International Journal of Electrical and Computer Engineering (IJECE)
Vol. 12, No. 4, August 2022, pp. 3595~3606
ISSN: 2088-8708, DOI: 10.11591/ijece.v12i4.pp3595-3606

Improving multimedia data transmission quality in wireless multimedia sensor networks though priority-based data collection

Mohammed Falah Abbood[1], Mohammed Falih Kadhim[2], Ahmed Raheem Kadhim[3]
[1]Central Library, University of Kufa, Al-Najaf, Iraq
[2]Information Technology Research and Development Center, University of Kufa, Al-Najaf, Iraq
[3]Faculty of Computer Science and Mathematics, University of Kufa, Al-Najaf, Iraq

Article Info

Article history:

Received Apr 30, 2021
Revised Mar 22, 2022
Accepted Apr 2, 2022

Keywords:

Multimedia routing
Packet prioritizing
Power consumption
Quality of service
Rechargeable sensors
Wireless multimedia sensor network
Wireless sensor network

ABSTRACT

Wireless multimedia sensor networks (WMSNs) are special kinds of wireless sensor networks (WSN) that can send multimedia data such as audio and video streams. Sensors used in WMSNs are smart, tiny, and resource constraint sensor nodes (SNs) distributed in a large area. Typically, multimedia data are large in comparison to other data types. As a result, WMSNs have to deal with high volumes of packet transmission, leading to a high rate of packet loss and network congestion. Network congestion can significantly affect the quality of service and usually lead to high energy consumption. Thus, to improve the quality of service (QoS) and transmission performance, it is necessary to deal with network congestion. In the past, different packet prioritizing methods were proposed to deal with this issue. However, improving QoS usually requires high energy to function correctly. Consequently, using rechargeable sensor nodes to reduce energy consumption is an acute solution. In this research, priority-based data collection is considered to cut down on data distortion and improve the QoS of the multimedia sensor network. Additionally, energy harvesting sensor nodes were used to reduce energy consumption due to the high transmission rate. The simulation result shows a noticeable improvement in the performance of our proposed method in comparison to previous methods.

Corresponding Author:

Mohammed Falih Kadhim
Information Technology Research and Development Center, University of Kufa
Kufa Street, Main Campus, University of Kufa, Najaf Governorate, Iraq
Email: mohammed.kadhim@uokufa.edu.iq

1. INTRODUCTION

A wireless sensor network (WSN) can be seen as a group of interconnected devices, also known as sensors or sensor nodes (SNs). Each node can sense characteristics of the surrounding environment, such as heat, light and sound; and react accordingly. With the improvement of WSN in the past years, wireless communication has become more applicable and affordable. SN, such as multimedia cameras and sound devices, can be easily implemented for WSN projects and simulation purposes. These nodes, also known as wireless multimedia sensor networks (WMSNs), utilize the wireless medium to interact. WMSN exchange multimedia data, which in this case varies from images and audio-based information with other nodes in real-time or non-real-time. WMSNs show significant effectiveness in surveillance and monitoring systems such as traffic monitoring, intrusion detection, industrial automated systems, and more. The potentials of

WMSNs are not yet fully discovered, and thus further research is required to implement and use WMSNs more effectively [1]–[3].

Power consumption plays a significant role in WSNs. Batteries can be seen as a common power source in these networks despite disadvantages such as the high cost of replacing them and their physical nature limitations [4], [5]. As a result, researchers start investigating further to find alternative energy sources and mechanisms to make energy consumption more efficient. Some research papers suggest harvesting energy from within the environment while others propose transferring energy wirelessly between sensor nodes within the network. While these suggestions can benefit a certain level, it can be challenging to find a good enough power source that replaces the battery without affecting the network's reliability and performance. It is important to note that multimedia sensor networks are designed for specific applications that require sensor nodes to operate independently over a long time.

This research focuses on the transmission of multimedia data, which is typically large, and thus management of power consumption becomes more important to ensure efficiency and reliability. Although rechargeable sensors are available and can be used, it can create reliability issues when used in this kind of networks as these sensors might discharge and turn off, leading to losing stability within the network. Another area that must be addressed in multimedia data transmission is the quality of data itself when transmitted to the network's central device. Unlike regular data types, multimedia data, which can be called packets, has certain features that must be preserved throughout the transmission process. These packets produced by the multimedia sensors might need to be prioritized differently. Some packets can have higher priority than the others and thus might require being sent before the other packets with less priority. Prioritizing multimedia packets can affect the quality of the file received by the central device of the network. Multimedia sensors are known to have limited buffer sizes. Since the multimedia data are typically large, as mentioned before, the sensor buffer might overflow early before all data arrive at the destination. As a result, multimedia data with a high priority will end up being discarded. This is another issue that will be addressed in this research. The goal is to implement an efficient mechanism in terms of power consumption and enable multimedia data to be transmitted without overflowing the wireless sensor's buffer, which ultimately means preserving the quality of multimedia files without consuming too much power.

