PS Telematics - Embedded Sensor Web Summer Term 08

Project: Sensornet

Project:	Project: Sensornet 1.0
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1 Introduction

Call For Tender

The HomeAutomationCompany™is offering a contract of undefined length of time to any company that meets the requirements and goals of this call for tender. In the case of multiple complying submissions the solution of the competitor with the most optional added features will be chosen as business partner. The evaluation will be done solely based on the requirements specified in this document and judged by a competent board of examiners well trained in the domain of wireless sensor networks. These and further conditions as defined in section 8 apply for the evaluation process.
All tenderers have access to the same documentation and resources. Each competitor has to comply with the rules set by *The HomeAutomationCompany*™. This does include but is not limited to...

- schedule,
- work flow,
- data formats,
- and used technologies.

The HomeAutomationCompany™reserves the right to adjust the set rules at any times if necessary because of various undisclosed factors. Each tenderer will be notified of changed requirements and/or goals the same time.

2 Definition Of Goals

Which goals shall be achieved by usage of the software?

An untrained person new to the domain of wireless sensor networks shall be able to monitor, manage, setup and use an installation of one of these. The notion of wireless sensor network shall from now on be abbreviated as WSN and defined according to this document.

Wireless Sensor Network: A wireless sensor network is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. (Source: Wikipedia)
The software component of a WSN consists of an operation system (OS) and a protocol stack analogous to the ISO/OSI reference model or the TCP/IP internet model.

Core functionality of the wanted solution comprises the integration of an user application and the WSN software. A browser based management and monitoring application is required that meets the human interface design guidelines and assists the user in setting up a WSN. The network shall be visually represented with each node and link displayed. A temperature and humidity contour map is to be provided. Apart from sensor data evaluation, actuators enable the user to interact with additional connected external hardware.
Integration of the elaborated solution in the products of *The HomeAutomationCompany*™ remains duty of the contracting entity.

3 Resources

What kind of resources are provided?

The HomeAutomationCompany™ provides any contender access to the same resources to ensure comparability. These resources have to be used to develop a solution for the call to tender but any further ones may also be used. The constraint especially refers to the usage of the version control system described in the following section.

3.1 Repository

Every team has to use the provided Subversion repository. Backup are done automatically and do not need an further user interaction. Contenders can therefore focus on a continuous and distributed development process. Members of the board of examiners (see 8) have read access at any time to any entry. This supervised approach in conjunction with the to be announced milestone presentations shall minimize aberrations.
The initial repository of each group will be populated with the following entries:

doc documentation as defined in 8.2, including presentation slides, API description

bib bibliography, store read literature during research here

src all source code

3.2 Hardware

Each contender will be provided with the same number of MSB430 scatterweb kits. The number is not set at the time of writing but will probably exceed 18 per team. Sets consist of...

- MSB430 scatterweb nodes with voltage supply board,
- FTDI USB to USART cables,
- JTAG to parallel port cables,
- parallel port extension cables,
- and a limited quantity of JTAG to USB cables.

Devices and cables should be handled with care and are offered with responsibility of the lending party. Lent hardware has be returned until:

23rd of July 2008, 24:00

Missed deadlines will be penalized during the evaluation process (see section 8).

3.3 Software Components

The provided software package includes a minimal operation system and multiple optional components. You may use, modify, or rewrite everything, but keep it documented.

3.3.1 Operation System

The operation system, also sometimes called ScatterOS, is basically an event-driven system, which is reacting to serial input, incoming packets, and expired timers. There is no scheduler, system management, or multithreading like in other well-known systems. But at the moment it does not seem to be useful to integrate such mechanisms.
The operation system is divided into three main parts. The first one includes all functions which are available on every platform like timers control, time/date, data gathering, serial port access, and radio communication. The second one contains special libraries which support specific functionality like routing, security, and management. The third on is your application itself which uses and controls the single components in a suitable way. So, the whole system is a combination of these three elements, known as firmware, middleware and application layer. Binding is done during compile time and is not modifiable at runtine.
The conclusion is that the minimal operation system offers enough hardware abstraction to focus on a higher level solution and a short description of the firmware is given in the following.
The timer module allows you to start and stop a software timer. You can set up the time in milliseconds, the function and the data value. So you are able you say: Start that function with this data value in X milliseconds. You could also read the timer inside of the function which gets called. This is useful when you want to generate continuous functions or create a timeout controlling.
The time/date module provides you with the system time of the node to add timestamps or measure the time itself. Keep in mind that the clocks will not be synchronized initially.
The data gathering component is needed when you are using an additional sensor module which can be attached to the top of the core module. This abstraction enables the application to collect data from the sensor module without being aware of the single sensors - independent of how they have to be configured or accessed.
The serial communication module is implemented as a simple C-like `printf`-function and a messaging architecture. Use the `printf`-function to debug your application, to write optional information, or to print out values. The messaging architecture part can be used to define and implement commands anywhere in your source code. These are available over all serial input lines (e.g. when you type `ping`, the ping command gets called and the software will send a ping request over the radio).
The radio communication module is one of the most important but also one of the most simplest modules available. The whole transceiver driver is capsuled and only two functions are required and need to be known by the user: One to send and another one called if a packet is received. Of course additional functions are provided, e.g. to set transmission range, change frequencies, and to disable the receiver.

