Performance Study of Node Placement to Minimize Packet Loss for Training Monitoring System on Track Cycling

M. A. Ruslee, N. M. Abdul Latiff, S. K. Syed Yusof, N. Fisal, K. Mohd Yusof, M. R. Abd Rahim, H. Sayuti
UTM-MIMOS Centre of Excellence
Faculty of Electrical Engineering, Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johor, Malaysia.
Email: muazzah@fke.utm.my

Abstract—**Recent technology advance in wireless sensor networks (WSNs) has enabled the growth of various applications that can assist or enhance existing systems. For instance, the technology provided by IEEE 802.15.4 protocol that operates in 2.4GHz ISM band is suitable to be used in many applications since it is a low cost and low power wireless communication. In this paper, we present a performance study of node placement for training monitoring system for cyclist using IEEE 802.15.4 technology. A series of experiments were carried out to obtain the best node placement in the system in order to minimize the packet loss during data transmission on track cycling. Details of experiments' results are presented and data collected will be used further to design the training monitoring system.**

Keywords—Wireless Sensor Networks, training monitoring system.

I. INTRODUCTION

Cycling is one of the most popular sports in Malaysia and significant interest is given to this sport recently. SRM [1] is the current device used by the national cycling team to measure the speed, cadence, heart rate and power of athletes in terms of their performance during the training sessions. Another device such as Heart Rate Monitor (HRM) is also used to monitor the performance of athletes. Furthermore, this device is also able to monitor athlete's health condition [2]. The data produced by SRM and HRM devices are reliable and accurate data. However, the data produced are stored first and must be transferred to a laptop or personal computer (PC) through universal serial bus (USB) cable to enable the coach to observe and analyze the data. Hence, this process is quite time consuming and inefficient for the coach to monitor their athletes performances continuously. Therefore, a wireless training monitoring system with low power consumption, long communication range between transmitter (cyclist) and receiver (coach) with minimum delay is really desirable in order for national cycling team to improve their performance as well as to prevent overtraining.

This work is supported by Ministry of Education and Research Management Centre, Universiti Teknologi Malaysia under Sport Research Grant Scheme no. R.J130000.7823.4L550.

This paper presents an initial work of a wireless training monitoring system design for cyclist. In particular, we investigate the design consideration of sensor nodes placement to minimize the packet loss during data transmission. There are various types of bicycle racing sports such as road bicycle racing, track cycling, time trialing, mountain bike racing, cyclo-cross, cycle speedway and BMX. In this work, we focus on track cycling racing, in which it is usually held at banked tracks or velodromes. An actual size of velodrome is considered in this work, which length is 330 meter as shown in Fig. 1 [3].

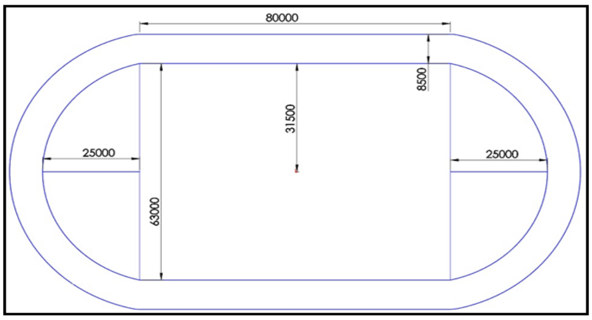

Fig. 1. Velodrome of 330 meter length [3].

The most important part in a wireless monitoring system is the sensor node. There are a lot of sensor nodes that have been developed by various research groups such as MIT Media lab, UCB and many more [4]. Nevertheless, since most of wireless sensor nodes developed can only send the data to the destination that is less than 100 meter from them, multi hop network is needed for successful data transmission [5]. Hence, the knowledge of a maximum distance that is reachable by the sensor nodes used in the system is very crucial during the design process in order to asses the reliability of the system. For that purpose, we have conducted six experiments that involved varied distance of transmitter and receiver measurements, varied heights of receiver measurement, measurement when the transmitter is moving, varied packet size against time taken measurement, varied transmit power against packet loss measurement, and packet loss measurement when the packet is transmitted from several nodes.

