Software Project Plan

Pond Environmental Measurement
SSNS - Smart Sensor Network Systems
Frankfurt University of Applied Sciences

Alexander K.,
Sabrina B.,
Rozana A.,
Alexander V.D.

July 3, 2013

Contents

1 Introduction

The Idea of this Project is to build a System, based on a Wireless Smart Sensor Network, to measure a ponds water Temperature and the weather conditions that influence the ponds temperature. The Data from the measurements shall be stored in some thing like a database and be visualizable on a PC. The goal is the visualization of a reliable 24/7 data aquisition.

For the breeding and keeping of fish in a pond it is often relevant to know the ponds temperature and the range in which the temperature stays over a longer period of time. We also expect some interesting results from a system like that.

2 Project Specification

2.1 Project Description

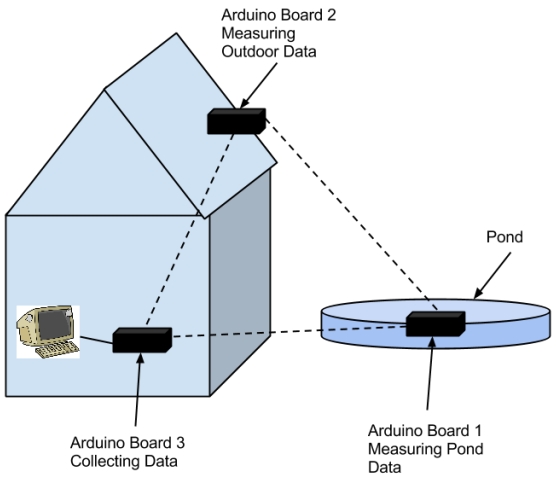
The System consists of the following Components:

- one underwater Temperature measuring Sensor Node
- one over water weather measuring Node (Temperature, Light)
- one indoor Node collecting and storing the measured Data, connected to ethernet
- A PC running a visualizing Application

The sensors measure the weather conditions and pond temperature. The values get forwarded to an indoor Data Collecting Node with ethernet access. There the Data is going to be logged. Using a Computer a history of the measurements (seen as tables and graphs) can be viewed via a special application.

The Three Nodes will communicate via the ZigBee Protocol, using XBee Modules.

Figure 1: Pond Envrionmental Measurement



The outdoor sensor nodes are going to operate independant of a power source meaning that these Nodes will be equipped with Solar panels and batteries. They should be able to run 24 hours every

day just by the power provided by the solar panel and the batteries (that get charged by the solar panel).

In this project we want to concentrate on the Software part of the System. To build the Outdoor Nodes in a Weather Proof way and designing them independant of a Power Supply by using Solar is a complex task. Finishing the Hardware is an optional aspect of our project. We will design the necessary circuits for attaching the sensors to the arduino Nodes and use the Nodes to test our Software on. The task of building weatherproof, solar powered Nodes based on the sensor circuit design is optional or can be done in a future project.

2.2 Process Model

As Process Model we chose the Rational Unified Process (RUP). RUP has the advantage of being iterative and incremental while also being relatively lightweighted. All Project activities can be used any time when needed, this gives us flexibility.

The Rational Unified Process is an Interactive software development process framework. It was created by Rational Software Corporation, a division of IBM since 2003. It enhances team productivity and creates and maintains models. It is also a guide to effectively use the Unified Modeling Language. Its goal is to deliver a high quality product that the customer actually wants.

The RUP model is mainly used in Telecommunications, Transportation, aerospace, defense, manufacturing ,financial services and in system integrators.

Well-defined and well-documented software development processes are key to the success of software projects. CMM(Capability Maturity Model) by the software engineering Institute (SEI) has become a beacon. Theoretical know-how fails to materialize in practice. Sometimes there is no process know-how at all. Resulting in chaos, failure and Loss. In this cases RUP can help. It is a mature, rigorous and flexible software engineering process.

