


Pure Aloha

- This was first developed at the University of Hawaii, using a ground-based radio system.
- Users transmit whenever they want. Colliding frames are destroyed.
- If a frame was destroyed, the sender just waits a random amount of time and sends again (otherwise a collision will occur again and again).
- Question: What is the throughput at low/high load?
- Under low load, there will be almost no collisions.
- The throughput will degrade after the channel reaches about 18% utilisation.

Pure Aloha (2)

- Why is the channel used so poorly in Pure Aloha?
- Example: T is the time to transmit a frame
  - Station A transmits a frame
  - Station B transmits a frame just before A is finished transmitting
  - After the round-trip time, each station hears both frames
  - A collision occurs where the transmissions overlap
  - Both frames are discarded
  - Therefore the collision wasted almost 2T time

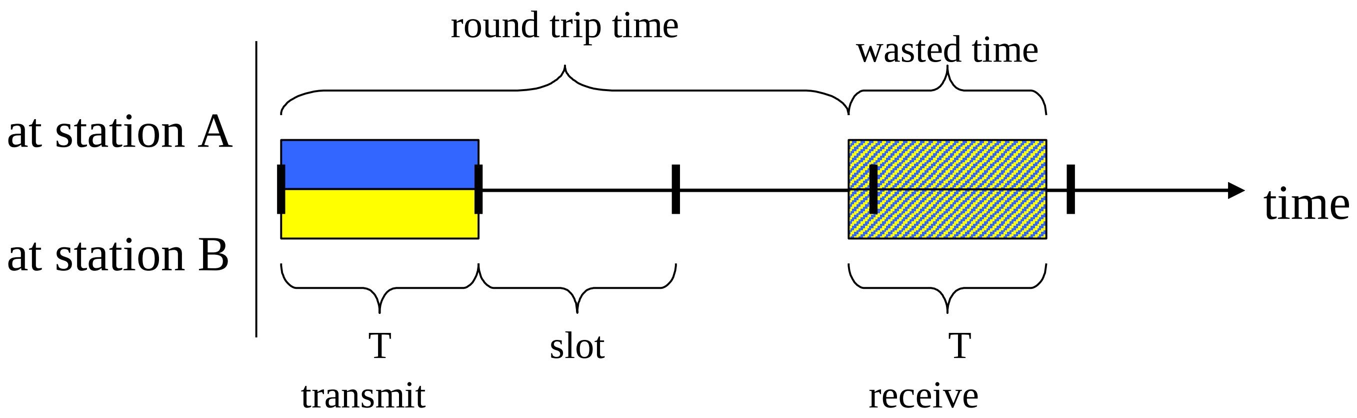


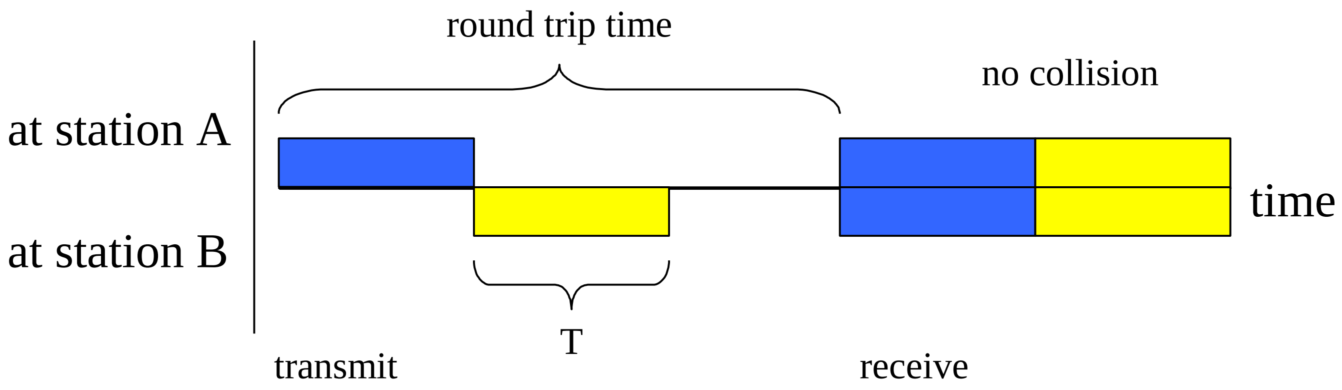
Slotted Aloha

- Improvement to the Pure Aloha system:
- Divide the time up into discrete intervals, each interval corresponding to one frame (slotted time).
- Stations can only transmit at the start of each time slot.
- This requires one special station to emit a “pip” at the start of each interval (or a series of intervals) for all others to synchronise (like a clock).

