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A New Approach for Traffic Management in Wireless Multimedia Sensor Network

Shyam Nandan Kumar*

M.Tech-Computer Science and Engineering, Lakshmi Narain College of Technology-Indore (RGPV, Bhopal), MP, India
*Corresponding author: shyamnandan.mec@gmail.com

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Abstract Multimedia applications have become an essential part of our daily lives, and their use is flourishing day by day. In Wireless Multimedia Sensor Networks (WMSNs), large volume of multimedia data is transmitted through the network. If the traffic load is greater than the available capacity of the sensor network, congestion occurs and it causes buffer overflow, packet drop, deterioration of network throughput and effect quality of service (QoS). The limited bandwidth should be adjusted for the packets with different priorities precisely. To emphasize the problem, the paper provides A New Approach for Traffic Management in Wireless Multimedia Sensor Network. According to the paper, sensor nodes in one collision area can adjust their sending states adaptively based on packet priority. To improve the received video quality in base stations, proposed technique keeps the I-frames and ignores the other less important frame types of compressed video. Also retransmissions of lost packets are provided with different priorities for enhancing the system performance. The simulations show that the bandwidth adjustment can protect the packets with high priority effectively, and the performance of the retransmission is well positioned to meet the requirement of the multimedia applications. MATLAB is used for simulation purpose.

Keywords: *wireless multimedia sensor network, traffic management, queuing model*

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1. Introduction

Wireless multimedia sensor networks (WMSNs) are a newly developed type of sensor network which has the sensor nodes equipped with cameras, microphones, and other sensors producing multimedia data content. It is mainly the networks of wirelessly interconnected devices that are able to ubiquitously retrieve multimedia content such as video and audio streams, still images, and scalar sensor data from the environment. WMSNs evolved from the traditional wireless sensor networks (WSNs) and enable a new large range of applications, like multimedia surveillance, traffic management, automated assistance, environmental monitoring, and industrial process control. WMSNs have more additional features and requirements than WSN, such as high bandwidth demand, bounded delay, acceptable jitter, and low packet loss ratio. These characteristics impose more resource constraints that involve energy consumption, memory, buffer size, bandwidth, and processing capabilities [1].

Processing of multimedia content has mostly been approached as a problem isolated from the network-design problem, with a few exceptions such as joint source-channel coding [2] and channel-adaptive streaming [3]. The processing and delivery of multimedia content are not independent and their interaction has a major impact on the levels of QoS that can be delivered. WMSNs will allow performing multimedia in-network processing algorithms on the raw data. Hence, the QoS required at the application level will be delivered by means of a combination of both cross-layer optimization of the communication process, and in-network processing of raw data streams that describe the phenomenon of interest from multiple views, with different media, and on multiple resolutions.

The first step in creating a WMSN is equipping a single sensor device with audio and visual information collection modules. As an example, the Cyclops image capturing and inference module, is designed for extremely light-weight imaging and can be interfaced with a host mote such as Crossbow's MICA2 [4] or MICAz [5]. In addition to the ability to retrieve multimedia data, WMSNs will also be able to store, process in real time, correlate and fuse multimedia data originated from heterogeneous sources.

In WMSNs, the effect of congestion may be even more pronounced as compared to traditional networks. When a bottleneck sensor is swamped with packets coming from several high-rate multimedia streams, apart from temporary disruption of the application, it may cause rapid depletion of the node's energy. While applications running on traditional wireless networks may only experience performance degradation, the energy loss (due to collisions and retransmissions) can result in network partition. Thus, congestion control algorithms may need to be tuned for immediate response and yet avoid oscillations of data rate along the affected path. Also multiple paths may exist between a given source-sink pair, and the order of packet delivery is strongly influenced by the characteristics of the route chosen. As an additional challenge, in real-time video/ audio feeds or streaming media, information that cannot be used in the proper sequence becomes redundant, thus stressing on the need for transport layer packet reordering.

