

# Bluetooth Low Energy as a means of Optimizing Power Consumption in IoT based Wireless Sensor Networks

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**Abstract**— Bluetooth low energy (formerly known as Bluetooth Smart) is a universal low-power wireless standard that makes it easy to connect any product to a smartphone or tablet. The main purpose of BLE is to run devices with very low power and thereby reduce battery consumption. This paper proposes an architecture that reduces the power consumption in IOT based wireless sensor devices allowing these sensors to improve their life. Efforts are equally been put in to make low cost efficient WSNs.

This paper looks at BLE a potential candidate to improve the battery life and reducing the power usage. Comparison between proposed architecture and existing wireless technologies used in WSN is done on the basis of power consumption.

**Keywords**—Bluetooth Low Energy; Bluetooth Smart; Wireless Sensor Network; low power WSN; NRF24L01P; Zigbee.

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## I. INTRODUCTION

Wireless Sensor Network (WSN) (or Wireless Sensor and Actor Network (WSAN)) is a network of sensor nodes spatially distributed in a region to monitor real-world physical parameters and report the sensed values to a central controller. WSAN adds the capability to take actions based on the sensed values. WSNs are rapidly becoming ubiquitous in the world of Environmental Monitoring, Healthcare monitoring, Smart Cities and Home Automation. [1]

Actions like setting the thermostat based on factors like weather and user preference, turning lights and fans on/off without human intervention can be achieved using WSN. However automating these processes requires acquiring data from a distributed array of sensors. A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable.

Wireless sensor nodes or sensors are hardware devices that are small in size, use low energy, function in high densities, are autonomous and operate unattended, and are adaptive to the environment. The flexibility, fault tolerance, high sensing dependability, low cost, and swift deployment characteristics of sensor networks have made their use in many new applications such as artificial intelligence, remote sensing etc. The idea of internet of things (IoT) was developed in parallel to WSNs.

## II. RELATED WORK (EXISTING ARCHITECTURES)

The architecture of WSN varies for a individual sensor node and the entire network. Energy efficiency, size reduction and

minimum cost are the main concern for sensor node architecture. [1]

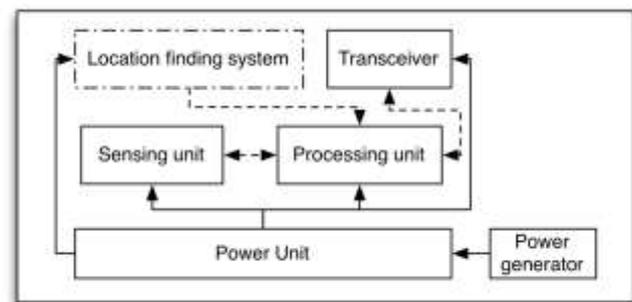


Fig. 1. Architecture of a wireless sensor node

A wireless sensor node or node is also known as mote and is made up of the following four functional components: sensing unit, processing unit, transceiver, and power unit

- 1) *Sensing Unit*: It consists of an array of sensors that can measure the physical characteristics of its environment.
- 2) *Processing Unit*: A sensor node uses a microcontroller which performs task, processes information and controls the working of other parts in the sensor node.
- 3) *Transceiver*: They are used to send and receive messages wirelessly. The functionality of both transmitter and receiver are combined into a single device known as a transceiver.

### A) Topology

In WSN the position of the nodes is known after the deployment of sensors. Three types of network topology architecture are popularly used for wireless sensor networks.

*Star topology*: A star topology is a single-hop system. Each node connects directly to a gateway. The main advantage of

this topology is that the network is not affected by node failure as long as the hub is active. Star topology centralizes control, as only the sink node is aware of the status of all the nodes. For a single node to transmit data, other nodes do not need to be active. The disadvantage is apparent as size of network increases. The distance between the hub and other newly connected nodes also increases, which necessitates higher radio power.