Slotted Aloha (2)

- The system peaks with a throughput of 37% channel utilization, double the efficiency of Pure Aloha.





Carrier Sense Multiple Access (CSMA)

- With Aloha, satellite stations don't (can't) listen
- Performance of Aloha systems could be improved if the stations do not transmit without first paying attention to what other stations are doing.
- Stations listen for (sense) the presence of a carrier signal and act accordingly. Variations are called:
  - 1-persistent
  - Non-persistent
  - P-persistent
  - CSMA/CD (Collision Detection)
- CSMA only makes sense on systems with short delays such as LANs.

CSMA 1-persistent

- When a station has data to send, it first listens to the channel to see if anyone else is transmitting.
- If the channel is busy, the station waits until it becomes idle.
- When the station detects an idle channel, it immediately transmits a complete frame.
- If the frame is damaged, the station waits a random amount of time and starts all over again.
- This protocol is called 1-persistent because the station transmits with a probability of 1 whenever it finds the channel idle. Intuitively, this is better than both ALOHA protocols.
- However, if two stations are waiting, both will detect that it has become idle and then transmit simultaneously.

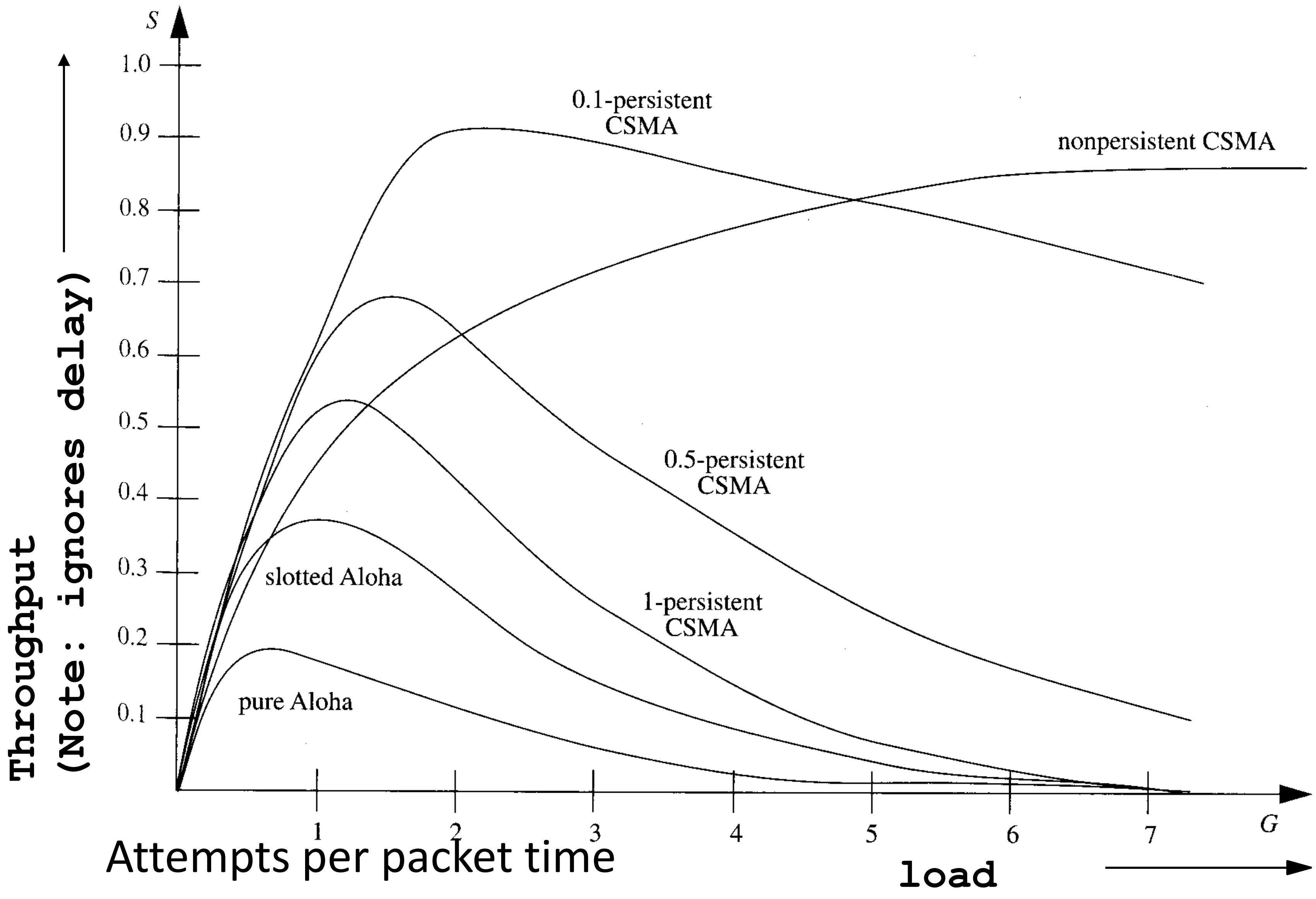
CSMA non-persistent

- This protocol is less greedy than 1-persistent.
- When the sending station detects that the channel is busy, it does not continuously sense it for the purpose of seizing it immediately upon detecting the end of the previous transmission.
- Instead it waits a random period of time and then repeats the algorithm.
- Intuitively, this algorithm should lead to a better channel utilisation (fewer collisions), but longer delays (waiting to sense), than 1-persistent CSMA.

CSMA P-persistent

- This protocol applies to ‘slotted’ channels. One ‘slot’ equals one packet transmission time – there is no ‘pip’.
- When a station becomes ready to send, it senses the channel. If it is idle, it transmits with a probability p (therefore the probability that it defers transmission until the next slot is $q = 1 - p$).
- If that slot is also idle, it either transmits or defers again, with probabilities p and q respectively.
- If a slot is busy, it waits a random amount of time and starts again.

Contention protocol comparison



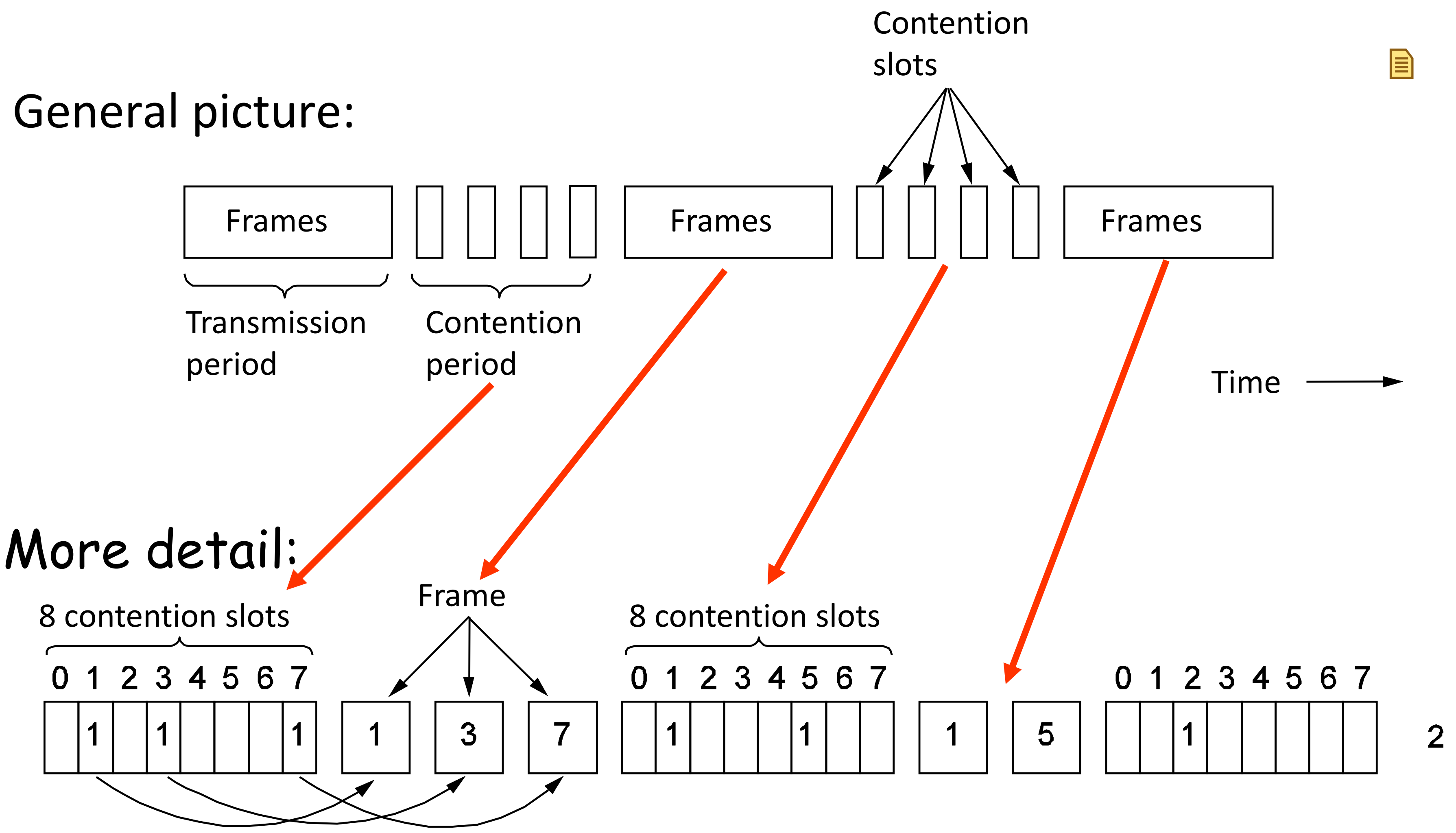
CSMA/CD (Collision Detection)

