

# **Communication Networks: Technology & Protocols**

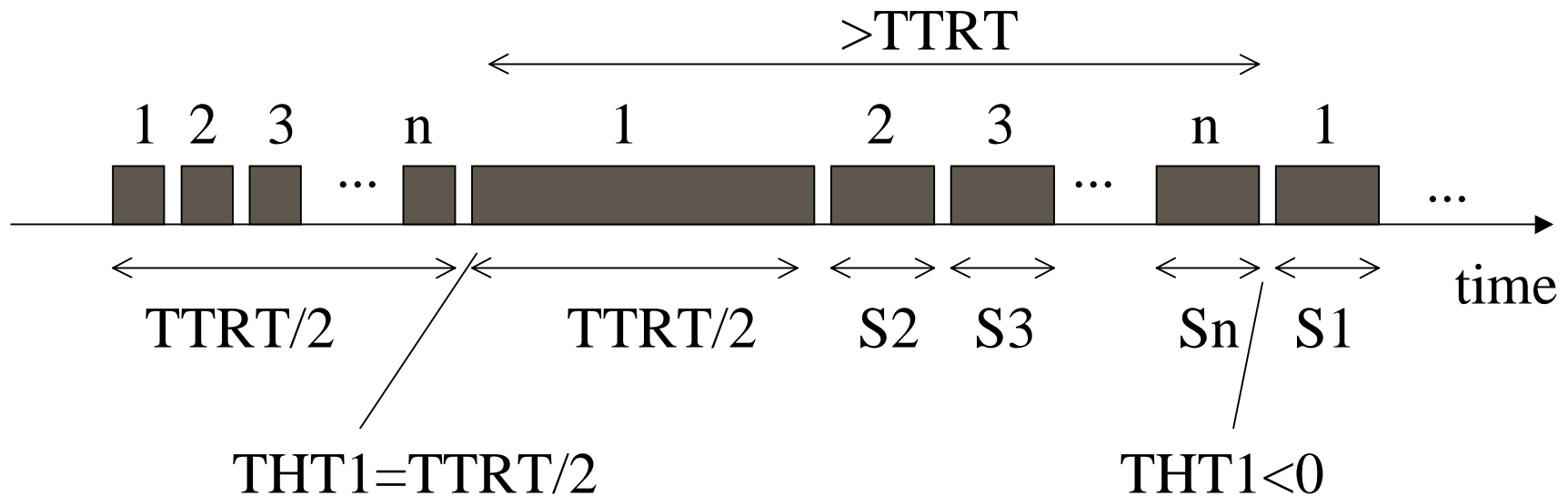


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# FDDI example:

- When node  $i$  receives the token:
  - $THT_i := TTRT - TRT_i$ ;
  - $TRT_i := 0$ ;
  - Transmit synchronous traffic for  $S_i$  time units.
  - If  $THT_i > 0$ , then transmit asynchronous traffic until  $THT_i$  reaches 0.



# FDDI analysis

- Can prove that for each node  $i$  :

$$\text{TRTi} < 2 \text{ TTRT.}$$

This implies that the medium access time is at most  $2 \text{ TTRT}$ .

Note book error: assumption  $2\text{TTRT} < \rho$  to be replaced by  $\text{TTRT} > \rho$ .

- Efficiency: close to 100%.

