Medium Access Control

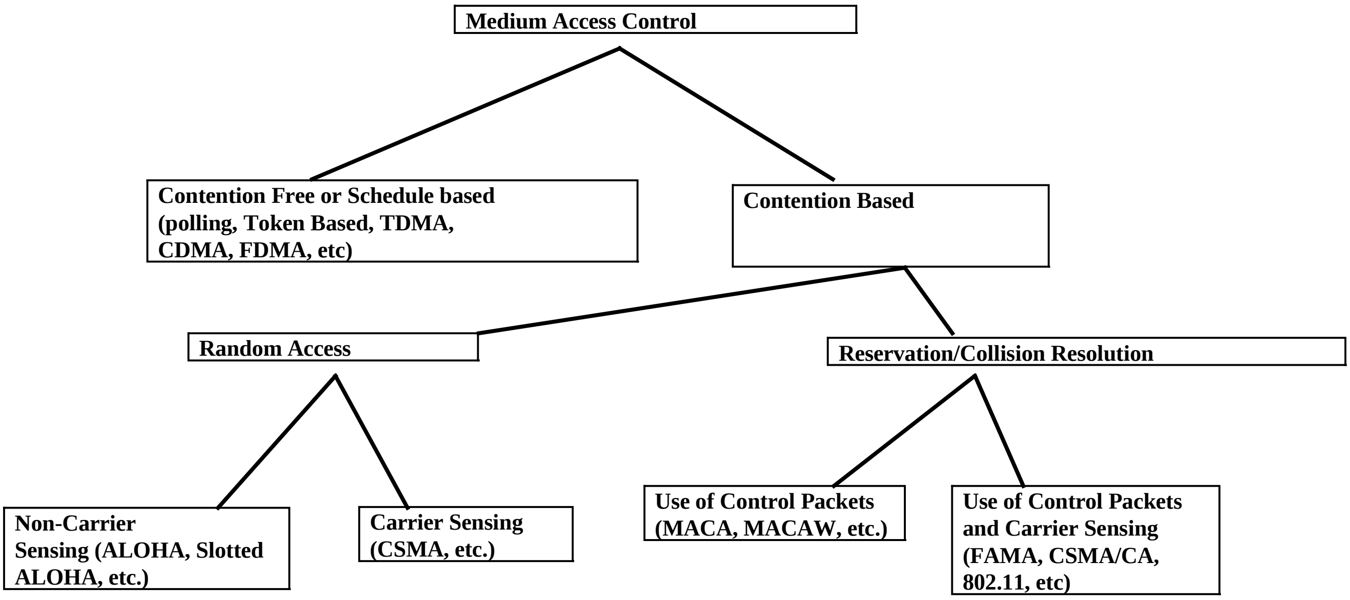
Responsibilities of MAC

- Facilitate single-hop communication
  - No routing here
  - Some broadcast!
- Sharing the medium
  - May perform carrier sense
    - No one else is sending
  - May exchange control packets
    - Tell other I am going to send
  - What if collision occurs?
    - Keep sending might not be a good idea!

Responsibilities of MAC

- Error detection and correction
  - Cyclic redundancy checks, Parity schemes
- Flow control
- Power management
  - Sleep management
  - Reduce idle listening
    - Idle listening state, a sensor node continuously listens to the medium
- Mobility issues

Classification of MAC schemes

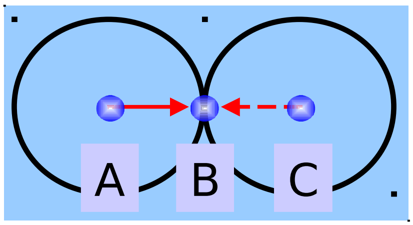


Carrier Sense Multiple Access With Collision Detection

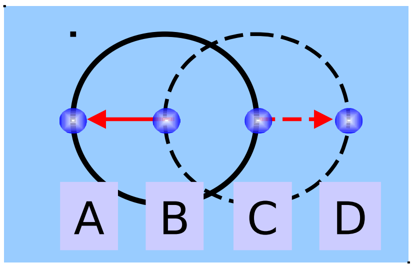
- Carrier Sense Multiple Access (CSMA)
  - Sense the medium
  - If not free
    - wait for till it is free
    - Transmit
- Carrier Sense Multiple Access With Collision Detection (CSMA/CD)
  - Sense the medium
  - If not free
    - Backoff random amount of time
    - Check medium again,
      - if free then transmit.
      - Otherwise Backoff again

