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Quality of Service for XBee in Implementation of Wireless Sensor Network

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Abstract: The implementation of XBee or ZigBee is usually applied on the wireless sensor network (WSN). In this case, the issues due to the Wireless Sensor Network (WSN) intends for wireless data communication applications are the usage of bandwidth, data rate, cost installation, low energy consumption and reliable data transmission. The WSN works with boundaries of optimal level of realibility of the network. In the process of communication, it need a good data delivery services. To determine the performance ofthe WSN, it should test the Quality of Service (QoS) of the XBee such as measuring the delay, throughput and packet loss percentage. Testing of this QoS based on Line of Sight (LoS) and Non Line of Sight (NLoS). The protocols of XBee has applied the IEEE 802.15.4 that are a network and application layer above the physical layer and Medium Access Control (MAC).

Key words: Network, QoS, wireless, WSN, XBee

INTRODUCTION

An XBee or A ZigBee is a device used in a network programmed to be a transmitter or receiver. Usually the XBee used in the Wireless Sensor Network (WSN) to monitoring system (Wibowo and Purwacandra, 2015). The implementation of the XBee is to coverage a specific areas where the environments don't support the direct data transmission via wired networks. The use of the network using a wired media is quite difficult because it should arrange for shielded cables and not disturbing the neighborhood. In addition, the installation of wired networks is costly and can't be used for applications that are remote. The cable networks are also less flexible, because if one day there were a change or addition to the device or the measurement site, so it ought to reset the cable installations.

The WSN is a network of some XBee devices and physical state sensor environments using a wireless transmission. A scattered wireless sensor network nodes should be programmed as router or coordinator (Ayars *et al*., 2010). A data communication process between XBee devices in a wireless sensor network is set by the communication protocol. The wireless communication protocol that is commonly used in building a WSN namely IEEE 802.15.4 and XBee protocol (Sabeel *et al*., 2013). The IEEE 802.15.4 protocol defines two layers those are the physical layer and Medium Access Control (MAC). These layers are intended for wireless data communication applications with the bandwidth, data rate, the installation cost and low energy consumption as well as reliable data transmission. The XBee protocols has been built on the IEEE 802.15.4 which has a network and application layer above the physical layer and Medium Access Control (MAC). The XBee has the ability to form a network of point to point, point to multipoint and mesh. The XBee also has a multi-hop communication abilities, so as to include a communication in a large area.

The XBee device should be physically connected via the physical layer in order to make the process of sending and receiving data. The IEEE 802.15.4 has two physical layersthoseoperateontwoseparate frequency band namely 868/915 MHz and 2.4 GHz. The 868 MHz frequency band commonly used in Europe while the 915 MHz frequency band is used in the United States and Australia and 2.4 GHz frequency band almost used in the worldwide. The 3ird frequency band is a frequency band of Industrial, Scientific and Medical (ISM) which is a frequency allocation of unlicense. In addition to media and communication protocols, transmitting a data of a WSN requires a network topology to provide observations on the WSN devices built so that data can be sent to the destination. The devices of a WSN system functioning to monitor an objects and the monitoring results are transmitted to the gateway device through a wireless media. The WSN system requires a wireless devices to be able accommodate the data transmission process. The XBee works on a frequency band of 2.4 GHz that supports a communication with a maximum data rate of 250 kbps and a maximum payload capacity up to 84 bytes in unicast transmission which is a data transmission to the device.

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The WSN works with limitations of energy and bandwidth, so a network performance measurement is necessary to be done in determining the optimal level of reliability of the network. In the process of communication, in order data could be transmitted to the destination in accordance with the time and monitored object value, then the system needs a good data delivery services. To determine the performance of a WSN, then it should do testing to the Quality of Service (QoS) on the XBee such as measuring the delay average parameters, average throughput and packet loss percentage based on the distance and weather (Sohni, 2014). This measurement should be done to know the performance level of a WSN built using a XBee modules. By measuring the parameters of Quality of Service (QoS) can be known for several performance levels of a WSN measurement scenarios and by analyzing the measurement data can be known the relationship among the variables of packet size, transmission distance and the time interval of sensor against the average value of delay, average throughput and packet loss percentage based on the distance and the weather (Nugroho and Wibowo, 2014).

