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Bluetooth Based Smart Distributed Sensor Networks

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ABSTRACT: **Various sensors are already in a broad use today as part of different devices or as standalone devices connected to a network usually to monitor industrial processes, equipments or installations. The advancements in technology, wireless communications have enhanced development of small, low power and low cost devices. Such devices when organized into a network, present a powerful platform that can be used in many interesting applications. Bluetooth is a low cost, short-range, wireless technology with small footprint, low power consumption and reasonable throughput. Bluetooth wireless technology has become global technology specification for "always on" wireless communication not just as a point-to-point but was a network technology as well.**

Key words: **DCS, Pico Net, TEDS, Scatter Net, LMP, Sensor**

1. INTRODUCTION

The communications capability of devices and continuous transparent information routes are indispensable components of future oriented automation concepts. Communication is increasing rapidly in industrial environment even at field level. In any industry the process can be realized through sensors and can be controlled through actuators. The process is monitored on the central control room by getting signals through a pair of wires from each field device in Distributed Control Systems (DCS). With advent in networking concept, the cost of wiring is saved by networking the field devices. But the latest trend is elimination of wires i.e., wireless networks.

Wireless sensor networks - networks of small devices equipped with sensors, microprocessor and wireless communication interfaces. In 1994, Ericsson Mobile communications, the global telecommunication company based in Sweden, initiated a study to investigate, the feasibility of a low power, low cost ratio interface, and to find a way to eliminate cables between devices. Finally, the engineers at the Ericsson named the new wireless technology as "Blue tooth" to honor the 10th century king if Denmark, Harald Blue tooth (940 to 985 A.D). The goals of blue tooth are unification and harmony as well, specifically enabling different devices to communicate through a commonly accepted standard for wireless connectivity.

2. BLUE TOOTH

Blue tooth operates in the unlicensed ISM band at 2.4 GHZ frequency band and use frequency hopping spread spectrum technique. A typical Blue tooth device has a range of about 10 meters and can be extended to 100meters. Communication channels support total bandwidth of 1 Mb / sec. A single connection supports a maximum asymmetric data transfer rate of 721 KBPS maximum of three channels.

2.1. Bluetooth–Networks: In blue tooth, a Pico net is a collection of up to 8 devices that frequencies hop together. Each Pico net has one master usually a device that initiated establishment of the Pico net, and up to 7 slave devices. Master's Blue tooth address is used for definition of the frequency hopping sequence. Slave devices use the master's clock to synchronize their clocks to be able to hop simultaneously.

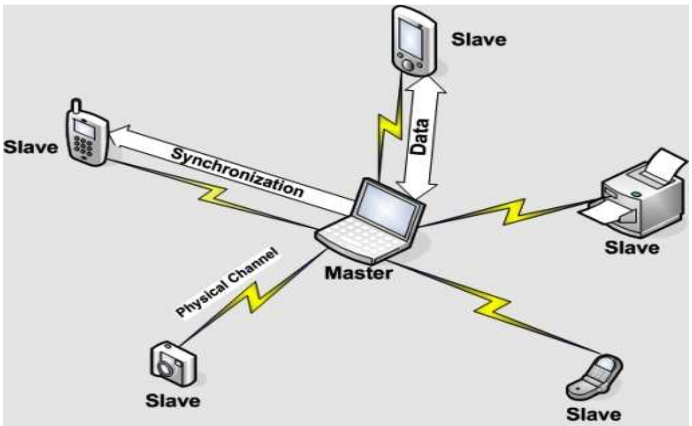

Figure.1. Pico Net

When a device wants to establish a Pico net it has to perform inquiry to discover other Blue tooth devices in the range. Inquiry procedure is defined in such a way to ensure that two devices will after some time, visit the same frequency same time when that happens, required information is exchanged and devices can use paging procedure to establish connection. When more than 7 devices need to communicate, there are two options. The first one is to put one or more devices into the park state. Blue tooth

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defines three low power modes sniff, hold and park. When a device is in the park mode then it disassociates from and Pico net, but still maintains timing synchronization with it. The master of the Pico net periodically broadcasts beacons (Warning) to invite the slave to rejoin the Pico net or to allow the slave to request to rejoin. The slave can rejoin the Pico net only if there are less than seven slaves already in the Pico net. If not so, the master has to 'park' one of the active slaves first. All these actions cause delay and for some applications it can be unacceptable for e.g.: process control applications that requires immediate response from the command centre (central control room). Scatter net consists of several Pico nets connected by devices participating in multiple Pico net. These devices can be slaves in all Pico nets or master in one Pico net and slave in other Pico nets. Using scatter nets higher throughput is available and multi-hop connections between devices in different Pico nets are possible. i.e., the unit can communicate in one Pico net at time so they jump from pioneer to another depending upon the channel parameter.