The remainder of this paper is organized as follows. Section II discusses on related previous works in this area. Section III describes about the experiments and measurement works that are conducted for node placement design. After that, analysis of results collected is presented in Section IV before conclusion remarks are given in Section V.

II. Related Work

There are several researches that are related to wireless cyclist monitoring system have been conducted in the recent years. Wireless communication protocols that are used for this system are Bluetooth, Wi-Fi, ZigBee, and Adaptive Network Technology (ANT). Bluetooth technology together with mobile phone is used by Aki Honkasuo *et al.* in [6] to monitor the speed, cadence and power of the bike. However, the main problem of using this technology is that Bluetooth is designed to have a short distance transmission range, which limits the performance of the system. In addition, the used of mobile phone leads to a very high power consumption.

In [7], Wi-Fi network is used by Kun-Ming *et al.* in a device that is able to plan route with a track area and to monitor the heart rate of a cyclist. It is a low cost system that is designed to improve the safety during recreational cycling. Nevertheless, since the system uses Wi-Fi for monitoring, the power consumption is quite high. Hence, it is not able to monitor basic parameters such as speed, cadence and power.

Our work focuses on IEEE 802.15.4 technology, where we carried out a series of experiments to measure the performance of data transmission in a wireless cyclist monitoring system. This IEEE 802.15.4 standard defines the physical layer and media access control layer of the Open System Interconnection (OSI) model. Particularly, we have conducted several measurements and analysis for the best node placement in monitoring system in order to increase the communication range between cyclist and the base station and minimize the packet loss. We used our own developed sensor node, named TelG, which was first appeared in [8], as a transmitter and a receiver. The main features of this TelG node are its flexibility, low power consumption, small in size and wearable. Self-built operating system (OS) called WiseOS is then embedded to this sensor node to support customized operation. Details of this sensor node can be found in [8].

III. Experiments Set Up

A. Varied Distance between Transmitter and Receiver

The purpose of this measurement is to observe the number of packets received when the distance of the transmitter and the receiver is varied. Fig. 2 shows the measurement set up. The distance of the transmitter and the receiver is varied at 10m, 20m, 30m, 40m, 50m, 60m, and 70m. Two hundred packets are transmitted for each transmission process. Ten received packet values are recorded for each distance.

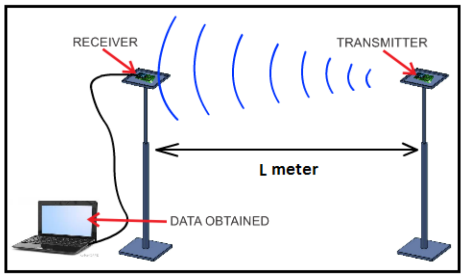

Fig. 2. The distance between transmitter and receiver is varied at *L* meter.

B. Varied Height of the Receiver

Next, our aim is to find the best height of the receiver while fixing the height of the transmitter at 70cm from the ground. We fixed this value since the transmitter will be placed under the seat of the bicycle during the real system implementation and the distance between the seat and the ground is 70cm. Based on the previous measurement where the distance of transmitter and receiver is varied, for the measurement to vary the height of the receiver, the distance between transmitter and receiver is fixed at 40m. Fig. 3 depicts the set up for this measurement.

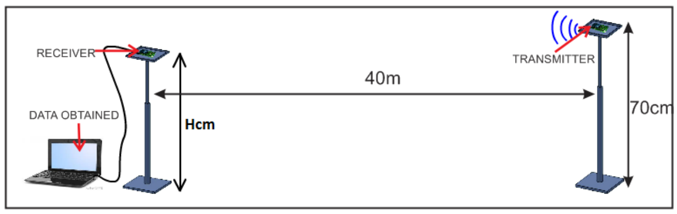

Fig. 3. Height of the receiver is varied at *H* cm.

C. Moving the Transmitter

In the real scenario for product implementation, the transmitter is fixed at the bicycle and the bicycle moves around the track. Therefore, it is important to take this measurement in order to observe the capability of packet received when the transmitter is mobile. The measurement set up for this purpose is shown in Fig. 4. The transmitter is attached at the bicycle while the bicycle moves from point A to point B. Furthermore, the distance between receiver and transmitter path is varied at 10m, 20m, 30m and 40m as shown in the figure. This process is repeated for six times and the number of packets received is recorded each time.