Quality of service (QoS) is a serious challenge in WMSNs. Typically, to guarantee QoS, a large volume of data must be transmitted between the sensors and sink, which may not be possible due to bandwidth limitations. Researchers had to experiment with different techniques to reduce the size of multimedia data. One technique is redundancy reduction, which reduces data size through local hardware data analysis [6], [7]. However, since this technique relies heavily on processing power to analyze and extract essential images from the data, additional hardware resources are required to perform this technique. Another solution is to use data compositing where the sink creates a summarization of data by collecting heterogeneous data from different sensors [6]–[8]. The method helps reducing data redundancy, which ultimately reduces the size of the data stream. Again, this method requires additional hardware resources to process and analyze the large volume of data. To address the hardware resources limitation, distributed source coding (DSC) is used. DSC encodes multimedia data on each node individually, which can also help reducing energy consumption [9]–[12]. Formerly, the sink is the central device for processing the data it collects from the nodes. However, due to rapid development in wireless networks, sensors can now include a dedicated processor and memory that allows data processing and storage without relying on the sink hardware [13], [14]. Additionally, to address bandwidth limitation in WMSNs, sensors can utilize various communication channels simultaneously at the media access control (MAC) layer level [15], [16]. Furthermore, radio equipment that features extreme bandwidth, such as ultra-wideband (UWB), can also be used to achieve QoS [17], [18].

One of the common video routing protocols is the adaptive shaper with real-time video streaming routing protocol (ARTVP) which incorporates two elements to route video streams; data traffic control mechanism and time-sensitive data transmission [19]. However, since the video file size is relatively huge, the author used H.264 codec to reduce data size. Furthermore, ARTVP uses a traffic shaper algorithm; also known as Token bucket; to control the traffic rate sent to the network. Token bucket goes through a sequence of steps, as explained: i) variable bit rate (VBR) packets are received in first-in-first-out (FIFO) order then stored in input buffer; ii) when the bucket has enough number of tokens to form one packet, the packet will be sent to the network. Additionally, consumed tokens will be discarded from the bucket; and iii) as soon as the input buffer is filled up with packets, excessive packets will be automatically discarded. Similarly, new arrival tokens will be discarded when the bucket becomes full.

The author outlines a problem with controlling the traffic rate during peak usage, leading to packet dropping when the output rate exceeds the channel bandwidth. This can be seen as the main drawback when implementing a token bucket algorithm. Furthermore, he suggests using a multipath routing protocol to send the multimedia data. The data can be divided into three categories; "I", "P", and "B" based on the packets' priority. Sensor nodes are used in this case to determine three optimal paths for each category. The path determination process is analyzed by counting the number of hops required for the packet to reach the final destination. Therefore, the optimal path will be used to send packets found in category "I". The second optimal path will be used to send packets in category "P". Finally, the third optimal path will be used to send packets in category "B" [19].

Improved relay traffic-based transmission power control (RT-TPC) is an algorithm and its primary function is monitoring and controlling the transmission power generated during the routing process. This can improve the stability of the network through efficient power distribution. During the monitoring stage, the improved version of RT-TPC checks the pattern of how the power is generated in the network. Likewise, the pattern on each node is sent to the preview nodes until the sink is reached. In addition to the power generation pattern, the nodes also share the information received from previews neighbors. Ultimately, the sink will collect the power generation pattern and data from all nodes in the network. The information can then be used to determine the charge-receive-send cycles' duration and be shared across all nodes. Then, each node can decide the best time to switch between the three modes: sleep, send, and receive, based on their cycle duration. According to the author, this process enables a node to change transmission power based on the queue's length. For example, when the queue is small, more power is transferred to the farther nodes, increasing the delivery rate. In summary, the improved version of RT-TPC depends heavily on the power generation patter to determine the next node during data transmission. The result shows significant decreases in packet drop rate when compared to the generic RT-TPC [20].

The two-phase geographic greedy forwarding plus (TPGFPlus), which is a revised version of the two-phase geographic greedy forwarding (TPGF), is a multi-path routing algorithm that balance energy consumption packet progress by adopting a model of energy recharging [21]. In this algorithm, each node collects its own information and information about its 1-hop and 2-hop nearby nodes. The information these nodes collect can be current energy levels, residual energy, energy harvested rate, and location. The authors confirm that the information gathered from this process is not stored as an overhead on top of this algorithm. Instead, the information is gathered on obligatory basis during energy consumed uniformly-connected k-neighborhood (EC-CKN) stage. The authors proposed and algorithm which consists of two phases. The first phase is 2-hop geographic forwarding. Unlike the traditional TPGF where nodes always forward packets to the next hop neighbor, the authors expand the forwarding process using TPGFPlus which uses two courses: greedy forwarding and step back and mark. However, a possible issue can occur with this method is that at some point, the discovery process might reach a dead end known as block situation. To solve this issue, the node will initiate a step back and mark process in which the block node steps back to the previous node which will attempt to select a different next hope node. The second phase of the proposed algorithm is path optimization which performs Label based optimization to eliminate path circles problem. Path circles occurs when at least two nodes are selected as neighbor of another node in the same path. Next, a command is sent to all unused nodes across the path which is used to release these nodes. The released nodes can later be used by other nodes to explore new routes. The final stage is transmitting multimedia data across the successfully assigned path.

Routing protocol for k-anycast communication (RPKAC) is a protocol that is based on the anycast tree scheme [22]. It works by utilizing multi-sinks distributed across the network. According to the authors, the multi-sinks method can improve network reliability, load-balancing, and security. In WSNs with a single sink, the energy consumption for the nodes surrounding the sink is significantly high, which may affect network reliability. Rechargeable sensors are used to replace traditional sensors to retain power for a longer time to reduce the load on these nodes.

Additionally, multiple sinks are utilized across the network to reduce the energy consumption of the nodes. At first, network topology must be created. To do this, each sink sends a control type message to sink neighbors via multi-cast transmission. Similarly, nodes send control messages to all nodes exchanging information about their neighbors. However, sensors usually face two challenges before delivering data: choosing the next-hop node from neighbors and selecting the right sink to deliver packets. In this method, choosing the next-hop node is based on specific criteria such as the amount of charge, distance, and energy load. When it comes to selecting the sink, the closest one is always chosen in order to reduce delay and network load. Utilizing multi-sink networks has shown significant improvement in terms of reliability and security despite the similarity in nature to the single sink one [22].

