Quality and Energy Aware Multipath Routing in Wireless Multimedia Sensor Networks

Jawwharlal R and L. Nirmala Devi
Department of Electronics and Communication Engineering, Osmania University, Hyderabad, Telangana, India
Email: rjlphdou@osmania.ac.in, nirmaladevi@osmania.ac.in

***Abstract*—**In Wireless Multimedia Sensor Networks (WMSNs), the sensor nodes are capable of acquiring the multimedia information like wildlife tracking, traffic accidents as well scalar data. Because of these factors, the WMSNs have a bright future in both academic and industry circles. Multimedia applications, on the other hand, generate a lot of network traffic, which causes a lot of delay and wastes a lot of energy. In WMSNs, both network duration and quality of service are critical, hence an effective routing algorithm that can manage more data while simultaneously extending network lifetime is necessary. Towards this objective, in this paper, we proposes a Quality Aware Multipath Routing (QAMR) that selects multiple paths based on three reference metrics; they are Expected Transmission Count, Energy and Delay. For a given source and sink node, the QAMR constructs a composite metric by combining these three metrics and selects node disjoint multiple paths. Since the multiple paths with common nodes has less efficiency in data forwarding, we opt for node disjoint paths in which no two paths have one common node. On the proposed system QAMR model, extensive simulation tests are performed, and the outcomes are evaluated using a variety of metrics such as energy consumption, throughput, delay, and packet delivery ratio.

***Index Terms*—**WMSNs, multi-path routing, energy, expected transmission count, queuing delay, and throughput**.**

I. INTRODUCTION

In recent years, Wireless Sensor Networks (WSNs) have gained a widespread significance due to its applicability is diverse fields like Environmental monitoring, forest fire detection, disaster management and visual surveillance etc. However, the conventional WSNs are composed of low-cost sensor devices those are capable of sensing only scalar data related to physical phenomena. For example, the temperature sensor can sense only the temperature values and send it to the respective base station. Similarly, a humidity sensor senses the humidity of surrounding environments and forwards it to the corresponding base station [1]. But the low-cost sensor devices are not able to capture large sized multimedia data. Recently, due to the advancement tin the hardware development technology, some sensor nodes with stronger capability can be equipped with multimedia functions and the aggregation of such kind nodes constitute a new WSN paradigm called as Wireless Multimedia Sensor Networks (WMSNs) [2]. The nodes present in WMSN are capable of capturing, transmitting and receiving the multimedia data [3] and they are enabled with distributed multimedia source coding [4] and signal processing algorithms [5]. There is a widespread applicability for WMSNs in several fields including automatic threat classification [6], security monitoring [7], situation awareness [8], wildlife tracking [9], detectionof the presence of insects [10], and detection of plant diseases [11]. The widespread use of WMSNs has made it an excellent platform for applications that require ubiquitous access to multimedia content. Hence the WMSNs have gained an increasing interest in research community as well in industry.

WMSNs have a promising future in terms of applications, but they face numerous research challenges, including ensuring dependable throughput, reducing time delays to facilitate real-time data transmission, and dealing with energy limits. [12], [13]. To ensure a high Quality of Service (QoS) of multimedia applications, reliability, throughput, energy and delay are the major problems to be concerned in the current WMSN research [14]. In earlier so many authors tried to solve these problems and developed so many methods in different prospects. The first and best solution is the removal of redundant data in multimedia data [15]-[17]. Since the multimedia data have huge correlations, the removal of unnecessary information from either videos or images results in more QoS. However, the removal redundant data involves an additional processing at node level and results in more delay. The second optimal solution is multipath routing in which the large sized multimedia data is transmitted to sink node through multiple paths. However, the major problem is multipath routing is the discovery of multiple paths. At multipath routing the first need to concentrate is the selection of node and link disjoint paths which is not that much in low dense networks. Moreover, the one more problem is the node selection criterion, i.e., parameters considered for nodes capability assessment. Most of the approaches considered energy as a base reference for node selection but a single energy is not an optimal solution.

In this paper, we propose a new multipath routing mechanism called as Quality Aware Multipath Routing (QAMR) for WMSNS. The QAMR establishes a composite routing metric by combining three individual

Manuscript received December 25, 2021; revised July 14, 2022.
Corresponding author email: van.nguyenngoc@hust.edu.vn.
doi:10.12720/jcm.17.8.643-651

metrics such as Expected Transmission Count, Energy and Delay. At the delay assessment, QAMR consider four types of delays, they are transmission delay, propagation delay, queuing delay and processing delay. Based on these metrics our method choses multiple paths for a given source and sink node pair. Moreover, QAMR concentrated on the selection of link disjoint paths such that congestion can be avoided at node level.

The rest of the paper is set out as follows: In Section II, related work is fully described. Section III delves into the specifics of the proposed approach mechanism. The details of the simulation results are explained in Section IV, and the concluding observations are provided in Section V.

II. Related Work

In earlier so many methods were proposed for the improvisation of QoS in WMSNs. GuiXie, M.N.S Swamy, M. Omair Ahmad [18] provided an optimal packet scheduling approach for streaming multi-description-coded video in wireless networks over various wireless pathways. This procedure, which was made up of packets in terms of bits and was used to rebuild the video at the receiving end, was made up of packets. The video description adaptively determines key packets for transmission based on the quality of the transmission path, taking into account bandwidth, bit rate, and delay, to reduce the overall video end-to-end delay in terms of Mean Square Error (MSE).

