Bol. Soc. Paran. Mat.
©SPM – E-ISSN-2175-1188
SPM: www.spm.uem.br/bspm

(3s.) **v. 2025 (43) 3** : 1–7.
ISSN-0037-8712
doi:10.5269/bspm.78679

Life Time improvement in sensors using Blue tooth nodes

Richa Tiwari*, Vatsya Tiwari, Sharmila

ABSTRACT: In this paper a Blue tooth node Topology is proposed for wireless body area sensor networks for the transmission of Electrocardiogram Signals from heart, where the continuous monitoring of patient is required without human. This topology is very much beneficial in this scenario for data integration. This topology used less number of nodes. In many medical situations, the continuous monitoring of data is necessary whereas in some situations, continuous monitoring is not an essential requirement, this topological scheme played an important role in the designing of link for WBASNs. In case of biological sensor network, it's very important that implanted nodes consume less power in transmission because the replacement of nodes is very complex surgical procedure in many medical situations the patient is on high risk. A node role change concept is introduced here. The main aspect of this paper is to present topology that provides fast and accurate transmission of biological signals with least used power. In this the smart sensor nodes topology is utilized these nodes incorporated with sensing and transformation capability. The node sense the biological signals and these signals are transferred from source to destination by using different relays. The life time of the module in side the human heart is improved by its correlation(Friendship)with the node out-side the human body. In this manner the fast transmission of Electrocardiogram data with life time improvement of implanted node becomes possible on low data rate sensor network link.

Key Words: Blue Tooth Low Energy (BLE), Low Power Nodes (LPN), Generic Attribute Profile (GATT), Dynamic Modulation Scaling (DMS), Cooperative MIMO (CMIMO), Distributed Source Coding (DSC), Transmission Power Control (TPC), Wireless Charging Equipment (WCE).

Contents

1. Introduction

Now a day, Wireless Body Area Sensor Networks (WBASNs) is a branch of sensor network that find its wide variety of applications in the field of healthcare and diagnosis. A WBASN is a network of intelligent devices that observe the data under different medical situation. There are many quality of service parameters associated with these networks such as low power consumption, high operating range, operated over a wide range of speeds. Currently the standard recommended for this network is IEEE 802.15.6. for example, some requirements associated with WBASN is that it must support up to 526 sensor devices and the removal and the insertion time of these devices is less than 3 seconds. When this technology is incorporated with ultra wide band (UWB) and support high data transmission rates, in this situation the power restriction is an important challenge because in WBASN the operating environment is sensors inside the human body. There are two types of sensors used in WBASN implanted sensor device and wearable sensor devices. These devices maintain the record of data collected from a person or data collected during critical situations, an example of these records are the electrocardiography that examines the typical heart activity, electromyography and electroencephalography for muscles and brain activity. Sensors are also used to monitor various attributes such as blood pressure, temperature, human motion

* Corresponding author.
2020 *Mathematics Subject Classification:* 62F15.
Submitted August 29, 2025. Published October 16, 2025

and various conversation data. The main crucial issue associated with sensors is how limited bandwidth, memory, and energy are utilized. In typical diabetes, cancer cell detection. and cardiovascular monitoring the implanted sensors are best choice but the replacement of these sensor is very complicated in many medical situations so the battery of these sensors play an important role during the implantation. The organization of rest of the paper is follows: After giving the detail methodology behind this work in the introduction part, in section 2, we presents the most of the mechanisms involve and the latest work in the designing of energy efficient sensor network. In section 3, we give the methods for designing a topology for WBASN by using the blue tooth node. In section 4, we give the simulation results that show the improvement of life time of a node under different scenarios.In section 5, we conclude the use of this topology for improving the life time of sensor network.