**Mesh topology:** Mesh topologies are multi-hop systems which allow peer-to-peer communication. The base station does not interfere in the selection of path. All nodes in mesh topology choose the best dependable path amongst available path for transmission by self-connecting to several nodes. However there is a drawback. For a node located at the edges of the mesh, to transmit a packet to an opposite edge of the mesh, the routing path will pass through multiple intermediate hops. Each hop consumes power in each of the nodes it passes through. Hence as size of the network (number of nodes as well as spatial region covered) increases, the average power consumption of the entire network goes up.

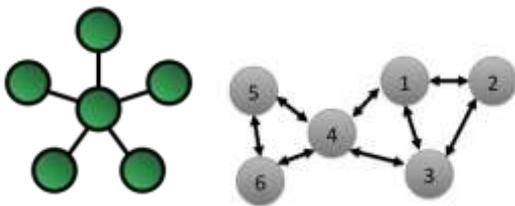


Fig. 2. Star and mesh topologies

## B. Wireless Technology

Wireless technology is a high power-consumption block of any WSN. Minimizing power consumption of each node is an important aspect of any sensor node. Energy is one of the scarcest resources for any sensor node. If the energy consumption is too high, it will require frequent replacement of power cells.

Typical WSN use uses Zigbee or RF modules like NRF24L01P and CC2500.

### 1) NRF24L01P

Wireless communication can be achieved using any RF modules. The small, low cost NRF24L01P is one of the popular choices. It wasn't designed to be power efficient.

NRF24L01P is capable of operating in 5 distinct modes[4].

*a) Power Down Mode:* In power down mode nRF24L01 is disabled with minimal current consumption. Only register and SPI interfaced are kept activated for accepting new configurations, hence providing minimal power consumption.

*b) Standby -I Modes:* Standby-I mode is used to minimize average current consumption while maintaining short start up times. Uses power slightly higher than power down mode.

*c) Standby -II Modes:* This mode is activated when data is to be transmitted at short notice. Extra clock buffer are activated.

*d)RX Mode:* Listens for incoming packets. In this mode the receiver demodulates the signals from the RF channel. Power consumption increases with increase in air data.

*e) TX Mode:* This is the mode wherein packets are actively transmitted. This mode has the highest power consumption as it is in this mode that the PWR\_UP bit is set high.

## 2) Zigbee

Zigbee's are one of the most popular choices for wireless communication in WSN. Operating on mesh topology, it is a high level communication protocol. It is well suited for WSN because of its low cost system. It has both low power sleep modes along with high power consuming modes.

## C. Power Saving Techniques

Low power consumption being the motto of WSN, many WSN architecture have adapted themselves to low duty cycle. The sensor nodes are kept in a low power state wherein it becomes active for short duration periodically sensing the values and relaying the value over the network after which it returns back to sleep state. This particular scenario is not suitable for real time data monitoring which requires the duty cycle of sensor node to be very high which increases the power consumption and reduces the battery life.

Another way to reduce power consumption is to use mesh topology. It reduces the cost of the node as well as reduces power consumption. However this method becomes a disadvantage for real time data monitoring. As network size grows the sensor node distribution increases as a result the power consumption per node increases[1].

## D. Accessing the Data

Sink node acts as the data collection center from all its connected nodes. Once the data is received, the data needs to be processed and action needs to be taken. A proper integration of WSN with a system is the need so that easy data accessibility can be provided so that collected data can be put to maximum use.

Following points are made clear:

- A wireless communication technology must consume minimum power as possible.
- Network topology chosen must consume less power for data transmission.
- Real time monitoring should be avoided unless it is necessary to reduce overall power consumption.
- A reliable method is required for better accessing network.

### III. PROPOSED ARCHITECTURE

If the above issues are addressed the efficiency of WSN can be improved. The following architecture based on existing research and practical observations-

#### A. Technology

A low-power solution for controlling and monitoring applications - Bluetooth Low Energy (BLE), was recently released as a distinctive new feature of Bluetooth Core Specification V4.0 technically called as Bluetooth Smart. This technology matches the power specification required for WSN. Access of data is an important aspect for sensor network. Rather than transferring the data to an internal storage from the central sink node, it would be more feasible to use the improved principles of IoT. IoT technology enables accessing sensor data's globally via internet[1][8].