Power consumption is also a fundamental concern in WMSNs, even more than in traditional wireless sensor networks. In fact, sensors are battery-constrained devices, while multimedia applications produce high volumes of data, which require high transmission rates, and extensive processing. The quality-of-service (QoS), as a measure of system performance is very important. Wireless transmission for multimedia with the guaranteed QoS in WMSNs is of prime importance due to higher data-rate requirements on the limited and variable capacity of channels. When the WMSNs are used for environment monitoring, the monitoring systems need to record and playback the video after some time. So the necessary and proper retransmission should be added to the real-time video transmission, without affecting the normal data streams. To solve such issues the paper proposed a new approach for traffic handling in wireless multimedia sensor network.

In this paper sections are organized as follows: Section 2 reviews some related works. Section 3 describes the proposed scheme. In section 4, analysis of proposed technique is presented. Section 5 concludes the paper and presents avenues for future work. References for this paper are given in section 6.

2. Related Work

In recent years, the research areas on Wireless Multimedia Sensor Networks have gained more and more attention. Today video is everywhere. Everywhere you turn video is streaming. Video on wireless network has transformed the way we live, as wireless multimedia sensor device adoption has increased rapidly across the globe. Previously proposed methods focused on data analysis, storage resource, bandwidth constraints and video file with limited size, and data security for wireless network. While a very few attempts focused on achieving these majors concepts together fairly.

Poojary, S.and Pai, M.M.M. [6] proposed Multipath Data Transfer in Wireless Multimedia Sensor Network. It provides simultaneous multiple paths for communication between any two nodes. This feature prolongs the lifetime of the network. Also from the data security point of view, MPDT is immune to some specific attacks.

Wei Wang, Dongming Peng, Honggang Wang, Sharif, H.and Hsiao-Hwa Chen [7] proposed Resource Management Architecture for WSN for handling multimedia. The proposed architecture provides digital image authentication, image transmission quality optimization, and high energy efficiency for WMSN.

Using Rate Compatible Punctured Turbo (RCPT) codes and forward Error correction (FEC) parity codes for video steam distribution in wireless access environment [8] was proposed by Duan Dagao, Han and Li Wenzheng. This wireless video transmission system packed video data into the different size and provides more satisfied video playback quality in 3G wireless networks with different bit error ration and packet loss ratio and improved overall network utilization efficiency.

Fard, G.H.E, Yaghmaee, Mohammad.H and Monsefi, R. [9] proposed idea about adaptive Cross-Layer multichannel QoS-MAC protocol for cluster based wireless multimedia sensor networks. It uses TDMA and CSMA/CA for assigning the channel and timeslots for active multimedia sensor nodes in clusters.

Huang Haiping and Wang Ruchuan [10] proposed clustered-control algorithm based on geographic locations, energy, priority of coverage, and multi-layers architecture. Queue based congestion control protocol with priority support (QCCP-PS) [11], is proposed by Yaghmaee, M.H and Adjeroh, D which save energy at each node. An important function of the transport layer in WMSNs is congestion control.

WCCP: A congestion control protocol for wireless multimedia communication in sensor networks [12] is proposed by Shahin Mahdizadeh Aghdam, Mohammad Khansari, Hamid R. Rabiee and Mostafa Salehi. WCCP employs a Source Congestion Avoidance Protocol (SCAP) in the source nodes, and a Receiver Congestion Control Protocol (RCCP) in the intermediate nodes. SCAP uses Group of Picture (GOP) size prediction to detect congestion in the network, and avoids congestion by adjusting the sending rate of source nodes and distribution of the departing packets from the source nodes. In addition, RCCP monitors the queue length of the intermediate nodes to detect congestion in both monitoring and event-driven traffics.

In order to set up a suitable traffic management for monitoring big video data on sensor devices, in the paper, inspired by above related work, a novel mechanism is proposed for wireless multimedia sensor network.

3. The Proposed Scheme

In this section system model for formation and transmission of video data frame is proposed for wireless multimedia sensor network. Based on frame operation transmission management for different frames are discussed.