Problem for MAC protocol

- Hidden Terminal
  - Node A is sending data to B
  - Node C perform carrier sense
    - Finds medium free.
  - Node C start sending to B
  - B had collision

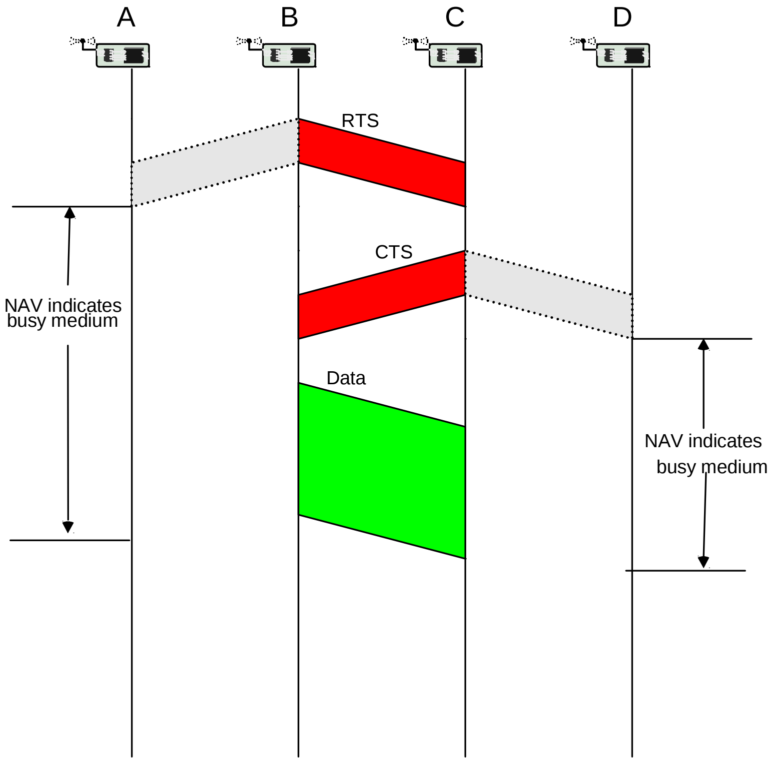


- Exposed terminal
  - Node B is sending data to A
  - Node C performs carrier sense
    - Finds medium occupied
    - Hence node C do not send data to D
  - Sending data to D was safe



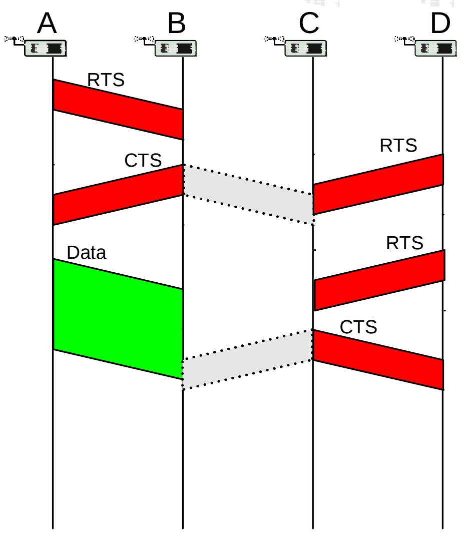
Multiple Access with Collision Avoidance (MACA)

- Sender B asks receiver C whether C will be able to receive a transmission
  Request to Send (RTS)
- "A" overhears B's RTS. It waits until Data should have been recieved.
- Receiver C if agrees to receive, sends out a **Clear to Send** (**CTS**)
- "D" overhears CTS. It waits until data should have been received. CTS has length of data specified inside it.



