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Proposed Technique for Transport Protocol in Wireless Sensor Network (WSN) for Multimedia Application

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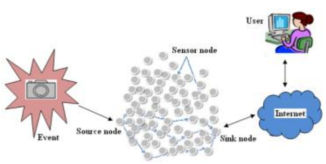
Graphical abstract



Abstract

Recently, reliable data transport in wireless sensor network becomes very crucial for real-time application with different application requirements. Real time multimedia application requires large bandwidth and big memory in the network in order to send video data and needs to arrive at destination in time. Data that arrives at the receiver not in time will be discarded and cannot be played because loss recovery through retransmission of data loss may introduce long delays. Therefore, an implementation of transport protocol in wireless sensor network for multimedia application is a challenging task. Traditional protocol likes TCP and UDP cannot directly applied for real-time communication over wireless sensor network because the lack of functions of real-time services and the unique characteristics of sensor node itself. However there is another transport protocol which is the Stream Control Transmission Protocol (SCTP) that provides multi-stream service for single connection. This feature can be applied for video transmission according to the type of frame to be transmitted. Thus, to achieve the high reliability video data delivery, the advantages of multi-streaming features in SCTP with the combination of low data rate wireless sensor networks will be applied for the new proposed transport protocol. Besides that, transport protocol algorithm also allows maximum network lifetime due to the limited operating lifetime of sensor node and multimedia also is a highly power consuming task. Thus, to prolong the lifetime of wireless sensor network, an efficient transport protocol need to support reliable message delivery and provide congestion control in the most energy efficient. This paper focuses on the existing transport protocols for real-time application and the future protocol that provides the entire requirement of transport protocol.

Keywords: Wireless sensor network; real-time multimedia application; stream control transmission protocol

1.0 INTRODUCTION

During the last few years, Wireless sensor networks (WSNs) have significant importances which are generally built up from hundreds or thousands of sensor nodes to cooperatively monitor different condition, such as temperature, sound, vibration, pressure and motion at different locations [1]. WSNs can be used in many applications such as habitat monitoring, security surveillance, target tracking, medical application etc. However, recently, there is an increasing demand for multimedia application over WSNs.

Data transfer in WSNs is more susceptible to loss than over wired networks such as the Internet. This is because in wired networks data loss occurs primarily due to congestion, whereas there are many reasons for data loss in WSNs such as node failures, environment interface, etc. Thus, reliability is one of the important criteria for judging the quality of WSN. But, the intrinsic features and limitation of sensor node give significant challenges for reliable communication in WSNs. Furthermore, there are additional challenges due to the unique requirement of multimedia delivery such as diverse reliability requirements, time constraints and high bandwidth demand for acceptable quality [2]. These factors are important as a guideline in order to design communication protocol for an efficient multimedia transmission in sensor networks.

Figure 1 shows the typical multimedia application over WSNs. A camera that is considered as a sensor node sends an emergent of message consists of image to the sink node once it detects an urgent or intrusive event. Different types of traffic have different packet delivery ratio and end-to-end delay [3]. Important message always have higher priority with minimum end-to-end delay. Meanwhile the low priority message has a longer end-to-end delay requirement. As a consequence, data that arrives at the receiver not in time cannot be displayed and will be discarded.

Therefore, multimedia transmission requires a new transport protocol which meets all the requirements of an application in order to handle all the limitations of a sensor node and the unique characteristics of multimedia communication. The main goal of a new transport protocol is to transmit real-time multimedia data over WSN in a promising way to achieve good reliability data with energy efficiency to extend the lifetime of the network. It is also required to provide congestion control mechanism to avoid any congestion in order to ensure the good quality of multimedia data. Thus, the most crucial requirement for real-time multimedia application is a reliable data transfer from source to destination.

The remainder of this paper is organized as follows. This section gives an introductory to the work with its related references. Section 2 briefly explains the existing transport protocol for multimedia transmission. In the same section, Stream Control Transmission Protocol (SCTP) used in this work is also discussed. In section 3, the proposed transport protocol is described thoroughly. Discussions and future works are provided in Section 4. Finally, Section 5 concludes this paper.