Consider the network environment, which is shown in Figure 1. The next-generation WSN is suitable for transmission of large-scale videos captured by the cameras. Video capture devices, such as cameras, generate large amounts of videos and transfer them to Hadoop sub-clusters through the WSN. The model of wireless multimedia sensor network is assumed to consist of one sink node and several identical static sensor nodes which send their packets to the sink node over multi-hops. The route of the network is a tree and each node sends its data packets to its parent. Each node has a certain storage capacity. If the nodes work at the high data rate, the collision can happen frequently, and the performance of the transmission is poor. Therefore, when some nodes are sending packet with higher priority, the interfering nodes need to decrease their data rate in order to protect the higher priority packet. When the high priority packets are sent over, the normal sending rate is resumed.

The length of a packet should meet the requirement of the transmission in the WMSNs. If one packet only contains few data, it wastes energy during transmission and also causes more collisions by the competitions in the wireless channel and increase the probability of the congestion. However, if one packet has large amount of data which may contain several frames, each packet needs to wait for all of the video frames generated, which causes more time delay. Furthermore, as one packet is successfully transmitted only if each bit in the packet is correctly received, the successful transmission rate is low if the length of a packet is large.

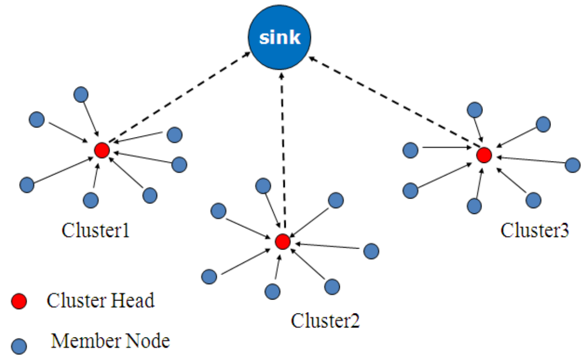

Figure 1. Network Environment

3.1. Frame Operation

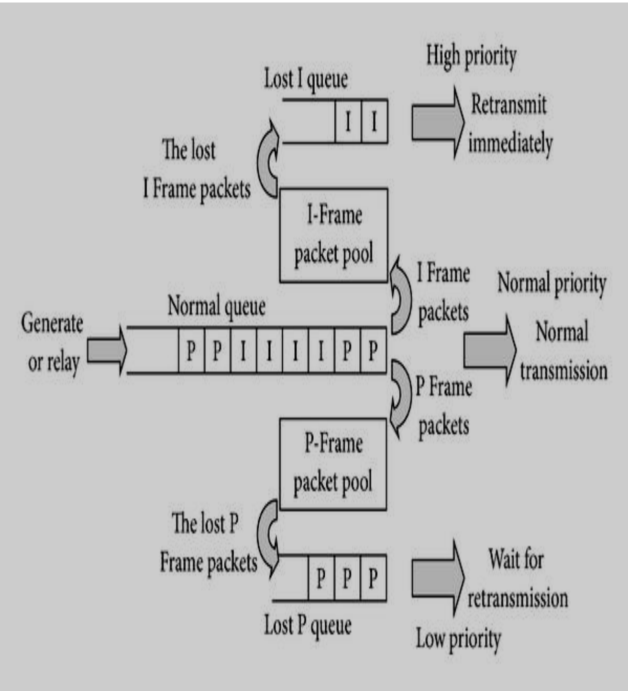

Figure 2. Frame Operation

As the coding and decoding of the bidirectional interpolated prediction frames (B Frame) need to wait for the next frames, we only use inter frames (I Frames) and predicted frames (P Frames). If a packet contains the data of I Frame, the packet is called I Frame packet, otherwise called P Frame packet. Different kind of frames has different and random amount of data. The I and P Frame packets are generated continuously and alternately. The data of I Frame is always much larger. However for P Frame, the amount of data can be large or small depending on the motion of the objects. Since the packet lost in the wireless network is an unavoidable characteristic, so if some P Frame packets are lost, the video decoding can still be going on, only with some mistakes in the video. If the retransmission of the lost I Frame packets is fast enough, the effect of the lost packets may not be notable. So the I Frame packets must have higher priority than the P Frame packets, and the quick retransmission of the lost I Frame packets is essential. Figure 2. shows the packet functions which are generally perform at a sensor node.

