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Research paper

Cross layer energy location aware routing protocol (XELARP) for wireless multimedia sensor networks WMSNs

Ablah AlAmri [1] *, Manal Abdullah [2]

[1] *Department of Computer & Information Technology, king Abdul-Aziz university KAU, Jeddah, Saudi Arabia*
[2] *Faculty of Computing and Information Technology, king Abdul-Aziz university KAU, Jeddah, Saudi Arabia*
**Corresponding author E-mail: asmalamri1@kau.edu.sa*

Abstract

The field of sensor networks has expanded to include many special applications of monitoring environment. Wireless Multimedia Sensor Networks (WMSNs) are networks which have sophisticated sensor nodes with embedded audio and video sensors. These sensors are deployed in specific area to sense the surrounding physical environment and extract useful information. Then, it transmits these information to a sink node wirelessly. WMSNs have many challenges related to the limitations of node resources. Multimedia data includes audios, images and videos which are larger in volume than scalar data. Transmitting multimedia data have many strict constraints on the quality of services (QoS) in terms of energy, throughput and end-to-end delay. The layered architecture is not the best for WMSNs. Cross layered architecture is a new concept that combines several layers of TCP/IP architecture to enhance network's QoS.
In this paper, a humble effort is made to propose a protocol called Cross Layer Energy Location Aware Routing Protocol (XELARP). XE-LARP uses cross layer design principles with multipath routing concept by combining three none adjacent layers: application, network and MAC layers. XELARP establishes three paths with awareness of node's residual energy and distance to the sink. XELARP increases QoS for multimedia data in terms of end-to-end delay, packet delivery ratio, throughput and network lifetime.

Keywords: *Multipath Routing Protocol; Cross Layer Architecture; Quality Of Service; Wireless Multimedia Sensor Networks.*

1. Introduction

The advanced technology in low power circuits, cheap sensor nodes with different functions have opened the door to the various sensor networks. Thousands of these sensor nodes are deployed to cover a specific monitoring area. These deployed sensor nodes cooperate together to create wireless sensor networks [1].
Wireless Multimedia Sensor Networks (WMSNs) include some nodes as video and audio [2], [3]. Today WMSNs are used in many applications such as surveillance, tracking the missing people, identifying the criminals, traffic controlling, smart homes and health care and thus are more sophisticated. WMSNs faces many challenges while transmitting the huge amount of multimedia data with quality of service (QoS) in terms of throughput, and speedy packets to the destination. These data packets are very sensitive to the delays, late deliveries and losses, as it leads to distortion in received multimedia data. Other challenges include: transmitting the data wirelessly, and limitations of sensor nodes capability [4].
Layered TCP/IP architecture has some drawbacks on WMSNs, where it requires cooperative nature between layers to enhance layer functionality.
A cross-layer design is more suitable to use in WMSN than layered architecture, since it increases the data gathering from WMSNs nodes to the sink, reduces the latency, increases the bandwidth and further reduces the energy consumptions.
This paper contributes with Cross Layer Energy Location Aware Routing Protocol (XELARP), which is a protocol that uses the cross-layer design principles with multipath routing concept. XE-LARP allows cooperation of three non-adjacent layers: application layer, network layer and MAC layer. These layers integrate to exchange information among them more efficiently and satisfy the QoS required for multimedia transmission in WMSNs.
The application layer participates with traffic classifier module to classify the multimedia frames based on their types (I, B, P). In network layer, our previous work Energy Location Aware Routing Protocol (ELARP) [5] is used. In MAC layer, packets coming from the network layer are scheduled, to access the media. According to priority information that is marked in application layer, and the network traffic load, assigns the packets to suitable location in queues.
The rest of this paper is organized as follow:
A literature review is in section 2, the proposed cross layer protocol XELARP is detailed in section 3, performance metrics that evaluate the protocol is in section 4. Results and analysis are in section 5. Finally, are the conclusion and future works in section 6.

2. Literature review

WMSNs has its usage in many arenas and disciplines. It is extensively used in multimedia surveillance sensor networks to track the object and take appropriate actions [6]. Another significant relevance can be observed while tracking the missing persons and locating them. Also, it is used to identify the criminals, thieves or potential terrorists. It plays a vital role in traffic controlling and monitoring system, which helps to avoid road congestions [2]. In smart home applications, its imperative functionality can be seen in conserving energy efficiently, controlling the temperature (heating, cooling), and also the light systems, based on human activities. Its central role can be appreciated in the health-care industry, where patients carry medical sensors to detect their body parameters. Further advancement can be noticeably seen in medical centres with remote patient monitoring vices, especially in case of emergency situations. It is also used to check and observe the environment and civilian structure such as bridges and under-passes. Industries also use WMSN sensors to control various business processes [2-7]. All these applications require QoS for multimedia transmission [6].

Numerous studies have been acknowledged, where researchers have been projecting different ideas regarding the designs and protocols for cross-layer architecture to increase the data gathering from WMSNs nodes to the sink, reduce the latency, increase the bandwidth and reduce the energy consumptions. This shows how WMSNs can be more efficiently used, even after the limitations of constraints and the requirements of QoS on specific application. This section summarizes the work that has been done on cross-layer multipath protocols, for WMSNs.

Multipath Routing: During the discovery stage, this type of routing technique is used to get separate path from the source node to the sink [8]. Different type of layer combinations are produced in this type, such as transport layer and network layers in [8-9], application layer, network layer, and MAC layers [10-13], application layer and network layers in [14-15], and network layer and MAC layers in [16].

A protocol that combined a cross-layer concept with context awareness is proposed by [9]. The aim of this protocol is to maximize the important information collected, instead of maximizing the throughput. It is called Multi-Path Multi-Priority transmission (MPMP) protocol, which splits video streams from the audio. At network layer, it uses Two-Phase Geographic Greedy Forwarding (TPGF) algorithm to discover the largest path from source node to sink node. Further at transport layer, a Context Aware Multi-Path Selection algorithm (CAMS) is used to select the largest number of disjoint paths. The most important stream is assigned to highest priority and to the best routing path that guarantees minimum end-to-end delay.

