Wireless Sensor Networks

9th Lecture

22.11.2006

CoNe Freiburg

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Media Access Control (MAC)

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- **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

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

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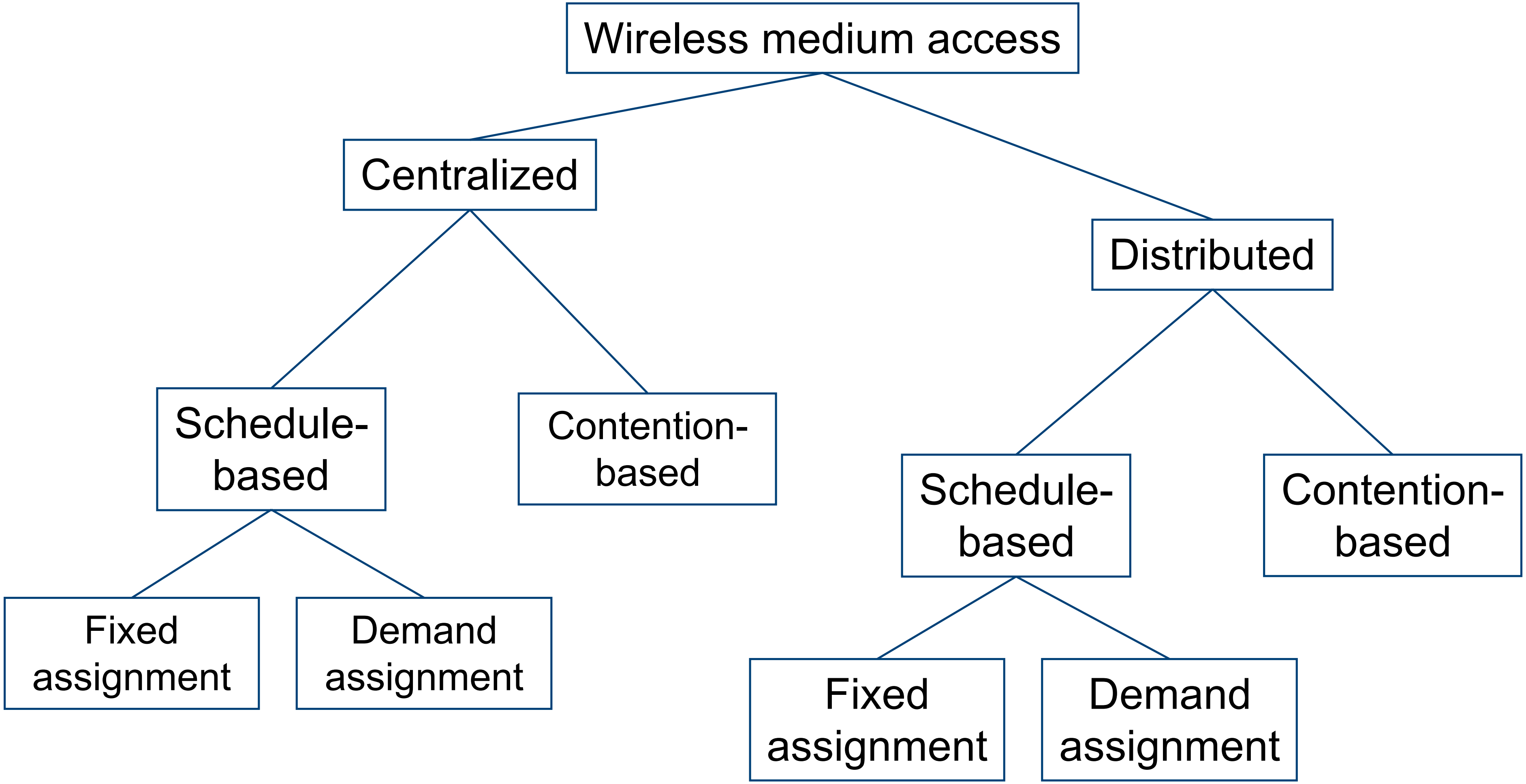
Main options