- In the previous protocols, a station sends a complete packet, then decides if it was damaged.
- With CSMA/CD, a station <u>aborts</u> its transmission as soon as it detects a collision.
- This requires some highly special electronics. The stations must sense the channel during transmission, and compare it with what they have sent (in real-time).
- Quickly terminating damaged frames saves time and bandwidth.
- This protocol, known as CSMA/CD, is widely used on LANs including Ethernet.

Collision-free protocols

- It is possible to arrange protocol features in such a way that collisions simply cannot occur.
- The essential feature of such protocols is that the channel is ‘divided up’ between the hosts, with each host having its own ‘private’ slot.
- Under light loads, this wastes some of the transmission capacity that is idle.
- Under high loads, it works at maximum efficiency.
- A good example is the Bit-map protocol.

Collision-free protocols – Example: bit map



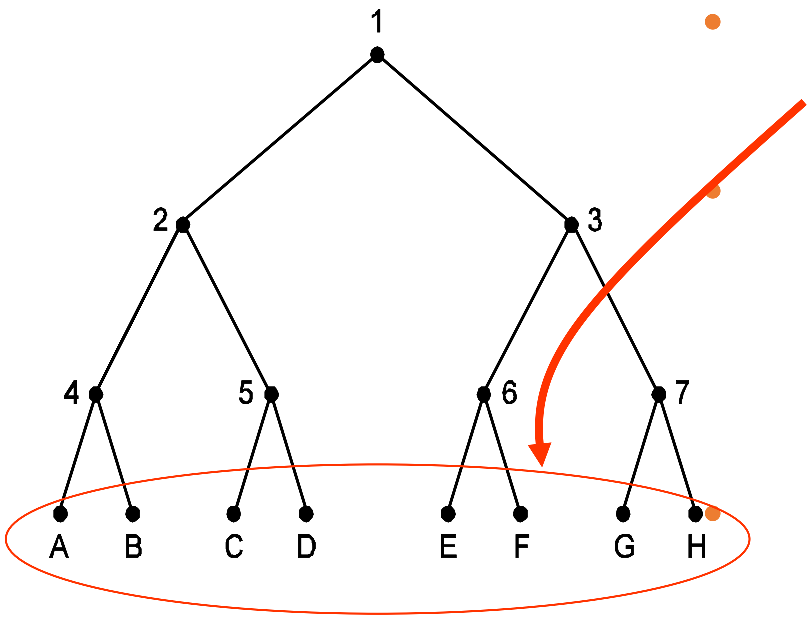
Limited contention protocols

- Under light load, contention is preferable due to its low delay (collision-free methods have a longer delay)
- As load increases, contention becomes increasingly less attractive. Collision-free methods have a better channel efficiency.
- Obviously, it would be nice if we could combine the best properties of the contention and collision-free protocols, arriving at a new protocol that uses contention at low loads to provide low delay, but uses a collision-free technique at high loads to provide good channel efficiency.

Limited contention protocols (2)

- Such protocols are called limited contention protocols.
- The probability of some station acquiring the channel can be increased only by decreasing the amount of competition.
- The limited-contention protocols first divide the stations up into groups.
- Only the members of group *j* are permitted to compete for slot *j*. Examples: the Adaptive Tree Walk protocol. Alternatively, the Binary exponential backoff protocol , can be used (Ethernet).

Adaptive Tree Walk protocol



- It is convenient to think of the stations as <u>leaves</u> of a binary tree.
- In the first **contention slot** following a successful frame transmission, slot 0, all stations are permitted to acquire the channel.
- If only one of them does so, fine.

- If there is collision, then during the next slot, slot 1, only those stations falling under node 2 in the tree (first sub-tree) may compete.
- If only one of the stations under node 2 acquires the channel, then the following contention slot is reserved for those stations under node 3. Etc…

Binary exponential back-off protocol

- After a collision, time is divided up into discrete slots whose length is equal to the worst case round-trip propagation time on the LAN cable.
- After the first collision, each station <u>independently</u> waits either 0 or 1 slot times before trying again. If two stations collide and each one picks the same random number (0 or 1), they will collide again.
- After the second collision, each one picks either 0, 1, 2 or 3 at random and waits that number of slot times.
- If a third collision occurs, then the number of slots to wait is chosen from the interval 0 to $2^3 – 1$.
- After 10 collisions, the number is frozen at 2^{10} -1(1023) slots.
- After 16 collisions, report failure to the computer. Further recovery handled by higher layers.