We choose RUP for our project because of its luxary features, usage of Best Practices and also for its development cycle process. The mensioned terms are explaing as follows:

Features of RUP :

- Iterative Development
- Requirements Management
- Visual Modeling of Systems
- Quality Management
- Change Control Management

Compare to the traditional waterfall process, the iterative process has the following advantages:

- Risks mitigated ealier
- Change is more manageable
- Higher level of reuse

- The project team can learn along the way
- Better overall quality

The 6 Best Practices are as follows :

1. Develop software iteratively
2. Manage requirements
3. Use Component-based architechtures
4. Visually model software
5. verify software quality
6. Control changes to software

2.3 Requirements

2.3.1 General Requirements

There are Three (Software) components to be developed:

- Software for the two measuring Nodes (only different in respect to the sensor configuration)
- Software for the collecting Node, with connection to Ethernet
- PC Application for Data visualization

Ofcourse there are also Hardware components that have to be developed:

- Weatherproof, Solar powered water temperature measuring Node
- Weatherproof, Solar powered weather measuring Node
- Data colloecting Node

When discussing the Requirements of the system it is necessary to distingush the components and to distingush the requirements for the Software from the requirements to the hardware.

2.3.2 Overall System Requirements

- reliable 24/7 data Aquisition
- Data being storaged on the collecting Node (Some sort of Database)
- Graphical visualization on the PC, reading Data from the collecting Node over Ethernet

2.3.3 Data Measuring Nodes Requirements

- Taking measures as the mean of multiple measurements over a short time period
- Measures get taken after a demand by the collecting Node
- Measures get stored localy until the collector acknowledges the receipt of the measure
- Based on Arduino UNO and Wireless Protoshield with an XBee Module

Optional:

- Weather proof housing
- independant from Power Supply by using Batteries and Solar

2.3.4 Collecting Node Requirements

- Coordinator Role in the ZigBee Network
- knows Date and Time, set via NTP
- Demands Measures from the measuring Nodes every half an hour
- Measuring Nodes have 30 sec. time to answer before their measures get stored as unknown.
- stores measures on SD-Card as CSV-File
- Sends CSV-File over Ethernet on demand
- Acts as TCP Server (On static IP Adress and fixed Port)
- Based on a Arduino Ethernet with Wireless Protoshield and XBee Module

2.3.5 PC Application Requirements

- Developed in Java, GUI using Swing
- Connects to the Collecting Node via IP/Ethernet
- Connects as TCP-Client to collecting Node on its static IP-Adress and fixed Port
- Data Visualization as Tables and Graphs
- Selectable Timeframe for shown Data
- Selectable Data to be shown in the same Graph (Pond Temperature, Air Temperature, Light Level)
- Data Export as CSV File (Coma-Seperated-Values)

3 System Architecture

3.1 Architecture

The Hardware Architecture describes the circuits for using the Sensors and the configuration of the three Network Nodes.

3.1.1 The Sensors

We are using two kinds of Sensors. The kind of Temperature Sensor and one kind of LDR Sensor.

- Temperature Sensor TMP36
- LDR GL5528

We chose these Sensors because of their easy sourcing and their wide usage. They are also relativel easy to use.

The Temperature Sensor is a solid State component which doesnt need calibration. It Outputs a voltage depending on the temperature. The relation between the temperature and the voltage is linear, so its very easy to calculate the temperature based on analog readings of the voltage.

Some relevant facts taken from the Datasheet:

- specified operating Temperature Range: -40°C to 125°C
- scalefactor of 10mV/°C
- offset of 0.5V
- Accuracy of ±1°C at 25°and ±2% in the range of -40°C to 125°C

This gives us the Formular: Temp [°C] = $\frac{Voltage[mv]-500}{10}$

The LDR (Light Dependant Resistor) is for Measuring the light Level. LDR's are usually not precise enough to really measure the light level, but are rather used to distinguish darknes from lightness. So we wont get very precise readings with it, but iwe will try to get the best out of it.