When a node generates or receives a data packet, it may be I Frame packet or P Frame packet but it is first placed into the normal queue to wait for being sent. After this packet is sent, it is transferred to the I-Frame packet pool or P-Frame packet pool depending on its attribute. These two pools are used to store the unconfirmed packets temporarily, waiting for the retransmission if needed. If one packet has large amount of data which may contain several frames, each packet needs to wait for all of the video frames generated, which causes more time delay. The I Frame is the most important in supporting the real time playing. So if it is lost, the retransmission of I Frame packets has the highest priority. They should be found in the I-Frame packet pool, put into the Lost I Queue, and retransmitted immediately.

The differences between the Lost I Queue and the Lost P Queue are only the priority and the retransmission time. The I-Frame and P-Frame packet pools make use of the memory of the sensor node to store the unidentified packets, without affecting the normal sending and receiving of the sensor nodes. This mechanism separates the packets with different priorities and simplifies the management and seeking of the lost packets.

3.2. Transmission Priority

For the video monitoring, real time is essential for video transmission. The data needs to be compressed as much as possible to meet the limited bandwidth of the wireless multimedia sensor networks. For bandwidth limitation and the real time, the QoS control in the WMSNs must be simple. If some I Frame packets are lost, they need to be retransmitted as quickly as possible. But if some P Frame packets are lost, the retransmission depends on the condition of the traffic. To overcome bandwidth limitation, the bandwidth usage of each node in the network needs to be programmed for better performance. This paper provides a new approach for traffic management in the transport layer of the network to support the quality of the video stream. It uses transmission priority to assign the bandwidth adaptively. A packet can have various priorities. The sending rate of a node needs to be adjusted adaptively to protect the packets with higher priority. These priorities can be defined as:

3.2.1. High Priority

It is only used for the retransmission of the lost I Frame packets. Because the lost I Frame packets need to be retransmitted as quickly as possible, these packets are not limited by the speed control. But the other nodes need to slow down to give up bandwidth.

3.2.2. Normal Priority

It is for the normal transmission and support the normal video generation.

3.2.3. Low Priority

It works on P frame operation.

3.3. Traffic Management

The traffic management in wireless multimedia sensor network is accomplished by the command packets whose packet format is shown in Figure 3. Since wireless transmission is in broadcast fashion, if one node receives all the data packets from its neighbors in the collision area, it will take a great burden for processing, computing, and storage. Therefore, besides the normal packet transmission, we adopt some command packets only for the network control. The multicast transmissions in our system are only for these command packets. For the bandwidth limitation, the WMSNs cannot afford too much bandwidth and time delay for transmitting the control packets iteratively. Thus, the control needs to be simple. Moreover, to improve the received video quality in base stations, we keep the I-frames and ignore the other less important frame types of compressed video.

Source Node ID (4 Bytes)
Destination Node ID (4 Bytes)
Sequence Number for Command Packet (4 Bytes)
Packet Direction (1 Byte)
Frame Type (1 Byte) 0 for I Frame, 1 for P Frame
Communication Type (1 Byte) 0 for Broadcast, 1 for Point-to-Point
Lost Packet (1 Byte) 0 for No Packet Lost, 1 for Some Packet Lost
Sequence Number for Lost Packet (4 Bytes)

Figure 3. Format of Command Packet

Traffic handling for I frame is differ from P frame. The I Frame packets request higher reliability and less time delay. Therefore, the control mechanism should be in synchronous communication. Each command packet needs to be confirmed in the duration of validity. But to the P Frame packets, we do not adopt the synchronous transmission for the control packets; that is, not all the command packets are expected to be transmitted successfully.