A Minimum Hop Disjoint Multipath routing algorithm with Time Slice load balancing congestion control scheme (MHDMwTS) is proposed by [8]. It uses a minimum hop to reduce the delay and to increase the reliability in WMSN. Minimum Hop Disjoint Multipath routing algorithm (MHDM) is built upon three disjoint paths: primary path, alternate path and backup path. This algorithm has two phases: path build up phase and path acknowledgment phase. The primary path is the first package that reaches the sink, and it has the least delay. A comparison is done between the new package and the primary path. The result is discarded if the joint node is present and further the alternate path is build up. At path acknowledgment phase, sink sends the acknowledgment message to the source (ACK), which contains the path and time information. When sink node allocates time, (called the time slice for the path) primary path usually takes more time than others. Each path takes a time slice. If it is up, then the sink switches the transmit data to another one. MHDMwTS protocol reduces the end-to-end delay, controls and prevents the congestion.

In a study conducted by [10], [11], few protocols are proposed considering the constraints such as bandwidth, end-to-end delay and reliability. The architecture consists of multiple components: Traffic classifier module, which classifies the types of frames, application layer which encapsulates the parameters like frame type, frame priority, and the group of pictures size (GOP size), to the header of the frame and sends the frame to the route classifier module. The route classifier module, uses three disjoint paths, that can reach the QoS requirements by using the multipath routing algorithm. The source increases the GOP size, when the required bandwidth is not available. MAC layer uses prioritized scheduling, to access the medium.

Two protocols for heterogeneous networks are proposed by [12], [13], which are named MEVI and video-aware MM transmission, where camera nodes (CN) are the cluster heads and sensor nodes (SN) are the members. At network layer, a multi-hop hierarchical routing is used: the intra-cluster communication between the members and its cluster head (CH) follow the TDMA schedule. This inter-cluster communications between CHs and the sink, create disjoint path routes to the sink, further they classify these routes based on residual energy, hop count and link quality. At application layer, the task of classifying the frame into I-frame, P-frames and B-frames are done, where I-frame is given the highest priority than other two types. The aim of video-aware MM transmission protocol is to balance the load and to enhance the video quality.

A cross-layer QoS architecture proposed by [14], which provides a very good understanding of this architecture. The study used packet marking algorithm at the application layer, which serves to mark the traffic based on its priority. The multipath algorithm at network layer classifies the packets into different colours such as green, red and yellow, in order to distribute the packets in different paths. The shortest path is assigned to the green packets that requires high quality transmission. Further alternating path are assigned to the red packets, considering the level of gy. Yellow packets are allocated to the path considering the level of quality and its distance to the sink. In order to avoid communication overhead, the architecture stores the important information from each layer in a shared database.

Cross-layer and multipath based video transmission scheme (CMVT) is the protocol proposed by [15]. At the application layer, MPEG-4 is used, to encode the video and the frame is marked with video type. At network layer, two main components are route discovery and data transmission. Route discovery discovers all possible routes from source to the sink, and data transmission estimates all paths and categorizes them into three categories based on evaluated value, frame type (assigned the frame to the path) and priority (where higher priority frame is assigned to best path).

A Cross-Layer-Based Clustered Multipath Routing (CMRP) is a protocol proposed by [16] for heterogeneous networks. CMRP combines network and MAC layers. CMRP is defined by two threshold values: upper and lower threshold. These are used to select the upper cluster heads of 1st level and node members. Later it establishes a link between all cluster heads by using the lower thresholds. The 2nd level cluster head will be selected toward the sink, and create a multipath routing. Further, sorting is done on these paths based on different criteria such as delay, hop counts, bandwidth, and link quality. The best paths are reserved for multimedia data, and the remaining paths for other data type. At MAC layer, TDMA with time slot is used, which gives the highest priority for multimedia data.

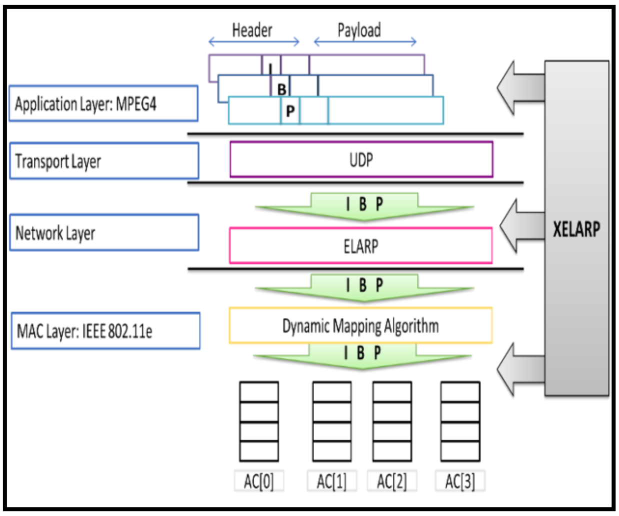


Fig. 1: XELARP Architecture.

3. Cross layer energy location aware routing protocol (XELARP)

Cross-layer: Energy Location Aware Routing Protocol (XELARP) is build based on cross-layer concept, where application, network and MAC layers cooperate together to enhance the work performance and achieve the QoS needed by the wireless multimedia sensor network. Fig. 1 shows the XELARP architecture and its processes are shown in Fig. 2.

XELARP uses MPEG-4 in application layer where frame type, frame priority, and GOP size (group of pictures size) encapsulates to the header of the frames and later passes these frames with their priority mark to the network layer. Network layer discovers three paths from source to sink with ELARP protocol proposed in [5]. MAC layer uses the information in the header by dynamic mapping algorithm to map the frame based on their video types and the network traffic load.

