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Bluetooth Networks and Wireless Sensors

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Abstract

Radio technology usage in an industrial environment requires special attention regarding destination. Bluetooth technology used to access a built-in user interface based on WEB/WAP technology is mainly destined for configuration and maintenance and are not mission-critical applications. Bluetooth usage to transfer real time information from process, between different devices in an industrial plant may be used for more or less mission-critical applications. In this case the radio link reliability is very important in order to reach high demands and real-time performance. Important issues are, for example, interference with other radio standards and other radiating sources, which could be industrial devices or commercial devices like microwave ovens. Another important issue consists on communication error detection and correction. This paper is presenting data transfer capabilities in wireless sensor networks (WSN) over Bluetooth.

Key words: *Bluetooth, wireless sensor network, data transfer, wireless network*

Introduction

Industrial distributed control system sensors, actuators and controllers communicate over a network. The advantage of this architecture is flexibility, which allows using the same computer for more than one control loops. Also relieves us to avoid the problem of placing the controller close to the controlled process. Those permit to build control systems in a hierarchical manner. The usage of networks has increased radically over the last years and new concepts and technologies were introduced. Twenty years ago the Ethernet technology was initially rejected by the industrial environment, considered as an unreliably data transmission method.

In today context wired networks are very reliable communication systems for instruments and controls. Wireless technology promises low-costs and low-power consumption than wired devices. Sensor and actuator networks are used in various domain like wireless data acquisition, machine monitoring, smart buildings, environmental monitoring and in many other areas.

A Wireless Sensor Network (WSN) protocol is represented by the corresponding OSI layers: application, transport, network, data link and physical. Currently two standard technologies are available for WSN: ZigBee and Bluetooth, but ZigBee don’t represent a concern of this paper. The approaches of this paper treat the Bluetooth link at the corresponding Data Link layer of OSI model. At this level data packets are prepared for the physical layer and are encapsulated in a frame similar to Ethernet frame.

Bluetooth packet format must be defined to encapsulate OSI layer 3 network protocols to enable devices to exchange information. This paper presents the packet format used to transport networking protocols over the Bluetooth link [2].

Bluetooth Technology Reliability

Bluetooth is a short-range wireless low-cost and low-energy technology, operating in the 2.4 GHz ISM band. Bluetooth model represent a layered architecture based on profiles. Devices such as notebook computers, phones, PDAs, and other computing devices incorporate Bluetooth as a part of the device. Bluetooth enabled devices have the ability to form networks and exchange information based on master-slave connection model [1]. The packet format is defined by Bluetooth Network Encapsulation Protocol (BNEP) based on Ethernet II as is specified by IEEE 802.3 standard. BNEP encapsulates packets from others networking protocols, which are transported directly over the Bluetooth Logical Link Control and Adaptation Layer Protocol (L2CAP) [2].

The Bluetooth protocol stack, profiles and functionalities was described in a previous paper [4] and more details are described in Bluetooth core specifications [1]. The main purpose of this paper is to present Bluetooth network functionalities and aspects that recommend Bluetooth links for use in industrial environment. We must have in mind that Bluetooth was designed with a big concern to the reliability and there are several concepts used to achieve this objective. [1]

Frequency-hopping Code Division Multiple Access

The Bluetooth operating radio band is divided into 79 channels at 1MHz each slots and new frequency slot is used at 625μS. Each pair of devices communicating establishes its own frequency-hopping schema at initial connection. Frequency hopping algorithm must be chosen in order to avoid conflicts and interferences as much as possible. This method is also known like Frequency Hope Spread Spectrum and is part of Bluetooth core specification.

Error Correction

Bluetooth uses two different Forward Error Correction (FEC) methods. One FEC codes uses, 1/3 rate code and the other uses 2/3 rate code. First method is used for the packet header and the second one is destined to application data. This is a short Hamming code version that enables to automatically correct all one bit errors and detect all two bit errors.

