Mobile Ad Hoc Networks

4th Week (Part I)
09.05.2007

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Computer Networks and Telematics
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Responsibilities of MAC

- **Facilitate single-hop communication**
  - No routing here
  - Some broadcast!

- **Sharing the medium**
  - May perform *carrier sense*
    - No one else is sending
    - Not all MAC protocol use it
  - May exchange control packets
    - Tell other I am going to send
    - Inform receiver
  - 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**
  - Do not send fast enough
- **Power management**
  - Manage power while doing above all
  - Sleep management
  - Reduce idle listening
    - Idle listening state, a sensor node continuously listens to the medium to look for any possible traffic when nothing is being send.
- **Mobility issues**

Classification of MAC schemes

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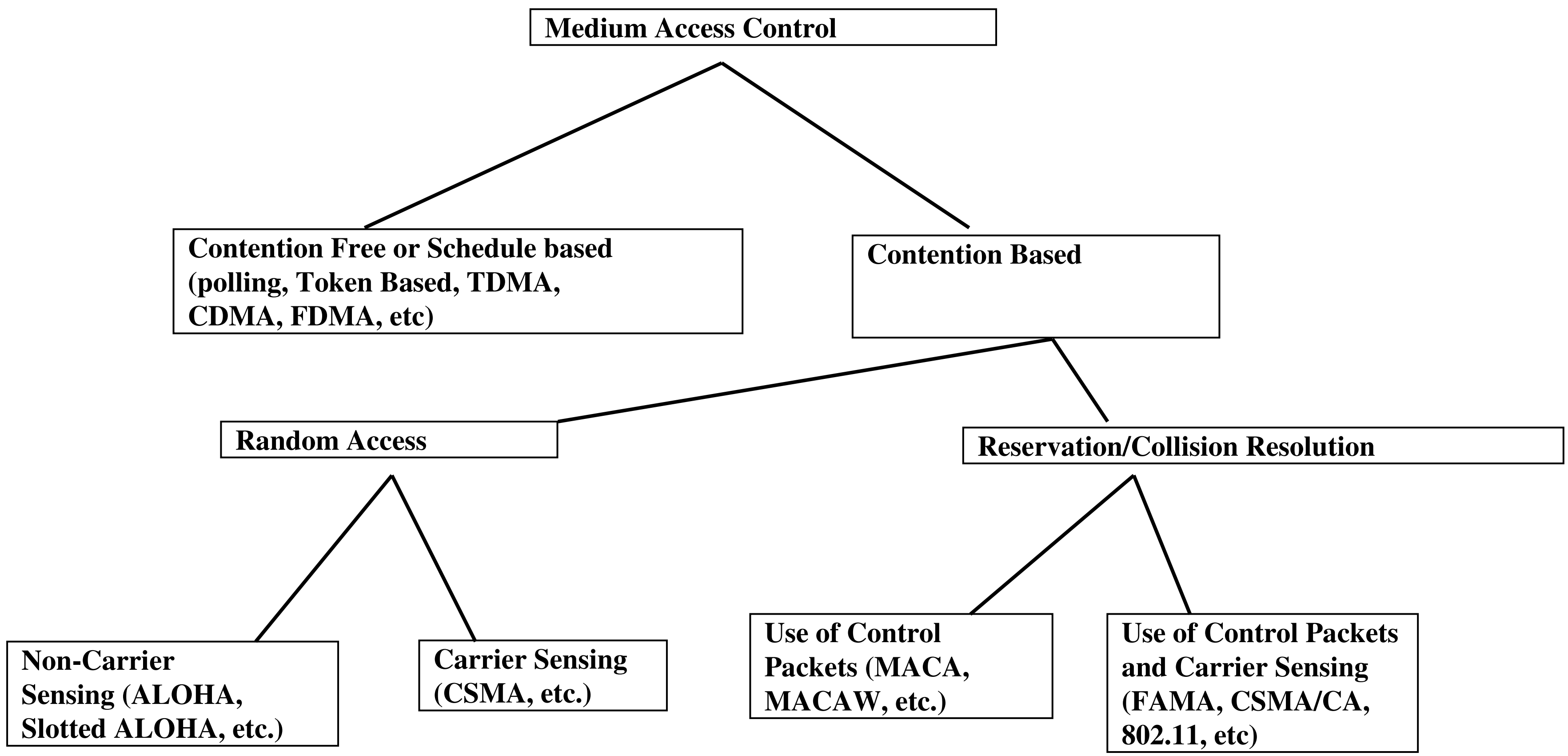

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Schedule- vs. contention-based MACs

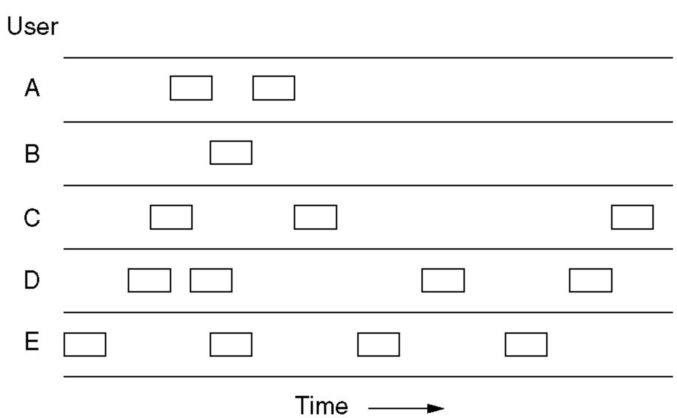
- *Schedule-based* **MAC**
  - A ***schedule*** exists, regulating which participant may use which resource at which time (TDMA component)
  - Typical resource: frequency band in a given physical space (with a given code, CDMA)
  - Schedule can be ***fixed*** or computed ***on demand***
    - Usually: mixed – difference fixed/on demand is one of time scales
  - Usually, collisions, overhearing, idle listening no issues
  - Disadvantage: time synchronization!
- *Contention-based* **protocols**
  - Risk of colliding packets is deliberately taken
  - Hope: coordination overhead can be saved, resulting in overall improved efficiency
  - Mechanisms to handle/reduce probability/impact of collisions required
  - Usually, ***randomization*** used somehow

