Mobile and Ubiquitous Computing
Revision Lecture (Part II)

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Overview

- MAC protocols
- Routing protocols
- Sensor networks: applications and research challenges
  - query processing
  - routing
  - storage management etc.
- Directed diffusion: a routing protocol for sensor networks
- Exam questions (tips and example)

Media Access Control

- Wireless medium is shared
- Many nodes may need to access the wireless medium to send or receive messages
- Concurrent message transmissions may interfere with each other => collisions => message drops
- A MAC protocol is needed to allow the efficient sharing of the wireless medium by multiple nodes

MAC design goals

- Design goals of a MAC protocol:
  - ***ensure reliable communication*** across wireless links (not end-to-end reliability, only 1-hop reliability)
  - ***maximize the use of available bandwidth*** (keep control overhead as low as possible)
  - ***ensure fair bandwidth allocation*** to contending nodes
  - ***minimize delay*** of sending/receiving messages
  - ***minimize energy-consumption*** of sending/receiving messages

Contention-based MAC protocols

- Assumptions in contention-based protocols:
  - nodes may try to use the medium at any time (they don't reserve any time slots)
  - they all use the same frequency
- Protocols:
  - CSMA
  - MACA and MACAW
  - IEEE 802.11
  - PAMAS

Time-division MAC protocols

- TDMA (Time Division Multiple Access) protocols
- Time is divided into timeslots
- Nodes transmit one after the other using their own timeslot
- TDMA requires good time synchronization
  - Scalability issue: hard to achieve time synchronization in large multi-hop networks
- Protocols:
  - IEEE 802.11 PCF
  - Bluetooth

Energy-efficient MAC protocols

- Energy savings are important in sensor networks:
  - battery-powered sensor nodes are left unattended in remote areas for large periods
- To increase lifetime of battery-powered nodes
  - Minimize the time that the radio is switched on:
    - Reduce collisions and packet retransmissions
    - Reduce overhearing

      (the receiving cost is comparable to the sending cost)
    - Reduce idle-listening

      (the listening cost is comparable to the receiving cost)
- Protocol: S-MAC (others are B-MAC, Z-MAC etc.)

Routing

- Routing methods
  - Link-State
  - Distance-Vector
- Distance-vector routing protocols
  - DSDV (proactive)
  - AODV (reactive)

Link-state vs. distance-vector

Link-state approach:

- Each node has a complete view of the network topology
- Each node propagates the costs of its outgoing links to all other nodes

Distance-vector approach (Distributed Bellman-Ford):

- Every node **i** maintains for each destination x a set of distances $\mathbf{d_{ij}(x)}$ for each neighbor node **j**: $\mathbf{d_{ij}(x)}$ is the cost (e.g. number of hops) of sending a data packet to **x** through neighbor **j**
- Node **i** selects to forward a data packet through neighbor **k** such that: $\mathbf{d_{ik}(x) = \min_j \{d_{ij}(x)\}}$
- Each node periodically broadcasts to its neighbors its current estimate of the shortest distance to every destination node.

DSDV: Destination-Sequenced Distance-Vector protocol

- Each node maintains locally a routing table
- Each entry of the routing table includes routing information for a destination node:
  - the next hop in the optimal path to the destination
  - the cost of the optimal path to the destination
  - the freshness (sequence no) of the path to the destination
- The node advertises the local routing table to its neighbors
  - Periodically
  - When topology changes are detected
- On receiving routing information from a neighbor, a node uses it to update its own local routing table

AODV: Ad Hoc On-Demand Distance-Vector protocol

- AODV
  - does not maintain routes from every node to every other node in the network.
  - discovers routes on-demand (reactively, not proactively)
- Say that a node wishes to send a packet to a destination node D. It first checks whether it has a valid route to D
  - If yes, it sends the packet to the next hop towards the destination.
  - If not, it initiates a ***route discovery process***.

DSDV vs. AODV

- Two distinct approaches to routing:
  - Proactive: nodes continuously maintain routes to all destination, even if they don't use them frequently (DSDV).
  - Reactive: nodes identify and maintain routes on-demand, i.e. when they need to send packets to a certain destination (AODV).
- Both DSDV and AODV are distance-vector protocols:
  - Nodes maintain distances (costs) to destinations and keep information about the next hop in the optimal path to a destination.
- Both DSDV and AODV are designed for adhoc (wireless mobile) networks

Sensor network applications and research problems

- Application scenarios and requirements
  - habitat monitoring
  - traffic control
  - emergencies
- Research problems
  - network deployment and configuration
  - query processing and storage management
  - network longevity and robustness
  - other research issues

Query processing and routing

Processing aggregate queries:

- Centralized processing
- ✓ In-network processing

  Madden et al (TAG),

  Chalermek et al. (Directed diffusion),

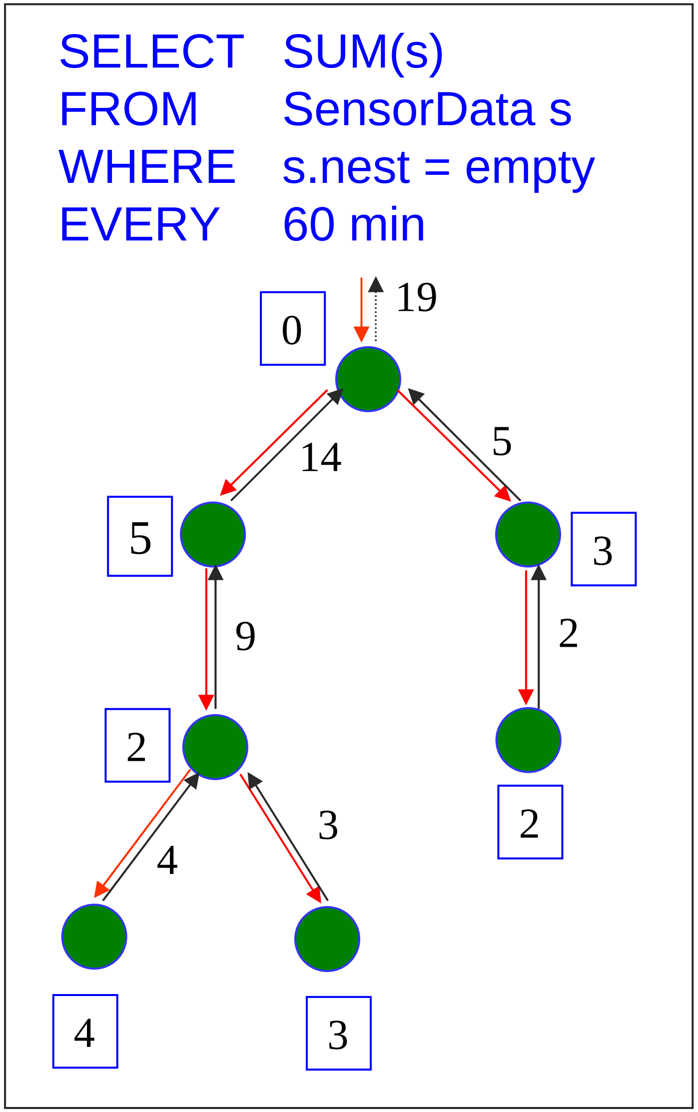
  Gehrke et al.(Cougar)

With in-network processing, the number of results at each edge remains constant.