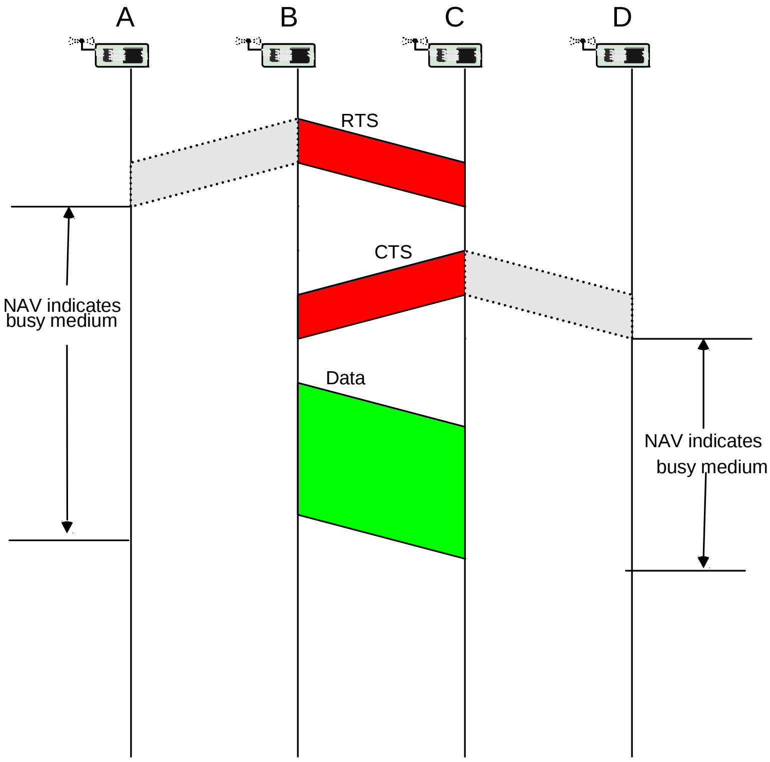
MACA and Hidden Terminal Problem

- MACA Solves Hidden terminal Problem?
  - Yes during data but not during RTC/CTS
  - In figure "C" has become hidden terminal and cannot hear first RTS due to CTS. It is because of this later CTS collides with data.



MACA and Exposed Terminal Problem

- A overhears RTS.
- Waits until CTS
- Medium busy because of the Data.
- Based on information in RTS.
  - A now know that it could send during data transmission.



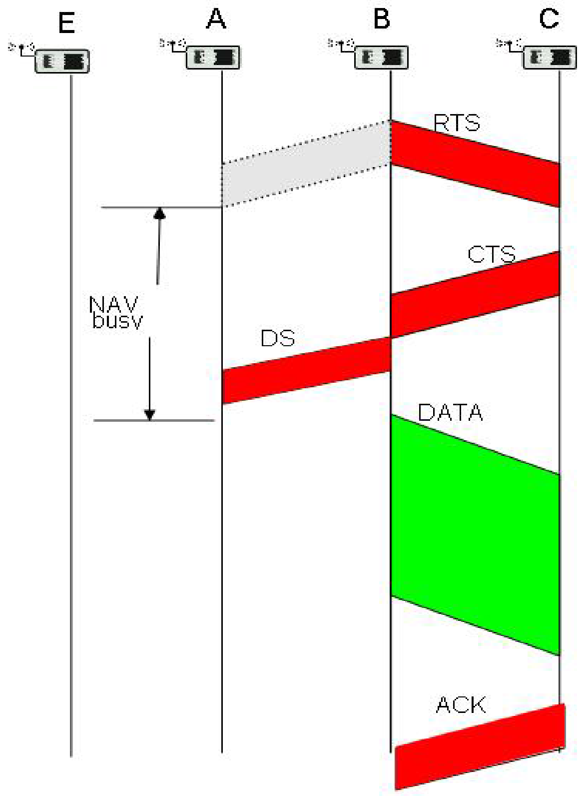
MACA Wireless (MACAW)