Some relevant specifications:

- not precise enough to measure the light level in Lux
- only measure darkness from light
- Reliable performance
- linear relation

To get the light value in Lux you have to execute following:

- Get voltage of Resistor
- Get Resistor Value with formula: $\frac{5.0-LightVoltage}{lightv} * 1000$

- Get Luxy with formula:

$$10 * \frac{14000}{LightResistor}^{\frac{1}{0.7}}$$

If you calculate the Error of Light and Temperature you will see, that Temperature has a quantisation error of $\pm 1°C$ and the light has a very big quantisation error. Ths let us see, that you cannot measure really exact.

3.1.2 Measuring Nodes

The Measuring Nodes consist of Arduino Uno's (or similar boards like Leonardo) which the Software is running on ant the Sensors are connected to. The Arduino Board is expanded using a Wireless Proto Shield with an XBee Module to provide ZigBee Network conectivity.

The Sensors are being used according to the following Circuit Diagram. BILD The **TMP36** is directly connected to the Arduino's 5V Power source and GND, the output voltage of the **TMP36** is read on the A0 Analog Input of the Arduino.

On the weather measuring Node the circuit is enlarged by the **GL5528 LDR**. The LDR is used in a voltage divider circuit. The Voltage of 5 Volt is being divided by the propordion of the resistances of the LDR and the fixed Resistor. This "proportional divided" voltage is supplied to the A1 Analog Input of the Arduino.

3.1.3 Collecting Node

The Collecting Node consists of an Arduino Ethernet Board (A simple Arduino with Ethernet Shield would also be possible). The Arduino Ethernet board is also extended with a Wireless Proto Shield and XBee Module to provide ZigBee connectivity. The Arduino Ethernet features a built in micro SD Card slot.

3.2 Software Architecture

3.2.1 Messaging

ZigBee Network Setup

The ZigBee Network consists of three Nodes

- Pond measuring Node
- Weather measuring Node
- Collecting Node

The Collecting Node will act as the ZigBee Coordinator, so its XBee Module will have to be loaded with the coordinator Firmware. the two measuring Nodes will be either End-Nodes (which means low power consumption), or routers (which gives them the ability to extend the Networks Radius by routing). Since both measuring Nodes only communicate with the collecting Node (very simple star-network-configuration) no additional routing Nodes are necessary. Also making the measuring Nodes act as routers will increase the power consumption of the Nodes.

So as long as both measuring Nodes are in reach of the collecting Node, it is best to stick to the end-device firmware for the measuring Nodes XBee modules, otherwise the routing firmware might enhance the networks reach.

In our Project we are going to use the ZigBee Network standard. This means that we won't concern ourself with the lower layers of the protocol stack. Because we only work on the upper Layers (Application Layer), the choice of firmware for the measuring Nodes is not relevant for our Software. ZigBee will take care that our packages get to their destination, either directly or via hopping the other measuring Node.

In order to work with the XBee Modules we will use the xbee-arduino Library:
http://code.google.com/p/xbee-arduino/

The XBee Modules are connected to the Arduino over a Serial Connection. The protocol to control the XBee Modules over the Serial connection is pretty easy, however the Library makes it even easier.

Every XBee Module comes with a 64 Bit long Serial number that is also used as its own ZigBee Network Adress. The coordinator must know the adresses of the two measuring Nodes. It is possible for the Collector to discover the other Nodes using broadcasts, however we are going to hardcode the Meaurement Nodes adresses into the collectors Sourcecode. The Measuring Nodes are going to adress the collector either by taking its adress from the collectors packets, or by using the reserved Adress 0x0000000000000000 (coordinators 64 Bit adress).