#### B. Topology

Network topology selected should be having the advantages of both mesh and star topology. A BLE device who initiates the connection acts as master and rest of connected devices become the slave. One master can be connected to multiple slaves. Master device initiates a connection and slave devices have to be polled to get a connection. Network of one master and multiple slaves is called a piconet. Upto 8 slaves can be connected in a piconet.

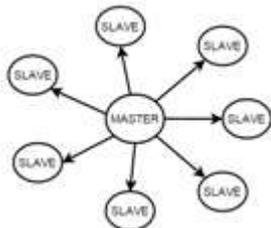


Fig. 3. Piconet with all slaves

Many such piconets can be connected to each other to form a scatternet. In this a slave node is shared among masters. This slave is not simultaneously connected to both masters but switching can be performed among them.

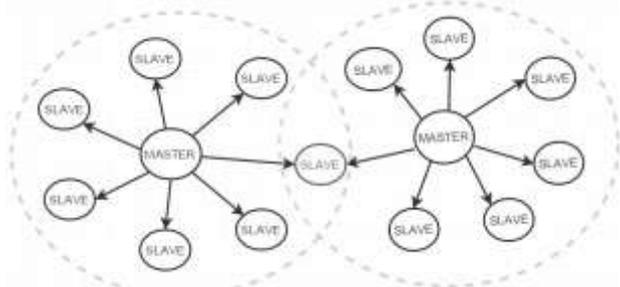


Fig. 4. Scatternet with 2 piconets

Following are the benefits of such topology[1]:

- 1) Individual node transmission requires lesser power in larger networks.
- 2) Control gets decentralized as network control and management are distributed amongst masters of each piconet.
- 3) Because of implementation of IoT, master devices are made to push data over the internet.
- 4) If any of the masters lose internet contact, other masters of the piconet can still push data in a scatternet.

### IV. RESULTS AND COMPARISONS

Consuming lesser power during transmission as well as lower average consumption over time will only make the system more power efficient.

NRF24L01P and Zigbee platforms are selected for comparison purposes. Implementations done in our system are done with the following consideration[1]-

1. Transmission of data is in packet format. Size of packets chosen is 1 byte, 2 byte, 4 byte and 8 byte.
2. Sleep time between transmissions vary from 0.1s to 5s.
3. All comparisons are performed for 0 dBm transmit power and the highest supported air data rate.

#### A. NRF24L01P

Power consumption details of the NRF24L01P are based on data provided in [2] and [4].

TABLE I. NRF24L01P POWER CONSUMPTION

Mode of operation	Power Consumption (V <sub>DD</sub> = 3V)
Power down mode	2.7 $\mu$ W
Standby-I mode	78 $\mu$ W
Standby-II mode	960 $\mu$ W
RX mode (@ 2 Mbps)	41.5 mW
RX mode (@ 1 Mbps)	39.3 mW
RX mode (@ 250 kbps)	37.8 mW
TX mode (@ 0 dBm)	33.9 mW
TX mode (@ -6 dBm)	27 mW

From the above table it can be observed that , during active mode the operational power of NRF is few tons of mW and in power down mode power consumption is of the order 1 $\mu$ W which is significantly higher power consumption with the other technologies compared in our discussion.

#### B. Zigbee

The typical power consumption on Zigbee is shown below. Power consumption of Zigbee provided under test conditions and values provided in [3] [4] [5] [6]

TABLE II. ZIGBEE POWER CONSUMPTION

Mode of operation	Power Consumption ( $V_{DD} = 3V$ )
Power down mode	<3.3 $\mu$ W
Sleep Mode	14 $\mu$ W
Wake up(RX mode)	20 mW
TX mode	31 mW

The readings are better than NRF but still poor that BLE.

C. Bluetooth Low Energy

The overall power requirement is lower in BLE and compared to NRF or Zigbee the connection establishment is faster [7]. The wake up times is faster for BLE allowing it to spend greater amount of time sleeping and thereby saving power.