Reliability and level of trust is assured by a packet retransmission schema. Each data packet contains a CRC checksum for errors detection. Also, each transmitted packet contains an ACK/NAK bit that indicates the status of previous received packet. Retransmission is done if packets are lost or NAK-ed. This mechanism is similar with Transmission Control Protocol (with minor differences) used in Internet to ensure de reliability of communications. [8]

Bluetooth Networking Encapsulation Protocol (BNEP)

Bluetooth protocol stack provide one protocol designed to support networking over Bluetooth wireless link: Bluetooth Networking Encapsulation Protocol (BNEP). This protocol is implemented using connection oriented Logical Link Control and Adaptation Layer Protocol (L2CAP) channels. At this level Bluetooth is considered to be a transmission link, L2CAP act like Media Access Control (MAC) sub layer of Ethernet and is based on physical addressing schemas. In this way BNEP must met some basic requirements like support for common

networking protocols such as IPv4, IPv6, and IPX and low overhead - the packet encapsulation must be bandwidth efficient.

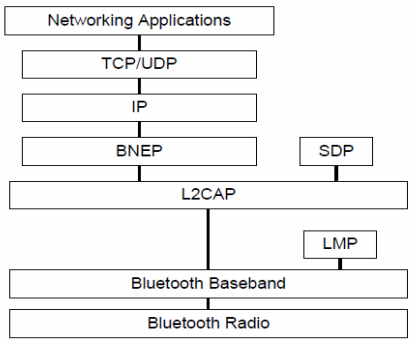

Fig. 1. Bluetooth network stack [2]

Bluetooth SIG BNEP specifications indicate that a minimum L2CAP MTU is 1691 bytes long and the accepted rules of network connectivity and topology as defined for IEEE 802.3 (like switching and routing) must be applied to Bluetooth in a manner compatible with IEEE 802.3 prescriptions. The Bluetooth network stack is presented in figure 1. BNEP act over the L2CAP at the same level with Service Discover Protocol (SDP) as seen in the figure. SDP work based on BD_ADDR to discover application services available on Bluetooth enabled device. Bluetooth BD_ADDR (OSI Layer 2 addressing support for Bluetooth) address space is administered by the IEEE, and is assigned from the Ethernet address space [2]. BNEP layer is at the same level with Logical Link Control Layer of Ethernet and have the main roll to ensure the transmission of data frames from the lower layers (physical layers, BB and BR) to the upper layers (Network, IP).

BNEP specifications cover only the Bluetooth networking encapsulation packet format. Other items like address allocation and resolutions, name resolution, routing and network security, discovery and formation are provided under the Personal Area Networking (PAN) Profile and will be covered in future researches.

Bluetooth Packet Encapsulation

In an Ethernet network, frames are switched to the destination based on 48 bits physical address, source and destination, contained in the header. In case of multipoint network, data packets could pass a variety of medium. At each hop along the path an intermediary device, known as bridge or media converter, accept the frame from one medium, decapsulate frames and forward the packets in new frame to the other medium. The new header of each frame is formatted for the specific medium that will cross.

In the same way BNEP removes and replaces the Ethernet header with the BNEP header. The BNEP format for transporting an Ethernet packet is shown in Figure 2.

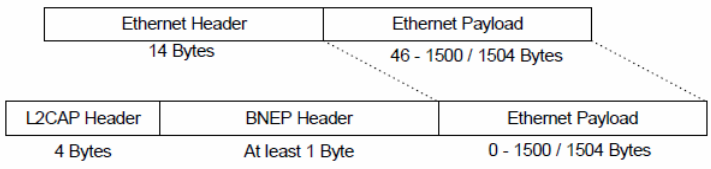

Fig. 2. Bluetooth packet over L2CAP [2]

BNEP Header and Ethernet Payload are encapsulated by L2CAP and are sent over the Bluetooth link. The maximum payload that will be accepted by BNEP from the upper layer is equal with the minimum value negotiated by L2CAP MTU packet (1691 bytes). From this value 191 bytes are reserved for BNEP headers. The minimum payload that BNEP will accept from the higher layer is zero. BNEP encapsulation is not required to pad payloads to the Ethernet minimum size (46 bytes).