B-MAC (Berkeley MAC)

- **Combines several of the above discussed ideas**
  - Takes care to provide practically relevant solutions

- **Clear Channel Assessment**
  - Adapts to noise floor by sampling channel when it is assumed to be free
  - Samples are exponentially averaged, result used in gain control
  - For actual assessment when sending a packet, look at five channel samples – channel is free if even a single one of them is significantly below noise
  - Optional: random backoff if channel is found busy

- **Optional: Immediate link layer acknowledgements for received packets**

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B-MAC

- **Low Power Listening (= preamble sampling)**
  - Uses the clear channel assessment techniques to decide whether there is a packet arriving when node wakes up
  - Timeout puts node back to sleep if no packet arrived

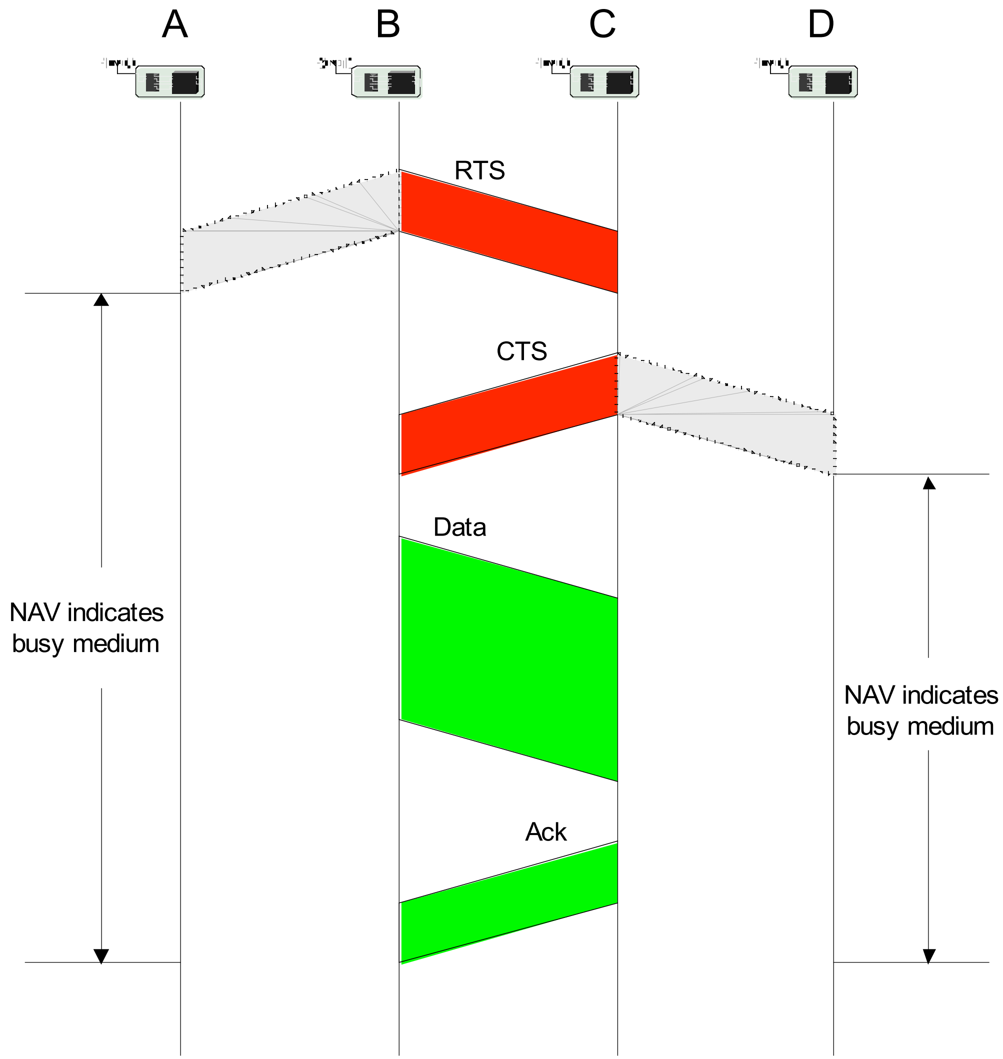
- **B-MAC does *not* have**
  - Synchronization
  - RTS/CTS
  - Results in simpler, leaner implementation
  - Clean and simple interface