2. RESEARCH METHOD

2.1. System model

In this section, the network model is explained in detail. Essentially, node deployment is considered one of the challenging processes in WSNs as it can affect sensing coverage and, ultimately, the quality of the network. Deploying nodes based on a good plan can significantly improve sensing coverage and reduce the total number of sensors required in the network. In reality, however, a well-planned deployment is not always achievable. In many scenarios, such as in the forests or on a battlefield, sensor nodes usually distributed randomly over the area [23]–[25].

The model comprises of N sensor nodes which randomly deployed within the network. However, once deployed, the location of these nodes and the base station will not change. Table 1 shows the node parameters used in the model and their indication. Each sensor node has a unique identifier (Id_i) and equipped with a multimedia recorder. Additionally, all sensors are homogeneous in nature. The amount of residual energy that each node has is presented in c_i percent. The base station can be located anywhere on the network. Furthermore, each sensor is equipped with a storage memory called an input buffer. This buffer requires more storage than other networks due to the nature of multimedia data which typically large in size. The amount of space left in the buffer is indicated by b_i. It worth mentioning that this model does not require each node to be aware of its geographical location within the network. However, it is important that each node can locate the neighbor nodes.

Table 1. Node parameters

Node Parameter	Indication
Id_i	Node identification
l_i	Node level
c_i	The amount of residual energy of each node is in percentage.
b_i	The amount of free space in the input buffer of each node is in percentage.
Ch_i	Group of node Children
P_i	Node parent's group
np_i	Number of parents for each node
nc_i	Number of Children for each node

2.2. Energy consumption and harvest

The model presented in this paper assumes that each sensor is energy-constrained but rechargeable. Each node can harvest energy from the local environment (e.g., using solar power) to recharge the battery. It is good to note that each sensor needs the energy to perform tasks like receiving, processing, sensing data within the environment, and sending the data, which is the most energy-demanding task.

2.3. Building network infrastructure

The network infrastructure is built when the sink broadcast a control message (*ConstructionMsg*) to all nodes. Typically, this message includes the sink ID and level {ID sink, 0}. Each node receives this message will compare its level value with the level value received from the message. If larger, the node will update that value and mark the sink as the parent. Similarly, the sink will mark all these nodes as children set. Furthermore, each node receives *ConstructionMsg* will read the level of the sender. If the level is less than the level of the receiver (i.e., $L_{sender}<L_{receiver}$), it will perform the following: i) the receiver will save the ID of the sender's node within the parent set, ii) number of parents is increased by one, iii) received value is increased by one. This value is set for the receiving node, and iv) send *AckMsg* to the sender. The contents of the message are {Id_i, id_{sender}, 1} where the value of 1 means receiver has marked the sender as the parent. Also, any other node receives *AckMsg* message it will store the sender ID within its children set. As explained in algorithm 1. In similar manner all other nodes within the network will broadcast the *ConstructionMsg* messages they receive to all neighbors until the level of all nodes is determined and the children and parents are identified for each node. Figure 1 shows format of messages exchanged during network building process.

Algorithm 1. Network construction mechanism

```
In node u;
Upon receiving a ConstructionMsg{ v, l_v } from node v:
if l_u>l_v
  l_u=l_v+1;
  np_u=np_u+1;
  insert v into P_u;
  send AckMsg{u, v, 1} to v;
  broadcast ConstructionMsg{u, l_u };
End if
Upon receiving a AckMsg{v, u, 1} from node v:
nc_u=nc_u+1;
insert v into Ch_u;
```

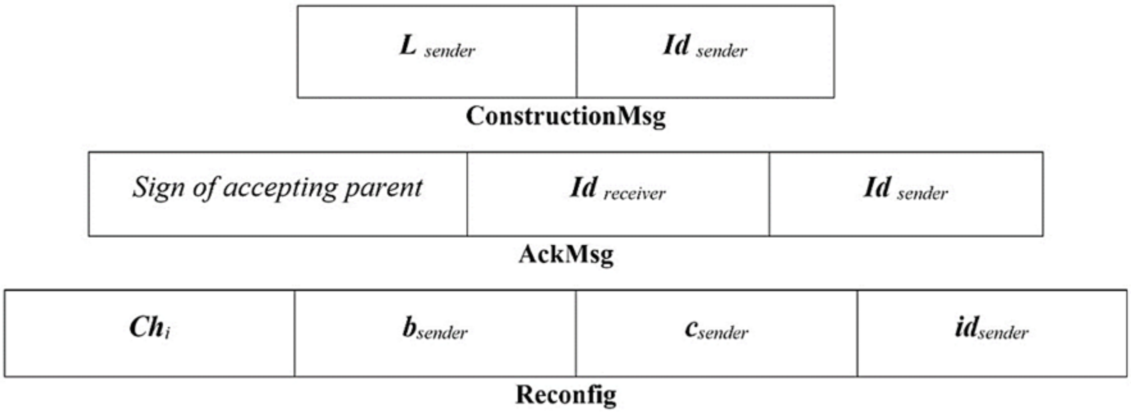

Figure 1. Format of the messages

2.4. Packet forwarding mechanism

Typically, packages containing multimedia data varies in term of priority and the type of information they carry. In packet forwarding mechanism, H.264 encoding is used in which frames can be categorized into type “I”, “P”, or “B” depending on their importance. So, frames type “I” are more important than frames type “P” because “I” frames holds most of the essential information hence why it has less compression and usually larger in size than the other frame categories. Furthermore, the pictures can be meaningless if “I” frames are not presented. Similarly, frames type “P” are more important than frames type “B” and it is encoded depending on “I” frames.

