ENERGY LOCATION AWARE ROUTING PROTOCOL (ELARP) FOR WIRELESS MULTIMEDIA SENSOR NETWORKS

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ABSTRACT

*Wireless Sensor Networks (WSNs)have sensor nodes that sense and extract information from surrounding environment, processing information locally then transmit it to sink wirelessly. Multimedia data is larger in volume than scalar data, thus transmitting multimedia data via Wireless Multimedia Sensor Networks (WMSNs) requires stick constraints on quality of services in terms of energy, throughput and end to end delay.Multipath routing is to discover multipath during route discovery from source to sink. Discover multipath and sending data via these different paths improve the bandwidth and decrease the end to end delay. This paper introduces an **E**nergy **L**ocation **A**ware **R**outing **P**rotocol (ELARP) which is reactive multipath routing protocol establishing three paths with awareness of node's residual energy and distance. ELARP has experimented with NS2 simulator. The simulation results show that ELARP enhances QoS for multimedia data in terms of end to end delay and packet delivery ratio.*

KEYWORDS

Multipath Routing Protocol, Quality of Service, Wireless Multimedia Sensor Networks, Wireless Sensor Networks

1. INTRODUCTION

Wireless Multimedia Sensor Networks (WMSNs) are new networks type that have audio or video sensor nodes integrated with cheap components such as CMOS cameras and microphones. These sensor nodes have ability to sense the surrounding environment, capture and transmit multimedia data such as video, audio and even image to the sink[1].

WMSNs have many challenges due to: transmission multimedia data which is large in volume and required quality of service (QoS) in terms of increasing throughput, and delivery speed of multimedia data packets to the destination. Because multimedia data packet is very sensitive to the delay and losses, losing these packets or arriving after deadline leads to distortion in received multimedia data. Other challenges include: transmit the data wirelessly, and limitations of sensor nodes capability, limitation on power, memory and capability of the processor[2].

Multipath routing is to discover multipath during route discovery from source node to the sink. Discover multipath and sending data via these different paths improve the bandwidth and decrease the end to end delay [3]. Multipath routing also provides different advantages such as balancing the traffic by dividing the traffic across alternative paths in case of use all paths simultaneously, thus balance the energy between nodes, increase the lifetime of the network and

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avoid congestion [4]. Also, multipath routing increases the reliability by protecting from route failure when uses another path if the main path is fail[5].

This paper contributes with an **E**nergy **L**ocation **A**ware **R**outing Protocol (ELARP) which is reactive multipath routing protocol, establishes three paths from source to the sink with a consideration of node's remaining energy and distance to the sink.

In WMSNs, considering energy and location of next node during establishing the path is important to guarantee quality of service QoS for multimedia transmission such as end to end delay and throughput. During creating the path, next node is selected with best residual energy to participant in the path and avoid path failure. Considering the location is made by choosing the node that is much close to the sink.

In this research, researchers used the concept of location aware node disjoint paths. By node disjoint paths, no node is sharing between two paths. So that every node joins only one path at a time. This avoids consuming node energy and causes less congestion which grantee QoS. If the node share between two paths which is link disjoint path and the node died, two paths are affected while in node disjoint path only one path is affected.

The rest of this paper is organized as follow: literature review is section 2.The proposed ELARP protocol is described at section 3.Performance metrics that evaluate the protocol is detailed in section 4.Results and analysis are in section 5.Finally are the conclusion and future works in section 6.

2.Literature Review

Wireless Sensor Networks (WSNs) are used in many applications to abstract information about certain environment. Many applications such as monitoring and surveillance require sensing the environment and send multimedia data not only scalar data. Multimedia data may include video, sound or even image .A WMSN is composed of ordinary nodes of WSNs as well as nodes with integrated cameras and microphones. WMSNs have sensor nodes that are capable to capture and communicate streams of multimedia data.

There are many researchers produced different routing protocols for WMSNs to better use of bandwidth, reduce the delay, and improve node's energy consumptions. This is to show how WMSNs can be more efficient depending on the constraints and the requirements of QoS on specific application. WMSNs protocols may be classified based on the routing techniques into four categories:

- Multichannel: sending the packets via different channels.
- Single path routing: at route discover stage, creating only one path from source to the sink. Sung-Lee et al. [6] presented routing protocol for MWSNs. It is energy aware that minimizes the control message overhead.
- Multipath routing: discover multipath from source to sink during route discovery. Poojary and Pai [7] proposed a multipath protocol with power awareness routing.
- Multichannel and Multipath routing: creating a multipath and send the data via multichannel[8].

Medjiah et al [9] introduced a multipath routing protocol that an enhancement of GPSR (Greedy Perimeter Stateless Routing) protocol called GEAMS(Geographic Energy-Aware Multipath Stream-based) which minimizes the queue size and enhances the network lifetime by adding load balance. The sensor node saves information about hop neighbor such as distance, residual energy and rate of the link.

