International Journal of Computer Applications (0975 – 8887)
Volume 183 – No. 3, May 2021

A Fuzzy Logic Adaptive Image Resize (Resolution) Level using Cross-Layering in Wireless Multimedia Sensor Networks

Mohammed Ameen A. Abdo
College of Engineering, Alzaiem Alazhari University, Khartoum, Sudan
College of Engineering, Azal University for Human Development, Sana'a, Yemen

Ala Eldin Abdallah Awouda
University of Bisha College of Engineering
Bisha, Saudi Arabia
Sudan University of Science and Technology
College of Engineering
Khartoum, Sudan

Yousif Elfatih Yousif
College of Engineering, Alzaiem Alazhari University, Khartoum, Sudan

ABSTRACT

The increasing interest in wireless sensor networks with the rapid growth in micro-electronics technology has made it possible to deliver multimedia content over Wireless Multimedia Sensor Networks (WMSNs). There are several main peculiarities that make the delivery of multimedia content over WMSN challenging. Most of these are due to the processing, timing, and other quality of service requirements. Furthermore, WMSNs are susceptible to rapid degradation since they deal with large amount of data that require processing and transmission power. The traditional protocol stack architectures were designed to follow a strictly layered approach that may not support the essential requirements of these networks. In order to overcome the challenges posed by the limited bandwidth and resources associated with WMSN, the integration of functionality between different layers should be exploited. In this paper, a cross-layer design approach is proposed to overcome such challenges. In the proposed approach, the concept of cross-layering and fuzzy logic have been exploited to monitor the network conditions and control the amount of the multimedia data in order to utilize the available resources efficiently and improve the applications quality of service (QoS). The simulation results have shown better resource utilization, stability, and fairness in quality metrics consideration. The proposed approach has shown to be efficient compared to the conventional scheme in terms of bandwidth utilization, power consumption, delay, loss, and images quality. Moreover, the proposed approach has proved its efficiency compared to other adaptive methods especially in term of the quality of the received images at the receiver side.

Keywords

Image resize, WMSN, Cross-layer, Fuzzy

1. INTRODUCTION

Dealing Wireless Sensor Networks (WSN) are a set of devices that are deployed randomly or manually and equipped with the necessary equipment to carry out certain task in the region of interest. Wireless sensor networks, which require distributing devices equipped with limited resources on an environment in isolation from supplement sources, are vulnerable to quick deterioration in performance and reduction in lifetime rapidly due to the consumption of the limited resources [1]. The introduction of CMOS multimedia devices such as cameras and microphones, and the ability to integrate these devices over low power and low-cost sensor nodes, has given birth to Wireless Multimedia Sensor Networks. This has paved the way for implementing several multimedia applications over wireless sensor networks such as environment monitoring, telemedicine, surveillance, traffic monitoring, and intrusion detection [2]. However, integrating quality of service in WMSN is very challenging since it requires maintaining the QoS metrics of the multimedia content, utilizing the available resources, and meeting the timing requirements of the multimedia applications. Many research studies concentrate on reducing the resource consumption in WMSN and improving the network performance as much as possible. The recent studies have demonstrated the efficiency of integrating the functionality of more than one layer in the communication stack, compared to the layered design, in improving the network performance and meeting the QoS requirements of the WMSN applications [3]. This integration is known as cross-layer design.

In this paper, the cross-layer concept is applied with fuzzy logic to provide QoS guarantee and efficient resource utilization in WMSNs. A fuzzy controller is used to keep track of the network conditions and resources using information derived from different layers and adapt the multimedia data transmission accordingly in order to satisfy the QoS requirements and maximize the network lifetime.

2. REALTED WORK

Cross layering is considered one of the best solutions to deal with the QoS requirements in WSNs. It aims at integrating the functionalities of different communication layers in order to improve the overall performance of the network and serve the application requirements [4]. Many research works have reported the efficiency of the cross-layer design in improving the QoS requirements for multimedia applications in WMSNs. These works have considered one or more of the QoS metrics such as the end-to-end delay, data loss, power consumption, and quality of received images or video.

Demir et al. [5] proposed cross-layer approach using the network and MAC layer to improve the delay, reliability and throughput in WMSNs. In this approach, each node has to know the quality level of the next hop to select the best route to the sink. The quality level here is a function of channel quality, data rate, and buffer size and accordingly the next hop is chosen.

An adaptive multimedia transmission approach was proposed by Costa et al. [6] to improve the energy consumption in WMSNs by discarding specific multimedia packets before being relayed to the next hop according to the energy level of the relay nodes.

Lecuire et al. [7] used the concept of priority in data transmission to improve the power consumption. The intermediate nodes relay the high-priority packets and discard the packets with lower priority based on the available power.

XL-WMSN is a cross layer protocol proposed by Hamid et al. [8] to improve the QoS according to the application requirements especially the real time applications over WMSNs. This protocol provides interaction between the routing, MAC, and physical layers using dynamic duty cycle, delay-aware routing, and energy-aware admission control. The protocol showed enhancement in delay and energy consumption; however, it did not consider the quality of the received data.