Each node categorizes the frames as they enter its input buffer. Then it decides the best time to send that frame according to the type, the route that it came from and the route it needs to be forwarded to. The goal is to forward the frames with high priority to the sink before anything else. It is worth mentioning that each node may have more than one parent. The control messages are used by the node to know the status of parent. The status usually includes the battery and buffer status. Using the content of these messages, each node obtains the value of S for all of its parents.

The equation (1) is used for node (X) to calculate the *S* value for all its parents:

$$S_i = \alpha * c_i + \beta * b_i \quad (1 \le i \le np_x) \tag{1}$$

where, C_i is Node battery charge and B_i is the amount of free space in the node buffer.

$$0 \le S_i \le 1 \tag{2}$$

2.5. Next hop selection

At the beginning of this stage, all nodes calculate the value of (S) for its parent set. Next, this value will be used to calculate the probability quantity (Q) for the parent. Based on this value, next node is determined for each packet.

$$Q_i = \frac{S_i}{\sum_{k=1}^{np_j} S_k} \tag{3}$$

Then a random value between zero and one is generated by each node. The generated value is related to that node’s parent, which is also selected as the next node. So, for each node, it uses almost all the parents as the next node to send data in a balanced quantity. However, it must be noted that the size of the multimedia data is relatively large. Thus, this mechanism alone might not be adequate for improving the service quality.

2.6. Parent status updating

Parent status is usually depending on the value of (S). This value is directly related to the battery charge and the free space in the buffer. Usually, the status of the node is continuously changing during data transmission. Therefore, each node must inform its children when the status is changed by sending a control message (*reconfig*) regularly. Similarly, if the battery charge or the free space in the buffer exceeds the threshold, this message will be sent to the children.

2.7. Discard packets by priority

Due to the relatively large size of multimedia data that leads to a buffer overflow in the nodes, it might be necessary to discard specific packets to free space. In this method, each node can decide when to send or receive data. The method is explained.

2.7.1. Receiving

Consider a node, which its input buffer is full, is about to receive a packet. The first step is to examine the type of that packet. If it is "B" type, the packet will instantly be deleted. If it is "P" type, the first "B" type packet located at the end of the input queue is discarded then the "P" type packet is inserted into the buffer normally. Similarly, if the packet is "I" type, same procedure is followed as "P" type packet however if no "B" type packet exists in the input queue, the first "P" type packet will be discarded instead. The receiving process is explained in Figure 2.

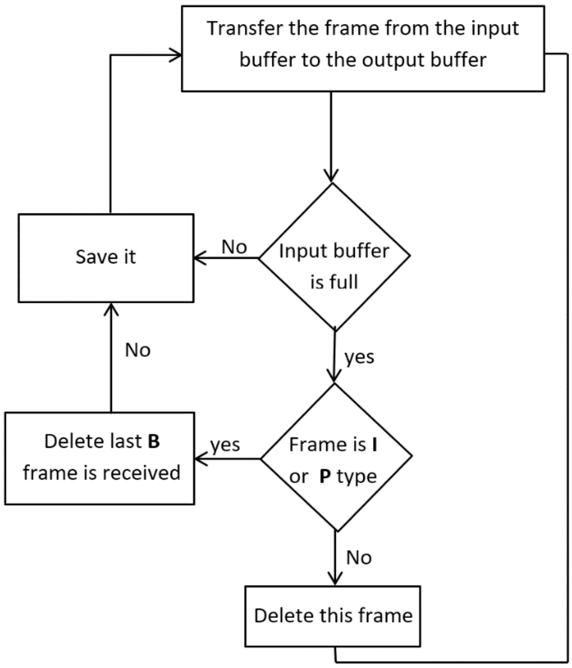

Figure 2. Flow chart showing the mechanism of receiving packets

2.7.2. Sending

In this case, three threshold values are considered for changing the node. First, the sending node determine the amount of charge. Then, a decision is made upon obtaining these values. Threshold values and node decision is shown in Table 2.

Table 2. Variety of decision conditions when sending each package

Threshold values	The sensor's decision to send the package
$C_i \geq 30\%$	Sends all frames.
$20\% \leq C_i < 30\%$	Deletes type B frames and sends the P and I.
$5\% \leq C_i < 20\%$	Removes frames B and P and only sends I.
$C_i < 5\%$	It does not send any frames

During data transmission, some nodes may experience packet discarding more than the other nodes. To prevent this from happening, each node records the IDs of the deleted packets. Then the node with the most deleted data will stop discarding packets to prevent further loss of information. The final step is, as mentioned earlier, sending a control message to all children whenever the battery charge or the size of the free space in the buffer exceeds the threshold. These messages help to increase the charging effect, as explained in relation 1.

The values of coefficients in relation 1 is tested under different conditions, and the result is shown in Table 3. Each node uses these values when calculating S for their parents. This behavior aims to reduce the load of nodes whose energy is depleted and cannot be charged due to high load; in other words, their energy consumption rate is higher than their charging rate. In fact, using these different coefficients in different conditions makes the routes more flexible. Flexibility means that the existing path from each node to the sink will change at any time according to the situation and will attempt to choose a path with the least amount of packet loss. In other words, it is more likely to choose routes where low-priority packets are less likely to be discarded. The packet sending process is explained in Figure 3 where different decisions are made based on the value of threshold.