MACAW – Basic Message Exchange

- Uses RTS-CTS-DATA-ACK
- Acknowledgement (ACK)
  - If data is received
  - No ACK, data is Resend

MACAW-DS

- Uses RTS-CTS-DS-DATA-ACK
- DS (Data sending)
  - To tell that CTS is received.
  - Every station that hears DS defer its transmission
  - DS holds the transmission length information



Power-aware MAC Protocol

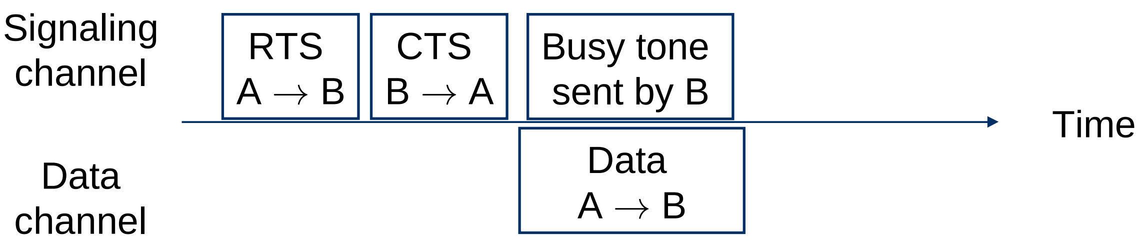
- MANET nodes are battery powered
  - Energy conservation
  - Efficient power utilization
- Principles of power conservation
  - Collisions avoidance: retransmission is expensive
  - Transceiver modes: Standby mode vs. Active mode
  - Lower power mode: based on distance to destination node
- Protocol implementation
  - Power management: alternating sleep and wake cycles
  - Power control: variation in transmission power

PAMAS

- Raghavendra & Singh (1998)
  - Power Aware Medium Access Control with Signaling
  - PAMAS = MACA + Separate Signaling Channel
- Signaling and data channel
  - Combine busy tone with RTS/CTS
  - Results in detailed overhearing avoidance, does not address idle listening
- Sleep and awake modes
  - Node powers off its data channel if busy tones is heard and it is neither the sender nor the receiver of the transmission

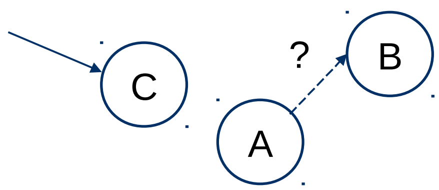
PAMAS

- Procedure
  - Node A transmits RTS on signaling channel, does not sense channel
  - Node B receives RTS, sends CTS on signaling channel if it can receive and does not know about ongoing transmissions
  - B sends busy tone on signaling channel as it starts to receive data

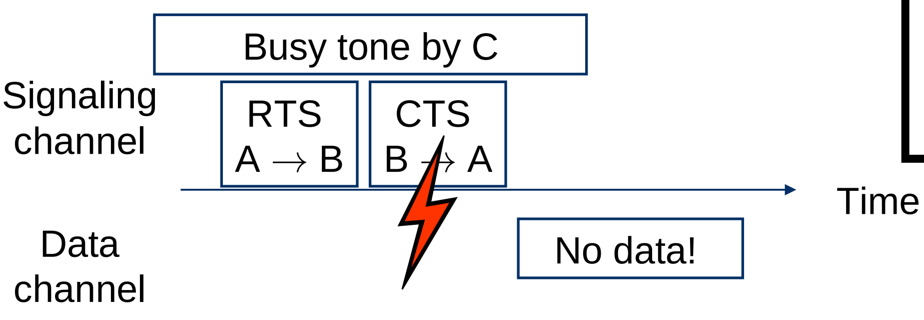


PAMAS: Already ongoing transmission

- Suppose a node C in vicinity of A is already receiving a packet when A initiates RTS