Literature review: The Wireless Sensor Networks (WSN) is a network composed by sensors distributed within the scope of a particular area that is connected via wireless communication to each bekarja same measurement and monitoring of physical phenomena such as temperature, sound, vibration, pressure, pressure or Events certain physical conditions. Generally The WSN consists of a target or a physical phenomenon that will be measured, the sensors take measurements of physical phenomena and coordinators are responsible for managing the network and collect data from the sensors. The WSN is an individual device for measurement, control and communication of the physical parameters. The sensor is composed of several modules such as microcontrollers, sensors and Radio Frequency (RF) transceiver devices with a minimum energy consumption (Horvat *et al.*, 2012).

There are various WSN applications that are monitoring, tracing and control. As in the military field, a WSN is used for surveillance and reconnaissance on the battlefields while in a factories, the WSN is used to perform a device maintenance, a building monitoring. In a residences, the WSN is used to create a smart home. In the monitoring application, the sensors deployed on an area to monitor a specific physical phenomenon. Normally the WSN consists of four components i.e. a sensor device, wireless media, coordinator/gateway and PC server/administrator. The basic components of WSN is shown in Fig.1. In this study, to measure the Quality of Service (QoS) of data transfer only uses 2 XBee modules and 2 pieces of computer.

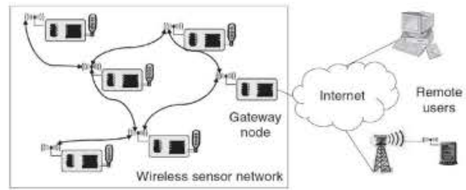

Fig. 1: Basic components of WSN

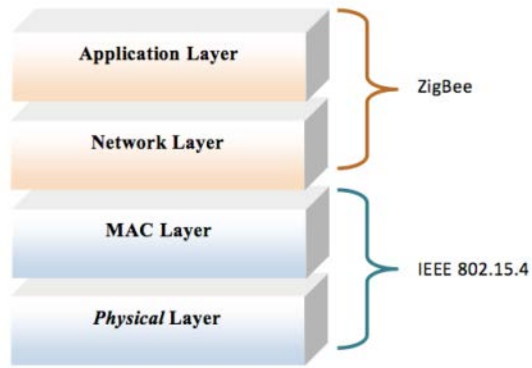

Fig. 2: XBee protocol stack

Sensor: The sensor is a device on monitoring or measurement of a particular physical phenomenon, with doing a processing of data obtained from the physical phenomena and sends the obtained data to the coordinator/gateway. A sensor device must meet minimum requirements in order to function properly on a WSN. In general, the sensor device to be small, inexpensive, efficient in consuming energy and equipped with the appropriate sensors to a monitoring, capable of performing the required computation and storage resources as well as having an adequate communication facilities.

Wireless media: A wireless media is a media without wired connection, it means that the communication uses a signal propagation. The signal propagation is not limited to the location or channels that have been determined in the specific transmission of shielded cables. In wireless media, an electromagnetic wave propagates in a free space between both transmitter and receiver, where the signal propagates in the media is not restricted as in cable transmission media. The wireless networks use a radio as a medium for transmitting an information. The radio is a technology for transmission of signals by means of modulation and electromagnetic waves. The wireless media has a signal attenuation level higher than the cable media.

A data quality depends on several factors including the frequency, the distance between transmitter and receiver, the relative speed, the environment especially the number of channels or paths traversed and weaken and others. The waves are transmitted through the wireless medium will experience some of the physical phenomena that distort the original waveform acquired receiver. The distortions cause uncertainty in the original modulated data and encoded that cause a bit errors at the receiver.

Quality of Service (QoS): A Quality of Service (QoS) indicates the ability of a network to provide a better service in the traffic service. The QoS of network refers to the level of speed and reliability of delivery of various types of data loads in a communication. The WSN capabilities in providing a treatment to a monitoring result data determine the level of performance of WSN that depends on the area of implementation. The development majority of WSN devoted to monitor a physical phenomena such as temperature, pressure, humidity or the location of an object. For such applications, the majority of WSN is designed only to get the results in the form of data or value calculation results of monitoring with a delay that can be tolerated and uses minimal bandwidth or small size. The WSN on the performance level of implementation will vary with the level of performance required for WSN applications on the implementation of the technology used to obtain different types of data. To obtain a QoS of WSN, it is necessary to do the quantification of several metrics that can represent the QoS parameters of the WSN[7]. Some of these parameters are delay, throughput, delay and packet loss.