The approach proposed by Abdo et al. [9] aims at improving QoS requirements in WMSNs by implementing a fuzzy logic-based cross-layer design model. That proposed model applies compression adaptation to provide smooth transition in the amount of generated traffic according to the network conditions in order to improve the overall network performance and resource utilization while maintaining the best possible visual quality at the receiver side.

In [10], Shu et al. proposed a cross-layer approach for video streaming using the cooperation of the transport and routing layers to maximize the gathering of the information value of video stream and minimize the end-to-end transmission delay.

The approach proposed by Lee et al. [11] reduces the network congestion by reducing the data transmission rate with low degradation in the perceived quality. This approach employed an adaptive compression-based congestion control technique, in which packets with less relevant data are discarded in case of network congestion.

A cross-layer optimization approach, proposed by Chen et al. [12], exploits the functionality integration between the application, routing, and MAC layers to improve the quality of the transmitted video. The proposed method exploits information about the available bandwidth, the end-to-end delay and the residual energy of the paths to select the appropriate path. The proposed method also uses selective packet dropping when the required bandwidth is larger than the available bandwidth, in which packets with the less important data are discarded causing degradation in the quality of the perceived video.

Pudlewski et al. [13] exploited the integration between the application, transport, and physical layers to improve video streaming over lossy channels in WMSNs. This approach estimates the quality of the received video based on the end-to-end round-trip time to determine the optimal sampling rate for the video encoder at the application layer.

Recently, Sonmez, et al. [14] proposed a cross-layer sensor fuzzy-based image transmission (SUIT) protocol to enhance the QoS for video streaming in term of congestion mitigation in WMSNs. SUIT employs cross layering among the application, transport, routing MAC layers by monitoring the ratio of incoming to outgoing packets within a time window, the number of contenders of neighbor nodes, and the buffer occupancy of the next-hop node. In case of congestion, SUIT adapts the video frame rate at the source node according to the level of congestion and decreases the quality of the frames at the intermediate nodes by dropping some packets of the frames. SUIT was compared to existing congestion control techniques and showed better performance in terms of energy consumption, frame loss, and frame latency, except of the received frame quality. So, the main limitation of SUIT is its performance regarding the received image quality which is one of the main targets for most multimedia applications.

In this paper, a cross-layer fuzzy logic-based approach has been proposed to improve the QoS in WMSNs. The proposed approach takes into account improving the overall performance of the network while ensuring that the quality of the received images satisfies the application requirements. In this approach, the spatial resize of transmitted images is adapted based on the network conditions in order to improve the QoS metrics. Many studies have described the relationship between the image/video quality and down-sampling to lower resize at low bit rate. Bruckstein et al. [15] reported that down-sampling video, prior to compression, and then up-sampling, after decompression, can achieve better visual quality compared to that achieved by direct compression at high resize for low bit rate. Shu et al. [16] also reported that adapting spatial resize has been an important factor in meeting the variation of target bitrates. In addition, several research works have used adaptive resize control to improve video transmission.

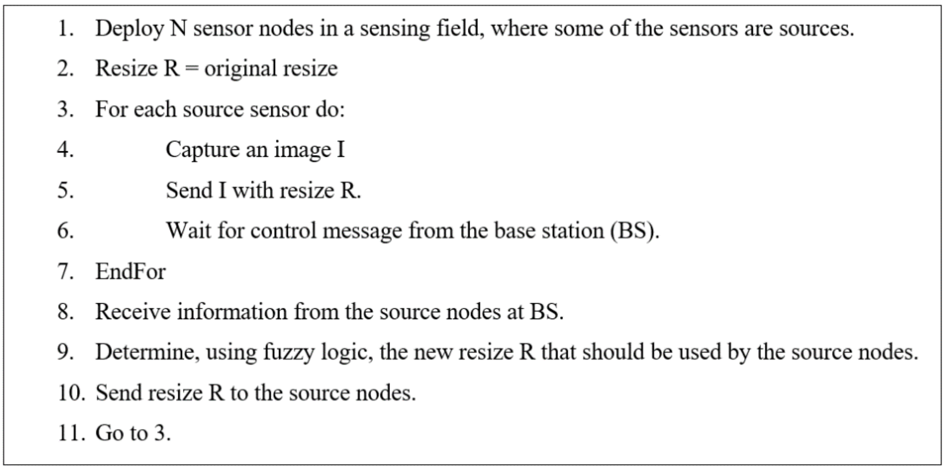
Lopes et al. [17] proposed a fuzzy adaptive spatial video transcoder (FAST) for wireless video transmission. The fuzzy logic controller, in adaptive manner, evaluates the suitable spatial transcoding filters based on the delay and signal-to-noise ratio and accordingly the spatial resize of the video is adjusted to fit the display of the mobile device. The simulation results showed improvement in the jitter and perceptual quality of transmitted video that employs spatial transcoding.

Lee et al. [18] proposed a mobile video streaming system to cope with the requirements of video streaming applications in mobile and cellular devices using the concept of spatial resize adaptation. This approach aims at achieving the most possible trade-off between image quality and power consumption based on a given bit rate.