A multipath routing used metadata to create the paths that meet QoS for multimedia data is produced by Lan et al[10]. They used routing decision cost function and advanced Dijkstra algorithm, excluded the neighbor nodes with insufficient delay, residual energy and bandwidth. This protocol described the packet used by metadata. The simulation results show that the proposed multipath protocol enhances the delay and energy consumption.

Guannan et al.[11] proposed a multipath routing and load balancing protocol for WMSNs to increase reliability, reduce energy, and control the congestion. The proposed protocol is reactive to reduce the overhead. The protocol creates three disjoint paths (primary, alternate, and backup paths) from source to sink nodes. The simulation results show an enhancement of network lifetime and throughput. The protocol shows fast deteriorate of network lifetime at higher transmission rate. Disjoint path is not suitable for WMSN, the shared node will cause high energy consumption.

Multipath routing protocol proposed by Li et al. [12] is path disjoint based on directed diffusion (DD) protocol. The protocol modified DD and used cost path which is based on expected transmission account (ETX) and delay as a metric. After the sink send interest, nodes calculate the ETX for the last three upstream links and add the mto the packet header.

3. Energy Location Aware Routing Protocol (ELARP)

All routing mechanisms that used to discover multipath in WSN and WMSN are based on different types of discovering the paths, such as start to discover single path each time and repeat the process until discover all possible paths or specific number of paths. Repeating the process consumes energy and increases delay. Flooding mechanism is a mechanism to discover maximum or fixed number of paths which have high energy cost. To avoid this cost, this research suggests an Energy Location Aware Routing Protocol (ELARP). ELARP mechanism discovers three paths at the same time with a consideration of node's remaining energy and distance to the sink.

ELARP is used at network layer in layered architecture. Figure 1 shows this architecture. From the figure, application layer MPEG4 distributed code algorithm is used, in transport layer User Datagram Protocol (UDP) is used to guarantee lower latency because it does not use hand-shaking mechanism nor end-to-end congestion control. Finally, IEEE 802.11 standard for scheduling is used in MAC layer. Following subsections discuss the role of each layer in the WMSN communication process.

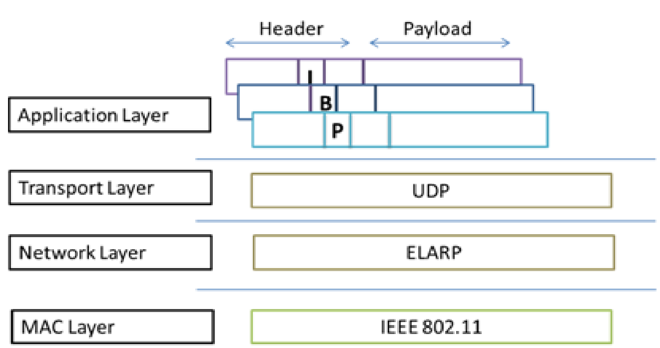

Figure 1. ELARP Layered Architecture

3.1 ELARP Network Model

The network is composed of N different heterogeneous sensor nodes distributed randomly in specific flat area, as shown in Figure 2. The network has one sink node which has special capabilities. Sink node is always switched on and it is non-mobile node. The network also has audio and video sensor nodes. All these nodes are mobile nodes with random movement with same speed in the network area. They have same transmission range and all nodes has access to neighbour's information such as energy and location.

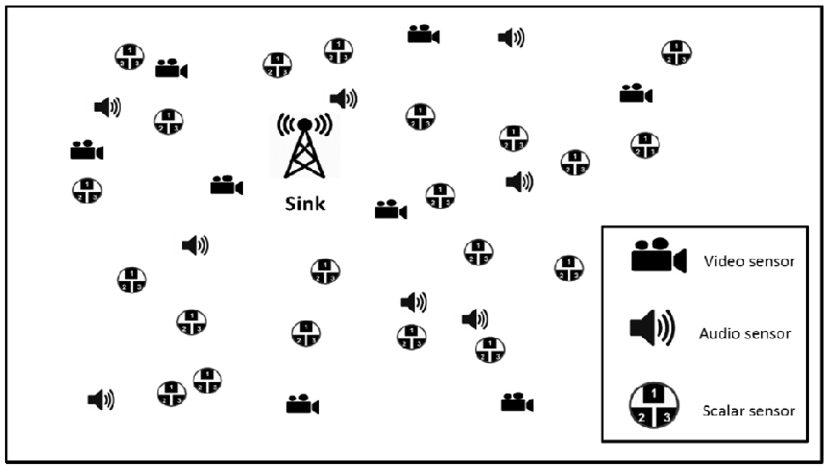

Figure 2. Simulation Network

3.2 Application Layer

MPEG-4 is a video structure that consists of three types of frames, these frames are:

I. Intra – coded frame. I frame is encoded and decoded independently without reference to any other types of frames.
P. Predictive-coded frame. P frame is encoded and decoded dependent on previous I or P frames in the sequence of the video.
B. Bi-directionally predictive coded frame. B frame is encoded and decoded dependent on other types of previous and successive frames in the sequence of the multimedia data.

