Wireless Sensor Networks

8th Lecture

21.11.2006

CoNe Freiburg

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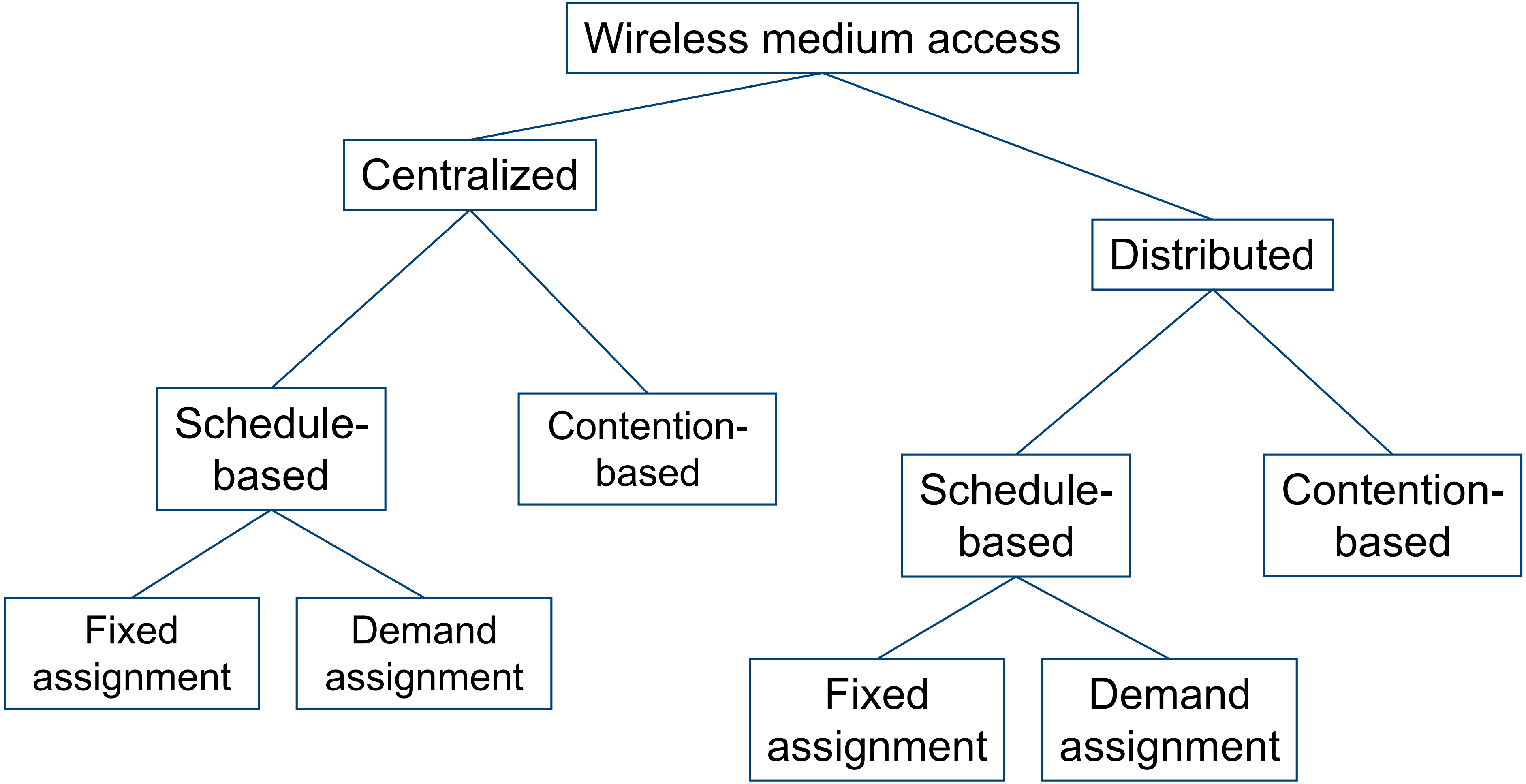
Media Access Control (MAC)

- **Controlling when to send a packet and when to listen for a packet are perhaps the two most important operations in a wireless network**
  - Especially, idly waiting wastes huge amounts of energy
- **This chapter discusses schemes for this medium access control that are**
  - Suitable to mobile and wireless networks
  - Emphasize energy-efficient operation

Overview

- *Principal options and difficulties*
- **Contention-based protocols**
- **Schedule-based protocols**
- **IEEE 802.15.4**

Main options



Centralized medium access

- **Idea: Have a central station control when a node may access the medium**
  - Example: Polling, centralized computation of TDMA schedules
  - Advantage: Simple, quite efficient (e.g., no collisions), burdens the central station
- **Not directly feasible for non-trivial wireless network sizes**
- **But: Can be quite useful when network is somehow divided into smaller groups**
  - Clusters, in each cluster medium access can be controlled centrally – compare Bluetooth piconets, for example

$\Rightarrow$ **Usually, distributed medium access is considered**

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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
  - Needed: 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

Overview

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- **Principal options and difficulties**
- *Contention-based protocols*
  - MACA (Multiple Access with Collision Avoidance)
  - S-MAC, T-MAC
  - Preamble sampling, B-MAC
  - PAMAS
- **Schedule-based protocols**
- **IEEE 802.15.4**