Packet and Path Priority Scheduling algorithm was proposed by R. Lari and B. Akbari [19] to improve Quality of video at the receiver side based on path condition and priority of packets, path condition was evaluated by using variant parameters such as hope count, packet loss, energy and buffer size. Next, N. Bashir and S. Boudjit [20] introduced a novel packet scheduling approach (PSSN) for avoiding collisions in wireless networks with a single path, it operates without the use of RTS and CTS control signals. For collision reduction along a single path, each packet in the PSSN was scheduled after a predetermined interval using a query-driven technique.

X. Wang, C. Li, J. Lu and D. Liu [21] presented Priority-based Multipath Routing Algorithm. This approach shows the local link reliability between nodes and distance between source nodes to sink node. N. Song, X. Jin and Y. Zhang [22] an adaptive multi constraint multipath routing protocol was described, which minimized loss rate, delay, and energy consumption. Inter cluster routing was done in this study using a weighted cost function, which implies network measurement metrics like loss rate, delay, and residual energy was used.

M. Z. Hameed, A. Shahid, S. A. Khan and Z. A. Khan [23] proposed multipath construction scheme for wireless multimedia network which leads disjoint, energy efficiency multipath between source video sensor node to base station or sink node, and minimum hop count priorities for path development on demand might be assigned based on the situation. M. Baseri, S. A. Motamedi and M. Maadani [24] presented novel scheduling algorithm for improving QoS in wireless multimedia sensor networks. In this study Load-Adaptive Beacon Scheduling algorithm enable mesh topology in IEEE802.15.4 for supporting of QoS in multimedia data.

Cooperation based scheduling algorithm is proposed by B. Zeng, Y. Dong and D. Lu, [25] It was an innovative and simple heuristic algorithm for conflict graph-based cooperation-based scheduling. Every node in the conflict graph has a minimum degree, and it schedule the transmission of video data from the source node to the base station or sink. In WMSNs, collaboration refers to the level of priority scheduling used to choose the best path for data transfer.

P. Wang, R. Dai, and I. F. Akyildiz [26] provided a Differential Coding-Based Scheduling Framework for WMSNs that includes two components: Min Max Degree Hub Location (MDHL) and Maximum Life Time Scheduling (MLS). MDHL's goal was to discover the best locations for the multimedia processing centre, which lead to different channels gathering images from nearby cameras, reducing the number of channels required for frequency reuse. J. C. Fernandez, T. Taleb, K. Hashimoto, Y. Nemoto, and N. Kato [27] devised a packet scheduling technique using multiple pathways to minimize receiver reordering delay. In this manner, the QoS service negations system negotiates a certain amount of bandwidth with the network's accessible interface. A time slot-based network implementation technique was utilized depending on the negotiated band width with the user.

E. Karimi and B. Akbari [28] proposed a new video transmission approach for WMSNs. Packets was sent through multipath routing protocol using a queue priority scheduling mechanism. The network under this technology has a high constant bit rate (CBR). In this study not every frame has the same effect on video quality and priority over the video packets of real time application, to their effects on the video distortion. Each routing path used control packets in periodical manner, the video source node having high priority are transmitted with better condition of the path and also buffer (Queue) was to make scheduled for transmission of video packets compared with other packets in network.

Priority-based congestion control for multipath heterogeneous traffic in WSNs was proposed by S. Sridevi, M. Usha, and G. P. A. Lithurin [29]. In a WSN, this strategy priorities real-time applications by allocating bandwidth to each sensor node's own route and data generated by other sensor nodes. Each sensor node's child node receives data from the parent node based on the data's source and transit traffic priorities. The packet service ratio is used for detection of congestion.

Multi-path routing protocols selection techniques for multi-description video transmission over multi-hop networks was proposed by J. Wu, Z. Zhu, X. Di, Z. Zhang, and J. Tian [30]. In terms of network metrics such as packet delivery ratio and end-to-end delay, this study had developed routing mechanism to allow efficient video transmission in real-time applications. H. Shiang and M. Van Der Schaar [31] presented packet-based distribution impact and delay constraints in a cross-layer algorithm to maximize video quality for multiple users engaged in diverse streaming over multiple hop networks. The optimization of energy in different users for transmission schemes in cross layer stock to multi hop networks that allow priority-based adaptability to varied channel conditions and available resource in wireless multimedia networks. The essential components of this strategy were the development of a low-complexity, dynamic routing algorithm to improve QoS.

In [32] Politis, I et al., proposed to minimize video distortion of all multiple video streams in different paths across the wireless networks. It consists of packet scheduling channel access condition and distortion prediction modal which predict characteristics of encoded techniques H.264/AVC for capture each video packet for all streaming in WMSNs. To reduce packet loss rate, energy, and time in WMSNs, J. Agrakhed *et al*. [33] proposed an adaptive multi-constraint multipath routing protocol. This method focused on the clustering mechanism, which was developed using a weighted cost function. Three characteristics, such as delay, energy, and loss rate, were used to create the cost function. For energy saving this approach supposed to keep the sensor node in sleep mode when it was not participating in routing process.

Recently, A. Genta *et al*. [34] proposed a multipath routing strategy by combining it with a cluster formation and dynamic cluster head selection. This approach mainly aimed at the reduction of energy consumption as well as routing overhead at node level. This approach employed Genetic Algorithm (GA) for optimizing the cost function which was established based on least energy dissipation and minimum distance. However, they didn’t focus on the delay and packet transmissions which were important factors for QoS improvisation in WMSNs.