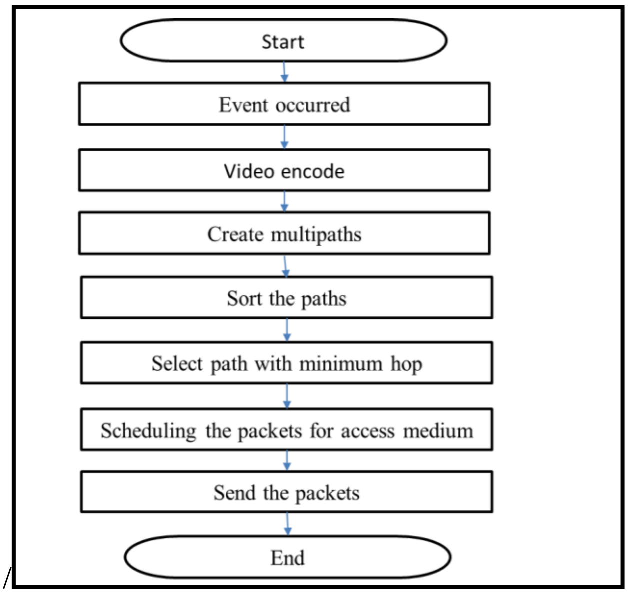


Fig. 1: XELARP Processes.

3.1. XELARP model

A network composed of N different heterogeneous sensor nodes distributed randomly in a specific flat area as shown in Fig. 2. This network has one sink node which has special capabilities that are different from other nodes. Sink node is always in ON state and is immobile. The network also has video and audio sensor nodes for multimedia sensing. All these nodes are mobile nodes with random movements and same speed in the network area. They have same transition range and all nodes have access to neighbor's information such as energy and location.

3.2. Application layer

MPEG-4 is a video structure that consists of three frame types: Intra-coded frame (I-frame), Predictive-coded frame (P-frame) and Bi-directionally predictive coded frame (B-frame). According to coding relationship in MPEG-4 structure and the dependent relationship between frames in encoding or decoding [17, 18], losing one I-frame will affect all frames in the same Group of Picture (GOP). As a result, this will affect the quality of video. Losing B-frame will affect the frame itself. So, I-frame is the most important type of frames, while P and B-frames have less significance. Application layer classifies the frames to I, B, and P types. Then encapsulates the frame type, frame priority, and GOP size in the header. Application layer passes these frames with their priority mark to the network layer.

3.3. Network layer

ELARP [5] is a multipath routing protocol. It is reactive routing protocol where the path is discovered, only when a node has data to send. The reactive approach is more suitable for WMSN to avoid energy consumed for creating and maintaining the routing table, and also to avoid control messages overhead. ELARP discovers multipath with awareness of remaining energy and location of the node. The overhead is reduced and energy is conserved by selecting only three paths based on their weights. Intermediate node selects only one node to complete the path, sink node is a special node which will be selected as a next hop, without checking the whole neighbour list.

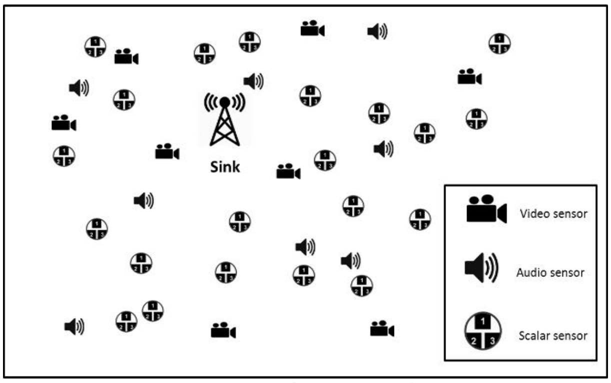


Fig. 2: Simulation Network.

3.4. MAC layer

IEEE 802.11e [19] Enhanced Distributed Channel Access (EDCA) provides four different traffic types. They are voice traffic (AC[0]), video traffic (AC[1]), best effort (AC[2]), and background traffic (AC[3]). A differential service scheme is used to improve the quality of video by giving high priority to the most important frame.

MAC layer is responsible for scheduling the packets that come from the network layer to access the media. According to the priority information that is marked in application layer, and the network traffic load determines the suitable allocation of ACs. So, XELARP uses dynamic mapping algorithm [20] instead of static mapping to allocate the frame into appropriate AC queue. The dynamic mapping algorithm provides different probabilities for mapping. Different probabilities Prob_TYPE, are assigned to different types of video frames, according to its coding significance. All Prob_TYPE values are between 0 and 1. Assigned large Prob_TYPE to less important video frame types, where Prob_B>Prob_P>Prob_I, with Prob_B holding the highest probability. Also, the dynamic mapping algorithm provides two types of threshold: threshold_low and threshold_high, which controls the congestion. Now the congestions are predicted by managing the queues, followed by predefining the probabilities for all video frame types. Later, the new threshold (Prob_New) is calculated according to Equation (1). This value is based on threshold values and queue length. Prob_New with higher value has greater chance to map into a lower priority queue.

$$Prob\_New = Prob\_TYPE * (qlen(AC[2]) - threshold\_low) / (threshold\_high - threshold\_low) \quad (1)$$

Where Prob_TYPE is the probability of each type of video packet such as Prob_I, Prob_P, and Prob_B, threshold_low and threshold_high are lower and upper threshold of the queue, qlen(AC[2]) is the length of queue of video category and Prob_New is the new probability.

4. Performance metrics

Different performance metrics are used to evaluate the performance of proposed protocol. These metrics are generic for both

WSNs and WMSNs protocols, and some are specific for multimedia sensor networks protocols.

4.1. General performance metrics

- Packet Delivery Ratio: It is the ratio between the total numbers of packets received by the sink, divided by the total number of packets sent by the source node.
- Average energy consumption by all nodes is calculated by the total energy that is consumed by all nodes, divided by total number of nodes.
- Average residual energy for all nodes is calculated by the total residual energy in all nodes, divided by total number of nodes.
- Network Lifetime: It is the duration of time, from when the network was deployed until the first node dies.
- Jitter: It is the variation delay of receiving packets.
- Drop Packet: It is the number of packets dropped.
- Throughput: It is the number of bits per second that are delivered to the destination.
- End-to-End Delay: It is all possible delays of the packet that are translated from source to destination.

