Mobile Ad hoc Networks COE 549
Random Access I

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Outline

- Medium Access Control Protocols
- ALOHA
- BTMA
- CSMA
- Some simulation results

Medium Access Control

- Nodes must decide when to access the channel, i.e., transmit
- Two conflicting targets:
  - Collisions of packets must be avoided
  - Bandwidth must not be underutilized
- Therefore, a balance is needed. This is the task of the MAC protocol

MAC Protocols

1. Random Access:
   - Nodes contend for the channel whenever they have a packet
   - Simplest example is Slotted Aloha: Nodes transmit packets whenever they arrive
2. Transmission Scheduling:
   - Each node can transmit during a preassigned set of slots.
   - Simplest example is TDMA/FDMA/CDMA.
3. Hybrid Protocols:
   - Nodes have preassigned slots but also contend.
   - Simplest example is Reservation Aloha: Nodes contend for a slot whenever they need it, but then have priority in following frames.

Properties of Each Scheme

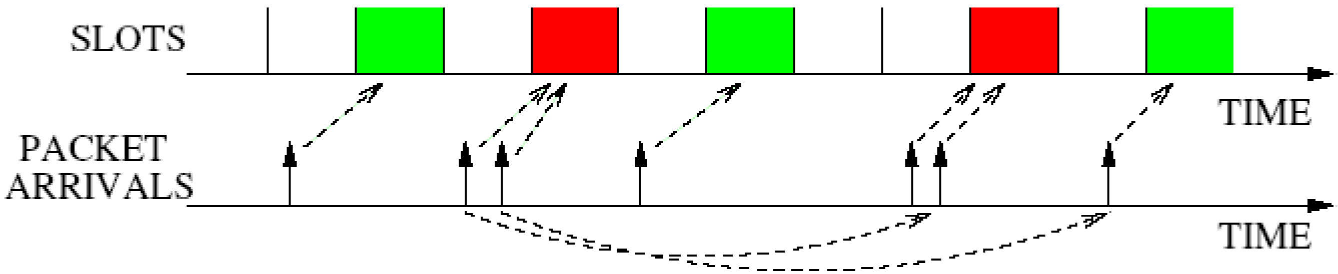
- Random access is preferable when:
  - traffic is bursty (e.g., data).
  - topology changes fast or is unknown.
- Transmission scheduling is preferable when:
  - traffic is periodic (e.g. voice traffic).
  - topology changes slowly.
  - quality guarantees are needed.
- Hybrid protocols are adaptable to the traffic/mobility conditions.

Comparison of Ad hoc and Infrastructure Network Topologies..

- Before CSMA/CA:
  - Slotted Aloha (Roberts ’72 [1])
  - Carrier Sense Multiple Access (CSMA) (Kleinrock ’72 [2])
  - CSMA with Collision Detection (CSMA/CD) (Metcalfe ’76 [3])
  - Busy Tone Multiple Access (BTMA) (Tobagi ’76 [4])
- CSMA with Collision Avoidance (CSMA/CA):
  - MACA (Karn ’90 [5])
  - MACAW (Bharghavan ’94 [6])
  - IEEE 802.11 standard (’97 [7])
- After CSMA/CA:
  - Fairness enhanced CSMA/CA (Ozugur ’99 [8])
  - Dual Busy Tone Multiple Access (DBTMA) (Haas ’99 [9, 10])
  - CSMA/CA with Power Control (Agarwal ’01 [11], Jung ’02 [12])
  - CATA (Tang ’99 [13])
  - Progressive Backoff Algorithm (PBOA), Progressive Ramp Up Algorithm (PRUA)
  - (Toumpis ’03 [14])

Slotted ALOHA

- Transmission time is divided into time slots
- BS transmits beacon signal for time and all MTs is divided into time slots to this beacon signal
- When MT generates a packet, it is buffered and transmitted at the start of the next time slot
- Assuming equal length packet, either we have a complete collision or no collision
- Throughput of slotted ALOHA = 36%, which is still low



