

REVISION - AD HOC AND SENSOR NETWORKS

1. Describe the difference between infrastructure-based networks and ad-hoc networks.

In an infrastructure-based network the network is managed by a dedicated set of nodes which are connected to a power supply and have a fixed/wired network connection.

In an ad-hoc network, there are no special controller nodes. Nodes can join and leave the system dynamically, and access to resources (like medium access) needs to be shared among the nodes using distributed protocols.

2. Describe two strategies for extending the lifetime of a wireless sensor network. Comment on the drawbacks of each method.

Two strategies which can be used to extend the lifetime of a wireless sensor network are as follows.

Strategy 1 - Aggregate traffic: When a node receives a message from a neighbour node which should be forwarded towards the sink, it will wait some time to see if it receives more messages from other neighbouring nodes. If several messages have been received the relaying node can bundle those messages together in order to reduce the cost of transmission. In case of duplicated information, some messages can be suppressed, and in some cases the data itself can be aggregated in the relaying node. The main drawback of this strategy is an increased delay from the time the message was first sent until it is received by the sink node.

Strategy 2 -Duty cyclic: The sensor network nodes go to sleep and only wake up with a certain period. This drastically reduces the energy consumption for each node. The drawback with this strategy is that it can result in a longer delay of detecting and sensing the environment. It also requires more complicated communication protocols since they must account for the fact that nodes are asleep most of the time.

3. Describe the RTS/CTS mechanism. Give an example of a situation where this mechanism prevents collisions.

In RTS/CTS system, a node which wants to send a message in this scheme first sends a request-to-send (RTS) message with information about the amount of data it wants to send and the intended receiver. The receiver node replies with a clear-to-send (CTS) message if it is idle. Surrounding nodes which overhear the RTS or CTS message will then refrain from sending any messages until the transmission is completed.

Example: Consider nodes A, B, and C, where node A and B are in communication range of each other, as well as B and C. However, A and C cannot hear each others transmissions. Now assume A wants to send a message to B. Once B has sent its CTS message, C will not send any messages and therefore collisions between A and C will not occur.

4. Describe three problems of medium access control that can cause energy waste.

Three problems of medium access control that can cause energy waste are as follows.

(a) Idle listening. When a node is in idle mode it consumes much more energy than when the radio is sleeping. If the node has nothing to send or receive, it would be better if the radio was in sleep mode.

(b) Overhead. If the protocol has to send a lot of signalling messages this will increase the energy consumption of the nodes.

(c) Overhearing. If a node receives a message for which it was not the intended receiver, it will consume quite some energy but get no benefit from this.

5. The IEEE 802.15.4 MAC protocol combines contention-access periods with guaranteed time slots, what are these used for?

The guaranteed time slots are used by applications which have real-time constraints. By having a dedicated slot in each cycle, the worst-case medium access delay can be computed.

ROUTING AND DATA COLLECTION

6. Routing protocols can be categorised as flat, hierarchical or location-based. Explain each of these categories.

Flat routing: All nodes are equal and route messages by building routing tables of where to send the message. Typically flooding is required to construct these routing tables.

Hierarchical routing: The network is structured so that only some nodes participate in message forwarding. Routing tables can be simplified and the flooding protocols does not need to involve all the nodes in the network.

Location-based routing: Every node knows its own location as well as the location of the destination node of a message. Forwarding is done by sending a message to a node which is geographically closer to the destination.

7. What is a collection tree, and how can it be constructed?

A collection tree is a structure in the network where the sink node is the root and the sensor nodes are leaves. Sensor information is forwarded through the tree towards the root (sink). A tree can be constructed by a flooding message which originates from the sink node. This flooding message has a hop count which allows every node to keep track of from where it received the message with the lowest hop-count. This will be the parent node in the resulting tree.

CELLULAR NETWORKS

8. In the Machine-to-Machine (M2M) terminology, sensors are categorised as direct or indirect. Which of these two sensor types is likely to have a lower power consumption? Why?

Indirect sensors are connected to the cellular base-station through an intermediate access point. This means that they only need to communicate with nearby nodes which is likely to result in a lower energy consumption compared with direct sensors.

9. What is the purpose of having different QoS classes in cellular communication?

Different applications can have different requirements on timeliness and reliability of the messages it sends and receives. For example, voice communication requires very little jitter, as opposed to email.

By specifying QoS classes, the base station can optimise limited resource usage to meet the requirements for each application class.

CLOCK SYNCHRONISATION AND POSITIONING

10. Explain how often a set of clocks need to be synchronised if they required clock precision should be at most p .

Let P be the precision achieved after synchronisation, T , the time between synchronisation, and r be the rate with which clocks drift.

Then we require $p > P + 2rT$, which means that $T < \frac{(p-P)}{2r}$

11. To determine its position, a node need knowledge of some other nodes position, direction and distance, two positions and two directions, three positions and distance or possibly some other combination. Describe three possible sources (measures) of the distance information, and relevant problems.

Time of arrival of a message - Given knowledge of the propagation speed, the distance can be derived from the time of flight. This requires very good clock synchronisation, as well as the ability to do precise time measurements.

Time difference of arrival - Given a fast and slow communication device (e.g., radio and ultra sound), the distance can be calculated from the time difference of arrival and the difference in propagation speed. This requires two communication devices, which might be costly in terms of energy consumption (as well as production cost).

RESOURCE MANAGEMENT

12. What is weighted fair queueing (WFQ)? Can WFQ provide absolute delay bounds?

WFQ is an approximation of Generalised Processor Sharing (GPS) adapted for packets, where messages are treated in the order of how an ideal GPS mechanism would finish each message. Absolute delay bounds can be guaranteed if the incoming traffic is well specified (e.g., according to the leaky bucket format).

13. Give two examples of enforcement-level QoS parameters in distributed systems (2p)

Jitter, the largest difference in latency between two messages.

Packet loss rate, the proportion of messages that are not received

DEPENDABILITY AND SECURITY

14. Describe the following attributes of dependability and how they can be measured in a real system
(i) Availability (ii) Reliability.

(i) Availability is the readiness of service, which means how likely it is that a service will be ready to use when requested. This can be measured with the uptime of a service, given a certain measured interval, the time the service was up divided by the total measured time.

(ii) Reliability is the continuity of service, which means how long the service will stay without failures. A typical measure is the mean time between failures (MTBF).

15. What is the difference between fault prevention and fault tolerance? Give one example method of each type.

Fault prevention tries to prevent faults from occurring. An example might be to use a very stable operating system in a product to prevent OS-related problems from occurring in the product.

Fault tolerance deals with faults that actually occur. An example might be to resend messages if an acknowledgement is not received.

ENERGY MANAGEMENT

16. Describe what are the rate capacity and the relaxation effects of batteries.

(This type of question will not be asked in the final exam)

Rate capacity: the total capacity of the battery is reduced with higher load.

Relaxation: the capacity of the battery can increase if not used for some time.

17. Explain the basic physical principle of why dynamic voltage scaling can be used to save energy. (2p)

The power consumption of a chip increases with the square of the voltage level, where as the frequency attainable increases with less than the square of the voltage. Therefore, by reducing the voltage (and frequency) a little bit, a lot of energy (by comparison) can be saved.