ALOHA

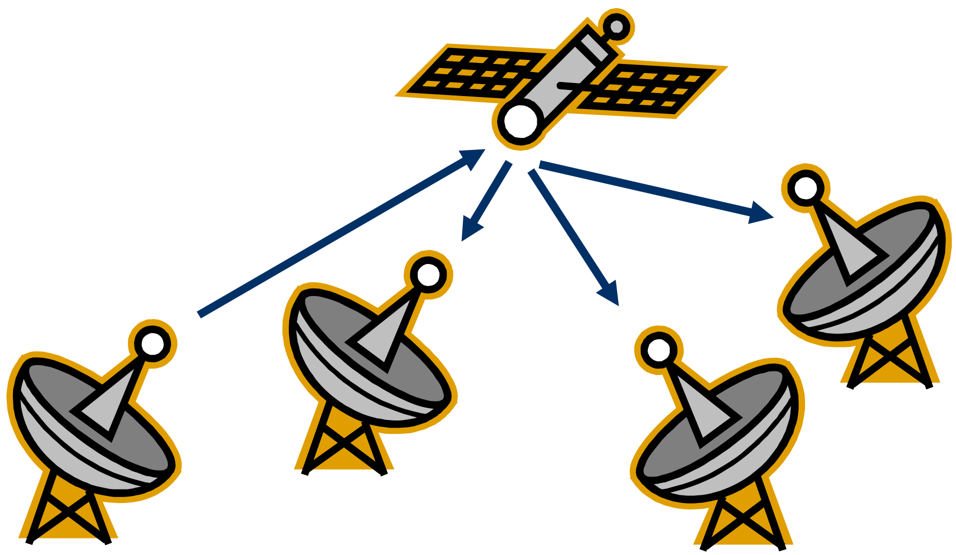
- **The simplest possible medium access protocol:**

  Just talk when you feel like it (no carrier sense)

  If message collide then try again
- **Formally: Whenever a packet should be transmitted, it is transmitted immediately**
- **Introduced in 1985 by Abrahmson et al., University of Hawaii**
- **Goal: Use of satellite networks**



Packets are transmitted at arbitrary times



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ALOHA – Analysis

- **ALOHA advantages**
  - Trivially simple
  - No coordination between participants necessary

- **ALOHA disadvantages**
  - Collisions can and will occur – sender does not check channel state
  - Sender has no (immediate) means of learning about the success of its transmission – link layer mechanisms (ACKs) are needed
    - ACKs can collide as well ☹

A slight improvement: Slotted ALOHA

- **ALOHA's problem: Long vulnerability period of a packet**
- **Reduce it by introducing time slots – transmissions may only start at the start of a slot**
  - Slot synchronization is assumed to be "somehow" available
- **Result: Vulnerability period is halved, throughput is doubled**

Carrier Sense Multiple Access With Collision Detection

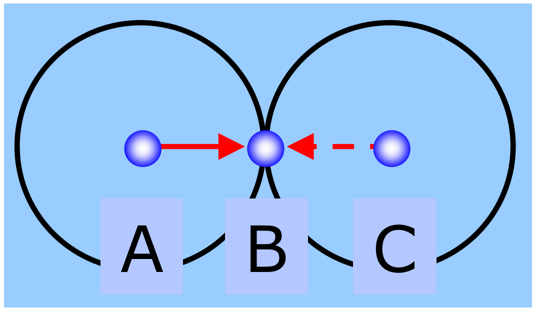
- **Carrier Sense Multiple Access (CSMA)**
  - Sense the medium
  - If not free
    - wait for till it is free
    - Transmit

- **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

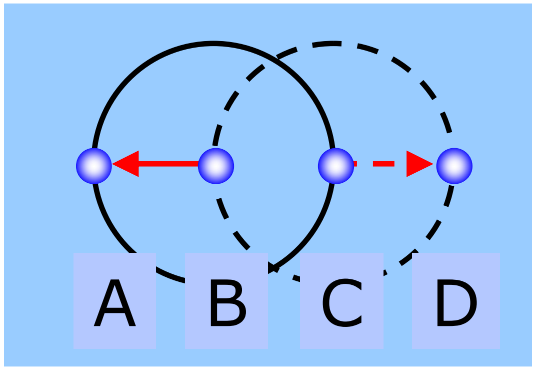
Problem for MAC protocol

- ***In any wireless communication interface is at receiver and not at sender***

- **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



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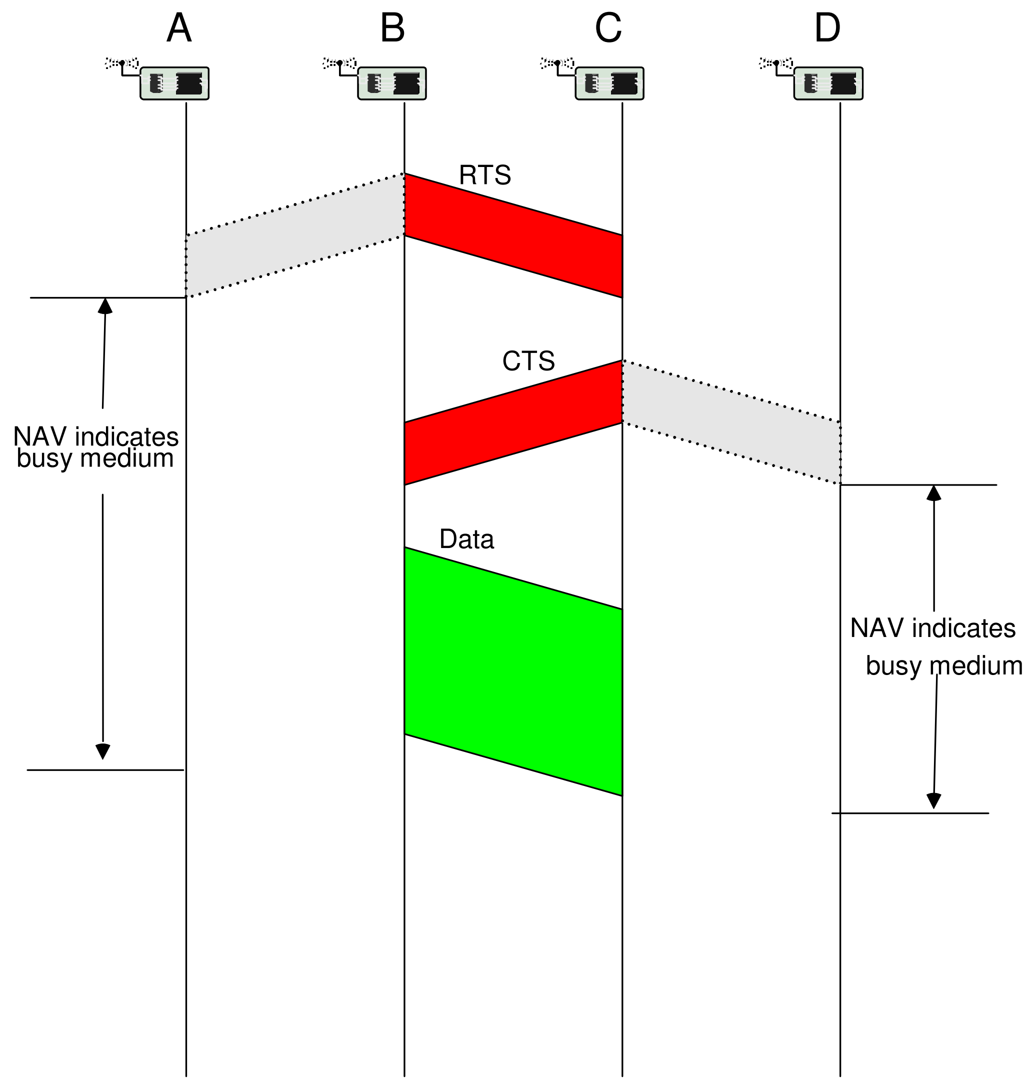
Multiple Access with Collision Avoidance (MACA)