There is also a 16 Bit PAN (Personal Area Network) Adress that has to be set up on all Nodes. The exact adress is irellevant (as long as its 16 Bit long and the same on every Node). The Adress we are using will be dec 56154 = 0xDB5A. By the way, this adress was chosen by multiplying 42 by 1337.

ZigBee Network Messages

Between the Measuring Nodes and the Collector there are two Messages that have to be defined. The first there is the Measurements Request that the Collector sends to the Measuring Nodes. The second Message is the answer from the Measuring Nodes to the collector.

Packages in the ZigBee Network transfer a payload of a certain number of bytes. In the Arduino language the payload would be an array of the type uint8_ t.

The following Messages with their specified structure are going to be transfered:

Measurement Request

Byte(s)	content	meaning
1	'R'=0x52	identifier for Measurement Request

1 Byte consisting of the uppercase letter 'R', indicating that this is a measurment request from the collector.

Weather Nodes Measurement Response

Byte(s)	content	meaning
1	'W'=0x57	identifier for Measurement response
2-5	float	float for temperature measurement in Celsius
6-9	float	float for light intensity in Lux

The first Byte indicates that this message is a measurement response from the Weather Measuring Node. The next 4 Bytes contain a float value of the measured temperature. The last 4 Bytes are are a float value for the measures light intensity.

Pond Nodes Measurement Response

Byte(s)	content	meaning
1	"P'= 0x50	identifier for Pond measuremnt response
2-5	float	float for temperature measurement in Celsius

The first Byte indicates that this is a measurement response from the Pond Measuring Node. The next four bytes contain a float value for the measured temperature in Celsius.

Communication between the Collector and the Application

The Collector is hosting a TCP Server (static ip Adress and portnumber, hardcoded into sourcecode). The Application is going to connect to the collector as a client. After the TCP 3-Way handshake id over the collector is immediately going to transfer its CSV-File over the TCP conection to the Application. After the complete File is transfered the connection is being closed.

3.2.2 Collecting Node

CSV File Format:

The Data Collecting Node will store a CSV-File (Coma Seperated Values) on a SD Card. Every half an hour the collecting Node will require measurements from the measuring Nodes. The Measuring Nodes then adds a Line to the CSV-File. Also the PC Application will require the collecting Node to send the CSV-File over Ethernet. Each Line represents a complete measurement of the whole System.

The Lines will have the following form:

hh,mm,ss,dd,mm,yyyy,ppppp,aaaa,llll

- **hh, mm, ss, dd, mm, yyyy** represent the point in time when the measurements were taken.
- **ppppp** is the temperature of the pond in °Celsius in the form of 12.5 meaning +12.5°C
- **aaaaa** is the air temperature in °Celsius and is coded in the same way as the Pond's temperature
- **llll** is the light level in Lux

In principle all values can be signed floating point numbers of arbitrary length, however only certain subsets of the possible values make sense. hh will be integer and of the interval [0 - 23]. mm and ss will be integer and of the interval [0-59]. For the temperatures float values from -30 to +45°C are realistic. Negative values get marked by a -. Unknown values might be left out, but the necessary comas will stay.

Example Line:

00,30,15,13,05,2013,11.5,9.7,

At 0:30h and 15 seconds on the 13th of May of 2013, the pond temperature was 11.5°C, the air temperature was 9.7°C, and the lightlevel is unknown. The Lines will be seperated by a Newline '\n'.

In this Format, for every complete measurement, a line size of approximately 34 Bytes will be written to the File. Based on this Line Size the following estimations on Filesize can be made:

- 1 Measurement = 34 Bytes
- 1 Day of measurements = 48 * 34 Bytes = 1632 Bytes
- 1 Month of measurements = 31 * 1632 Bytes = 50.592 Bytes
- 1 Year of measurements = 12 * 50.592 Bytes = 607.104 Bytes ≈ 593 kByte

With just a 32MB sized SD Card this System could collect Data for about 55 years. Since we will hardly be able to find an SD-Card of a size lower than 1GB it is obvious that Filesize is not going to be a problem.

