Wireless Sensor Networks

7th Lecture

15.11.2006

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Medium 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

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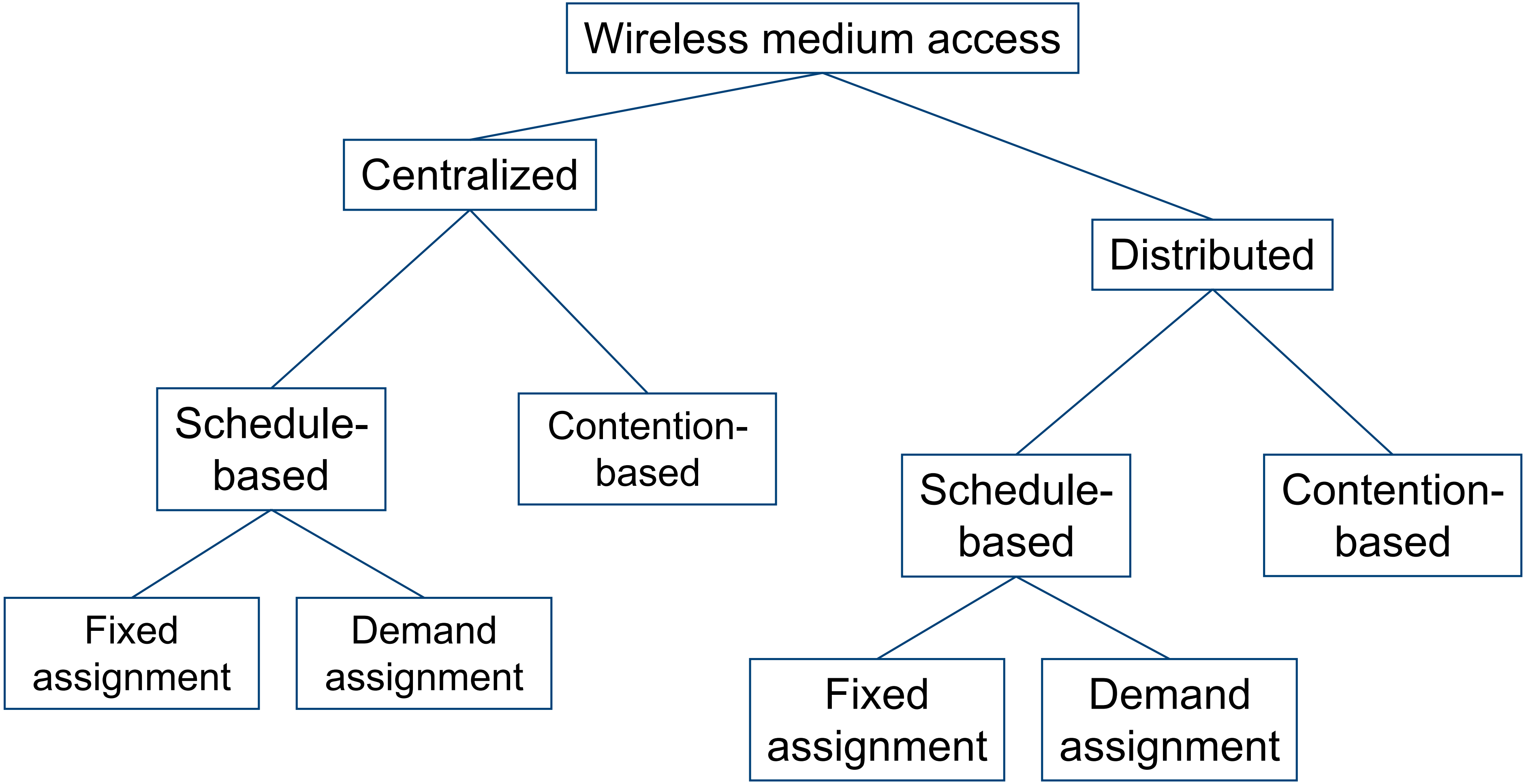
Overview

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

Main options



Principal options and difficulties

- **Medium access in wireless networks is difficult mainly because of**
  - Impossible (or very difficult) to send and receive at the same time
  - Interference situation at receiver is what counts for transmission success, but can be very different from what sender can observe
  - High error rates (for signaling packets) compound the issues

- **Requirement**
  - As usual: high throughput, low overhead, low error rates, …
  - Additionally: energy-efficient, handle switched off devices!