Table 3. Different values of α and β coefficients

$\boldsymbol{C_i}$	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$
$C_i \geq 30\%$	$\alpha = 0.5$	$\beta = 0.5$
$20\% \leq C_i < 30\%$	$\alpha = 0.6$	$\beta = 0.4$
$5\% \leq C_i < 20\%$	$\alpha = 0.7$	$\beta = 0.3$
$C_i < 5\%$	$\alpha = 0.75$	$\beta = 0.25$

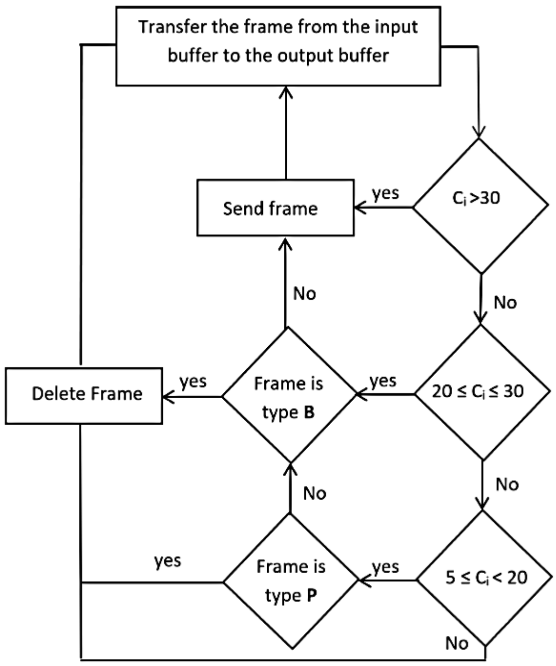

Figure 3. Flow chart showing the mechanism of sending packets

3. RESULT

3.1. Experiment setup

To simulate our proposed algorithm MATLAB is used. The experimental network involves 150-300 nodes, and one sink all were randomly deployed across 500*500 m square field. The reason why random distribution is used in this experiment is explained in Section 3.1 which is to simulate real-life scenarios were proper node distribution is not achievable. The maximum communication range of each node is set to be 50 m. The energy device of each node is set to be rechargeable, were initial energy is 50 j. The size of each packet is 250 bytes, while the configuration message is 50 bytes. Typically speaking, packet size and priority are not correlated. The result section below is obtained by capturing the average of 20 different runs with random seeds and node deployment for each run. It is good to note that no significant changes on the results were observed between the 7th and 20th run. Which is why it was decided to stop after 20 runs.

3.2. Evaluation criteria

- Packet dropping rate: Refers to the rate of packets that were lost for various reasons on the way to the sink.
- End-to-End delay: The average time needed for packets to reach the sink after being produced.

– Service quality: The quality of multimedia data received by the sink where the quality is measured using Peak signal-to-noise ratio (PSNR) coefficient.

3.3. Experiment result

The output is analyzed and evaluated after each run. Typically, when experimenting with similar algorithms, one or more videos is used to evaluate the outcome. In this experiment, the specification of the videos is Container, 300 frames, 288*352 resolution and Garden video, 112 frames, 240*352 resolution. Below is the result for each criterion.

3.3.1. Packet dropping rate

The total number of nodes was 250 and the data transmission rate is 2-10 kb/s. Figure 4 shows the frame dropping rate of "B" type packets which appear to be higher in comparison to other methods due to the fact that all other methods do not pay attention to the priority of the packages. Figures 5 and 6 show the drop rate of "P" and "I" type packets respectively. It can be seen that the transmission rate has increased from 2 kb/s to 10 kb/s. The packet loss of "P" type packets has been reduced in comparison to "B" and somewhat close to the average of the other methods. However, the drop rate of "I" type packets has significantly reduced and it is easily noticeable when compared to the other methods.