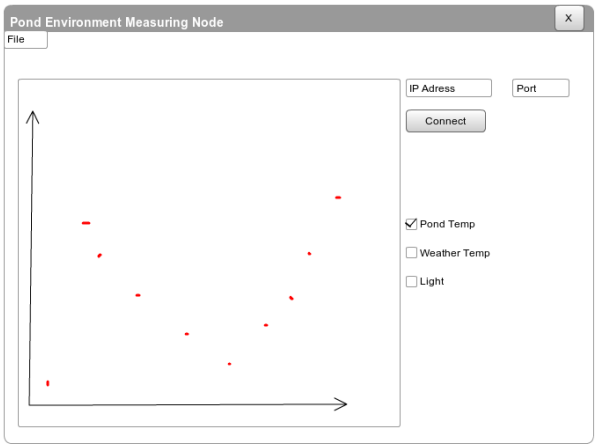
3.2.3 Measuring Nodes

The Measuring Nodes have implemented several functions. One function calculate the

3.2.4 Application

The features of the Application are described in the list of requirements. To imagine how the application behaves and how to modularize it we begin by creating a mock-up of the GUI: This is the

Figure 2: Mock-Up: Application



graphical user Interface. On the left side is a **plotting area** where the history of measured Data is shown as a plot. On the right side are some necessary controlls.

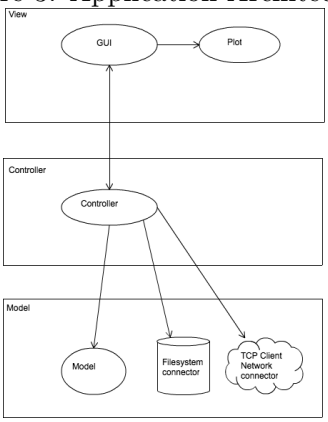
First there are two **input boxes** where the IP Adress and Port number, to reach the Collecting Node's TCP Server, are specified. After this input is made the connection can be established by clicking the **connect button**. If the connection fails an error dialog box will pop up, if it works the application will receive the CSV File's contents as byte stream (maybe show a progress bar dialog) and store it in local memory. After that the Data is being processed and plottet in the **plotting area**.

On the right side are also three **check boxes** to select the values to be plottet. So by selecting the checks, curves are being drawn or removed from the **plotting area**. The curves are drawn in different colors so that they are distinguishable.

On top of the GUI is a **menue bar** with a menue **"file"**. This menue only contains the entry **"Export as CSV"**. On selection of this entry a "save file" Dialog will pop up which allows to save the CSV files contents in a CSV-File on the PC's hard drive (like a copy of the CSV File on the Collecting Node).

The Software Architecture follows the MVC Pattern and has the components shown in the following Graphic:

Figure 3: Application-Architecture



4 Project Estimates

4.1 Estimation technique Function Point

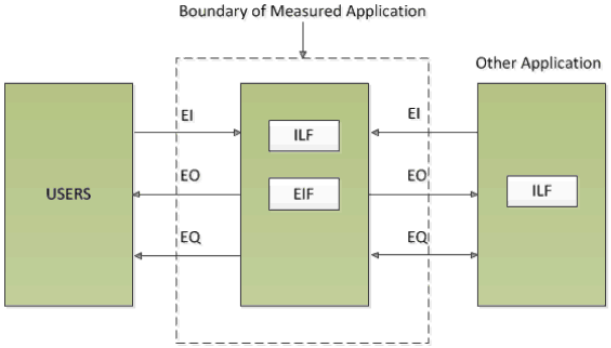
Function Point Estimation was developed by A.J. Albrecht of t he IBM Corporation in the early 1980s. The idea behind Function Points is to identify and quantify functionality required for a project. This procedure is decomposed into three parts:

1. Defining the Unadjusted Function Point Count
2. Determining the Value Adjustment Factor
3. Determining Function Points