A delay is the delay time caused by the transmission from one point to another. The delay (δ) is expressed as the difference average between a numbers of delivered data (η) and a throughput (τ) that is written as Eq 1:

$$\delta = \frac{\eta}{\tau} \quad (1)$$

The throughput measurements performed with a number of data that is sent from one place to another or by measuring the amount of data that can be processed at any given time. In general, the throughput measurement is done in units of bits per second (bps). Throughput calculation doesn't include the frame header but only consider the payload delivered. This is because the throughput is the value of the actual data that arrive at the receiver without including the value of the amount of packet headers that are inserted during data transmission. The average throughput (τ) obtained from the ratio of total data (ξ) up to the time that is used to convey a data (σ) as written in Eq. 2:

$$\tau = \frac{\xi}{\sigma} \quad (2)$$

A packet loss is a value that states the number of packets that failed delivered to specific objectives through the transmission media. The packet loss can be caused by various factors including signal degradation on a network channels, a corrupted packages cause the rejection of packets in transit, the failure on the network device, a failure in the network routing. The percentage of packet loss is obtained as Eq. 3:

$$\zeta = \frac{\alpha - \beta}{\alpha} 100\% \quad (3)$$

Where:
ζ = A packet loss (%)
α = A numbers of sent packets
β = A numbers of delivered packets

XBee protocol: An XBee specification is a communication protocol that refers to the IEEE 802.15.4 standard for networking Wireless Personal Area Networks (WPANs). The XBee focuses on the close range application of Radio Frequency (RF) with low transfer power, a long life battery and secure networking. The XBee protocol stack as shown in Fig.2. It consists of IEEE 802.15.4 defining two bottom layers namely the Physical layer (PHY) and the Medium Access Control layer (MAC) while XBee alliances build the network layer and application layer above the IEEE 802.15.4 as shown in Fig. 2.

Physical layer (PHY) defined as the physical characteristics and electrical network such as modulation and deployment techniques of the information signal bits. The basic task of the physical layer is the transmission and reception of data by translating data packets from a series of bytes to RF spectrum and back again. Features of the physical layer are to enable and disable the RF transceiver, the detection energy in the channel, a link quality indication for receipt of the package, choose the channel, Clear Channel Assessment (CCA) for Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA) and transmitting and receiving a data packets on the transmission medium. The IEEE 802.15.4 has two physical layer functions that operate on two separated frequency band ranges i.e. 868/915 MHz and 2.4 GHz. A low frequency physical layer includes two frequency bands, namely, 868 MHz which is commonly used in Europe and 915 MHz is used in the United States and Australia. Whereas the high frequency physical layer, namely, 2.4 GHz is almost used in the worldwide. Both the frequency bands using modulation of Direct Sequense Spread Spectrum (DSSS).

A Medium Access Control (MAC) layer provides a features to manage beacons, channel access, manage Guaranteed Time Slot (GTS), frame validation and acknowledged frame. The MAC layer defines the IEEE 802.15.4 in the access mechanisms to avoid collisions using a Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA). The MAC layer implements an addressing mechanism based on 64 bits for a long addressing and 16-bits for a short addressing. The MAC layer coordinates a transceiver device to access a shared radio link.

Layer network ensures operation at the MAC layer and provides the interface to the application layer. Layer network supports star network topology, tree and mesh. When trying to build a network ZigBee coordinator, coordinator scan signal to find a good channel to form a new network. After determining the channel, the coordinator of the network set identification, also called Personal Area Identifier Number (PAN ID) that is used by all devices to join the network.

An application layer consists of three sublayers, namely Application Support Sublayer (APS), application framework and ZigBee Device Object (ZDO). An APS sublayer provides services to forward messages between devices, defining and managing the addressing of the group, mapping 64 bit addressing to the device of 16 bit network address, splitting and joining package and reliable transport of data. A sublayer application framework is an object execution application to send and receive data. The object applications are defined by the XBee-based device makers. The ZDO sublayer includes a device management such as initialization of APS sublayer and the network layer, defines the operating mode of the device as a coordinator, router and end device. It is also determination of the application services, initiating and responding to requests and managing security.