2.2. Scatter net:

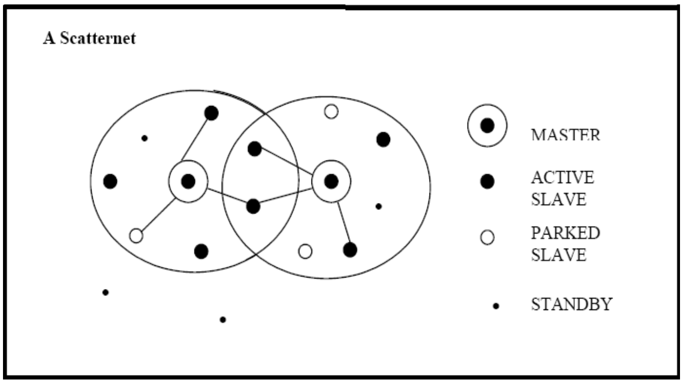

Figure.2. Scatter net

The main challenge in front of Bluetooth developers now is to prove Interoperability between different manufactures devices and to provide numerous interesting applications. One of such applications is wireless sensor networks. Wireless sensor networks comprise number of small devices equipped with a sensing unit, microprocessors, and wireless communication interface and power source.

- An important feature of wireless sensor networks is collaboration of network nodes during the task execution.
- Another specific characteristic of wireless sensor network is Data-centric nature.

As deployment of smart sensor nodes is not planned in advance and positions of nodes in the field are not determined, it could happen that some sensor nodes end in such positions that they either cannot perform required measurement or the error probability is high. For that a redundant number of smart nodes is deployed in this field. These nodes then communicate, collaborate and share data, thus ensuring better results. Smart sensor nodes scattered in the field, collect data and send it to users via "gateway" using multiple hop routes.

2.3. Wireless sensor network:

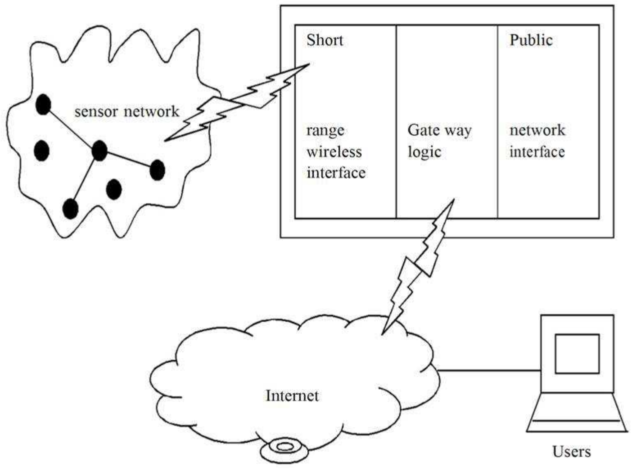

Figure .3: Wireless sensor network

From the user point of view tasking are two main services provided by wireless sensor networks. Queries are used when user requires only the current value of the observed phenomenon. Tasking is a more complex operation and is used when a phenomenon has to be observed over a large period of time .Both queries and tasks of time to the network by the gateway which also collects replies and forwards them to users.

2. SENSOR NETWOR IMPLEMENTATION

The main goal of our implementation was to build a hardware platform and generic software solutions that can serve as the basis and a test bed for the research of wireless sensor network protocols. Implemented sensor network consists of several smart sensor nodes and a gateway. Each smart node can have several sensors and is equipped with a micro-controller and a blue tooth radio module. Gate way and smart nodes are members of the Pico net and hence maximum seven smart nodes can exist simultaneously in the network. For example, a pressure sensor is implemented, as blue tooth node in a following way. The sensor is connected to the blue tooth node and consists of the pressure sensing element, smart signal-conditioning circuitry including calibration and temperature compensation, and the Transducer Electronic Data Sheet (TEDS). These features are built directly into the sensor microcontroller used for node communication control plus memory for TED's configuration information.

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2.1. Smart Sensor Node Architecture: The architecture shown in figure can easily be developed for specific sensor configurations such as thermocouples, strain gauges, and other sensor technologies and can include sensor signal conditioning as well as communications functions.