III. Proposed Methodology

A. Overview

We present a new multipath routing strategy for efficient data transmission in WMSNs in this paper. The proposed mechanism finds an optimal and multiple paths for video data transmission from source node to destination. The route discovery process involves the next hop forwarding node selection for multiple paths. In this approach we focus on the discovery of link disjoint paths thereby there is no possibility of a common link for the obtained multiple paths. Since the video data is of larger size and it introduces a more delay, we adopt for link disjoint multipath routing. In the case of common links for more than two paths, there is a possibility of congestion occurrence and again it results in more end-to-end delay. Next, for the selection of next hop forwarder, we propose a composite routing metric which is formulated by the integration three individual metrics which are distinctive in nature. The three metrics are namely Expected Transmission Count (ETC), Energy and Delay. The ETC refers the quality of a link connected between two nodes, energy explores the forwarding capability and delay explores the congestion status. For a given set of neighbor nodes, the selection follows a higher ETC, lower energy consumption and lower delay. Fig. 1 shows the overall schematic of proposed routing mechanism.

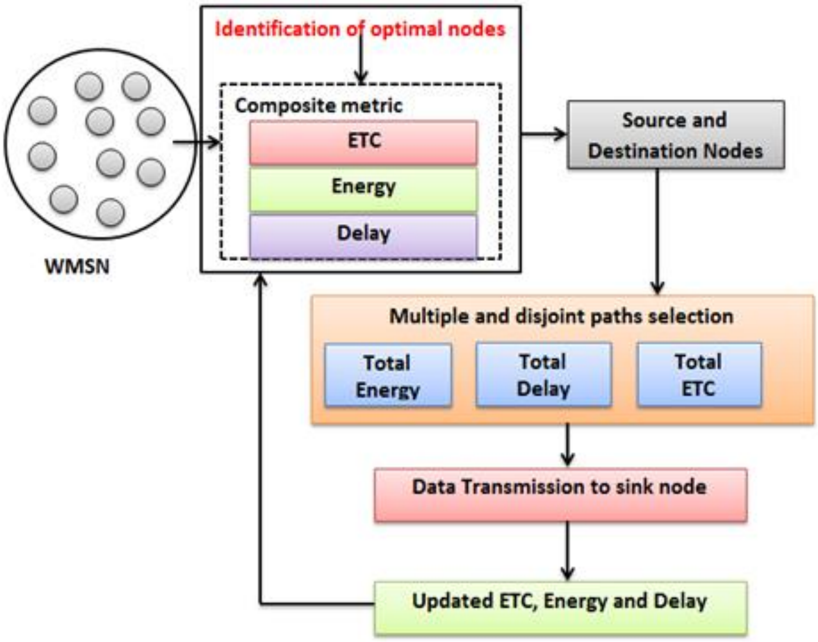

Fig. 1. Overall mechanism proposed routing method

B. Expected Transmission Count (ETC)

The Expected Transmission Count (ETC) [35] is a metric that measures the total number of transmissions (including retransmissions) required for a packet to reach its destination node successfully. The ETC allows for interference between a route's consecutive links, as well as asymmetry in loss ratios between the directions of each link and the implications of link loss ratios for determining throughput routes on multihop wireless networks. The Link Quality (Q_L) and the Neighbor Link Quality (Q_{NL}) are used while calculating the ETC of a link. The Link Quality (Q_L) can be defined as the measured probability of successful arrival of a data packet at a succeeding node (ex: node B) when it originated at a given node (ex: node A. The Neighbor Link Quality (Q_{NL}) is defined as the number of data packets transmitted from node B that are received by node A, implying that it is a measure of the link quality in the opposite direction. The probability after successful receiving a data packet by the neighbor node, then the neighbor node replies a response successfully with a data packet is $Q_L \times Q_{NL}$. By the consideration of Bernoulli trial for each attempt to transmit a packet, then the number of transmissions expected is specified as

$$ETC = \frac{1}{Q_L \times Q_{NL}} \tag{1}$$

Let K be the total number of intermediate nodes present between source and destination pair, the total ETC is obtained by the addition of the ETC metrics along the route is given by

$$ETC_{total} = \sum_{i=1}^{K} ETC_i \tag{2}$$

where K denotes the number of hops along the end to end route.

C. Energy Metric

One of the most essential system design goals in a wireless sensor network is energy optimization. The energy depletion model is used in the MAC and Physical layers of wireless sensor networks [36]. It is based on the concept of depleted energy, which is directly proportional to the communication distance. Two channel propagation models are used in this example. One is a free space channel for establishing an energy model; the others are single hop or direct communication for packet transmission (d^2 power loss) and multi path fading (d^4 power loss) for multi hop communication purpose. Then for transmission of *n* bits of data packet over the distance'*d*' meters, the consumption of energy is evaluated as

$$E_T(n,d) = \begin{cases} nE_e + n\varepsilon_{fs}d^2, & d < d_0 \\ nE_e + n\varepsilon_{mp}d^4, & d \geq d_0 \end{cases} \tag{3}$$

Her ε_{mp}& $\varepsilon_{fs}$is the amplifier energy is proportional to the distance communicated.. $E_e$represent the unit energy at trans receiver, d is the distance between the source and destination nodes and the d_0 threshold and it is computed as.