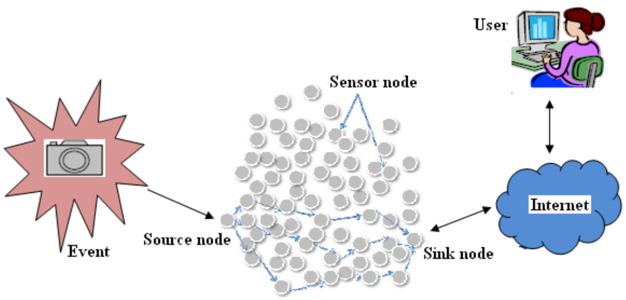


Figure 1 Multimedia services over Wireless Sensor Network (WSN)

2.0 RELATED WORKS

Reliable transport mechanism is important in order to achieve efficient multimedia transfer in WSN. In traditional communication networks, the transport protocol is responsible for bridging the application and network layers using multiplexing and demultiplexing [4]. However, the main purpose of transport layer protocol in WSN is to achieve reliable data transport and to perform flow control and congestion control with low energy consumption [5]. The transport protocol for multimedia transmission is a more challenging task due to accommodate both of the unique characteristic of WSN paradigm and multimedia transport requirements.

There are several transport protocols that have been designed for wireless sensor networks. A list of relevant related works on transport protocol wireless sensor network is given in [5]. The existing transport protocols are distinguished by three different categories which are reliability for upstream and downstream in [6], [7], [8], [9], [10], congestion control in [11], [12], [13], [14], [15] and protocol that provides both reliability and congestion control in [16], [17], [18].

There are many existing approaches proposed for sending real-time multimedia over wired or wireless networks and wireless sensor network as shown in Figure 2. In [19], the Real-time Transport Protocol (RTP) is proposed to send multimedia data over IP based network. RTP also does not support traffic portioning or reassembling. Implementing RTP directly over WSN is not practical because RTP is not power aware.

Another protocol is Stream Control Transmission Protocol Partial Reliability (PR-SCTP) which is an extension of SCTP [20]. PR-SCTP has a function of setting reliability level according to specific messages which is differentiate its retransmission service for each message. To differentiate the reliability of each frame in MPEG video transmission, [21] the number of transmission is limited according to the type of frames to be transmitted.

K. H. Kim [22] proposed transmission control SCTP (TC-SCTP) to prevent and minimize unnecessary transmission. TC-SCTP has multiple buffers to differentiate transmission for different type of messages. TC-SCTP will check if each frame stored in buffers has sufficient time to ensure data can be played back at the receiver by limit the maximum number of retransmission. This protocol also introduced Delay Constrained Retransmission scheme as a error control method. In this method, receiver request packet retransmission and sender retransmit the lost packet when time for display is expected. TC-SCTP adopts the existing PR-SCTP to support various type of reliability for multimedia service.

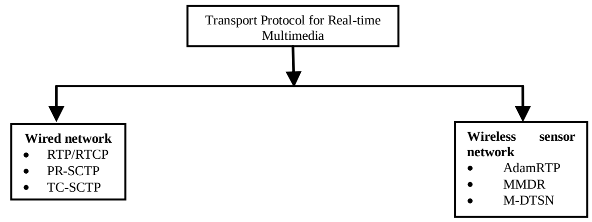


Figure 2 The existing transport protocol for real-time

A Multiflow Real-Time Transport Protocol (MRTP) [23] is proposed for ad Hoc networks. MRTP is an extension of the existing RTP that combine with multipath transport capability. This protocol uses Multiple Description Coding (MDC) encoder to split a stream of data into several flows and sent on a separate path. MRTP protocol is a session oriented protocol to establish any data transmission.

All of the above protocols are proposed for wired network which only consider multimedia transport requirement and do not take into consideration about the unique characteristics of sensor node. This is especially for energy efficiency due to sensor node is an energy constraint device.

However, there are several protocols that are proposed for WSN to transmit multimedia data. Jose F. [24] proposed efficient multimedia transmission in WSN that is Multimedia Distributed Transport for Sensor Network (M-DTSN). M-DTSN will estimate the sending of certain amount of information and also the channel condition either to complete the transmission or not. This protocol considers several factors to achieve efficiency of the transmission. The factors considered are multimedia flows which are time-constrained and sensor is limited in the amount of energy allowed for the transmission. But, this protocol does not provide any congestion control mechanism which is important to avoid any congestion from happening.

