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Multipath Routing with Dupes Group in Wireless Multimedia Sensor Networks

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Abstract : **In the today's digital world, the importance of multimedia applications is increasing gradually in situations like visual target monitoring, video surveillance systems, smart home, military security systems, commercial systems etc. Wireless Multimedia Sensor Networks (WMSNs) are the technologies to collect and transmit the multimedia data required for these applications. The major challenge in WMSNs is to run these multimedia applications smoothly without compromising for minimum Quality of Service demands. One of the possible solutions is to run node-disjoint multipath routing protocol to achieve the target quality demands of these multimedia applications. This paper proposes a new protocol MPR-Dupe Group, a node-disjoint multipath routing protocol to improve the smooth delivery of multimedia data from a source node to sink node in WMSN. The performance analysis of the proposed work shows the significant improvement in network performance.**

IndexTerms - **WMSNs, multipath routing, AODV, multimedia data transmission.**

1. Introduction

In WMSN, the sensor nodes are equipped with cameras to capture the photos and videos from the surrounding coverage area of the network. The captured data is transmitted to the sink node for the processing needed by the multimedia applications running over the network. WMSNs are very popular in deploying the multimedia-based network applications like monitoring environment, visual target object monitoring, city surveillance system with video cameras, smart home appliances, health care monitoring systems making use of images and videos, etc[1]–[7]. WMSNs are different from the traditional Wireless Sensor Networks (WSNs) in the sense that the nodes in WSN are able to capture scalar data only but the nodes in WMSNs are able to capture images, videos and audios along with scalar data. As shown in figure 1, the sensor nodes are placed as per the constraints of the applications in WMSN so that they can capture the multimedia data from the surrounding areas. The captured data must be processed further to be useful to the application. The sensor nodes have to transmit the captured data to the sink node for processing. In-time delivery, reliable and secure transmission of multimedia data from the source node to the sink node is critical in improving the performance of multimedia application running over the network.

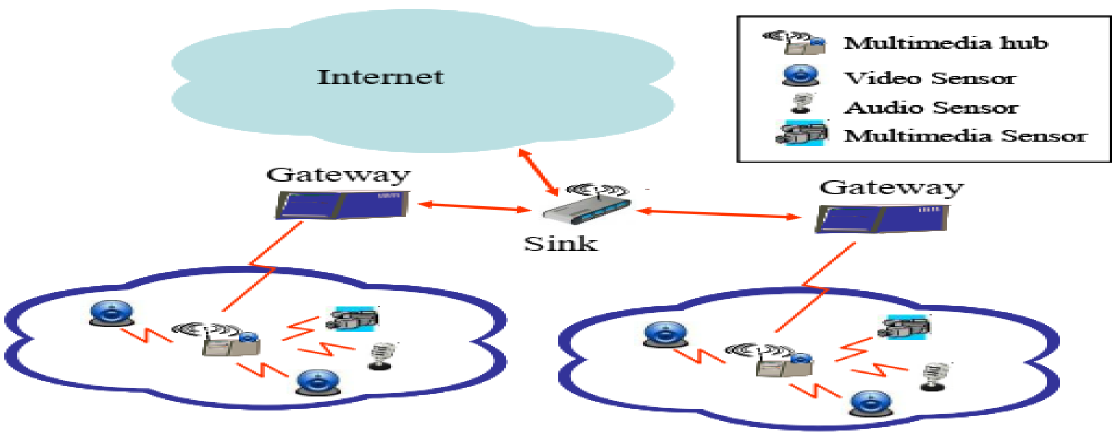

Figure 1. WMSN Architecture [8]

1.1Importance of MPR

The routing protocols play an important role in improving the performance of multimedia applications running over the network. Routing protocols discover the data transmission path as per certain criteria between a pair of nodes in the network. The research challenges in designing the routing protocols for WMSNs include limited battery power of sensor nodes, limited processing capabilities, node mobility, varying wireless link quality, error prone wireless links etc. Researchers proposed several routing protocols[5], [9]–[18] to improve the data transmission throughput, data delivery delay etc. Most of the previous work focused on improving the battery life of sensor nodes. Energy efficient routing protocols were proposed by the most of the previous work. It is also mentioned that multipath routing achieves more throughput compared to unipath routing[2]–[4], [19]–[26].