2. Related Works

There are many energy efficient techniques that are used for improving the life time of the sensor network. Sing et al. [1], presents a classification based on battery management, transmission power management, and system power management. This paper is an extension that clearly classify the optimization techniques for energy in sensors, many methods are presented for improving the life time of the sensors network. In the battery management the node battery power has been saved.The transmission power management is a part of radio optimization,where several techniques from researchers have been addressed such as optimization through various modulation and coding technique. In Tiwari and Kumar[12],a link has been proposed for WBASN network, this work show that coding techniques reduce the total energy consumption of any link and modulation techniques also play an important role in this optimization. Gumuslan et al.[2], give Dynamic Modulation Scaling(DMS) techniques that manage the constellation size and change the energy consumption of the network this technique used in combination with the topology control. Many Cooperative Communication techniques also comes in picture in the field of sensor network, but the installation of multiple antenna is not practically suitable for sensor network in many situations. Recently research are going on in the area of Cooperative MIMO(CMIMO), this technique utilize the space time block coding scheme and useful in long distance communication and also suitable for reducing the energy consumption of sensor network. Singh and Amin,[3] shown that in case of high node density the high degree of correlation exist between so Distributed Source Coding(DSC) with virtual MIMO data transmission is useful as compare to CMIMO.

Transmission Power Control(TPC) adjust the transmission power of the radio and help in designing an energy efficient network. This technique also play a crucial role in Wireless body area network [4,5]. A recent paper in the field of Under-power Wireless Sensor Networks(UWSNs) uses the TPC, in this technique the source nodes adjust transmission power or the transmission power depend upon the distance between the source and the destination node, if the distance is large then transmission power increase if it is low then node transmit less power,[6]. Data reduction also play an important role in designing the energy efficient network.For this three techniques are used in market Data Aggregation, Data Compression, and Data Prediction. In data aggregation the data are collected from different nodes and useful information are extracted from the aggregated data. Algorithms based on maximum, minimum, and average are used for this.The extracted information has been forwarded to the final base station. Vinodha et al.,[7] gives details about various data aggregation techniques in which data has been collected inside the cluster head from different nodes and this cluster head aggregate the data and finally send this to the destination. Another reduction technique is data compression, is very useful in case of multimedia sensor network(MSN) in this the data is compressed by minimizing the number of bits required to represent the data.There are two type of data compression Distributed data compression and Local data compression. The choice of compression technique depends on the size and density of network. If the sensor network are sparse then the local data compression is good choice but if the node density in an area is high the distributed data compression is best. The sensor nodes encode the data(image and video) using various transform based compression such as cosine transform or wavelets transform, and on base station side all the correlated flows are decoded.Distributed transform coding (DTC) is not practically suitable for sensor network, the difficulty is that the requirement of knowledge about all measurements in the network at each node. This is overcome by using Distributed Source Coding(DSC)[8,9]. The inter-communication between the sensor node is not required in this, this is

besed on Slepian -Wolf Theorem. The Compressed Sensing(CS) is the most feective technique in WSNs, IOT and MSN[10,11]. Sinde et al. The main requirement associated with 5G networks, massive IoT and sensor networks is the low cost, power and complexity.Recently Energy harvesting from radio frequency is main area of interest.Various antenna optimization schemes are also discussed in [13-16].

3. Material and Methods

The blue tooth technology is a special tool that is very helpful in automation, sensor technology and for many IoT based solution.

3.1 Physical Modeling of Topology for Wireless Body Area Sensor Network Link

The Mathematical modeling of the link for WBAN has been done in previous paper Tiwari and Kumar,(2021). Now, in this work a Blue tooth mesh topology has been proposed for this link. The blue tooth mesh networking of this link, all nodes are divided into four parts Nodes for sensing data, Relay Node for transmitting information, Friend Node and Low Power Node. The friend now have no under power issue so help our Low Power node for improving his life time. Before giving the detail about the proposed topology first of all the assignment of work for different nodes has been discussed, now an example should be considered for monitoring a heart patient in the environment of covid-19 disastrous situation, In second decade of covid-19 in year 2021, its become too much difficult for hospitals to recognize every patient, if any heart patient suffer from corona virus then its become too much difficult to recover this person via home isolation because in this case the regular monitoring is essential, in most of the countries Hospitals rooms are limited so many patient will not be able to get single rooms. So if, organize the system in such a manner that the limited number of sensors is helpful in monitoring the person from remote area, then its become easy to monitor and isolate heart patient. Before the Chronic Heart Failure(HF), the early sign is the increase in the pressure of Pulmonary Artery(PA) and Right Ventricular(RV). By the regular monitoring of these pressure, it become possible for doctors to provide the tailored treatment for patient to avoid cardiac decompensation and hospitalization.