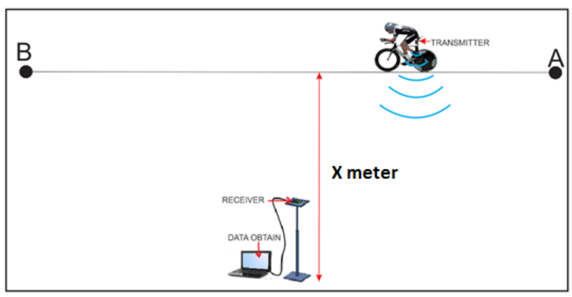

Fig. 4. The receiver is varied at *X* meter from the transmitter's path.

D. Packet Size Against Time Taken for Data Delivery

The next experiment is to determine whether the size of packets sent affects the time taken for the packet to be delivered from the transmitter to the receiver. The distance of the transmitter and the receiver is varied from 10m to 50m as shown in Fig. 2. Meanwhile, the packet size is varied from 10 bytes to 100 bytes. Ten data are collected for each distance.

E. Transmit Power Against Packet Loss

The set up for the next experiment is illustrated in Fig. 2 where the distance between the transmitter and the receiver is varied from 10m to 50m. However, this time we varied the power to transmit at 0dBm, -2dBm, -4dBm, -6dBm, and -10dBm for each distance. The purpose of this measurement is to analyze the packet loss when two parameters, the transmit power and the distance from the transmitter and the receiver, are varied.

F. Data Transmission from Multiple Sensor Nodes

This measurement is important to determine whether the packets received will be affected when several packets are sent at the same time from several transmitters. During this experiment, each transmitter sends two hundred packets to the same receiver. For each transmission, the packet size is ten bytes. The number of packet loss during data transmission is recorded. The set up for this measurement is depicted in Fig. 5.

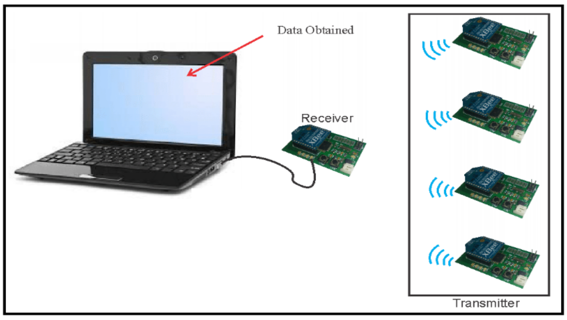

Fig. 5. Data transmission from several transmitters to a receiver.

IV. Results and Analysis

Fig. 6 shows the result of the packet received ratio versus distance between the transmitter and the receiver from experiment A. From the graph, it can be seen that the packet received ratio decreases as the distance increases. The packet received ratio drops drastically when the distance between the transmitter and the receiver exceeds 50m. The transmitter is not receiving any packet when the distance between the transmitter and the receiver exceeds 70 meter. Next, Fig. 7 depicts the result from experiment B where the packet received ratio is plotted against the height of the receiver that is varied from 60cm to 150cm. It is observed from the graph that the higher the receiver from the ground, the better packet received ratio.

Meanwhile, the packet received ratio obtained from experiment C where the transmitter was moving while measurements were being done is shown in Fig. 8. The ratio starts to decrease when the distance of the transmitter and the receiver exceeds 35m. Fig. 9 shows the result of varied packet size sent to the destination against time taken to reach the destination. In other words, the time indicates the end to end delay for data delivery. It is observed that, the bigger the packet size is, the longer is the time taken for the packet to travel from one node to another node. It is noted that, although the distance between the transmitter and the receiver is varied from 10m to 50m, the delay for data delivery is the same for all cases.

