

The Feasibility Study of BLE Based Wireless Sensors

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Abstract- This paper is all about the results obtained from a feasible study about Bluetooth low energy based wireless sensors. The important demands of wireless technologies like low energy consumption and a resource saving simple protocol stack, have been met by the development of industrial wireless sensors. These fundamental necessities are rather fulfilled by Bluetooth low energy (new wireless standard). In order to explore the common applicability of BLE for wireless sensor systems, a self-designed BLE sensor system have been used. The results of various analyses made with BLE based wireless sensors are presented in the paper.

Keywords:— Bluetooth, ZigBee, Bluetooth low energy, wireless sensors

I. INTRODUCTION

It was only the availability of wireless technologies like Bluetooth, ZigBee and wireless hart which made science and industry to explore and develop miniaturized wireless sensors. Meanwhile, the development of these wireless sensors faced many challenges, few of which are listed below:

- ♣ There is an aim to supply the wireless sensors with an energy harvester, so it does power consumption itself.
- ♣ The calculation power of the included microcontroller and the resource limitations of memory.
- ♣ The possible wireless network structures.

These challenges are significantly affected by the choice of wireless technology and are definitely crucial for the success of wireless sensor. These challenges are supposed to be handled by the new Bluetooth low energy standard which has been published in 2010 by the Bluetooth SIG. It has been designed to resolve many disadvantages for the wireless sensor systems of the traditional Bluetooth technology. Explorations are now necessary for more precise predictions about the applicability of BLE for wireless sensors performance.

It is due to these facts that BLE based demonstration sensor systems have been developed. This system comprises of a BLE chip from Texas instruments.

II. HOW IS THE BLE SENSOR SYSTEM DESIGNED?

In order to evaluate the BLE wireless technology and to demonstrate the wireless functionality of BLE, a BLE based demonstration sensor system has been developed.

A. Architecture of the BLE Sensors System

The basic part of the system is based on a Carrera racing course with a self-developed Carrera cars. Several sensors and a transceiver chip which includes a microcontroller are contained by the chassis. The Carrera car is transmitting sensor data like acceleration while driving through the racing course. For further computation, the data will be send to a PC based system and the PC uses an off the shelf BLE dongle for sensor data acquisition. If required, the dongle and Carrera car allowing a bidirectional data link.

The central unit of the sensor system is a BLE One-Chip-Solution CC2540F256 from Texas instrument [TI]. The CC2540F256 consists of a BLE transceiver as well as an integrated 8051microcontroller. In addition to those told above, the BLE CC2540F256 consists of a BLE software stack which is given for free by Texas Instrument.

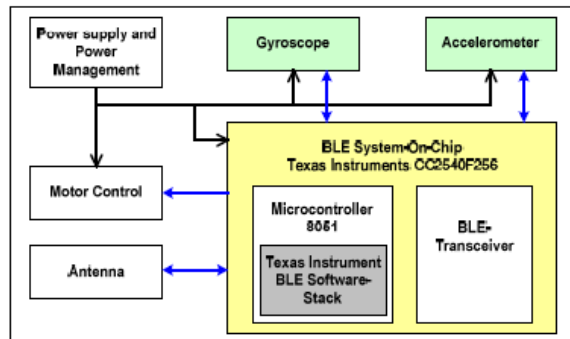


Figure 1: BLE Architecture

B. Features That BLE Transceiver Chip Possess

A boon from Texas instrument i.e. a wireless BLE transceiver CC2540F256 is a small and powerful chip with 256 Kbyte programmable flash and 8 Kbyte SRAM with a possibility to switch the chip in three different power-down- modes during operation and this switching is important to save energy. It [CC2540F256] operates like a specified in the 2.4 GHz ISM band at 2402 MHz-2480 MHz It is the transmission power of the BLE transmitter which varies between 0.01mW[-20dBm]and 2.5mW[+4 dBm]. For the data transmission, BLE is using the frequency hopping spread spectrum [FHSS]. Additionally, BLE combines two multiple access schemes:

1. Frequency division multiple access[FDMA]

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1. Frequency division multiple access[FDMA]
2. Time division multiple access[TDMA] 40 RF channels separated by 2 MHz are used by BLE. Out of which 3 are used for advertising and 37 are used for the data communication itself. The credit for the development of the wireless BLE sensor system basically goes to the Texas instrument which supplied them development kits, software and detailed documentation as well as the BLE dongle is from TI. The possibility to run a small operating

system called OSAL on the chip is one of the most interesting features of the chip and this OSAL helped to program CC2540F256.

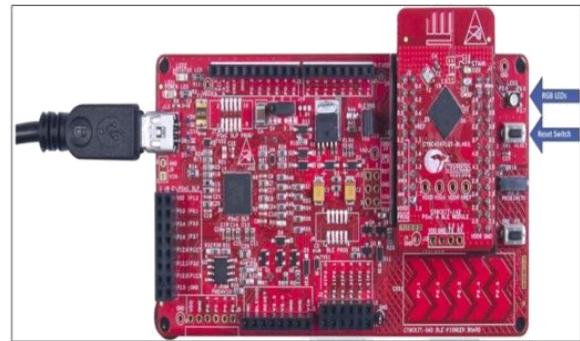


Figure 2 : BLE Device

III. TIMING BEHAVIOUR OF THE BLE SENSOR SYSTEM

Common operation modes of BLE help in the determination of the timing behavior of the BLE sensor system. These common operation modes of BLE are described by the state machine of the Logical-Link-Layer and the state machine of a BLE device has been kept very simple. The wireless BLE is connection oriented wireless technology which means two devices eager to exchange data must enter a fixed connection before a transmission data is possible. Connectionless data like a broadcaster to scan devices is also possible i.e. in the case of state “advertising” BLE devices (so called advertisers). The advertising BLE devices can also signalize scanning and initiating devices that are ready to go into a fixed connection. But only three out of 40 data channels are used for the advertising communication. Listening for packets from a specific advertising device is possible for a device in the “scanning” [a scanner] and the state “initiating” and then this device respond to these packets to initiate a new connection. There are basically two different roles within a state “connection” and these roles are named as “MASTER” and “SLAVE” role. While changing from the state “Initiating” to the state “Connection”, the device will said to have the Master Role and while entering the state “Connection” from the state “Advertising”, the device will said to have the Slave Role. Please note that the master defines all timings of the transmission.