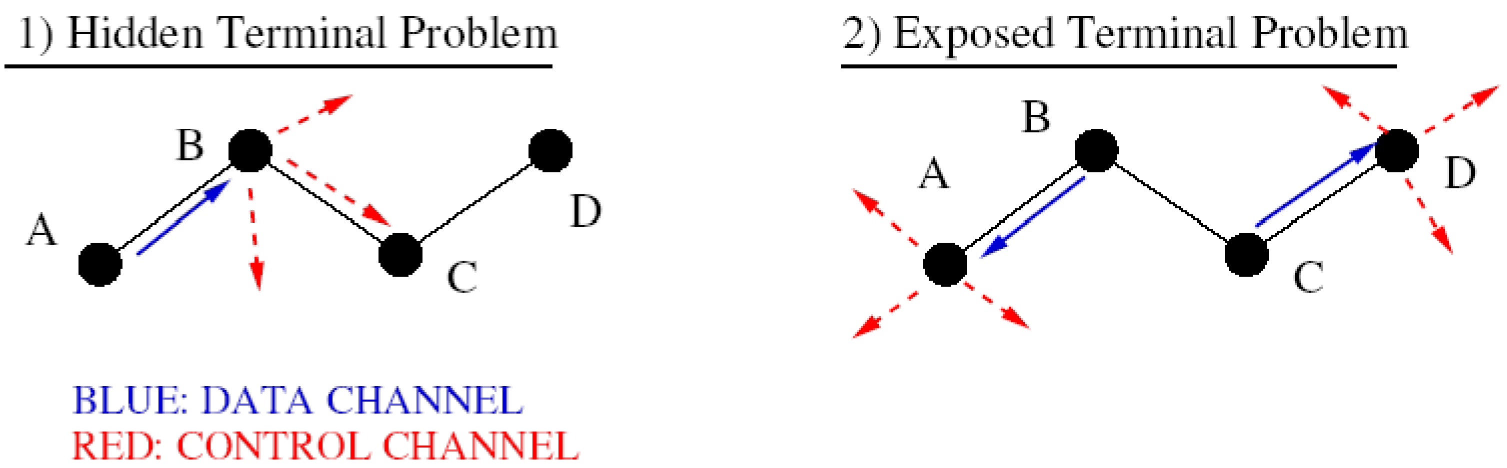
Carrier Sense Multiple Access (CSMA)

- It is possible that a node sense the channel to idle, but should not transmit (the hidden terminal problem).
- It is possible that a node senses the channel busy, but should transmit

- (In the examples, only nodes connected by a straight line can listen to each other's transmissions.)

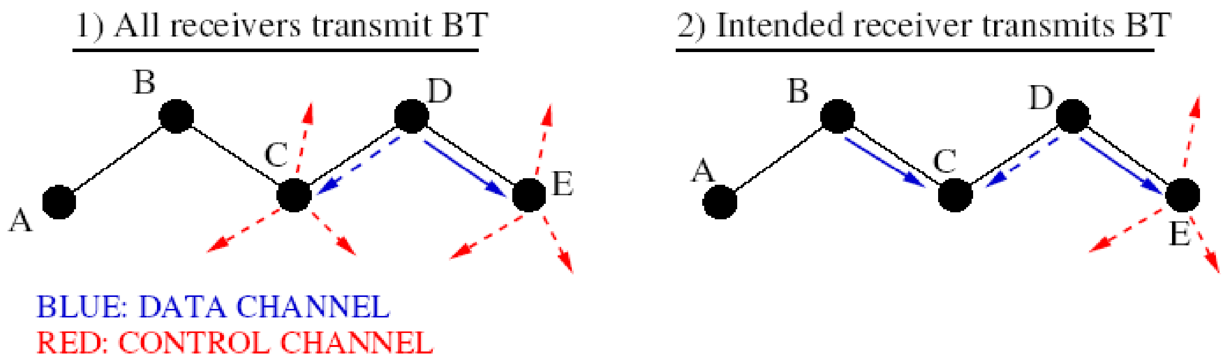
Busy Tone Multiple Access (BTMA)

- Receiver transmits a busy tone in another channel (control channel).
- Nodes sense the control channel before transmitting.