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{4}$$

The energy consumption for receiving n bits of data is calculated as

$$E_{Rr}(n) = nE_e \tag{5}$$

The total energy of a link established between two nodes separated by d is computed as

$$E_{link} = E_{Tr}(n,d) + E_{Rr}(n) \tag{6}$$

where $E_{Tr}(n,d)$ is the Transmitting Energy and $E_{Rr}(t)$ is the Receiving energy Based on the obtained E_{link} the present energy (residual energy) at node is calculated as

$$E_R = E_I - (E_{link}) \tag{7}$$

where E_I is the initial energy, and E_R is the residual energy based on the E_{link} The total expanded energy at each and every link along the route for transporting data from source to destination is calculated as the route's energy consumption.

$$E_r = \sum_{i=1}^{L} E_{link}(i)\,, r = 1,2, \ldots. R. \tag{8}$$

Energy consumption of a route E_r need to be less than or equal to the minimum required energy E_{req} for transmission of *n* bits of data packet. There are several pathways for a given source and destination node. Among the several choices, the path is selected based on the minimum energy consumption objective, i.e., the path with minimum energy is chosen as an optimal path. Let f_E be the energy objective function which needs to be consider at path selection, it is formulated as

$$f_E = \min_j\{E_P\} \tag{9}$$

D. Delay Metric

Many applications are affected by delays in WSNs. As a result, the delay is the most significant statistic to consider while evaluating QoS. The time elapsed between the departure of a data packet from the source node and its delivery at the destination node is described as delay. Let the delay metric between two nodes is termed as $D_{link}(i)$ is expressed as

$$D_{link}(i) = d_P + d_C + d_Q + d_T \tag{10}$$

where d_T is the transmission delay and it is the time elapsed between the departure of first bit at source node to the arrival of the last bit at destination node. Mathematically the transmission delay is measured as

$$d_T = \frac{total\ number\ of\ bits\ transmitted}{bits\ transmitted\ per\ every\ second} \tag{11}$$

Next, d_P is the propagation delay and it is the time taken by one bit to travel from source to destination node. Mathematically the propagation delay is measured as

$$d_P = \frac{distance\ between\ source\ and\ destination\ (m)}{rate\ of\ transmisison\ (m/s)} \tag{12}$$

Next, the Processing time (d_C) can be defined as the time required for the selecting the next hop sensor to transmit the data packet. Finally the Queuing time (d_Q) is before the processing of data packet the amount of delay time to hold data packet by each intermediate sensor. The Queuing time is totally dependent on ten nature of intermediate node, i.e., for how many nodes it is working as a relay. Moreover, It is also affected by the total number of packets in the buffer. Every packet will have some queuing delay because packets received at forwarding nodes are forwarded in a First in First out (FIFO) manner. In the case of a single forwarding node for numerous source nodes, the queuing latency is greater. Consider a node i with n neighbor nodes: it will always have n sliding windows, each with a length of m. The m here refers to previous queuing delays caused by packet waiting in buffer. The new or updated queuing delay is determined using the previous m queuing delays;

$$d_{i,j}^{(q)}(u) = \delta * t_q + (1-\delta)\frac{\sum_{k=u-m}^{u-1} d_{i,j}^{(q)}(k)}{m} \tag{13}$$

where $d_{i,j}^{(q)}$ is updated queuing delay between node *i* and *j*, t_q is the amount of time it takes for a data packet to reach the transmission queue head of node j. Based on these four delay parameters, the link selection is done s first followed by path selection. The total delay for a given path between two sensor nodes is calculated as the summation of delays incurred at each link in the available path. For a possible path P, the delay is measured as

$$D_r = \sum_{i=1}^{L} D_{link}(i)\,, r = 1,2, \ldots . R \tag{14}$$

For any source and destination node pair, the delay must be less which reflects that the path is more qualitative and can process the packets with less delay. Here, we design an objective function fd to ensure that the route delay on the selected single path is as low as possible, so that $D_{route} \leq D_{req}$, where D_{req} is the specific threshold value depends on application which reflects and require single path route for data delivery. In multi path routing model depending upon the number of used routes, the route selection is done based on the following expression;

$$f_D = \min_j \{D_P\} \tag{15}$$

E. Composite Metric

We create a composite route metric based on these three measures, which aids in the selection of the best route for a given source and destination node pair. The composite metric is formulated as

$$C_r = \alpha * ETC_{total} + \beta * f_E + \gamma * f_D \tag{16}$$

where $C_r$is the composite route metrics and the r varies from 1 to R (the total number of available, paths). In the above expression, α, β and γ are three arbitrary constants those signify the weights of individual metrics. Three constants' values must be chosen in such a way that they satisfy the condition, $\alpha + \beta + \gamma = 1$.

IV. Results of the Simulation

In this section, we go over the specifics of the simulation tests that were run on the suggested model in order to analyze its performance efficacy. First, we'll go through the specifics of the simulation setup, such as the network parameters that were used to replicate the proposed model. Following that, we go over the specific performance metrics that were observed during the simulation with various network configurations.

A. Simulation Setup

Under the simulation setup, we establish a random network with N nodes and suppose that all of the nodes are homogeneous in nature, which implies that they all have the same resources such as energy, memory, and so on. Here we tried to realize the concept of WMSN and hence the resources of nodes are assumed be more than the conventional sensor nodes. The area of deployed network is considered as $1000\text{ m} \times 1000\text{ m}$. Within this network area, we deployed different number of nodes like 30, 40 and 50. The communication range of each nod is considered as 1/4th of network area, i.e., $\frac{1}{4} * 1000 = 250\text{ m}$. Means, every node can communicate with the nodes those are under the communication range of 250 m from itself. The traffic type is considered as varying bit rate and the size of each packet is considered as 2048 bytes. The simulation time is considered as 200 seconds with the pause time of 5 seconds. (See Table I)

TABLE I: SIMULATION PARAMETERS

Network Parameter	Value
Number of nodes	20, 30, 40 and 50
Node deployment	Random
Network Area	1000 m × 1000 m
Communication Range	250 m
Simulation Time	200 Seconds
Pause time	5 Seconds
Packet size	2048 bytes