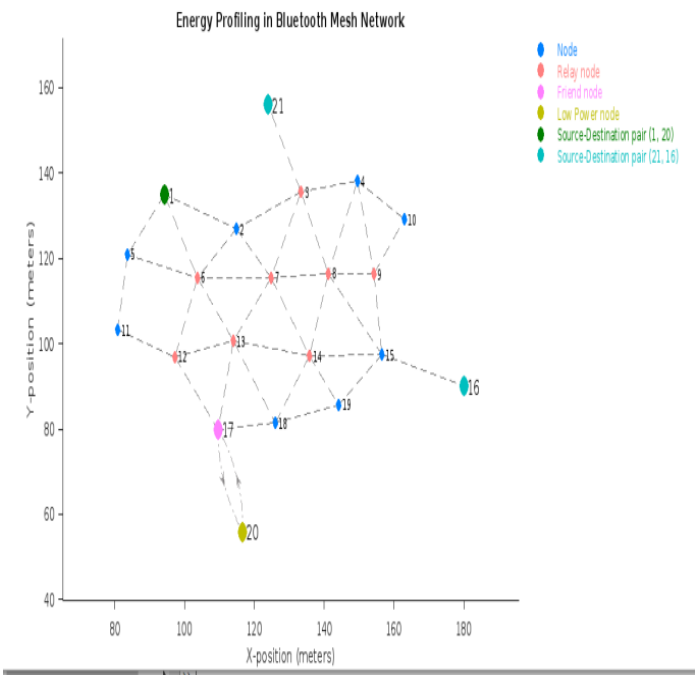

Figure 1: Topological Structure

There are many technologies available in market for hemodynamic monitoring, It is equipped with an internal power source. It is incompatible with MRI and Resynchronization therapy.PAP sensors family

consist of two types of sensors. First Cardio MEMS this device is compatible with MRI, Implantable Cardioventer Defibrillator(ICD) and Cardiac Resynchronization Therapy(CRT), but patient are required to take 1 month dual antiplatelet and lifelong aspirin therapy, after implantation the trial confirm that no sensors of this is failure up to 31 months. Another one is Cordella PAP Sensors system implanted in the right PA and it is able to measure other vital parameters such as arterial blood pressure, heart rate and oxygen saturation. PAP is allowed to measured daily by a wireless hand held reader and patients are required to take daily readings. Now if we organize these PAP devices as a Low Power Node device of this topology and place a friend node near this device outside the human body, then the change outside the body are able increase the life time of this Lower Power Node.The importance of these blue tooth device is understood by the fact that With nearly eight billion Bluetooth enabled devices forecasted to ship in 2029 alone, the opportunities are significant. Bluetooth Channel Sounding can address a wide range of fine-ranging applications while being easy and cost effective to deploy. The enhanced centimeter-level accuracy of Bluetooth Channel Sounding has the potential to also create new innovative features for Bluetooth LE-enabled devices, including human-interface devices (HID), proximity interactions and automation, and human-machine interface (HMI).

