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# WBAN Health Monitoring System Using TEEN Protocol: Threshold Sensitive Energy Efficient Network Protocol

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***Abstract*— Wireless Body Area Network is a wireless network of biomedical sensors that are attached to the human body. The aim of WBAN is to facilitate continuous recording and monitoring of a person's health and transfer the data over a long distance communication network. Wearable sensors like Wristband Blood pressure sensor, glucowise sensor, fever alarm armband, ring sensor and tattoos sensor are attached on the body of patient by which values are to be taken and analyzed by healthcare system. TEEN protocol has been simulated for routing the patient's data in wireless body area network and its demonstration has been explained by number of critical events monitored for each iteration, calculation of critical parameters of each patient, energy consumption for each iteration and false acceptance rate vs. false rejection rate of TEEN protocol. Section I explains about the wireless body area network, section II gives the detailed architecture of WBAN. In section III, the routing issues and challenges faced has been explained. Section IV explains the proposed work and section V explains the detailed simulation results in Matlab.**

***Index Terms*— Wireless Body Area Network, Data transmission, Routing, Quality of Service, Radio Frequency.**

## I. Introduction

WBAN is an IEEE 802.15.6 standard which uses remote sensor hubs to keep a check on health monitoring of patients [1]. It is also called Wireless Body Sensor Network (WBSN).These sensor hubs can be worn externally or implanted inside the body to screen numerous bio parameters, (for example, blood oxygen saturation, blood pressure and heart movement) of different patients at a central area in the hospital. It is a radio frequency based wireless networking innovation. Here patient's health status can be observed at any time or place without affecting his/her ordinary day by day life exercises. A WBAN can be seen as a great help in the case where a paraplegic person is equipped with sensors deciding the position of the legs or with sensors joined to the nerves [2]. Another region of utilization can be found in the area of public safety where WBAN can be utilized by firefighters, policeman or in a military situation [3].

WBAN is a short range, low complexity, low cost and low power consumption network and the novel innovation idea behind the human body monitoring is to improve the patient health quality and increasing the life span of patients [4]. Advanced innovation has emancipated a lot towards medical sensors which can be worn or embedded in the human body. The sensors gather and exchange the patient's information with the medical server in which the information is stored and investigated. A remote system is planned for checking the health parameters so as to protect the system from the physical portability requirements which a wired system may bring about. A remote system gives better throughput and empowers more prominent physical portability. Remote communications support ubiquitous integration, better interoperability and encouraging modest arrangement [5].

A WBAN is a scaled down, intrusive light weight wireless sensor nodes that screen the human body parameters. Also, it underpins various creative and intriguing applications, for example, pervasive health care, entertainment, interactive gaming and military applications. Present day WBANs perform single application per system, processing and stockpiling limits are rare and there is no portability support [6].

In fact, complex WBAN application solutions recently discovered that preparing computationally complex information and handling sensor information on a routine PC is unfeasible and inaccurate[7].

**Fig 1: Diagrammatic representation of wearable BSN architecture**

Source: Body Sensor Network by Guang- Zhong Yang (2nd edition, Pg.no 4)

## II. ARCHITECTURE OF WBAN

Wireless Body Area Network (WBAN) is built from sensors, battery and processor. The building design of WBSN can broadly be divided taking into account the three distinct levels[8], as shown in Figure 2:

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**Tier 1 (Intra-WBSN):** In Intra-WBSN, the on-body and /or embedded wearable sensors hubs send the sensed information to the base station.

**Tier 2 (Inter-WBSN):** In Inter-WBSN, base stations send the received information to the sink after handling the information and collection of information from the nodes.

**Tier 3 (Beyond-WBSN):** In this level, the sink send the gathered information to the remote medical server by means of standard base, for example, web.