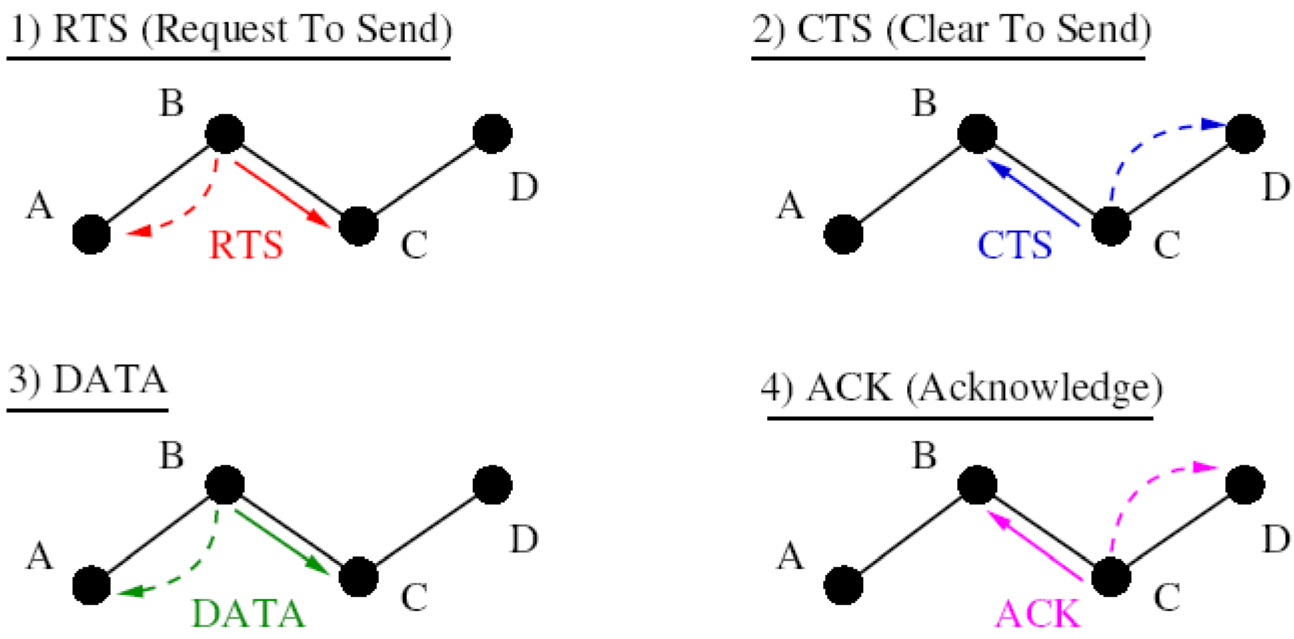
Disadvantages of BTMA

- Some bandwidth is sacrificed, and nodes must be full-duplex (harder than half-duplex)
- If all receivers transmit BT, some transmitters are unnecessarily stopped
- If only intended receiver transmits BT, there are collisions elsewhere



- In first case, C can not transmit a packet to A (he should have been allowed)
- In second case, B transmits a packet to C and there is collision (bandwidth is wasted)

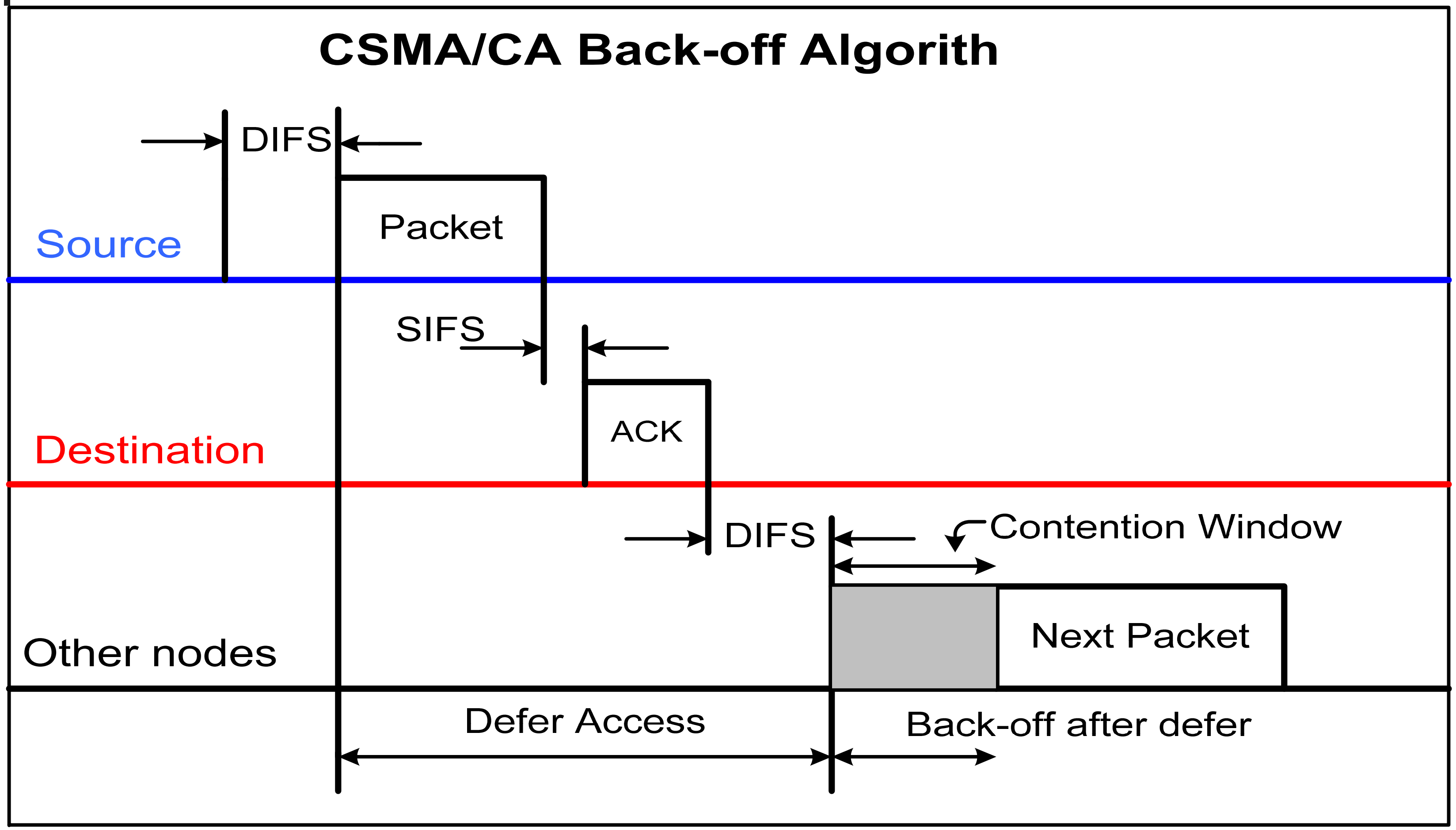
Carrier Sense Multiple Access Collision Avoidance (CSMA/CA)