- **Sender B asks receiver C whether C will be able to receive a transmission** *Request to Send (RTS)*
- **"A" overhear 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" overhear CTS. It wait until data should have been received. CTS has length of data specified inside it.**



MACA and Hidden Terminal Problem

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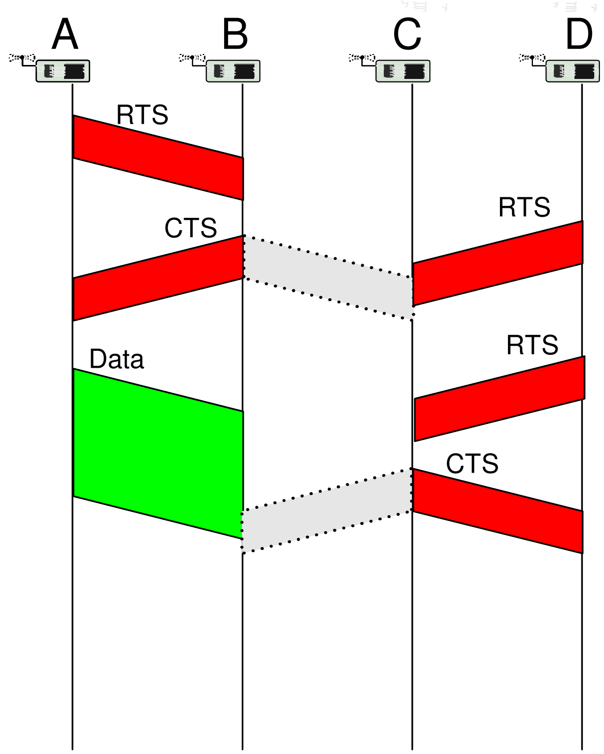
- **MACA Solves Hidden terminal Problem?**
  - –Yes during data but not during RTC/CTS
  - –In figure “C” has become hidden terminal and cannot hear first RTS due to CTS. It is because of this later CTS collide with data.



MACA and Exposed Terminal Problem

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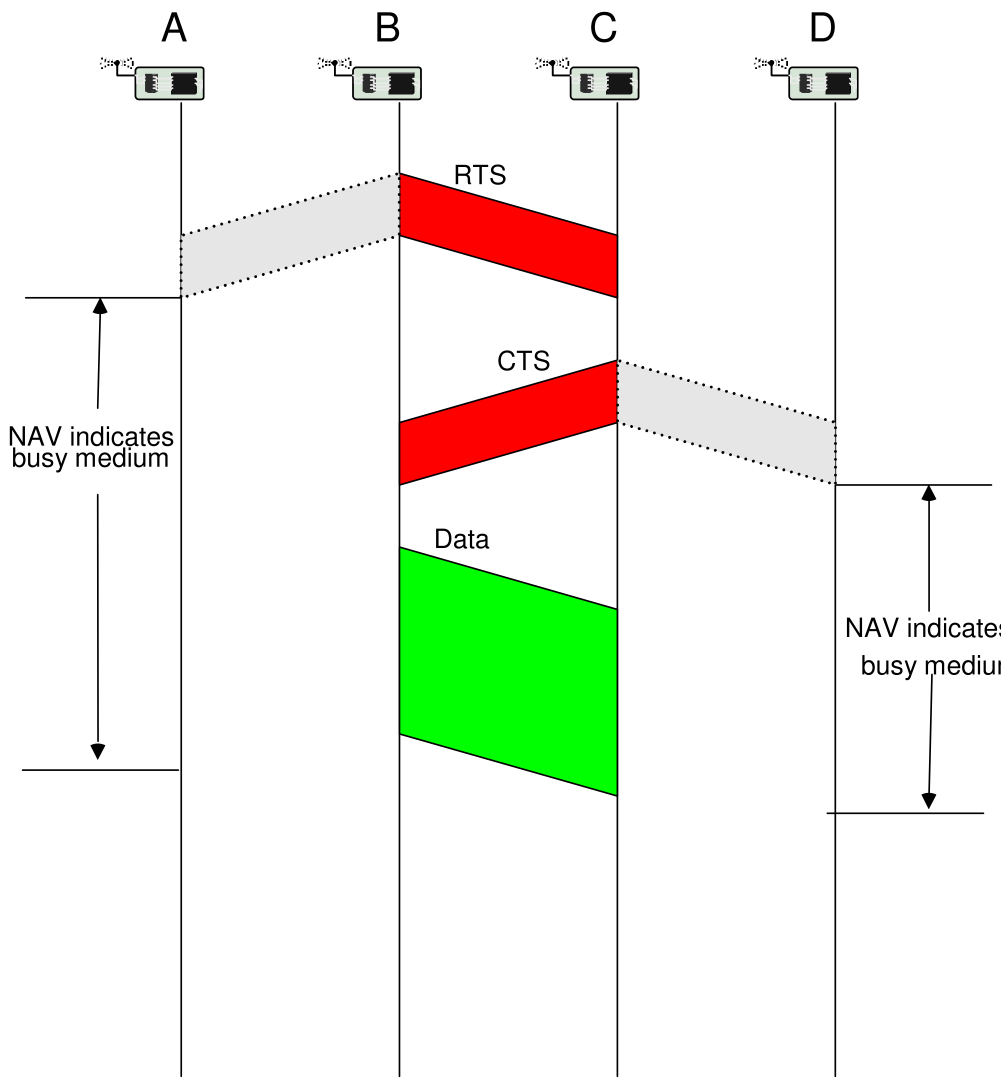
- **"A" overhear RTS.**
- **Waits until CTS**
- **Medium busy because of the Data.**
- **Based on information in RTS.**
  - "A" now know that it could send during data transmission.
- **Exposed Terminal solved?**
  - (Answer in Exercise!)

