Medium Access Control

Part II

Revisit Assumptions

• So far, we assumed that all nodes are in close proximity such that
  – They all could sense each other’s carrier
  – Two simultaneous transmissions will always interfere to cause collision.

• Let us now relax this assumption.
Carrier Sense Threshold

- If received power is less than $P_{CS}$ (carrier sense threshold), channel is assumed idle, otherwise busy.

![Diagram showing power versus distance with points A, B, C, and D, and a line indicating D's CS Threshold.]

Assume, D is sensing channel

Important Tradeoff

- Lower carrier sense threshold means less spatial reuse or less concurrency.
- On the other hand, higher threshold means more spatial reuse, but more possibility of interference.
- Need a balance for the best performance.
Impact of CS Threshold on Interference

- Suppose C transmits even though A is already transmitting

\[ P_t g_{AC} \leq P_{CS} \Rightarrow P_t \leq \frac{P_{CS}}{g_{AC}} \]

Interference \( I_{CB} = P_t g_{CB} \leq \frac{P_{CS} g_{CB}}{g_{AC}} = P_{CS} \frac{g_{CB}}{g_{AC}} \)

[Interference at B due to C]

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Impact of CS Threshold on Interference

- Suppose C transmits even though A is already transmitting

\[ P_t g_{AC} \leq P_{CS} \Rightarrow P_t \leq \frac{P_{CS}}{g_{AC}} \]

\[ I_{AD} = P_t g_{AD} \leq P_{CS} \frac{g_{AD}}{g_{AC}} \]
Hidden Terminals

\[ I_{CB} \leq P_{CS} \frac{g_{CB}}{g_{AC}} \]

- Collisions may occur despite carrier sensing.
- Smaller carrier sensing threshold \( P_{CS} \) can help.
- But increases the possibility of exposed terminals.

\[ \text{[C can carrier sense B, but C-E transmission cannot collide with B-A transmission as the interference at A from C (or at E from B) is not significant enough.]} \]

Hidden & Exposed Terminals
Hidden & Exposed Terminals

• Difficult to eliminate all collisions using carrier sensing alone.

• There is a trade-off between hidden and exposed terminals.
  – Both are bad for performance.
  – Hidden terminal -> transmit but collide, exposed terminal -> do not transmit.

• “Optimal” carrier sense threshold is a function of network “topology” and traffic characteristics.

Two Important Design Elements

1. Contention window size (cw) for backoff.
   Note that this is a proxy for the transmit probability $p$.

2. Carrier sense threshold $P_{CS}$.

Successful CSMA protocol design would depend on the right setting of these two parameters.
Solutions to Hidden Terminal Problem

• Note that the hidden terminal issue arises as \textit{transmitter cannot carrier sense at the receiver}, while collisions happen at the receiver.
• Thus, we must somehow carrier sense at the receiver.
• Two approaches
  – Busy tone: receiver sounds a busy tone in a different channel, carrier sense on this tone only.
  – Virtual carrier sensing via RTS/CTS exchange: additional control message exchange to silence any transmitter within range of a receiver.

Virtual Carrier Sensing

• Sender sends RTS to receiver specifying the packet duration
• Receiver responds with CTS and copies the packet duration
• Any host hearing RTS or CTS stay silent until the entire exchange is complete.
IEEE 802.11

RTS = Request-to-Send

Pretending a circular range

IEEE 802.11

RTS = Request-to-Send

NAV = remaining duration to keep quiet
IEEE 802.11

CTS = Clear-to-Send

A B C D E F

CTS

IEEE 802.11

CTS = Clear-to-Send

A B C D E F

NAV = 8
IEEE 802.11

• DATA packet follows CTS. Successful data reception acknowledged using ACK.
IEEE 802.11

- The broad protocol operation is same as in physical carrier sensing.