BNEP provide transport for control and data packet over Bluetooth media to ensure networking capabilities for Bluetooth enabled devices. BNEP offer capabilities that are similar to OSI layer 2 standard Ethernet. [2]

That mean it is possible to build Bluetooth network access point as bridge media between Bluetooth devices and an Ethernet network.

Bluetooth BNEP Header Formats

BNEP headers are in a format as shown in Figure 3. All Bluetooth devices supporting BNEP must be able to interpret defined BNEP packet types. Bluetooth devices that are BNEP capable may transmit the BNEP compressed headers.

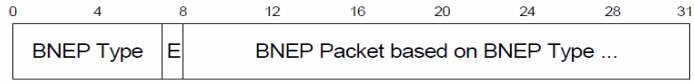

Fig. 3. BNEP packet header [2]

As seen in the table 1 Bluetooth packets may be of various types and specify the compatibility with Ethernet standard.

Bluetooth enabled devices can form networks (Pico nets and Scatter nets) based on unicast, multicast and broadcast address communication. Those reveal to us that is no differences between wired network and Bluetooth wireless network at the OSI layer 2.

Table 1. BNEP packet type [2]

Value	BNEP Packet Type
0x00	BNEP_GENERAL_ETHERNET
0x01	BNEP_CONTROL
0x02	BNEP_COMPRESSED_ETHERNET
0x03	BNEP_COMPRESSED_ETHERNET_SOURCE_ONLY
0x04	BNEP_COMPRESSED_ETHERNET_DEST_ONLY
0x05 – 0x7E	Reserved for future use
0x7F	Reserved for 802.2 LLC Packets for IEEE 802.15.1 WG

To see how it's work let's consider a simple example (figure 4). In this example an IP packet is sent from an Ethernet device with IEEE 48 bit address 01 : 23 : 45 :67 : 89 : AB to a Bluetooth device with IEEE address 00 : 11 : 22 : 33 : 44 : 55 using BNEP.

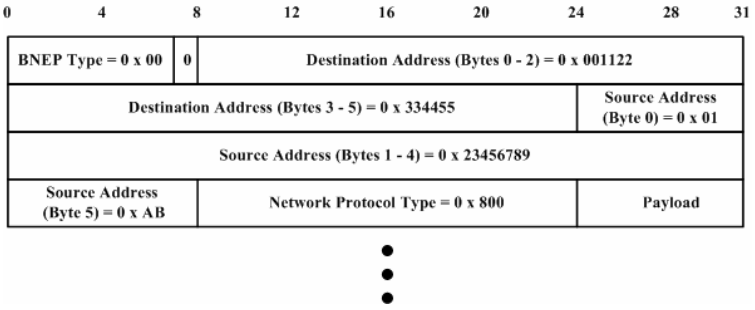

Fig. 4. Sending a simple IP packet example

In example BNEP Packet Type is BNEP _ GENERAL _ETHERNET and Networking Protocol Type is IP. Source and destination address represent different type of device, but in same representation: 48 bit IEEE address.

Bluetooth Wireless Sensors and Actuators Network

Bluetooth wireless sensor and actuators network model is based on concept of Wireless Sensor Network (WSN). This model, from the Bluetooth technology point of view, was first defined at the end of the past decade by Mats Andersson [9]. At that moment Bluetooth WSN was just a conceptual model of data communications in industrial field. In the meantime Bluetooth technology, like other technologies, was evolved rapidly. In June 2010 Bluetooth SIG released

the 4.0 version of Bluetooth specifications, but in industrial environment are still used version 2.1 + EDR. [8]

Bluetooth media link usage in many fields is growing year after year. In the last years many researches were done on radio system use (especially Bluetooth) in the industrial environment. Measurements in real life environments conducted to the conclusions that an RF system works very well in this type of environment. [6]