Problems of the MACA-Protocols

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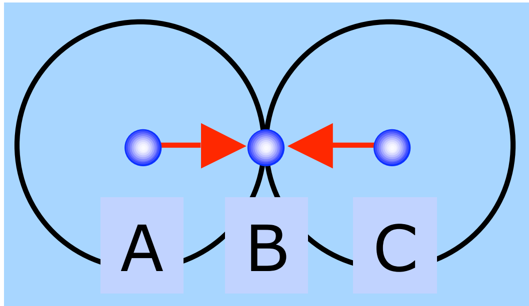
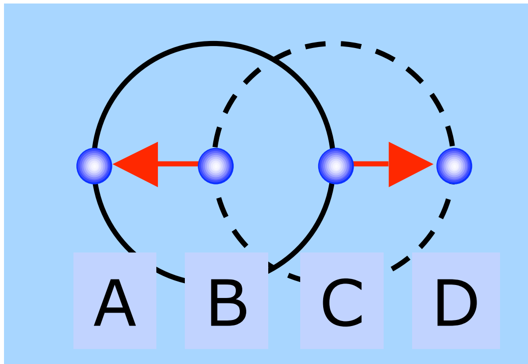
- **Hidden Terminal Problem**



- **Exposed Terminal Problem**

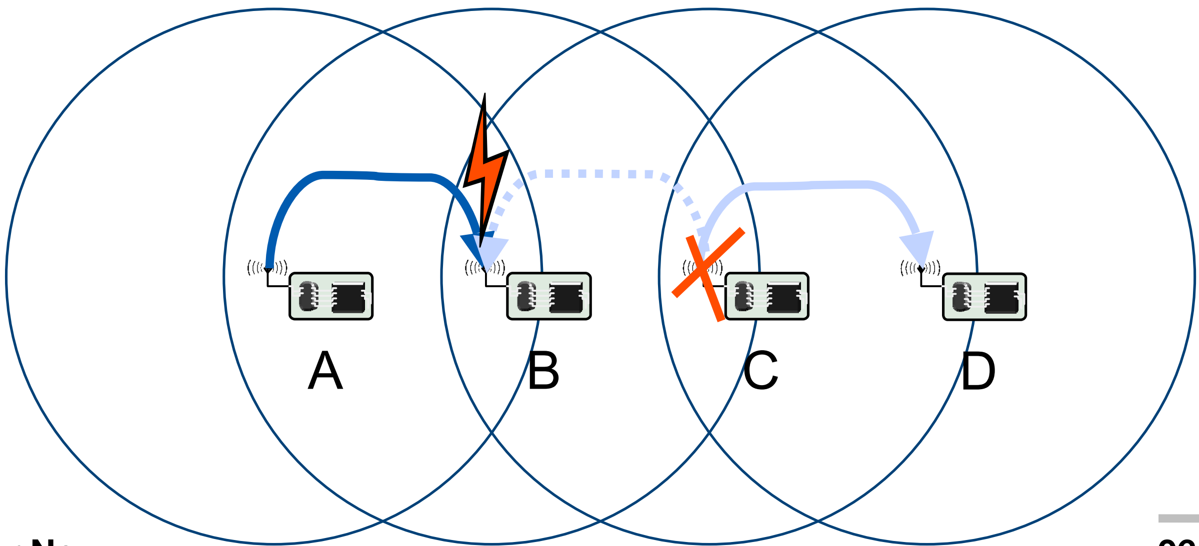


Distributed, contention-based MAC

- **Basic ideas for a distributed MAC**
  - ALOHA – no good in most cases
  - Listen before talk ***(Carrier Sense Multiple Access, CSMA) –*** better, but suffers from ***sender*** not knowing what is going on at ***receiver***, might destroy packets despite first listening for a

⇒ **Receiver additionally needs some possibility to inform possible senders in its vicinity about impending transmission (to “shut them up” for this duration**

Hidden terminal scenario:



Also: recall exposed terminal scenario

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Main options to shut up senders

- **Receiver informs potential interferers** *while* **a reception is on-going**
  - By sending out a signal indicating just that
  - Problem: Cannot use same channel on which actual reception takes place

  ⇒ Use separate channel for signaling
  - ***Busy tone*** protocol
- **Receiver informs potential interferers** *before* **a reception is on-going**
  - Can use same channel
  - Receiver itself needs to be informed, by sender, about impending transmission
  - Potential interferers need to be aware of such information, need to store it

Multiple Access with Collision Avoidance (MACA)