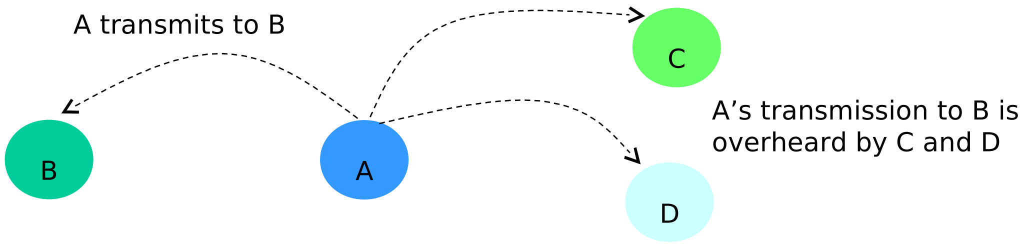


- Procedure
  - A sends RTS to B
  - C is sending busy tone (as it receives data)
  - CTS and busy tone collide,
    A receives no CTS, does not send data



Similarly: Ongoing transmission near B destroys RTS by busy tone

PAMAS: Power Conservation

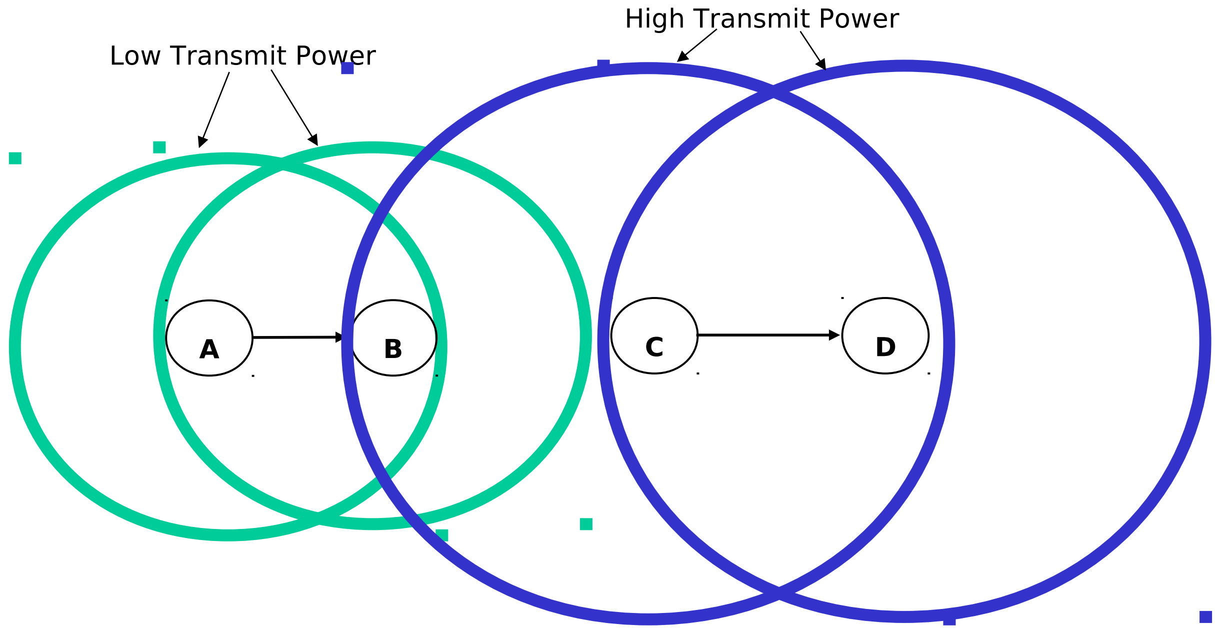


- When does a node enter the power-off state?
  - Condition 1: The node has no packets for transmission and if a neighbor begins transmitting.
  - Condition 2: A neighbor node is transmitting and another is receiving packets at the same time (data channel is busy, it cannot transmit or receive a packet)
- Duration of power-off state
  - Duration field in RTS frame
  - Probe message on signaling channel