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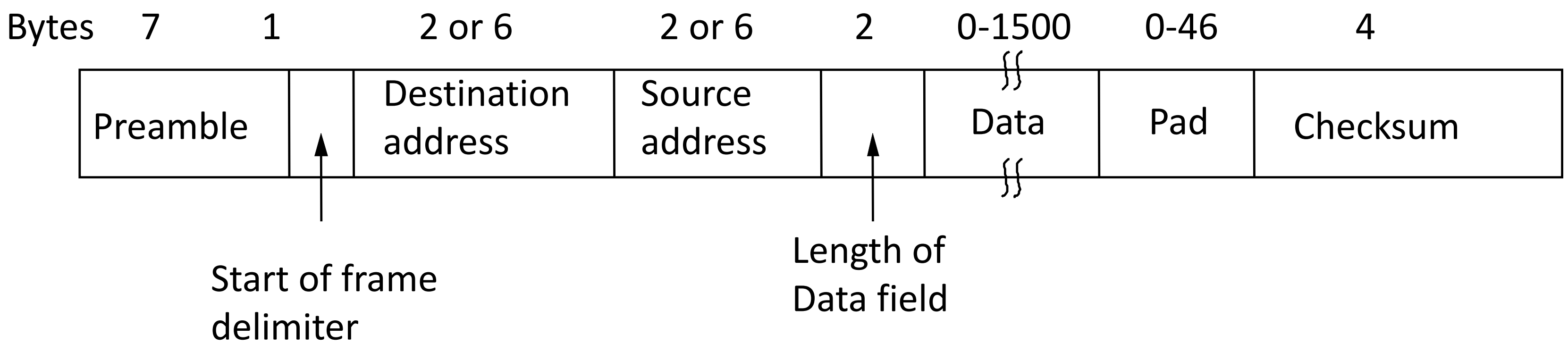
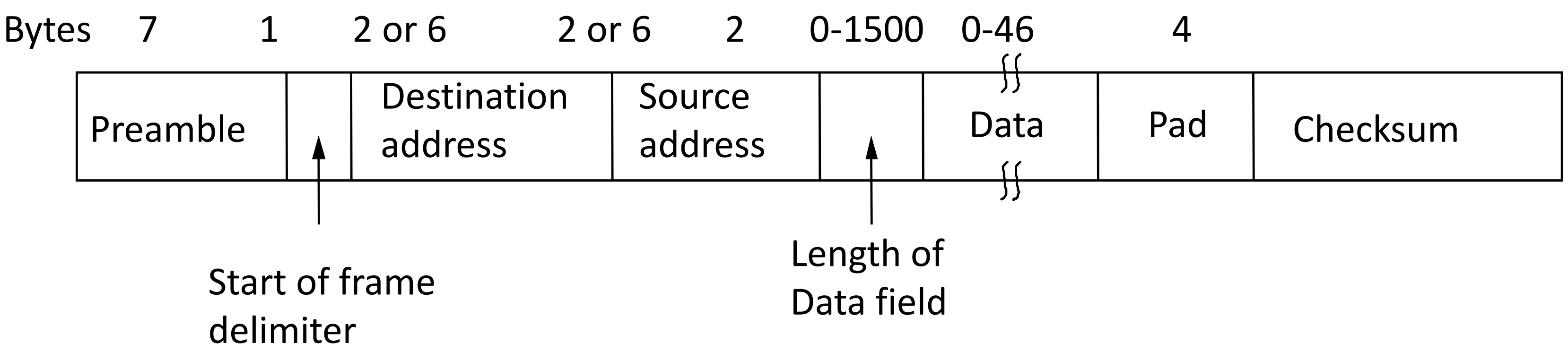
802.3 MAC (Ethernet)

- It is a 1-persistent CSMA/CD LAN. It uses the Binary Exponential Backoff Algorithm.
- The packet format is shown below. It is also called the MAC frame.



- Preamble (7 bytes): allow the receiver's clock to synchronise (10101010 bit pattern)
- Start of Frame delimiter (1 byte): denote start of the frame (101010<u>11</u> bit pattern)

802.3 MAC (Ethernet) (2)



- Destination address (2 or 6 bytes):
- Source address (2 or 6 bytes)
- Length of data field (2 bytes):
- Data (0-1500), <u>Pad (0-46 bytes) for min 64 byte frame</u>
- CRC Checksum (4 bytes)

802.3 MAC (Ethernet) (4)

- A minimum frame length of 64 bytes is required. Use padding if required. Reason:
- Station can only detect a collision while it is transmitting, therefore it must continue to transmit frame until the first bit has had time to reach the other end of the cable, and a *collided* bit had time to return (= round trip time).