Controlling process of I frame is shown in Figure 4. All control of I frame packets are checked carefully and sent immediately. This mechanism is like the traditional TCP control, but the difference is the broadcast of the command packets. When beacon start initially, packets are broadcasted to all the nodes in the collision area. Before a group of I Frame packets begin to be sent, the node broadcasts a start beacon to the nodes in the collision area. The interference nodes adjust their states according to this command packet. When a base node receives an initial beacon, it knows the next packet contains the data of I Frame. If all the I Frame packets of the I Frame are received by base node, it returns an acknowledgment (ACK) to the child node and the transmission of this I Frame is finished. If not, the base node returns the sequence number of the lost packets. After that the child node begins to retransmit the lost packets. These two kinds of return packets are broadcasted to all the nodes, and they should be guaranteed to be received by its child node. For preventing the control packets from being lost, each control packet needs to be confirmed by the base node and child node. If the child node does not receive any confirmed packet in some time, it needs to send end beacon to tell its base node that time is out for waiting for the confirmation. The base node needs to resend the return packets. Once confirmed that the I Frame packets have been received by the base node successfully, they can be deleted in the pool of the child node. The control retransmission of the I Frame packets needs to be enforced. However, there is no mechanism to guarantee the broadcast command packets being received by all the nodes in the collision area due to the unreliable bandwidth. The other nodes do not give any feedback to the sender. If some command packets are lost at some nodes, these nodes cannot change their states. Fortunately, this situation does not cause much problem to the transmission.

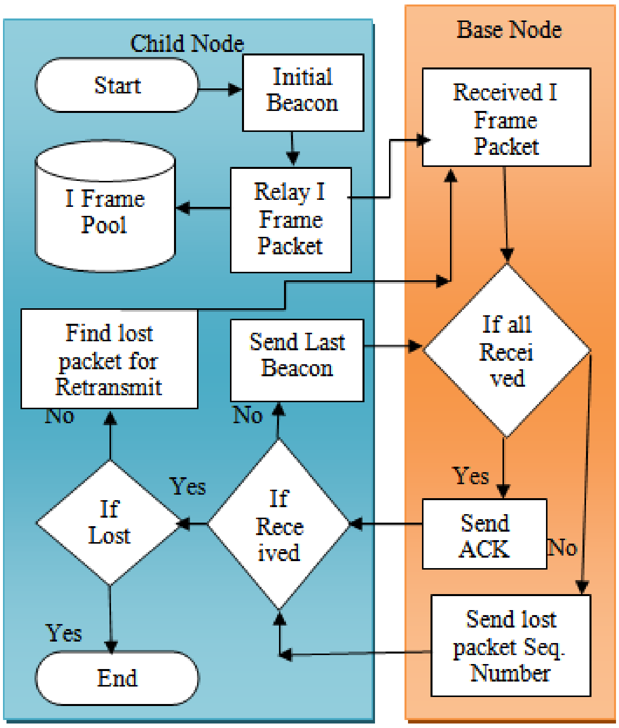

Figure 4. I Frame Traffic Management

Figure 5 shows the traffic management of P frame. Its transmission process is much easy than that of the I Frame packets. For the P Frame packets, the network overflow should be considered in the confirmation mechanism. There is only one chance for the parent node to give the confirmation after receiving/sending a group of P Frame packets. The confirmation contains the packet sequence number which is lost but still has chance to be retransmitted. And the lost P Frame packets need to be retransmitted when the network link is available. After the sink node receives the packets out of order, it adjusts the packet order according to the packet sequence number.

There is no broadcast step in P frame transmission. Each group of the P Frame packets has only one chance to get confirmation. After the base node receives a group of P Frame packets, if no P Frame packets need to be retransmitted, the transmission of this group is finished with no ACK packet. Otherwise, if the base node still has some lost P Frame packets, it returns their sequence numbers. If the lost ones can be found in the P-Frame packet pool, these packets will be retransmitted at a proper time. If the base node still waiting for receiving the requested packets after calling for retransmission for several times, it thinks that the packets are lost from its child node and will not recall these packets anymore. If some new packets come when the P Frame pool is full, the packet with the highest sending vacancy ratio at the sending time will be overwritten. If several continuous P Frames all contain small data amount, the maximum number of frames in one packet needs to be introduced to limit the time delay.