- **Currently: Often considered as the** *default WSN MAC* **protocol**

Multiple Access with Collision Avoidance (MACA)

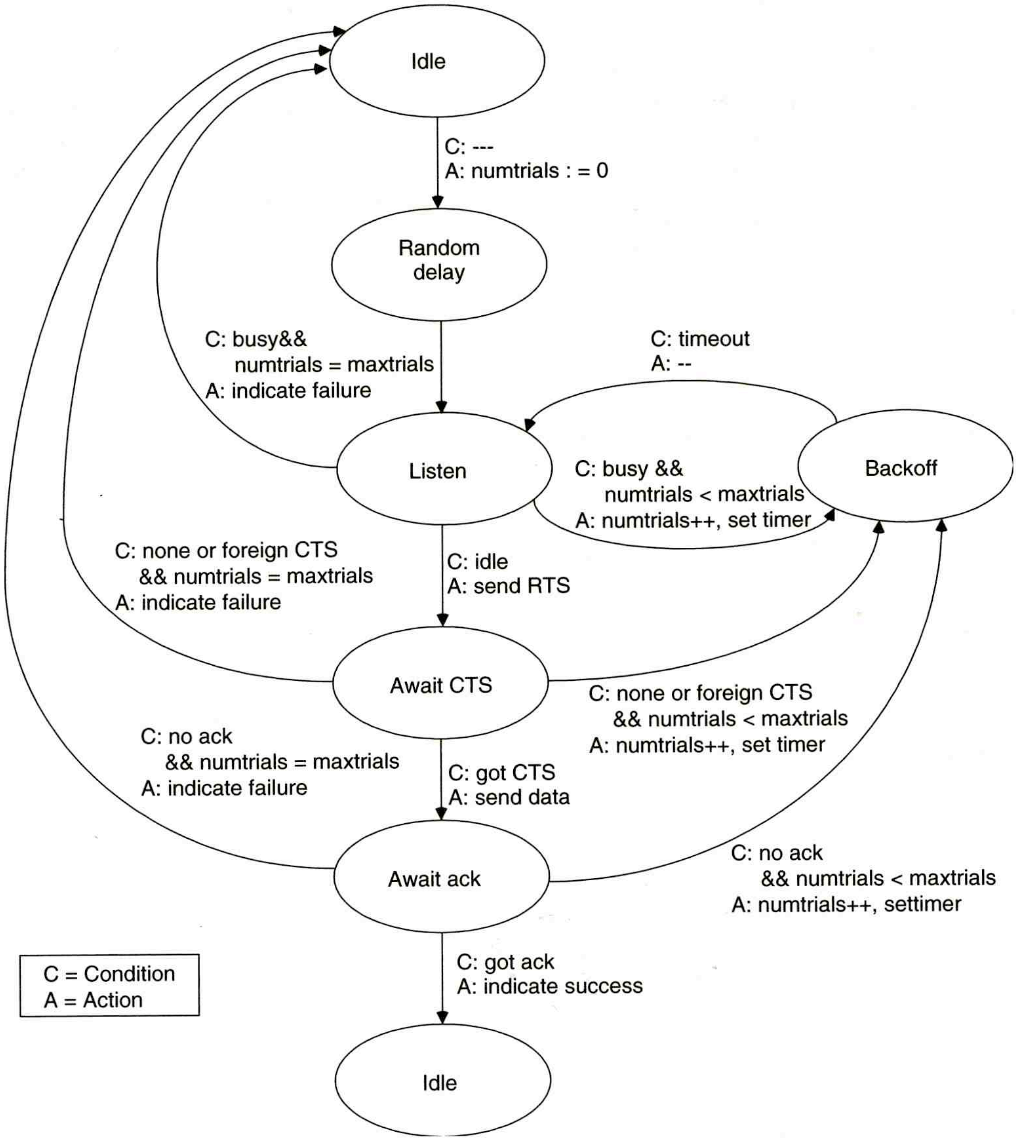
- **Sender B asks receiver C whether C is able to receive a transmission**
  Request to Send (RTS)
- **Receiver C agrees, sends out a** *Clear to Send* **(***CTS***)**
- **Potential interferers overhear either RTS or CTS and know about impending transmission and for how long it will last**
  - Store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