Adaptive Multi-flows Real-time (AdamRTP) Multimedia Delivery over WSNs is proposed in [25]. AdamRTP looks similar to MRTP. However, MRTP is designed for ad hoc network that has session oriented protocol while AdamRTP is designed for WSNs. AdamRTP splits the multimedia source stream into smaller independent flow using MDC encoder and send data for each flow to the destination using joint/disjoint path. This protocol does not have any session oriented because the sender simply sends multimedia data to the sink as soon as it detects an event. AdamRTP protocol provides the adaptation mechanisms for changing number of flows and rate adaptation to enhance quality of service (QoS) and to extend the life time of WSN.

S. B. Qaisar and H. Radha [26] is proposed Multipath Multi-stream Distributed Reliability (MMDR) in WSN. MMDR protocol has three strategies to enhance the received video quality which are splitting source coded video into prioritized stream, using path diversity to route video packets and partially and progressively decode the data packets. This protocol also uses low density parity check (LDPC) codes for channel coding the video sensor data. Although MMDR provides reliability scheme in

WSN for multimedia data, but it does not provide any congestion control mechanism.

Most of the existing transport protocols for WSN only provide reliability mechanism and do not take into consideration the congestion control mechanism. The congestion control mechanism is important to help in reducing energy consumption during multimedia data transmission. Energy efficient need to be emphasized in future transport protocol for WSN especially for multimedia data that required high bandwidth demand and real-time delay requirements. This is due to sensor nodes have a limited operating system lifetime. Since a mechanism for energy efficient is very crucial in WSN, an efficient transport protocol needs to support reliable message delivery and provide congestion control in the most energy efficient and also taken into consideration of multimedia requirements.

■3.0 PROPOSED TRANSPORT PROTOCOL

As discussed in section 2.0, the main objectives of transport protocol are to bridge application and network layers, to ensure reliable data delivery between the source and destination according to the specific application requirements and to perform congestion control by regulating the amount of traffic injected to the network [4]. Depending on the application, both reliability and congestion control are important functionalities for transport protocol to achieve high data delivery from source to the sink node as proposed in [5].

However, multimedia sources usually have a large amount of real-time data and introduce new requirement for WSNs. A higher bit rate is needed to deliver an acceptable multimedia quality and application which typically is sensible to delays or jitter [27]. Thus, a new proposes protocol needs to consider both requirements of sensor node characteristic and multimedia data communication.

Multimedia data stream such as MPEG video encoder that consists of images (I, P and B frames), video and audio which have different level of reliability. However, at this stage, the data transmission only considers an image transmission. Stream Control Transmission Protocol Partial Reliability (PR-SCTP) [20] protocol will be adopted for the new proposed transport protocol that supports various type of reliability. The transmission of MPEG multimedia data will be differentiated according to the type of image data as shown in Figure 3. This transmission will used three streams because there are three types of image data. Stream 1 is for I-frame transmission which has the highest priority compared to others. If I-frame are corrupted or lost during data delivery, all the P-frame and B-frame up to next I-frame is useless [28]. This transmission consists of two parts which are queue priority and differentiation of data transmission