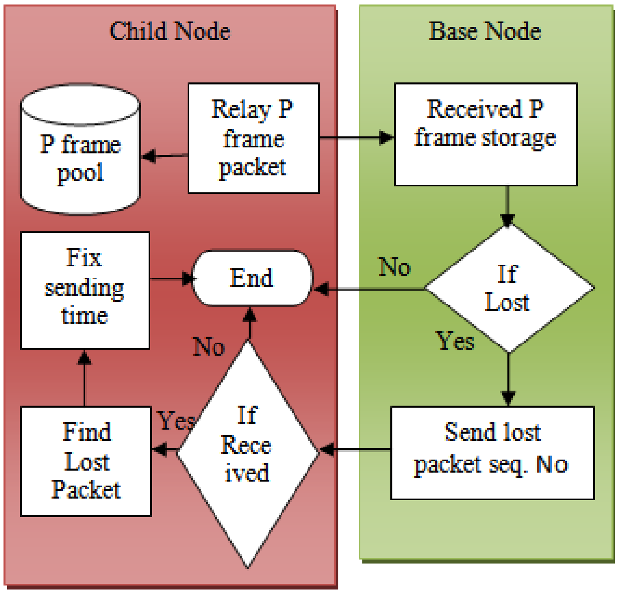

Figure 5. Traffic Management in P Frame

4. Analysis of Proposed Technique

To analyze the Traffic Management approach, we examine the experimental results in the term of Transmission priority, Packet lost ratio, Retransmission of lost packet and Time delay. First, we give out a simulation system model of a typical monitoring application. Based on this model, the simulation and analysis results for different parameters are compared. For simulation purpose, MATLAB is used. It is assumed that the node-to-node packet lost ratio follows the Gauss distribution. The average value of the lost ratio increases with the larger data amount transmitting at the same time. The amount of the video is simulated as the monitoring video using in the rooms; as shown in Table 1. Table 1 contains simulation parameters. Frame length can be taken random for both I and P frame.

Table 1. Simulation Parameters

Parameters	Value
I frame length	10-20Kb
P frame length	13-1300kb
I frame pool size	17kb
P frame pool size	24kb
I frame interval	34frame
Frame frequency	32f/s
Max. node bandwidth	2.1mbps
Avg. I frame data rate	54kbps
Avg. source node data rate	98-231kbps
Data sending rate	5ookbps
Max. packet length	1300b
Max. frame per packet	7

During simulation we use three types of nodes as shown in Figure 6. They are:

- **Sink Node:** The sink node is assumed with sufficient hardware to support any request of the network. It perform main task in wireless multimedia sensor network. It receives and processes the packets for the video storage and play.
- **Relay Node:** The relay nodes have double capacity than the source nodes. But it has no camera facility. Relay Node is only used for the packet forwarding.
- **Source Node:** It has camera to generate the video data for supporting multimedia operation.