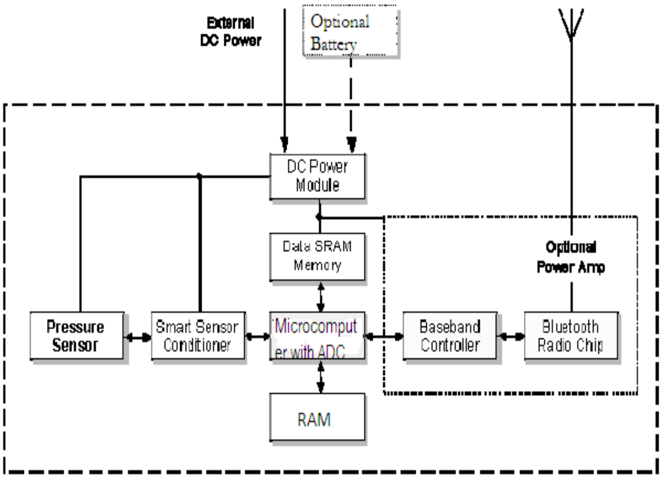

Figure.4. Bluetooth wireless smart pressure sensor node

Conditioned along sensor signal is digitized and digital data is then processed using stored TEDS data. The pressure sensor node collects data from multiple sensors and transmits the data via blue tooth wireless communications in the 2.4 GHZ base band to a network hub or other internet appliance such as a computer. The node can supply excitation to each sensor, or external sensor power can be supplied. Up to eight channels are available on each node for analog inputs as well as digital output. The sensor signal is digitized with 16-bit A/D resolution for transmission along with the TEDS for each sensor. This allows each channel to identify itself to the host system. The node can operate from either an external power supply or an attached battery. The maximum transmission distance is 10 meters with an optional capability to 100 meters.

The IEEE 1451 family of standards are used for definition of functional boundaries and interfaces that are necessary to enable smart transducer to be easily connected to a variety of networks. The standards define the protocol and functions that give the transducer interchangeability in networked system, with this information a host microcomputer recognized a pressure sensor, a temperature sensor, or another sensor type along with the measurement range and scaling information based on the information contained in the TEDS data. With blue tooth technology, small transceiver modules can be built into a wide range of products including sensor systems, allowing fast and secure transmission of data within a given radius (Usually up to 10m). A blue tooth module consists primarily of three functional blocks – an analog 2.4 GHz. Blue tooth RF transceiver unit, and a support unit for link management and host controller interface functions.

The host controller has a hardware digital signal processing part- the Link Controller (LC), a CPU core, and it interfaces to the host environment. The link controller consists of hardware and software parts that perform blue tooth based band processing, and physical layer protocols. The link controller performs low-level digital-signal processing to establish connections, assemble or disassemble packets, control frequency hopping and correct errors and encrypt data.

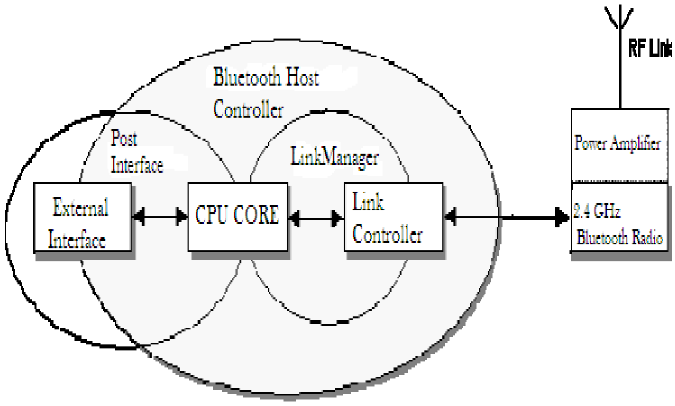

Figure.5. Blue tooth module Hardware Architecture

The CPU core allows the blue tooth module to handle inquiries and filter page request without involving the host device. The host controller can be programmed to answer certain page messages and authenticate remote links. The link manager (LM) software runs on the CPU core. The LM discovers other remote LMs and communicates with them via the link manager protocol (LMP) to perform its service provider role using the services of the underlying LC. The link manager is a software function that uses the services of the link controller to perform link setup, authentication, link configuration, and other protocols. Depending on the implementation, the link controller and link manager functions may not reside in the same processor. Another function component is of course, the antenna, which may be integrated on the PCB or come as a standalone item. A fully implemented blue tooth module also incorporates higher-level software protocols, which govern the functionality and interoperability with other modules. Gate way plays the role of the Pico net's master in the sensor network. It controls establishments of the network, gathers information about the existing smart sensor nodes and sensor attached to them and provides access to them.