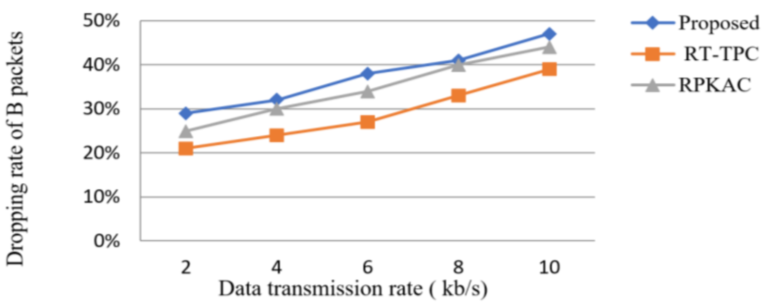

Figure 4. Dropping rate of "B" packets

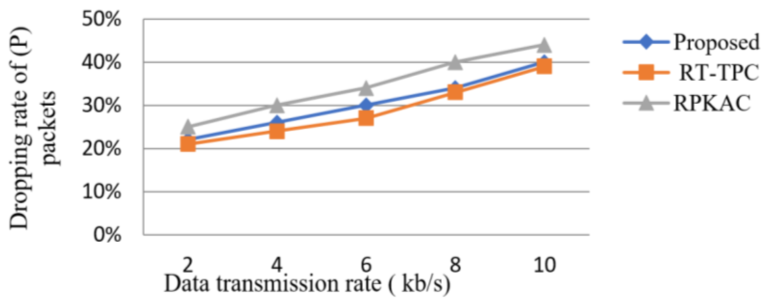

Figure 5. Dropping rate of "P" packets

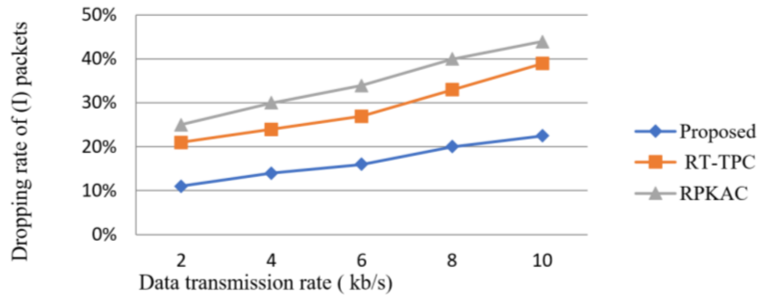

Figure 6. Dropping rate of "I" packets

Figure 7 shows the average dropping rate when transmission is set at 4 kb/s utilizing different set of nodes. It can also be seen that the success rate is increased after considering packet priority. Low priority packets are more likely to be dropped in this method. In contrast, high priority packets show significant increase in delivery success rate.

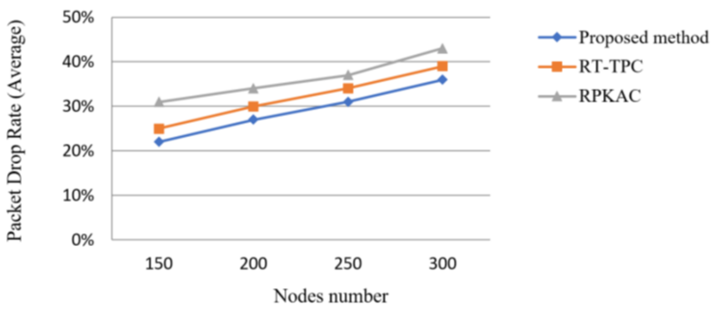

Figure 7. The average rate of packet loss is increasing with the number of nodes

3.3.2. End-to-end delay

Delay is a crucial issue in multimedia data transmission. The time needed for the packages to reach the sink depends on the empty space in the buffer. In our proposed algorithm, this factor is taken into account when selecting the next hop node to reduce end-to-end delay. The following graph shows a comparison of end-to-end delay between our proposed method and two other competitors. Figure 8 shows the average delay in sending packets. In RPKAC method, after constructing the network topology and determining the paths, an optimization process begin to determine low-cost paths in which least number of hops is needed for each packet to reach destination. The result is significant reduction in delay compared to RT-TPC method. However, in RPKAC method, packet priority and buffer space are ignored. As a result, our method shows noticeable reduction in average delay compared to RPKAC. Figure 9 shows the average delay when sending data at 6 kb/s using different set of nodes. In all three methods, increasing the nodes also increases the delay. Although, our algorithm has noticeable reduction in delay compared to the other algorithms.

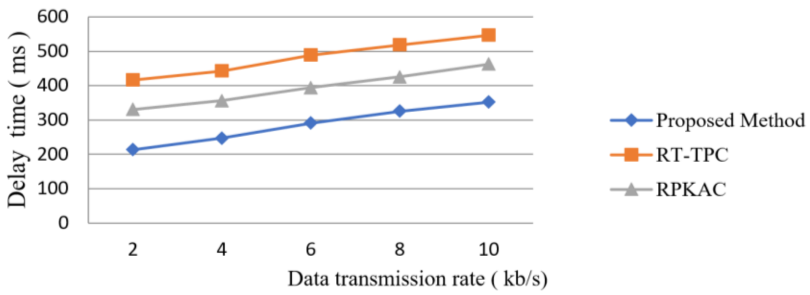

Figure 8. Average delay in sending according to transmission rate

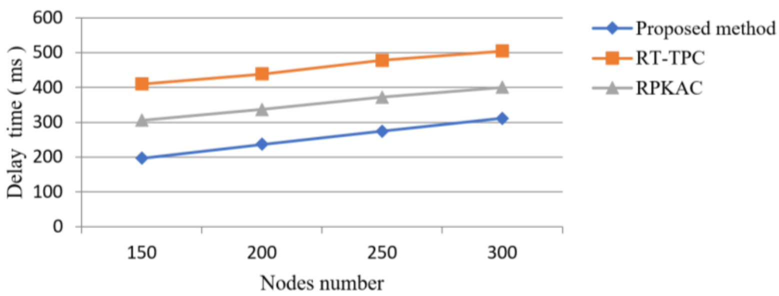

Figure 9. Average delay in sending packets with increasing number of nodes

3.3.3. Service quality

Typically, data stored in multimedia packages are varied in terms of importance. Important packages usually have a significant impact on video resolutions. In our proposed algorithm, these packages are given higher priority when sending and receiving. And to determine the improvement of quality when our algorithm is used, the peak signal to noise ratio (PSNR) value is calculated and compared against other methods. PSNR shows the differences in terms of quality between the raw video file and the file received by the sink. When the value of PSNR increases, it means a more efficient transfer of data to the sink.

In Figure 10, it can be seen that the values obtained using the proposed method are more significant in comparison to the other methods. The reason behind this is packet prioritizing as more high priority packets reach the sink. It worth noting that high priority packets play the primary role in shaping the original video file. In contrast, other methods always ignore the priority of packets. As a result, a large number of high priority packets are ended up being dropped, which impact the construction of the file when in comparison to the original. Figure 11 focuses on the quality of data received by the sink at 4 kb/s rate. As explained earlier, the proposed method shows better result in term of quality due to priority-based data transmission.