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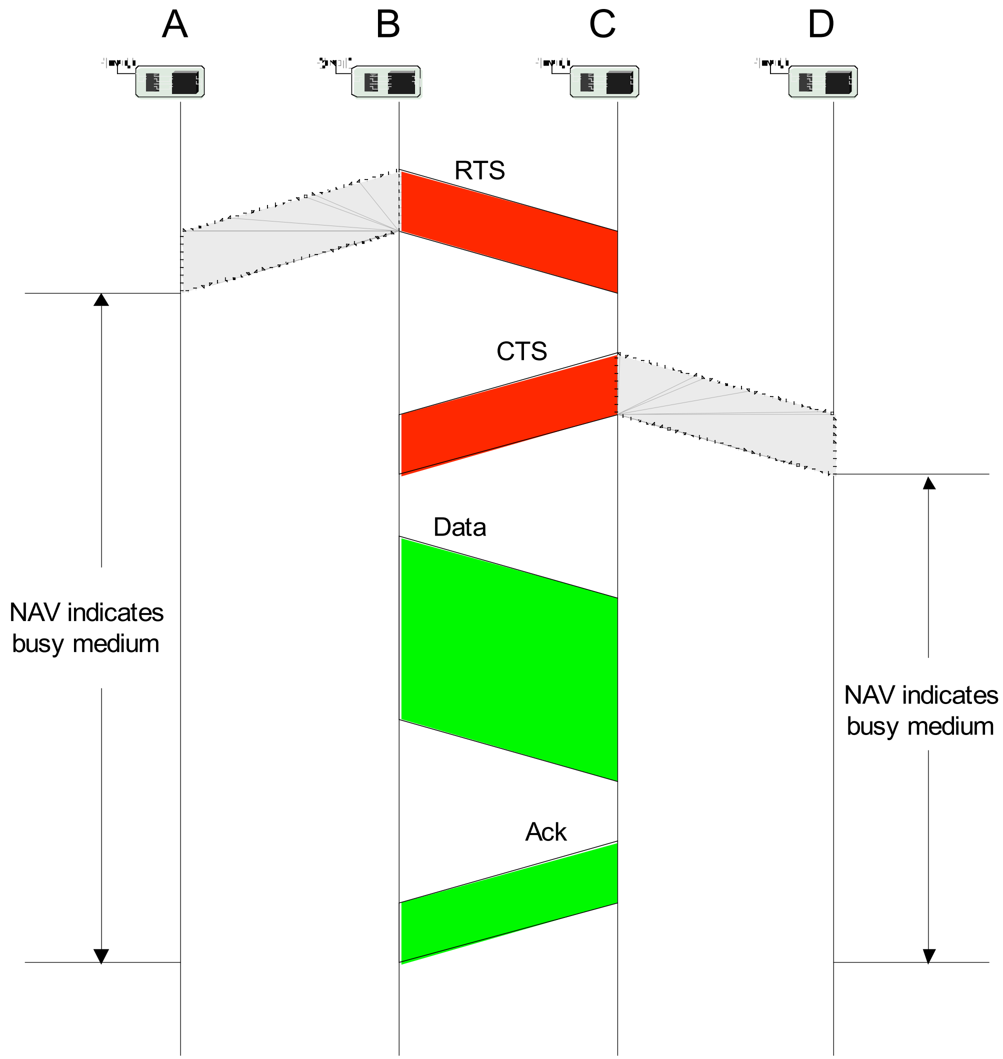
- **Sender B asks receiver C whether C is able to receive a transmission**
  Request to Send (RTS)
- **Receiver C agrees, sends out a** *Clear to Send* **(***CTS***)**
- **Potential interferers overhear either RTS or CTS and know about impending transmission and for how long it will last**
  - Store this information in a ***Network Allocation Vector***
- **B sends, C acks**

⇒ *MACA protocol* **(used e.g. in** *IEEE 802.11***)**



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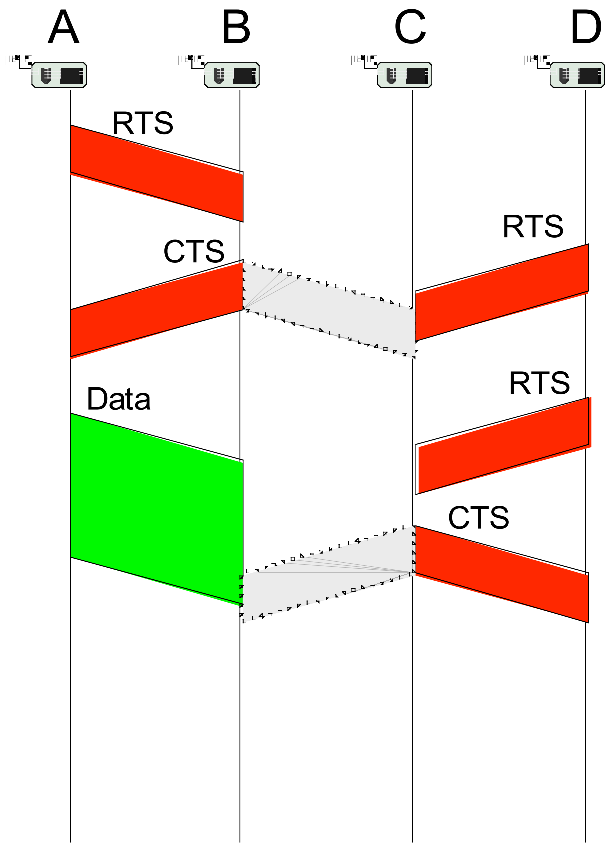
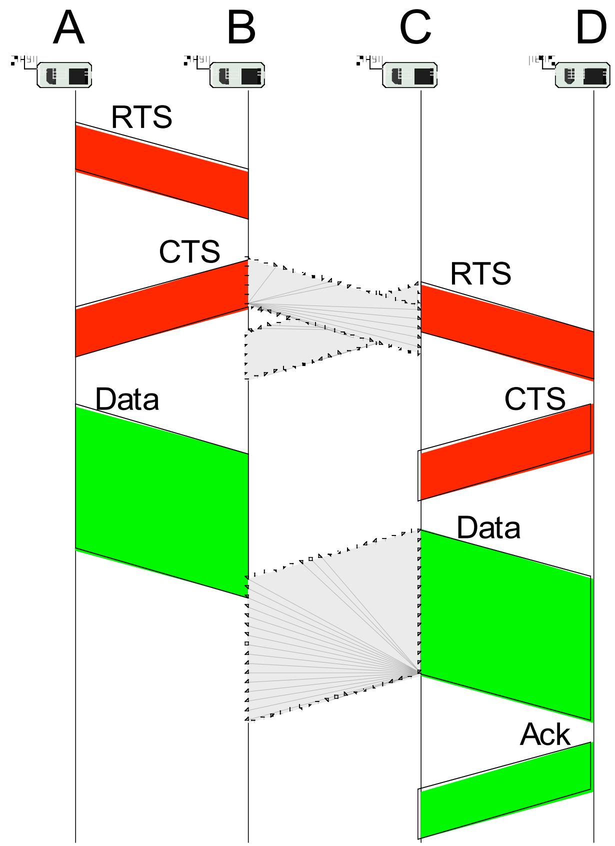
RTS/CTS