Unlike single path routing, the data is transmitted simultaneously through multiple and different paths between source and destination pairs in multipath routing scheme. Load balancing, security and reliability are few important benefits of multipath routing over unipath routing protocols. Unlike the previous work, this paper proposes a unique multipath routing protocol, MPR-Dupe Group which establishes node-disjoint stable, energy-efficient and reliable multiple paths from a sensor source node to sink node. The protocol MPR-DG discovers node-disjoint multiple paths by forecasting the node's residual energy, traffic load and node's movement in near future. Two paths, primary and secondary paths are selected for data transmission between the pair of communicating nodes. The source node transmits the data through two paths simultaneously but the destination node receives the data from only primary path. The one-hop neighbor node called Dupe node in the secondary path stores all the backup copy of data received from the source node. When the primary path fails in successful data transmission to the destination node due to node failure or link failure or nodes movement, the destination node receives the data from the Dupe node. The simulation analysis of the proposed protocol, MPR-DG, shows the remarkable performance in achieving network throughput, end-to-end data delivery time and energy efficiency.

The remaining sections of the paper are organized as follows: Section 2 presents the review of literature that motivates the proposed work, MPR-DG. The model and algorithm of MPR-DG are given in Section 3. Performance of MPR-DG is analysed using NS2.35 [27][28] network simulator and the results are discussed in Section 4. The concluding remarks of the work are given in Section 5.

2 Literature Review.

The main limitation of unipath routing protocols in WMSNs is the route maintenance. During data transmission, if a node or link failure occurs in the path then the source node tries to find alternate path to transmit the data to the destination node. The data loss occurs until the alternate path is arranged between source and destination nodes. Moreover, time delay in setting up alternate path causes problem to the reliable and timely delivery of multimedia data to the destination node. On the other hand, when the alternate path is readily available, the delay can be minimized and prevents data loss.The researchers suggested to use multiple data transmission paths from the sender node to receiver node for the smooth delivery of multimedia data in WMSNs [3], [24], [25], [29]

Multipath routing has two variations: node-disjoint and link-disjoint. As shown in Fig. 2a, no common nodes present in multiple paths in case of node-disjoint multipath routing. Similarly, in link-disjoint multipath routing, all the links are different but the common nodes might present in multiple paths as shown in Fig 2b.

Node-disjoint paths are preferrable over link-disjoint paths with respect to high throughput, delay, load balancing and security. So most of the research work is done on designing node-disjoint multipath routing protocols for WMSNs [2], [30]–[37].

Authors in [19] proposed a multipath routing protocol using packet priority values in choosing data forwarding paths such that urgent services are accomplished in time with suitable delay. The data packets are classified into four categories based on reliability and real-time application characteristics. A few parameters considered while establishing the paths are available buffer space, residual energy, ratio of packet successful reception, hop-count and delay. But the node mobility is an important factor affecting the network performance which is missing in the work.

Another work [1] focused on improving the QoS requirements of WMSNs applications. The multipath routing protocol achieves load balancing in the network but failed to consider important parameters affecting the network performance such as node mobility, reliability.

Multiple routing paths without common nodes are established using the node trust values in [2]. A few parameters like remaining energy and packet delivery rate are considered to form the trust value of a node. But the node mobility is not considered in the work.