CSMA/CA..

- IEEE 802.11b has four types of Inter Frame Space (IFS):
  - Short IFS (SIFS): is the period between the completion of packet transmission and the start of the ACK frame. (The minimum IFS)
  - Point Coordination IFS (PIFS): is SIFS plus a Slot Time, which is optional and we do not use it in our study
  - Distributed IFS (DIFS): is PIFS plus a Slot Time
  - Extended IFS (EIFS): is a longer IFS used by a station that has received a packet that it could not understand. This is needed to prevent collisions

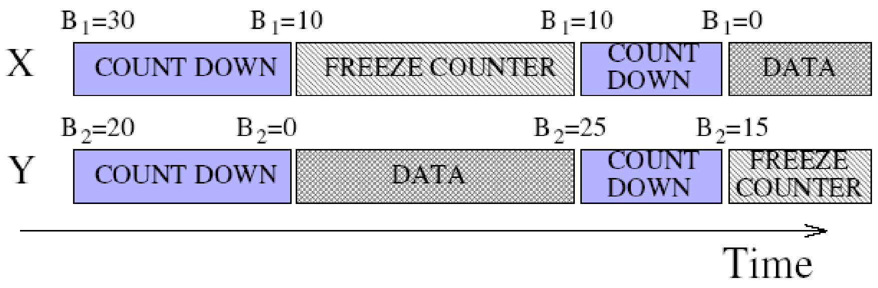
CSMA/CA..



CSMA/CA Back-off Algorith
DIFS
Packet
Source
SIFS
ACK
Destination
DIFS
Contention Window
Next Packet
Other nodes
Defer Access
Back-off after defer

Backoff Mechanism

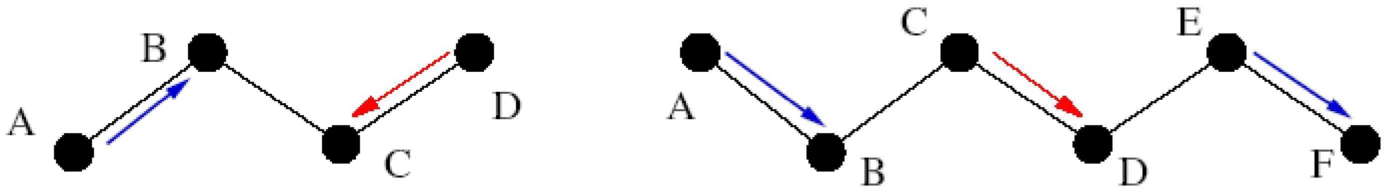
1. Motivation:
   - When channel becomes available, maybe more than one node have packets to transmit
   - If all of them transmit, there will be collisions
2. Solution: nodes backoff for random times:
   - Each selects a random number for backoff counter between 1 and the contention window CW
   - While channel is idle, nodes reduce backoff counter
   - First one to hit 0 transmits
   - The rest freeze their counters