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



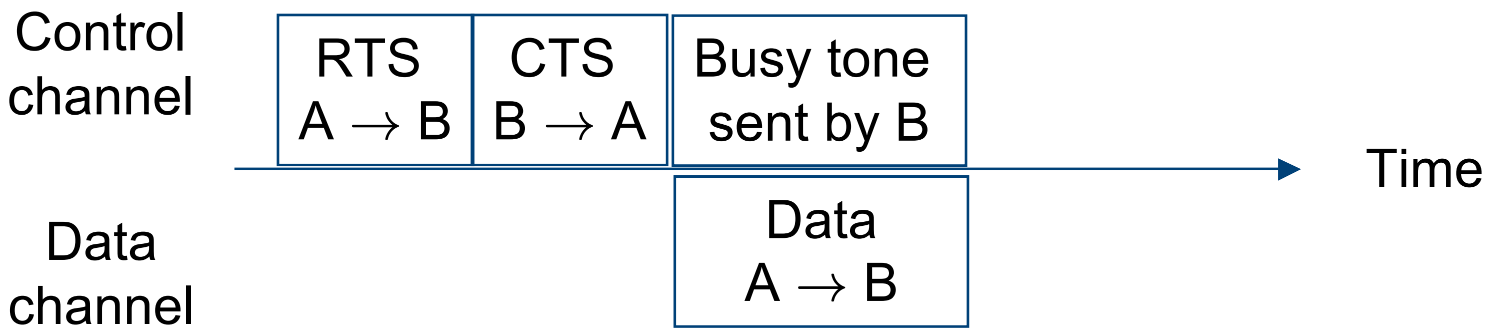
CSMA

- State diagram of CSMA sender



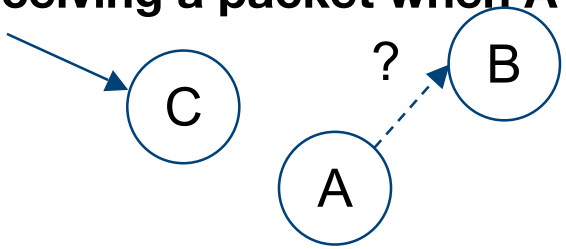
Power Aware Multi-Access with Signaling – PAMAS

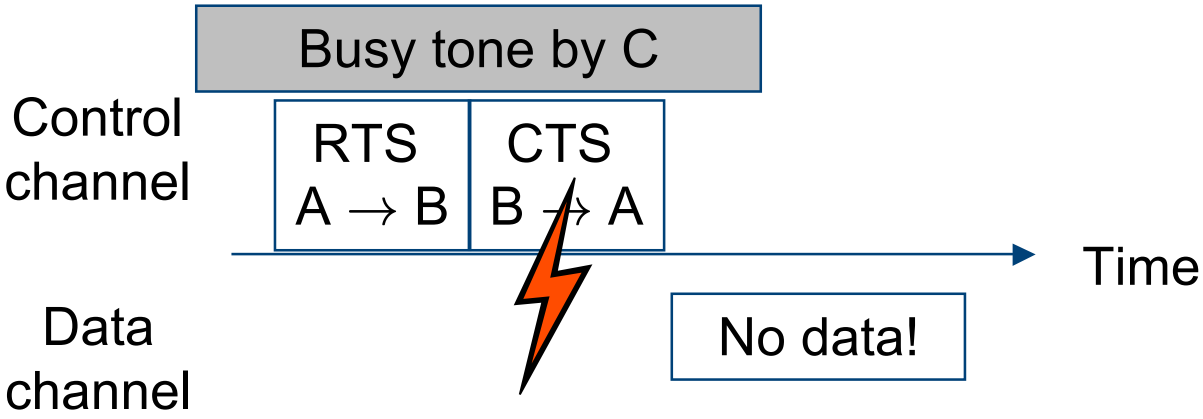
- **Idea: combine busy tone with RTS/CTS**
  - Results in detailed overhearing avoidance, does not address idle listening
  - Uses separate ***data*** and ***control channels***
- **Procedure**
  - Node A transmits RTS on control channel, does not sense channel
  - Node B receives RTS, sends CTS on control channel if it can receive and does not know about ongoing transmissions
  - B sends busy tone 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