Requirements for energy-efficient MAC protocols

- **Recall**
  - Transmissions are costly
  - Receiving about as expensive as transmitting
  - Idling can be cheaper but is still expensive
- **Energy problems**
  - ***Collisions*** – wasted effort when two packets collide
  - ***Overhearing*** – waste effort in receiving a packet destined for another node
  - ***Idle listening*** – sitting idly and trying to receive when nobody is sending
  - ***Protocol overhead***
- **Always nice: Low complexity solution**

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

⇒ **Usually, distributed medium access is considered**

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

- **Principal options and difficulties**
- *Contention-based protocols*
  - MACA
  - S-MAC, T-MAC
  - Preamble sampling, B-MAC
  - PAMAS
- **Schedule-based protocols**
- **IEEE 802.15.4**

ALOHA

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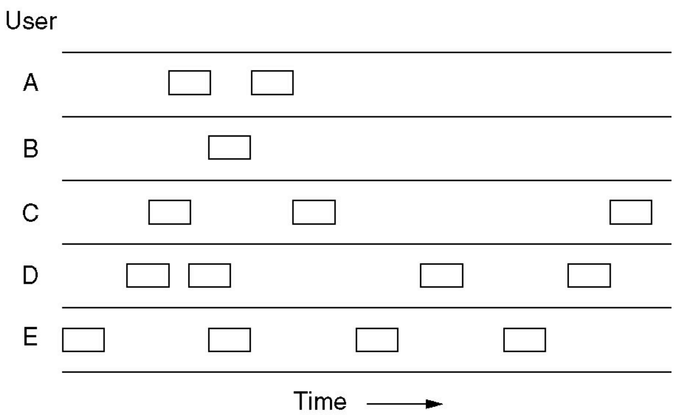
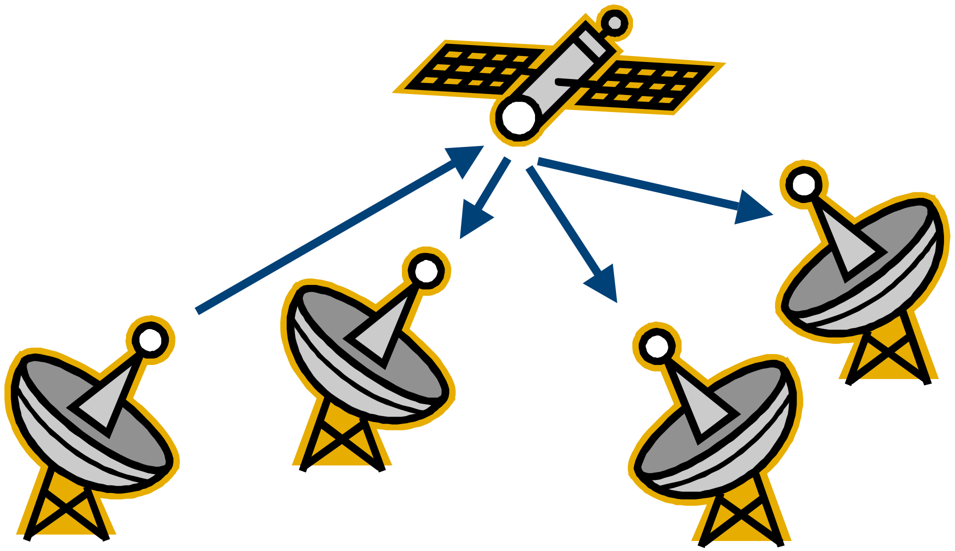
- **The simplest possible medium access protocol:**

  Just talk when you feel like it

- **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



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 ☹

ALOHA – Performance

- **Assume a *Poisson arrival process* to describe packet transmissions**
  - Infinite number of stations, all behave identically, independently
  - Time between two attempts is exponentially distributed
  - Let G be the mean number of transmission attempts per packet length
  - All packets are of unit time length
  - Then: $$P(k \text{ attempts in time } t) = \frac{(Gt)^k}{k!} e^{-Gt}$$
- **For a packet transmission to be successful, it must not collide with any other packet**
- **How likely is such a collision?**
  - Question: How long is a packet "vulnerable" by other transmissions?