Congestion Control

- The contention window size should reflect the level of congestion in the network:
  - If there is little traffic, the contention window should be small
  - If there is a lot of traffic, the window should be large to reduce collisions
- The solution of IEEE 802.11:
  - If a node transmits but fails, it doubles the contention window, until it reaches CWmax
  - If a node transmits and succeeds, it resets the contention window to CWmin
  - CWmin = 15 and CWmax =1023 slot time (50 micro-second)

Problem1: Fairness



Assume heavy traffic: all nodes need the channel all of the time.

- But red and blue transmissions cannot coexist (see previous slide).

In 4-node example, if A has the channel, D can not get it back

- We have long-term fairness but not short-term fairness.

In 6-node example, C can only initiate transmission if both A and F are silent at the same time.

Backoff algorithm makes matters worse!

- Nodes that fail in handshake double their contention window.

Problem 2: Spatial Reuse with CSMA/CA

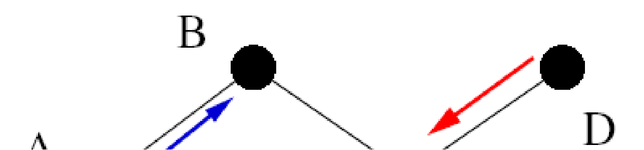
CSMA/CA ensures fewer collisions, but introduces artificial restrictions on transmissions.

- In following examples, the blue and the red transmission are compatible, but CSMA/CA does not allow them
- Reason: With CSMA/CA, transmitter is also required to receive, receiver is also required to transmit

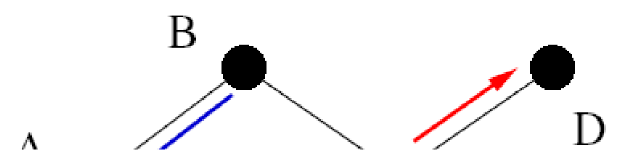
Hidden terminal problem morphs to another problem!

Exposed terminal problem not solved at all!

1) Receivers cannot be neighbors



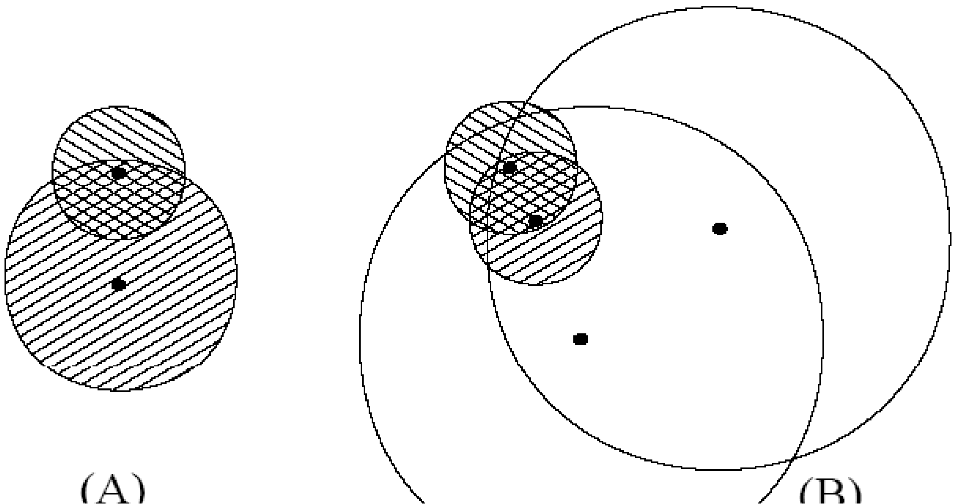
2) Transmitters can not be neighbors



Problem 3: CSMA has no Power Control

Transmitter receiver pairs must use the same power because communication must be bidirectional (setting (A)).

Different pairs must use same power, otherwise strong transmitters kill weak transmitters (setting (B)).