IEEE 802.15.4 Standard: An IEEE 802.15.4 standard intends to offer the fundamental lower network layers of the type of Private Wireless Network (WPAN) which focuses on the communications cost and low speed. This can be compared with other networks such as Wi-Fi, which offers more bandwidth and requires more power. The emphasis is on the communication with a very low cost with little basic infrastructure devices, plans to develop devices with lower power consumption again. The default is communication as far as 10-30 m with a transfer rate of 250 kbit sec^{-1} that is possible to support more devices with needs for lower power, through multiple layers of physical, initially had sufficient standard at the lower transfer speeds of 20 and 40 kbit/s but it has been revised that the lowest speed for this standard is 100 kbit sec^{-1}, even the lowest level can be considered with the resulting effect on the power consumption. As already mentioned, the main features on the IEEE 802.15.4 standard for WPANs is the importance of achieving a manufacturing and a very low operating cost and simplicity of technology, without sacrificing flexibility.

MATERIALS AND METHODS

Tools and materials: The XBee is a wireless communication module which is manufactured by Digi International, which supports a variety of communication protocols including IEEE 802.15.4 and XBee. The XBee modules can communicate with the microcontroller through an Universal Asynchronous Receiving Transmitting (UART) serial communication and also have extra pins that can be used for applications XBee independently, for example, the router device can be built without a microcontroller. XBee module is divided into two versions of the XBee and XBee-Pro. The XBee-Pro has a larger power consumption and further communication range than the XBee. The specification of XBee S2 module has a data rate of up to 250 Kbps with a payload delivery capability reaches 84 bytes and has an outdoor transmission range of up to a distance of 120 m.

For QoS measurements consist of measurements of the average delay, average throughput and packet loss percentage on the sunny conditions at high temperature and low temperature rainy weather. This is expected to determine the level of performance of WSN. The stages of measurements of delay, average throughput and packet loss are as follows:

The average measurement of throughput on the state of line of Sight (LOS) in the sunny and rainy weather with variations in transmission distance value settings are testing is done using a star network (point to point), using two devices of router (transmitter) and coordinator (receiver). A data packets large transmitted is 1000 bytes for 0.2 sec and the variations in this configuration are 5, 10, 20, 50, 100 and 120 m. The baud rate is set on 115200 bps.

The average measurement of throughput on the state of Non-Line of Sight (NLOS) in the sunny and rainy weather with variations in transmission distance value settings are testing is done using a star network (point to point), using two devices of router (transmitter) and coordinator (receiver). A data packets large transmitted is 1000 bytes for 0.2 sec and the variations in this configuration are 5, 10, 20 and 40m. The baud rate is set on 115200 bps.

The average measurement of delay on the state of Line of Sight (LOS) in the sunny and rainy weather with variations in transmission distance value settings are testing is done using a star network (point to point), using two devices of router (transmitter) and coordinator (receiver). A data packets large transmitted is starting from 10-80 bytes for 100 times in each 1 sec and the variations in this configuration are 5, 10, 20, 50, 100 and 120 m. The baud rate is set on 115200 bps.

The average measurement of delay on the state of Non-Line of Sight (NLOS) in the sunny and rainy weather with variations in transmission distance value settings are testing is done using a star network (point to point), using two devices of router (transmitter) and coordinator (receiver). A data packets large transmitted is starting from 10-80 bytes for 100 times in each 1 second and the variations in this configuration are 5, 10, 20 and 40 m. The baud rate is set on 115200 bps.

The packet loss measurements are done on three conditions, namely LOS in sunny condition, rainy weather and the condition of NLOS. The measurements of packet loss for LOS in sunny condition and rain are done using a star network (point to point) for both transmitter and receiver. The transmission distance variations are 5, 10, 20, 50 and 100m. The data packets are transmitted in text format with the size of the data packets transmitted at each distance are 80 and 120 bytes for each 1 second using baud rate of 115200. While for NLOS, the measurements of packet loss in transmission distance variations are 5, 10, 20 and 40 m. The data packets are transmitted in text format with the size of the data packets transmitted at each distance are 80 and 120 bytes for each 5 sec.

RESULTS AND DISCUSSION

The data resulted with optimalized configuration have been obtained the values of throughput, delay and packet loss from Xbee S2 devices. The throughput of LoS condition within 6 varies of distance was resulted as shown in Fig. 3. From this case shows that the throughput of XBee S2 is effected by the distance. The futher its distance, the smaller its bandwidth. The biggest throughput is on the distance of 5 m that is of 32.68 kbps and the smallest is on the distance of 120 m that is 13.61 kbps. This case has same result when it is implemented on the rainy and almost there isn't effect on the throughput. While in the NloS condition, the biggest throughput is on the distance of 5 m that is of 32.20 kbps and the smallest one is on the distance of 40 m that is of 22.64 kbps (Fig. 4).