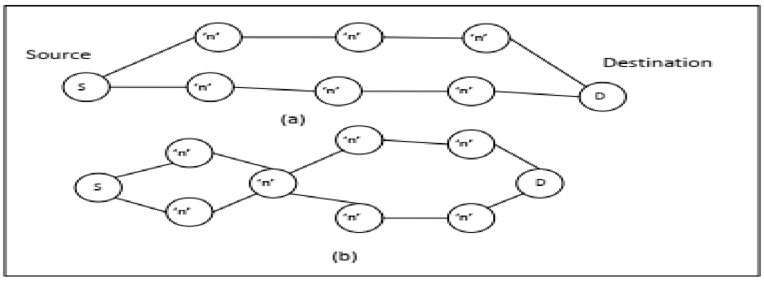

Figure 2: Types of Multipath Routing: (a) Node-Disjoint Routes (b) Link-Disjoint Routes

The multipath data transmission protocol in [24] aimed to balance the network load. To choose multiple paths for transmitting the data, the protocol uses number of hops and residual energy parameters. The protocol considers static nodes and unable to address the issue if the node moves away from the data path.

Authors of [3] proposed a multipath routing protocol that considers link quality, traffic load and node's location while selecting multiple paths for data transmission from sender to receiver. The protocol operates in two phases: first phase deals with setting up of highly reliable paths and load balancing is maintained in the second phase.

In [11] authors designed a geographic multipath routing protocol using a new metric called triangle link quality for establishing the node-disjoint paths that have minimum inter-path interference. The wireless link quality is the major parameter considered in the metric but the protocol doesn't handle frequent node movements while maintaining the load balancing.

Unlike the previous work mentioned above, this paper introduces a different multipath data transmission protocol without common nodes, MPR-Dupe Group, that is more reliable, secure and stable.

3. System Model

The proposed protocol MPR-Dupe Group uses two paths, primary path and backup path, simultaneously to deliver the multimedia data to the sink node from a source node. The dupe node, one-hop neighbor of sink node in the backup path, stores the data but not deliver to the sink node as long as primary path is working well. Moreover, the sink node gives a list of its one hop neighbor nodes to the Dupe node to order them with respect to their efficiency towards data transmission. The dupe node maintains the list of neighbor nodes with the updated values from time to time received from the sink node. Node failure or link failure in the primary path causes failure in successful data transmission to sink node. Then, the sink node receives the data from readily available backup path. The dupe node then comes into action and delivers the data to the sink node. When the dupe node fails in delivering the data successfully to the sink node, then most efficient node in the list of neighbors of sink node becomes the dupe node.

MPR-Dupe Group protocol actually uses AODV routing protocol but no major modifications are done. Existing route request RREQ and route reply RREP packets are used to establish multiple node-disjoint paths between source and sink node. No new packets are introduced in MPR-Dupe Group protocol. The source node broadcasts RREQ to all its neighbor nodes and in turn they forward the packet to their neighbors. This packet forwarding process continues until RREQ reaches the sink node. As per AODV protocol, the intermediate nodes can give RREP if they know path to reach the sink node. But in MPR-DG, only sink node gives RREP and no other intermediate node gives RREP. This condition is implied to preserve node-disjointness property of multiple paths. The sink node gives at least two route replies to the source node. The first RREP establishes primary path and the second RREP gives backup path. The sink node notes down the address of Dupe node while giving the second RREP so that it can contact the Dupe node to receive the data packets when primary fails.

The number of RREPs given by sink node can be increased based on the number of multiple paths required.

The route discovery process is same as AODV and no overhead is introduced in MPR-DG.

Path switching delay is also minimized because the sink node receives the data immediately from the Dupe node in the backup path when the primary path failed.

MPR-Dupe Group protocol uses AODV protocol with little modifications in the process to keep it simple to implement and compatible with other protocols.