- **RTS/CTS ameliorate, but do not solve hidden/exposed terminal problems**
- **Example problem cases:**





MACA Problem: Idle listening

- **Need to sense carrier for RTS or CTS packets**
  - In some form shared by many CSMA variants; but e.g. not by busy tones
  - Simple sleeping will break the protocol
- **IEEE 802.11 solution: ATIM windows & sleeping**
  - Basic idea: Nodes that have data buffered for receivers send ***traffic indicators*** at pre-arranged points in time
  - Receivers need to wake up at these points, but can sleep otherwise
- **Parameters to adjust in MACA**
  - Random delays – how long to wait between listen/transmission attempts?
  - Number of RTS/CTS/ACK re-trials?
  - …

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STEM
Sparse Topology and Energy Management Protocol

- **Two channels**
  - Wakeup channel
    - On the wakeup channel data is announced
  - Data Channel
    - Otherwise the data channel is always in sleep mode
- **Status of a sensor**
  - Monitor state
    - nodes are idle, no transmission
  - Transfer state
- **STEM-B**
  - Transmitter wakes up the receiver by a beacon on the wakeup channel
  - no RTS/CTS
- **STEM-T**
  - Transmitter sends busy tone signal on the wakeup channel to get the receiver‘s attention

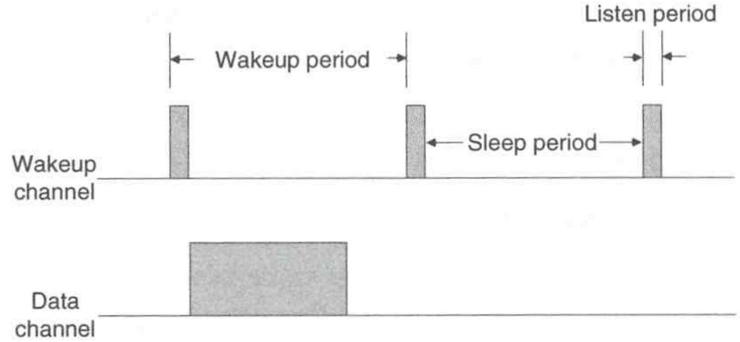
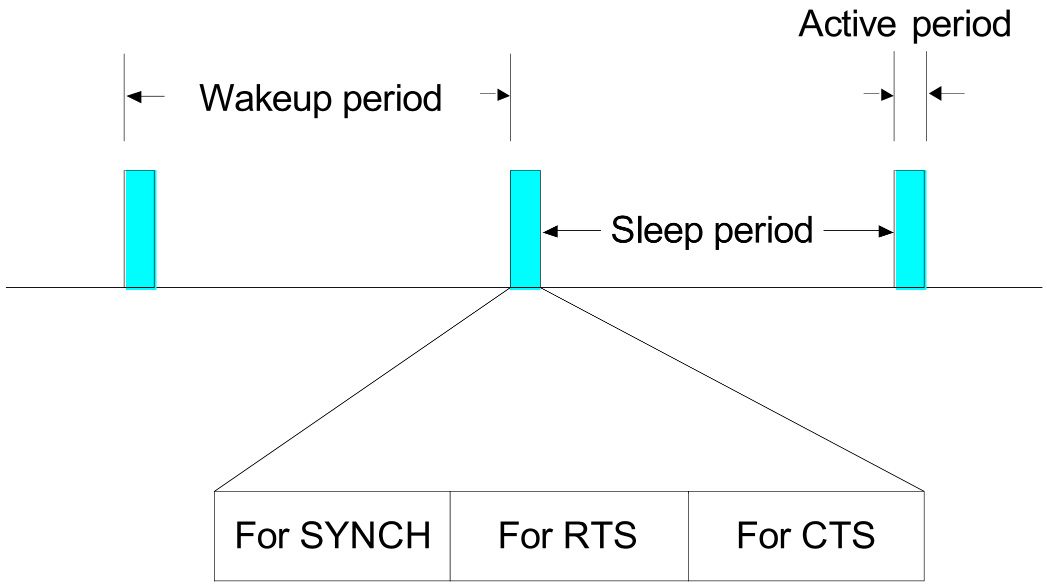