B. Metrics of Performance

For the performance analysis, we have referred several parameters like Throughput (T), Packet Delivery Ratio (PDR), Average End-to-End Delay (AE2ED), and Average Energy Consumption (AEC). Among these metrics, AE2ED, PDR and Throughput are used to explore the QoS and finally the AEC is used to explore the additional computational energy required for successful data transmission in the network. The definitions of all these metrics are demonstrated as follows;

Throughput: The throughput is defined as the total number of packets received (in Kilobytes) by the time at a destination node (in a sec). The throughput metric investigates the quantity of productivity transmitted from the source node to the destination node. Packets received are measured in Kilobytes, and time is measured in seconds, hence throughput is measured in Kilobytes per second (Kbps). Mathematically the Throughput is calculated as follows

$$Throughput(kbps) = \frac{Pakcets\ delivered\ in\ bytes}{time\ takes\ to\ recive} \quad (17)$$

Packet Delivery Ratio (PDR): The ratio of the total number of packets delivered at the sink node to the total number of packets sent from the source node is known as PDR.

$$PDR = \frac{Pakcets\ delivered}{Packets\ Sent} \quad (18)$$

Average End-to-End Delay (AE2ED): The ratio of the total time it takes data packets to reach the sink from the source node to the total number of packets delivered at the destination node is known as AE2ED. Propagation, buffering, queuing, and retransmission are all referred to as AE2ED. The AE2ED is calculated mathematically a;

$$\text{AE2ED} = \frac{1}{Q}\sum_{j=1}^{Q} Delay(j) \quad (19)$$

where Q is the total number of packets, Delay(j) is the packet transmission delay, and the time difference between the two times is measured as the time difference between the packet received time at the destination node and the packet transmitted time at the source node..

Average Energy Consumption (AEC): The AEC is the ratio of total energy spent divided by the total number of nodes. Let n be the total number of nodes obtained on the way to the sink node in order to calculate the AEC measure, and the total energy is $E_{total}(i)$ for each node i, be evaluated as;

$$\text{AEC} = \frac{1}{n}\sum_{i=1}^{n} E_{total}(i) \quad (20)$$

C. Numerical Results

In the simulation environment, the performance evaluation is carried out by measuring the performance metrics AE2ED, average packet delivery ratio, AEC, Throughput. The metric AE2ED evaluated based on two cases, one is for varying the packet size and second one is for the variation of communication range. The obtained performance metrics of proposed method are compared with the values of existing methods and the results observed are depicted in the following figures.

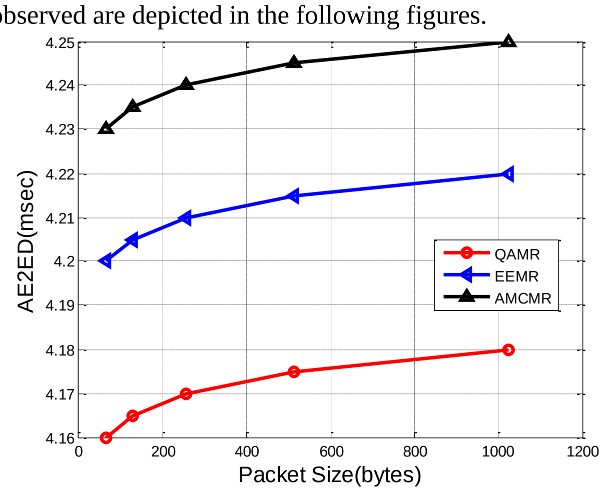

Fig. 2. Average end-to-end delay for varying packet size

Fig. 2 explains the varying details of Average end to end delay with the variation of packet size in bytes. From the Fig. 2 it can be understand that the AE2ED increasing in nature with an increment in the packet size. But the AE2ED of QAMR is noticed as low compared to the AE2ED of existing methods. For a particular packet size AE2ED of QAMR is lesser than the conventional approaches EEMR&AMCMR. A larger packet requires additional time to reach destination than smaller packets and also if more packet drops are there in the network, then it needs more packet retransmissions then delay increases. However the proposed method is quality aware and it is concentrate on the QoS parameter (Energy, ETC &delay) during the node selection hence the proposed method is observed to have less average end to end delay. In the case of conventional EEMR, they considered only en metrics that is energy for the selection of intermediate nodes. However the energy consideration will improve the network lifetime but it dint have any link with throughput. The throughout is mostly related with expected number of packet sent from source nodes and received at sink node. Moreover, the throughout is also dependent in the time span. The proposed QAMR considered these two metrics in the form of delay and ETC and thus it has gained a better throughput then the EEMR. Next, even though the AMCMR considered energy, delay and loss ratio as reference metrics for node selection, they didn't focus on the queuing delay much. In multipath routing the queuing delay is more important because in a network with less number of nodes, the paths suffers from node disjointness means nodes will work as forwarders for multiple paths. In such environments, the packets will get buffered in the queue of intermediate nodes which induces an excessive delay. Our method considered this as a reference metric and hence it prevents the nodes those are common for more than two paths. On an average the proposed QAMR Method has gained average end-to-end delay is of 4.17 m sec while the conventional methods, it is noticed as 4.21msec and 4.24 m sec for EEMR and AMCMR respectively.

