Research Planning Assignment 2

Power Efficient Wireless Intelligent Technology for Wireless Sensor Networks

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1. Research area and project

My research area is in wireless sensor networks (WSN). A wireless sensor network is a network of small sensor nodes which have one or several sensors attached to it together with a radio component and some kind of data processing unit. The sensor nodes communicate wirelessly over some kind of radio interface like for instance the radio standards Bluetooth or ZigBee. These sensor nodes can be deployed in large numbers, in order of hundreds or thousands of nodes, over a geographical area to measure some kind of phenomena. Wireless networks can be used for many purposes and some application fields may be environmental surveillance, health monitoring, equipment monitoring and security surveillance etc.

When developing a WSN a number of design factors have to be accounted for in the design process. These can be as stated in [1] fault tolerance, scalability, production cost, operating environment, sensor network topology, hardware constraints, transmission media and power consumption.

In my project we are interested in the power consumption issue. This is an issue since the sensor nodes typically are battery powered and left unattended and therefore low power consumption is directly related to the lifetime of the sensor network. The most power consuming component in a sensor node is the radio and a lot of research is being made to develop power efficient ways to communicate. This includes issues like routing, clustering and synchronization.

However in this research simple inaccurate or incomplete power consumption models are often used. A complete and accurate power consumption model for the latest radio standards does not exist today and therefore our research is aimed to develop such a model for the Bluetooth radio standard version 2.0.

Bluetooth [3] is a leading radio standard for short-range wireless data communication. It was initially designed for low power consumption cable replacement but the radio interface can also be used to create multi-hop ad hoc networks called scatternets. This makes it possible to create wireless sensor networks with Bluetooth technology although its use as a large scale ad hoc networking technology has some problems as described in [8].

In Bluetooth a master device can be connected to up to seven slave devices, this is called a piconet. A piconet can only have one master device and in the piconet only master-slave or slave-master communication are allowed. A device can assume several roles simultaneously in different piconets and thus creating a scatternet. For example it can be a slave in one piconet but be a master in another
A piconet is a network of Bluetooth devices where there exists more than one piconet. An example of a scatternet is illustrated in figure 1.

Bluetooth has some power saving mechanisms built in and these are adjustable transmit power and the hold, park and sniff modes of the slaves. In hold mode the slave is inactive for a specified time length, sniff mode is similar to hold mode but with the difference that the inactive period is repeated regularly. In park mode the slave is inactive except for small periods of time where the master has the possibility to activate the slave again.

In our project we want to develop a power consumption model that takes several power consumption affecting parameters into account for example the different activity modes (master, slave, active, hold, park etc.), transmitted power level, interference, noise, data rate, scatternet structure, QoS settings etc.

2. Research method

Our method is to first develop a measurement platform. This platform will be based on the Bluetooth radio standard and consist of several sensor nodes implemented in hardware which are monitoring their power consumption. These sensor nodes will form the wireless network together with a node connected to a computer which controls the network. This control node will have the capability to reform the network structure and collect the sensor nodes power consumption data.

Secondly the power consumption model will be developed. Model parameters for this will be extracted from the measurement platform.
3. Research overview

The concept of wireless sensor networks is described well in the papers “A survey on Sensor Networks” [1], “Next Century Challenges: Scalable Coordination in Sensor Networks” [2] and “Wireless integrated network sensors” [9]. These papers I believe can be called seminal papers since they are often cited by others.

The first mentioned paper [1] describes as stated the concept of WSNs but it also identifies many open research issues regarding WSNs. The paper divides the research issues by their place in the OSI seven layer model. Power efficiency is a repeated topic in many of the lower layers research issues. In the physical layer it concerns low power modulation schemes and power efficient hardware design. In the data link layer it may be power saving modes of operation. At the network layer it is power efficient routing protocols and network topology.

In [2], the scalability issues of WSNs are the main concern. They believe among other things that wireless sensor networks will unlike traditional networks be Data-Centric which means that a node may not have an identity. A sensor network application won’t ask: “What is the temperature at sensor node X” but rather ask the network: “What is the temperature at location Y”.

The last mentioned paper [9] also describes the concept of WSNs and it also describes different challenges divided into physical principles, signal processing architectures, network architecture and node architecture when designing a sensor network.