  - Time to transmit whole frame > = round trip time

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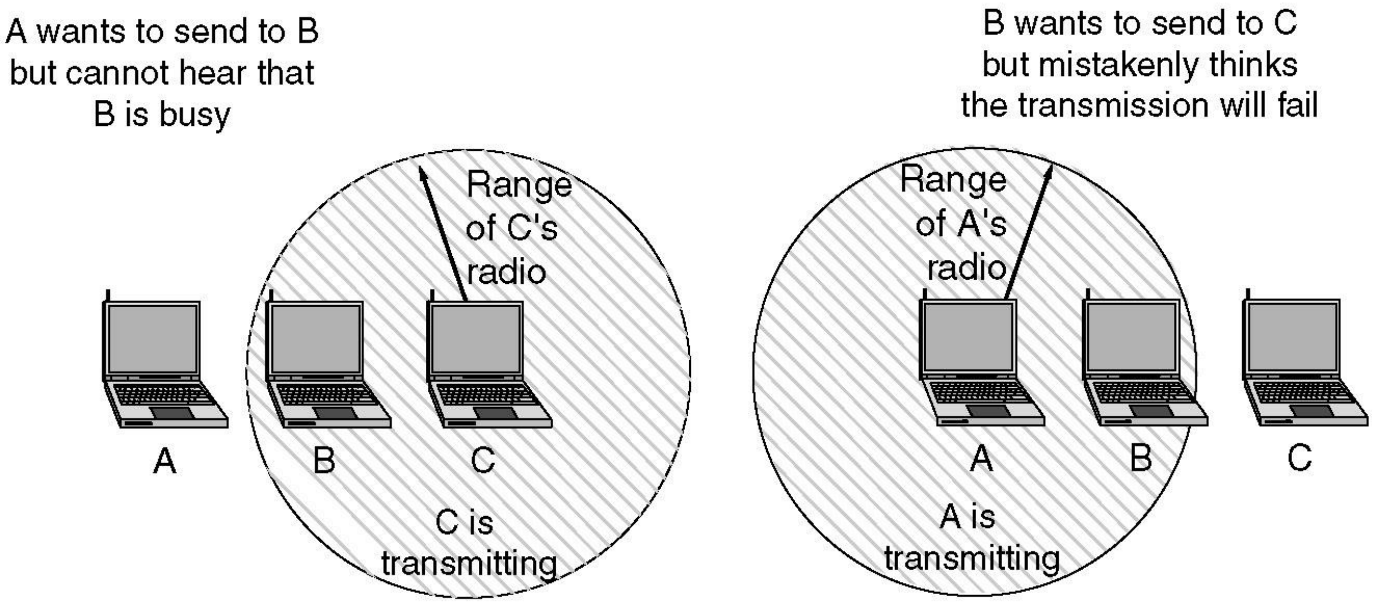
Wirless LANs