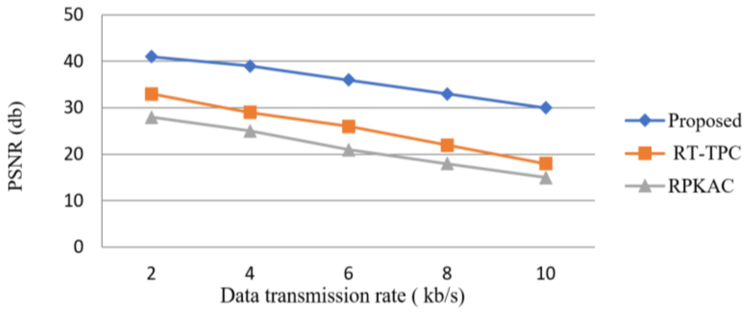

Figure 10. Service quality based on transmission rate

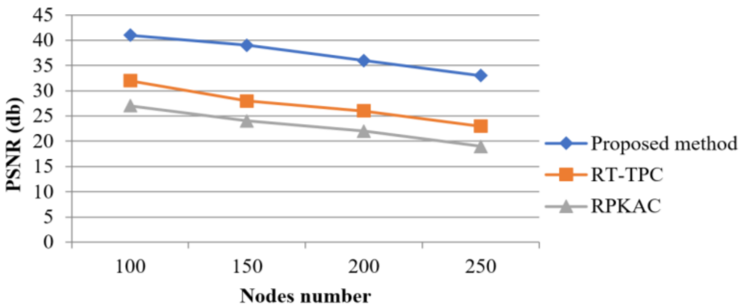

Figure 11. Service quality with after number of nodes

4. CONCLUSION

This research introduces an improved method that reduces multimedia data distortion with enhanced QoS through prioritizing data in WMSNs. Considering the nature of multimedia sensor networks, incorporating priority-based data collection, load balancing, rechargeable sensors, and buffer capacity management significantly improves data latency and QoS. Based on an experiment conducted using MATLAB software, our proposed algorithm seems to reduce packet dropping rate, end-to-end delay, and noise ratio compared to previous methods. Similarly, the quality of multimedia data, which is measured using PSNR criterion, is mostly sustained during transmission as more high priority packets successfully reach the sink.

REFERENCES

[1] V. Bhandary, A. Malik, and S. Kumar, "Routing in wireless multimedia sensor networks: a survey of existing protocols and open research issues," *Journal of Engineering*, vol. 2016, pp. 1–27, 2016, doi: 10.1155/2016/9608757.

[2] N. Ameen, N. Jamal, and L. A. Raj, “Comparative analysis of energy based optimized dynamic source multipath routing protocol in WSNs,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 16, no. 1, pp. 441–455, Oct. 2019, doi: 10.11591/ijeecs.v16.i1.pp441-455.

[3] A. Tamizharasi, S. J. Jasmine, A. K. Priya, M. R., and H. M., “Energy aware heuristic approach for cluster head selection in wireless sensor networks,” *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 6, no. 1, pp. 70–75, Mar. 2017, doi: 10.11591/eei.v6i1.598.

[4] A. S. Altaan, “Effects of sensor properties on power consumption in wireless sensor network,” *2010 Second International Conference on Computer Research and Development*, pp. 335–339, 2010, doi: 10.1109/ICCRD.2010.41.

[5] B. Abood and Y. K. Al-Rikabi, “Lifetime enhancement for clustering protocols in heterogeneous wireless sensor networks,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 14, no. 3, pp. 1305–1314, Jun. 2019, doi: 10.11591/ijeecs.v14.i3.pp1305-1314.

[6] A. Pinto, Z. Zhang, X. Dong, S. Velipasalar, M. C. Vuran, and M. C. Gursoy, “Energy consumption and latency analysis for wireless multimedia sensor networks,” *2010 IEEE Global Telecommunications Conference GLOBECOM 2010*, pp. 1–5, Dec. 2010, doi: 10.1109/GLOCOM.2010.5683898.

[7] S. Hengstler, D. Prashanth, S. Fong, and H. Aghajan, “MeshEye: A Hybrid-Resolution Smart Camera Mote for Applications in Distributed Intelligent Surveillance,” 2007 6th International Symposium on Information Processing in Sensor Networks, 2007, pp. 360-369, doi: 10.1145/1236360.1236406.

[8] M. Younis, K. Akkaya, M. Eltoweissy, and A. Wadaa, “On handling QoS traffic in wireless sensor networks,” *37th Annual Hawaii International Conference on System Sciences, 2004*, vol. 37, no. C, 2004, doi: 10.1109/HICSS.2004.1265688.

[9] Z. Xiong, A. D. Liveris, and S. Cheng, “Distributed source coding for sensor networks,” *IEEE Signal Processing Magazine*, vol. 21, no. 5, pp. 80–94, 2004, doi: 10.1109/MSP.2004.1328091.

[10] W. Liu, K. R. Vijayanagar, and J. Kim, “Low-complexity distributed multiple description coding for wireless video sensor networks,” *IET Wireless Sensor Systems*, vol. 3, no. 3, pp. 205–215, Sep. 2013, doi: 10.1049/iet-wss.2012.0115.

[11] P. Wang, R. Dai, and I. F. Akyildiz, “A spatial correlation-based image compression framework for wireless multimedia sensor networks,” *IEEE Transactions on Multimedia*, vol. 13, no. 2, pp. 388–401, Apr. 2011, doi: 10.1109/TMM.2010.2100374.