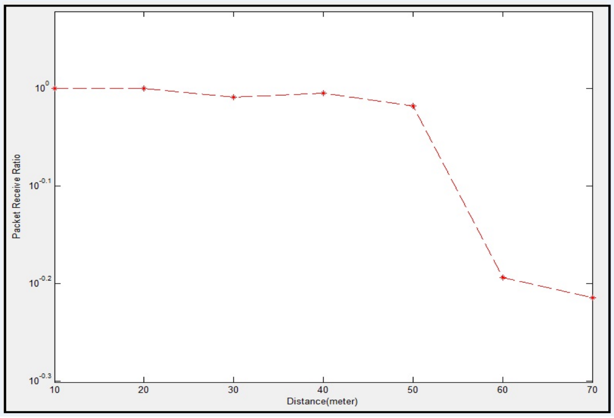

Fig. 6. Packet received ratio versus varied distance between transmitter and receiver.

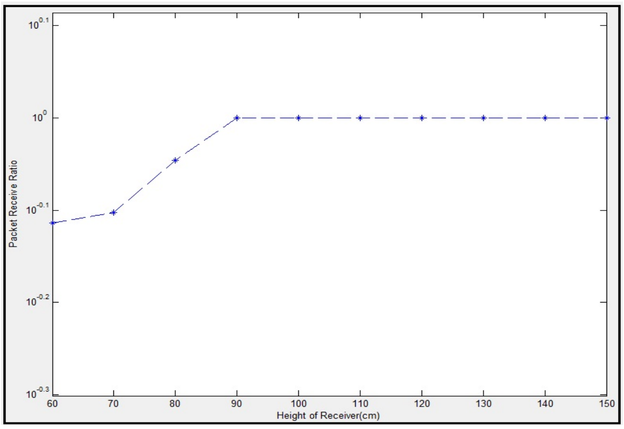

Fig. 7. Packet received ratio versus varied height of the receiver.

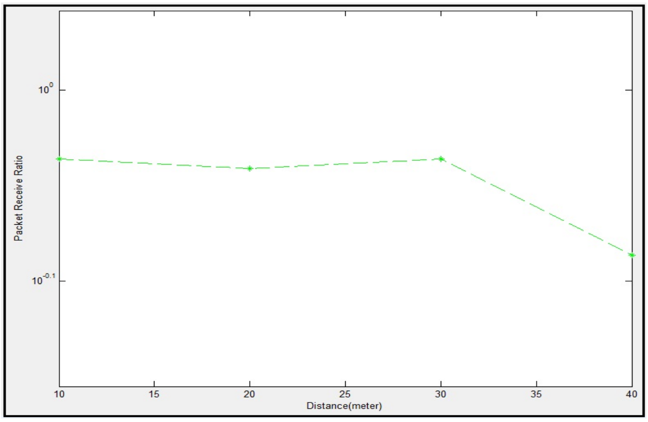

Fig. 8. Packet received ratio versus varied distance from the receiver to the transmitter's path while the transmitter is moving.

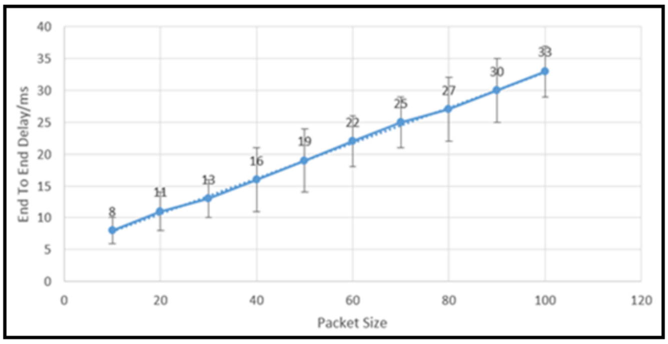

Fig. 9. End to end delay versus varied packet size.

The result obtained from experiment E is plotted in Fig. 10. It can be seen from the graph that the packet loss increases as the transmit power decreases. At 0dBm, the packets sent start to drop when the distance between the transmitter and the receiver is 50m. When the power is fixed at -2dBm, -4dBm and -6dBm, the packets start to drop as the distance exceeds 30m. The scenario is the worst when -10dBm power is used, in which the packets are dropped when the distance is more than 10m.