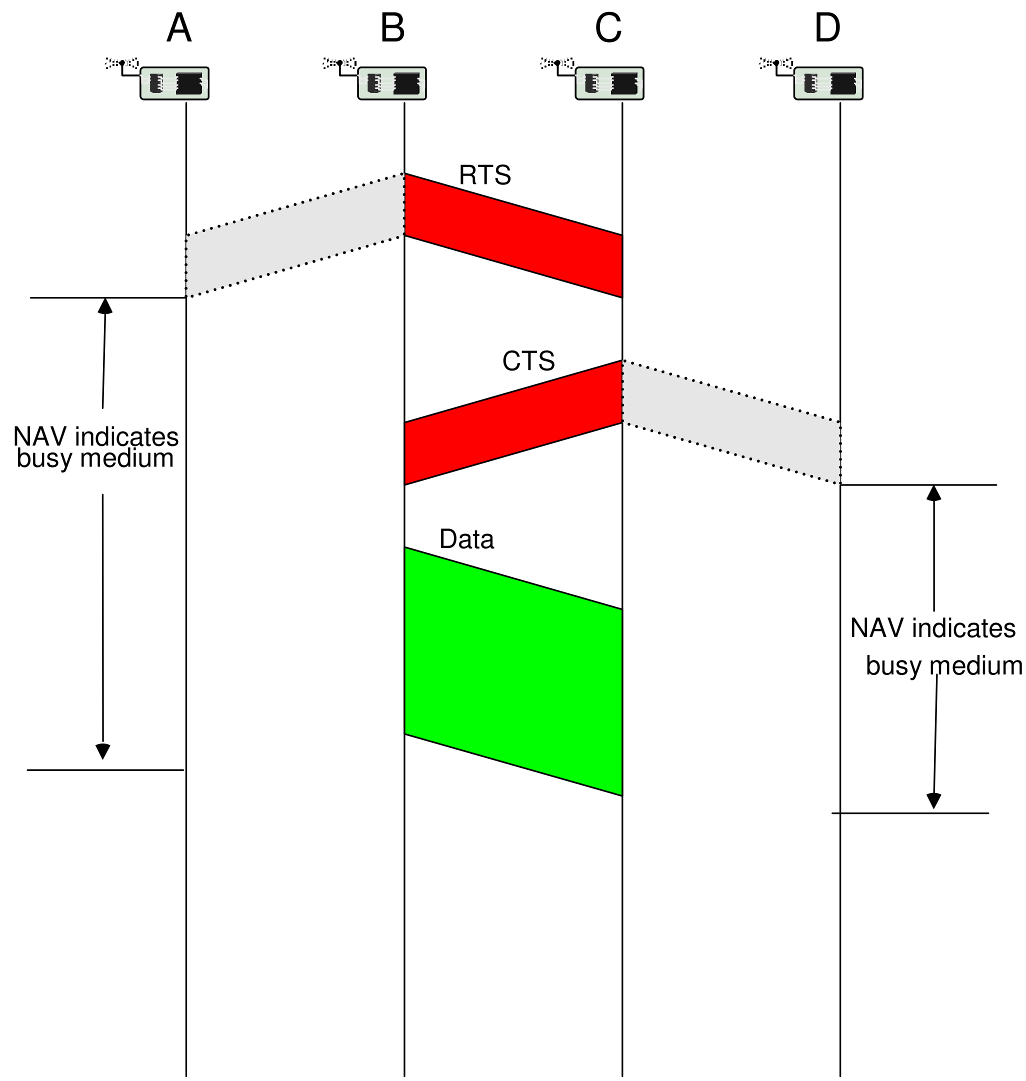


MACA Wireless (MACAW)

- **Uses RTS-CTS-DS-DATA-ACK**

- **Acknowledgement (ACK)**
  - If data is received
  - No ACK, data is Resend

- **DS (Data sending)**
  - To tell that CTS is received.