Figure 5.5 STEM duty cycle for a single node [742, Fig. 3]

Sensor-MAC (S-MAC)

- **MACA's idle listening is particularly unsuitable if average data rate is low**
  - Most of the time, nothing happens
- **Idea: Switch nodes off, ensure that neighboring nodes turn on simultaneously to allow packet exchange (rendez-vous)**
  - Only in these ***active periods***, packet exchanges happen
  - Need to also exchange wakeup schedule between neighbors
  - When awake, essentially perform RTS/CTS
- **Use SYNCH, RTS, CTS phases**



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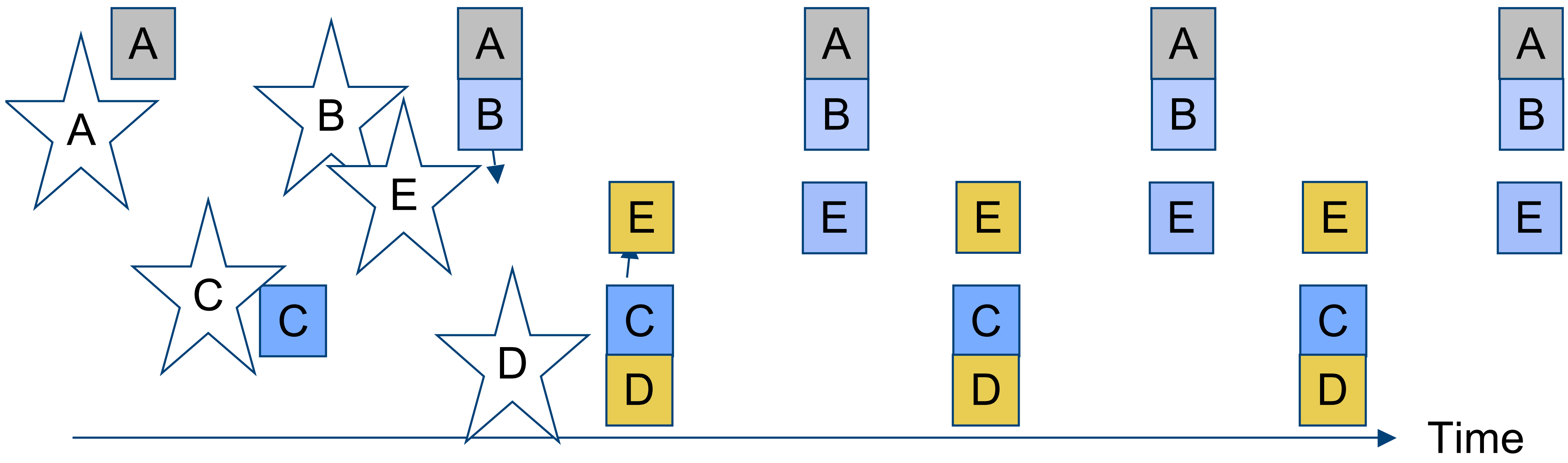
S-MAC synchronized islands

- **Nodes try to pick up schedule synchronization from neighboring nodes**
- **If no neighbor found, nodes pick some schedule to start with**
- **If additional nodes join, some node might learn about two different schedules from different nodes**
  - "Synchronized islands"
- **To bridge this gap, it has to follow both schemes**



- **S-MAC adopts a message passing concept**
  - long messages are broken into small frames
  - only one RTS/CTS communication for each messages
  - each frame is acknowledged separately
  - each frame contains the information about the message length
- **The NAV (not available) variable of suppressed neighbors is adjusted appropriately**
- **Problems: Fairness**