4. Results and Discussion

In this section, The network topology is simulated under three different scenarios. The Life time of low power node is compared. The configured hardware parameters for 1200 mAh battery are simulated under parameters of Table1,

Table 1: Simulation Parameters

Simulation Parameters	Values
Data Rate(Kb/Sec)	100
Packet Size(Bytes)	10
Self Discharge time consumption	0.0013699 mA
Listening time consumption	10.3mA
Sleep time consumption	0.2mA
Ideal time consumption	1.19mA
Transmission Time consumption	7.77mA
Simulation time	5 Sec

In MATLAB the topology of 21 Bluetooth node has been simulated under different friend node schemes. The Relay nodes=[3 6 7 8 9 12 13 14 15] ,Source Destination Pairs=[1 20; 21 16] ,Friend=17 ,LPN=20

The Timing Matrics at node 20 is, Transmission Time=0.016704 sec ,Listen Time =1.2 Sec ,Sleep Time=2.2957 Sec ,Ideal Time=0.5813 Sec

The plot of different node states are given in Fig. 2, The life time of node 20(LPN) is 18.1607 days.

If the friend node of the LPN has been changed then its life time has been improve for example in fig.3, the friend node is node number 13 and in fig.4, the friend node is 15 respectively, the results are following,

The Relay nodes=[3 6 7 8 9 12 14 15 17] ,Source Destination Pairs=[1 20; 21 16] ,Friend=13 ,LPN=20

Transmission Time=0.012528 sec ,Listen Time =0.9 Sec ,Sleep Time=2.2183 Sec ,Ideal Time=0.43247 Sec

For Third simulation the considerations are followings, The Relay nodes=[3 6 7 8 9 12 13 14 17] ,Source Destination Pairs=[1 20; 21 16] ,Friend=15, LPN=20

Transmission Time=0.006264 sec ,Listen Time =0.45 Sec ,Sleep Time=1.326 Sec ,Ideal Time=0.21774 Sec

The life time of node 20(LPN) is 24.1981 days for friend node 13 and the life time of node 20(LPN) is 47.9454 days for friend node 15. The simulation results shows the improvements in the life time low power nodes successively.

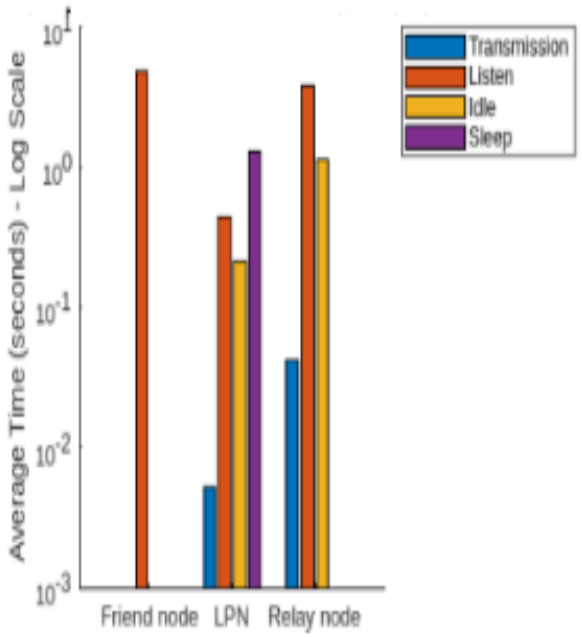

Figure 2: Average Time of Different Nodes(Friend node 17)

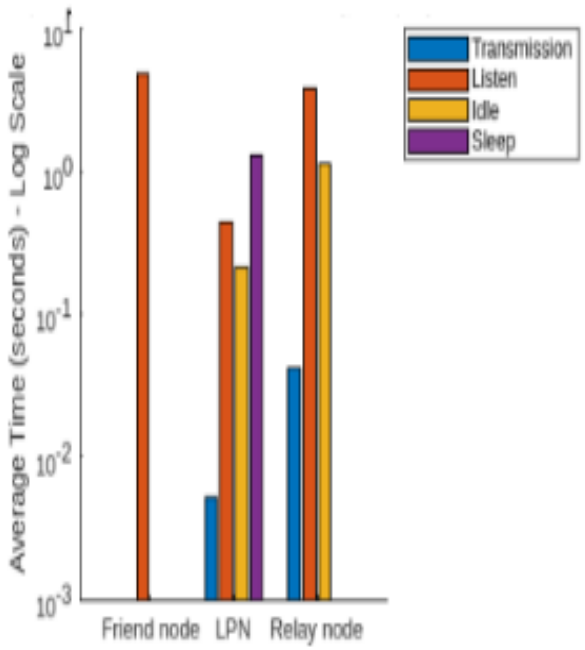

Figure 3: Average Time of Different Nodes(Friend Node 13)