Indeep information is provided in the documents available on the ScatterWeb website[1].

3.3.2 Optional Components

The following software components are additionally provided by *The HomeAutomationCompany*™. Not all of them are available for the current hardware platform (MSB430) but for the deprecated ESB. The state of each component is given to the best knowledge.

Component	Branch	Description	State
AODV	ESB	see RFC3561[a]	development
AMRIS	MSB	A Multicast Protocol for Ad hoc Wireless Networks[b]	development
DSR	ESB	see RFC4728[c]	development
DSDV	ESB	see Sigcomm 94 publication[d]	stable
RTS/CTS	ESB	Media access protocol using a request to send and clear to send scheme	
S-MAC	ESB	Sensor Media Access Control	
T-MAC	ESB	Timeout Media Access Control	
ScatterTree	ESB	many-to-one routing	stable

[a] http://www.ietf.org/rfc/rfc3561.txt
[b] http://citeseer.ist.psu.edu/286588.html
[c] http://www.ietf.org/rfc/rfc4728.txt
[d] http://portal.acm.org/citation.cfm?doid=190314.190336

3.4 Contact

Each Wednesday 14:00 to 18:00 meetings will be held - starting 16.04.2008 and ending 09.07.2008. Attendance is mandatory. During this time questions regarding the requirements or about technical issues may be asked. Members of the board of examiners will be present of course. You should keep close contact to ensure your solution is developed according to the specification and set requirements.

[1] http://cst.mi.fu-berlin.de/projects/ScatterWeb/

4 Product Setting

Who is the anticipated target audience and what is the setting of the WSN?

4.1 Scenario

The envisioned scenario is defined as follows. The nodes of a WSN are spatially distributed over a random number of locations inside a building. This includes multiple floors and rooms. Each of the used MSP430 sensor nodes of the *Scatterweb* project[2] may be a source or destination of data and/or a router of the network.
A subset of these nodes is equipped with Sensirion SHT11[3] temperature and humidity sensors. The user application is installed on a normal off-the-shelf personal computers running a modern operation system like MS Windows XP or Linux 2.6 and might be present at any location. One MSP430 connected via the universal serial bus (USB) serves as gateway to and from the sensor network. The computer is connected to the gateway at any time.

4.2 Users

The target audience includes but is not limited to...

- scientific staff,
- students of a scientific major,
- and even untrained laymen.

It has to be taken special care that even people new to the domain of WSNs are able to use the developed solution. Basic computer usage skill may be assumed.

[2] http://cst.mi.fu-berlin.de/projects/ScatterWeb/
[3] http://sensirion.com/de/01_humidity_sensors/02_humidity_sensor_sht11.htm

5 Product Functions

What are the main function of the product?

5.1 Visual Representation

The human machine interface is a critical part of the whole product. The graphical representation of the sensor network is the central and primarily visible component. Therefore it should be especially taken care that...

- usability standards are met,
- common desktop metaphors are applied,
- and an application specific layout is used.

It is optional to the tenderer to provide separate user interfaces for different user groups depending on their domain knowledge, e.g. a less powerful but easier to use version for beginners.
The application is required to be browser based. Java has to be used as programming language. This shall ensure a platform independent solution is developed.
Apart from requirements in this section, optional features are defined in appendix A.

5.2 Nodes and Links

The user shall be able to view a visual representation of the sensor network including each node. The wireless links between the nodes shall also be indicated. The user may specify whether all or only individual links should be visualized. At least the options of displaying all or only one link have to be provided. The software has to support the display of floor plans. Nodes will be placed by the user into the rooms. As defined in the setting description (see 2) display of multiple floors has to be supported. The figure 1 shows an exemplary solution.
Physical topology detection and node localization are not part of this call for tender and have to be excluded. You can assume the user knows where the nodes are. He/she places them accordingly into the maps at the right spot. New or unplaced nodes shall also be displayed, e.g. in an separated area defining an "unknown position". This ensures no nodes are forgotten. Therefore all alive MSB430s have to somehow be displayed.