Metric Formulation:

To formulate the routing metric of MPR-Dupe Group protocol, the WMSN is modeled as a graph with 'm' edges and 'n' vertices where each vertex represents a node and edge represents a link as shown in Fig.3

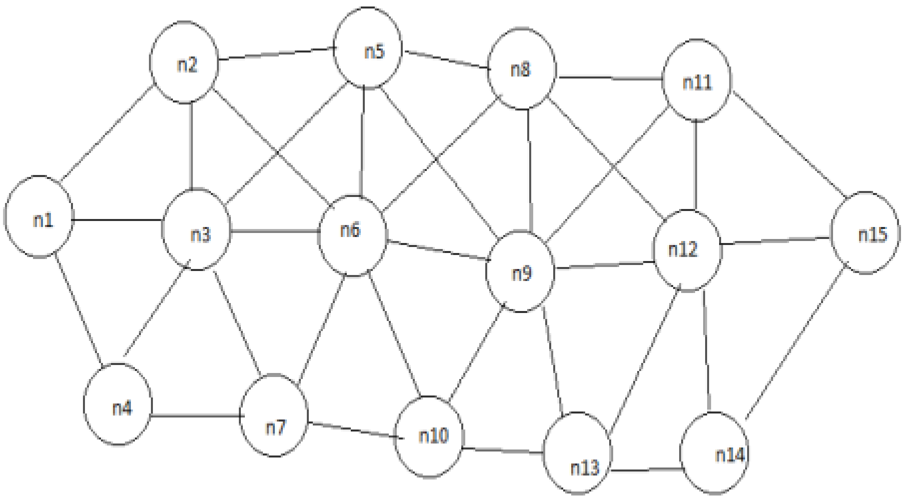

Figure 3: WMSN graph model

Assume that N is the set of nodes and L is the set of links such that

$N = \{n_1, n_2, n_3, \ldots n_n\}$ and $L = \{e_1, e_2, e_3, \ldots, e_m\}$

The objective of MPR-Dupe Group protocol is to establish multiple node-disjoint paths between source and sink nodes as shown in Fig.4

For all the paths discovered by MPR-Dupe Group protocol, the ranks are assigned based on their efficiencies.

When the source node s receives RREP packet from destination node d, the source node assigns a rank to the path p based on the ranks of the nodes $n_1, n_2, \ldots$ present in the path.

$R(p) = \min(R(n_1), R(n_2), \ldots)$ ----------------------------------- (1)

Here R(p) is the rank of path p and $R(n_i)$ is the rank assigned to node n_i.

$R(p) > \omega$ where ω is the threshold value based on the application used in the network.

As per MPR-Dupe Group protocol, the node rank is calculated based on three parameter values: node's remaining battery power, node movement and node's traffic load as follows:

$R(n) = a * EF(n) + b * SF(n) + c * (1 - TF(n))$ ------------------- (2)

where EF(n) is the energy factor of node ‘n’, SF(n) is the stability factor of node ‘n’ and TF(n) is the traffic factor of node ‘n’.

Also, note that three weighing parameters a, b, and c are used such that a + b + c = 1

The values of a,b and c can be changed as per the requirements of application and network constraints.

For example, if the application requires to run for most of the time then the weight of a will be more than b and c. MPR-Dupe Group uses same weights for all three parameters a, b and c because MPR-Dupe Group protocol considers a node which is more stable and sustainable with low traffic load is more efficient.

MPR-Dupe Group protocol forecasts residual energy levels, movements and traffic load of a node to calculate its rank.