Moreover, dynamic resize control has been used for congestion control, in which video traffic is adjusted to the network conditions by dynamically changing the temporal (frame rate) or spatial (frame size) resize of the video at the source. Suzuki et al. [19] proposed a dynamic resize control approach which aimed at improving the QoS for video streaming applications in wireless local area networks. In this approach, the amount of video traffic can be adjusted by changing the temporal resize of the video at the source nodes. The destination calculates the multimedia receiving rate periodically and sends it back to the source node to adjust the video resize before being transmitted. Accordingly, the source chooses a temporal resize from among 20, 10, and 5 media units (video frames) per second (MU/sec). The initial transmission rate is assumed to be 20 MU/sec which is decreased by one step based on a pre-specified receiving rate threshold. When the receiving rate becomes higher and exceeds another receiving rate threshold, the source increases the resize by one step. Despite that this approach uses a few transitions among the given resizes which do not support enough flexibility to cope with the change in the receiving rate, the proposed approach proved its efficiency in improving the overall performance of the network.

3. THE PROPOSED FRAMEWORK

The proposed model uses the cross-layer concept together with fuzzy logic to monitor the network conditions and adapt the data transmission in order to ensure the best utilization of the available resources, and the best possible quality of service. In this model, a fuzzy logic controller is used to control the behavior of multiple layers in an integrated manner. Based on this, each layer can send control messages to the relevant layers to modify their behavior, either temporarily or permanently, in order to recover the stability of the network and reduce the consumption of its resources. In order to get realistic results, the application layer deals with real images and performs the necessary processing and compression, while the transmission of the images over the network is simulated with the ability to test the quality of the transmitted images when passing through any node in the network. The application and physical layers take into account the energy consumed during capturing, processing, compression, and transmission of the images over the network. Figure 1 shows the pseudo-code of the proposed model. As shown in the figure, the sink node collects information about the average packet loss, delay, and power consumption from the relevant layers as will be discussed in the next section.



```
1.  Deploy N sensor nodes in a sensing field, where some of the sensors are sources.
2.  Resize R = original resize
3.  For each source sensor do:
4.          Capture an image I
5.          Send I with resize R.
6.          Wait for control message from the base station (BS).
7.  EndFor
8.  Receive information from the source nodes at BS.
9.  Determine, using fuzzy logic, the new resize R that should be used by the source nodes.
10. Send resize R to the source nodes.
11. Go to 3.
```

Figure 1: Pseudo-code for the cross-layer model

This information is used as inputs for the fuzzy model which uses them to estimate the suitable image resize that should be used by the source nodes. Then, the sink sends control messages to the source nodes, according to the network-wide cross-layer architecture, in order to adapt their images to the suitable resizes. After that, the sink node starts again collecting information from the relevant layers and analyses them using the fuzzy controller to send new control signals to the source nodes in order to keep or modify the current resize.

In our proposed model, improving the QoS for image transmission over WMSN has been focused particularly. In WMSN, the key factor behind the network performance deterioration is the amount of data transmitted over the network because more traffic means more power consumption, more congestion, more data losses, and more delay, which affects the quality of the received multimedia data.

The proposed approach represents an adaptive system which controls the amount of data to be sent over the network. The proposed system as a controller determines the suitable image resize before being sent according to the current conditions of the network.

The adaptive system aims to make the application more flexible in responding to the rapidly and continuous changing in network conditions in order to receive images with better resize. The system monitors the QoS metrics continuously then gives the most affected metric the priority until being recovered from its deterioration. Sending images with lower resize does not mean degrading the images quality, but this action will be taken when the network conditions are not suitable for sending large amount of data, such as sending images with high resize, which may distort or hamper the received images. This means that receiving images with lower resize is better than receiving corrupted images. So our adaptive system interacts with the corresponding layers in the communication stack continually to update its information about the QoS metrics of the network and then sends this information to a smart controller to analyses the information and select the suitable resize of the images to be sent.

3.1 Cross-layer System Architecture

Figure 2 shows the proposed cross-layer system architecture. As shown, the proposed system is designed according to the bottom up architecture, in which the upper layers change their traditional behaviors in order to adapt to the changes occurred in the lower layers. The layers that are involved in the system architecture are the physical layer, the network layer, and the application layer.