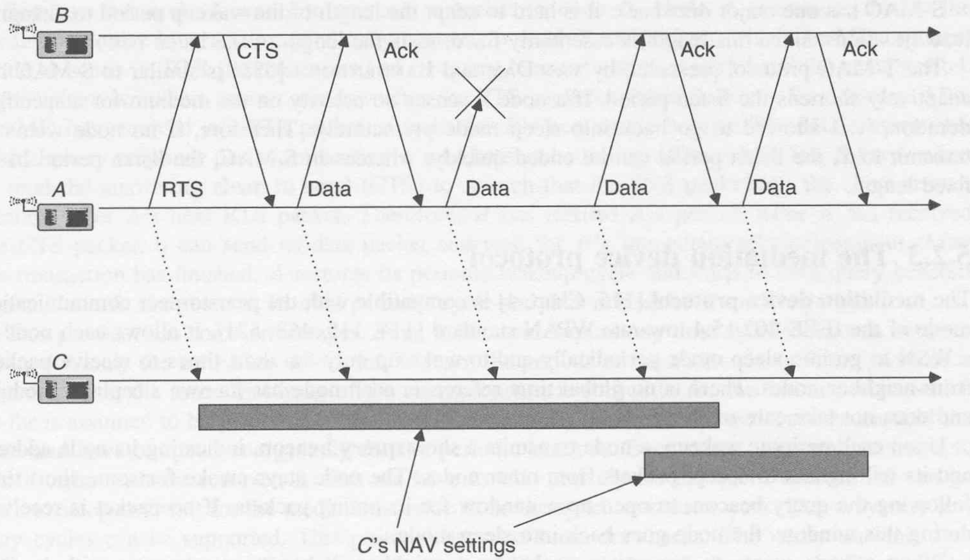
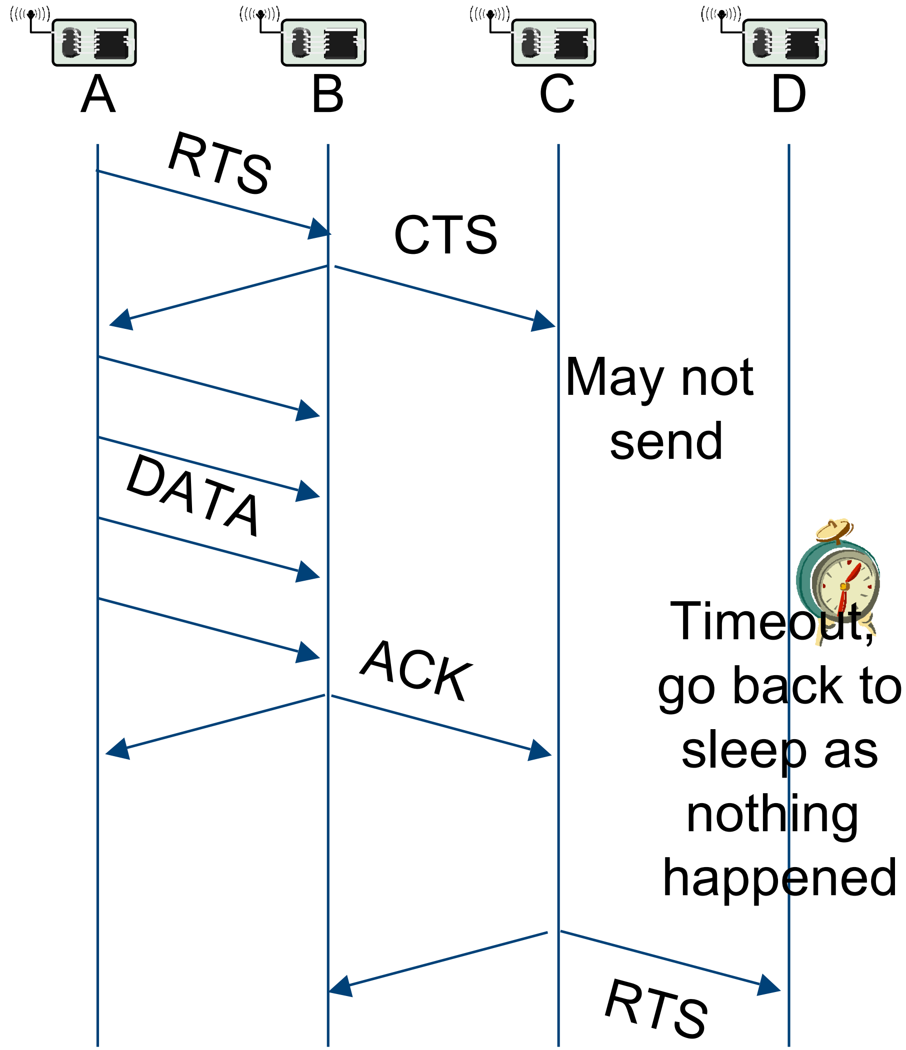


Figure 5.7 S-MAC fragmentation and NAV setting

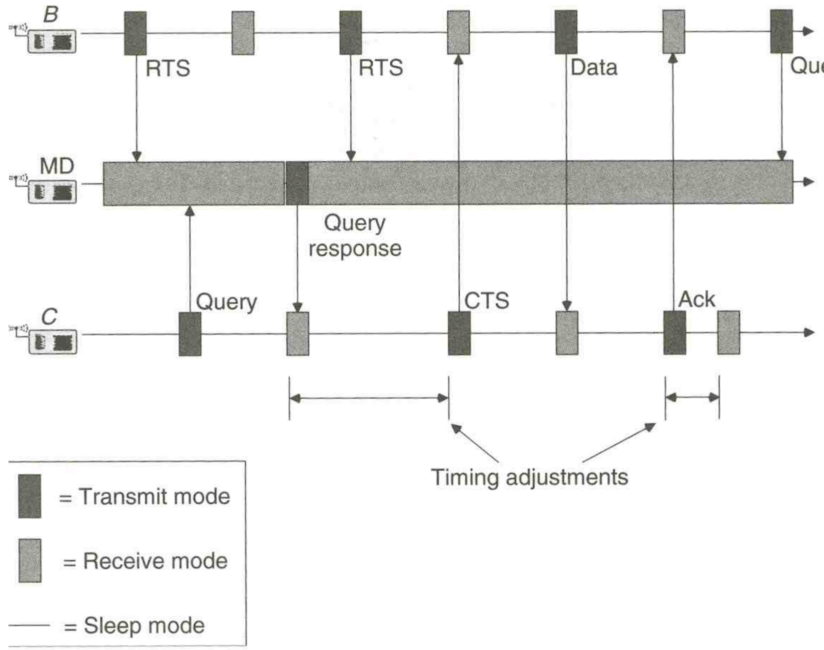
Timeout-MAC (T-MAC)

- **In S-MAC, active period is of constant length**
- **What if no traffic actually happens?**
  - Nodes stay awake needlessly long
- **Idea: Prematurely go back to sleep mode when no traffic has happened for a certain time (=timeout) → T-MAC**
  - Adaptive duty cycle!
- **One ensuing problem: Early sleeping**
  - C wants to send to D, but is hindered by transmission A→ B
  - Two solutions exist