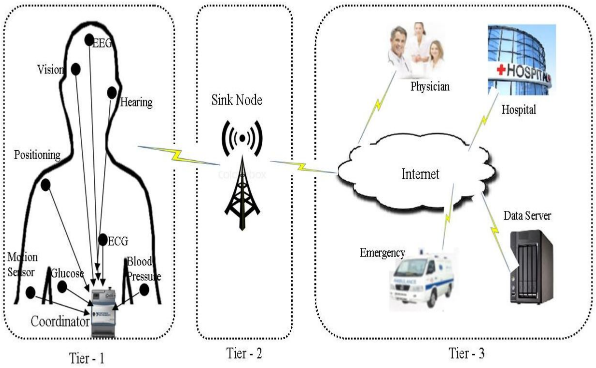


**Figure 2: Architecture of Wireless Body Sensor Networks**

[Source: http://www.mdpi.com/1424-8220/14/1/1322/htm]

The advancement in Wireless Body Area Network is the result of the current wireless sensor network. Various tiny remote sensors, deliberately set on the human body, make a wireless body area network that can screen different basic parameters, giving feedback to the user and medical server. In a WBAN, every wearable sensor screens diverse basic parameters, for example, blood pressure, body temperature, glucose level, body fluid level and pulse Oximetry.

The framework comprises of numerous sensor hubs that screen body movement and heart action, a system organizer, and an individual server running on an individual analog PC. Information gathered by wearable sensors is transmitted to the coordinator which is responsible for device synchronization. The coordinator acts as a link between the network of sensors and a medical server. The sensors are constantly transmitting the information to the coordinator. This setup causes high vitality utilization in every single wearable sensor and decreases their operational time.

## III. ROUTING ISSUES AND CHALLENGES IN WBAN

The implementation and designing of wireless routing protocols in WBAN [9] has been of great interest to the researchers because of their immense advantages and applications [8].

In the accompanying segments, the routing issues and difficulties of WBAN have been discussed:-

- **Network Topology**: Network Topology portrays the intelligent path in which the diverse communicating gadgets communicate with one another. Productive routing protocol advancement obliges a legitimate system topology as it impacts the general execution of the communication framework [10]. Proper network topology is essential for WBAN due to the vitality imperative, body postural movements, heterogeneous nature of sensors and short transmission range. WBAN has a single hop/Star topology, where every hub communicates specifically with the destination node, while WSN has a multi hop/Mesh topology.
- **Limited Resources:** Along with restricted vitality source, WBAN likewise have short Radio Frequency (RF) transmission range, poor calculation abilities, constrained capacity limit, and in addition low bandwidth – which may continue changing because of commotion and different interferences. Researchers must be aware of these constrained assets while planning the routing protocols in WBAN.
- **Quality of Service (QoS):** In WBAN, diverse sorts of information require distinctive nature of strategy as it manages fundamental indications of human body. Researchers have arranged the patient information into discriminating information (like EEG, ECG and so on), delay sensitive information (for instance video streaming), unwavering quality delicate information (like essential parameters monitoring respiration monitor and PH monitor) and conventional information (for instance temperature, heartbeat and so on). The other information driven uses of WBAN can't endure idleness and/or any loss of packets [14]. The proposed conventions should be mindful of the distinctive sorts of nature of administration needed for diverse sorts of patients essential parameters related information.
- **Radiation Absorption and Overheating:** The two source of temperature ascent of a hub are antenna radiation absorption and power utilization of hub hardware [15], which will influence the heat sensitive organs of the human body [15] and may harm a few tissues [16]. Researchers ought to deliberately build up the routing protocols for WBAN to keep human tissues safe from any overheating brought on by radiation ingestion and operation of the embedded bio-restorative sensor hubs.
- **Security and Privacy:** Like different uses of WBAN, security and protection are among the essential necessities of WBAN. It is difficult to apply the ordinary procedures of security and protection due to the low vitality accessibility, restricted assets and different imperatives [19]. Researchers ought to deal with the protection and security of the patient's information while planning routing protocols for WBAN.

## IV. PROPOSED WORK

The proposed system of work is designed around the study of WBAN network working which has a proper linear way of data transmission. In this applied area of work based on monitoring concept of various sensor readings taken from the patient's body, this linearity is needed as a proper database needs to be formed in orderly manner and updated timely, as there has been no real control systems introduced in the WBAN system. The WBAN works with a randomness of user monitoring system, for this application the vagueness in system response has to be controlled; this control of the sensor network forms the main control and service issue which is important as the users are not stationary.

