



# **iJRASET**

International Journal For Research in  
Applied Science and Engineering Technology



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# **INTERNATIONAL JOURNAL FOR RESEARCH**

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

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**Volume: 2**

**Issue: XI**

**Month of publication: November 2014**

**DOI:**

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# Implementation Issues in Bluetooth Based Smart Sensor Network

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**Abstract**— In this paper we focus on wireless sensor networks and Bluetooth issues related to its use in sensor networks. An implementation platform for a Bluetooth based sensor network is presented and functionalities are described. We explore hardware platform, software implementation issues and possible solutions of a Bluetooth based sensor network with visible near future application scenario.

**Keywords**—Smart Sensor Node, Sensor Network Gateway, JXTA middleware, Gateway Abstraction Layer

## I. INTRODUCTION

As Bluetooth is a low-cost, short-range wireless technology, small power consumption has reasonable throughput and hence suitable for various small, battery driven devices like mobile phones, PDAs, cameras, laptops etc. Hence for these reasons, Bluetooth is now developing not just as a point-to-point, but as a network technology as well.

The main challenge in front of Bluetooth developers now is to prove interoperability between different manufacturer devices and to provide numerous interesting applications. An example of these applications is a wireless sensor network. The main issues during the implementation of Bluetooth based sensor network like connection establishment delay and networking functionality, have to be solved before Bluetooth can be deployed in large sensor networks are presented in this paper.

## II. BLUETOOTH BASED SENSOR NETWORK

Bluetooth operates in the 2.4GHz frequency band and uses frequency hopping spread spectrum technique. There are 79 channels, each 1MHz wide, available for hopping. Time required for communication establishment can be lengthy of around 5s (minimum is 0.00375s and maximum is 12.8s-33.28s). Hence delay becomes the limiting factor for applications that require instant connection establishment which is unacceptable in applications like process control that requires immediate response from the command centre. Using scatternets give higher throughput and multi-hop connections between devices in different piconets are possible. But, hardware currently available does not support this functionality due to following reasons:

- Scheduling the switches between piconets in such a way so as to maintain uninterrupted communication links with devices.
- Clock Synchronization- Each time a device switch between piconets it might lose up to two slots for communication due to difference in piconet's clocks.
- Lack of Specifications for Slave- There is no way a slave to demand park, hold or sniff mode. It can only request it from the master so there is no guarantee that the slave will be allowed to leave one piconet and join the other. Several schemes for scatternet operation are proposed [1], [2], but so far none of them is implemented. A possible solution, before scatternet is supported by Bluetooth hardware, could be to perform switching between piconets at application level.

### A. Scatternet Building Mechanism

For the Scatternet building mechanism it is assumed that all nodes in the network are peer nodes. A mitigating circumstance for sensor networks is that gateway can be used to direct establishment of the scatternet. Using such centralized approach it was possible to generate more optimum network topology and solve scheduling, bandwidth allocation and routing easier [3].

The additional request for scatternets in sensor networks does complicate building of scatternet. Various sensor types produce different amount of data (like video sensor and temperature sensor). If too many high-output sensors are connected to the same branch in the scatternet it can cause link congestion or buffer overflow in intermediate nodes. Hence, parameters like number of sensors, amount of data generated by sensor per measurement and buffer size should be taken into account during building scatternet topology.

## III. SENSOR NETWORK IMPLEMENTATION TECHNIQUE

This section focuses on building a hardware platform and generic software solutions that can serve as the basis for the wireless sensor network. It intends to discuss the support for ad-hoc deployment of sensors, sensor characteristics that can be automatically collected and presented in a structured way using XML. Also it must have no limits in terms of sensor type, number of sensors, generic functions for querying sensors and collecting replies and the basis for attribute-based routing.

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Software architecture is such that new protocols can be added easily without affecting current functionality. The sensor network should consist of several smart sensor nodes and a gateway. Each smart node can have several sensors and is to be equipped with a micro-controller and a Bluetooth radio module. Gateway to have wireless interfaces: Bluetooth for communication with sensors and GPRS for communication with users. Gateway and smart nodes are members of one piconet and hence maximum 07 smart nodes can exist simultaneously at a given time in the network.

### A. Smart Sensor Node Implementation

The smart sensor node comprises of three functional blocks sensing, data processing and communication (Figure.1). One or more sensors can be attached to the microcontroller like temperature, pressure etc.