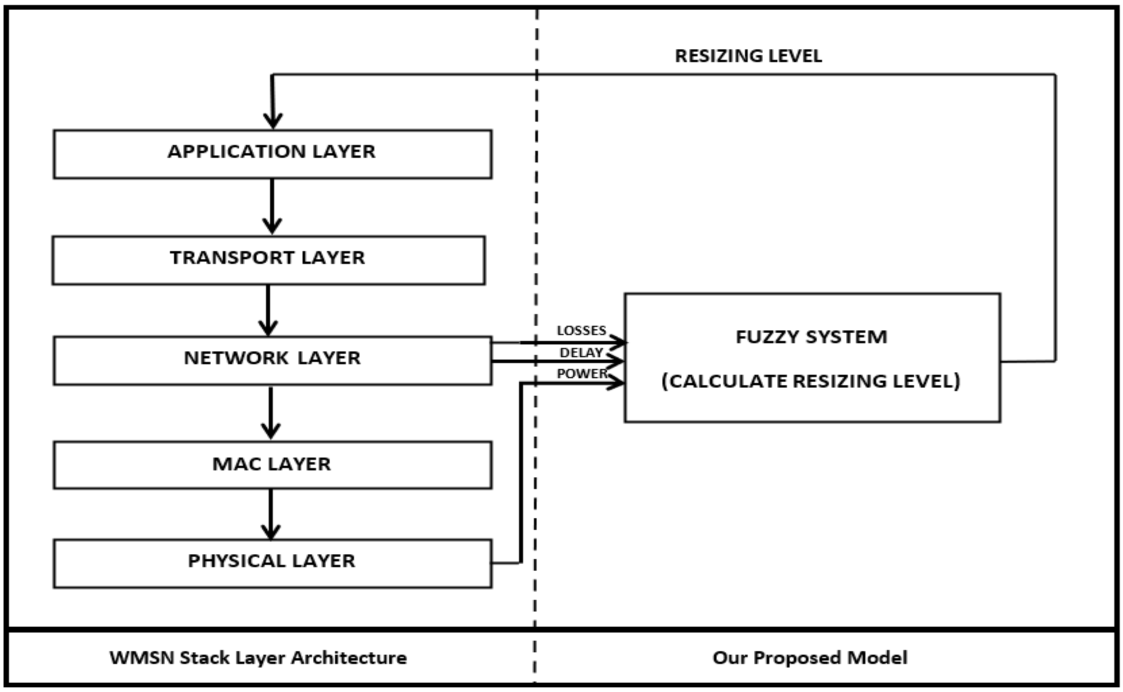


Figure 2: The Proposed Framework

The adaptive system sends frequent control messages to the application layers of the source nodes to change their behaviors according to the information obtained from the other layers.

The system here deals with the average power consumed by all the sources, not for each source node independently, to prevent the sources from sending their own resizes independently from each other which may make variations in the received images and discrepancy in resize at the receiver side. The system also aims to make smooth transition in images resize to give the receiver the chance to receive images organized as groups according to their resize. So, the adaptive system here sends uniform control messages to all of the sources.

3.2 The Proposed Fuzzy Inference System

The proposed fuzzy system is designed based on the Mamdani model. The system was conceived in the light of many experiments applied to different scenarios with different conditions. The proposed fuzzy inference system (FIS) consists of three inputs as shown in Figure 3 These inputs are the average remaining power in the network, the average network delay, and the average loss rate.

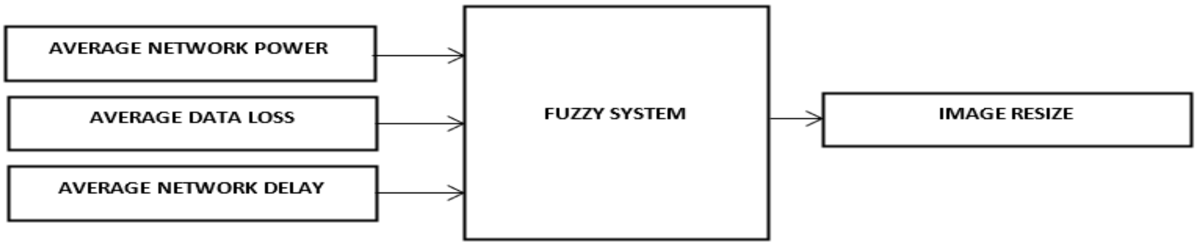


Figure 3: Fuzzy Model Architecture

Each input represents a fuzzy variable which is represented by fuzzy sets. The AND operator was used to combine the three inputs in the IF-THEN rules; as a result, there are 30 different rules, as shown in Table 1, to cover the possible conditions that the network may face.

Table 1: Fuzzy System Rules

SEQ	POWER	DELAY	LOSS	RESIZE
1	HIGH	VHIGH	EHIGH	LOW
2	HIGH	VHIGH	HIGH	HIGH
3	HIGH	VHIGH	LOW	EHIGH
4	HIGH	HIGH	VHIGH	MEDUIM
5	HIGH	HIGH	MEDUIM	VHIGH
6	HIGH	MEDUIM	EHIGH	LOW
7	HIGH	MEDUIM	HIGH	HIGH
8	HIGH	MEDUIM	LOW	EHIGH
9	HIGH	LOW	VHIGH	MEDUIM
10	HIGH	LOW	MEDUIM	VHIGH
11	MEDUIM	VHIGH	EHIGH	VLOW
12	MEDUIM	VHIGH	HIGH	MEDUIM
13	MEDUIM	VHIGH	LOW	HIGH
14	MEDUIM	HIGH	VHIGH	LOW
15	MEDUIM	HIGH	MEDUIM	MEDUIM
16	MEDUIM	MEDUIM	EHIGH	VLOW
17	MEDUIM	MEDUIM	HIGH	MEDUIM
18	MEDUIM	MEDUIM	LOW	HIGH
19	MEDUIM	LOW	VHIGH	LOW
20	MEDUIM	LOW	MEDUIM	MEDUIM
21	LOW	VHIGH	EHIGH	ELOW
22	LOW	VHIGH	HIGH	LOW

23	LOW	VHIGH	LOW	HIGH
24	LOW	HIGH	VHIGH	VLOW
25	LOW	HIGH	MEDUIM	MEDUIM
26	LOW	MEDUIM	EHIGH	ELOW
27	LOW	MEDUIM	HIGH	LOW
28	LOW	MEDUIM	LOW	HIGH
29	LOW	LOW	VHIGH	VLOW
30	LOW	LOW	MEDUIM	MEDUIM

The fuzzy sets range and the universe of discourse of their membership functions were selected carefully according to many studies and different experiments applied to different scenarios. These scenarios are also applied under different conditions to study the effect of these changes on the QoS metrics.

