Autonomous Networking

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Today’s plan

- Exercises

Exercise 1

- Explain the problem of energy consumption in sensor networks

Exercise 1: solution

- The problem of energy consumption in sensor networks is a critical challenge that arises due to the inherent constraints of sensor devices.
- **Limited Energy Resources**
  - sensors **rely on batteries** as their primary power source.
- **Harsh Conditions**
  - Batteries have finite energy capacity and can be **challenging to replace or recharge**, especially in remote locations. Once the energy is depleted, the sensor becomes non-functional until the battery is replaced or recharged. Battery replacement is a costly process to be avoided as much as possible

Exercise 1: solution

- **Energy Consumption**
  - **Continuous operation**: Sensors continuously monitor and collect data, leading to a constant power draw.
  - **Transmission distance**: The longer the transmission distance or the higher the data rate, the more energy is required.
  - **Collision**: When a node receives more than one packet at the same time, these packets are termed collided, even when they coincide only partially. All packets that cause the collision have to be discarded and retransmissions of these packets are required, which increase the energy consumption.
  - **Overhearing**: meaning that a node receives packets that are destined to other nodes.
  - **Control-packet overhead**: A minimal number of control packets should be used to make a data transmission.
  - **Idle listening**: listening to an idle channel in order to receive possible traffic.
  - **Overemitting**: caused by the transmission of a message when the destination node is not ready.

Exercise 2

- Discuss the challenges of routing in wireless sensor networks

Exercise 2: solution

- Routing in wireless sensor networks (WSNs) poses several challenges due to the unique characteristics and constraints of these networks.

- **Energy Efficiency**: Sensor nodes in WSNs are typically battery-powered, and replacing or recharging batteries may be impractical in many deployment scenarios. Routing algorithms must be energy-efficient to prolong the network's overall lifetime.

- **Dynamic Network Topology**
  - **Node Failures and Additions**: Sensor nodes in WSNs may experience failures due to factors such as energy depletion or environmental conditions. Additionally, new nodes might be deployed to replace failed ones or to extend the network.
  - **Node Mobility**: In some applications, sensor nodes may be mobile or deployed in environments with mobile elements. Dynamic node mobility introduces additional complexities in routing, as nodes may change their positions, affecting the network topology dynamically.

Exercise 2: solution

- **Scalability**:
  - **Increasing Node Density**: As the number of nodes increases, the routing protocol must scale efficiently. Traditional routing algorithms designed for smaller networks may become inefficient or impractical for large-scale WSNs. Scalability challenges involve optimizing routing for networks with a large number of nodes.

Exercise 3

- Explain the difference between Framed Slotted Aloha and Tree Slotted Aloha protocols in RFID systems.

Exercise 4

- In a slotted aloha protocol for RFID systems how is estimated the tag population participating into intermediate frames?

Exercise 4: solution

- When a frame is executed
  - ***N*** is the number of slot in a frame (known)
  - ***n*** is the number of tags participating into a frame (unknown)
  - $\mathbf{C_0}$ is the number of empty slots (known)
  - $\mathbf{C_1}$ is the number of identification slots (only one tag replied) (known)
  - $\mathbf{C_n}$ is the number of collision slots (known)

- Probability theory says that:

Given N and a possible value of n, the expected number of slots with r tags is estimated as

$$a_r^{N,n} = N \times \binom{n}{r} \left(\frac{1}{N}\right)^r \left(1 - \frac{1}{N}\right)^{n-r}$$

Exercise 4: solution

- The total number of tags is estimated according to the outcome of the frame and the estimated values
- Chebyshev's inequality

$$\varepsilon(N, c_0, c_1, c_k) = \min_n \left| \begin{pmatrix} a_0^{N,n} \\ a_1^{N,n} \\ a_k^{N,n} \end{pmatrix} - \begin{pmatrix} c_0 \\ c_1 \\ c_k \end{pmatrix} \right|$$

- N: size of completed frame
- $<c_0, c_1, c_k>$ triple of observed values
- $<a_0, a_1, a_k>$ triple of estimated values

Exercise 5

- Explain the binary splitting protocol for RFID systems

Exercise 5: solution

- Suppose we have a set of tags to identify
- Each tag has a counter initially set to zero.
- The tags with the counter = 0 reply to the reader query
- The reader sends a query
- All tags reply → collision
  - Each tag generates a random binary number (0,1) and sums it to the counter
- The process repeats
  - The reader sends a query
  - All tags with C=0 replies
  - If collision → each replying tag generates a random binary number and sums it to its counter
  - Each other tag (silent) → C=C+1
  - If none or one tag replies → all tags: counter = counter - 1

Exercise 6

- Explain the differences between proactive and reactive routing in sensor networks. Discuss the advantages and disadvantages.

Exercise 6: solution

- Proactive Protocols
  - Routing protocol always tries to keep its routing data up-to-date
  - Active before tables are actually needed
  - Also known as table-driven
- Reactive Protocols
  - Route is only determined when actually needed
  - Protocol operates on demand
- Proactive approach is fast but involves overhead
- Reactive approach generate much less overhead but it is slower