TABLE III. BLE POWER CONSUMPTION[11]

Mode of operation	Power Consumption ( $V_{DD} = 3V$ )
Sleep Mode	2.6 $\mu$ W
Wake up(RX mode)	15 mW
TX mode	15 mW

As we can see, the overall power consumption and performance of BLE is an improvement over NRF and Zigbee.

D. Increasing sleep time

A graph showing effects of increasing the sleep time are shown below. If the sleep time is allowed to be longer, the sensor niode can remain in low power state and thus saving more power.

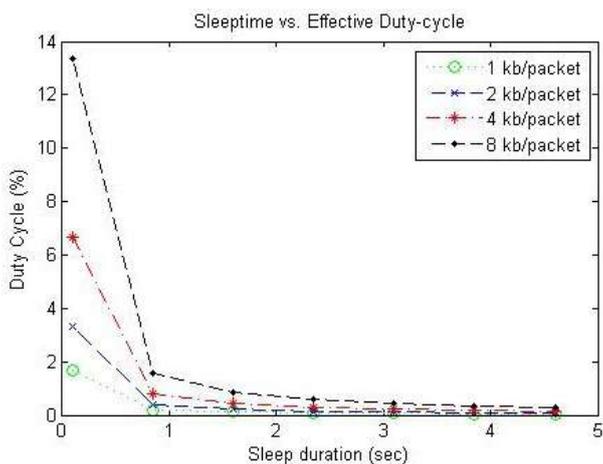


Fig. 6. Sleep time vs. Effective duty cycle for packets of varying sizes[1]

As the sleep duration increase, the duty cycle of wireless communication also goes down. If real-time monitoring is not a requirement, then it makes sense to allow the transceiver to sleep for longer time and then transmit any data collected during that duration in a single burst.

V. CONCLUSION

Current WSN technologies use RF or Zigbee based wireless system. But employing newer technologies like Bluetooth Low Energy which are specifically designed for ultra-low power applications can thus reduce the energy costs and thereby improving the functionality of the network. The connection time of BLE is faster that other existing technologies allowing it to stay in low power sleep mode for longer duration and still achieve same data throughput as traditional wireless techniques. Issues related to real time data monitoring can be solved using BLE in sensor networks. BLE ensures that real time data monitoring can be carried out whenever required without additional hardware so that power consumption can be greatly reduced.

REFERENCES

- [1] Optimizing Power Consumption in IoT based Wireless Sensor Networks using Bluetooth Low Energy, Karan Nair, et 978-1-4673-7910-6/15.2015 IEEE
- [2] Designing Wireless Sensor Network with Low Cost and Low Power, S. S. Sonavane et. al., ICON 2008
- [3] Development of A Control System for Home Appliances Based on BLE Technique, Hideki Matsuoka et. al., IEEE 2014
- [4] NRF24L01+ Preliminary Product Specification, Nordic Semiconductors
- [5] SOC design of a Low Power Wireless Sensor network node for Zigbee Systems, Ninad B. Kothari et. al., IEEE 2006
- [6] A Study of ZigBee Network Topologies for Wireless Sensor Network with One Coordinator and Multiple Coordinators, Shayma Nourildean, Tikrit Journal of Engineering Sciences/Vol.19/No.4/December 2012
- [7] The Analysis and Summary About Energy Saving Technologies of Wireless Sensor Network, Yingchao Han et. al., International Conference on Electronic & Mechanical Engineering and Information Technology
- [8] Performance Analysis of an Bluetooth Low Energy Sensor System, 978-1-4673-4679-5/12 ©2012 IEEE
- [9] Energy Analysis of Device Discovery for Bluetooth Low Energy, 978-1-4673-6187-3/13 ©2013 IEEE
- [10] Bluetooth Low Energy for Data Streaming:Application-level Analysis and Recommendation, 978-1-4799-8981-2/15©2015 IEEE
- [11] PSoC 4: PSoC 4XX7\_BLE Family Datasheet, Cypress Semiconductors