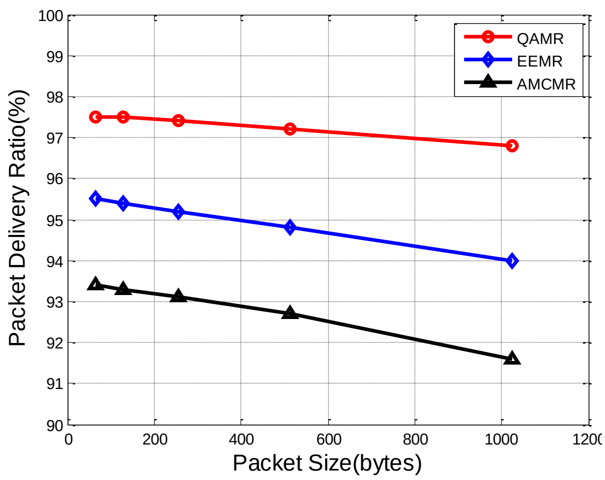

Fig. 3. Average packet delivery ratio for varying packet size

The PDR can be defined as the ratio of actually received data packets at the receiver end to those which were actually sent by sender. Fig. 3 explains the details of Average Packet Delivery Ratio (APDR) for variation in packet size. From the Fig. 3, as the size of the packet increases it can be noticed that the APDR shows declined characteristics. With an increasing an packet size there is a requirement of more number of nodes for successful packet transmission at this situation even for a minimum packet drop at every node the accumulated drop is more. Hence the packet delivery ration has shown decreasing characteristics with the packet size. But the APDR of proposed QAMR is observed as high compared to the conventional methods EEMR &AMCMR. Since the proposed method on multipath routing with multiple constraints the proposed method has more PDR. In case of EEMR they consider only energy as a reference metric for a node selection in a multipath routing. A single energy metric can't provide a proper decision about node selection. even though AMCMR consider energy and delay as reference metric they didn't focused on ETC which has significance impact on the PDR On an average the proposed QAMR Method has gained average Packet delivery ratio is of 97.26 % while the conventional methods, it is noticed as 94.96 % and 92.86 % for EEMR and AMCMR respectively.

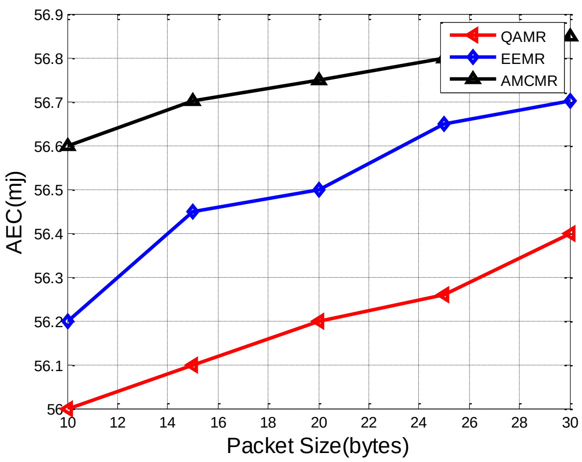

Fig. 4. Average energy consumption (mj) for varying packet size

As shown in Fig. 4 average Energy consumption for the different methods is increasing in nature for an increase in packet size. We observed from the above Fig. 4 energy consumption is less for QAMR when we compare with existing methods. In the proposed method we consider the energy metric for node selection and focused on the selection of node those are disjoint in nature means no common node will exist for any two paths. In such case the node over one path have only less burden of packet forwarding due to this reason the proposed method have less energy consumption. Even though the conventional methods considered the energy has a reference metric they were not focused node disjointness. On an average the proposed QAMR Method has gained average energy consumption of 56.19 m j while the conventional methods, it is noticed as 56.5mj and 56.74 m j for EEMR and AMCMR respectively.

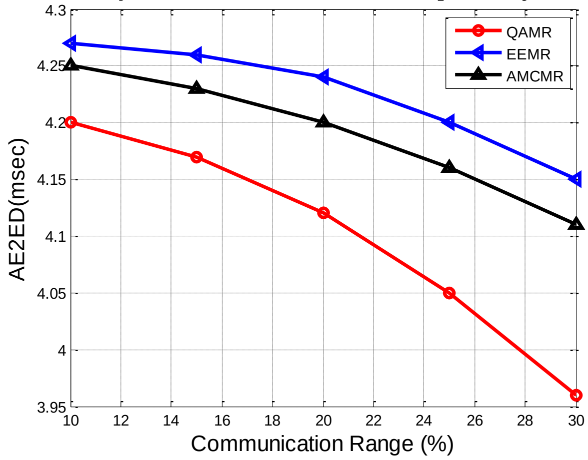

Fig. 5. Average end-to-end delay for varying communication range of sensor nodes

It can be observed from the above figure average end to end delay (AE2ED) is calculated for varying communication rage of sensor nodes. Here we noticed that if the communication range is increasing the AE2ED is decreasing. From the above simulation results AE2ED is very less for proposed approach when we compared with conventional approaches. When the communication range of the node increases in the network, communication between the intermediate nodes is reduces. Due to this consideration AE2ED is very less in the proposed method compared to the conventional methods. With an increase in the communication range the requirement of additional nodes decreases and results in less delay. On an average the proposed QAMR Method has gained average end-to-end delay over the communication range is of 4.096 m sec while the conventional methods , it is noticed as 4.224 m sec and 4.192 m sec for EEMR and AMCMR respectively. (See Fig. 5)

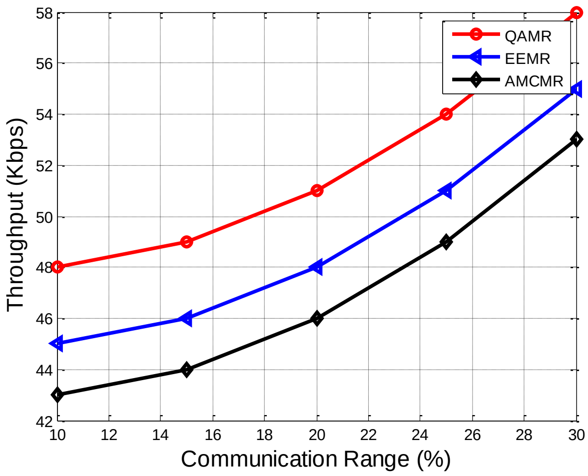

Fig. 6. Average throughput (kbps) for varying communication range of sensor nodes