4.2. Multimedia performance metrics

Two main performance measures are used for WMSNs:

- Frame Loss: It is the number of frames lost in each type of video frame I, P and B. Usually; I-frame is given more consideration than other type of frames.
- Peak Signal-to-Noise Ratio (PSNR): It is a measure for video quality. It can be also said as, a measure of the signal noise by comparing maximum energy signal to corrupting noise. To see the quality of PSNR to the video, mapping has to be done for PSNR to Mean Opinion Score (MOS) levels. where PSNR>37 is excellent and PSNR<20 is bad. When PSNR is in the range 25-31, it is fair.

5. XELARP performance evaluation

XELARP is cross-layered design, which uses ELARP in the network layer. It is analyzed in different scenarios. XELARP protocol is compared against ELARP protocol to see the effect of using cross-layer concept over layered multipath routing protocol. Also, it is compared with other cross-layer protocols such as adaptive cross-layer mapping algorithm for MPEG-4 and video transmission XAODV [20]. Ten runs are conducted for each point and the average is shown. Two main scenarios are used. Firstly, a study is conducted to examine the effect of increasing number of video nodes. Then the effect of increasing network load is observed.

5.1. Network setup

The protocol is simulated using network simulation version-2 NS2 [21] with myEvalvid [22] to test multimedia data transmission.
The network consisted of 50 heterogeneous sensor nodes and one sink node. The number of video and audio nodes varied from 2 to 16. These nodes are distributed randomly in specific area of 100 m x 100 m. All sensor nodes are mobile nodes with random independent movement in the area with speed equal to 5 m/s. The sink node is placed in the center of the field, while the heterogeneous sensor nodes are distributed randomly. There are two events during the simulation time, generated randomly. Table 1 shows 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, IEEE 802.11e
Routing Protocol	ELARP, AOMDV
Initial energy of sensor node	5 Joule
Initial energy of video node	30 Joule

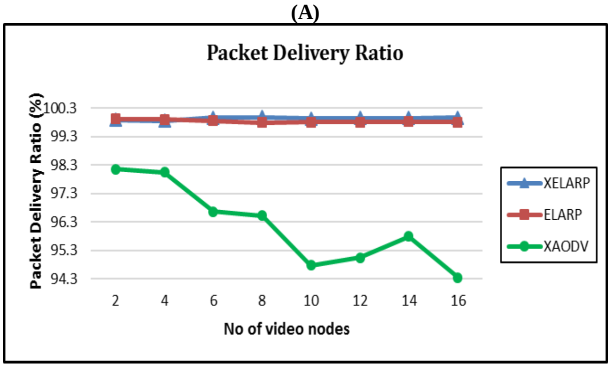
5.2. Results and analysis

XELARP is cross-layered design, which uses ELARP in the network layer. It is analyzed in different scenarios. XELARP protocol is compared against ELARP protocol to see the effect of using cross-layer concept. Also, it is compared with other cross- layer protocols such as XAODV [20].

5.2.1. Ratio of video nodes

To study the effect of changing number of video node, researchers increase the video and audio node from 2 nodes to 16 nodes.
First measure is Packet Delivery Ratio: As shown in Fig. 3, XAODV protocol shows worst packet delivery ratio than ELARP and XELARP. XELARP and ELARP use multipath techniques to increase the packet delivery, while XAODV creates a single path during path establishment. XELARP protocol shows better delivery of packets than ELARP as shown in Fig. 3 (B). Thus, it can be inferred that the cross-layer and dynamic mapping techniques has increased the packet delivery ratio of XELARP.

(A)



(B)

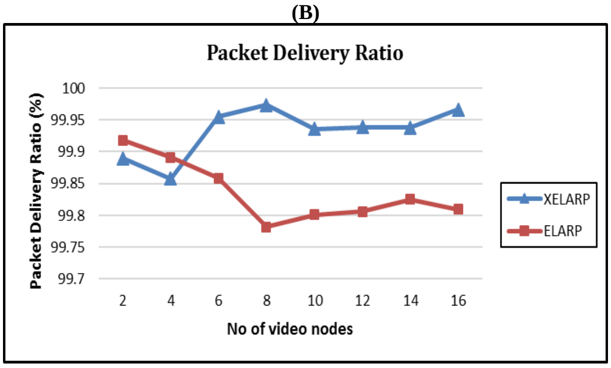


Fig. 3: Packet Delivery Ratio vs. Increase Video Nodes. A) All Compared Protocols B) XELARP and ELARP Protocols.

Average Energy Consumption: Fig. 4 shows how XELARP consumes more energy than other two protocols for different values. XELARP and ELARP consume energy during the path establishment procedure, as it performs some calculation of node weight, update neighbor and block lists. XELARP and XAODV also consume energy to manage the ACs queue at MAC Layer. Fig. 4 shows that increasing in the number of video nodes, also increases the energy consumed by XAODV. ELARP protocol is not affected by increased in the number of video nodes.
Average Residual Energy: XAODV protocol demonstrates better average residual energy than ELARP and XELARP as shown in

Fig. 5. Increase in the number of video nodes, increases the average residual energy for ELARP protocol. Decreasing the average residual energy for XAODV and XELARP protocols, shows a minor effect.

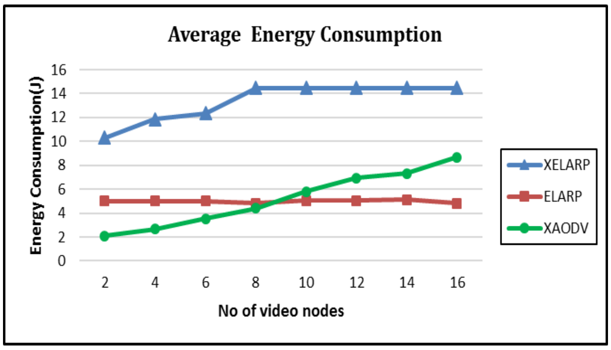


Fig. 4: Average Energy Consumption vs. Increase Video Nodes.