[12] Q. Lu, W. Luo, J. Wang, and B. Chen, “Low-complexity and energy efficient image compression scheme for wireless sensor networks,” *Computer Networks*, vol. 52, no. 13, pp. 2594–2603, Sep. 2008, doi: 10.1016/j.comnet.2008.05.006.

[13] Y. Diao, D. Ganesan, G. Mathur, and P. Shenoy, “Rethinking data management for storage-centric sensor networks,” in *CIDR 2007-3rd Biennial Conference on Innovative Data Systems Research*, 2007, pp. 22–32.

[14] H. Li, D. Liang, L. Xie, G. Zhang, and K. Ramamritham, “TL-Tree,” in *Proceedings of the 27th Annual ACM Symposium on Applied Computing-SAC ’12*, 2012, vol. 10, no. 4, doi: 10.1145/2245276.2232028.

[15] S. Gonzalez-Valenzuela, H. Cao, and V. C. M. Leung, “A multi-channel approach for video forwarding in wireless sensor networks,” *2010 7th IEEE Consumer Communications and Networking Conference*, vol. 1, pp. 1–5, Jan. 2010, doi: 10.1109/CCNC.2010.5421731.

[16] J. Mo, H.-S. W. So, and J. Walrand, “Comparison of multichannel MAC protocols,” *IEEE Transactions on Mobile Computing*, vol. 7, no. 1, pp. 50–65, Jan. 2008, doi: 10.1109/TMC.2007.1075.

[17] E. Karapistoli, I. Gragopoulos, I. Tsetsinas, and F.-N. Pavlidou, “UWB technology to enhance the performance of wireless multimedia sensor networks,” *2007 IEEE Symposium on Computers and Communications*, Jul. 2007, doi: 10.1109/ISCC.2007.4381637.

[18] I. Oppermann, L. Stoica, A. Rabbachin, Z. Shelby, and J. Haapola, “UWB wireless sensor networks: UWEN-a practical example,” *IEEE Communications Magazine*, vol. 42, no. 12, pp. S27–S32, Dec. 2004, doi: 10.1109/MCOM.2004.1367555.

[19] A. A. Ahmed, “A real-time routing protocol with adaptive traffic shaping for multimedia streaming over next-generation of wireless multimedia sensor networks,” *Pervasive and Mobile Computing*, vol. 40, pp. 495–511, Sep. 2017, doi: 10.1016/j.pmcj.2017.01.010.

[20] F. Sato, “A synchronization and routing protocol for rechargeable sensor networks,” *2014 IEEE 28th International Conference on Advanced Information Networking and Applications*, pp. 665–672, May 2014, doi: 10.1109/AINA.2014.82.

[21] G. Han, Y. Dong, L. Shu, H. Guo, and J. Niu, “Geographic multipath routing in duty-cycled wireless sensor networks with energy harvesting,” *2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing*, pp. 31–39, Aug. 2013, doi: 10.1109/GreenCom-iThings-CPSCom.2013.31.

[22] D. Gao, H. Lin, and X. Liu, “Routing protocol for k-anycast communication in rechargeable wireless sensor networks,” *Computer Standards and Interfaces*, vol. 43, pp. 12–20, Jan. 2016, doi: 10.1016/j.csi.2015.07.002.

[23] F. Attivissimo, C. G. C. Carducci, A. M. L. Lanzolla, A. Massaro, and M. R. Vadrucci, “A portable optical sensor for sea quality monitoring,” *IEEE Sensors Journal*, vol. 15, no. 1, pp. 146–153, Jan. 2015, doi: 10.1109/JSEN.2014.2340437.

[24] Y. Qu and S. V Georgakopoulos, “A distributed area coverage algorithm for maintenance of randomly distributed sensors with adjustable sensing range,” *2013 IEEE Global Communications Conference (GLOBECOM)*, pp. 286–291, Dec. 2013, doi: 10.1109/GLOCOM.2013.6831085.

[25] P. -J. Wan and C. -W. Yi, “Coverage by randomly deployed wireless sensor networks,” in *Fourth IEEE International Symposium on Network Computing and Applications*, 2005, vol. 2005, no. 3, pp. 275–278, doi: 10.1109/NCA.2005.14.

BIOGRAPHIES OF AUTHORS

Mohammed Falah Abbood is Assistant lecture at Central Library, University of Kufa, Iraq. He received his B.S. degree in computer engineering from the Islamic University College in Najaf in 2010 and M.S. degree Computer architecture from Tabriz University, Iran in 2018. His research interests are computer network, wireless sensor network, and cloud computing. He can be contacted at email: mohammedf.abood@uokufa.edu.iq.

Mohammed Falih Kadhim is the directing manager of Software department at ITRDC, University of Kufa. He and his team are responsible for developing and administrating all websites in the University and its faculties. Earned his bachelor degree in Computer Technique Engineering from the Islamic College University in 2010. Later, he earned his Master degree in Information Technology from the University of Technology, Sydney, Australia in 2015. His research interests are mostly Network and web related such as front-end web development, WSN, learning management systems, peer-learning using social media platforms. He can be contacted at email: mohammed.kadhim@uokufa.edu.iq.

Ahmed Raheem Kadhim is Assistant lecture at faculty of computer science and mathematics, University of Kufa, Iraq. He received his B.S. degree in computer engineering from university of Basra in Basra in 2010 and M.S. in degree network engineering from K. N. T University, Iran in 2017. His research interests are computer network, internet of things, and cloud computing. He can be contacted at email: ahmedr.alkhafajee@uokufa.edu.iq.