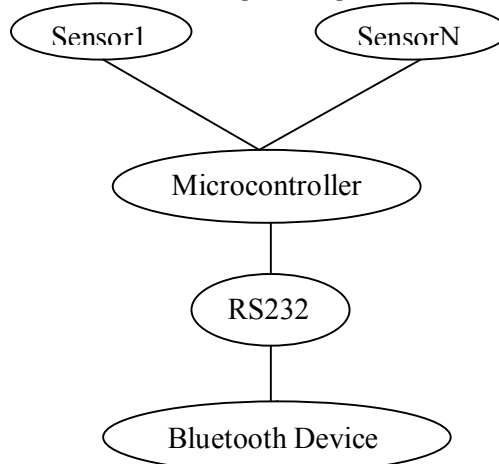


Figure.1 Smart Sensor Node

Microcontroller is responsible for the smart sensor node logic. An application gathers data from sensors and controls Bluetooth module and communication with the gateway. It also stores sensors profiles and data.

The microcontroller provides set of AT commands for control of Bluetooth connections over serial communication like RS232 interface. Use of microcontroller and serial interface however gives the following drawback:

- SDP (service discovery protocol) is not supported and it is not possible to assign major and minor device class, and service class of the device.
- Only serial port profile is supported.
- Size of the smart sensor node is much bigger than required for many applications.

### B. Implementation Issues For Sensor Network Gateway

The gateway controls the network establishment, information collection about current smart sensor node and sensors relating it. As the gateway is master of the piconet, in a sensor network it provides access to them. Accordingly, it is desired to have a set of core services for common procedures like logging, scheduling, event description etc. for software architecture (figure.2). Communication Interface for sensor network interacts with sensors that use Bluetooth to access the network. Hence using Bluetooth many sensor networks get attached with Gateway.

Many bluetooth stacks are available in market for various operating systems. They support different HCI (host controller interface) interfaces (serial port, USB, etc.) and provide different APIs. This resulted in a Bluetooth stack API standardization so called JSR-82 JABWT (Java API for Bluetooth Wireless Technology). Also a Bluetooth PCMCIA card may be used for the Bluetooth interface. GPRS connection can be established either over a GPRS PCMCIA card or using infrared connection with GPRS enabled mobile phone.

| Applications  |                                 |                 |
|---------------|---------------------------------|-----------------|
| Core Services | Sensor N/W API                  | JXTA API        |
|               | Abstraction Layer of Sensor N/W | JXTA Middleware |
|               | Network Interface               |                 |
|               | Bluetooth                       | GPRS            |

Figure.2 Software Architecture of Gateway

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The sensor network abstraction layer and its API are independent of the underlying communication technology and provide information about and access to all available sensors in the network. Public network interface provide access to GPRS services of a public network. JXTA middleware acts as a framework for establishment of a P2P network of gateway over a wide area network. Application layer designates either local applications that reside on the gateway itself or remote applications that access the network over the GPRS network.

### *C. Discovering a Smart Sensor Node*

This is a first process after gateway initialization. Its function is to discover all sensor nodes in the region followed by making a list of sensor's characteristics and network topology. This process is periodic to check addition/deletion of sensors. The method can be summarized as follows:

Initialization of Gateway- As new Bluetooth device is discovered, its major and minor device class are checked. These parameters are obtained along with the Bluetooth address and other parameters. The parameters are set by each node to define type of the device (Major class = "smart sensor node") and type(s) of attached sensors (Minor class = "temperature"). Service class field can be used to give additional description of offered services like sensor accuracy, manufacturer, etc. When discovered device is not smart node it is rejected. If the discovered device is smart node then the SDP is invoked and service database of the discovered smart node is searched for sensor services. Then the database is searched for the serial port profile connection parameters.

When the connection string is obtained from the device Bluetooth link is established and data exchange with smart node can begin.

1) *Implementation Issues In Method:* Since Bluetooth does not support SDP connection link. Recent work [7] first builds connection string by concatenation of Bluetooth address of discovered device and server channel number used by smart nodes Bluetooth module. After this, establishing connection is attempted. However this may always not be successful. If the connection is established successfully protocol for data exchange with sensors has to be invoked. If this is done communication with microcontroller needs to be established.