⇒ Reduces communication overhead

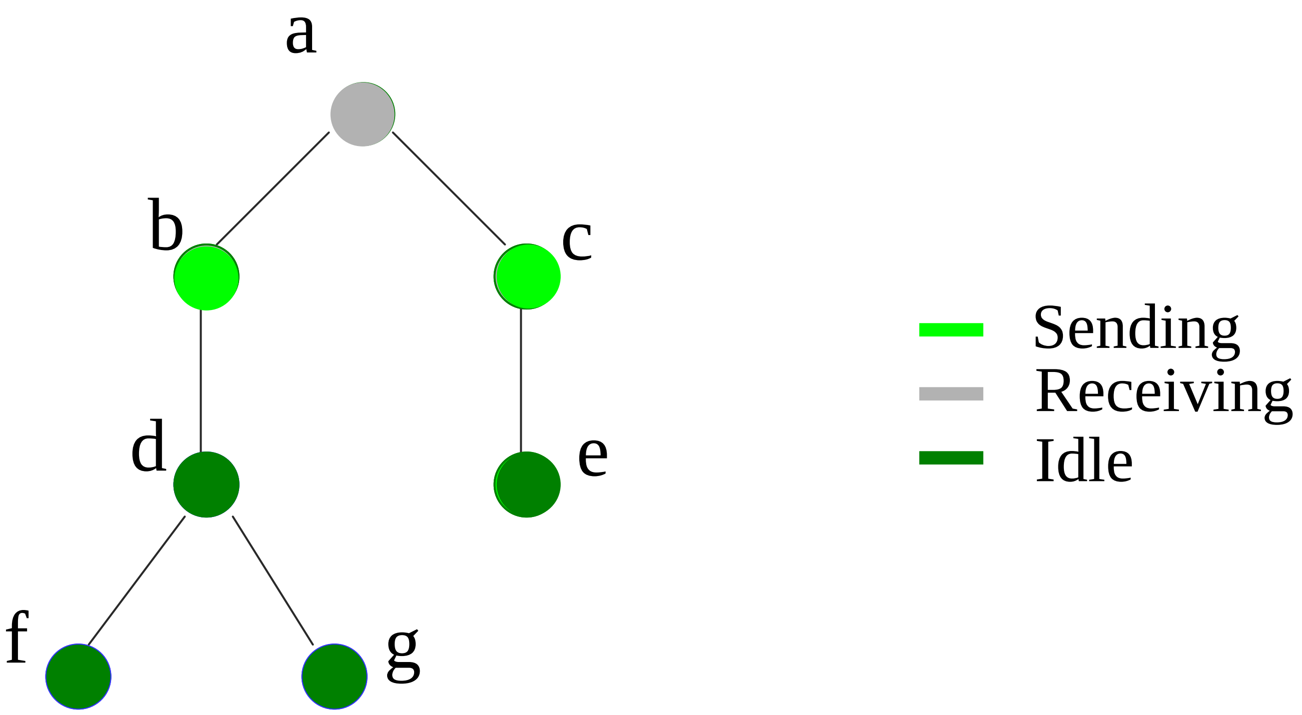
⇒ Reduces energy consumption

⇒ Increases network lifetime



Node scheduling in TAG (TinyAGgregation Trees)

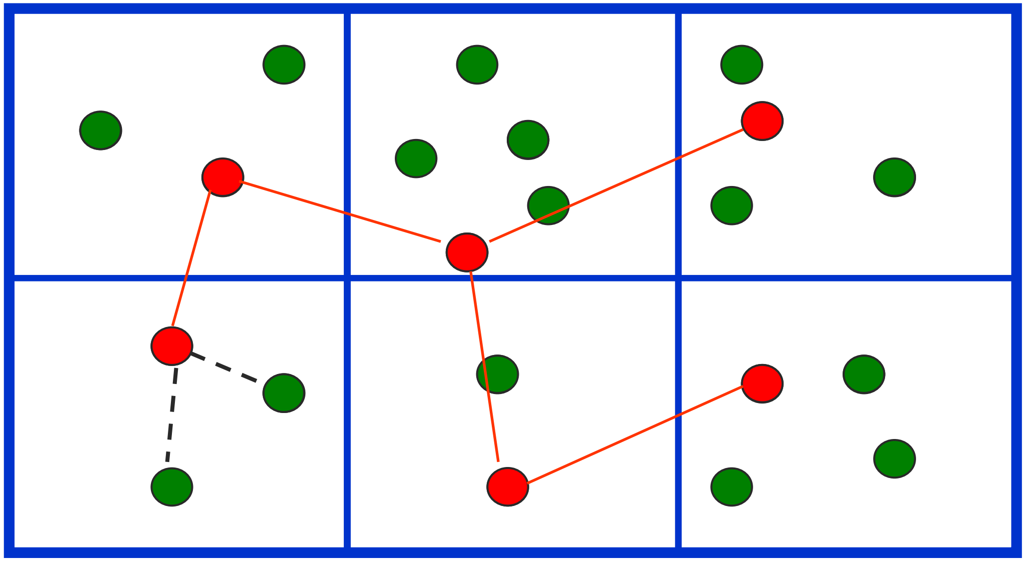
[Madden et al. 2002]



Topology control

Energy-aware participation in routing and sensing operations:

- Topology control schemes (e.g. GAF)
- As node density increases, there is redundancy in:
  - nodes participating in routing backbone
  - number of sensing devices



e.g. GAF [Xu et al.]: Geographic Adaptive Fidelity

Storage management

Data-centric storage:

- GHT (Geographic Hash Table) hashes sensor readings to locations where they should be stored (like in P2P systems).
- It then stores the data at sensor nodes close to these locations.
- Queries retrieve sensor readings from the designated storage nodes.

Ratnasamy, Shenker, Karp, Govindan, Estrin, Yin, Yu

Directed diffusion

Directed diffusion [Intanagonwiwat et al.] is suitable for addressing attribute-value requests, for example:

type = animal
instance = horse
interval = 30 min

- The sink diffuses the request to the entire network, asking for information in very low frequency.
- The source sends back matching events through multiple paths.
- The sink reinforces optimal paths (e.g. it asks information in high frequency to arrive through the min-delay path).

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Exam questions

- There are six questions on the paper. Candidates should attempt only four of them.
- Each question has 25 marks.
- Each question is divided into (typically 2 to 5) sub-questions. The marks of the sub-questions (which are clearly shown) add up to 25 marks.

Tips for exam questions

- Allocate time cautiously; don’t spend too much time on a single question.
- Read the questions carefully. Sometimes we tend to answer what we want to be asked, rather than what we are actually asked.
- Make your answers legible.
- At the end, look over your answers to see what you have done.
- Don’t make your answers too long; be concise.

Example of an exam question

1. (a) Draw an example of the hidden node problem and briefly explain how the problem occurs.
   (5 marks)

   (b) Explain how (TDMA) time-division MAC protocols differ from congestion-based MAC protocols.
   (5 marks)

   (c) Describe briefly the MACA algorithm.
   (10 marks)

   (d) Which is the most important design goal of MAC protocols for sensor networks and why?
   (5 marks)

Questions?