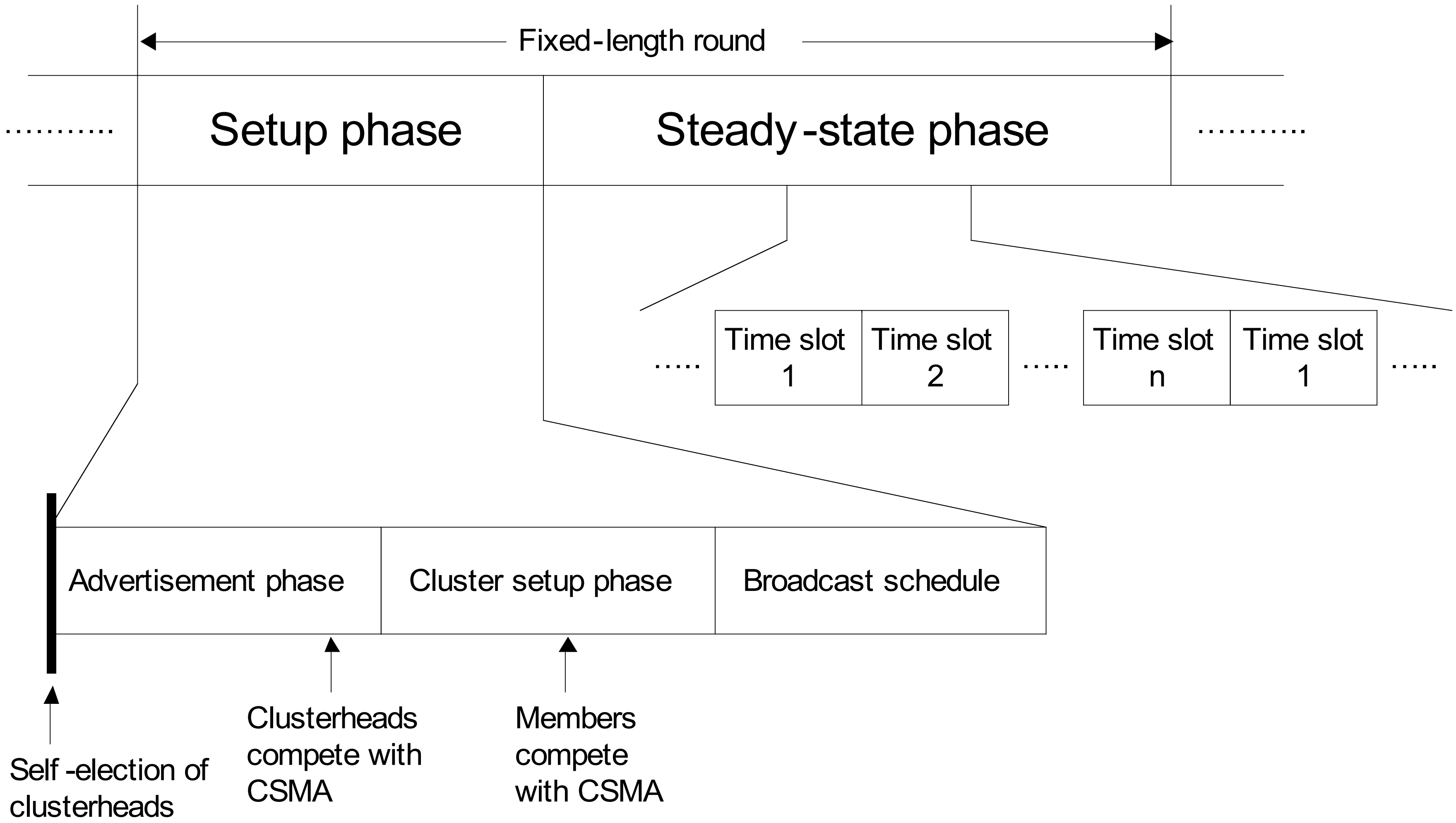
Overview

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

Low-Energy Adaptive Clustering Hierarchy (LEACH)

- **Given: dense network of nodes, reporting to a central sink, each node can reach sink directly**
- **Idea: Group nodes into "*clusters*", controlled by** *clusterhead*
  - Setup phase; details: later
  - About 5% of nodes become clusterhead (depends on scenario)
  - Role of clusterhead is rotated to share the burden
  - Clusterheads advertise themselves, ordinary nodes join CH with strongest signal
  - Clusterheads organize
    - CDMA code for all member transmissions
    - TDMA schedule to be used within a cluster
- **In steady state operation**
  - CHs collect & aggregate data from all cluster members
  - Report aggregated data to sink using CDMA

LEACH rounds



SMACS
Self-Organizing Medium Access Control for Sensor Networks

- **Given: many radio channels, super-frames of known length (not necessarily in phase, but still time synchronization required!)**
- **Goal: set up directional *links* between neighboring nodes**
  - Link: radio channel + time slot at both sender and receiver
  - Free of collisions at receiver
  - Channel picked randomly, slot is searched greedily until a collision-free slot is found
- **Receivers sleep and only wake up in their assigned time slots, once per superframe**