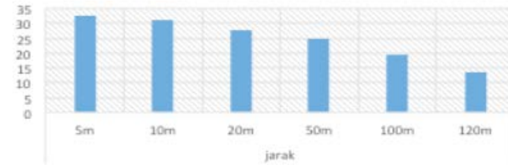

Fig. 3: Throughput for LoS

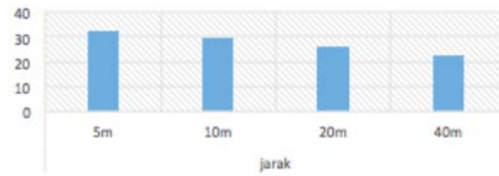

Fig. 4: Throughput for NloS

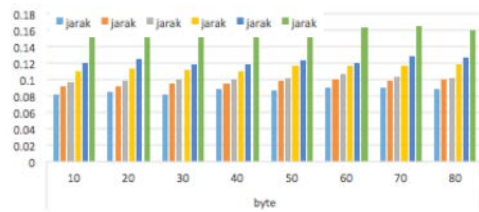

Fig. 5: Delay for LoS

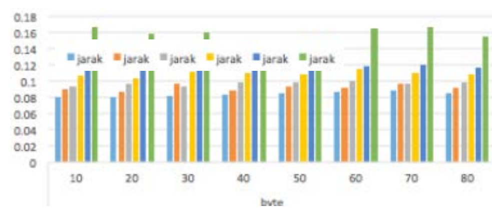

Fig. 6: Delay for LoS in rainy

The delay on the LoS condition with 8 varies of data package and 6 varies of distance. The result of the delay is shown in Fig.5. From Fig. 5. there is a big difference on the data package that doesn't effect the delay but the distance of transmission effecting the delay in the transmission. The shortest delay is 79.4 m on the distance of 5 m while the longest delay is 166.4 m on the distance of 120 m. The delay of LoS in the rainy with 8 varies of data packet and 6 varies of distance is shown in Fig. 6. From Fig. 6, the rainy condition is almost not effecting the delay in the varies of data packet. In the NLoS, the delay is increasing and data packet is almost not effecting the delay. The fastest delay is 85.8 m on the distance of 5 m while the longest delay is 169.6 m on the distance of 40 m (Fig. 7).

The packet loss was obtained using LoS and NLoS conditions. The procentage of packet loss is increasing as

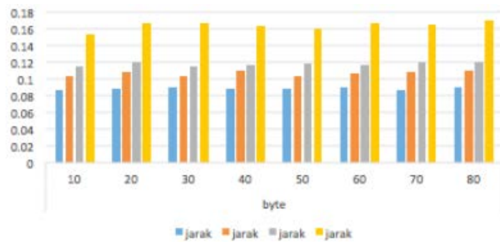

Fig. 7: Delay for NloS

Table 1: Packet loss within los, transmitted data of 80 and 120 bytes on the 6 varies of distance

Distance (m)	Transmit (bit)	Receive (bit)	Lost (byte)	Packet loss (%)
5	80	80	0	0.00
	120	120	0	0.00
10	80	80	0	0.00
	120	120	0	0.00
20	80	80	0	0.00
	120	120	0	0.00
50	80	73	7	8.75
	120	108	12	10.00
100	80	66	14	17.50
	120	99	21	17.50
120	80	49	31	38.75
	120	68	52	43.33

well as the further of transmission distance. The transmission distance of less than 20 m has packet loss of 0% and the transmission distance of higher than 50 m has an increasing numbers of packet loss up to 43.3% in the distance of 120 m (Table 1).

CONCLUSION

The average value of the transmission delay tends to increase in line with increasing transmission distance for each type of packet size is sent, the rain hardly gives influence is quite visible, the total average value of 166.4 m delay in the sunny and 168.3 m in the rainy with a distance of 120 m. The average value of throughput tends to decrease with greater the distance between XBees for each type of data packet size that is transmitted. The average values of the largest throughput are 32.68 kbps in sunny and 32.52 kbps in rainy with the closest distance is 5 m. At a distance of over 50 m, the packet loss starts to happen and progressively increased with increasing transmission distance. From the test results, throughput of XBee S2 didn't reach 250 kbps as written on the datasheet or product specifications. This device hasn't been met the IEEE 802.15.4 standard for throughput on reaching of 100 kbit sec^{-1} at a distance of 30 m.

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