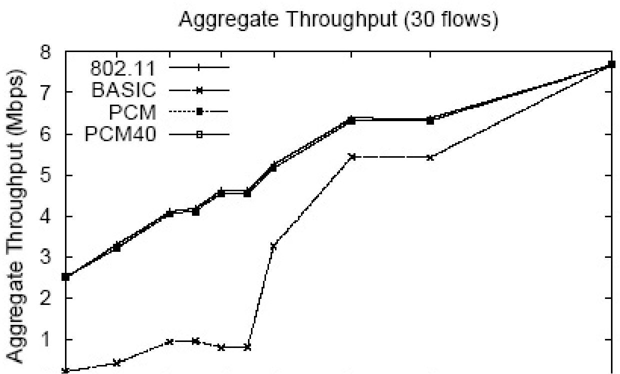
Performance Evaluation [11]

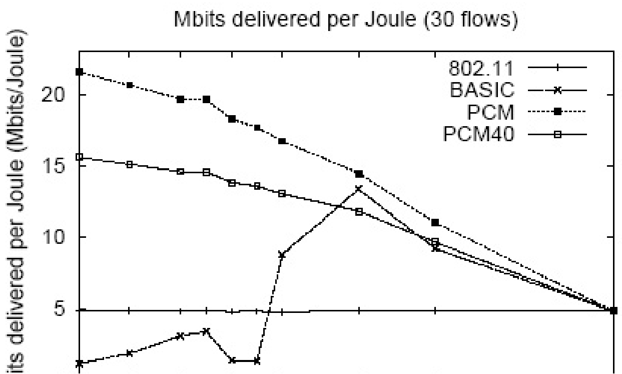
Have all the nodes transmit the RTS/CTS packets with maximum power, and the DATA/ACK packets with less power.

- Transmissions are protected, power is conserved

Actually a bad idea:

- Still nodes must be separated more than necessary
- It is harder for potential interferers to sense the channel

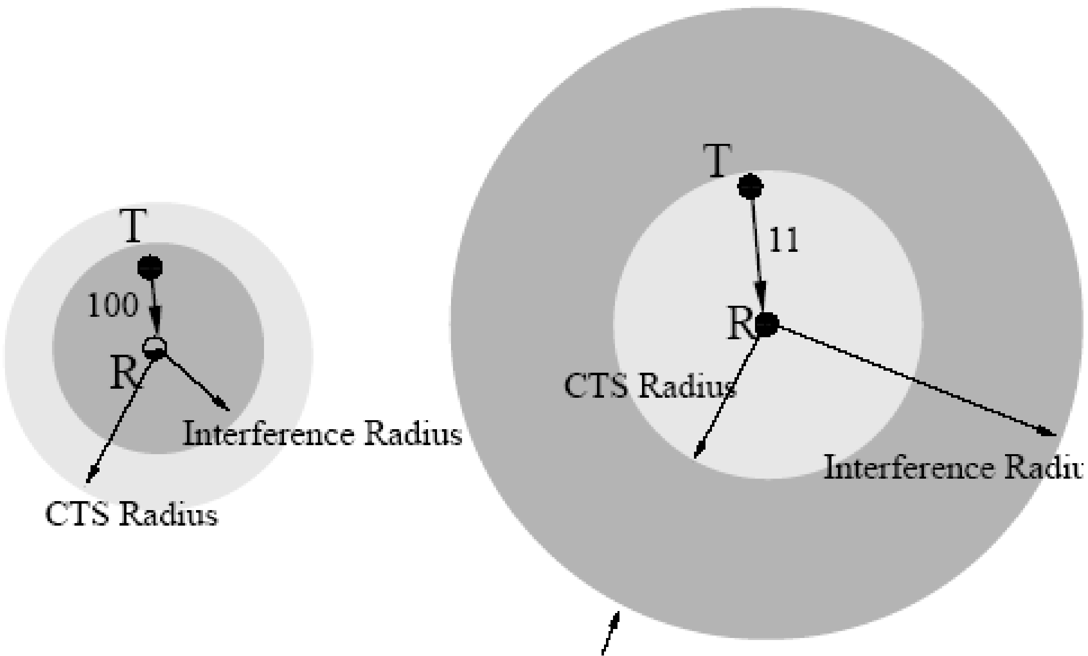




Problem 4: Transmissions over weak links are not protected

(Minimum S/R required for successful reception: γ_T = 10.)

Problem is typically masked by poor physical layer mode.



Other Problems

Control packets might collide.

Nodes must decide a power threshold for declaring the channel busy.

- Placing the threshold too high will prohibit some transmissions that could take place.
- Placing it too low will not protect sufficiently other transmissions.
- No matter where you place the threshold, mistakes will be made.
- The problem is that you are sensing at the wrong place (i.e., the transmitter, not the receiver.)

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