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

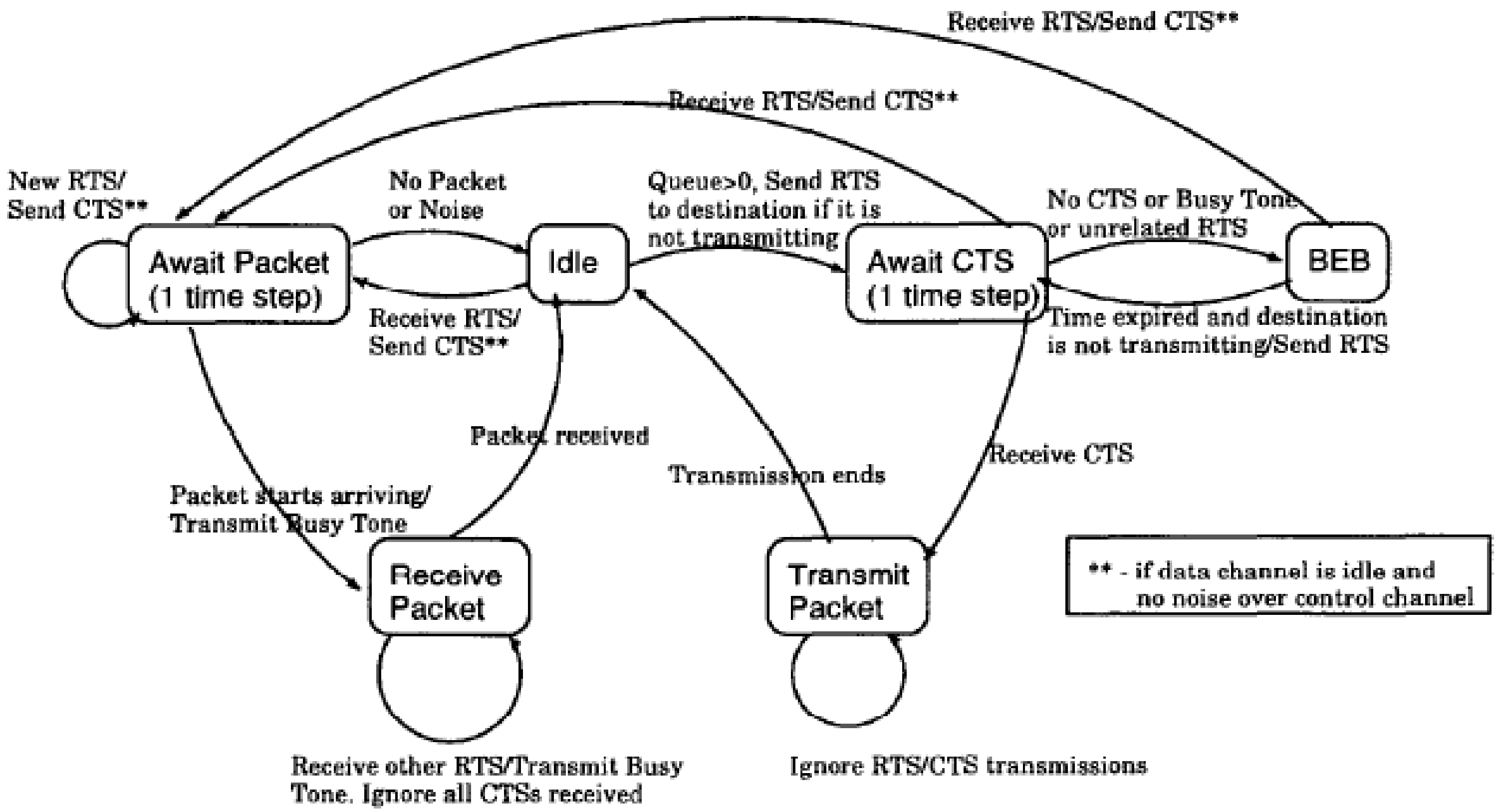
Motivation

Model	Transmit	Receive	Standby
GEC Plessey DE6003 2.4 GHz	1.8 W	0.6 W	0.05 W
Lucent's 15 dBm 2.4 GHz Wavelan radio	1.75 W	1.475W	0.08 W

PAMAS

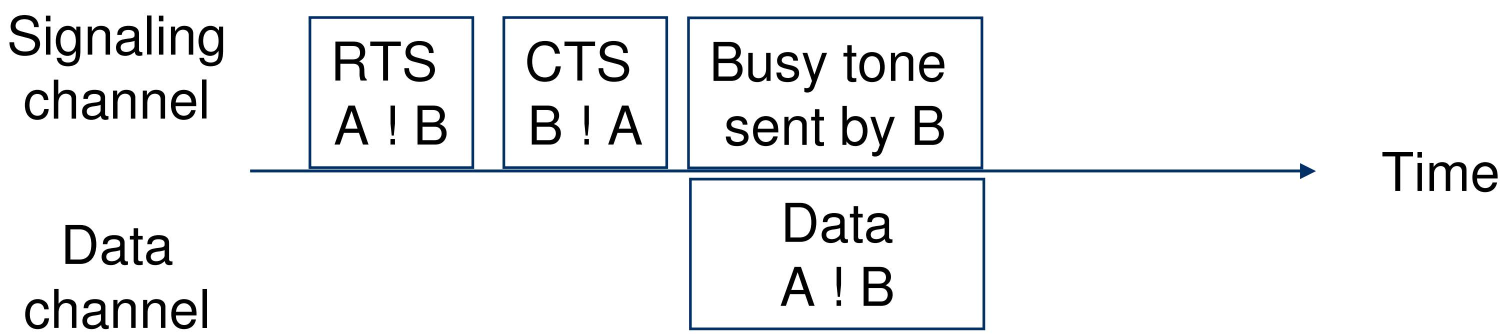
- **Raghavendra & Singh (1998)**
  - Power Aware Medium Access Control with Signaling
  - PAMAS = MACA + Separate Signaling Channel
- **Signaling and data channel**
  - Combine busy tone with RTS/CTS
  - Results in detailed overhearing avoidance, does not address idle listening
- **Sleep and awake modes**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

PAMAS


Receive RTS/Send CTS**
Receive RTS/Send CTS**
New RTS/
Send CTS**
No Packet
or Noise
Queue>0, Send RTS
to destination if it is
not transmitting
No CTS or Busy Tone
or unrelated RTS
Await Packet
(1 time step)
Idle
Await CTS
(1 time step)
BEB
Receive RTS/
Send CTS**
Time expired and destination
is not transmitting/Send RTS
Packet received
Transmission ends
Receive CTS
Packet starts arriving/
Transmit Busy Tone
Receive
Packet
Transmit
Packet
** - if data channel is idle and
no noise over control channel
Receive other RTS/Transmit Busy
Tone. Ignore all CTSs received
Ignore RTS/CTS transmissions

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

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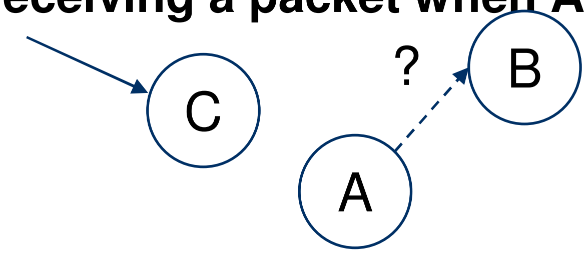
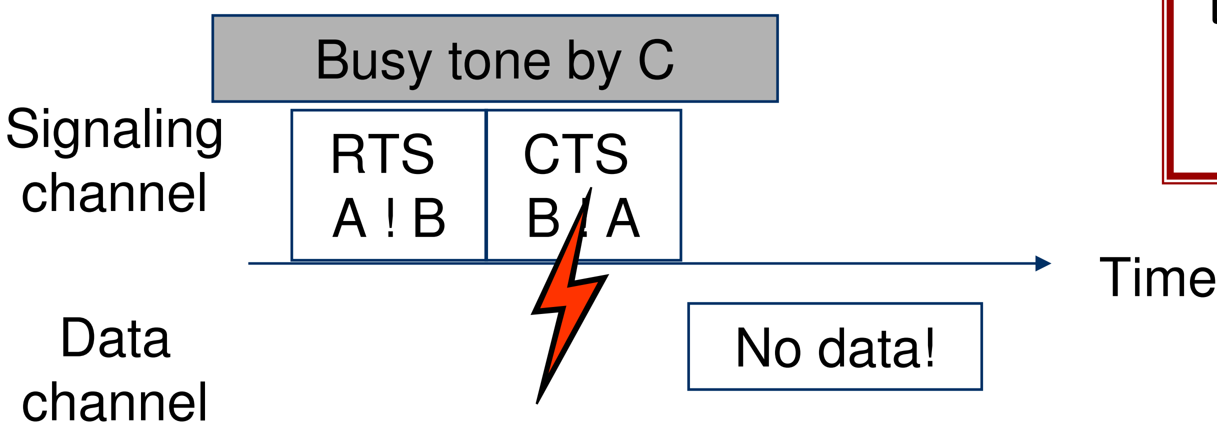
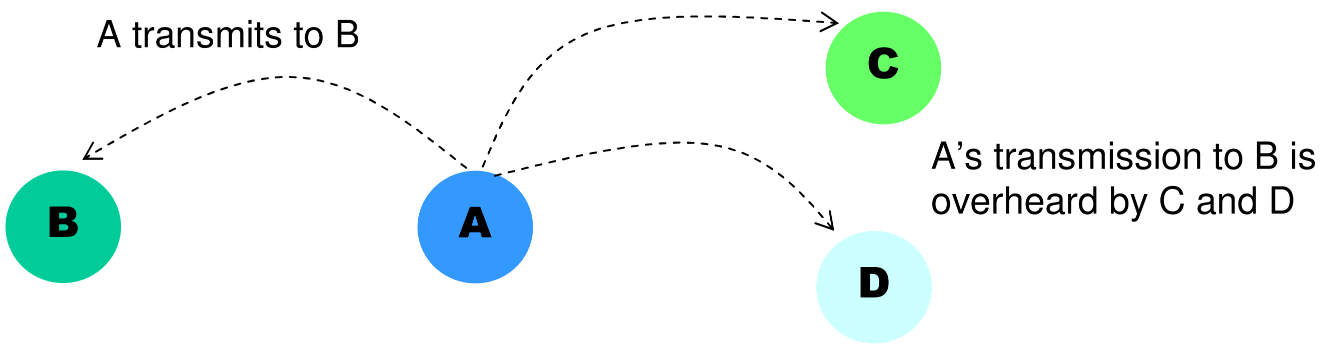
- **Suppose a node C in vicinity of A is already receiving a packet when A initiates RTS**
- **Procedure**
  - A sends RTS to B
  - C is sending busy tone (as it receives data)
  - CTS and busy tone collide, A receives no CTS, does not send data