According to this coding relation in MPEG-4 structure and the dependent relationship between frames in encoding or decoding, losing one I frame will affect all frames in same Group of Picture (GOP).As a result this will affect the quality of multimedia data. Losing B frame will affect itself only. So, I frame is the most important type of frames then P and B frames has less importance.

Decomposing video sequence into small units using GOP is referred to the number of frames falling between two I frames. GOP is defined by two parameters G (N,M) where N is the distance between I frames and M is the distance between I and P frames. [13, 14]

Application layer classified the frames to I, B, and P types. Then encapsulates frame type, frame priority, and GOP size in its header.

3.3 Network Layer

ELARP is reactive routing protocol where the path is discovered only when a node has data to send. Reactive approach is more suitable for WMSN to avoid energy consumption for creating and maintaining the routing table and also to avoid control messages overhead.

3.3.1 Packet Format

ELARP protocol has different types of packet format. These packets are:

- Hello Packet: are broadcasted every period of time to update the neighbor list.
- Route Request (RREQ): is a packet format that is used to create the paths and has three special fields used by ELARP. It contains the fields shown in Figure 3

Source Addr	Source Seq#	Broadcast ID	Dest Addr	Dest Seq#	Hop_ Cnt	First_ Hop	Best Add1	Best Add2	Best Add3

Figure 3. Route Request RREQ Packet Format

- Route Reply (RREP): is a packet format that is used to reply the route request.

- Route Reply Acknowledgment (RREP-ACK): is used to response to route reply.

- Route Error (RERR): is a packet format that is used in maintenance phase if failure is detected.

3.3.2 Routing Table Structure

ELARP routing table contains five fields. These fields are: destination address, sequence number, advertised hop count which contains the maximum hop count that available in the rout list, rout list which is a pair of next hop and hop count and expiration time for this entry. Figure 4 shows the header of the routing table

Destination address	Rout list {(nexthopi, hopcounti), (nexthopj, hopcountj)}	Advertised hop count	Sequence number	Expiration time out

Figure 4. Routing Table Structure

3.3.3 Next Node Selection Mechanism

A reactive approach is work on demand. Whenever an event is detected, it starts route discovery. ELARP protocol has two lists:

A. Block List: A list contains all nodes that do not have any neighbors.

B. Neighbor List: a list contains all neighbor nodes excluding source node, block nodes and nodes have already joined a path.

ELARP selects next node in a route based on two criteria: the remaining energy on neighbor node to avoid hole in the path and distance to the sink. Calculate the weight of the node is based on equation (1). For each node i in the neighbor list N_x of current node x, $W_i$is given by:

$$W_i = \alpha E_{remain\ i} + \gamma\, \overline{D_{dist_i}} \tag{1}$$

Where (α, γ) is appropriate weight with value between 0 and 1. $E_{remain\ i}$ is the remaining energy, and $\overline{D_{dist_i}}$ is the complemented distance to the sink. $D_{dist_i}$is the distance between two nodes i and s(the sink node), and is calculated using equation (2). Node that has long distance should be given less weight, equation (3)is used to calculate this parameter.

$$D_{dist_i} = \sqrt{(Y_i - Y_s)^2 + (X_i - X_s)^2} \tag{2}$$

$$\overline{D_{dist_i}} = 1 - D_{dist_i} \tag{3}$$

Neighbor node with high weight has high probability to be a next node in route discovery process using equation (4).

$$\text{Next Node} = MAX(W_1, W_2, \ldots, W_{Nx}) \tag{4}$$

3.3.4 Route Discovery Mechanism

When an event occurs and some node has a data to send, the source node checks the neighbor list. If the list is empty, then source node marks itself as block node and updates the block list. Otherwise calculate the weight for each neighbor. Then it selects next node with high weight as calculated by equation (4).

Source node establishes three paths by sending the request to best three neighbors then after the paths are established, each node select the best neighbors to send the request and this process is repeated until the paths reaches the sink and generate RREP. A route with minimum hop count is used to send the data. The other two paths are used as back up. A new route discovery process is repeated only if all paths are failed. The steps of ELARP mechanism techniques are shown in Algorithm1.

4. PERFORMANCE METRICS

Different performance metrics are used to evaluate the performance of ELARP. These metrics may be general for WSNs and WMSNs protocols or specific for only multimedia networks:

4.1 General Performance Metrics:

- Packet delivery ratio: the ratio between the total numbers of packets received divided by the total number of packets sent by the source node.
- Network Lifetime: the duration of time from network deployed until the first node dies.
- Drop Packet: the number of packets dropped.
- End to end delay: possible delays of a packet being transmitted from source to destination.
- Jitter: the variation delay of receiving packets.