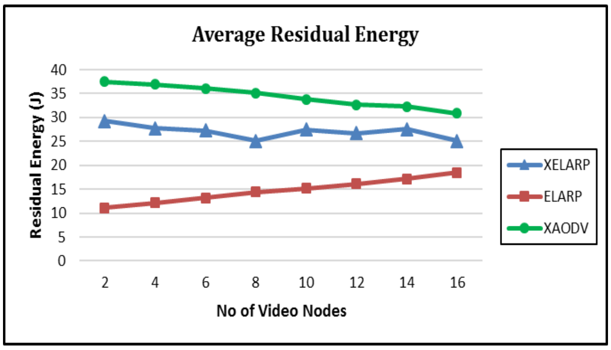


Fig. 5: Average Residual Energy vs. Increase Video Nodes.

Network Lifetime: XELARP protocol was tested with the following values of initial energy for sensor node as 5 J, initial energy for video node =30 J and network simulation = 500 s. During the simulation time, no node perished. To test the network lifetime, researchers reduce the initial energy for sensor nodes to 0.5 J and video sensor node to be 5 J and retested the performance of XELARP, ELARP and XAODV. Fig. 6 shows the network lifetime with the new parameters. XELARP outperforms ELARP and XAODV protocols. Increase in the number of video nodes, decreases the XELARP from 410 to 247J, but ELARP remains stable around 30 J.

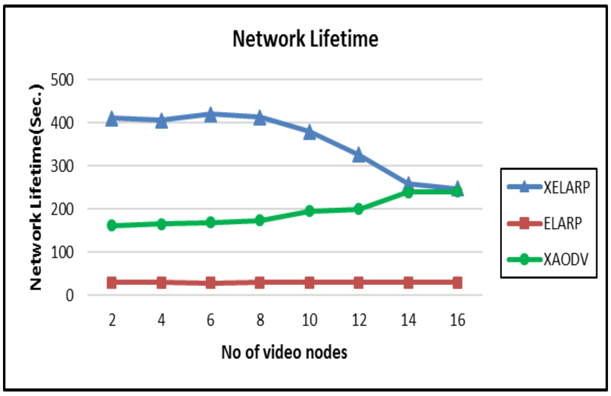


Fig. 6: Network Lifetime vs. Increase Video Nodes.

Jitter:

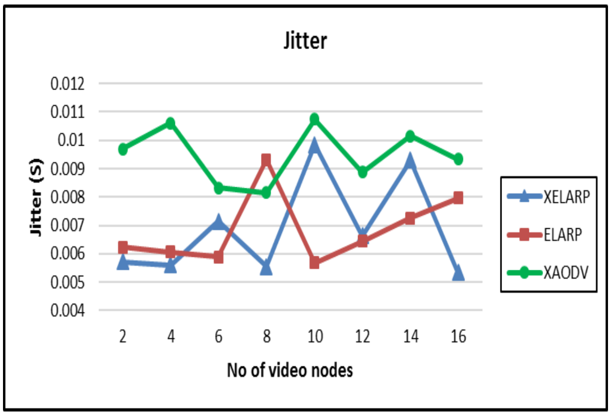


Fig. 7 shows that XAODV protocol has higher jitter than ELARP and XELARP. For all protocols, jitter lies between 0.005 and 0.011 which is almost linear.

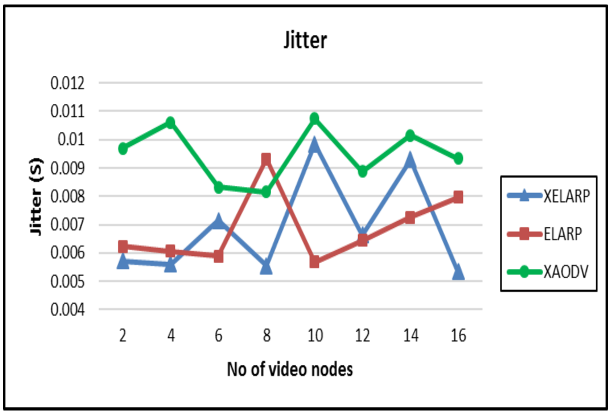
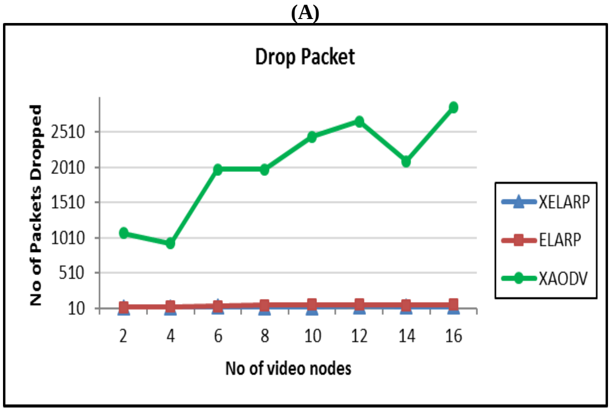


Fig. 7: Jitter vs. Increase Video Nodes.

Packet Drop: XAODV shows maximum packet drop than XELARP and ELARP protocols as shown in Fig. 8 (A). The difference of ELARP and XELARP is shows in Fig. 8 (B) The figure also shows that if the number of video nodes and source nodes increased, the number of packets drop also increased. XELARP uses dynamic mapping algorithm at MAC layer that schedules the packets based on its type and the network traffic, thus reduced packet drop.