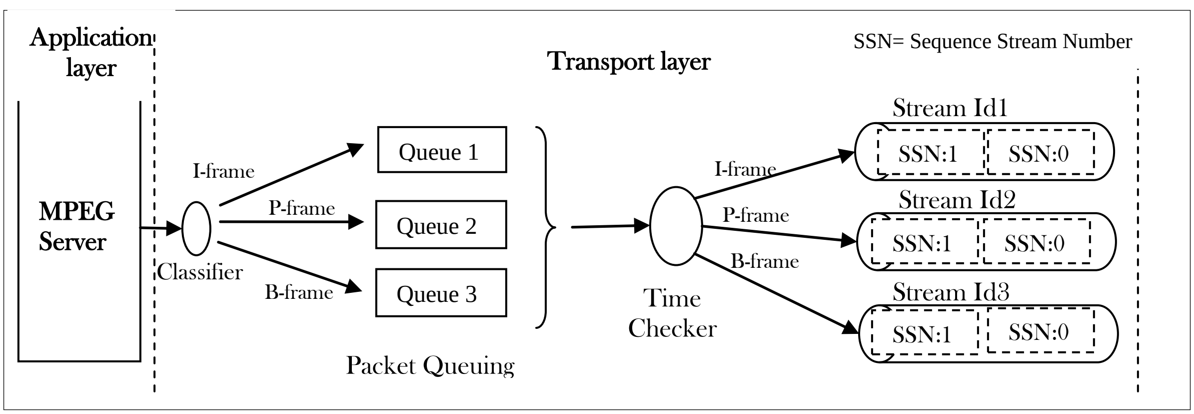


Figure 3 : Multimedia data transmission according to data type

3.1 Priority Queue

Figure 4 shows the flow chart of priority queue of the proposed protocol. This priority queue takes some advantages from the active queue management which is designed for transport protocol congestion control such as TCP [3]. This protocol will use only one buffer compared to multiple buffers as in [22].

First, when there is an incoming packet from the application layer, buffer computes the current average queue length and compare with the threshold value, either it is minimum or maximum threshold. If the average value is higher than maximum threshold (max_thres), the incoming packet will be dropped. The maximum threshold can be calculated as [3].

$$\text{Maximum threshold} = \frac{\text{Queue size}}{2} \tag{1}$$

While if the average value is smaller than minimum threshold (min_thres), the incoming packet will be kept and sent to the priority queue based waiting for transmission. The minimum threshold can be calculated as [3].

$$\text{Minimum threshold} = \frac{\text{Max threshold}}{3} \tag{2}$$

Lastly, if the average value is between minimum threshold and maximum threshold, the packet dropping probability or packet error rate (PER) will be calculated using packet reception rate (PRR) [29] as shown in equation 3 and 4 respectively.

$$\text{PER} = 1 - \text{PRR} \tag{3}$$

$$PRR = \left[1 - \left(\frac{1}{30}\right)\sum_{j=2}^{16}(-1)^j\left(\frac{16}{j}\right)\exp\left(20SNR\left(\frac{1}{j}-1\right)\right)\right]^m \tag{4}$$

When the incoming packet meets the condition to queue, the queuing is based on the priority where the high priority is belongs to I-frame. Thus, if the incoming packet is I-frame, it will be put at the front of queue and followed by P-frame at the middle and B-frame at the back of queuing. This process will be repeated for every incoming packet to ensure the highest priority is given to the I-frame compared to the other frames.