4.2 Multimedia Performance Metrics:

- Frame loss: the number of frames loss in each type of video frame I, P and B. In this research, we consider only loss of I frame.
- Peak signal-to-noise ratio (PSNR): is a measure for video quality. PSNR measures the signal noise by comparing maximum energy signal to corrupting noise. To see the quality of PSNR to the video, map the PSNR to Mean Opinion Score (MOS) levels[15], where PSNR>37 is excellent and PSNR<20 is bad. When PSNR is in the range 25-31, it is fair.

Algorithm 1: Route Discovery Algorithm

```
Require: Route Request Packet (RREQ)
Ensure: Minimum delay path
Output: Route Reply
Initialization: N=3, M=1
If Source Node have data to send
        Check Neighbour list
        IF (Neighbour list is empty)
        Add the node to Block List, Else
        foreach node in Neighbour list do
        Calculate weight W
        End
        Sort Neighbour list based on W
        Send RREQ to best N node
If node Receive Route Request Packets (RREQ)
        If (node address is not in the packet OR RREQ  already received)
          drop the packet, Else
          Set reverse route
        If (node is intended receiver)
          Send Route Reply Packets (RREP), Else
          Check neighbour list
        IF (Neighbour list is empty)
          Add the node to block List, Else
        foreach node in neighbour list do
          Calculate weight W
         End
         Sort neighbour list based on W
         Forward RREQ to best M node
```

5. ELARP RESULT AND ANALYSIS

ELARP is analysed under two different scenarios. It's performance is compared with Ad hoc On-demand Multipath Distance Vector(AOMDV)[16]. To insure correct and no deviated results, average of ten runs is presented in each case.

5.1 Network Setup

The protocol is simulated using network simulation version-2 NS2 [17] with my Evalvid[18] to test multimedia data transmission. The network consists of 50 heterogeneous sensor nodes and one sink node. The number of video node is varied from 2 to 10, the number of audio node is varied from 2 to 10. These nodes are distributed randomly in area 100 x 100 m. All sensor nodes are mobile nodes with speed equal to 5 m/s. The sink node is centred placed, while the heterogeneous sensor nodes are distributed randomly in the area. The two test scenarios are: First, changing number of video and audio nodes and generating non-overlapping two events during the simulation time. Event's location are generated randomly. Second, events are overlapped in three different scenarios. Table 1 summarizes the network parameters.

Table 1: The Network Parameters

Simulator	NS-2.35
Simulation Time	500 s
Simulation Area	100 m* 100 m
Number of Sensor Nodes	50 nodes
Number of Video Nodes	Vary from 2 to 10
Number of Audio Nodes	Vary from 2 to 10
Queue Type	Drop Tail
Propagation Models	Two Ray Ground
Data Rate	1 Mbps
MAC Protocol	IEEE 802.11
Routing Protocol	ELARP, AOMDV
Initial energy of sensor node	5 Joule
Initial energy of video node	30 Joule

5.2 Ratio of Video Node

To study the effect of number of video nodes on network performance, researchers increase the video and audio nodes from 2 to 16 nodes. Again, the results are taken as average of 10 runs. Packet delivery ratio metric, shown in Figure 5, has ELARP is better than AOMDV on average. It is noticeable that increasing network video nodes would cause decreasing the packet delivered because of the higher probability of congestion, packet drooped and node death.

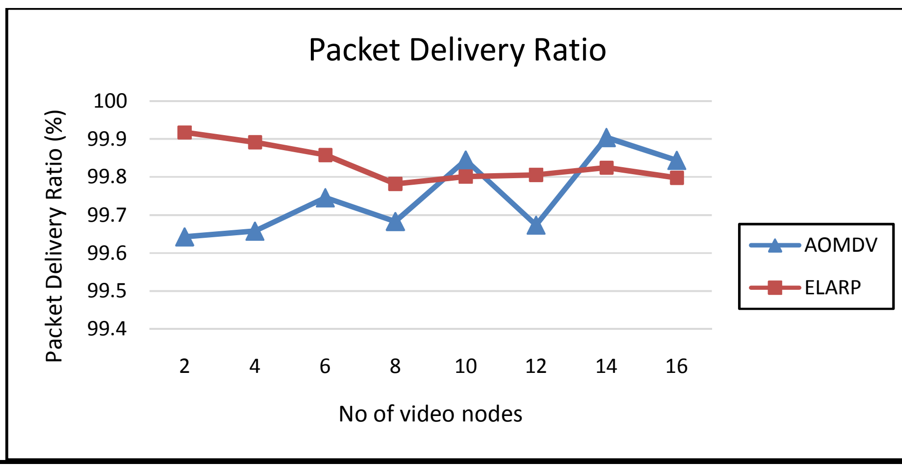

Figure 5. Packet Delivery Ratio vs. Increased Video Nodes

ELARP shows minor improvement in network lifetime over AOMDV as shown in Figure 6. Network lifetime decreases from 390s to 350s with increasing video nodes from 2 to 10 nodes. More than 10 video nodes causes dramatic drop in the network lifetime to 220s.