Sensor networks architectures have been changed greatly over the last years, from the analogue 4-20 mA designs to the bus and network topology of today. WSN could function in a wide range of environments and could provide advantages like low-cost, network modularity and flexibility, and power consumption. In a network, when a node cannot directly contact the base station or access point, the message may pass multiple hops (Scatternet topology). Based on auto detection and auto configuration set up concepts, the WSN could continue to operate even if a node are moved, added or removed. WSN applications have been developed in medicine, agriculture, environment, military, machine, building and more other fields. Bus architectures reduce wire usage and communication bandwidth. Also, wireless sensors use decrease wiring needs and provide new opportunities for distributed intelligence architectures [6, 7].

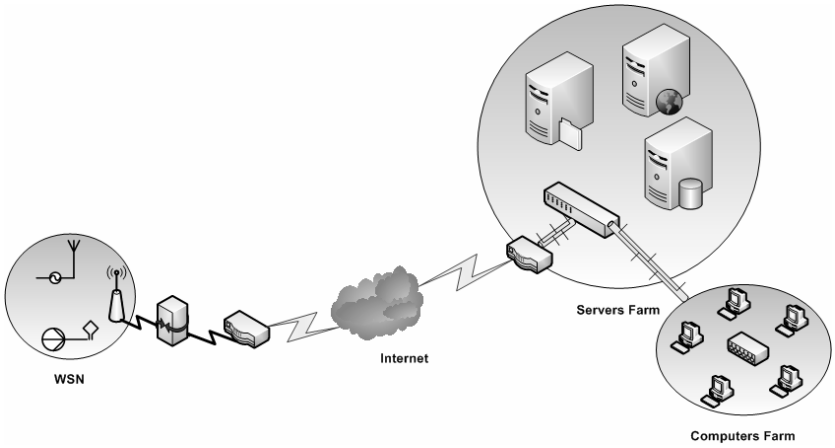

Fig. 5. WSN architectural model concept

In fieldbus architecture persists the risk of cutting the bus that connects the sensors. WSN eliminates problems upcoming from wires. This is the main advantage of using such technology. Another advantage of wireless sensor devices usage is the possibility of installation in places where cabling is impossible [5, 6, 7].

Conclusions

Recent research in wireless sensor networking domain permit the development of low-cost, low-power wireless sensor nodes. Those types of nodes enable multifunctional usage on sensing and data processing. Bluetooth wireless devices embedded with a variety of sensors, such as temperature, humidity and volatile compound detection, allow applicability in different environments. Also, Bluetooth industrial are able to communicate and form network with other sensor systems to exchange. All of these considerations recommend Bluetooth media link like a feasible and reliable communication medium in industrial environment.

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Rețele Bluetooth şi senzori fără fir

Rezumat

Prezenta lucrare abordează utilizarea rețelelor fără fir bazate pe tehnologie Bluetooth ca mediu de comunicație stabil şi de încredere. Utilizarea legăturilor Bluetooth este analizată, prezentată şi propusă, în cadrul acestei lucrări, din perspectiva nivelului 2 corespondent al modelului de comunicație OSI (Open Systems Interconnect), model care stă la baza tuturor modelelor de comunicație în rețelele de date, atât în mediul casnic cât şi în cel industrial. La fel cum tehnologia Ethernet a fost primită cu reticență la început în mediul industrial, fiind considerată o tehnologie destinată transportului de date cu încredere scăzută, şi utilizarea tehnologiilor fără fir, printre care şi Bluetooth, a fost primită cu rezerve. Cercetările şi dezvoltările, în domeniul acestor tehnologii fără fir, din ultimii ani au impus Bluetooth, ZigBee, RFID ca tehnologii utilizabile în rețelele industriale de date. În prezent există o gamă variată de dispozitive industriale de comandă şi control care au implementate ca şi protocoale de comunicație tehnologii fără fir.