- **In effect: a local construction of a schedule**

TRAMA
Traffic Adaptive Medium Access Protocol

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- **Nodes are synchronized**
- **Time divided into cycles, divided into**
  - Random access periods
  - Scheduled access periods
- **Nodes exchange neighborhood information**
  - Learning about their two-hop neighborhood
  - Using ***neighborhood exchange protocol***: In random access period, send small, incremental neighborhood update information in randomly selected time slots
- **Nodes exchange schedules**
  - Using ***schedule exchange protocol***
  - Similar to neighborhood exchange
- **Adaptive Election Protocol**
  - Elect transmitter, receiver and stand-by nodes for each transmission slot
  - Remove nodes without traffic from election

TRAMA – adaptive election

- **Given: Each node knows its two-hop neighborhood and their current schedules**
- **How to decide which slot (in scheduled access period) a node can use?**
  - Use ***node identifier*** x and globally known ***hash function*** h
  - For time slot t, compute ***priority*** $p = h(x \oplus t)$
  - Compute this priority for next k time slots for node itself and all two-hop neighbors
  - Node uses those time slots for which it has the highest priority

Priorities of node A and its two neighbors B & C

	t = 0	t = 1	t = 2	t=3	t = 4	t = 5
A	14	23	9	56	3	26
B	33	64	8	12	44	6
C	53	18	6	33	57	2