(A)



(B)

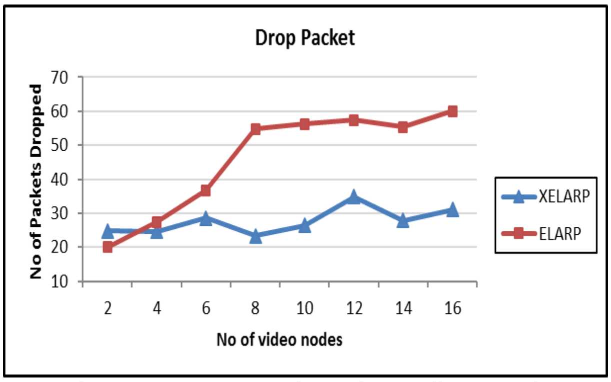


Fig. 8: Packet Drop vs. Increase Video Nodes A) All Compared Protocols B) XELARP and ELARP Protocols.

Throughput: XELARP protocol outperforms the two other protocols in throughput as shown in Fig. 9. XELARP shows a linear throughput, when the number of video nodes are increased.

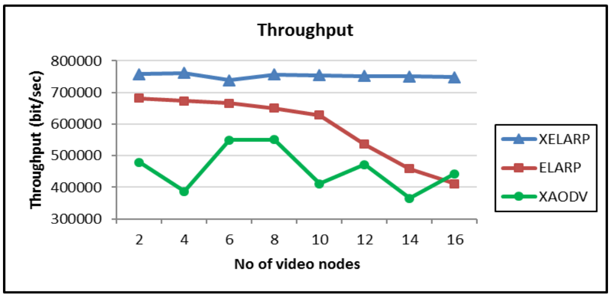


Fig. 9: Throughput vs. Increase Video Nodes.

End-to-End Delay: It is clear from Fig. 10 that XELARP protocol has best end-to-end delay than XAODV and ELARP.

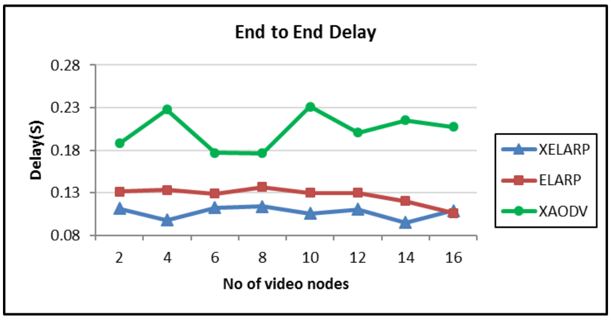


Fig. 10: End-to-End Delay vs. Increase Video Nodes.

I-Frame Loss and Average of PSNR: There is no loss of I-frame for all the protocols XELARP, ELARP and XAODV. The average PSNR = 27.87, which lies in fair MOS level for video quality [23]. The average PSNR for the protocols is not affected, when the number of video nodes are increased.

5.2.2. Events overlap

To study the effect of time overlap of reporting events, video and audio nodes have to be increased from 2 nodes to 16 nodes. Further, the number of video and audio nodes that report events should be amplified. The event starts after 10 seconds of the simulation time. The three cases which are used in ELARP test, are used also here. They are:
Case A: the overlap time is 10 second
Case B: the overlap time is 20 second
Case C: the overlap time is 30 second
By fixing other network parameters, following performance metrics are tested.
Packet Delivery Ratio: Fig. 11 shows the packet delivery ratio in the three cases with different scales. In all cases: XELARP protocol shows best delivery packets, and XAODV shows the worst delivery packets as shown in Fig. 11(A). Fig. 11(B) and Fig. 11 (C) are used to elaborate the results due to scale of Fig. 11(A). ELARP has better delivery ratio than XAODV in all three cases as shown in Fig. 11(B). Fig. 11(C) shows XELARP in case B and C is more stable but in case A the result is different. It shows that the packet delivery decreases, when the network load and number of video nodes increases.

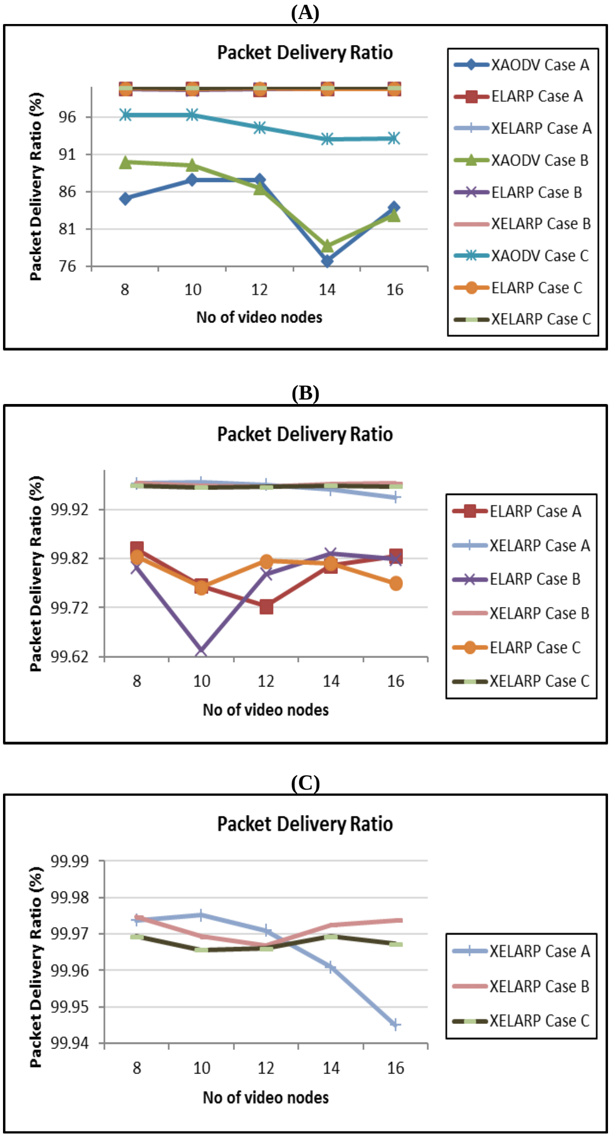
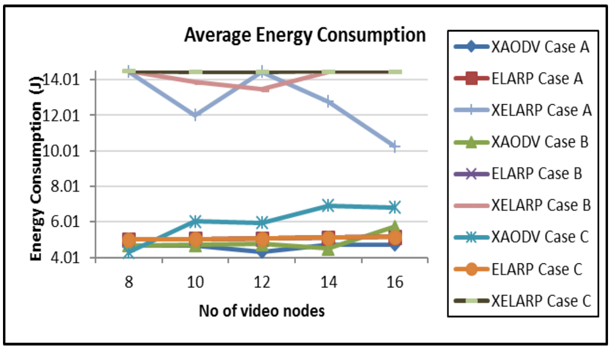