Classification of WBAN with respect to mode of functioning is done on the basis of the number of sensors attached to the patient's body. These sensor networks, respond immediately to changes in the relevant parameters of interest. **TEEN (Threshold sensitive Energy Efficient Sensor Network Protocol)** is suitable for this kind of network. It is a reactive protocol which uses a data centric mechanism and makes clusters in a hierarchical fashion. Two threshold values are broadcast to the nodes: **Soft Threshold** and **Hard Threshold**. Hard threshold is the minimum possible value of an attribute. Sensor nodes send data to the cluster head only if the sensed value is greater than the hard threshold. If the threshold is not reached, then the nodes will never communicate. TEEN has high cluster stability, small delivery delay, low scalability, good load balancing, high algorithm complexity and very high energy efficiency. Here, TEEN protocol has been applied for monitoring criticalities in parametric sensing applications.

### PROPOSED SYSTEM FLOWCHART

Select the WBAN observation area to monitor, input the number of users and the number of iterations.

↓

Initiate TEEN protocol based on Queue priority.

↓

Select the most critical patient on the basis of parametric evaluation.

↓

Subsidize criticality with priority to the most critical node.

↓

Make the most critical more stable to reduce time in serving.

↓

Repeat the protocol control for the total number of user defined rounds and record the performance evaluation parameters, monitored critical time, energy consumption and FAR vs. FRR for each round.

Finally, complete content and organizational editing before

**Figure 3: TEEN Based WBAN Flowchart**

### PROPOSED SYSTEM OF WORK

- In the proposed system, the sensor nodes are deployed in a pre–defined confined area of 100* 100 meters.
- As per user requirement, the number of service iterations and the service nodes are selected.
- The network is initiated with user given randomized critical parameter for all the sensor.
- The parameters for all the patients are recorded initially and referenced with the normalized parameters.
- The decision on the criticality is made on the basis of queuing distance and parameter which is critical.
- The nodes are served till the criticality is normalized and then the total served time is also calculated for all the served nodes.
- Also the parameter for served count per node is calculated.
- The energy consumption for each iteration and false acceptance rate vs. false rejection rate is calculated.

### OBSERVED ACTUAL VALUES FOR USERS

**Table 1: Actual Values for Normal patient**

| Parameters | Normal Values | |
|---|---|---|
| Blood Pressure | Below 120 mm Hg(SYSTOLIC) and Below 80 mm Hg (DIASTOLIC) | |
| Glucose level | 4.0 to 5.9 mmol/l(Before meals) 7.8 mmol/l(2 hours after meals) | |
| Body Temperature | 97.8°F to 99°F(36.5°C to 37.2°C) | |
| Pulse Oximetry | 95 to 100% | |
| Fluid level | Total body fluid | 60% (70 kg male) 70%(infant) |
| | Extracellular Fluid | 20% ( 70 kg male) 30% (infant) |
| | Plasma | 5% (70 kg male) 5% (infant) |
| | Interstitial Fluid | 15% ( 70 kg male) 25% (infant) |

These are the actual normal values of body parameters of the patients. The force exerted by the flow of blood on blood vessels along with the variation between systolic and diasystolic and pressure in cardiac cycle gives the readings for blood pressure. Continuous monitoring of blood glucose helps in reducing the risk of hypoglycemia caused by high level of insulin in the body.

Oxygen saturation levels in human blood as well as blood volume changes in the skin are measured by a device i.e. pulse oximeter sensor.

**FAR (False Acceptance Rate)** = Number of wrong criticalities/total number of detected patients.

**FRR (False Rejection Rate)** = Number of actual criticalities/total number of detected patients.

## V. RESULTS

The various parameters are to be kept in mind while simulating TEEN protocol in Wireless Body Area Network (WBAN).

**Table 2: Simulation Parameters Value**

| S.NO | PARAMETER | DETAILS |
|---|---|---|
| 1. | Users/ Patients placement | Random |
| 2. | Number of Users/Patients | 7( Seven) |
| 3. | Number of sink(Destination) | Zero (Node 0) |
| 4. | Number of Patients nodes | Node 1 to Node 7 |
| 5. | Number of rounds | 4(Four) |
| 6. | Area of Simulation | 100 m* 100 m |

For implementing TEEN Protocol in WBAN, first a graphic user interface (GUI) is designed in MATLAB. In graphic user interface, the number of users/patients and for how many iteration the parameters value need to be monitored has to be entered by user.

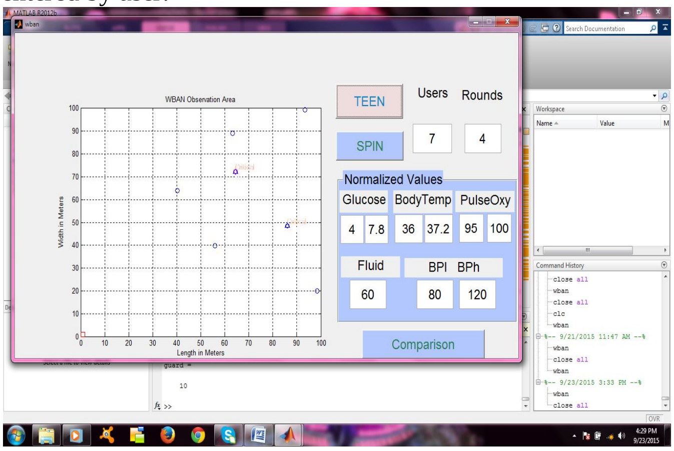


**Figure 4: WBAN Observation Area Monitored By TEEN**

After the number of users and number of iterations have been entered by user, the TEEN protocol will work by monitoring the criticality of patients, time served for each patient, energy consumption in each round, false acception rate vs. false rejection rate and patient's body parameter.

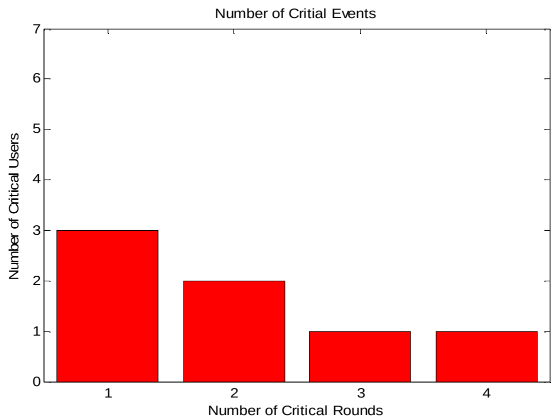


**Figure 5: Monitored Critical Events for Each Iteration**

In figure 5, the criticality of patients is monitored for each round. In 1st round, three patients are critical, in 2nd round two patients are critical and in 3rd and 4th round only one patient is critical.

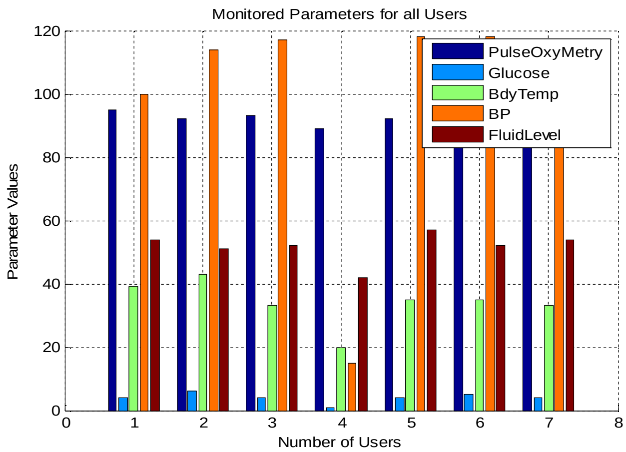


**Figure 6: Monitored Critical Parameters of the seven patient network under WBAN using TEEN**

Figure 6 depicts the changes in parameters like body temperature, fluid level, blood pressure, glucose level and Pulse Oximetry of patient's body under TEEN based WBAN system. It shows fluctuation in body temperature of patient 2nd and 4th being critical and fluid level of 4th patient being critical.

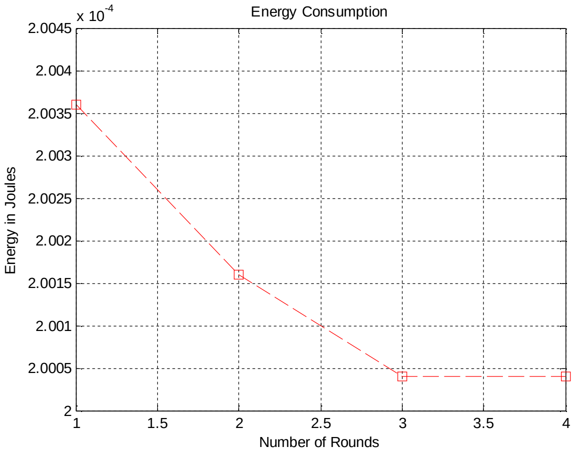


**Figure 7:Energy Consumption of the WBAN output for TEEN**

Figure 7 shows the output of the TEEN with the energy consumption for monitoring of the given 100m * 100m area, the energy is measured to be at maximum 200 joules for first round and for last round it drops to below 200 joules.

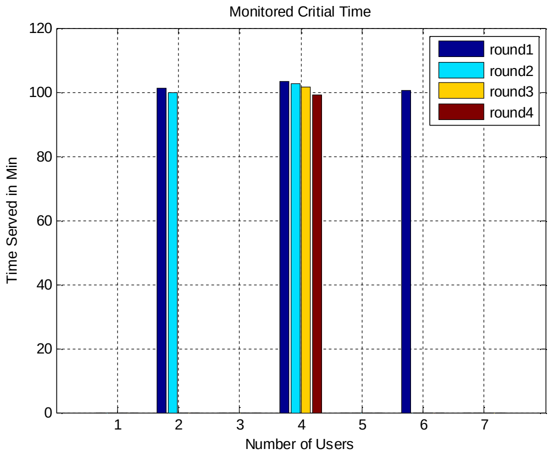


**Figure 8: Monitored Critical Time served by each patient under TEEN**

Figure 8 shows the critical monitored time for all the observed patients and also shows the number of times the criticality is monitored for each patient under observation. The observed patients were monitored for four rounds until normalization.
The second, fourth and sixth patient have been served critical by TEEN. Fourth patient has been served for four rounds, second patient has been served for two rounds and sixth patient has been served for one round only.

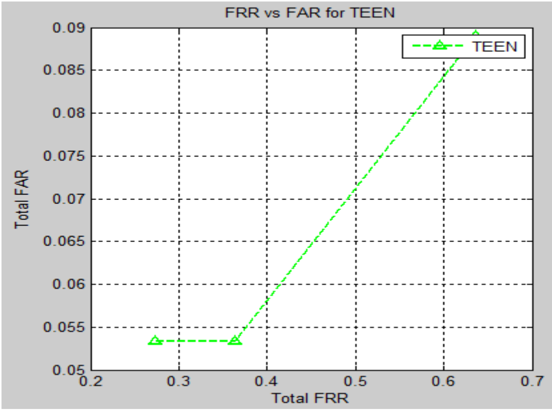


**Figure 9: False Rejection Rate v.s. False Acceptance Rate for TEEN**

Figure 9 shows the output of the TEEN with the FAR and FRR for monitoring of the given 100x100 section, the FRR is measured to be at maximum 0.65 metric with FAR metric to be at 0.9 showing high resistance to false alarming by critical event. FAR tells us about the wrong interruption of patient's body parameters and FRR is the rejection of wrongly detected patient's body parameters. False acceptance rate decreases where as false rejection rate increases..

## CONCLUSION

This paper provides an insight study of monitoring critical data transmission within WBAN by using TEEN protocol. TEEN has been proven more fruitful to be applied to control the data monitoring of patient's body parameters. TEEN is more specific for service on priority as it queued the importance on the basis of parameter change, which triggered the simulation of normalization of the critical parameter. Teen has shown high efficiency in terms of time and served critical events making it more favorable for WBAN system.

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