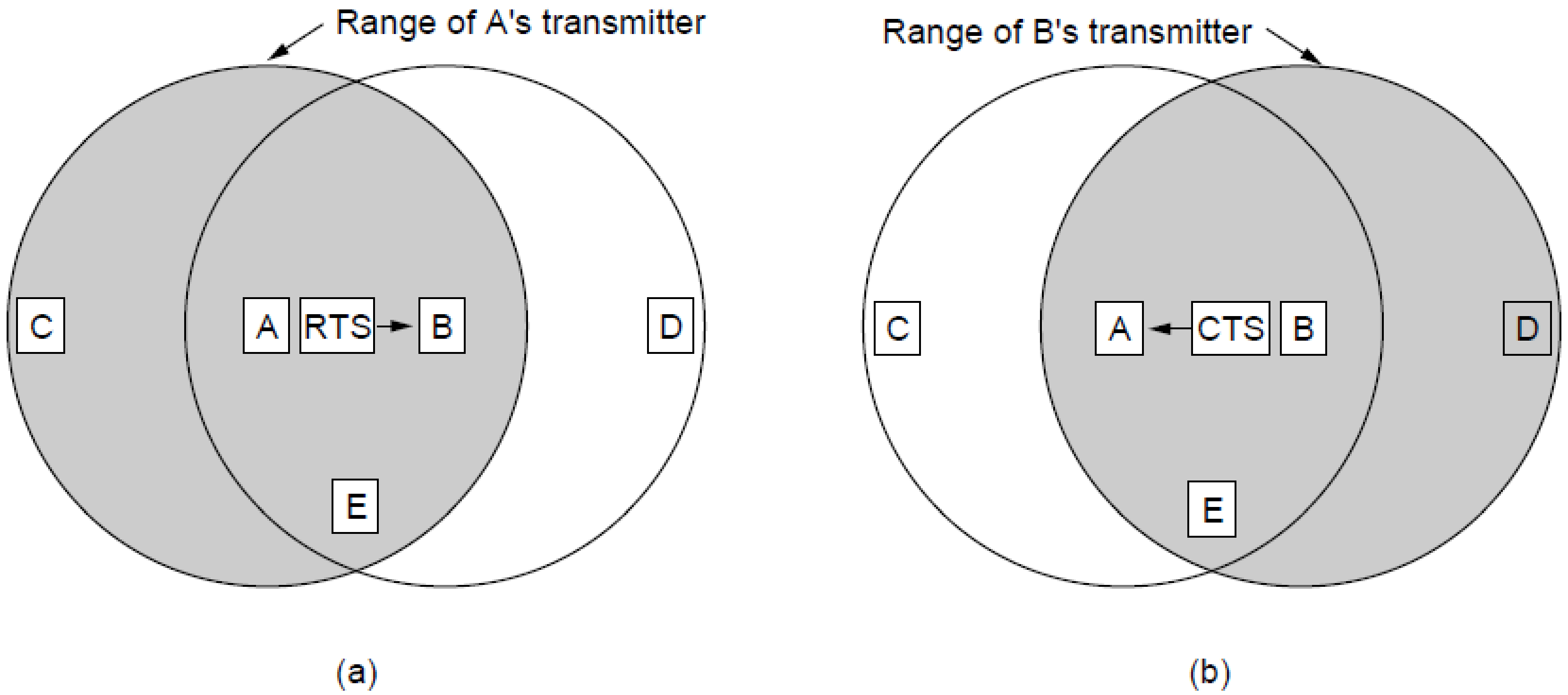


(a) (b)

- Ethernet protocols do not work
  a) If A tries to transmit it will not detect collision with C and will assume that transmission was successful (hidden station problem)
  b) B is prevented from transmitting to C as it will detect a collision with A (exposed station problem)

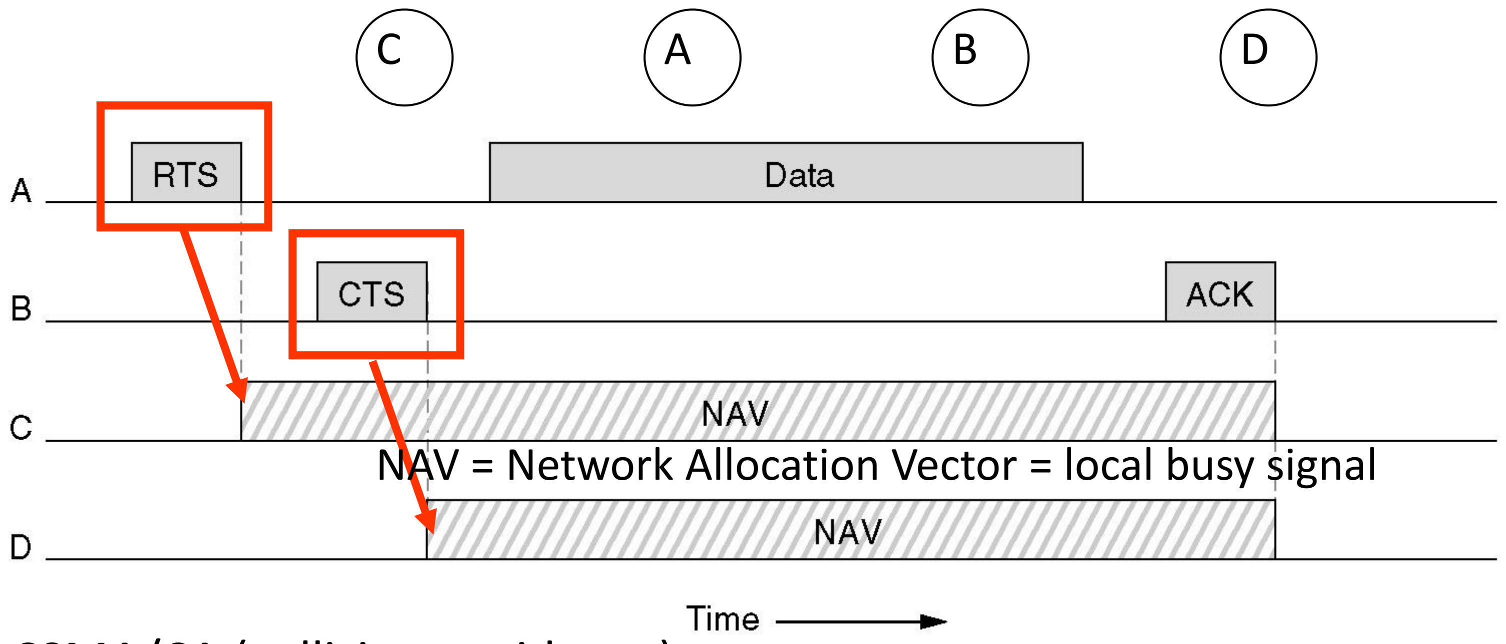
The MACA protocol
Multiple access with collision avoidance