Fig. 11: Packet Delivery Ratio vs. Events Overlap. A) Packet Delivery Ratio for All Protocols. B) Packet Delivery Ratio for EALRP and XELARP. C) Packet Delivery Ratio for XELARP.

Average Energy Consumption: Fig. 12 shows the energy consumption in different scales to present the difference between compared protocols. In all three cases, XELARP protocol shows higher energy consumption than other protocols, as shown in Fig. 12 (A). ELARP protocol in all cases shows identical and linear energy consumption as shown in Fig. 12(B). It shows higher energy consumption and also demonstrates sharp increase in XAODV than ELARP in case C.

(A)



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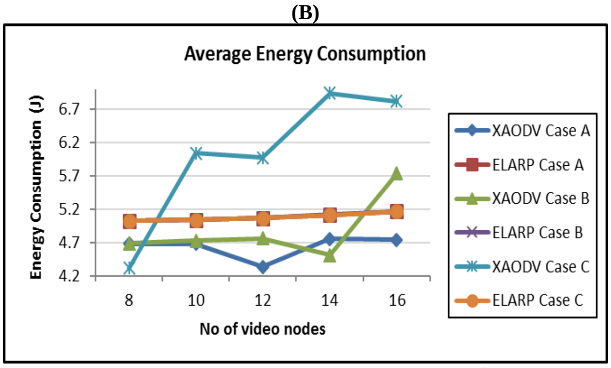


Fig. 12: Average Energy Consumption vs. Events Overlap. A) Average Energy Consumption for All Compared Protocols. B) Average Energy Consumption for XAODV and ELARP Protocols.

Average Residual Energy: Fig. 13 shows that XAODV in case C has higher residual energy. XELARP protocol shows better average residual energy than XAODV (case A and B) and ELARP, in all cases. ELARP in all cases shows identical and uniform increase in residual energy. XAODV case A and B show linear and minimum residual energy.

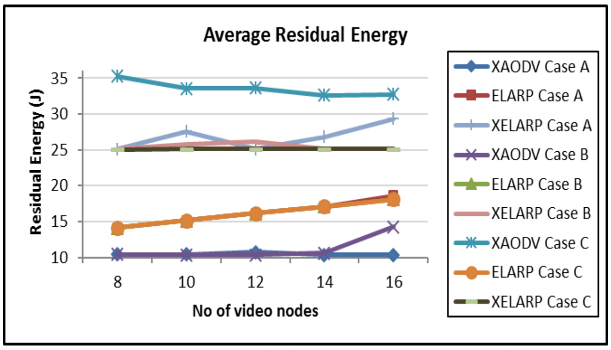


Fig. 13: Average Residual Energy vs. Events Overlap.

Network Lifetime: Due to long lifetime of nodes with default network parameters used in the experiment, researchers uses initial energy for sensor node is changed to 0.5 J and video sensor node is 5 J. Fig. 14 shows that XELAP has highest network lifetime in all cases when compared to the other two protocols. Increasing the number of video nodes, decreases the XELARP network lifetime. ELARP protocol in all cases shows identical and linear and shortest network lifetime. XAODV lifetime is higher than ELARP but less than XELARP protocol.

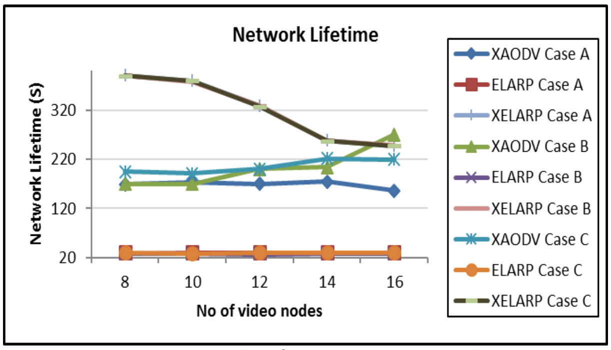


Fig. 14: Network Lifetime vs. Events Overlap.

Jitter: Fig. 15 shows that XAODV has higher and increasing jitter in all cases. XELARP protocol shows improvement in jitter over other protocols.

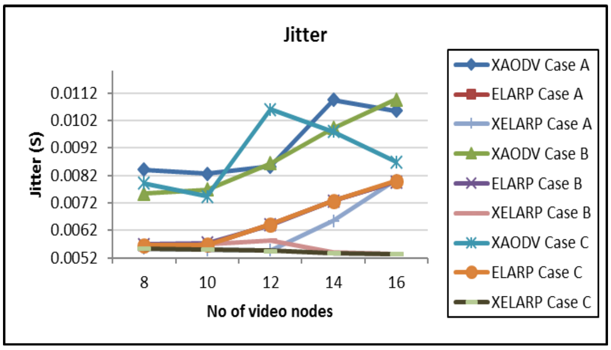
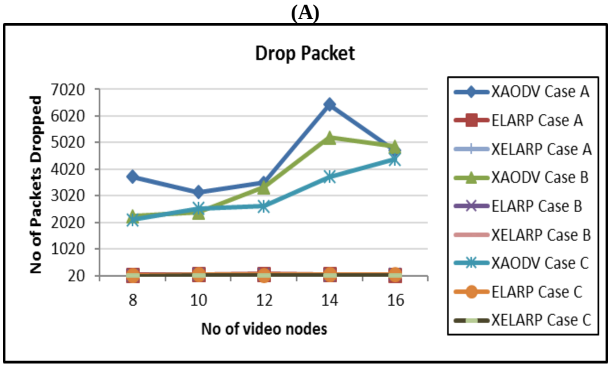


Fig. 15: Jitter vs. Events Overlap.