PCM

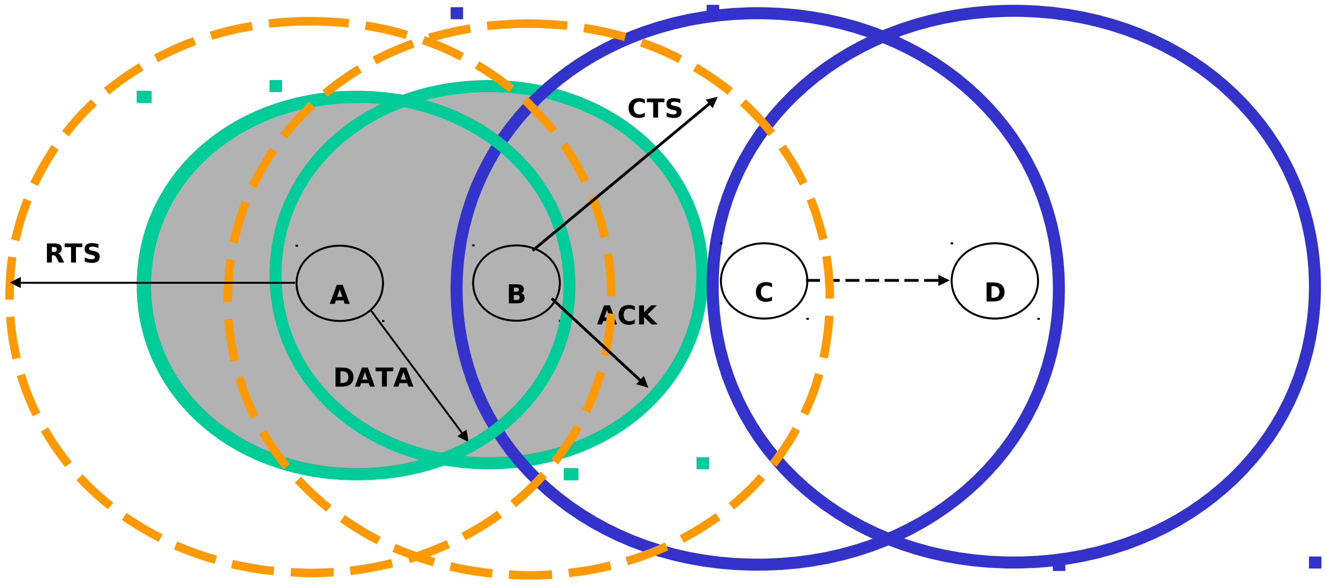
- Jung & Vaidya (2002)
  - Power Control MAC
- Based on BASIC power control protocol (Gomez et al., 2001)
  - Varied transmission power
    - Max. Power: RTS/CTS
    - Min. Power required: Data & ACK

Problem of Using Different Transmit Power



- Asymmetric situation causes collision
  - Node C starts transmitting to D as it does not sense transmission between A and B