Finally, we examine the result from experiment F, where multiple nodes transmit the data to the receiver. In this experiment, the transmission rate is varied from 100ms to 500ms. It can be seen that the transmission rate gives only little effect to data delivery. Fig. 11 shows that for measurement at 100ms transmission rate, only seven packets are lost while no packet loss for 500ms transmission rate.

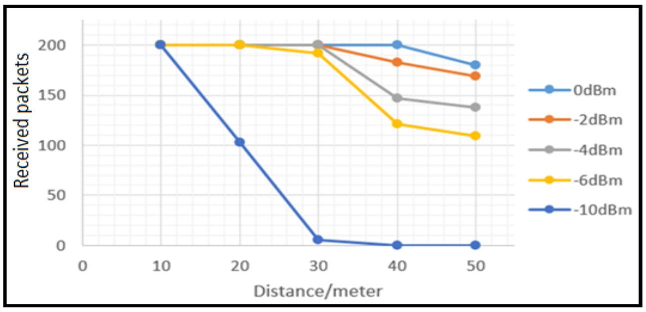

Fig. 10. The number of received packets as the distance between the transmitter and the receiver is varied for different transmit power used.

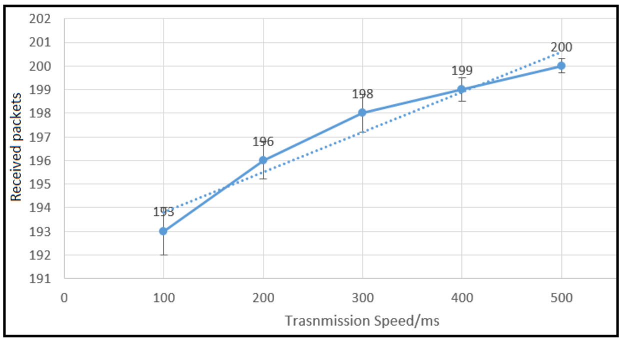

Fig. 11. The number of received packets against varied transmission rate.

V. Conclusion

This paper has presented the measurement and analysis of the performance of IEEE 802.15.4 protocol that is applied for training monitoring system for cyclist. Due to the importance of every single data produced during cyclist training, we focus on minimizing the packet loss during data transmission process. Six different types of measurement were conducted to analyze the performance of IEEE802.15.4 and to obtain the best node placement for the monitoring system. For future work, a whole training monitoring system for cyclist will be designed based on the collected data from these experiments.

Acknowledgment

The authors wish to express their gratitude to Ministry of Education and Research Management Centre, Universiti Teknologi Malaysia for the financial and technical support of this project under Sport Research Grant Scheme no. R.J130000.7823.4L550.

References

[1] "SRM Training System", http://www.srm.de/product/. Last access on 24th Jul 2014.

[2] P. Tiwati, L. Gite, M. Pandey, and A. Shrivastava, "Pedal power for accupational activities: Effect of power output and pedalling rate on physiological responses," International Journal of Industrial Ergonomics, vol. 41, pp. 261, May 2011.

[3] David Mozer. (2012, October 27). Bicycle racing. Retrieved from http://www.ibike.org/encouragement/racing.htm.

[4] Y. M. Yussoff, H. Hashim, "Trusted Wireless Sensor Node Platform" WCE London, U.K, vol 1, June 2010.

[5] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E, Cayirci, "Wireless Sensor Networks: A Survey," Georgia Institute of Technology, 2001

[6] A. Honkasuo, A. Hamalainen, P. Jappinen, J. Jaaskelainen, and J. Porras, "Mobile bicycle monitoring system," 7th IEEE Workshop on Mobile Computing Systems and Applications, WMCSA'06, 2005,pp. 44-44

[7] T. Kuhn, T. Jaitner, and R. Gotzhein, "Online-Monitoring of multiple track cyclists during training and competition," in the Engineering of Sport 7. Springer, vol. 1, pp. 405-412, 2008.

[8] M. R. A. Rahim, et. Al., "Development of TelG Mote for Wireless Biomedical Sensor Network (WBSN) Application," Informatics Engineering and Information Science, vol. 253, pp. 678 – 688, Springer Berlin Heidelberg, 2011.