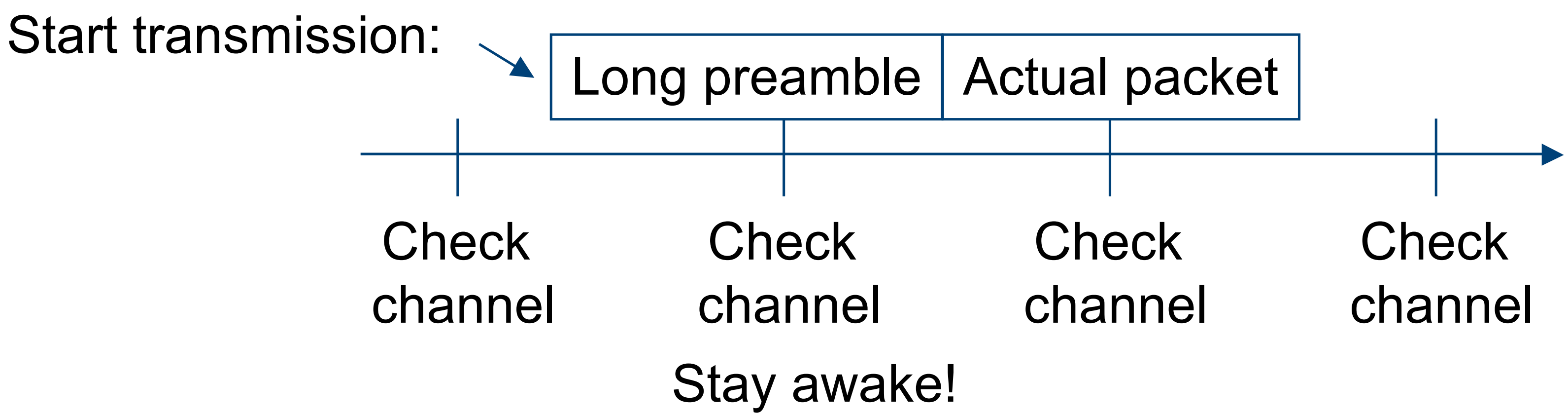
Mediation Device Protocol

- **Goal: Avoid useless listening on the channel for messages**
- **Uses: mediation device (MD) which is available all the tim**
- **Protocol**
  - Sender B sends RTS to MD
  - MD stores this information
  - Receiver C sends query to MD
  - MD tells reciever C when to wake up
  - C sends CTS to B (now in sync)
  - B sends data
  - C acknowledges
  - C returns to old timing
- **Main disadvantage:**
  - MD has to be energy independent
  - Solution: Distributed Mediation Device Protocol
    - Nodes randomly wake up and serve as mediation device
- **Problem: no guarantees on full coverage of MD**



Preamble Sampling

- **So far: Periodic sleeping supported by some means to synchronize wake up of nodes to ensure rendez-vous between sender and receiver**
- **Alternative option: Don't try to explicitly synchronize nodes**
  - Have receiver sleep and only periodically sample the channel
- **Use** *long preambles* **to ensure that receiver stays awake to catch actual packet**
  - Example: WiseMAC



Preamble sampling - a popular MAC mechanism

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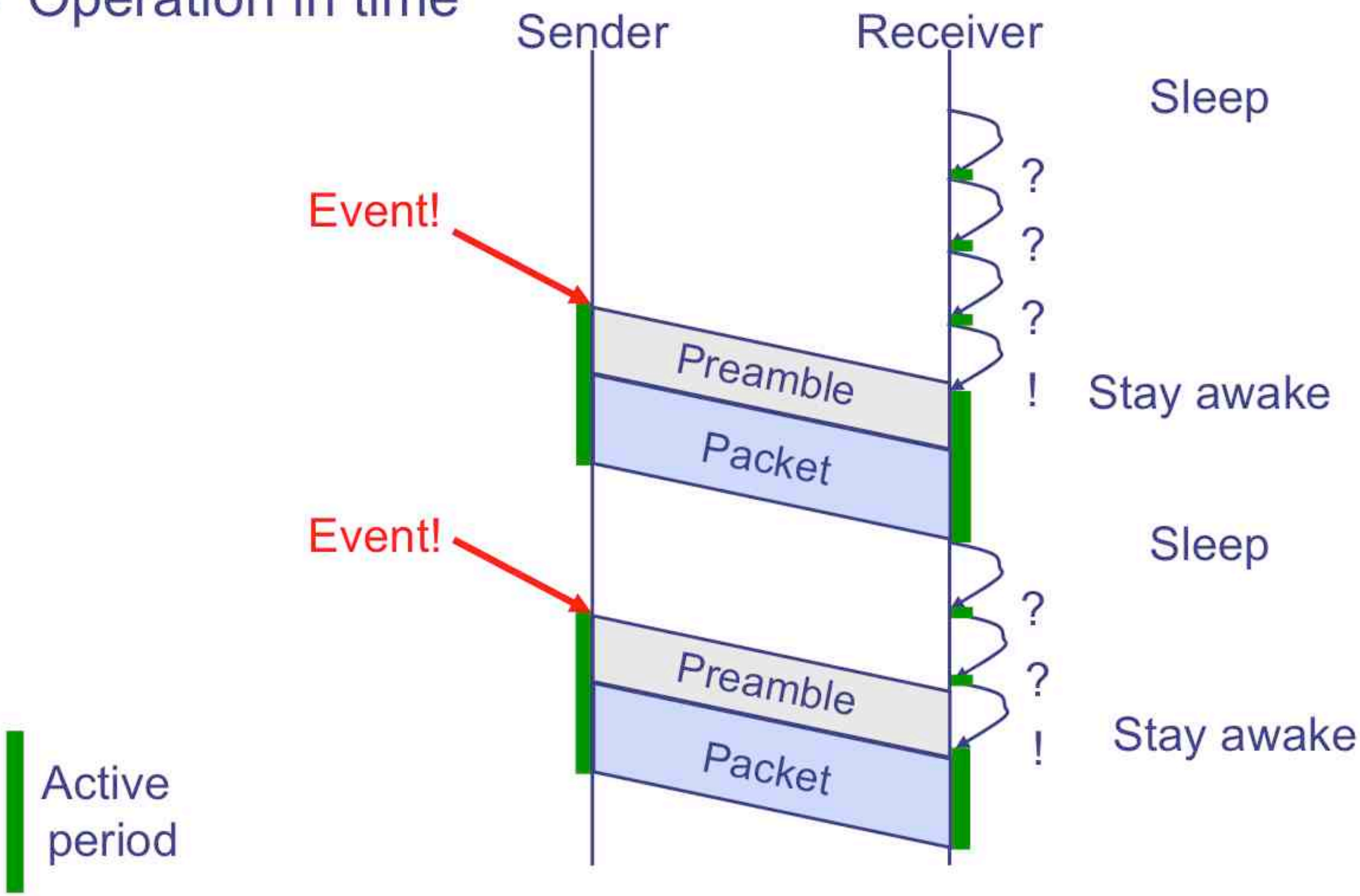
- Operation in time