3.3 The Resize Output

Table 1 shows the fuzzy sets of the resize as a fuzzy output. As shown, these sets are symmetrically divided to form seven membership functions ranging from extremely low to extremely high (extremely low, very low, low, medium, high, very high, and extremely high), with total range of 100 units. Each fuzzy set represents a set of resizes and the defuzzification value is mapped to one of 46 different resizes ranging between 50x50 and 500x500 as shown in Table 2.

Table 2: Resize Mapping Table

NO	Resize	Range	NO	Resize	Range
1	50x50	[0.0x2.3]	24	280x280	[50.1x52.3]
2	60x60	[2.3x4.5]	25	290x290	[52.3x54.4]
3	70x70	[4.5x6.7]	26	300x300	[54.4x56.6]
4	80x80	[6.7x8.9]	27	310x310	[56.6x58.8]
5	90x90	[8.9x11.0]	28	320x320	[58.8x60.9]
6	100x100	[11.0x13.2]	29	330x330	[60.9x63.1]
7	110x110	[13.2x15.4]	30	340x340	[63.1x65.3]
8	120x120	[15.4x17.5]	31	350x350	[65.3x67.5]
9	130x130	[17.5x19.7]	32	360x360	[67.5x69.6]
10	140x140	[19.7x21.9]	33	370x370	[69.6x71.8]
11	150x150	[21.9x24.0]	34	380x380	[71.8x74.0]
12	160x160	[24.0x26.2]	35	390x390	[74.0x76.1]
13	170x170	[26.2x28.4]	36	400x400	[76.1x78.3]
14	180x180	[28.4x30.6]	37	410x410	[78.3x80.5]
15	190x190	[30.6x32.7]	38	420x420	[80.5x82.6]
16	200x200	[32.7x34.9]	39	430x430	[82.6x84.8]
17	210x210	[34.9x37.1]	40	440x440	[84.8x87.0]
18	220x220	[37.1x39.2]	41	450x450	[87.0x89.2]
19	230x230	[39.2x41.4]	42	460x460	[89.2x91.3]
20	240x240	[41.4x43.6]	43	470x470	[91.3x93.5]
21	250x250	[43.6x45.8]	44	480x480	[93.5x95.7]
22	260x260	[45.8x47.9]	45	490x490	[95.7x97.8]
23	270x270	[47.9x50.1]	46	500x500	[97.8x100]

3.4 Experiments Setup

The simulation parameters used in the experiment are shown in Table 3

Table 3: Simulation Parameters

Parameters	Values
Network size	250 x 250 m2
Number of nodes	100 nodes
Packet size	256 bytes
Images transmission intervals	10 - 70 sec
Communication range	30 m
Routing protocol	GPSR
MAC protocol	TMAC
Initial energy	50 J
Simulation time	500 sec

4. RESULTS AND ANALYSIS

4.1 Average Image Resize

Table 4 shows the resize of the transmitted images and the average resize when using the proposed approach. As shown in Table 4, the proposed approach has higher average resize which is an indicator of better quality of the received images. Table 4 also shows the flexibility of the proposed approach regarding the resolution transition compared to the conventional scheme with fixed resolution.

Table 4: The percentages and average resize of the transmitted images using the adaptive scheme

Resize	Proposed
500x500	1%
490x490	0%
480x480	1%
470x470	0%
460x460	0%
450x450	0%
440x440	0%
430x430	1%
420x420	0%
410x410	0%
400x400	2%
390x390	2%
380x380	2%
370x370	2%
360x360	1%
350x350	1%
340x340	0%
330x330	2%
320x230	0%
310x310	0%
300x300	0%
290x290	0%
280x280	2%
270x270	1%
260x260	5%
250x250	5%

240x240	2%
230x230	11%
220x220	27%
210x210	10%
200x200	3%
190x190	2%
180x180	3%
170x170	2%
160x160	1%
150x150	2%
140x140	3%
130x130	1%
120x120	3%
110x110	2%
100x100	0%
90x90	0%
80x80	0%
70x70	0%
60x60	0%
50x50	0%
Average Resize	**267x267**

4.2 Packet Loss Rate

Packet loss rate is the percentage of packets lost in a transmission. Deliverability, which is the opposite of loss, is the percentage of the packets delivered successfully. Figure 4 shows the average packet loss rate. As shown, the proposed approach achieves lower loss rate compared to fixed 270x270 resize. Moreover, the proposed approach has proven its efficiency compared to the conventional scheme with fixed resolution of 270x270. In the first time, the proposed approach was able to send images with higher resize than 270x270 which leads to increase the loss with small ratio compared to the conventional scheme.