Defining the Unadjusted Function Point Count

The application boundary defines what is external to the application. The number of Unadjusted

Figure 4: Function Point Model



Function Points is derived from the number and complexity of transactions functionalities like:

- **External Inputs (EI)** which are elementary processes (an elementary process is the smallest unit of activity that is meaningful to the user) in which data crosses the boundary from outside of the application. They come from input screens or other applications.
- **External Outputs (EO)** which are elementary processes in which derived data passes across from inside to outside. These screens, reports, graphs, messages are created from one or more logical files and external interface files.
- **External Queries (EQ)** which are processes with both input and output components that result in data retrieval from one or more internal logical files and external files.

and data functionalities like:

- **Internal Logical Files (ILF)** which are user groups of logically related data that reside within the application boundary. They are maintained through external inputs.
- **External Interface Files (EIF)** which are user groups of logically related data that are use for reference only.

Figure 5: Unadjusted Function Point Count and Multipliers (Degree of Complexity)

	Measurement Parameter	Count		Weighting Factor Low	Average	High		Total
1.	External Inputs		x	3	4	6	=	
2.	External Outputs		x	4	5	7	=	
3.	External Inquiries		x	3	4	6	=	
4.	Internal Logical Files		x	7	10	15	=	
5.	External Interface Files		x	5	7	10	=	
	Unadjusted Function Point Total						→	

Using above data we can calculate the Unadjusted Function Points. After having all basic data and transactional functionalities of the system we can use the following table below to calculate.

Determining the Value Adjustment Factor

Further we can calculate the Value Adjustment Factor based on 14 general system characteristics:

1. Data Communication Complexity
2. Distributed Data Processing Complexity
3. Performance Complexity
4. Heavily Used Configuration Complexity
5. Transaction Rate Complexity
6. On-line Data Entry Complexity
7. End-User efficiency Complexity
1. On-Line Update Complexity
2. Complex processing Complexity
3. Reusability Complexity
4. Installation Ease Complexity
5. Operational Ease Complexity
6. Multiple Sites Complexity
7. Facilitate Change Complexity

The general system characteristics are estimated on a scale of 0 to 5 (Degree of Influence)
Total Degree of Influence = Sum of Degree of Influence