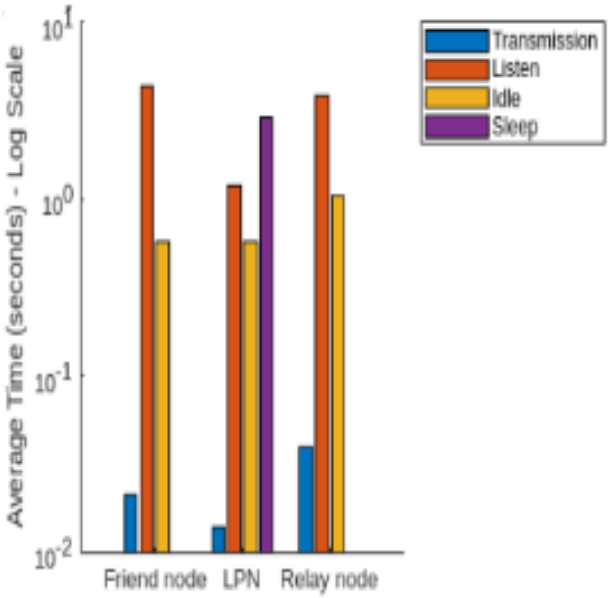

Figure 4: Average Time of Different Nodes(Friend Node 15)

5. Conclusion

In this paper a topology is proposed for the transmission in case of wireless body area sensor network. The amount of data generated by the biological signals is very large. The bandwidth of sensor network is limited many times the continuous monitoring of this data is required for critical patients. In that situations the nodes inside human body spend much energy in transmission, if the network topology is operated in such a manner that life time of internal nodes improved by the change in the configuration of outside node that is the friend node for this internal node(LPN),then network operate comparatively long time duration. In this link the hardware used a 1200mAh battery. It means that this battery supply 4mA average current to the load and life time of the battery is approximately 300 hours, that is near about 12.5 days. This topology is very helpful to increase the life time of nodes. Our simulation results indicate that energy consumption can be greatly minimized by using this type of topology in Biological sensor network. Comparative analysis of results indicates that the minimization in energy consumption is directly related to the transmission, sleep, listen and the ideal time of any node. sensor nodes consumed high power in the transmission of data. If nodes inside the human body are Bluetooth programmed devices that have sensing and small distance transmission capability then this scheme automatically control node life time externally. No energy is wasted on long distance transmission. In biological sensors the data samples have strong correlation, the transmission of all samples are the wastage of energy and storage capacity so if outside relay nodes are programmed with complex algorithms then the life time of nodes inside the body has been improved because no power constraints are there for such type of node.

References

1. Singh, J.; Kaur, R.; Singh,D. A survey and taxonomy on energy management schemes in wireless sensor networks. J. Syst. Archit.2020,111. [CrossRef]

2. Gumusalan, A.; Simon, R.; Aydin, H. Dynamicmodulation scaling enabled multi-hop topology control for time critical wireless sensor network. Wirel. Netw. 2020,26, 1203-1226.[CrossRef]

3. Singh, M.; Amin, S. Energy- efficient data transmission technique for wirless sensor networks based on DSC and virtual MIMO. ETRI J. 2020,42,341-350.[CrossRef]

4. Fernandes,D.; Ferreira, A.; Abrishambaf,R.; Mendes, J.; Cabral, J. Survey and taxonomy of transmission power control mechanisms for wireless body area network. IEEE Commun. Surv. Tutor.2018,20,1292-1328.[CrossRef]