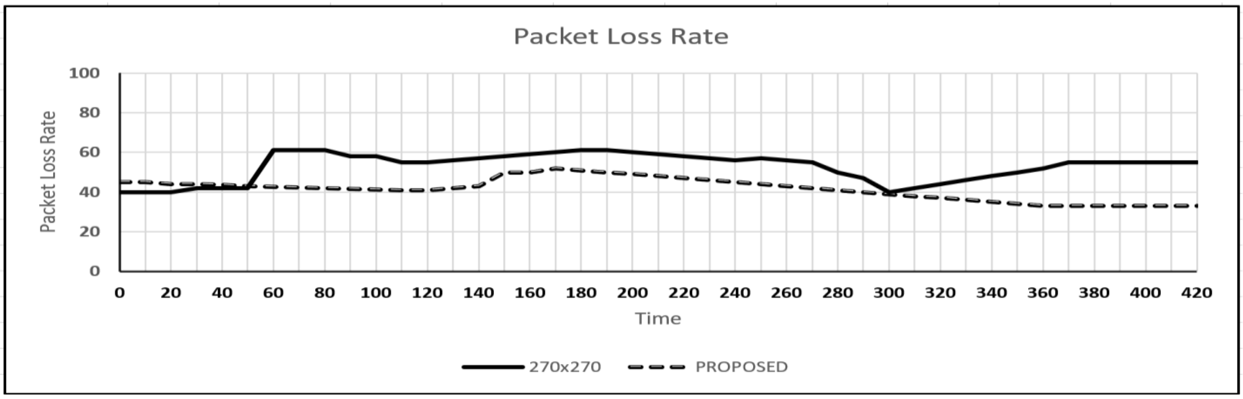


Figure 4: Packet Loss Ratio

4.3 Network Delay

Network delay, or latency, is the transmission time that a packet needs to travel between two end points. This metric is noticeable when real time and interactive applications such as multimedia applications are being used. In our model, transmission, propagation, and queuing delay have been concentrated. There are variations of the delay values in the upper layer such as the processing delay which depends on the behavior of the application; however, this delay is mostly small and negligible, compared to the transmission delay. Figure 5 shows the average network delay as a function of time. As shown, the proposed approach introduces lower delay compared to the conventional scheme with fixed resolution.

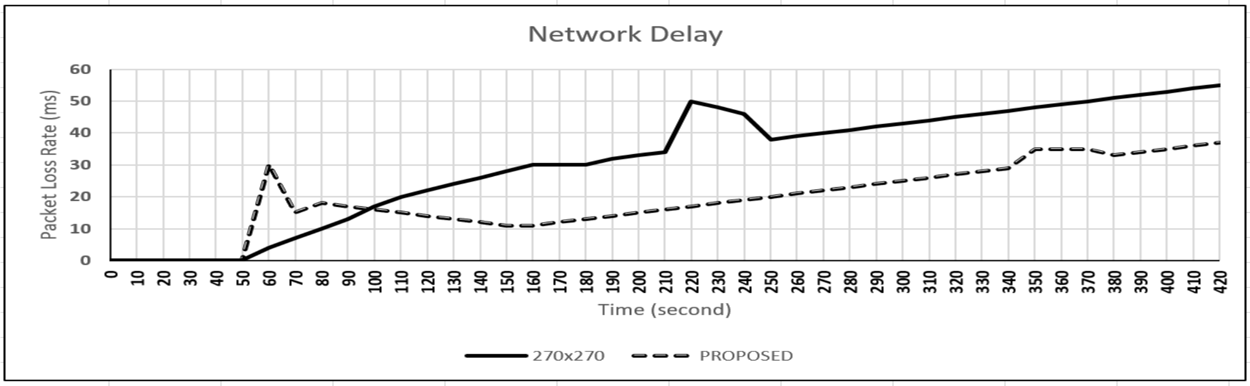


Figure 5: Network Delay

4.4 Network Lifetime

There are several concepts for network lifetime; sometimes it refers to the time of the first node's death. It can also be represented by calculating the death of the first x nodes. The strong relationship between the power consumption and network lifetime led some researchers to join the concept of network lifetime with the power consumption. Therefore, some researchers suggested to calculate the time of consuming x% of the total power to give indication about the network lifetime. In this paper, the concept of network lifetime as the first dead node will be considered. The image resolution has direct effect on the amount of data being sent which also affects the power required to process and send these data. Figure 6 shows the number of the live nodes as a function of time. As shown, the proposed approach outperforms the conventional scheme. The results demonstrate that the proposed approach was able to exploit the network conditions and send images with the suitable resize according to the residual power and the other network conditions.