The total number of packets successfully transported between the source and destination nodes for a given period of time is known as throughput. As can be observed in Fig. 6, throughput increases as the communication range of sensor nodes expands. For an increase in communication range, the proposed approach (QAMR) is observed to have rising throughput. As the communication range grows, the number of new nodes involved in packet transmission decreases. As a result, there's a potential that more packets will arrive at the target node within the chosen time frame. When a result, as the communication range expands, throughput increases. When compared to traditional approaches, the throughput of QAMR is observed to be higher for a specific moment of communication range. On an average the proposed QAMR Method has gained average throughput is of 52 kbps while the conventional methods; it is noticed as 49 kbps and 47 kbps for EEMR and AMCMR respectively.

V. Conclusion

We proposed QAMR, a new multipath routing strategy for efficient data transfer in WMSNs, in this study. For a given source and sink node, the QAMR selects multiple paths based on three metrics such as ETC, Energy and Delay. The multiple paths are chosen in such a way they must be node disjoint in nature. At the delay calculation, we particularly focused on the queuing delay which has a great effect on the QoS in WMSNs. Among the available, the paths are selected those have less energy consumption, less delay and more ETC. A composite route metric is created for each node, and only the nodes that satisfy the above conditions are chosen as final pathways. For experimental validation, we conduct an extensive experiments and the performance is analyses through energy consumption, throughput and delay. A comparative analysis between proposed and several existing methods had shown that the proposed QAMR has outstanding performance than the conventional methods.

Conflict of Interest

The Authors Declare No Conflict of Interest.

Author Contributions

R Jawwharlal: Contributed towards the design and development of proposed method, further he contributed towards the implementation and analysis of proposed mechanism.

L Nirmala Devi: Contributed towards the design of proposed method and suggested to identify a problem from literature review further, she also contributed towards the quality analysis and formatting of paper.

References

[1] C. Conti, A. Dardari, and R. D. Verdone, "An overview of wireless sensor networks technology and evolution," *Sensors*, vol. 9, pp. 6869-6896, 2009.

[2] C. W. Chong, *et al*., "Low memory image stitching and compression forWMSN using strip-based processing," *Int. J. Sensor Netw*., vol. 11, no. 1, p. 22, 2012.

[3] I. T. Almalkawi, M. G. Zapata, J. N. Al-Karaki, J. Morillo-Pozo, "Wireless multimedia sensor networks: Current trends and future directions," *Sensors*, vol. 10, pp. 6662–6717, 2010.

[4] W. Feng, C. Hu, Y. Wang, J. Zhang, and H. Yan, "A novel hierarchical coding progressive transmission method for WMSN wildlife images," *Sensors*, vol. 19, p. 946, 2019.

[5] A. Abed and D. Moussaoui, "Enhancement of compressed image transmission in WMSNs using modified-nonlinear transformation," *IEEE Communication Letters*, vol. 22, pp. 934-937, 2018.

[6] M. Koyuncu, A. Yazici, M. Civelek, A. Cosar, and M. Sert, "Visual and auditory data fusion for energy-efficient and improved object recognition in wireless multimedia sensor networks," *IEEE Sens. J.*, vol. 19, pp. 1839–1849, 2019.

[7] M. Usman, M. A. Jan, X. He, and J. Chen, "A mobile multimedia data collection scheme for secured wireless multimedia sensor networks," *IEEE Trans. Netw. Sci. Eng.*, 2018.

[8] H. Wang, A. O. Fapojuwo, and R. J. Davies, "A wireless sensor network for feedlot animal health monitoring," *IEEE Sens. J.*, vol. 16, pp. 6433–6446, 2016.

[9] J. P. Dominguez-Morales, A. Rios-Navarro, M. Dominguez-Morales, R. Tapiador-Morales, D. Gutierrez-Galan, and D. Cascado-Caballero, "Wireless sensor network for wildlife tracking and behavior classification of animals in Doñana," *IEEE Commun. Lett.*, vol. 20, pp. 2534–2537, 2016.

[10] H. Shi, K. M. Hou, X. Diao, L. Xing, J. J. Li, and C. D. Vaulx, "A wireless multimedia sensor network platform for environmental event detection dedicated to precision agriculture," arXiv2018, arXiv:1806.03237.

[11] A. K. Mahlein, "Plant disease detection by imaging sensors–parallels and specific demands for precision agriculture and plant phenotyping," Plant Dis., vol. 100, pp. 241–251, 2016.

[12] M. Hu, Z. Chen, K. Peng, X. Ma, P. Zhou, J. Liu, "Periodic charging for wirelesssensor networks with multiple portable chargers," *IEEE Access*, vol. 7, pp. 2612–2623, 2019.

[13] M. Chen, Y. Miao, Y. Hao, and K. Hwang, "Narrow band internet of things," *IEEEAccess*, vol. 5, pp. 20557–20577, 2017.

[14] J. Chen, C. Wang, Z. Zhao, K. Chen, R. Du, and G. J. Ahn, "Uncovering the face of android ransomware: Characterizationand real-time detection," *IEEE Trans. Inf. Forensic Secur*., vol. 13, no. 5, pp. 1286–1300, 2018.

[15] A. A. Ahmed, "An optimal complexity H.264/AVC encoding for video streaming over next generation of wireless multimedia sensor networks," *Signal Image and Video Processing*, vol. 10, no. 6, February 2016.