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

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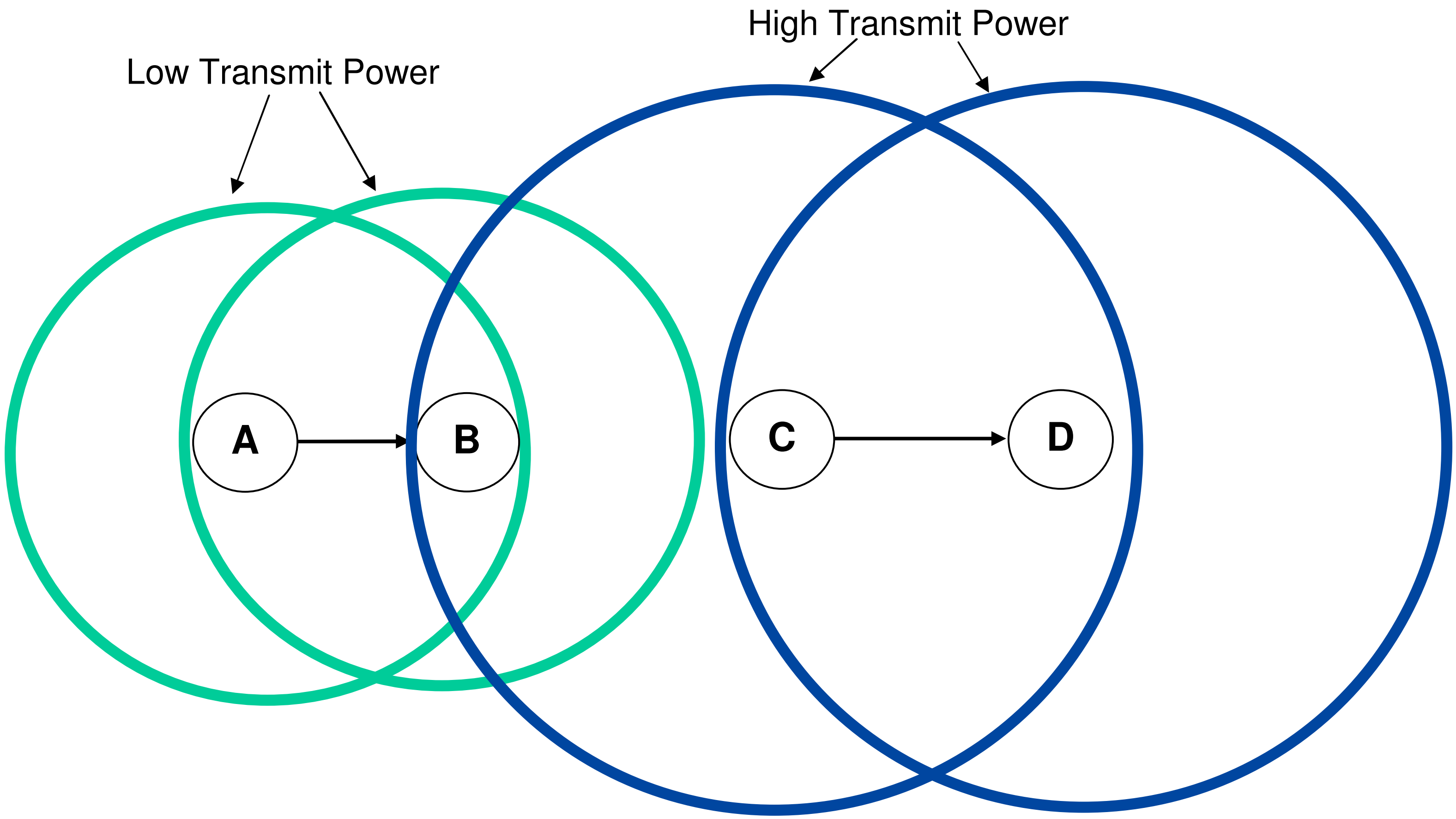
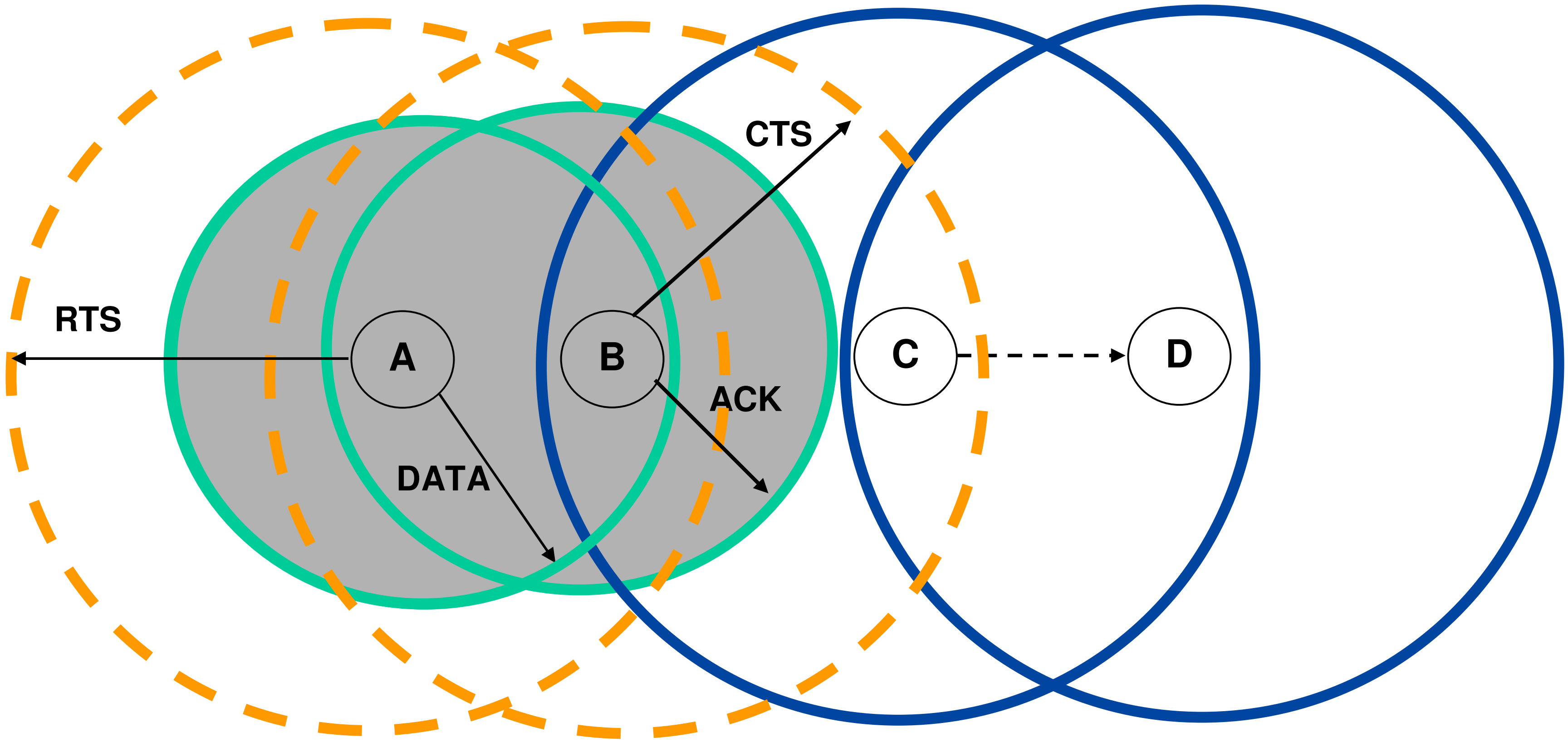
Problem of Using Different Transmit Power