# Wireless LANs

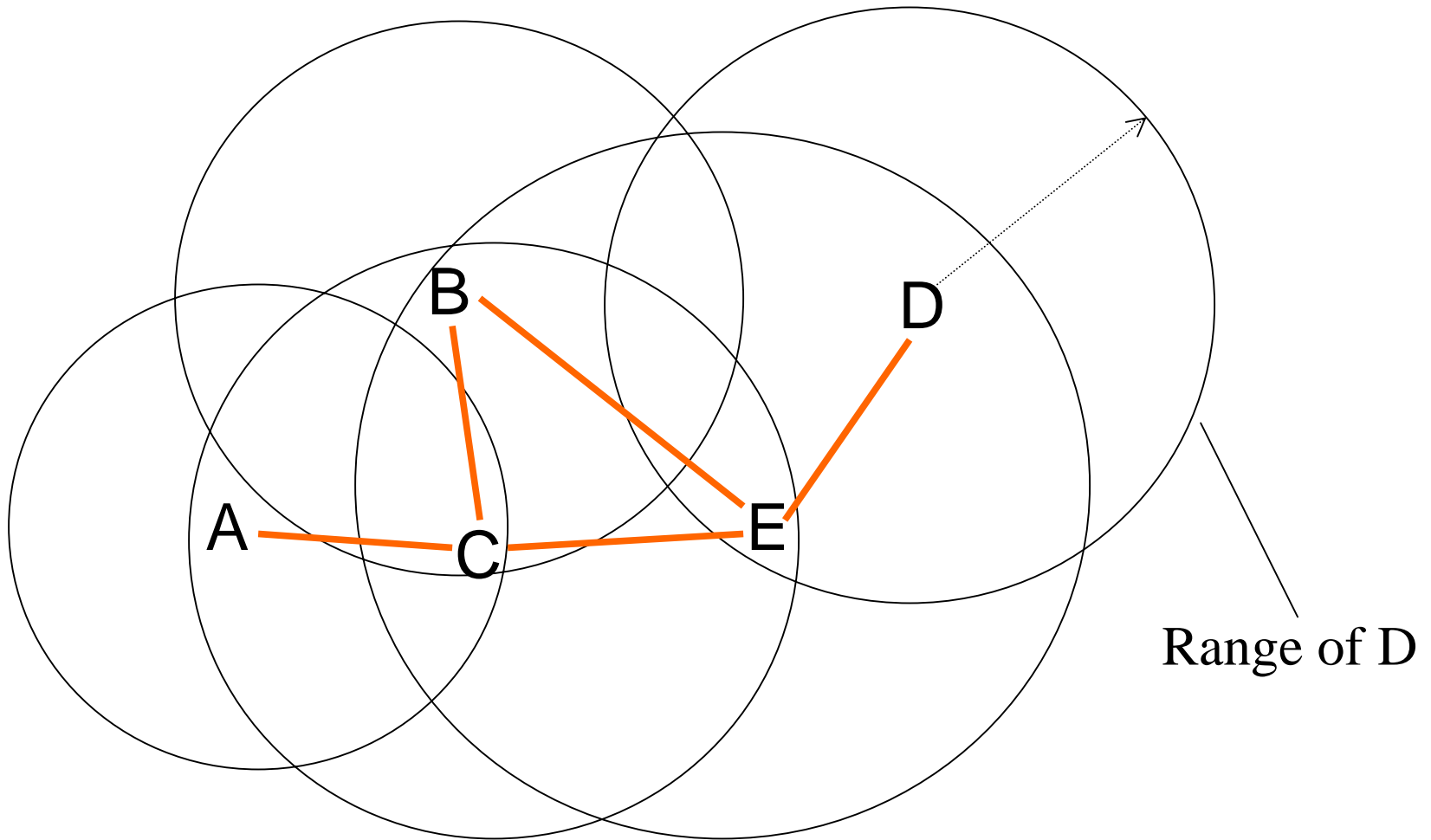


- Unique features of wireless networks.
- Emerging standards:
  - Europe: ETSI Hiperlan
  - US: IEEE 802.11
- Emerging products:
  - WaveLan (Lucent)
  - Metricom
  - Ricochet
  - Nokia
  - etc.

# Characteristics of wireless networks

- Medium: 3D space.
- Signals: radio waves on specific frequencies.
  - Frequency is a precious resource.
- “Difficult” medium:
  - Interference, noise, shadowing, multipath effect.
  - Higher bit-error rates, lower capacity (1-2Mbps).
- Power limitations  $\Rightarrow$  non-broadcast medium.
  - Carrier-sense not very helpful.
  - Collision-detection would require full-duplex radio channel  $\Rightarrow$  too expensive.
- Mobility of hosts.

# Simplified view of wireless network

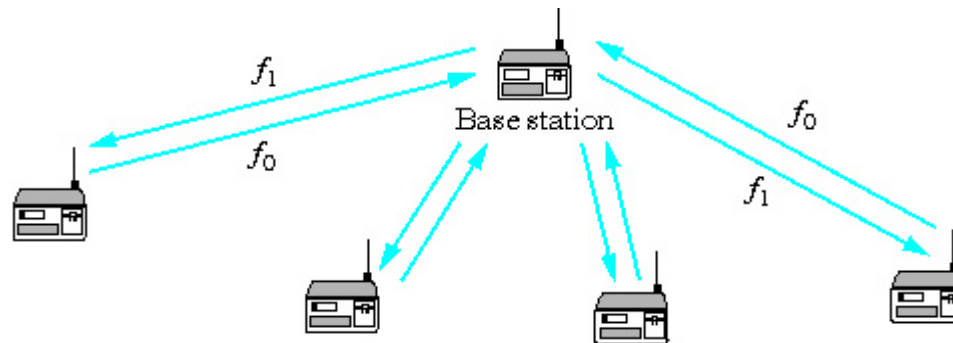


# Difficulties for carrier-sense and collision-detection.



- *Hidden-terminal problem* : A cannot “hear” C transmitting. If A wants to transmit to B and hears nothing, it cannot assume that collision won’t happen, so carrier-sense does not help. Collision-detection not possible at sender’s side.
- *Exposed-terminal problem* : C can hear B transmitting but does not know who the receiver is. C can still transmit to D while B transmits (to A or some other node) without the two signals interfering at the receivers’ sides.