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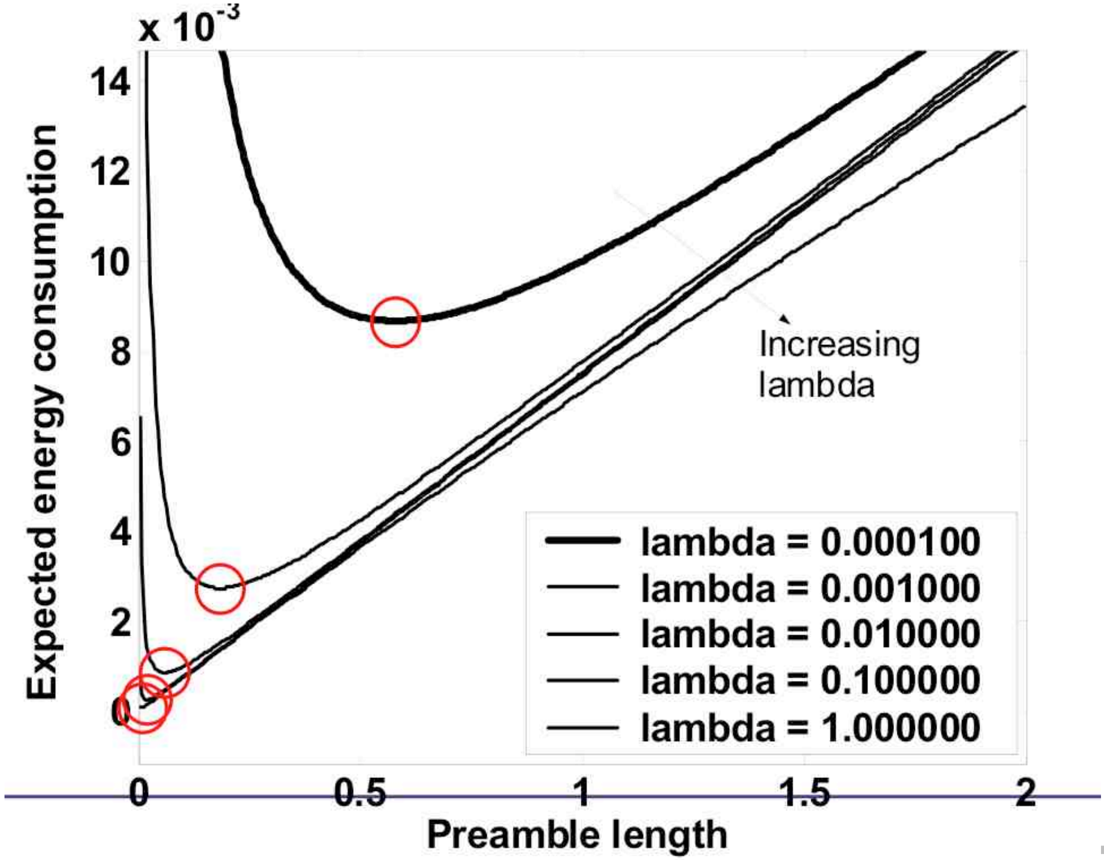
Efficiency of Preamble Sampling

- **Assumption: Event arrival is a Poisson process of rate λ**
- **Analysis of expected energy as function of λ, Δ**



Thank you

(and thanks go also to Holger Karl for providing slides)

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