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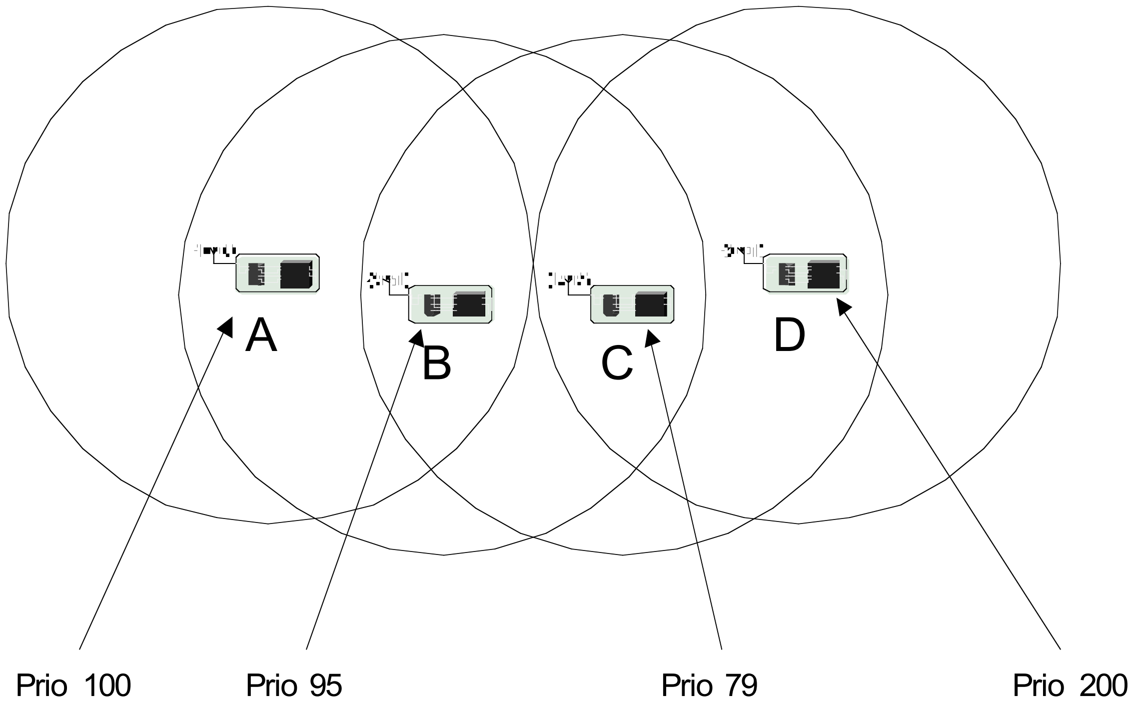
TRAMA – possible conflicts

- **When does a node have to receive?**
  - Easy case: one-hop neighbor has won a time slot and announced a packet for it
  - But complications exist – compare example
- **What does B believe?**
  - A thinks it can send
  - B knows that D has higher priority in its 2-hop neighborhood!
- **Rules for resolving such conflicts are part of TRAMA**



Comparison: TRAMA, S-MAC

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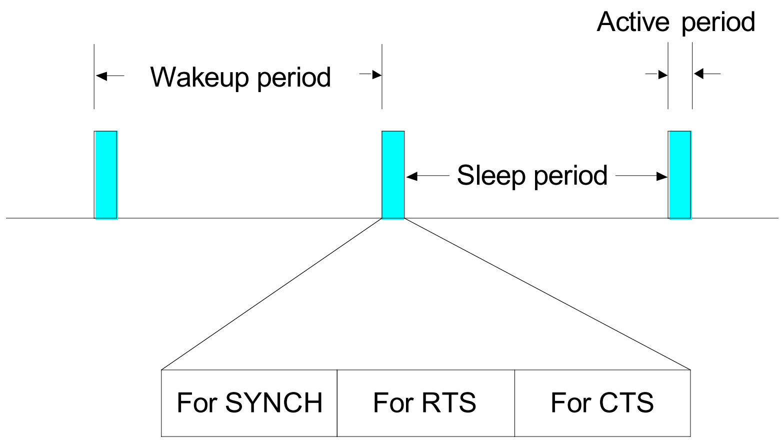
- **Comparison between TRAMA & S-MAC**
  - Energy savings in TRAMA depend on load situation
  - Energy savings in S-MAC depend on duty cycle
  - TRAMA (as typical for a TDMA scheme) has higher delay but higher maximum throughput than contention-based S-MAC

- **TRAMA disadvantage: substantial memory/CPU requirements for schedule computation**

S-MAC:



Thank you

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

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