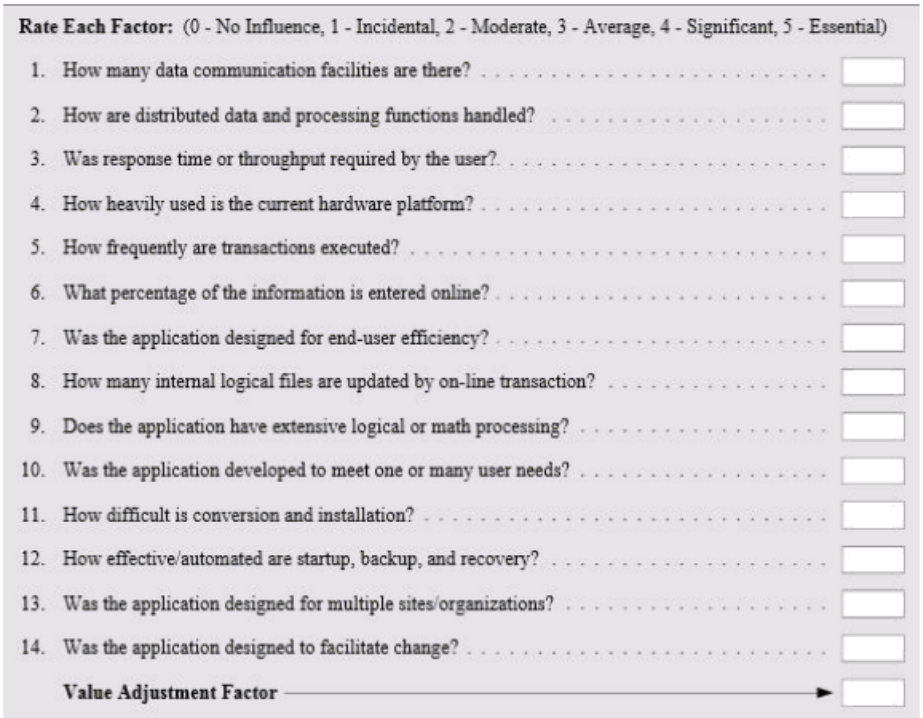
Determining Function Points

Determining Function Points consists of factoring Unadjusted Function Points and Value Adjustment Factor together.
Value Adjustment Factor = 0.65 + (0.01 x Total Degree of Influence)
Function Points = Unadjusted Function Points x Value Adjustment Factor

Example 1: How long will a project take?
Let us assume we have:

- Unadjusted Function Points = 22
- Value Adjustment Factor = 0,84
- Function Points: 22 x 0,84 = 18,48

Figure 6: Total Degree of Influence)



Rate Each Factor: (0 - No Influence, 1 - Incidental, 2 - Moderate, 3 - Average, 4 - Significant, 5 - Essential)

1. How many data communication facilities are there?
2. How are distributed data and processing functions handled?
3. Was response time or throughput required by the user?
4. How heavily used is the current hardware platform?
5. How frequently are transactions executed?
6. What percentage of the information is entered online?
7. Was the application designed for end-user efficiency?
8. How many internal logical files are updated by on-line transaction?
9. Does the application have extensive logical or math processing?
10. Was the application developed to meet one or many user needs?
11. How difficult is conversion and installation?
12. How effective/automated are startup, backup, and recovery?
13. Was the application designed for multiple sites/organizations?
14. Was the application designed to facilitate change?

Value Adjustment Factor →

Here is a table, which shows a general Function Point estimation:

Project	Function Points	Man-Months
ASD	11	1
KWO	24	2
RMD	53	5
WBO	72	6

Having a look at an organization project benchmark we estimate a result of 1.5 Man-Months. At the end of our project we do have in effect an actual amount of 1.2 Man-Months which we then update in our organization estimation chart.

Project	Function Points	Man-Months
ASD	11	1
Arduino	22	1.2
KWO	24	2
RMD	53	5
WBO	72	6

Effort in Person Month = FP divided by number of FP per month (Using an organization or industry benchmark)
The Programmers in a company average 18 FP per month.
197 FP / 18 FP = 11 Man- Months

5 Project Schedule

6 Staff Organization

6.1 Team structure

The team is organized without any hierarchically behaviors, all team members are equal. The members are:

- Alexander K. - knoetig@stud.fh-frankfurt.de
- Sabrina B. - sabrina.bajorat@gmail.com
- Rozana A. - rozanamail1@yahoo.com
- Alexander V.D. - vallejodirektor@googlemail.com

6.2 Management reporting and communication

There are every week status reports of done and open tasks for the current and next week. The main organization and communctions follows over the Wiki (http://vs1164102.vserver.de/dokuwiki/doku.php?id=ssns:ssns-project).

7 Protocol

Week 16

- Team Formation
- Resarch of Hardware (Arduino, XBee)

Week 17

- Research of Hardware
- Collecting Project Ideas
- Experiments with Arduino

Week 18

- Decision on Project Goal
- Project Specification
- Requirement Analysis
- Experiments with Arduino

Week 19

- Requirement Analysis
- Project Plan
- Create Circuit-Design

Week 20

- Project Plan Version 1
- Create Circuits

Week 21

- Create System Architecture: Hardware Architecture
- Continue with Project Plan

Week 22

- Create System Architecture: Software Architecture
- Implementation of Collecting and Measuring Nodes
- Continue with Project Plan

Week 23

- Implementation of ZigBee Network
- Continue with Project Plan

8 Appendix

References