This is inefficient way of connection building as it wastes energy and causes unnecessary delay due to establishment of unnecessary links.

### *D. Smart Sensor Node Communication*

For sending and receiving data to and from sensors flexible data exchange protocol is required. Reply messages should relay information about any type of sensor. Also the messages should have a flexible structure (preferably XML based). Gateway can request list of sensors attached to particular smart sensor node or the sensor data. All relevant information about a sensor is contained in its profile (sensor type, measuring unit, accuracy, manufacturer, calibration date, etc.), gateway can automatically build knowledge of sensor network and its characteristics. Hence the sensors be deployed in an ad-hoc fashion.

As soon as event happens on the sensor side, the sensor will send information to gateway about it, since Bluetooth links are maintained as long as smart sensor node and gateway are in range.

However, power is required to maintain communication link and only 07 smart nodes are possible in one piconet .

### *E. Abstraction layer*

Gateway abstraction Layer uses sensor profile to create list of objects that represent each sensor in the network. Each object provides way that enable sending and receiving data from sensor. Application can access sensor objects for data of their interest using query. After this the data description is compared in the query and profiles associated with each sensor, gateway determines the sensor that has data/answer. Collected replies can be forwarded to users in a structured XML.

For larger network and scatternet topology functionality has to be provided by each master in the scatternet and appropriate attribute-based routing solutions would be required to handle queries. Data aggregation rules would have to be defined and could be easily combined with the XML structured description.

## IV. APPLICATIONS

The feature of this method would result in wide range of applications for sensor networks. Possible scenarios are highlighted below:

Military and security - The initial push towards wireless sensor network research came from military agencies. Military applications are various and vary from monitoring soldiers in the field, to tracking vehicles or enemy movement.

Sensors attached to soldiers, vehicles and equipment can gather information about their condition and location to help planning



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activities on the battlefield.

In case of nuclear or biological attacks, sensor fields can gather valuable information about the intensity, radiation people to danger.

Seismic, acoustic and video sensors could be deployed to monitor critical terrain and approach routes or reconnaissance of enemy terrain.

Health monitoring - Wireless sensor networks can be used in various ways to improve or enhance health care services. Monitoring of patients, health diagnostics, drug administration in hospitals, tele-monitoring of human physiological data and tracking and monitoring doctors and patients inside a hospital are some of the possible scenarios. Various sensors (blood pressure, heart monitoring, etc.) can be attached to the patient's body to collect physiological data that can be either stored locally (on a PDA or home PC) or forwarded directly to the hospital server or to the doctor in charge.

Wearable sensors can also be used to track patients and doctors in the hospital or to monitor and detect behavior and health condition of elderly persons and children.

Industrial safety - Similar to personal health-care scenarios, wireless sensor networks can be used for "health-care" of buildings, bridges or highways. In such scenarios thousands of various sensors could be deployed in and around monitored object and relevant information is gathered and analysed in order to assess condition of the object after a natural or man-made disaster.

Similarly, sensor can be used to monitor the status of different machines in factories, along with the air pollution or fire monitoring.

Environmental monitoring - Fire detection, water pollution monitoring, tracking movements of birds, animals or insects, detection of chemical and biological agents are some of the examples of environmental applications of wireless sensor networks.

For example, numerous smart sensor nodes with temperature sensors on board can be dropped from an airplane over a remote forest

Other applications - Home automation, smart environments, environmental control in office spaces, detecting car thefts, vehicle monitoring and tracking, interactive toys are examples of other possible applications

### V. CONCLUSION

Wireless sensor networks are an interesting research area with many possible applications. They are based on collaborative effort of many small devices capable of communicating and processing data. Bluetooth presents a great chance for sensor-network architecture. This architecture heralds wireless future for home and also for industrial implementation. Bluetooth is a possible choice for data communication in sensor networks. Good throughput, low-power, low-cost, standardized specification and hardware availability are Bluetooth advantages, while slow connection establishment and lack of scatternet support are some of the deficiencies. With a Bluetooth link, users only need to bring the devices within range and the devices will automatically link up and exchange information. Thus implementation of Bluetooth technology for sensor network not only cuts wiring cost but also integrates the industrial environment to smarter environment.

An initial implementation platform of a Bluetooth based sensor network is presented and functionalities are described. The platform intends to present a good environment for further research and development of sensor network protocols and algorithms

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