ELARP shows stable and linear drop packets over AOMDV as shown in Figure 7.The figure shows that ELARP packet dropped is between 20 to 60 packets with linear increase with increasing number of video nodes. While the packet dropped for AOMDV starts at 80 packets with high fluctuations.

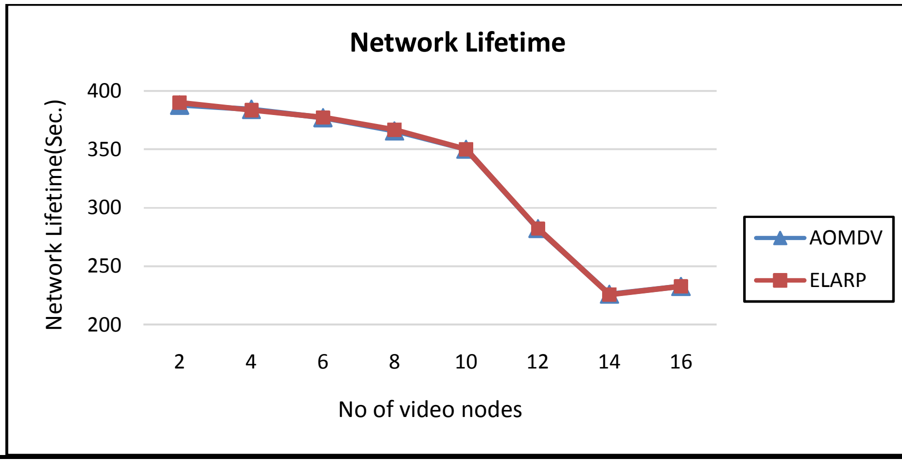

Figure 6. Network Life time vs. Increase Video Nodes

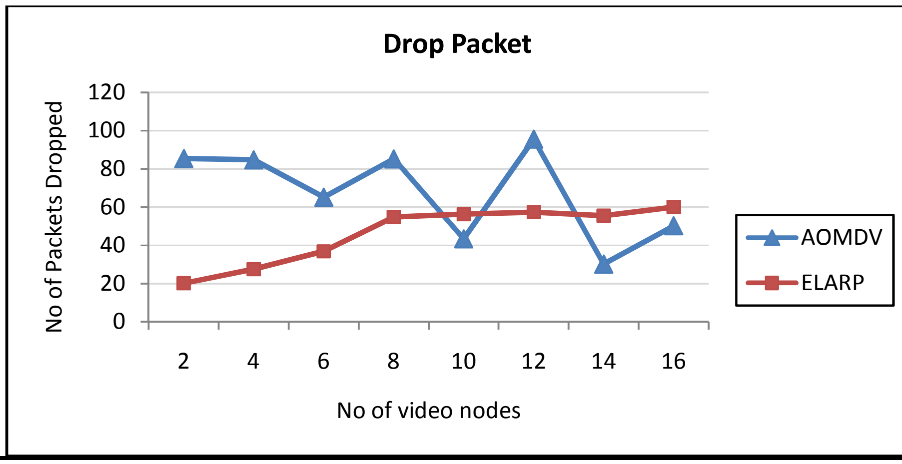

Figure 7. Packet Drop vs. Increase Video Nodes

End to End delay is an important metric especially for WMSNs. Figure 8 shows the improvement done by ELARP over AODMV. ELARP delay is more linear and stable.

Jitter is important metric denoting the stability of the network. ELARP protocol is little low jitter over AOMDV. Figure 9 shows that more than 10 video nodes among 50 network nodes, jitter has sharp increase.

Frame Loss of types I, P and B is special performance metric for WMSN. The average PSNR for both ELARP and AOMDV protocols are not affected by increased the number of video nodes. There is no loss of I frame and average PSNR = 27.87, which represents “fair” quality of the video.