5.2.1 Persistency

Node positions and used floor plan(-s) are to be stored using the general-purpose markup language XML. The application of course has to be able to restore this information. The document type definition (DTD) is to be defined by each team independently.
The software component responsible for saving and loading should be exchangeable (keep it modular).

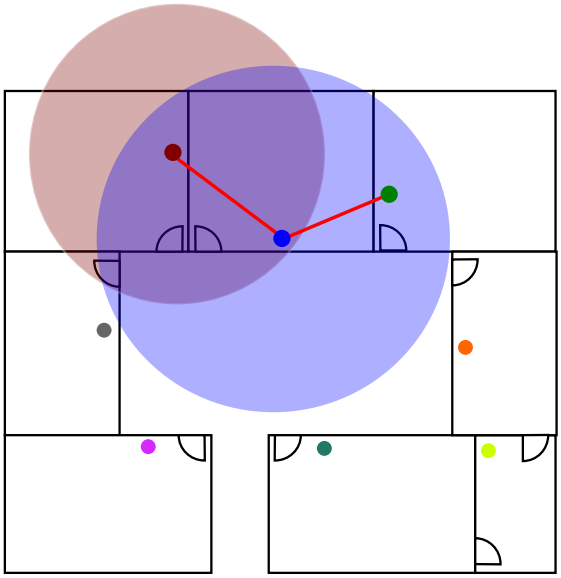

Figure 1: Example visual representation

5.2.2 Node Information

Information about the nodes shall be displayed in a unobtrusive way. This includes but is not limited to...

- node ID,
- remaining energy,
- temperature and humidity values (see 5.3),
- used channel number
- and external connected hardware.

Panel or ballonshaped popup based solutions are advised.

5.2.3 Selections

Based on various parameters, subsets of nodes that match these criteria shall be highlightable or the complementary group be made unobtrusive, e.g. by painting them half transparent. Examples include...

- "Select all nodes measuring a temperature of more than $20°C$."
- "Select all nodes of ID > 4."
- "Select all nodes with external hardware."

Regional selection like "all nodes on floor 2 or in room 123" may be excluded as the only mapping of node IDs to locations is done by the user and the devices itself are location unaware.
The more selection features are offered the better. It is up to each team to use a flat file or SQL database as data storage.

5.3 Monitoring

Monitoring is the main task of the WSN. Data has to periodically sent to or polled by a data sink and handled as well as stored by the user application. For an indeep description of the process of data aggregation and routing see section 7.
The following data has to be acquired from the WSN. The user shall be able to set or unset an update interval for all nodes. Additionally individual nodes may be queried by the user at any time (once - not continuous).

5.3.1 Temperature Monitoring

Temperature values measured by each node shall be displayed in the user application. Celsius and Fahrenheit have to be the supported units. As these values are never updated realtime a timestamp should indicate the age of the information.

5.3.2 Humidity Monitoring

Humidity values measured by each node shall be displayed in the user application. Percent relative humidity is the supported unit. As these values are never updated realtime a timestamp should indicate the age of the information.

5.3.3 Voltage and Levels

The MSP430 microcontroler of the MSB430 includes an analog-digital and digital-analog converter (AD/DA). An external voltage source may be connected to one of the input pins of the device. These values have to be displayed with the unit of Volt.
Apart from the converter, port 1 and 4, each consisting of 8 pins, are exposed. The usage of port 4 is described in 5.5. Port 1 supports interrupts on falling or raising edges. For simplicity it should be initialized to trigger an interrupt on falling edges only. The user has to be notified of this events, e.g. by a popup message including the corresponding pin number. A typical use case would be an intrusion detection system.

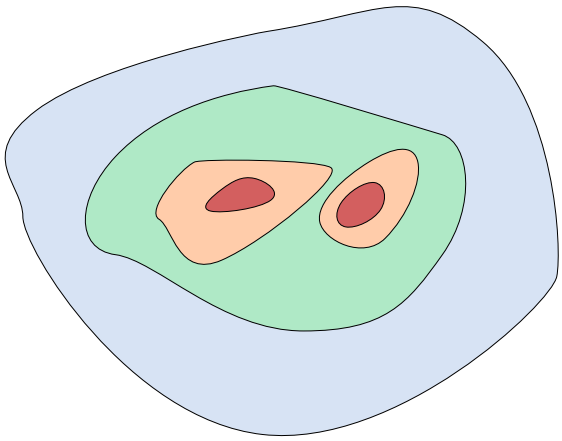

Figure 2: Example contour map

5.4 Contour Map

Based on the measured temperature and humidity values a contour map should be displayed.