The MACA protocol



(a) *A sending an RTS to B. (b) B responding* with a CTS to *A.*

The MACA protocol (2)



- Uses CSMA/CA (collision avoidance)
- A wants to send data to B so it sends a short RTS
- C is within range of A, hears the RTS and keeps quiet
- B is within range of A hears RTS then sends CTS to allow A to transmit
- D is not within range of A and so can't hear RTS but is within range of B, hears CTS and keeps quiet
- C estimates time to keep quiet (using RTS info), D stays quiet until it hears ACK

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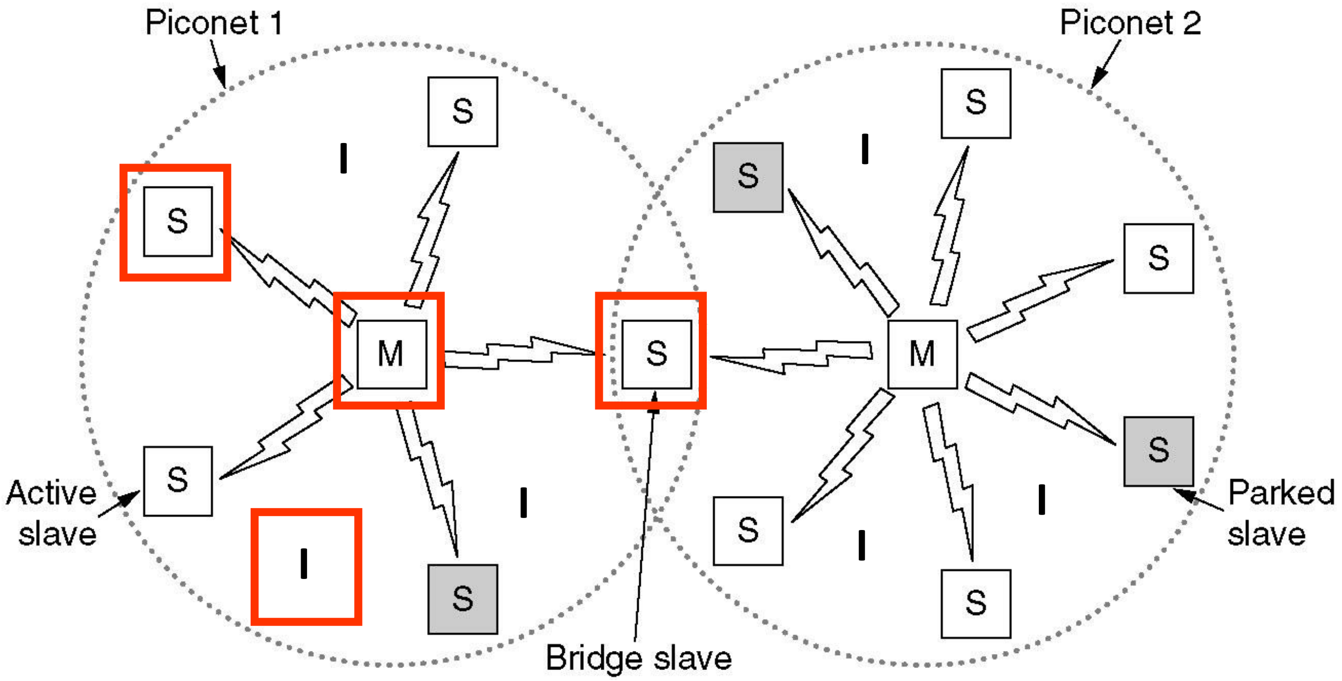
Bluetooth



- A piconet contains a master node
- …and up to seven active slave nodes within a radius of 10 metres
- A piconet can also contain up to 255 parked (inactive) nodes which have been placed in standby by master
- Multiple piconets can be connected into a scatternet by a bridge slave node