[16] H. R. Swathi, S. S. Surbhi, and G. Gopichand, "Image compression using singular value decomposition," in *Proc. IOP Conf. Series: Materials Science and Engineering*, 2017.

[17] A. Arab, J. Harbi, and A. H. Abbas, “Image compression using principal component analysis,” *Al-Mustansiriyah Journal of Science*, vol. 29, no. 2, pp. 141-147, 2018.

[18] G. Xie, M. N. S. Swamy, and M. O. Ahmad, “Optimal packet scheduling for multi-description multi-path video streaming over wireless networks,” in *Proc. IEEE International Conference on Communications*, Glasgow, UK, 2007, pp. 1618-1623.

[19] R. Lari and B. Akbari, “Network-Adaptive multipath video delivery over wireless multimedia sensor networks based on packet and path priority scheduling,” in *Proc. International Conference on Broadband, Wireless Computing, Communication and Applications*, Fukuoka, Japan, 2010, pp. 351-356.

[20] N. Bashir and S. Boudjit, “A collision avoiding packet scheduling and energy-efficient routing technique for video wireless sensor networks,” in *Proc. International Symposium on Networks, Computers and Communications*, Montreal, QC, Canada, 2020, pp. 1-6.

[21] X. Wang, C. Li, J. Lu, and D. Liu, “QoSPMR: QoS-Aware and priority-based multipath routing algorithm for WMSNs,” in Spring Congress on Engineering and Technology, Xi'an, China, 2012, pp. 1-5.

[22] N. Song, X. Jin, and Y. Zhang, “A multi-path routing protocol for target tracking in WMSNs,” in *Proc. 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM)*, Chengdu, China, 2010, pp. 1-4.

[23] M. Z. Hameed, A. Shahid, S. A. Khan, and Z. A. Khan, “Tree based multipath data diffusion for multimedia wireless sensor networks,” in *Proc. 15th International Multitopic Conference (INMIC)*, Islamabad, Pakistan, 2012, pp. 355-360.

[24] M. Baseri, S. A. Motamedi, and M. Maadani, “A Load-Adaptive Beacon Scheduling algorithm for IEEE 802.15.4 mesh topology improving throughput and QoS in WMSNs,” in *Proc. Fifth International Conference on Computing, Communications and Networking Technologies*, Hefei, China, 2014, pp. 1-5.

[25] B. Zeng, Y. Dong, and D. Lu, “Cooperation-Based scheduling algorithm in wireless multimedia sensor networks,” in *Proc. 7th International Conference on Wireless Communications*, *Networking and Mobile Computing*, Wuhan, China, 2011, pp. 1-4.

[26] P. Wang, R. Dai, and I. F. Akyildiz, “A differential coding-based scheduling framework for wireless multimedia sensor networks,” *IEEE Transactions on Multimedia*, vol. 15, no. 3, pp. 684-697, April 2013.

[27] J. C. Fernandez, T. Taleb, K. Hashimoto, Y. Nemoto, and N. Kato, “Multi-path scheduling algorithm for real-time video applications in next-generation wireless networks,” in *Proc. Innovations in Information Technologies*, Dubai, United Arab Emirates, 2007, pp. 73-77.

[28] E. Karimi and B. Akbari, “Improving video delivery over wireless multimedia sensor networks based on queue priority scheduling,” in *Proc. 7th International Conference on Wireless Communications, Networking and Mobile Computing*, Wuhan, China, 2011, pp. 1-4.

[29] S. Sridevi, M. Usha, and G. P. A. Lithurin, “Priority based congestion control for heterogeneous traffic in multipath wireless sensor networks,” in *Proc. International Conference on Computer Communication and Informatics*, Coimbatore, India, 2012, pp. 1-5.

[30] J. Wu, Z. Zhu, X. Di, Z. Zhang, and J. Tian, “Multi-path selection and scheduling scheme for multi-description video streaming in wireless multi-hop networks,” in *Proc*. *International Wireless Communications and Mobile Computing Conference*, Paphos, Cyprus, 2016, pp. 970-975.

[31] H. Shiang and M. V. D. Schaar, “Multi-user video streaming over multi-hop wireless networks: A distributed, cross-layer approach based on priority queuing,” *IEEE Journal on Selected Areas in Communications*, vol. 25, no. 4, pp. 770-785, May 2007.

[32] I. Politis, M. Tsagkaropoulos, T. Pliakas, and T. Dagiuklas, “Distortion optimized packet scheduling and prioritization of multiple video streams over 802.11e networks,” *Advances in Multimedia*, 2007, pp. 1–11.

[33] J. Agrakhed, G. S. Biradar, and V. D. Mytri, “Adaptive Multi Constraint Multipath Routing Protocol in Wireless Multimedia Sensor Network,” in *Proc. International Conference on Computing Sciences*, Phagwara, India, 2012, pp. 326-331.

[34] A. Genta, D. K. Lobiyal and J. H. Abawajy, “Energy efficient multipath routing algorithm for wireless multimedia sensor network,” *Sensors*, 2019, p. 3642.

[35] D. Couto, D. Aguayo, J. Bicket, and R. Morris, “A high-throughput path metric for multi-hop wireless routing,” *Wirel. Netw*., vol. 11, no. 4, pp. 419–434, 2005.

[36] K. Kulothungan, S. Ganapathy, S. I. Gandhi, P. Yogesh, and A. Kannan, “Intelligent secured fault tolerant routing in wireless sensor networks using clustering approach,” *Int. J. Soft Comput*., vol. 6, no. 5–6, pp. 210–215, 2011.