2.2. Discovery of the Smart Sensor Nodes: Smart sensor node discovery is the first procedure that is executed upon the gateway installation. It goals to discover all sensor nodes in the

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area and to build a list of sensor's characteristics and network topology. Afterwards, it is executed periodically to facilitate addition of new or removal of the existing sensors. The following algorithm is proposed. When the gateway is initialized, it performs blue tooth inquiry procedure. When the blue tooth device is discovered, the major and minor device classes are checked. These parameters are set by each smart node to define type of the device and type of the attached sensors. Service class field can be used to give some additional description of offered services. if discovered device is not smart node it is discarded. Otherwise service database of the discovered smart node is searched for sensor services. As currently there is no specific sensor profile, then database is searched for the serial port profile connection parameters. Once connection strings is obtained from the device. Blue tooth link is established and data exchange with smart mode can start.

3. DESIGN

We must take into account the following characteristics of our platform when designing a multi hope network assembly procedure:

3.1. Bluetooth Connection Establishment: Bluetooth connections are established between a master and a slave. The assembly procedure must establish the role of each node with respect to a connection. Note that nodes cannot exchange information before they have established a connection. In addition, slaves cannot communicate with other slaves or overhear the communication taking place on other connections. As a result, we cannot use protocols involving spontaneous communication among neighbor nodes.

3.2. Dual Radio Approach: There are three possible configurations for each dual-radio node:
(i) a node can be connected as slave on its two radios,
(ii) a node can be connected as slave on one radio and as master with up to seven connections on the other radio
(iii) a node can be connected as master with up to seven connections on both its radios.

3.3. Device Discovery Protocol: In order for two devices to discover each other, they must be in two complementary states at the same time: Inquiry and inquiry scan. The inquiring device continuously sends out is anybody out there messages hoping that these messages (known as ID packets) will collide with a device performing an inquiry scan. To conserve power a device wanting to be discovered usually enters inquiry scan periodically and only for a short time known as the inquiry window. During this period, the device listens for inquiry messages.
The main challenges for the assembly procedure are thus
(a) To pick up pairs of nodes that should be connected and
(b) To decide the attribution of slave and master for each connection.

A first approach would be for the nodes to discover their physical location (e.g., each node discovering its neighbors), and to exchange this information with each other in order to reach a decision concerning their configuration. Such an approach would allow constructing robust networks with multiple paths between nodes. Bluetooth however offers limited support for such solutions. The device discovery protocol can be used to discover neighbors; however connections need to be established between pairs of nodes to distribute the discovered information. A second approach consists in configuring each node a priori. Each node is configured with a radio operating as a master and the other operating as a slave. This obliterates the need for the discovery and information exchange phases from the first approach. The second approach constitutes a baseline. We chose to implement it on top of our Tiny Bluetooth stack. Our baseline solution, inspired by Blue Tree (discussed below), is the following.

- When a node boots up, it enables one of its radios (the slave radio) and starts looking for another node to connect to. In this stage, the node will not be discoverable/visible for other nodes
- it considers itself an orphan looking for a network. If it discovers other nodes, it tries to connect to one of them as a slave4. If the connection succeeds, it will consider itself member of the network, and turn on its other radio (the master radio), making it discoverable and ready to accept connections from nodes that are not currently members of the network.
- If the connection as a slave fails, it is because the master has reached its limit on the number of connection it can accept (recall that a master can connect to seven slaves).
- The node then tries to connect to one of the other nodes it has found in its vicinity. If there is no such other nodes ready to accept a connection then the node tries to connect again to the first node it contacted. If a master connected to seven slaves receives three repeated connection requests from the same node N, then it disconnects one of its slaves and accepts the connection from the node N.
- It has been shown that when a master is connected to more than five slaves, additional slaves are in connection range with at least one of the connected slaves. As a consequence, it is probable that the disconnected node will find a node that it can connect to in its vicinity.
- When a node is disconnected from its parent (on its slave radio), it does not try to find a new parent node to which it could connect (because it is probable that it will try connecting to its own children). Instead, it disconnects in turn all the connections

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on its master radio. As a consequence, when a node is disconnected (due to a failure or because a master has more than seven slaves), all nodes directly or indirectly connected to this node will end up being disconnected. They start again as orphan nodes; the assembly procedure is restarted, and a connected multi hop network is reconstructed (if at all possible).

4. CONCLUSION

Blue tooth represents a great chance for sensor-networked architecture. This architecture heralds wireless future for home and also for industrial implementation. With a blue tooth RF link, users only need to bring the devices with in range, and the devices will automatically link up and exchange information. Thus implementation of blue tooth technology for sensor networks not only cuts wiring cost but also integrates the industrial environment to smarter environment. Today, with a broader specifications and a renewed concentration on interoperability, manufacturers are ready to forge ahead and take blue tooth products to the market place. Embedded design can incorporate the blue tooth wireless technology into a range of new products to meet the growing demand for connected information appliances. Future work is aimed to develop and design a blue tooth-enabled data concentrator for data acquisition and analysis.

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