Contour Map: A contour map uses contour lines to join points of equal value and thus show different regions where all nodes inside one of these have measured the same value, e.g. an isotherm is a line connecting points on a map that have the same temperature.

The used difference to define regions shall be user configurable. Figure 2 shows an example.

5.5 Actuators

Actuators enable the user to control various external connected components. Each pin of port 4 of the MSP430 shall be configured as output with a default level on system startup of low. The user application has to provide the functionality to change levels from/to high and low as well as display the current setting.
A typical use case for this feature would be a sun-blind control.

6 Data Acquisition

What metrics are important for data acquisition?

All data stored, evaluated, and displayed by the described user application must be aggregated from the network. Various metrics have to be considered:

Up-to-date Information: All displayed data represent the current state of the network. Depending on the physical values different inaccuracies are allowed:

- displayed temperature shall never differ more than 1° from the current measured value
- displayed humidity shall never differ more than 5% from the current measured value
- displayed voltage shall never differ more than 0.1V from the current measured value

These margins are given to decrease packet generation rate and prevent network congestion.

Immediacy: Triggered events have to be relayed to the sink node and further on to the user application. No more than 5s shall be between occurrence and notification independent of network size or path length.

Changed actuator setting also have to take effect in a maximum time of 5s.

Reliability: Messages sent should be routed reliable to their destination.

Stability: Even under intentional or unintentional influences that disturb the functionality of the network it shall remain usuable, e.g. by changing to another free channel without interference.

To achieve this goals it is obvious a structured approach has to be taken. A layered solution analogous to the ISO/OSI reference model is advised.

7 Medium and Network

While the user application is the most visible part of the whole software product, the sensor nodes itself need a customized firmware. This component can be split in two parts:

1. data acquirement
2. medium access, route discovery and packet forwarding

The first part is introduced and described in section 5 and 6. Drivers are provided but have to be customized. The available software component are listed in subsection 3.3.
What is left are the features that provide the sensor network with communication functionality. Medium access in the current version of the operation system and drivers is done with clear channel assessment and a backoff mechanism. This approach may be optimized but does not have to.
Route discovery and packet forwarding are part of the network layer in the ISO/OSI reference model. Depending on the chosen approach the nodes might or might not need routing tables. *The HomeAutomationCompany*™ provides no guidelines on this topic. One of many routing principles may be used. Only requirements and metrics defined in this document have to be regarded. Some of the more popular approaches are DSR, AODV or even simple flooding. Even tree based protocols like AMRIS may be chosen.
For the final evaluation a detailed statement in the submission is required (see 8.2) including answers to the following questions:

- "What alternatives have been considered?"
- "Why has the used routing algorithm been chosen?"
- "Are there limits to this approach?"
- "Does it scale?"
- "Is mobility handable?"

As mentioned in this document a layered architecture is advisable for team based development processes.

8 Evaluation Process

How is the evaluation of the different submissions done?

Presentation of each tenderers submissions will take place on:

16th of July, 2008 - 14:00 to 18:00

A finer grained schedule will be provided a week before and include preparation times for each team and a break. Order of presentation will be chosen randomly. Each presentation will be attended by all competitors.
The evaluation will be done solely based on the requirements specified in this document and judged by a competent board of examiners well trained in the domain of wireless sensor networks.
A presentation includes but is not limited to...

- high level architecture description,
- in detail introduction to the various components,
- and demonstration of the software.

On average 60min per team are expected, with all members participating - each one should do a part of this duty.
To raise the challenge and hopefully generate better outcome, adversarial teams are allowed and advised to ask questions about the competitors solutions. The primary goal is to expose drawbacks to upvalue their own submission.

8.1 Demonstration in a real world setting

Teams will be given preparation time to flash a bunch of MSB430 scatterweb nodes with their firmware. The number is not set at the time of writing but will probably exceed 30.
Afterwards the board of examiners will deploy these nodes in random locations of the building. A map with their whereabouts will be provided. In the first part of the demonstration it has to be showcased how these locations have to be input in the mentioned user application. Simple and straight forward approaches as described in section 5 will now start to pay off.
In the next step monitoring and sensornet configuration features have to be presented. After this introduction more detailed information should be provided, including reasons for the choice of...