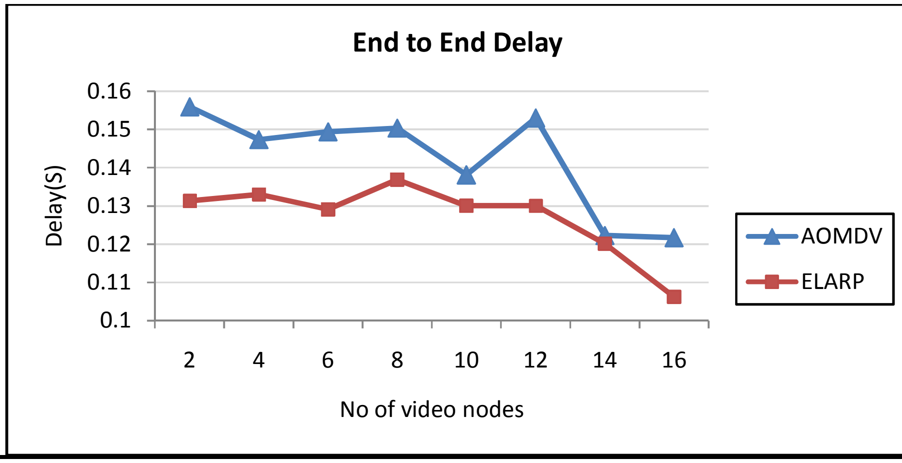

Figure 8: End to End Delay vs. Increase Video Nodes

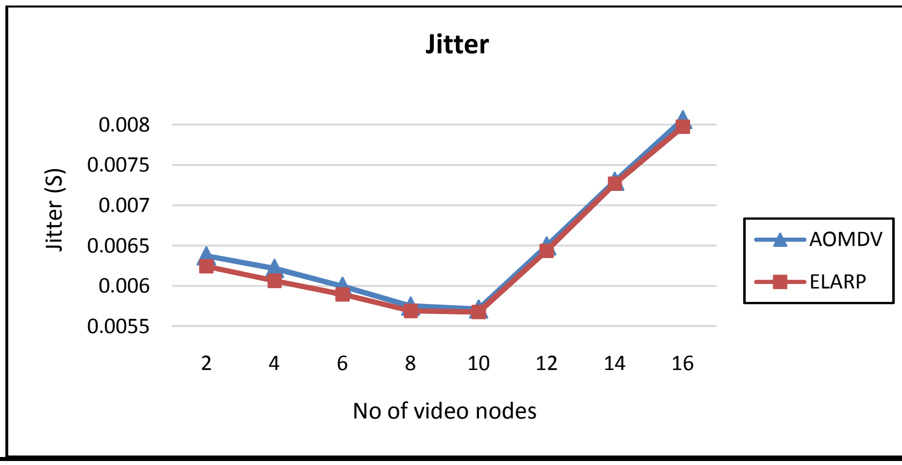

Figure 9. Jitter vs. Increase Video Nodes

5.3 Events Overlap

By event overlap, we mean how much time the events share sending data in the network. This parameter represents increasing network load. To study the effect of time overlap of reporting events and sending data, with also increasing he video and audio nodes from two to 16 nodes, the research increases number of video and audio nodes that reporting events by considering three cases:

Case A: the overlap time is 10 second
Case B: the overlap time is 20 second
Case C: the overlap time is 30 second

Packet delivery ratio of ELARP is outperforms AOMDV in all the three cases A, B, and C as shown in Figure 10. ELARP shows also linear distribution regardless of network load.

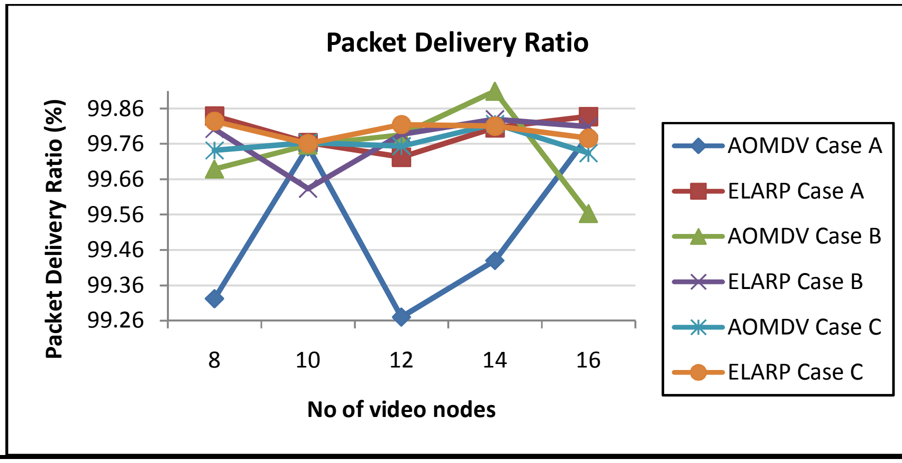

Figure 10: Packet Delivery Ratiovs. Events Overlap

Although network lifetime is greatly affected by average energy consumption, Figure 11 shows that both protocols are identical in the three cases. The figure also shows linear drop from 10 video nodes and up to 220 s lifetime.