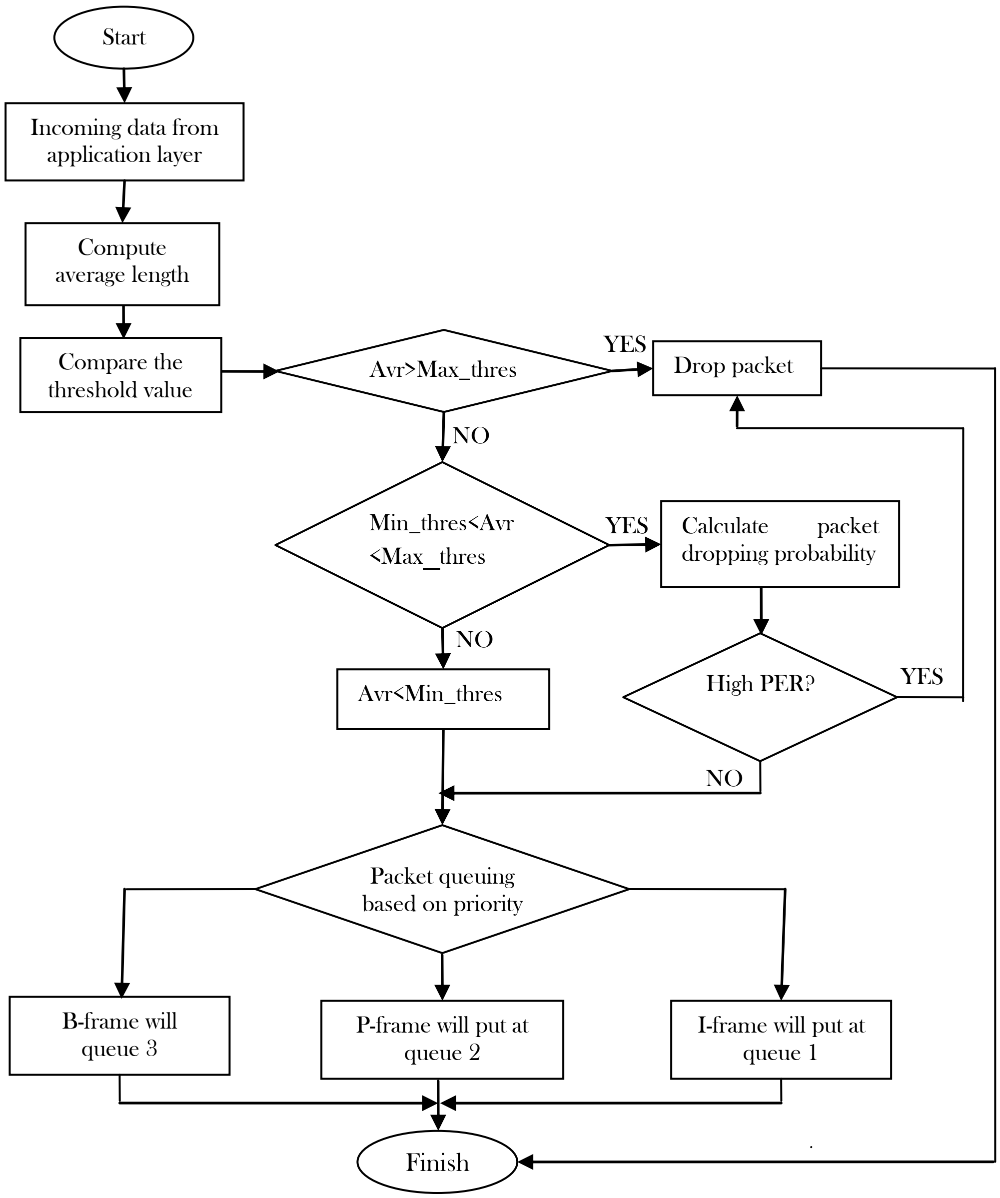


Figure 4: Packet Queuing at Transport Layer

3.2 Data Transmission According to Data Type

Figure 5 shows the flow chart of data transmission based on data type. This part will takes some advantages from PR-SCTP [20] and TC-SCTP [22] protocol. PR-SCTP protocol is used to differentiate the transmission depending on the importance of data by limiting the number of retransmission for each data to prevent unnecessary retransmission. TC-SCTP protocol is use to prevent unnecessary transmission by checking the time transmission for each data before transmitting the data. Although these protocol are for wired network, but the new protocol will apply this algorithm in the IEEE 802.15.4 wireless sensor network. The proposed protocol will take into consideration the entire requirements of WSN and multimedia data communication.

The proposed protocol will implement the time constrainer of TC-SCTP [22] as shown in Figure 3 that is used to determine whether data in the buffer can be played at the receiver side or not. However, the proposed protocol only uses one buffer and is not necessary to assign different time constraints. The transmission time will be assigned by estimating the maximum time allowed for each data in the sender to be played at the receiver side.

To estimate the time for playing back data at the receiver, T_p, the offset delay time, T_{os} and the time receiving data from upper layer, T_r are required. The offset delay can be defined as the maximum time for data received from upper layer to be delivered to the receiver. Thus, the playback time, T_P can be defined as

$$T_P = T_r + T_{OS} \quad (5)$$

One of the ways to achieve reliability data delivery between source and destination is to prevent unnecessary transmission which is the time check in the buffer will check transmission time, T_X for transmission of each data before transmission. It is to ensure the time for transmission is long so that the data is transmitted to the receiver successfully. If the transmission time is shorter than a specific value, the sender will not continues the transmission and removes data from buffer. The transmission time can be defined as the difference between the estimated time of playing, T_p of each data and the current time of the time constrainer, T for data as

$$T_X = T_p - T \quad (6)$$

Table 1 Notation

Symbol	Meaning
Tp	Time duration to playback data at the receiver
Tr	Time duration to receive data from upper layer
Tos	Offset delay time
T_X	Estimation of transmission time
T	Current time of the time constrainer