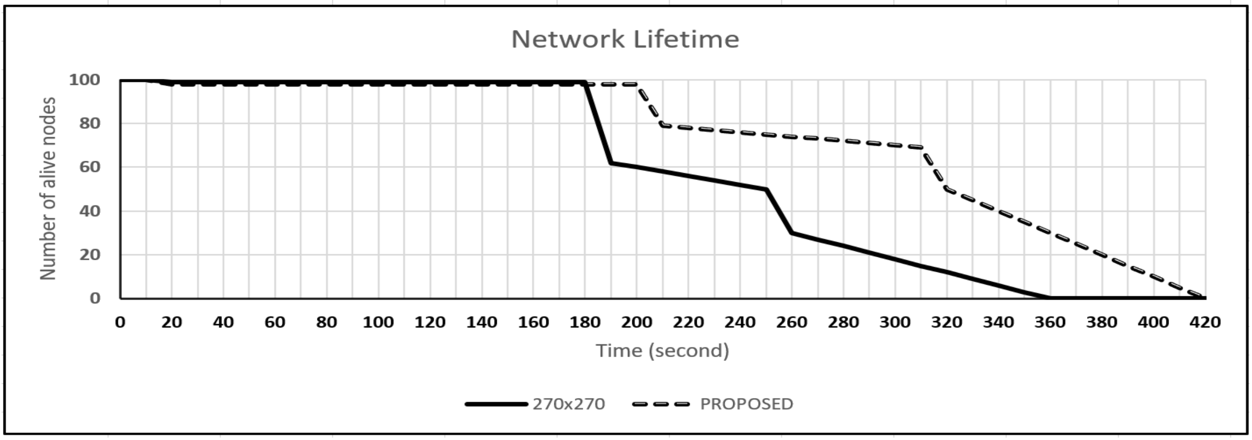


Figure 6: Network Lifetime

4.5 Image Quality

Image quality is defined to be the subjective impression of how well the content of the image is presented or reproduced. Image quality may also be defined as an impression of the overall degree of merit of an image as perceived by an observer. Regarding to images applications, image quality is the degree of its adequacy to the dedicated goal within a specific application. Figure 7 shows the average PSNR of the received images for the network. In general, we can notice the efficiency of the proposed approach regarding its ability to receive images with better quality compared to the conventional scheme, due to smooth transition in the image resize according to the network conditions. Note that, for 0% loss rate, the PSNR value of images with low resizes is lower than that of images with higher resizes because of down-sampling before transmission and up-sampling after receiving the images.

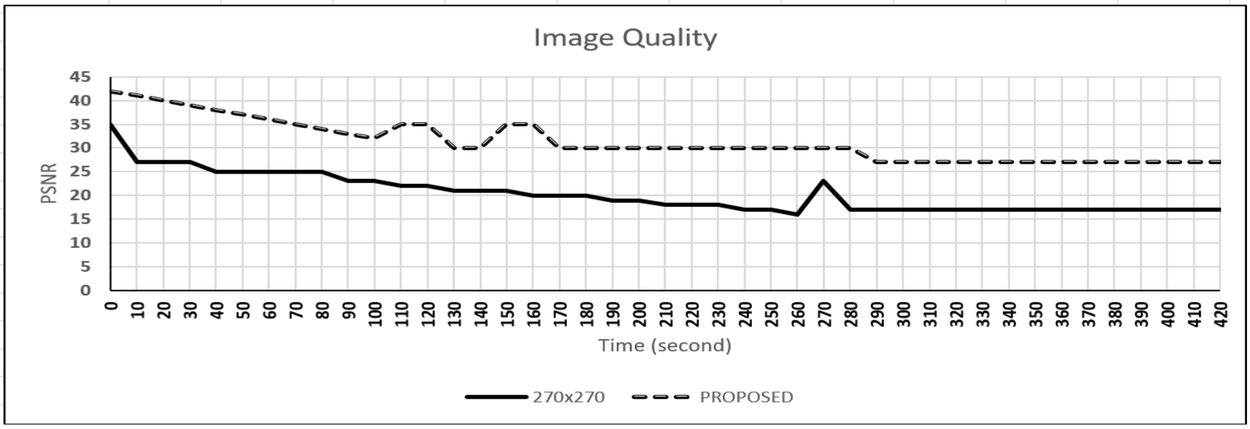


Figure 7: PSNR (Image Quality)

5. CONCLUSION

In this paper, we have proposed an efficient fuzzy logic-based cross-layer design approach to improve the QoS requirements in wireless multimedia sensor networks. The proposed approach applies spatial resize adaptation to provide smooth transition in the amount of generated traffic according to the network conditions in order to improve the overall network performance and resource utilization while maintaining the best possible visual quality at the receiver side.

The proposed cross-layer design was developed according to the bottom up architecture to exploit the functional integration of the application, network, and physical layers to keep track of the network conditions regarding the power consumption, network delay, and loss rate. Adapting the resize of the images is carried out by fuzzy logic controller based on the instantaneous conditions of the network. After estimating the suitable resize of the images, control messages are sent to the source nodes according to the network-wide cross-layer architecture to adjust their images resize.

In order to evaluate the system performance, we simulated the transmission process of real images taking into account different network scenarios and used power simulator to consider the power consumed in image processing at the application layer. The simulation results showed the efficiency of the proposed system in terms of resource utilization, fairness between the quality metrics, stability, and eventually improving the quality of the received data. The proposed approach has proved its efficiency compared to the conventional scheme in terms of bandwidth utilization, power consumption, delay, loss, and image quality. Moreover, the proposed approach has proved its efficiency compared to other adaptive methods especially in term of the quality of the received images at the receiver side.