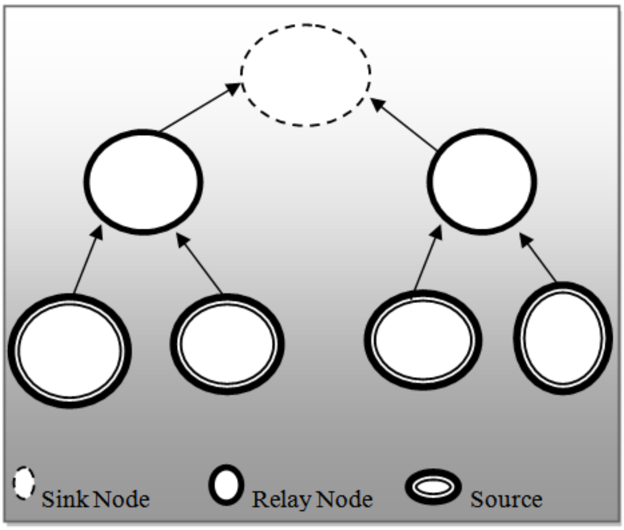

Figure 6. Nodes Used in Simulation

4.1. Effect of Packet Ratio on Transmission Priority

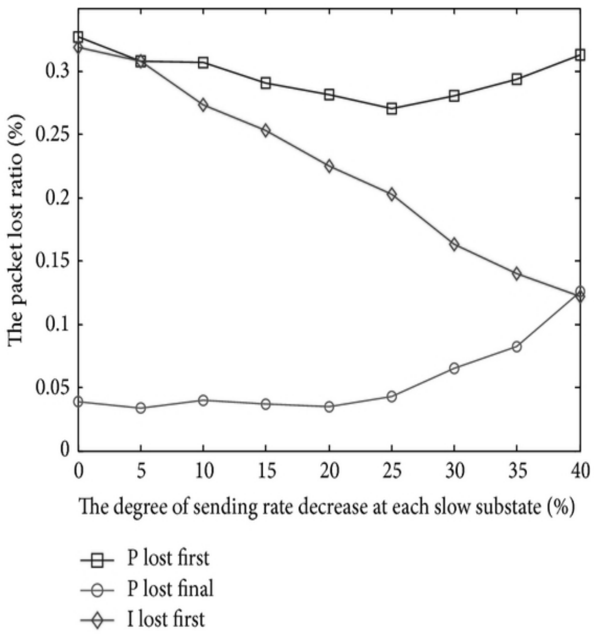

Figure 7. Packet Lost Ratio Vs. Data Transmission Rate

The proposed technique in this paper fully protects the packets with high priority for transmission which enhances the system performance. Figure 7 shows the effect of the ratio of slowdown for each slow sub-state. As the increase in the sending rate declines for each slow sub-state, the lost ratio of the P Frame packets at the first time transmission first decreases and then increases. Also the packet lost rate of the I Frame at the first time transmission is lower. The decrease of sending rate for each slow sub-state plays an important role in the performance.

When the I Frame packets are generated and transmitted, the data amount is large at the moment, which makes the wireless channel to be busy. If the number of P Frame packets to be sent at this time is reduced, the transmission successful ratio will increase. But if the interference nodes decrease their data sending rate too much, there will be more chances to transmit P Frame packets at the other time. Therefore, the lost rate of the P Frame packets will rise.

4.2. Analysis of Packet Ratio

The packet lost rate for I and P Frame packets are shown in the Figure 8. Proposed mechanism has a certain effect to protect the I Frame packets, as well as the retransmitted P Frame packets. The lost I Frame packets are retransmitted until they can be received successfully; that is, no matter what is the lost rate of the I Frame packets at the first time transmission, the final lost rate is always 0. If the I Frame packet is lost, there would be an error in the video in the time of this period and it cannot be played. If the P Frame packet is lost, the video in the next time of this period still can be played, but it would be affected.

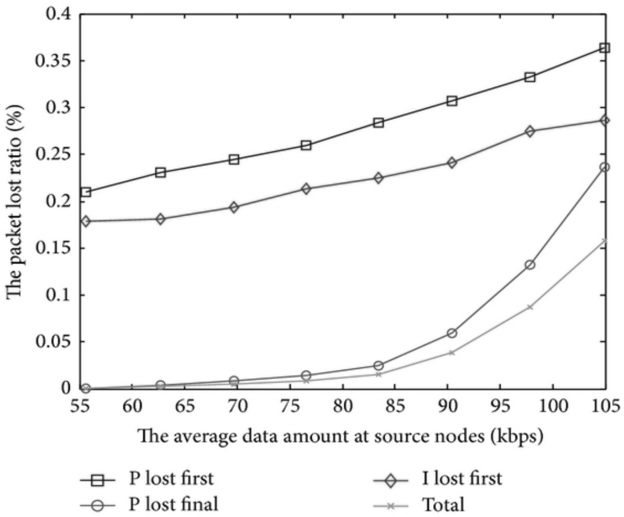

Figure 8. Analysis of Packet Lost Ratio

4.3. Analysis of Retransmission of Lost Packet

Figure 9 shows the simulation result of the retransmission probability for lost P Frame packets, where the size of the P-Frame packet pool is assumed to be unlimited. With the increase of the retransmission probability, the more lost P Frame packets can be sent and received. If there are too many retransmissions, this will lead to retransmission of the lost P Frame packets at the time when the network traffic is relatively crowded. An appropriate retransmission probability should be carefully chosen to meet the requirement of retransmission. If the retransmission probability is very small, the retransmission is only allowed when the network instantaneous traffic is very low. There is not enough chance for retransmitting the lost P Frame packets. Thus, the impact of the retransmission to the normal network traffic can be minimized.