After calculating the transmission time, the type of data is check to know either it is I-frame, P-frame or B-frame as shown in Figure 5 to meet the condition of transmission time, T_X. If the data is I-frame and the transmission time, T_X is longer than Th1, the data will send to stream 1. The data of P-frame will send when the time check is between Th1 and Th2, Th2 $\leq T_C \leq$Th1. While, the B-frame data will send when the time check is between Th2 and Th3, Th3 $\leq T_C \leq$Th2.Finally, if the transmission time is shorter than Th3, the data will be dropped without being transmitted [22].

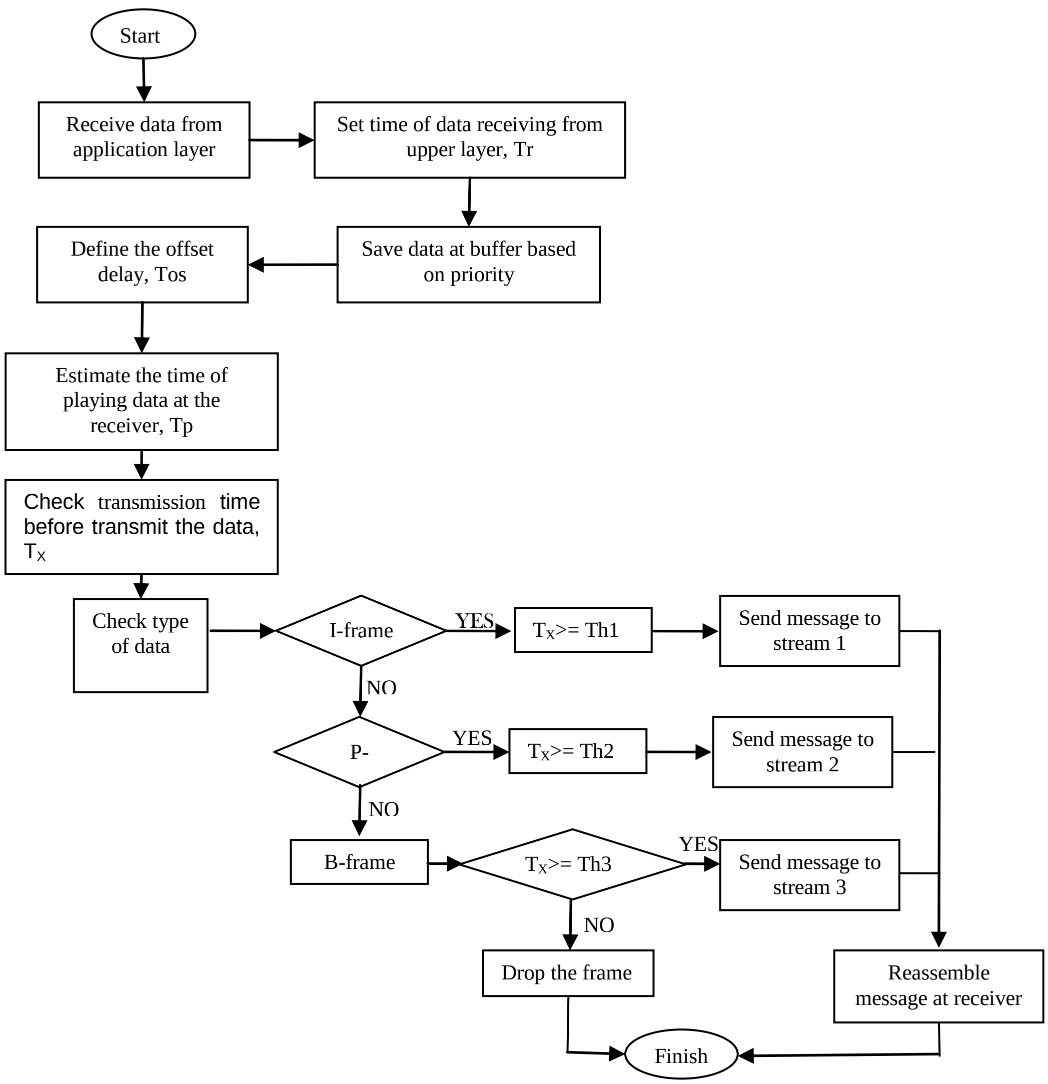


Figure 5 Multimedia data transmission

The parameter values of Th1, Th2 and Th3 are set using the Retransmission Timeout (RTO). The thresholds are considered as [22] which shown in equation 7.