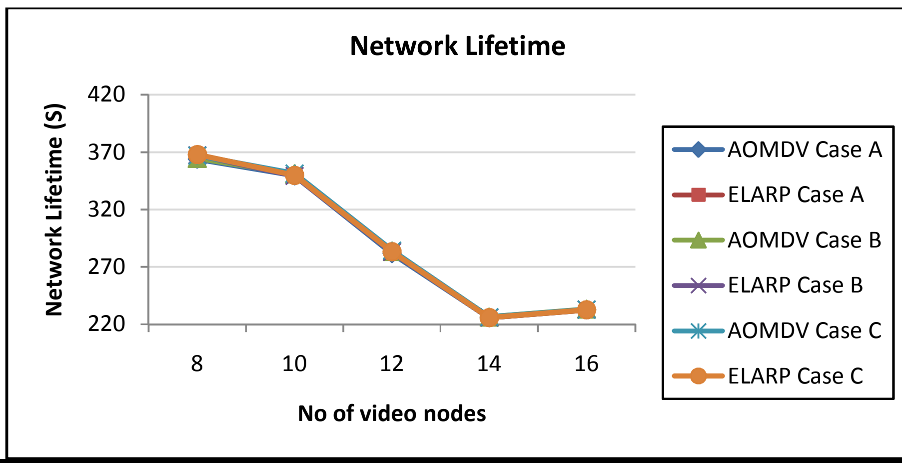

Figure 11: Network Lifetimevs. Events Overlap

Figure 12 shows packet drop metric where ELARP has minimum drop packets than AOMDV especially when WMSN is loaded by events overlap.

ELARP has achieved good results over AOMDV in end to end delay. Figure 13 shows that while the number of video nodes increased, the end to end delay decreased for both protocols. The improvement is better when the network is more loaded (case C).

Jitter is nearly constant when WMSN contains less than 10 video nodes and it has linear fast increase when numbers of video nodes are more than 10 nodes. Figure 14 shows minor improvement of ELARP over AODMV especially when the network is loaded (case C).