One of the important points that can be taken into account and considered as a future work is to improve the current model by considering routing information from the neighboring nodes to estimate the suitable next hop. The residual energy of the next hop can also be considered as one of the estimation factors, which may improve the lifetime of the relay nodes. Furthermore, the relay nodes with critical energy level can be dedicated only for the source nodes which have no other choice to relay their traffic using other relay nodes.

6. REFERENCES

[1] H. I. Kobo, A. M. Abu-Mahfouz, and G. P. J. I. a. Hancke, "A survey on software-defined wireless sensor networks: Challenges and design requirements," vol. 5, pp. 1872-1899, 2017.

[2] D. Kandris, C. Nakas, D. Vomvas, and G. J. A. S. I. Koulouras, "Applications of wireless sensor networks: an up-to-date survey," vol. 3, no. 1, p. 14, 2020.

[3] S. Parween, S. Z. J. A. i. S. Hussain, Technology, and E. S. Journal, "A Review on Cross-Layer Design Approach in WSN by Different Techniques," vol. 5, no. 4, pp. 741-754, 2020.

[4] S. Amirtharaj and T. J. W. P. C. Sabapathi, "Cross Layer Approach and ANFIS based Optimized Routing in Wireless Multi-Hop Ad Hoc Networks," pp. 1-23, 2021.

[5] A. K. Demir, H. E. Demiray, and S. J. W. n. Baydere, "QoSMOS: cross-layer QoS architecture for wireless multimedia sensor networks," vol. 20, no. 4, pp. 655-670, 2014.

[6] D. G. Costa, L. A. Guedes, F. Vasques, and P. J. S. Portugal, "Research trends in wireless visual sensor networks when exploiting prioritization," vol. 15, no. 1, pp. 1760-1784, 2015.

[7] V. Lecuire, C. Duran-Faundez, N. J. E. J. o. I. Krommenacker, and V. Processing, "Energy-efficient transmission of wavelet-based images in wireless sensor networks," vol. 2007, pp. 1-11, 2007.

[8] Z. Hamid, F. J. E. J. o. W. C. Bashir, and Networking, "XL-WMSN: cross-layer quality of service protocol for wireless multimedia sensor networks," vol. 2013, no. 1, pp. 1-16, 2013.

[9] M. A. A. Abdo, A. E. A. Awouda, and Y. E. J. I. J. o. C. A. Yousif, "A Fuzzy Logic Adaptive Image Compression Level using Cross-Layering in Wireless Multimedia Sensor Networks," International Journal of Computer Applications, vol. 975, p. 8887, 2021.

[10] L. Shu, Y. Zhang, Z. Yu, L. T. Yang, M. Hauswirth, and N. J. T. J. o. S. Xiong, "Context-aware cross-layer optimized video streaming in wireless multimedia sensor networks," vol. 54, no. 1, pp. 94-121, 2010.

[11] J.-H. Lee and I.-B. J. S. Jung, "Adaptive-compression based congestion control technique for wireless sensor networks," vol. 10, no. 4, pp. 2919-2945, 2010.

[12] M. Chen, V. C. Leung, S. Mao, and M. Li, "Cross-layer and path priority scheduling based real-time video communications over wireless sensor networks," in VTC Spring 2008-IEEE Vehicular Technology Conference, 2008, pp. 2873-2877: IEEE.

[13] S. Pudlewski, A. Prasanna, and T. J. I. T. o. M. C. Melodia, "Compressed-sensing-enabled video streaming for wireless multimedia sensor networks," vol. 11, no. 6, pp. 1060-1072, 2012.

[14] C. Sonmez, S. Isik, M. Y. Donmez, O. D. Incel, and C. Ersoy, "SUIT: A cross layer image transport protocol with fuzzy logic based congestion control for wireless multimedia sensor networks," in 2012 5th international conference on New technologies, mobility and security (NTMS), 2012, pp. 1-6: IEEE.

[15] A. M. Bruckstein, M. Elad, and R. J. I. T. o. I. P. Kimmel, "Down-scaling for better transform compression," vol. 12, no. 9, pp. 1132-1144, 2003.

[16] H. Shu, L.-P. J. I. t. o. c. Chau, and s. f. v. technology, "The realization of arbitrary downsizing video transcoding," vol. 16, no. 4, pp. 540-546, 2006.

[17] R. F. Lopes, C. D. M. Regis, M. P. Sousa, W. T. A. Lopes, and M. Alencar, "FAST: a fuzzy adaptive spatial video transcoding system," in Proceedings of the 13th International Symposium on Wireless Personal Multimedia Communications (WPMC 2010), 2010.

[18] H. Lee, Y. Lee, J. Lee, D. Lee, and H. J. I. T. o. C. E. Shin, "Design of a mobile video streaming system using adaptive spatial resolution control," vol. 55, no. 3, pp. 1682-1689, 2009.

[19] T. Suzuki, K. Yamada, M. Kato, and S. Tasaka, "Application-level and user-level QoS assessment of audio-video transmission with EDCA of IEEE 802.11 e," in 2005 IEEE 16th International Symposium on Personal, Indoor and Mobile Radio Communications, 2005, vol. 4, pp. 2727-2733: IEEE.