Wireless Sensor Networks in Heterogeneous Environments

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I. Introduction

WIRELESS sensor networks (WSNs) consist of a large amount of small and cheap sensor devices (Fig. 1). These devices are equipped with a sensor (for sampling their environment) and a simple radio (for communication with other sensor nodes).

Wireless sensor networks are typically used for environmental monitoring, home automation or as a warning system for natural disasters [1]. Due to the low cost of sensor nodes, even large areas can have many measure points. Thus, it is possible to get a very accurate view of the measured area.

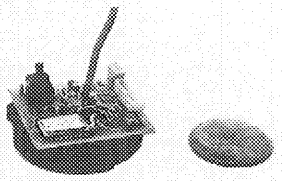

Figure 1. Size of a typical sensor node

Besides monitoring applications, WSNs are also used for *wireless building automation*: a building is equipped with many different types of sensor nodes so that different parameters like temperature, sun light and humidity can be measured. This information can be exploited to optimize the energy management, or can be used to detect emergency situations (Fig. 2).

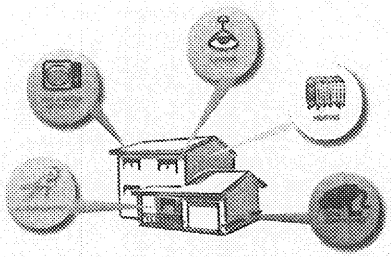

Figure 2. Wireless sensor networks can be used for the automation of buildings or remote areas.

II. Modular approach

To keep the cost of sensor nodes cheap, the capabilities of sensor nodes are very limited[1]. Thus, the software that can be installed on a sensor node is also very limited.

To communicate with neighboring nodes, each sensor node requires a protocol stack. This protocol stack contains several layers, whereby each layer fulfills several predetermined communication functions (Fig. 3a). However, this protocol stack is too complex to be programmed on sensor nodes.

It is better to let each node support only the functions which are *absolutely* required for this type of node. Therefore, we have defined an architecture where functionality is divided in modules (Fig. 3b) [2]. Network developers are free to divide these modules over the nodes as they see fit.

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[1] Available memory of a typical sensor node: 48k ROM and 10k RAM.

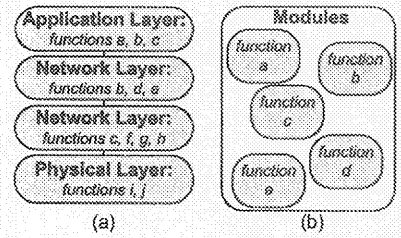

Figure 3. a) Traditional protocol stack: several layers with predefined functions. b) Modular architecture: several modules implementing different functions.

A. Supporting heterogeneous networks

When a WSN is used for *wireless building automation*, many different sensor nodes are required: light switches, fire detectors, ventilation controllers, etc. All these sensor nodes have diverging characteristics.

A modular approach can be used to support these *heterogeneous networks* [3]. Based on their capabilities, we could e.g. define 3 types of nodes: *lightweight nodes*, *advanced nodes* and *computing nodes* (Table 1).

Type node	Typically used for:	Capabilities
Lightweight	Light switches; temp. sensors	Very limited
Advanced	Light bulbs; smoke detectors	Limited
Computing	Heating and ventilation control	PC-like

Table 1. Different types of nodes used in wireless building automation

Depending on the capabilities of the nodes, more or less modules ('functions') are added.

- A lightweight node contains only a data-gathering module (which is required to sense information from the environment) and a MAC module (which is responsible for transmitting information to neighboring nodes).
- An advanced node also contains a routing module, which can forward information to a central processing PC. Advanced nodes can also check if a packet is received without errors (error correction module).
- A computing node can make intelligent decisions based on the received measurements. Computing nodes can also adjust the required QoS parameters in the network.

B. Advantages of the modular approach

The modular approach has several advantages:

- The resulting code is smaller, since only the *necessary* functions are implemented;
- Heterogeneity is promoted: additional or more advanced modules can be added to a node according to it's capabilities;
- Duplication of functionality is prevented;
- Information exchanges between the modules are possible;
- Through the replacement of modules, it is easy to adapt to changing network conditions and future developments.

III. Conclusions

Current sensor networks have several key requirements that can not be supported using the traditional layered protocols. To support advanced applications for wireless sensor networks, heterogeneity must be supported and the memory size of communication protocols must become smaller. Therefore, we proposed a modular architecture in which functionality is divided in modules.

The proposed architecture has been implemented using the TinyOS operating system [4]. Preliminary results indicate that, using our modular architecture, a lightweight node requires as little as 18kB ROM and 4kB RAM. At the same time, complex network functionalities, such as QoS, are still possible by adding more advanced nodes. The use of modular protocols is thus a very promising approach for heterogeneous sensor networks.

References

[1] Akyildiz, I. and Su, W. and Sankarasubramaniam, Y. and Cayirci, E., *Wireless sensor networks: a survey*, Computer Networks, 2002, pp 393-422.

[2] De Poorter, E. and Latré, B. and Moerman, I. and Demeester, P., *Universal Modular Framework for Sensor Networks*, International Workshop on Theoretical and Algorithmic Aspects of Sensor and Ad-hoc Networks (WTASA'07), June 28-29, 2007, pp 88 - 96.

[3] Yarvis, M. and Kushalnagar, N. and Singh, H. and Rangarajan, A. and Y. Liu and Singh, S., *Exploiting heterogeneity in sensor networks*, in Proceedings of the IEEE Infocom, vol. 2, March 2005.

[4] *TinyOS operating system*, http://www.tinyos.net/

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