Packet Drop: Fig. 16(A) shows that in each case XAODV shows high packet drop. When the number of video nodes increased, the number of packet drop also increased. In Fig. 16 (B) the scale is changed, to show the difference between protocols in different cases. Fig. 16(B) shows that XELARP protocol shows minimum packet drop than other protocols. ELARP in case B is more stable than other cases. XELARP in all cases shows stable and linear drop packets.

(A)



(B)

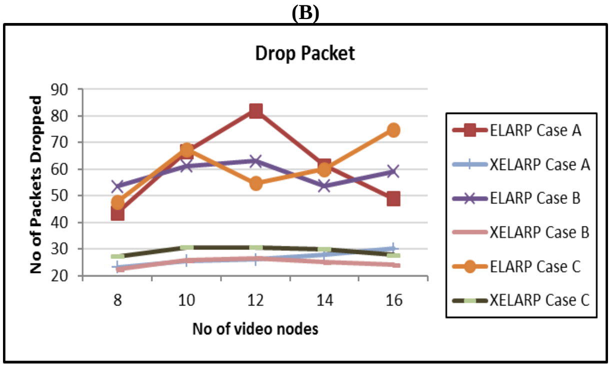


Fig. 16: Packet Drop vs. Events Overlap.

Throughput: XELARP protocol shows maximum throughput than ELARP and XAODV in all cases as shown in Fig. 17. ELARP and XAODV protocols show considerable decrease in throughput when the number of video nodes are increased.

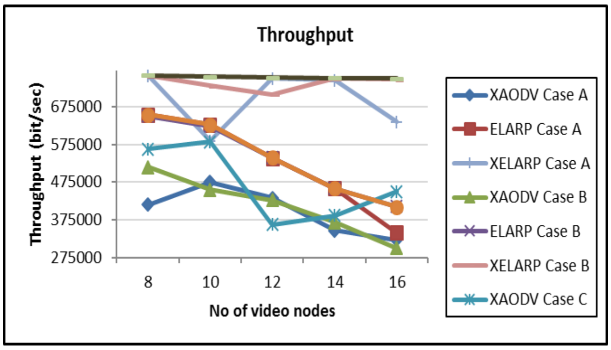


Fig. 17: Throughput vs. Events Overlap.

End-to-End Delay: End-to-end delay has an improvement in XELARP over ELARP and XAODV protocols as shown in Fig. 18 .XELARP's end-to-end delay is identical and linear for the three cases. ELARP protocol has an identical and linear end-to-end delay but it is higher, when compared with XELARP. XAODV shows highest end-to-end delay over other protocols.

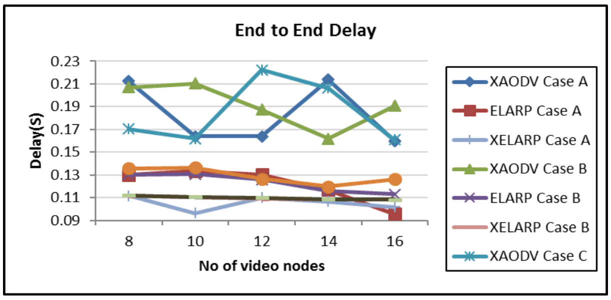


Fig. 18: End-to-End Delay vs. Events Overlap.

I-Frame Loss and Average of PSNR: The average PSNR for all protocols in all cases is not affected by increase in the number of video nodes and network load. There is no loss of I-frame when the average PSNR = 27.87. Thus, this value represents fair quality of the video.

6. Conclusion

WMSNs require QoS in terms of end-to-end delay, energy consumed, and guarantee data delivery. XELARP is cross-layer protocol using three layers: application, network and MAC layers. These layers integrate, collaborate and exchange information among them to efficiently satisfy the QoS required for the multimedia transmission in WMSNs.

Applying the ELARP protocol in cross-layer concept enhances the performance of ELARP protocol. To summarize the experiment results where XELARP is compared with all other protocols, it can be said that:

XELARP outperforms both XAODV in cross layer environment and ELARP protocol, which is layer architecture in packet delivery and end-to-end delay which, are the most important performance metrics required by WMSNs. Regarding network lifetime, XELARP has improvements over the other two protocols. Because XELARP uses EALRP routing, which is more reliable than link disjoint multipath. Node sharing is not permitted between two paths to save node energy and to reduce overhead on shared node. ELARP also consider the energy and distance, during selection of next node. Cross-layered and ic mapping algorithm, that is used by XELARP reduces the packets drop and end-to-end delay, increases the throughput and also raise the packet delivery ratio.

XAODV outperforms ELARP in some parameters as energy consumptions by 15% to 80% in some points, and residual energy by 67 % in some points. XAODV outperforms XELARP in energy consumptions by 66%, and residual energy by minimum 14% and maximum 29%.

XELARP and XAODV outperforms ELARP in I-frame loss and PSNR. This is because the two protocols use the ic mapping algorithm in XELARP and XAODV, which gives priority to video frame.

As a future work, the proposed protocol may be enhanced by clustering nodes to save node energy, use all three paths to send the data and assign best path to multimedia data. The proposed protocol used block list mechanism, where the node adds itself to the block list when its neighbor list is empty. This leads to path lost. This problem can be solved by using the rollback mechanism, where the node will not be considered as the part of the path, until few conditions are satisfied. The node has at least one neighbor to avoid holes and minimize delay.

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