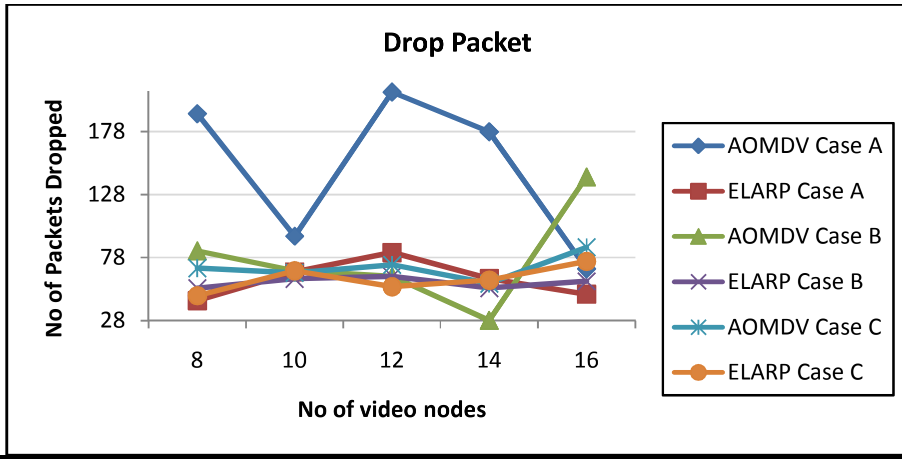

Figure 12: Packet Dropvs. Events Overlap

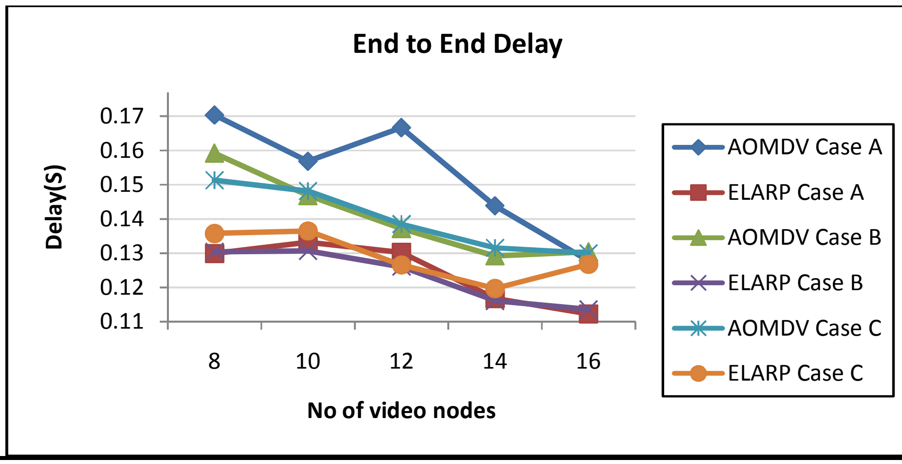

Figure 13. End to End Delayvs. Events Overlap

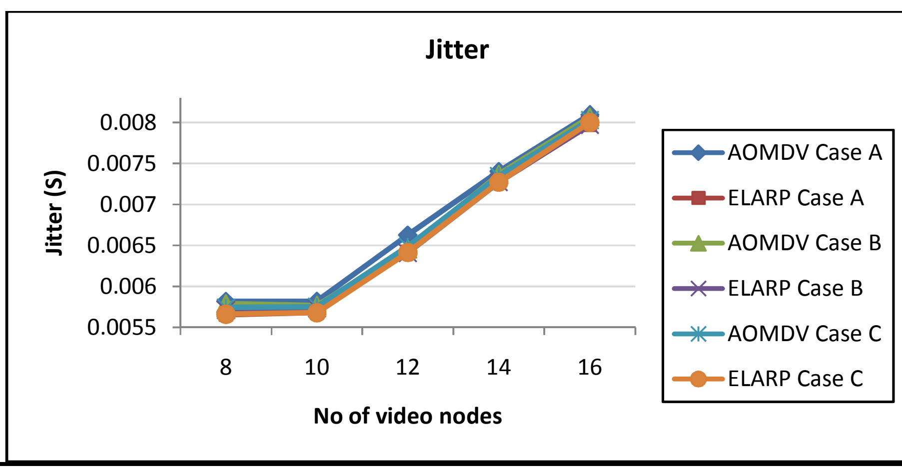

Figure 14. Jitter vs. Events Overlap

Frame loss of I frame affects the quality of the video data transmitted. ELARP in case B and C did not loss any I frame. AOMDV in same cases show highest loss of I frame as shown in Figure 15. In case A both protocols loss the same number of frames. The PSNR is affected by loss frames, as shown by Figure 16, more frames lost causes less PSNR. In all cases AOMDV and ELARP protocol lie in fair MOS level.

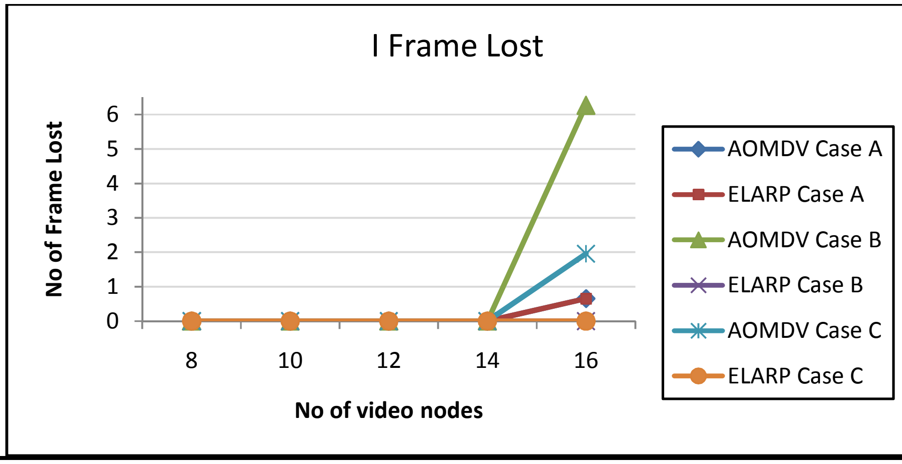

Figure 15. I Frame Lostvs. Events Overlap

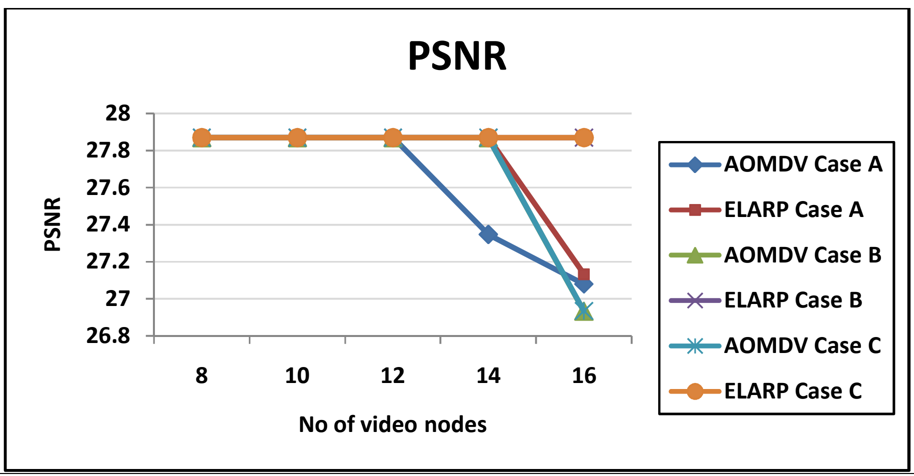

Figure 16. Average PSNR vs. Events Overlap

6. Conclusions And Future Work

QoS is an important issue for WMSNs in term of end to end delay and guarantee data delivery. In this work, ELARP with awareness of location and energy of the node is developed. A multipath routing which does aware of remaining energy and location of the node, reduce overhead and save energy by selecting three paths based on their weight. Only one path is used to send the data and othersareback up in case of failure. ELARP's performance is compared against AOMDV protocol. NS2 simulator is used to simulate ELARP. The results are analysed using two parameters: increasing number of video nodes in the network and events overlap which reflects network load. From the results, ELARP enhances the packet drop and delay over AODMV. Increasing number of video nodes more than 10 nodes makes a big difference in protocol performance. While increasing network load represented by event overlap has also improved packet delivery ratio and end-to-end delay as well as I frame loss and PSNR.

As a future work, ELARP is used in Cross Layer environment where different layers are collaborated to enhance the performance of ELARP.

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