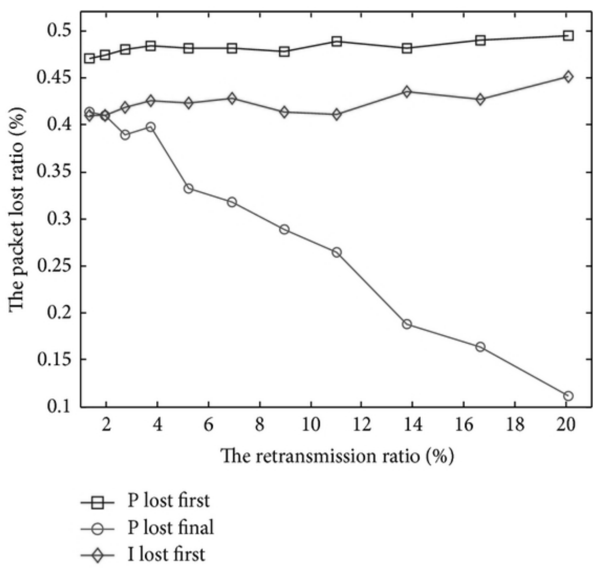

Figure 9. Analysis of Retransmission of Lost Packet

The size of the packet pool does not affect the first time packet transmission. As the I Frame packet length does not change much, the retransmission can be predicted accurately. The size of I-Frame packet pool can be determined easily. However, the P Frame packet length varies and is difficult to be predicted. The size of the P-Frame packet pool should be as large as possible. For the video replay, with the adaptive retransmission of the P Frame packets, many lost P Frame packets can be retransmitted and fill in the blank of the video.

4.4. Time Delay Analysis

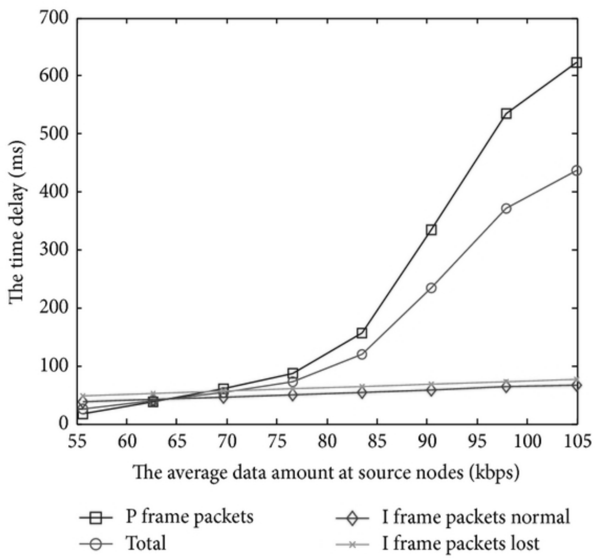

Figure 10. Time Delay Vs Average Data Amount

Because the retransmission of the lost I Frame packets always happens at the time when normal I Frame packet transmission is finished, the average data rate has a little impact on the I Frame packet transmission as shown in

Figure 10. The transmission of the I Frame packets happens in a short period of time. With the increase in average data rate, the workload for P Frame packet generation and transmission increases. The competition for the wireless channel increases as well. So the queue becomes longer and the time delay also increases. In this paper time delay is defined as the time from the frame generation to reception by the sink. It contains the time for packet generation, the time for waiting in the queue at both the source node and the relay node.

5. Conclusion and Future Work

The growing interest in applications of Wireless Multimedia Sensor Networks (WMSNs) imposes new challenges on traffic management. Efficient traffic handling in Wireless Multimedia Sensor Network is an important issue since the WMSN nodes that sense the data need to be communicated to the base station, to take necessary decision.

The simulations show that the proposed new approach for Traffic Management has good performance in terms of the packet protection and retransmission. The important video frames can get more bandwidth during the transmission and retransmission. In addition, the retransmission of the lost P Frame packets has little effect on the normal transmission, but the performance of the video playback can be significantly better than the real-time playing.

In this paper we have researched various issues regarding traffic management in wireless multimedia sensor network and analyzed numerous problems in implementing the system. Comparing the proposed technique with different analysis stages, the results show that the proposed system is more efficient to handle multimedia on wireless sensor network.

In the future, we can work on Storage Capacity to handle large-scale of Video data on wireless sensor network.

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