ALOHA – Performance

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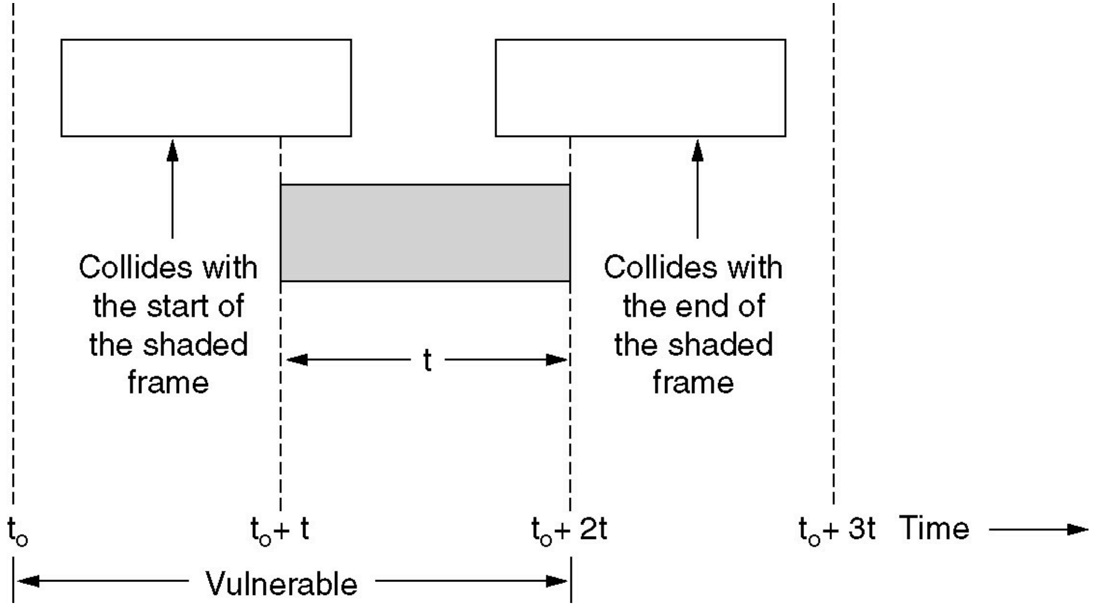
- **A packet X is destroyed by another packet either**
  - Starting up to one packet time ***before*** X
  - Starting up to immediately before the end of X



- **Hence: Packet is successful if there is no *additional* transmission in two packet times**
  - Probability: P_0 = P (1 transmission in two packet times) = $2Ge^{-2G}$
  - Throughput S (G) = 1 Packet / 2 time units * Probability = Ge^{-2G}
  - Optimal for G = 0.5 $\rightarrow$ S = 1/(2e) $\approx$ 0.184

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**
  - $S(G) = Ge^{-G}$
  - Optimal at G=1, S=1/e