In the area of power consumption models for Bluetooth devices some efforts have been done. In [5] “The Power Consumption of Bluetooth Scatternets” such a model is presented. It is the most complete model in the literature today and it has been validated by hardware measurements. However the model lacks power consumption affecting parameters like transmitted power level, interference, noise, park and hold modes etc.

In [6] “FSM-Based Modeling of Wireless Protocols: the Case of Bluetooth” a high level modeling methodology is used in contrast to the node-level model presented in [5]. The modeling methodology is based on Finite State Machines used to predict the energy consumption of a certain communication task.

In [4] “Power Characterization of a Bluetooth-based Wireless Node for Ubiquitous Computing” a node level analysis of the power consumption characteristics of a Bluetooth device has been done. No regards has been taken to scatternet situations, transmitted power level or power saving modes of operation.
Besides the efforts to create a power consumption model for bluetooth nodes various research has been made to make WSNs more power efficient. An example of this is the paper [7] “Power-Efficient and QoS-Aware Scheduling in Bluetooth Scatternet for Wireless PANs” in which a scheduling algorithm is proposed to eliminate wasted time slots due to guard time in the bridge nodes between two piconets. In [10] two power management policies that selects the best configuration between two bluetooth nodes is presented. In [11] a new scatternet formation algorithm is presented that enhances the lifetime of the network.

4. Key conferences

There exist few conferences dedicated purely to wireless sensor networks but many conferences has it as a topic amongst others.

**EWSN**  The European conference on Wireless Sensor Networks goal is to be a forum for researchers with different backgrounds to discuss cross-layer integration, new solutions to problems and the future of wireless sensor networks.

**SenSys**  ACM conference on embedded networked sensor systems. A forum to present research results within the area of embedded networked sensors and to discuss research challenges concerning the design, deployment, use and fundamental limits of these systems.

**MobiCom**  Annual International Conference on Mobile Computing and Networking sponsored by ACM. This conference covers all areas of mobile computing and mobile and wireless networking at link layer and above.

**Mobihoc**  ACM International Symposium on Mobile Ad Hoc Networking and Computing. This symposium focuses on wireless mobile ad hoc networking and computing.

**MASS**  International Conference on Mobile Ad-hoc and Sensor Systems sponsored by IEEE. The conference focuses on multi hop, ad hoc and sensor networks covering areas from the physical to the application layer.

**WCNC**  IEEE Wireless Communications and Networking Conference. WCNC is a conference for researchers, industry professionals and academics which address all areas of wireless communication.

**INFOCOM**  IEEE Conference on Computer Communications. INFOCOM cover topics in computer communication and networking including sensor networks.
SECON is the IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks. SECON is a conference with participants from the industrial, academic and government sector and focuses on the communication, networking, applications, systems, algorithmic and implementation aspects of mesh and sensors networks.

5. Leading research groups

Today wireless sensor networks research is conducted at several places and some of these places are:

**Universidad Politécnica de Valencia:** The Fault-tolerant Systems Research Group and the Sensors and Magnetism Research Group perform research on sensor networks, related network protocols and their use in environmental and agricultural applications.

**Massachusetts Institute of Technology (MIT):** Computer Science and Artificial Intelligence Laboratory. The Networks and Mobile Systems Group conducts research in several areas of networking and mobile computing including sensor networks.

**MIT:** The µAMPS project performs research in the design and implementation of wireless sensor network. Some of the key design elements in the µAMPS project are scalability, energy efficiency, self-configuration, reconfigurability and flexibility.

**University of California at Berkeley:** Berkeley Wireless Research Center conducts research in wireless communication. One of their more interesting project is the Picoradio project where they have developed a small wireless sensor node with low power consumption.

**Swiss Federal Institute of Technology Zurich (ETH Zurich):** The Communication Systems Groups core research topics are wireless and ad hoc networking, future internet architecture and protocols and network measurements and vulnerability analysis.

**Defence Advanced Research Agency (DARPA):** The SensIt program conducts research in large scale sensor networks. Some of their key issues are scalability, self-organizing, energy and bandwidth efficiency, flexibility and low latency.

**University of California Los Angeles (UCLA):** Center for Embedded Networked Sensing (CENS) is researching in the area of embedded networked sensing technology. Their research is both technology and applications oriented.
6. References