$$\begin{aligned} Th1 &= (RTT \times 2) + \alpha_1 \\ Th2 &= (RTT \times 1) + \alpha_2 \\ Th3 &= RTT + \alpha_3 \end{aligned} \tag{7}$$

The Th1 is set to two times of retransmission. Followed by Th2 are set for one time of retransmission and there is no retransmission for Th3. All of the number of retransmission is based on the type of multimedia data transfer.

3.3 Analysis of Real-time Multimedia Transmission

Performance of transport protocol for multimedia data transmission can be evaluated using metrics such as packet delivery rate, end-to-end packet delay, energy efficiency and frame peak signal-to-noise ratio (PSNR).

Packet delivery rate will be used to see the performance of data transmission because packet loss may occur at any stage of the network especially during congestion happens. Packet delivery rate can be calculate as

$$\text{Packet delivery rate} = \frac{\text{Number of packet receive by sink}}{\text{Total number of packet generated by source}} \tag{8}$$

The end-to-end delay is the total delay to deliver a packet from the source to the sink nodes. The total delay at the intermediate node includes the processing, queuing, transmission, propagation and retransmission delays [3]. For real-time application, delay is very important because the longer delay will affect the reliability of data transmission. Thus, to decrease the average end-to-end delay, we can decrease the number of packet retransmission as proposed for the new protocol.

Sensor nodes have limited energy and it is important for the transport protocol to maintain a high energy in order to achieve maximize system lifetime. Packet loss ratio will result in energy loss per node and the whole network which is important to evaluate energy efficiency at the transport protocol level. Assuming dropped packets have a direct relation with energy wastage, the energy loss per node and the total amount of energy remaining in the sensor node can be measured by equation (9) and (10) respectively [30]

$$\text{Energy}_{\text{node}} = \frac{\text{Number of packet drop by node}}{\text{Total numebr of packet receive by node}} \tag{9}$$

$$\text{Energy} = \frac{\text{Remaining energy}}{\text{Initial energy}} \tag{10}$$

The quality of video sequence at the decoder will be measured by using the Peak Signal to Noise Ratio (PSNR) and can be measured as [31]

$$PSNR = 20 \log \frac{255}{\sqrt{MSE}} \tag{11}$$

where the mean square error MSE is

$$MSE = \frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (p_{ij} - \hat{p}_{ij} OB)}{MN} \tag{12}$$

with M and N re equal to 176 and 144 respectively representing the dimension of QCIF frame while p_{ij} and $\hat{p}_{ij}$ represent the original and predicted pixel values.

4.0 CONCLUSIONS

In this paper, we had done a survey on the existing transport protocol for real-time application and proposed a new transport protocol. The most important functions of transport protocol have been focused that provides a reliable data transfer and effective congestion control mechanism. Both factors of congestion control and reliability will helps in reducing packet loss which result in an energy efficiency over WSN. Additionally, the proposed protocol considered the requirements of both characteristic of WSNs and multimedia communication requirement over WSN. High bandwidth demand, less real-time delay, energy efficient, limited memory and processing are the most important challenges that need to be considered for new transport protocol in WSNs.

5.0 FUTURE WORKS

The new proposed transport protocol will be implemented in network simulator 2 (NS-2) for future works to evaluate the performance of this protocol. In the simulation, we will use the physical layer consists of IEEE 802.15.4 compliant radio transmitter and receiver that operates in the ISM band at 2.4GHz with 250kps of data rate. The video encoder to be used for transmitting data over IEEE 802.15.4 network is MPEG-4.

Another factor will be taken into account for enhancing an efficiency of proposed transport protocol is the cross layer optimization algorithm. Cross layer optimization also helps in increasing the reliability and to improve quality of the network. Different layer can co-operate with each other to share the information which finally minimizing the results in energy consumption.

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