Performance dependence on offered load

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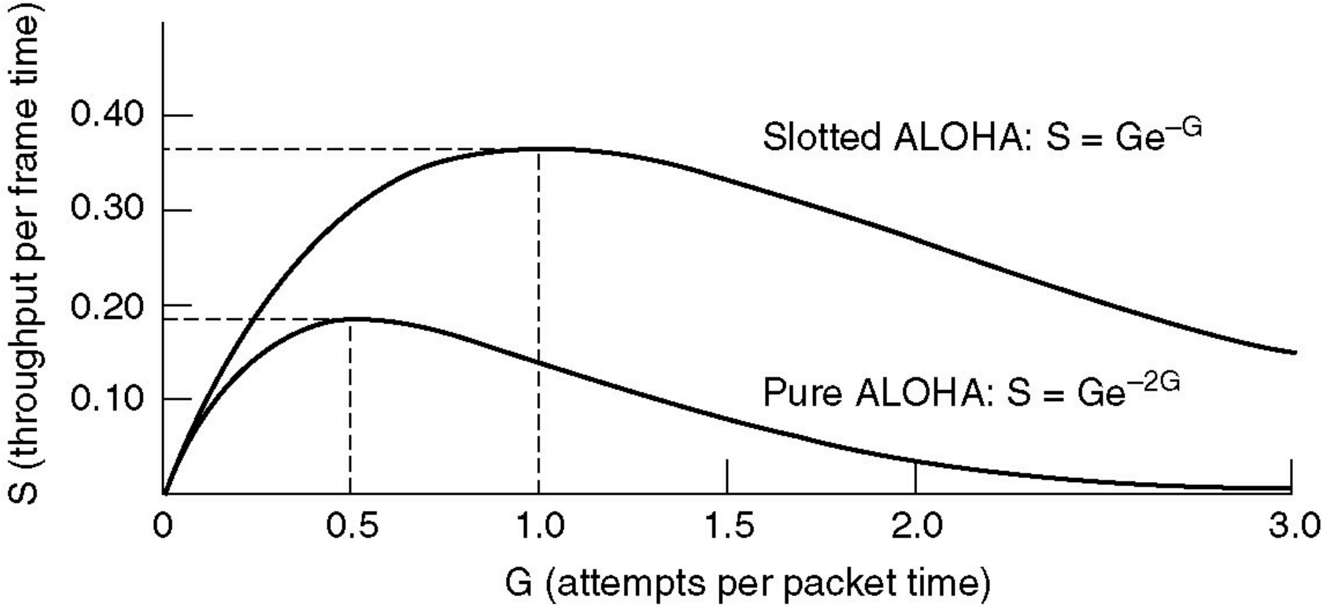
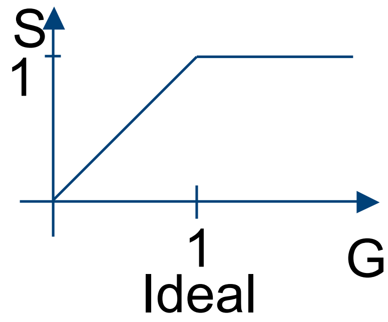
- For (slotted) ALOHA, closed form analysis of throughput S as function of G is simple



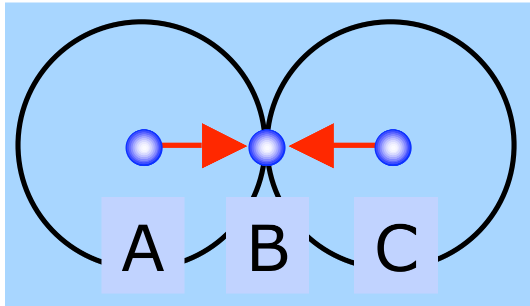


→ **Anything but a high-performance protocol**

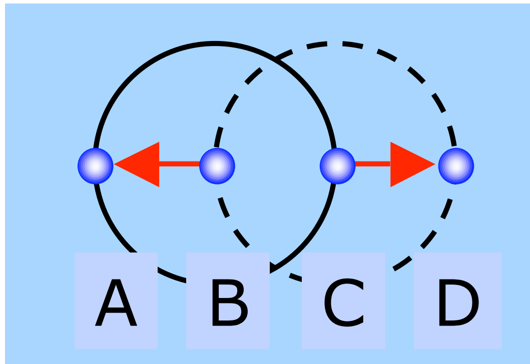
- **In particular: throughput collapses as load increases!**

Problems for the MAC-Protocol

- **Hidden Terminal Problem**



- **Exposed Terminal Problem**



Thank you

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

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