ET016A Laboratory Project
Implementation of a Simple Sensor Network

Sebastian Bader

1 Background and Goals

In this assignment, you will integrate the knowledge you have gained in the previous laboratory exercises in order to implement a small sensor network application. You will collect sensor data and use the network to transport your data to its final destination.

Through the implementation and documentation of this project you will demonstrate that you are able to:

- describe the concept and benefits of a WSN application
- obtain data from an external sensor
- utilize communication functionalities in Contiki
- combine previous knowledge to implement and analyze a simple sensor network application
- document your implementation and explain how the utilized technologies work

1.1 Required Equipment

- a minimum of two Zolertia Firefly nodes
- an external sensor
- a computer with the Contiki-NG development environment

1.2 Evaluation

This exercise will be evaluated based on a report (see Section 5). The report will be graded A-F. In addition, a functional implementation of your application needs to be demonstrated and you need to be able to motivate your implementation and answer questions related to it.

2 Application concept and requirements

Congratulations! You have just been hired to *Sensor Network Startup Unlimited* to develop a first prototype of a wireless sensor network system. Your first task is to propose an interesting application example that could lead the company to become a successful player in this field and pitch it to your colleagues. In addition, a simple concept of a potential implementation based on the companies key technologies should be demonstrated.

Based on an application area of your choice, you will propose and motivate an own (simple) application of a wireless sensor network in this area. For the demonstrator, the companies key technologies should be used. These technologies are based on the Firefly sensor node platform, an open-source OS, and a standardized network stack.

For a first prototype, the requirements have been reduced a little bit, and the important aspect is that we get a basic system structure that could be scaled to a full system later on. The key requirements can be summarized as:

- A minimum of two sensor nodes should be used in the demonstrator.
- Data packets with multiple parameters will be transmitted and received.
- At least one external sensor will be used to generate data.
- The received data will be visualized in text format at the receiver node.
- The wireless communication uses an explicitly defined communication channel and PAN ID.

3 Implementation choices

The application requirements described in Section 2 can of course be achieved based on different implementations, and you have flexibility to decide yourself how to accomplish the presented specification. In this section, a number of considerations and alternatives are presented in order to support you with your implementation choices.

A first decision you will need to make is how complex your communication stack should be. The network might be implemented with a simple star topology, in which each transmitter node directly communicates with the receiver. This could be achieved by using the *nullnet* approach used in lab exercise 2 (`examples/nullnet`). Alternatively, we can include higher layers such as investigated in lab exercise 3, allowing for a more scalable, but also more complex network architecture. In this case, the `examples/rpl-udp` example is a good starting point for your application. Complexity will be taken into account in the grading of your implementation. As you will work with a limited number of nodes, Cooja simulations can be of interest to document behavior at larger scale. While this is optional, it might provide interesting inputs to your documentation.

In more detail, you can implement the MAC layer based on contention-based (CSMA) or contention-free (TSCH) communication. While this choice will not have any visible effects on the nodes' behavior, it significantly affects how the channel access is handled.

Regarding sensor measurements, you have access to a module based on a GL55 photodiode (for light measurement) and an DHT22 temperature and humidity sensor. Examples for obtaining sensor values from these modules can be found at `examples/platform-specific/zoul/test-grove-light-sensor.c` and `examples/platform-specific/zoul/test-dht22.c`. There is also a limited number of other sensors available, including sound level measurement and movement detection (based on PIR). Contact one of your supervisors to get one of these sensors if needed.

Your application, of course, might require other data/sensors that are not available to us currently. In the presentation of your application idea, you can of course refer to such sensors. For the implementation, the easiest is to assume their presence and to just transmit dummy data.

Finally, you have a number of choices how to write and organize your code. While these choices are up to you, the use of timers and processes might help you get an efficient and well-structured code.

4 System analysis

Finally, there are a number of analyses to be performed. In the company, we are mainly interested to dimension the system based on communication range and operating lifetime.

Depending on the application scenario, it might be of interest to determine the maximum communication distance, or the minimum RF output power to be used. This analysis can be performed with the help of key information about the Firefly node (found in the datasheet) and a simple path loss model (Friis equation). If desired, the application environment may be taken into account using other path loss exponents.

For battery lifetime analysis, a fixed battery capacity of your choice can be assumed. To determine the nodes average power consumption, datasheet values and an approximate duty cycle should be applied. The nodes duty cycle can be assumed with a constant value of your choice, or can be approximated by measuring timings in the code or by using the Energest module https://github.com/contiki-ng/contiki-ng/wiki/Documentation:-Energest.

5 Demonstration, report and evaluation

Your implementation will be evaluated based on an oral presentation with demonstration, as well as a written report.

The presentation should be short 5-10 minutes and should focus on your application area and idea, but also shortly demonstrate your implementation (as well as the implementation choices you have made).

The objective of the written report is to document in more detail the application, implementation and analysis. Your report should include the following parts:

1. *Introduction:*

   Here you can provide information what this report is about, how it is organized, and what the reader can expect from it.

2. *Application scenario:*

   Here you should provide the a description of your chosen application idea, including a motivation why the implementation with a wireless sensor network is suitable.

3. *Implementation:*

   Here you describe the implementation and the utilized technologies. Key information is your network stack (i.e. the different protocols applied at each layer), as well as an overview of your transmitter node and receiver node implementations. Remember that it is normally not a good idea to include actual source code in your report, but that it is better to present an application at higher abstraction level (e.g. a flowchart or state diagram). You can also give some example figures demonstrating key results of your systems behavior. This may be outputs that you get from the physical nodes or results that you could obtain from Cooja simulations.

4. *System Analysis:*

   Finally, you document your system analysis with respect to communication range and battery lifetime.

Your project will be graded based on the *implementation*, as well as *documentation accuracy, completeness, format and language*. Complexity of the implementation will be considered in the examination. However, a well-understood simpler system typically leads to a better grade than a complex system that is not understood.