5. Lee, W.; Kim, H.; Hong, M.; Kang, M.G.; Jeong,S.; Kim, N. A survey of the transmission power control schemes in wireless body sensor networks.KSII Trans. Internet Inf. Syst. 2018,12,1854-1868.[CrossRef]

6. Mohsan, S.; Amjad, H.; Mazinani, A.; Shahzad, S.; Khan, M.; Islam, A.; Mahmood, A.; Soban, A. Investigating transmission power control strategy for underwater wireless sensor network. Int. J. Adv. Comput. Sci. Appl. 2020,11, 281-285.[CrossRef]

7. George, R.; Mary, T. Review on directional antenna for wireless sensor network applications. IET Commun. 2020, 14, 715-722. [CrossRef]

8. Vinodha, D.; Mary Anita, E. Secure Data Aggregation Techniques for Wireless Sensor Networks: A Review. Arch. Comput. Methods Eng. 2019, 26,1007-1027. [CrossRef]

9. Tekin, N.; Gungor, V. Analysis of compresssive sensing and energy harvesting for wireless multimedia sensor networks. Ad Hoc Netw. 2020, 103. [CrossRef]

10. Aziz, A.; Osamy, W.; Khedr, A.; El- Sawy, A.; Singh, K. Grey Wolf based compressive sensing scheme for data gathering in IoT based heterogeneous WSNs. Wirel. Netw. 2020,26,3395-3418. [CrossRef]

11. Manchanda, R.; Sharma, K. Energy efficient compression sensing -based clustering framework for IoT- based heterogeneous WSN. Telecommun. Syst. 2020,74, 311-330. [CrossRef]

12. Tiwari,R.; Nagaria, D.; kumar, R. Smart biological sensor network for efficient energy consumption. Int. J. Circ. Theor. Appl. 2021; 49: 2138-2146.

13. Kundu, Krishanu. "Past, Present, and Future of Rate Splitting Multiple Access for Wireless Networks: A Review." In Radar and RF Front End System Designs for Wireless Systems, edited by Shilpa Mehta and Rupesh Kumar, 275-295. Hershey, PA: IGI Global, 2024. https://doi.org/10.4018/979-8-3693-0916-2.ch011

14. K. Kundu, S. Chaurasia, P. Pandey, M. Gupta and R. K. Gatla, "Simulating a Local Area Network with Cisco Packet Tracer: A Comprehensive IP Packet Switching Network Demonstration," 2023 International Conference on Power Energy, Environment & Intelligent Control (PEEIC), Greater Noida, India, 2023, pp. 247-252. doi: 10.1109/PEEIC59336.2023.10450793.

15. R. Salgotra, S. Singh, U. Singh, K. Kundu and A. H. Gandomi, "An Adaptive Version of Differential Evolution for Solving CEC2014, CEC 2017 and CEC 2022 Test Suites," 2022 IEEE Symposium Series on Computational Intelligence (SSCI), Singapore, Singapore, 2022, pp. 1644-1649. doi: 10.1109/SSCI51031.2022.10022308.

16. K. Kundu, R. Dev, A. Rai, N. N. Pathak and R. Agarwal, "Design of a Dual band Complementary Antenna for WIMAX & WLAN Application," 2022 10th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), 2022, pp. 1-4. doi: 10.1109/ICRITO56286.2022.9964772.

Richa Tiwari,
Department of Electronics and Communication Engineering,
G.L. Bajaj Institute of Technology and Management, Greater Noida, ,
India.
E-mail address: richa.tiwari@glbitm.ac.in

and

Vatsya Tiwari,
Department of Information Technology,
Pranveer Singh Institute of Technology Kanpur (U.P),
India,
E-mail address: vatsyatiwari@gmail.com

and

Sharmila,
Department of Electronics and Communication Engineering,
Raj Kumar Goel Institute of Technology, Ghaziabad (U.P),
India
E-mail address: sharmila1ece@gmail.com