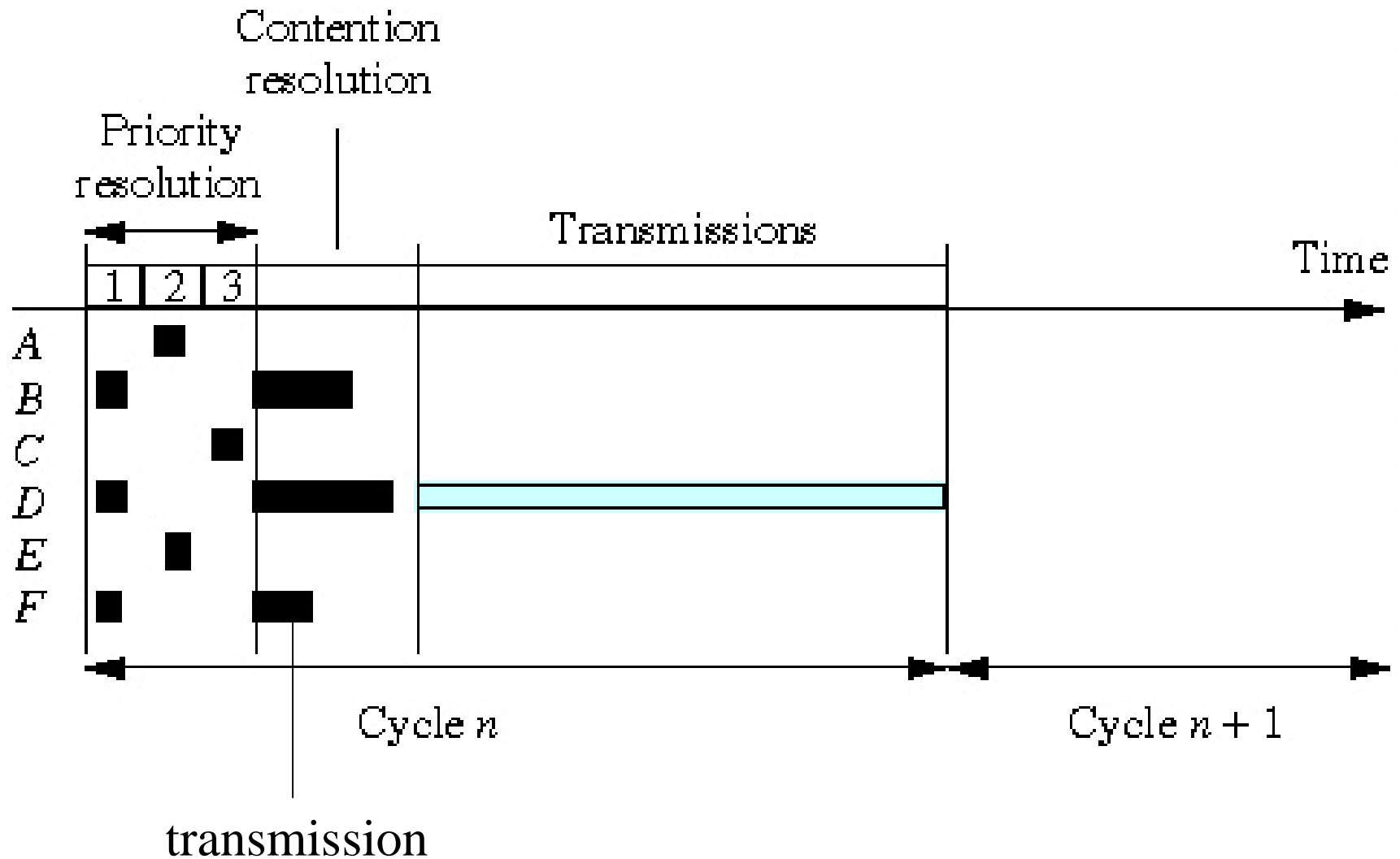
# ALOHA protocol



- Multiple access without carrier-sense or collision-detection (two terminals cannot hear each other).
- Two versions:
  - Pure ALOHA: a station can transmit at any time.
  - Slotted ALOHA: time divided into slots (each slot is enough for 1 packet), stations can transmit only at the beginning of a slot. Better performance, harder to implement (need to synchronize clocks).