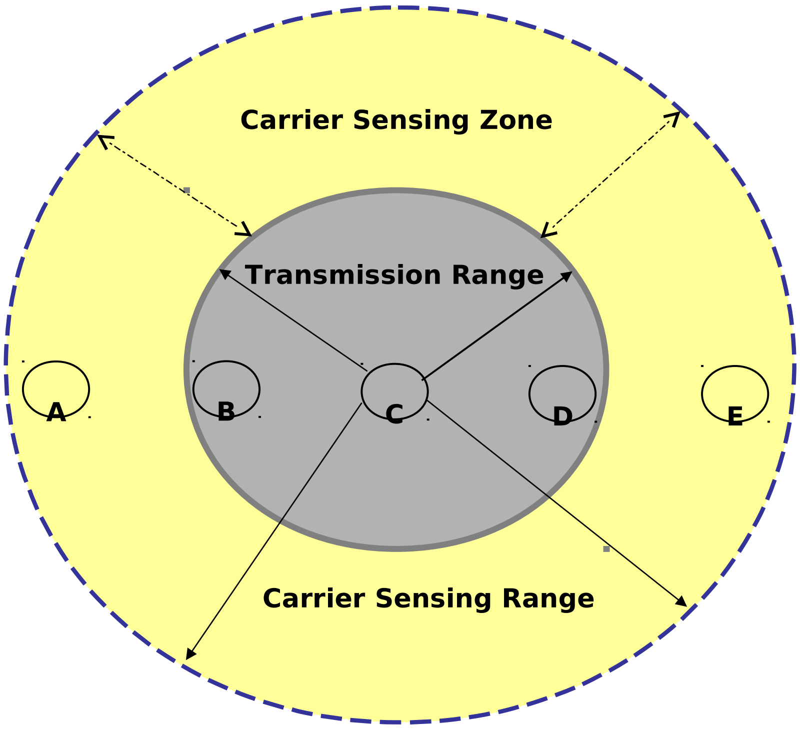
Solution: BASIC Protocol



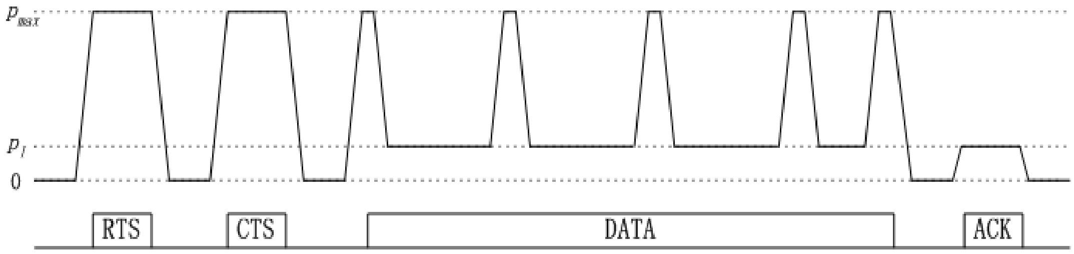
Transmit Power Level

- Method 1: $$Pt_i\_des = \max\{\frac{RX\_Des}{G_{ij}}, \frac{SIR\_Des \cdot Pn\_D_j}{G_{ij}}\},$$
  - Transmit Power of RTS is indicated in RTS
  - Gain can be computed based on both sender and receiver power of RTS
  - Signal-to-noise level is considered to compute transmit power level for DATA
- Method 2: $$p_{desired} = \frac{p_{max}}{p_r} \times Rx_{thresh} \times c$$
  - CTS is sent at max. transmit power

Carrier Sensing vs. Transmission Range



PCM



- RTS-CTS are transmitted at maximum power level
- DATA are transmitted at minimum necessary power level BUT at the maximum level periodically
- ACK are transmitted with minimum necessary power

PCM

- Highlights:
  - Comparable performance to IEEE 802.11
  - Less energy consumed than IEEE 802.11
- Solve drawback of BASIC partly
  - Periodic use of Max Power for DATA
  - But does not completely prevent collision (collision with DATA)
- Drawbacks
  - Accurate estimation of received packet signal strength is difficult (e.g. fading, shadowing)
  - Difficult implementation of frequent change of transmit power level

Literature

- H. Karl and A. Willig: Protocols and Architectures for Wireless Sensor Networks. Wiley, ISBN: 978-0-470-09510-2, 2005.
- Suresh Singh, C. S. Raghavendra: PAMAS - power aware multi-access protocol with signalling for ad hoc networks. Computer Communication Review 28(3): 5-26 (1998)
- Eun-Sun Jung, Nitin H. Vaidya: A power control MAC protocol for ad hoc networks. ACM MOBICOM 2002: 36-47.
- Vaduvur Bharghavan, Alan J. Demers, Scott Shenker, Lixia Zhang: MACAW: A Media Access Protocol for Wireless LAN's. ACM SIGCOMM 1994: 212-225.