- **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

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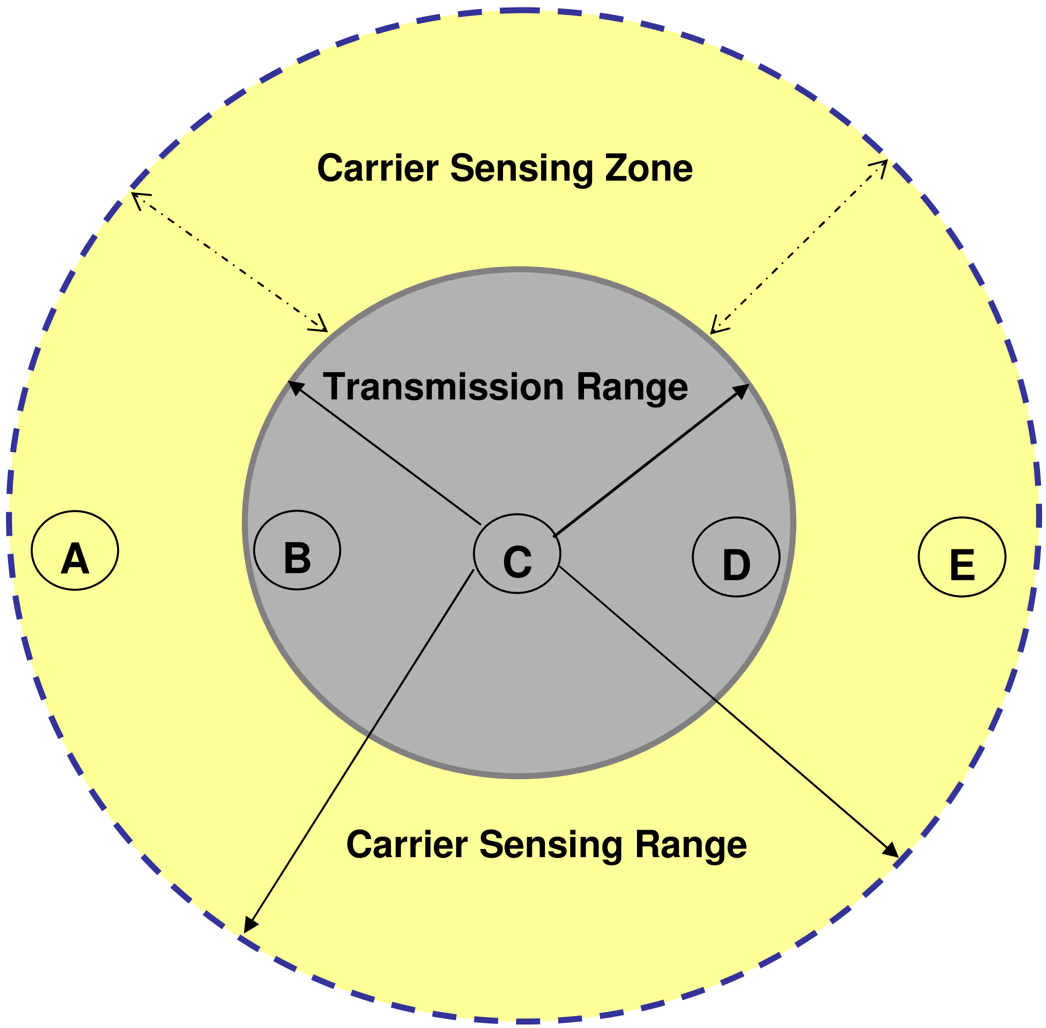

