Exercises Correction – Applications and Hardware

Exercise 1

Describe how the sensor network application characteristics given in class (environment, lifetime, cost, sensed data, network topology, user interaction) apply to the following application areas:
- Warehouse monitoring
- Health care
- Structural monitoring (e.g., a bridge)

Warehouse monitoring
- Environment: indoors (temperature, humidity, ...)
  - Powered source are a possibility. Battery powered source in case of power failure, for ease of placement/maintenance.
  - Why not ethernet? Wireless for ease of placement. Wireless ethernet too energy consuming for battery powered nodes.
- Lifetime: months, maintenance is possible
- Cost: moderate: tens of euros
- Sensed data: low rate (temperature, humidity), high rate (imaging, sound for surveillance)
- Network topology: multihop, clusters per room or per machine connected to a gateway
- User interaction:
  - Alert management: how is the situation now? Notification in case of alert, possibility to zoom in on region where problem comes from.

Health care
- Environment: sensor nodes around/inside a patient (body area network)
- Lifetime: months, maintenance is not a preferred option
- Cost: high: possibly hundreds of euros
- Sensed data: low rate (from a measurement every few minutes to hundreds of measurements per second in case of emergency)
- Network topology: single hop to a personal server, UWB to transmit from inside body
- User interaction:
  - Alert management
  - Monitoring of blood pressure, implants, hearing

Structural Monitoring (bridge)
- Environment: inside/outside a bridge
  - Battery powered nodes in case of power failure
  - Wireless nodes for ease of installation
- Lifetime: years, maintenance is not an option inside the bridge
- Cost: small: some euros
- Sensed data: response to vibration ambients or forced – high data rate > 100 Hz from many locations
- Network topology: single hop, possibly multihop to increase ease of deployment
- User interaction:
  - Alert management (e.g., in case of earthquake)
  - Constant acquisition (data is obtained from all nodes at a given sampling rate)

**Exercise 2**

Given an application example that requires the use of a multi-hop network.

Multi-hop topologies are relevant when
- The space to cover is large
- Autonomy is high
- Deployment density is high
- Multiple sensor modalities are used (interaction across sensor nodes is high)
- The environment is hostile

For example: habitat monitoring, multi-target tracking, Disaster area monitoring, home automation.

**Exercise 3**

Consider the Nissin warehouse with the following key characteristics:

<table>
<thead>
<tr>
<th>Temperature Control Zone Details</th>
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<tbody>
<tr>
<td>Temperature Zone</td>
</tr>
<tr>
<td>Constant temperature: -5 °C to +15 °C</td>
</tr>
<tr>
<td>Rapid freezing room: -40 °C</td>
</tr>
<tr>
<td>Pre-cooling room: +10 °C</td>
</tr>
<tr>
<td>Inspection room: -5 °C to +15 °C</td>
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<tr>
<td>Preparation room: room temperature</td>
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</table>

Describe the infrastructure needed to monitor and control the temperature in this warehouse:
- What are realistic temperature range, accuracy and response time for a temperature sensor (check on the Internet)?
- How would you place temperature sensors in the preparation room?
- What is the expected data rate for the sensors?
- When should the actuators (thermostat) be activated?
- How should the actuators be activated?
- What are the arguments in favour of battery-driven sensor/actuator nodes?

- Temp range (-50°C to +300°C), accuracy 0.1°C, response time milliseconds
- Sensor node placement
Temperature varies with elevation so placing sensors at different heights is a good idea. We could have sensor nodes every meter vertically.

If we assume that temperature is constant over a few meters then monitoring 132m² would require sensor nodes every 5 meters horizontally.

- Expected data rate is a few measurements per second
- When temperature is within a few degrees of the bounds given for each room then the actuators should be activated to modify the trend.
- Ease of placement, resilience to power failure

**Exercise 4**

Consider a volcano. Volcanic activity can be measured with seismic sensors or infrasound sensors. Seismic sensors measure vibrations due to earthquakes. Infrasound sensors measure the low frequency acoustics (1-50Hz) that results from shock wave due to gas emission from volcanic conduit. Those shock wave have a very high amplitude (130db at 1km)\(^1\).

A – Consider a sampling rate of 100 Hz. Each sampled data item occupies 16 bits. Data is stored on flash before it is sent over the radio. How large should flash memory be if data is to be transmitted every 5 minutes. What should be the radio data rate then if we want to transmit for 10 sec?

B - The sensor node is equipped with a 128 Kb flash and with a radio whose data rate is 40 kbps. Sampled data items occupy 16 bits. What is an appropriate sampling rate? What can be done to increase the sampling rate?

C – (*) You are using sensor nodes equipped with a microphone.
- How do you choose an appropriate microphone?
- What is the output of the microphone?

A –

16 bits at 100 Hz. That makes for 1600 bits / sec.
After 5 minutes we have 1600*60*5 = 60 KiB
The radio should be able to transmit at 6 KiB/sec if we transmit data during 10 sec.

B -
The radio is the limiting factor if we want to transmit continuously.
Sustaining a data rate of 40 kbps requires sampling 16 bits at 2.5 kHz.
Increasing the sampling rate would require another radio.

\(^1\) See the Tungurahua experiments for more info on using wireless sensor networks for monitoring volcanic activity.
Exercise 5

Consider the following AA battery.
- Nominal voltage: 1,2 V
- Rated discharge capacity: 2000 mAh

The sensor node you consider consumes an average of 5 mW.

What is the expected lifetime of the sensor node when it is connected to one such AA battery?

The sensor node
5 mW
at 1,2V that gives a consumption of 5/1.2 = 4,2 mA / sec

The battery gives 2000mA during 1hour
And thus 4,2mA during 2000/4,2 = 477 hours
That is the expected lifetime.

Exercise 6

Consider the following chart tracing current consumption (in ampere on the y-axis) for the duration of a TinyDB experiment\(^2\) (time on the x-axis).

![Graph of current consumption over time](image)

The sensor node is powered with the following AA battery.
- Nominal voltage: 1,2 V
- Rated discharge capacity: 2000 mAh

What is the power consumed by the sensor node during the experiment?
How long is the sensor node life time is the experiment is continually repeated?

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\(^2\) The graph is extracted from *The Design of an Acquisitional Query Processor For Sensor Networks* (SIGMOD'03) by Madden et al.
The sensor node operates at
4 mA during 0.4 sec
15 mA during 0.9 sec
19 mA during 0.7 sec
4 mA during 1 sec

That is a consumption of 42 mA during 3 sec.
At 1.2 V that is a power $P = 1.2 \times 42 = 50.4$ mW

At 2000 mAh that is a lifetime of $2000 \times 3/42 = 144$ hours.