A. The Connection Setup Time

Bluetooth based wireless sensor system in the state “Connection” has comparatively large power consumption than in the state “Standby”. In order to save energy during the operation of a wireless sensor system it

is preferred to build up the connection between two Bluetooth devices only if data is exchanged. The traditional Bluetooth BR/EDR technology has its connection setup time which varies between several seconds. One of the great disadvantage for the sensor system is long connection setup time, especially if the wireless sensor system reacts quickly to incoming sensor events.

The new BLE technology has reduced the connection setup time. The longest connection setup time measured till now is 4.5 milliseconds. In this way, it becomes possible to switch the wireless sensors system to energy saving standby node and also to react quickly to sensor events which must be transmitted.

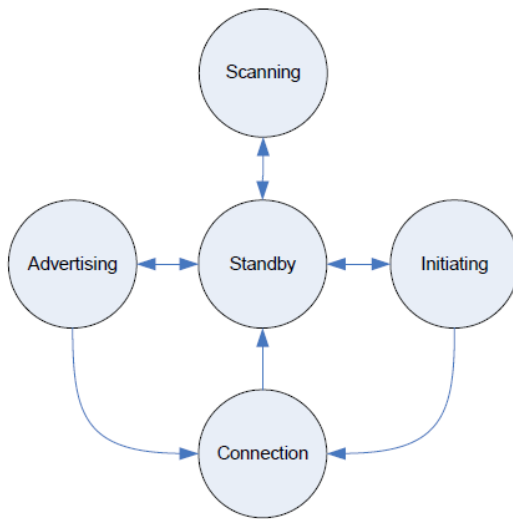


Figure 3: State Diagram of a BLE Device

B. Data Throughput

It is possible to estimate whether the achieved data throughput of BLE is sufficient for wireless sensor systems because the data throughput of the implemented BLE sensor system can be measured. The sending and receiving data on a specific data channel is possible if BLE devices are connected. This action is named “connection events”. The connection interval is defined as the time between two connection events and it varies from a minimum of 7.5 milliseconds to a maximum of 4 seconds. Many options are available to exchange data for a BLE device which is placed in the state “connection”. As an example for the data transmission from the sensor system to the PC, the transmission of notifications which involves the messages which allow asynchronously data transmission has been investigated. There is one more possibility to exchange data between BLE devices is the response-request-procedure. The transmitting device can request an acknowledgement from the receiving through

this procedure and a successful data transmission will be acknowledged from the receiving data via a “response”. Two connection intervals at least is necessary to transmit one data packet with at most 20 bytes data which leads to the fact that a maximum data throughput of 1, 3 Kbytes/s if more than 20 bytes can be transmitted. The result of the measurements proves that the throughput is good enough for many wireless sensor applications.

IV. THE BLE STACKS REQUIRES STORAGE

It was the complexity of the BLE stack which was reduced to obtain a lightweight stack for sensor node applications. It led to the fact that many transceiver manufacturers succour the developers and researches by means of software stacks free of charge. There are two different BLE stacks by which TI succours and supplies the developer of wireless sensor systems:

1. A stack for slave devices
2. A stack for master devices

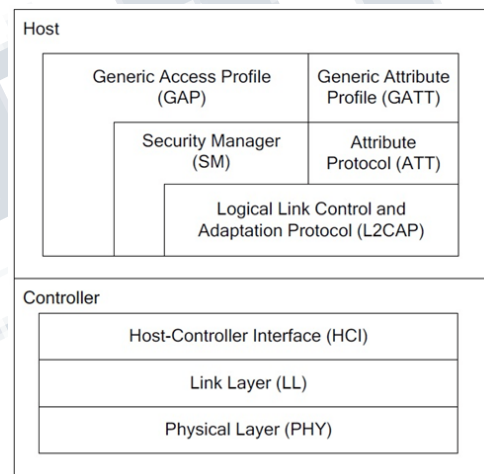


Figure 4: BLE Stack

V. POWER CONSUMPTION

The BLE sensor system is associated with few facts on the power consumption based an elaborate energy analysis which was done. The influence of the different states to the power consumption of the BLE sensor systems is obtained from the current consumption and the electrical discharge characteristics have precisely measured the detailed information.

A. Measurement Method

A measurement resistor with 1 ohm and an oscilloscope have been used to measure the current consumption of the BLE sensor system.

B. Energy Harvesting

In the days to come the wireless sensor system shall be operating only with energy harvester and that too without batteries. It was due to the power measurements that a short estimation has been done whether a BLE sensor can supply only by energy harvesters.

VI. CONCLUSION

Last but still not the least a self-designed BLE sensor system has been used to explore the common applicability of BLE for wireless sensor systems. The results have clearly stated that BLE is a very interesting wireless technology for wireless sensor systems that too especially for the wireless sensor system powered by energy harvester. The facts of BLE based wireless sensor system are as follows:

- It consumes less power
- It has good data throughput
- It is with small and simple software stack which is applicable for 8 bit microcontrollers

In the upcoming days, the detailed lifetime of the BLE based sensors and to compute new BLE simulation models can be calculated with the help of the overall investigation results.

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