- routing algorithm,
- media access strategy,
- and data/packet/segment formats.

8.1.1 Malicious Behavior

To testcase the behavior in "problematic" settings each team has to provide two sensor-nodes with jamming, interference, and/or intrusion features. Each of them shall try to bring the competitors network down, render it unusable, and/or inject fake data. Placement of the nodes will be done by members of the board of examiners.

8.2 Submission

After giving a talk about the solutions every team has to hand in their work consisting of...

- a scientific paper describing the solution:
  - introduction of the problem and the task to solve,
  - related work (papers must be also handed in)
  - description of the solution,
  - guide to the software,
  - documentation of non mandatory features,
  - remaining problems (why couldn't they be solved?)
- API of the developed source code (as addendum) created with Doxygen
- presentation slides
- all source code

Documentation and slides have to be handed in on schedule and in the Adobe Portable Document Format (PDF). Other formats will be not accepted.
The repository is to be used to hand in the submission.

8.2.1 Text Format

To achieve consistency and comparability all textual submissions (API documentation excluded) have to be typesetted with LaTeX[4]. The *IEEE Latex Template for Reports* is to be used[5]. Formatting rules as described in the contained documentation do apply.
Deadline for submissions is set to:

23rd of July, 2008 - 24:00

8.3 Final Stage

The last stage of the evaluation process will be done after the submission deadline and is not public. The board of examiners will discuss all solutions, based on a scientific and formal point of view. Missed deadlines, formal or other shortcomings will be penalized.

[4] http://www.latex-project.org/
[5] http://cst.mi.fu-berlin.de/teaching/SS08/19554-S-TI/IEEEtran.tar.gz

A Optional Features

The following features are not required but may be optionally implemented by each team. As mentioned before, every optional feature will be rewarded during the evaluation process (see 8).

Feature	Description
Display size Independence	The user application is destined to be run on a normal up-to-date PC. A screen resolution of minimum 1024x768px may be assumed. Future versions of the application are planned to be used on a small screen devices, e.g. a PDA or a Google Android platform mobile phone. If usability remains intact even in resolutions of about 320x240px and independently of the orientation (portrait or landscape mode) this will be a big plus.
Pamphlet	A so called flyer about the developed solution to attract customers is required to advertise the product.
Product Website	A website about the developed solution to attract customers.
Shell/Script Interface	A textual management and configuration interface.
Eye Candy	While the primary user group consists of scientific people, the usual consumer is attracted to colorful and playful interfaces. Make the layout, color and icon scheme configurable and provide samples. It should be up to the user to choose one or the other setting.

B Time Record

Fill in the time record table. Round times to the nearest whole 5 minutes, e.g. 133min → 135min.
If more than one page is required, carry the sum over to the next one. The pages have to be numbered in order.

Name: _____

First Name: _____

Team: _____

Main Task: _____

Page: _____

Date [DD.MM.YY]	Start [HH:MM]	End [HH:MM]	Duration [HOURS]	Duration cumulated	Task
			Carry-Over:		
			Sum:		

C Sample Subtask Checklist

The following checklist is provided to support the development process of all tenderers. Subtasks listed are crucial for the whole project and should neither be neglected nor disregarded. Every team should update and extend their own version of a list like this.
The list is based on the layers of the ISO/OSI reference model. Some entries might not fit into this structure.

Layer	Task	Description	Done
7	Data Acquisition	Measurement of temperature, voltage, etc. values	☐
2-7	Protocol Stack	Define interfaces for the different layers of your protocol stack	☐
2	Media Access	Handle media access to the shared medium: avoid collisions, handle hidden/exposed station, ...	☐
3	Forwarding	Relay of packets to neighbored nodes toward the destination	☐
3	Routing	Select and modify an appropriate routing algorithm resp. protocol used to update routing tables or for reactive path selection; alternative: conceive a new routing protocol	☐
4	Reliability	Ensure that sent packets/segments are received by the destination node	☐
7	Data Store	Storage of data collected from the network; could be responsible to update values if polling is used	☐
7	Visualisation	Visualisation of the sensor network, links between nodes, their radio range, etc.	☐
7	Contour Map	Visual evaluation of the measured values	☐
7	Configuration	Widgets or windows to change sensor node settings, like AD/DA output, ID, etc.	☐
2-4	Malicious Behavior	Conceive and implement an attack on the competitor's network.	☐