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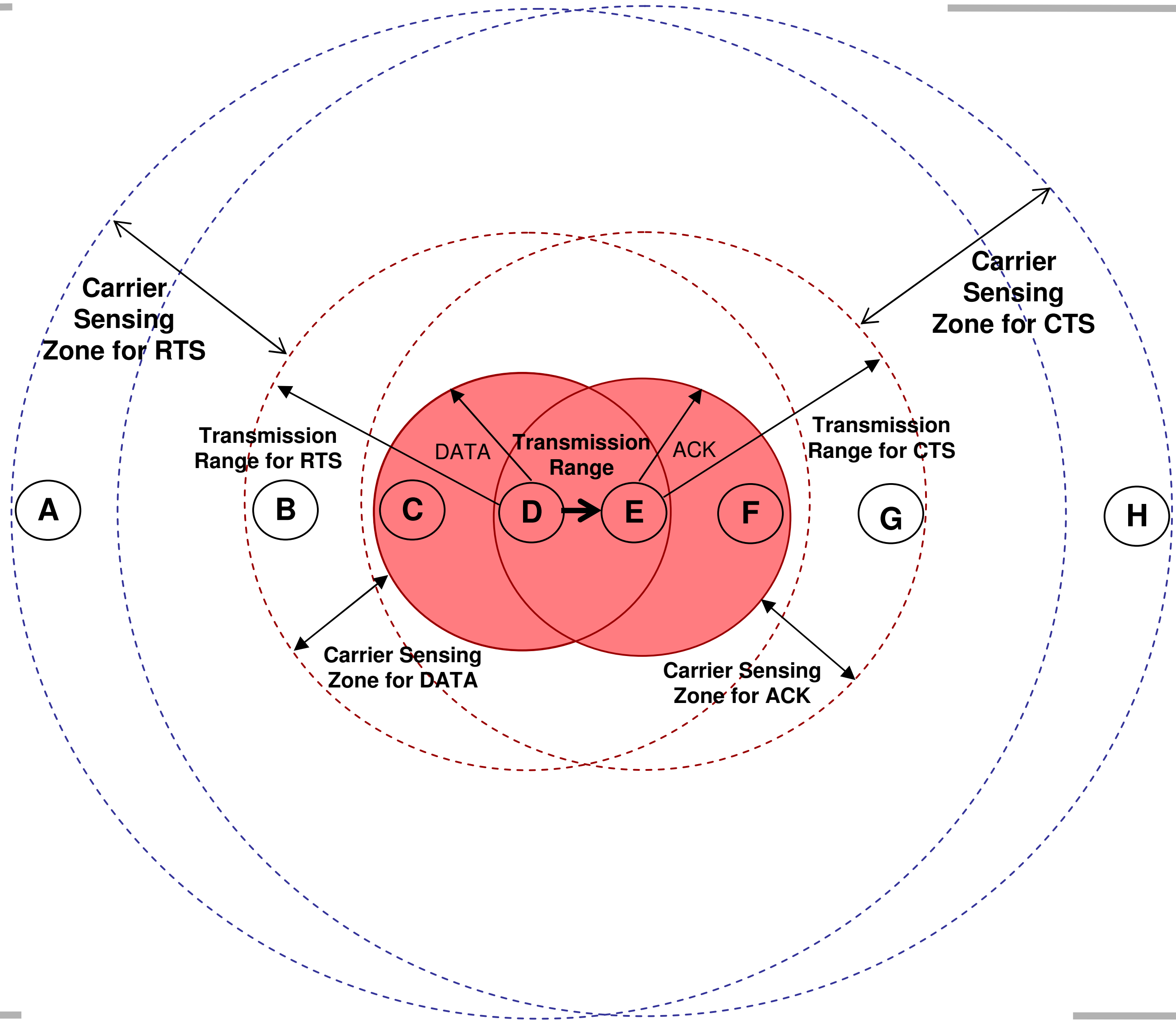
Drawback of *BASIC* Protocol



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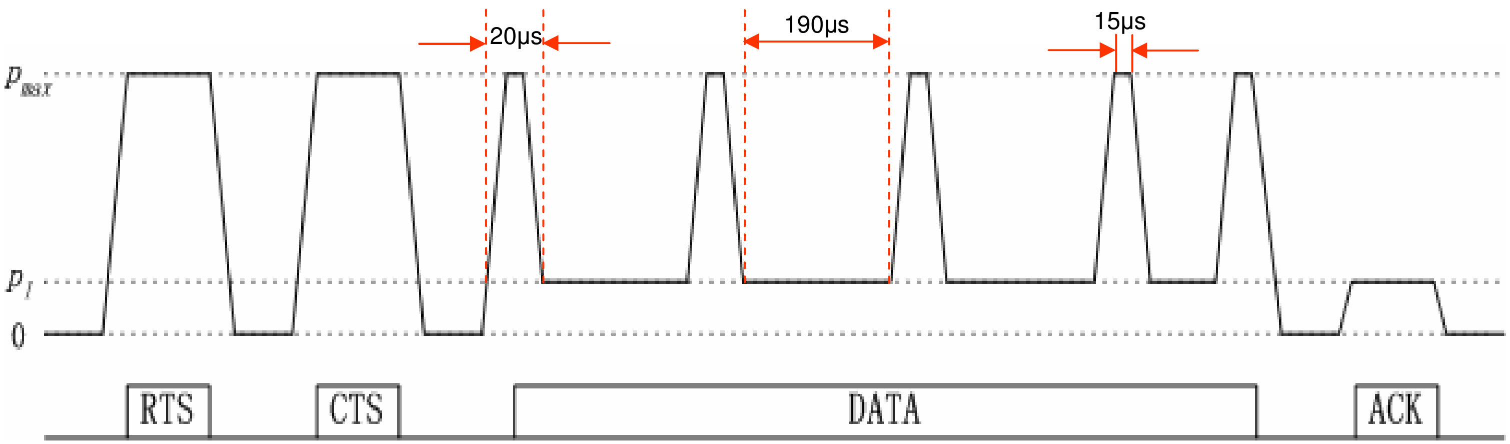

- RTS-CTS are transmitted at maximum power level
- DATA are transmitted at minimum necessary power level BUT at the maximum level periodically
- ACK are transmitted with minimum necessary power
- Intervals between two adjacent electricity pulses are slightly shorter than EIFS

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 (e.g. fading, shadowing makes it difficult)
  - – Difficult implementation of frequent change of transmit power level

Thank you!

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