# ETSI Hiperlan standard

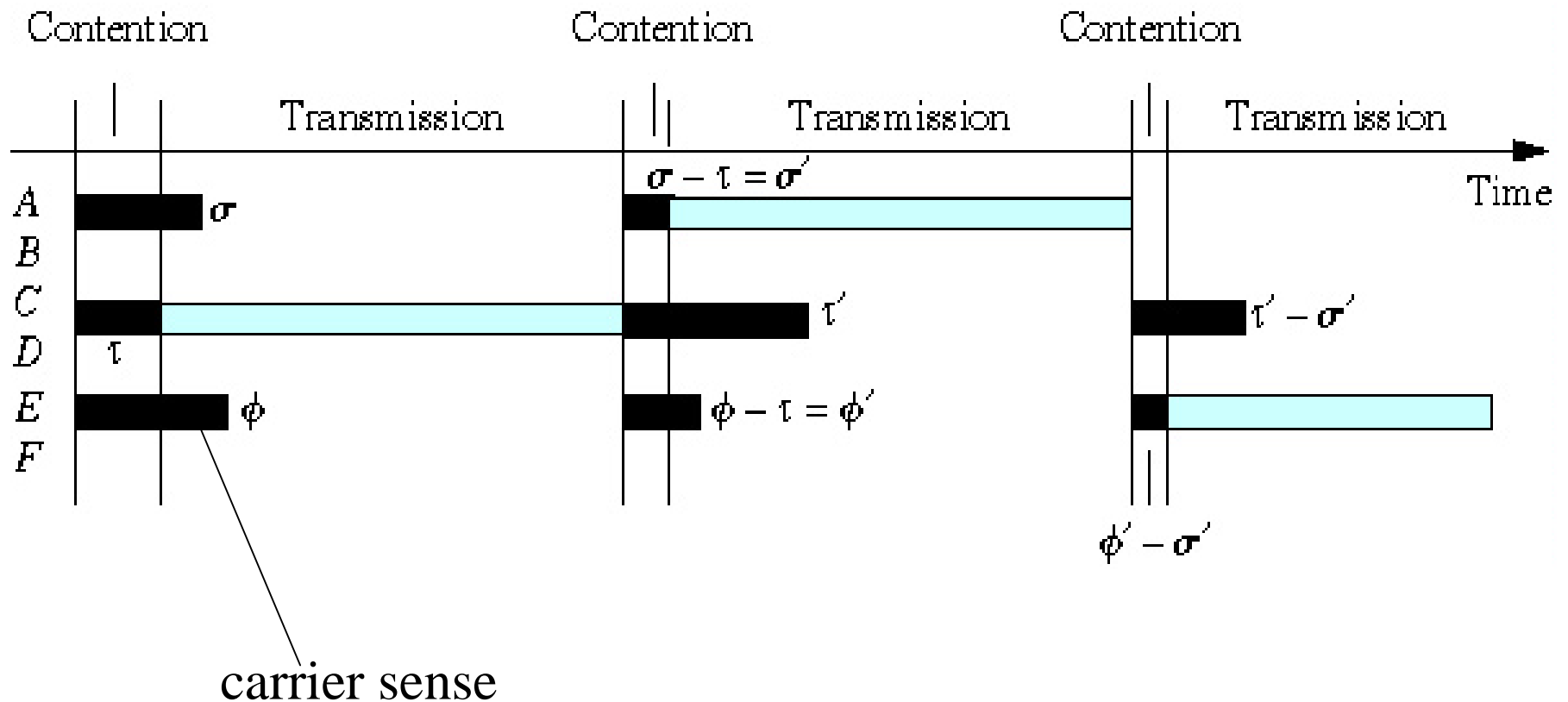


# IEEE 802.11 standard

- Physical and MAC specifications.
- “Open” standard, leaves many possibilities for implementation ⇒ not clear whether different 802.11-compliant devices can inter-operate.
- Physical:
  - Unlicensed bands, e.g., in US: 900MHz, 2.4GHz, 5.7GHz.
  - Various restrictions on use.
  - Direct-sequence or Frequency-hopping spread-spectrum.
- MAC: different modes of operation:
  - Centralized: a base station gives access to the nodes one-by-one.
  - Distributed: CSMA/CA.

# IEEE 802.11 MAC (cont'd)

## Carrier-sense:



# IEEE 802.11 MAC (cont'd)

- Collision-avoidance (stemmed from MACA protocol):
  - Sender transmits special Request-to-send (RTS) packet: the packet contains the length of data to be sent,  $L$ .
  - Receiver replies with Clear-to-send (CTS) packet: this packet also contains the length of data (same as before).
  - Every node hearing the RTS remains quiet for  $CTS+L$ .
  - Every node hearing the CTS remains quiet for  $L$ .
  - If sender does not receive CTS, it knows the receiver is busy and does not transmit data.
  - CTS/RTS packets may still collide, but they are small, so the probability of collisions is reduced.

# IEEE 802.11 MAC: example

■ Example:

