IJCTA, 9(9), 2016, pp. 4093-4102

An Efficient DTDM H-MAC Protocol with self-calibrating Algorithm in BSN for Sporting Application

M. Mohammed Mustafa[1], V. Parthasarathy[2], M. Rakesh Kumar[3] and S. Hemalatha[4]

ABSTRACT

As the wireless medium requires highly optimized medium access protocols to avoid interferences, a dynamic TDMwith HMAC protocol along with an efficient time management algorithm which ensures all nodes to communicate to the hub at different time interval to fortify the optimal utilization by all the connecting nodes is proposed in this paper. Further, a self-calibrating algorithm is implemented which will hook the interval position points and sequence of an individual with a running cycle for each individual as it differs from one another. Based on the simulation results it is identify that the proposed BSN with Dynamic TDM HMAC technique and self-calibrating algorithm has remarkably 17% and 12% of less energy consumption, 15% and 7% of better throughput and 27% and 14% of reduced delay, than the reported dynamic TDMA MAC and TDMA.

Keywords: Wireless: *Dynamic TDMA, H-MAC, BSN, TDMA, Interactive application, Self-Calibrating Algorithm.*

1. INTRODUCTION

Body Sensor Networks (BSN) connects or operates with or within or proximal to human body to monitor the vital signs, day-to-day activities, Gait Patterns and motor fluctuations. The body sensor network along with home network is afirst-rate platform for collecting personal information. The sport application has brought the attention of researchers for developing a system with help of sensor networks and wireless communication. Body sensor network plays asignificant role in the design of this interactive application. There are wireless body area networks which are implanted or wearable (eye glasses and clothing devices)[1].A time division multiplexing system was designed with multiple nodes one on the chest of the human busy which act as hub, other two on limbs and two on wrists respectively [2]. Another strategy of cycling experiment was considered, where pedaling takes place, in that the nodes are connected to the limbs, when the movement takes place, the data are sent to the hub [3].

A TDMA mechanism improves the networks efficiency by exploiting the data from different nodes placed in the human busy at different time periods [7]. The data from various nodes are sent to the hub and then transmitted to the remote computer for further processing. Thereal-timefeedback is used in sports for athletes, coaches and for public [8]. TDMA strategy has some of the advantages as little communication overhead, long sleep times for the sensor to transmit and receive and robustness to communication errors [5]. The data packets from each node transmitted is very important because there may chances of losses of data packets, so we design and evaluate the routing and medium-access protocols for sensor networks [4].

[1,3] Research scholar, Department of Information Communication and Engineering, Anna University, Chennai, *Emails: Musti_musy@yahoo.co.in, rakeshkumarmahendran@gmail.com*

[2] Professor, Department of Computer Science and Engineering, Vel Tech Multi Tech Dr. RangarajanDr. Sakunthala Engineering College, Avadi, Chennai 600062, Tamil Nadu, India, *Email: sarathy.vp@gmail.com*

[4] Assistant Professor, Department of Information Technology, Vel Tech High Tech Dr.RangarajanDr.Sakunthala Engineering College, Avadi 600062, Chennai, India, *Email: hema.vtht@gmail.com*

The calibration of wireless sensor is that the athlete is asked to wear the implanted sensor nodes at the chest, arm and wrist and asked to perform the following tasks. Once the sensor is positioned on the human body they are asked to stand motionless to check whether any data transmission takes place, and then start slowly the leg and wrist movement to check the data transmission to the hub and then to the remote computer. [10]The most important sensor position on human busy is on thigh and wrist. [6]The proposal is that a wireless sensor network with the help of Dynamic Time Division Multiplexing (DTDM) mechanism is followed to achieve error free communication and also various algorithms to identify the running style of the athlete and fabrication of the sensors, so that error can be minimized.

2. DESIGN AND EXPERIMENT OF THE APPLICATION

2.1. Sensor Configurations

The Crossbow Company's Mica2Dot Motescan to be used for experiments. The sensor node covers a frequency range of 916MHz with a data rate of 38.4kbps. It is a programmable one with a dimension of 26*6mm^2, transmission power of -20 to +10db. The power consumption for transmitter and receiver is 25mA and 8mA respectively at 3V. The experiments showed that each sensor node overcomes various failures. Erasure code helps to get high reliability by tolerating packet losses. Route fix is a mechanism in which itresponds quickly to link failures. With the right combination of primitives we can yield more than 99% reliability. Motescope is the new version of this Motetestbed and is constantly evolving. The MICAz motes also use an Atmel ATmega128L microcontroller and an indoor range of 20 to 30 meters. The devices can be used to connect a variety of analog and digital sensors. Interfacing to sensors including accelerometers, gyroscopes, magnetometers, electrical current sensors can be done. [16]

Shimmer sensor is another kind of sensor that is used for monitoring body sensor that captures physiological and kinematic data used for sports application.

2.2. Design/Architecture of the Application

The sensor node consists of microcontroller, five wireless transceiver with PCB built in antenna, memory, powersource battery) minimum of 3hours capacity and an accelerometer sensor with acceleration sensitivity of 2g.

2.2.1. Microcontroller

It is an ATmega128L used to receive command from RF transceiver and the send the power and control signals to sensor.

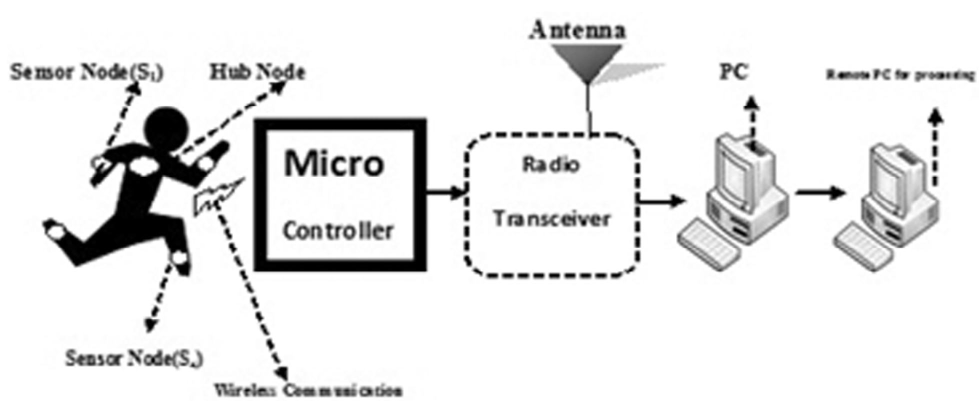

Figure 1: Architecture design of BSN

2.2.2. Wireless transceiver

It is used to transmit and well as receive signal to or from the sensor nodes to other device for processing. Narrow band antenna can be designed so that mode switching capability (receive and transmit) to improve communication.

2.2.3. Memory

A 512kb of flash memory can be used at the sensor node to store the data or to transfer the data to the Hub.

2.2.4. Multiplexer

It is used to combine all the output signals from various nodes to hub and then transmit to the PC for further processing.

2.2.5. ADC (Analog to Digital Converter)

It is used to convert the analog signal from the sensor to digital and send to the PC for processing.

2.2.6. Power

The nodes should operate for days or months without recharging the battery. An energy harvesting mechanism can also be used so that the energy is stored from the solar system.

2.3. Experiment of the application

The signals received from human body are weak and so amplified and filtered and the sent to multiplexer for combining the analog electrical signals. An ADC converter to digitize the data for further processing and micro controller will code the data before it is sent to transceiver and then to PC for processing. The transmitting and receiving antennas were vertically polarized when the human stands upright with hands.

To ensure the wearable node is stable, the sensor was attached to fabric band to the wrist and foot.

The sensors can be placed in a horizontal position of the wrist so that all the four positions give clear readings and it was used to calculate swing time. A UART (universal Asynchronous reception and transmission0 is used to send the data from sensor to other device for processing.

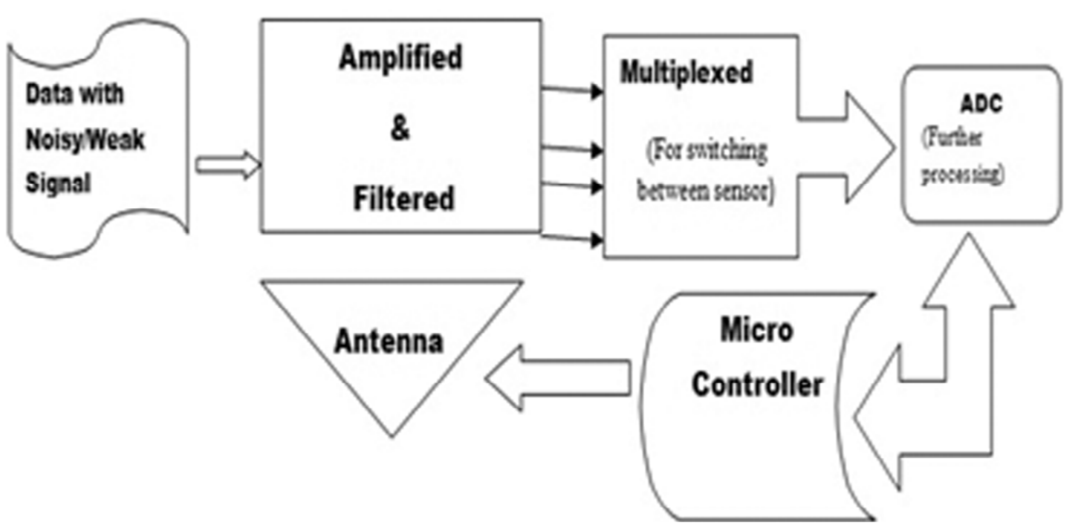

Figure 2: Sensor design for BSN

3. DETERMINATION OF THE LINK PERFORMANCE BETWEEN NODES

A wireless accelerometer module is used to determine the link performance between nodes by recording the data on different runners for different locations**.** A wireless sensor network is a self-organizing network of tiny sensor nodes. Each node is usually called mote senses certain characteristics of human body such as running style and transmit the data to the system for processing. Whenever there is a communication between sources to destination the communication may be disrupted due to packet loss. In a wireless network, nodes cooperate in routing traffic. The network reliability depends upon speed and amount of information received. At first, an adversary pretends to be a cooperative node in the route discovery process. Previous work dealt with determining the best node location on human chest. [19].

Correlation would analyze the characteristics of the node to identify the root cause of packet drop. The Correlation is made, which is verified and validated by Homomorphic Linear Authenticator (HLA) to verify the truthfulness of the packet loss. In wireless network we need to send the packet through the node. Every node has communication range. If source and destination node exists within the communication range, source can directly transmit the packet. Otherwise, we need to select the intermediate node based on the transmission range for transmit the packets. Here the transmitting nodes are Nodes on the wrists and the legs; receiver node is the hub which is placed on the chest. The gait patterns of the athlete are determined by using wireless accelerometer sensors with 100 samples per second. Each sensor records the swing and sends the samples to central unit (hub) and then to further analysis. The result showed installing the sensor on wrist provides the best result for good communication. There is also a correlation between the swing time and running style of different runners. [12]Numerical models can be used to estimate morphological variations of human body.

A swing time algorithm was used to find the each consecutive foot contacts with the ground of the right or left leg. The participant was asked to run for a 25 meters distance at a moderate speed. The swing speed was calculated instead of running speed to find the relationship between the speed of limb and link reliability.

The technique allows sensed acceleration data to perform actions, therefore energy cost is reduced for multiple transmissions and reliability of network is increased.

i) Swing Time Algorithm

```
Start the process
Initialize the window size = 0;
Initialize the swing count = 0;
Calculate the value of swing count using formula C = Swing count* window size;
Increment the count value such that count = Count++;
If Count = Swing count* window size plus the window size
    Then increment swing count
Else
    Increment count value and find minimum value
Increment swing count;
Record the location of lower value;
If swing count = even;
    Then Calculate swing time;
Else
    Increment the count value and find the minimum value;
End of the Process
```

4. FINDING THE RUNNING CYCLE OF THE PARTICIPANTS USING SELF CALIBRATING ALGORITHM KINEMATIC CHANGES

Different runners having different running patterns, so different programming for each runner to make sure that data is sent at particular event. Here we need to consider two parameters for best communication as Acceleration value that is reading of sensor and its location. For this we are using a self-calibration algorithm.

Experiment was conducted, in which participants of different skills were asked to run it was surprised to see that the beginners who are less experienced changed their running style when comparing to experienced runners. It was observed that the beginners increased their foot contact, indicated they were not able to lift their feet any more. They performed more vertical oscillation, indicating a less economic movement. For experienced runners, they changed their running pattern towards a less economic one. [6].

4.1. Methods to find the running pattern of the athlete.

a) Step frequency (SF)-it is often used as the model for measuring the running kinematics.
   It can be assessed from magnitude of acceleration data collected on the foot. Calculated by the formula $S = \sqrt{S_x^2 + S_y^2 = S_z^2}$. Magnitudes are collected from three different axes.
b) Normalized foot contact (NFC) – a time duration in which a foot is on the ground normalized by the step duration. Athletes try to shorten the NFC.
c) Vertical Oscillation (VO) – the extent an athlete lifts himself during a single step.
d) Heellift (HL) – the deflection of left leg in terms of angle between the lower leg and the vertical.
e) Objective analysis is made in which raw sensor data are resulted in meaningful form. The negative spikes in accelerometer spikes determine the athlete is running. With the help of magnitude of the spikes the runner's ground reaction can be calculated.

Athletes benefit from such analysis and optimize the efficiency of their movements. Once we finalize the algorithm we run some more test data to check the efficiency of the data. We continue to fine tune and optimize the algorithm until there is accuracy.

4.2. Self Calibrating Algorithm

Different athletes have different running style; therefore a self-calibrating algorithm was used where different programming was also done to make sure that the data is sent at particular event. This algorithm gives a reliable communication between the hub and other nodes for various runners. There are two important factors to be considered, one is the acceleration value and communication time. Controlling both the parameters would result in best performance.

In this self-calibrating algorithm there are two modes of operation to be considered as transmit mode and receive mode. The parameters to be considered are the location of the node, number of counts, cycles. First assign the mode value to be 1, which means it transmits the data and sends the data request until the window size not becomes W. Then we need to calculate the value of average cycle and then if message delivered end the process, otherwise resend to node

If the mode value not equal to one, then it is receive mode, so check for data availability if available save it until the hub receives data from all the nodes. Stop the process.

5. DESIGN OF AN INTERACTIVE APPLICATION FOR COACHES

The interactive application is the main objective of the paper such that in the previous work, they have used many wireless communication techniques such as CSMA which are subject to energy cost and idle listening phase. In CDMA technique require complex hardware to perform frequency signal spread spectrum. Standard time division multiplexing which has following drawbacks as only 60% of the reliability and almost 40% of the data is lost. There is an H-MAC, which is a TDMA based mechanism specially designed for star topology which we are using in our work. There is a Bayesian statistical model for MAC which is a contention-based MAC protocol to control active and sleep times in WSNs. RL-MAC (Reinforcement learning techniques) was introduced to reduce the energy usage and increase the throughput.

The TDMA based mechanism assign s different time slots to each body sensors to avoid collision. The MAC achieves the TDMA time synchronization without distributing the periodic information. This reduces the energy cost.

5.1. Experiment

The hub was set to transmit some 2000 requests for each node with 10ms burst time. The test dint showed any time difference between hub and the node. If the hub is communication with one node it will give 200 samples per second, but since it is communicating with four nodes, then each node provide 50 samples per second. Therefore the time difference between samples will be 40ms. [1] A time division multiple access mechanism for body sensor networks (BSN) was designed the medium access control (MAC) helps to improve the BSN energy efficiency by the periodic synchronization beacons. [7].

A transmission method based on human gesture that is during running of the athlete can be used so that the data from accelerometer can be sent to the hub during running itself, so that no idle time and energy cost required and multiple transmissions can be avoided. [1]

Such a technique is Dynamic time division multiplexing [DTDM] which reduces time synchronization cost and helps network reliability to increase. So an efficient Dynamic time division multiplexing [DTDM] can be used. These protocols are helpful in improving the fairness if the network, bandwidth utilization and

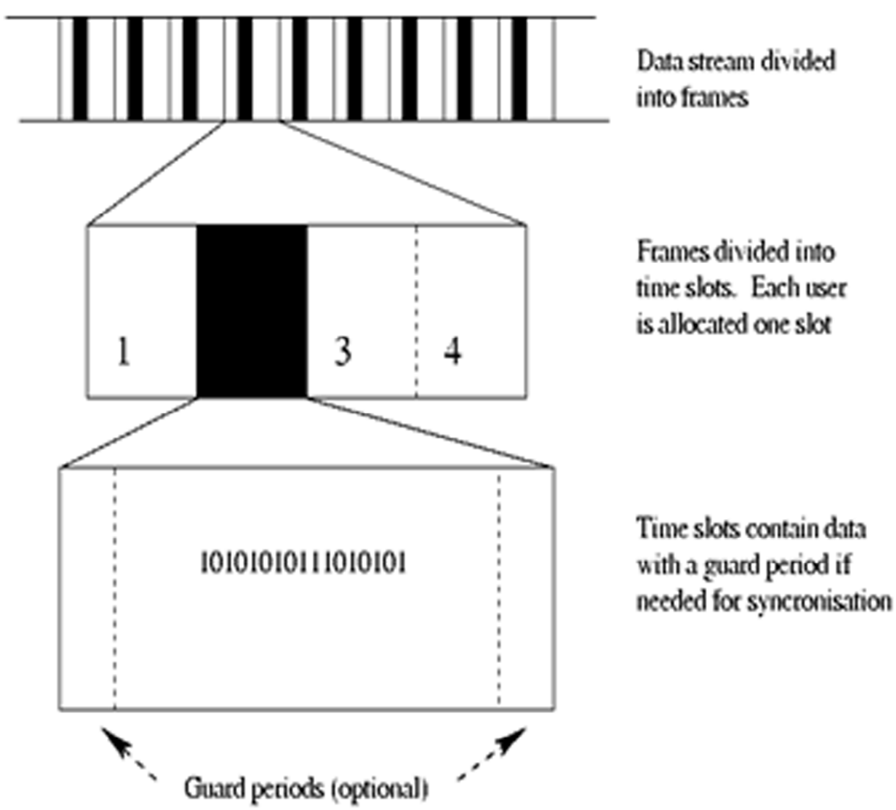

Figure 3: MAC Layers

throughput. The important features of MAC protocol are support of scalable data rates, low power consumption, light weight sensor nodes, secure data transmission, quality of service, cooperation with wireless technologies and formation of communication network with 2 metres.

The DTDM allows nodes to send data depending on human gesture and only four transmissions can be done per cycle. At each time slot only the respective node can transmit the data, so that collision can be avoided. In this mechanism first the nodes were calibrated using self-calibrating algorithm for transmit and receive, and then a carrier sensing algorithm can also be used to prevent collision.

6. FABRICATION OF THE SENSORS FOR LEFT AND RIGHT LIMB

This process is one of the important processes in the design of this application since there should be symmetry between right and left limbs, also the positioning of various nodes is important and hub position is necessary and suitable hub position was found to be the chest for communication**.** The communication that takes between nodes and hub is highly affected by its proximity to human body. There is a chance of attenuation, delay and distortion. Therefore fabrication of the sensor is necessary to remove the drawbacks.

The sensors that can be used are fabricated with the help of layered moldingandcasting. Theprocess was dividing into four major steps as:

6.1. Silicone casting

Silicone elastomer containing the micro channels.The sensors uses liquid metal (eutectic Indium Gallium alloy, a.k.a. EGaIn) inside the micro channels.

6.2. Embedding flex-circuits

Positioning on the inner layer of the circuit board

6.3. Bonding and injection

Injection molded ferrite has lower magnetic properties due to ferrite features

6.4. Final sealing.

It deals with the integration of all the devices to final product.

The size of the sensor can be of width 40mm, length 30mm, and thickness1.5mm.

In the previous work there is a hysteresis loss caused by the magnetic properties of the sensor. In this paper the loss is reduced with the help of by embedding the equal area of anti-ferromagnetic material along with the sensor.

7. RESULT AND SIMULATION ANALYSIS

7.1. Bit Rate Analysis

This section discusses on the simulation results obtained from the network that uses the proposed dynamic TDMA H-MAC protocol. The performance is studied in terms of power consumption, network synchronization, throughput and average end to end delay. The bit rate analysis is carried out to determine the packet error and packet loss rate in a wireless body sensor network, since the error and loss rate in WBSN is found to be higher compared to the open medium communication channels. The analysis is carried out using the following equation.

$$x = 1 - (1 - z)^r$$

Where “x” represents the packet error rate (PER), “z” denotes the bit error rate and “r” represents the size of the data packet.

7.2. Network Synchronization

The evaluation is done in terms of average energy consumption, throughput and end-to end delay of the data packets. The topology includes the following parameters: No. of sensors (N) = 15, No. of projections (M) = 20, bit rate = 250 Kbits, target delay = 0.27 seconds (per hop). The traffic across the entire network ranges from 1 to 16 Kbits. The sensor nodes need to be aware of their slot during the contention period even if there is no data to transmit.

As the traffic load increases, the average energy consumption of the proposed dynamic TDMA H-MAC protocol decreases to about 17 % and 12% compared to the existing TDMA MAC and dynamic TDMA MAC protocol.

The network throughput is presented as a function of the traffic load of source nodes. For instance, for a traffic of load upto 4 kbps, the proposed method achieves a throughput of 3.9 kbps, whereas the TDMA MAC protocol results 3.4 kbps and dynamic TDMA MAC protocol results a throughput of 3.6 kbps. The throughput for varying traffic load of 6, 8, 10 etc are shown in figure5.

7.3. End to End Delay

The delay increases with traffic and decreases with the number of slots.

Picture send again

Figure 4: Comparison of the average energy consumption

Picture send again

Figure 5: Comparison of throughput

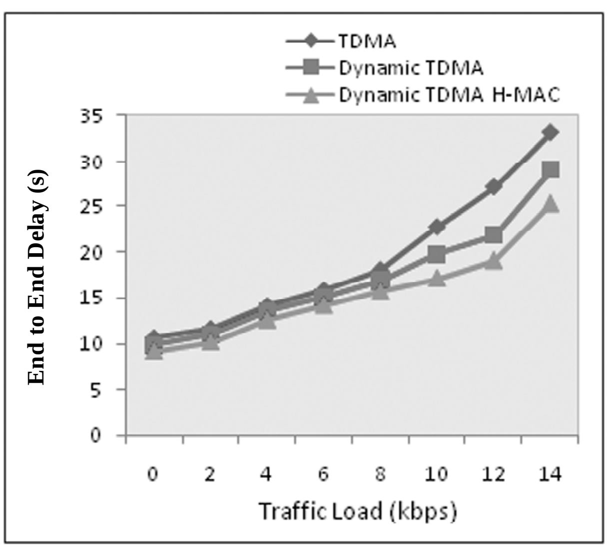

Figure 6: Comparison of average end-to-end delay

Since the static TDMA and dynamic TDMA MAC protocol fails to keep below the target delay as traffic increases, they cannot be used in a generic situation where the amount of traffic that will be generated is unknown. At the usage of more number of slots it is possible to satisfy the delay constraint but the power consumption may likely increase. But the proposed dynamic TDMA H-MAC protocol satisfies the delay constraint and achieves lower power consumption with many slots as shown in figure 4 and 6.

8. CONCLUSION

The result reported in section VII proves that the proposed dynamic TDM HMAC protocol works better than the existing dynamic TDM MAC and TDMA protocols in terms of energy consumption, throughput and the packet delivery delay in the wireless body sensor network. Then to understand the running style of an athlete a self-calibrating algorithm is used, followed by the design of the application with the help of Dynamic time division multiplexing HMAC protocol in which time synchronization is improved around 15% and finally the fabrication of sensors show the symmetry between the right and left limbs and also to remove the attenuation, distortion and any sort of kinematic changes from the human body.

REFERENCES

[1] Haider Abd Ali Sabti and David Victor Thiel, “Self-Calibrating Body Sensor Network Based on Periodic Human Movements,” IEEE sensors journal, vol. 15, no. 3, march 2015.

[2] H. A. Sabti and D. V. Thiel, “Movement based time division multiplexing for near real time feedback body area network applications,” in Proc. IEEE Int. Workshop Antenna Technol., Sydney, Australia, 2014, pp. 23–25.

[3] Raluca Marin-Perianu • Mihai Marin-Perianu et al., “A performance analysis of a wireless body-area network monitoring system for professional cycling”, PersUbiquitComput (2013) 17: 197–209

[4] J. Zhao and R. Govindan, “Understanding packet delivery performance in dense wireless sensor networks,” in Proc. 1st Int. Conf. Embedded Netw. Sensor Syst., New York, NY, USA, 2003, pp. 1–13.

[5] Michael Gasser et al., “Motion Estimation Using Inertial Sensor Technology with Applicationsto Sporting Exercises”, European Athletics Innovation Awards 2014.

[6] Christina Strohrmann, Holger Harms et al., “Monitoring Kinematic Changes With Fatigue in Running Using Body-Worn Sensors”, IEEE transactions on information technology in biomedicine, vol. 16, no. 5, September 2012.

[7] H. Li and J. Tan, “Heartbeat-driven medium-access control for body sensor networks,” IEEE Trans. Inf. Technol. Biomed., vol. 14, no. 1, pp. 44–51, Jan. 2010.

[8] H. A. Sabti and D. V. Thiel, “A study of wireless communication links on a body centric network during running,” Proc. Eng., vol. 72, pp. 3–8, 2014.

[9] Shih-Lun Chen, Ho-Yin Lee etal., “Wireless Body Sensor Network With Adaptive Low-Power Design for Biometrics and Healthcare Applications”, IEEE systems journal, vol. 3, no. 4, december 2009.

[10] David V. Thiela,*, Hugo G. Espinosaa et al.,” Arm movement: The effect of obesity on active lifestyles”, Procedia Engineering 60 (2013) 182–187.

[11] Fei Hu, Yang Xiao, Congestion-Aware, Loss-Resilient Bio-Monitoring Sensor Networking for Mobile Health Applications”, IEEE journal on selected areas in communications, vol. 27, no. 4, May 2009.

[12] H. A. Sabti and D. V. Thiel, “Node position effect on link reliability for body centric wireless network running applications,” IEEE Sensors J., vol. 14, no. 8, pp. 2687–2691, Aug. 2014.

[13] H. A. Sabti and D. V. Thiel, “Time multiplexing-star shape body sensor network for sports applications,” in Proc. IEEE APSURSI, Memphis, TN, USA, Jul. 2014, pp. 969–970.

[14] Hugo G. Espinosaa,*, Daniel A. James,” Sports monitoring data and video interface using a GUI autogenerationMatlab tool”, Procedia Engineering 60 (2013) 243–248.

[15] S. Marinkovic, C. Spagnol, and E. Popovici, “Energy-efficient TDMA-based MAC protocol for wireless body area networks,” in Proc. 3rd Int. Conf. Sensor Technol. Appl., Jun. 2009, pp. 604–609.

[16] Sukun Kim et al., Reliable Transfer on Wireless Sensor Networks.

[17] Yigit Menguc,1; 2, Yong-Lae Park1; 2, et al.,” Soft Wearable Motion Sensing Suit for Lower LimbBiomechanics Measurements”, IEEE International Conference on Robotics and Automation (ICRA)Karlsruhe, Germany, May 6-10, 2013

[18] Wang Yun Toh, Yen Kheng Tan, Senior Member et al.," Autonomous Wearable Sensor Nodes WithFlexible Energy Harvesting", IEEE sensors journal, vol. 14, no. 7, July 2014.

[19] Tao Shu and Marwan Krunz., "Privacy-Preserving and Truthful Detection of Packet Dropping Attacks in Wireless Ad Hoc Networks", IEEE transactions on mobile computing, vol. 14, no. 4, April 2015.

[20] Angelica Reyes-Muñoz 1,*, Mari Carmen Domingo," Integration of Body Sensor Networks and Vehicular Ad-hoc Networks for Traffic Safety", Sensors 2016, 16, 107.

[21] Mohammad Abu Alsheikh 1, 2, Shaowei Lin 2, Dusit Niyato1, "Machine Learning in Wireless Sensor Networks: Algorithms, Strategies, and Applications", arXiv:1405.4463v2 [cs.NI] 19 Mar 2015

[22] S. Taherian, M. Pias, R. Harle, etal., "Profiling Sprints using On-Body Sensors.

[23] Tao Gu, Member et al., "Recognizing Multiuser Activities Using Wireless Body Sensor Networks", IEEE transactions on mobile computing, vol. 10, no. 11, november 2011.