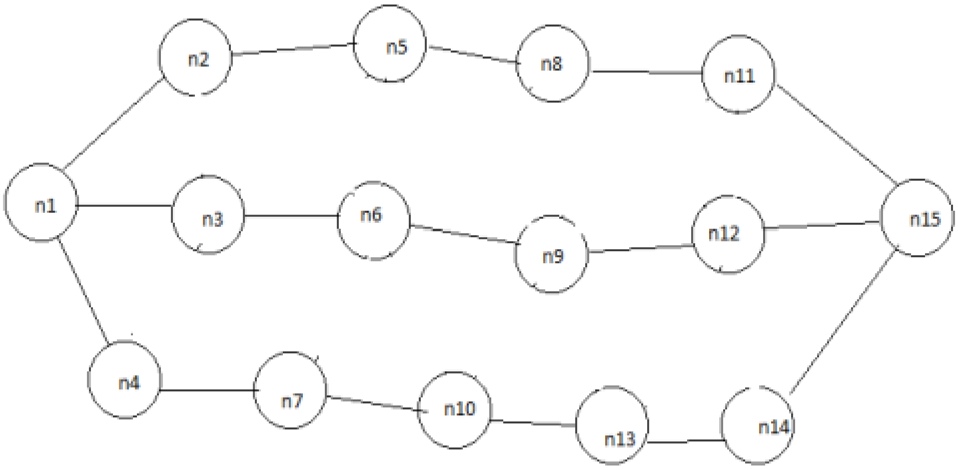

Figure 4: Node-disjoint paths between source and sink node

Forecasting of Residual Energy Levels of a node:

Node residual energy levels determine the life of node in the network. MPR-Dupe Group considers the nodes only with the longest life time duration. MPR-Dupe Group forecasts the life time of a node as follows:

$$EA(n) = IE(n) - EC(n)$$

where EA(n) is the energy available in node ‘n’, IE(n) is the initial energy level of node ‘n’ and EC(n) is the amount of energy consumed by node (n)

$$EC(n) = ECT(n) + ECR(n)$$

where ECT(n) is the energy spent on transmission by the node ‘n’ and ECR(n) is the energy spent on reception by node ‘n’

MPR-Dupe Group calculates EC(n) at time ‘t’ as follows:

$$EC(n)_t = 0.5 * EC(n)_t + 0.3 * EC(n)_{t-1} + 0.2 * EC(n)_{t-2}$$

where $EC(n)_t$, $EC(n)_{t-1}$ and $EC(n)_{t-2}$ are the energy spent by node n at time t, t-1 and t-2 respectively.

MPR-Dupe Group forecasts the life of node ‘n’ for the next six time slots as below:

$$EF(n) = \begin{cases} 1 & \frac{if EA(n)}{EC(n)} \geq 6 \\ \frac{EA(n)}{6 * EC(n)} & otherwise \end{cases}$$

One RTT (round trip time) is considered as one time slot in MPR-Dupe Group model.

Forecasting of Node Movements:

Node movement causes route failure and thereby data loss. MPR-Dupe Group forecasts node movements in future time slots and considers only stable nodes in the path. MPR-Dupe Group protocol adopts node stability model described in [38]. A node with lower average displacement is stable.

$$D(n)_t = \sqrt{(x(n)_t - x(n)_{t-1}) + (y(n)_t - y(n)_{t-1})}$$

where $D(n)_t$ is the displacement of node ‘n’ in time ‘t’, $(x(n)_t, y(n)_t)$ represents the position of node ‘n’ at time t and $(x(n)_{t-1}, y(n)_{t-1})$ is the position of node ‘n’ at time ‘t-1’.

Mobility factory of node ‘n’, MF(n) in time slot t+1 is calculated as moving average

$$MF(n)_{t+1} = 0.5 * D(n)_t + 0.3 * D(n)_{t-1} + 0.2 * D(n)_{t-2}$$

MF(n) for the next 6 time slots is calculated as follows.

$$MF(n) = \begin{cases} 1 & if \frac{TR(n)}{MF(n)_{t+1}} \geq 6 \\ 6 * MF(n)_{t+1} & otherwise \end{cases}$$

where TR(n) is the transmission range of node(n). MPR-Dupe considers TR(n)=250 meters in the simulation analysis.

Forecasting of Traffic Load:

Most of the applications of WMSN are delay-sensitive. If an intermediate node has more packets to forward, then it results in delay. MPR-Dupe Group protocol considers the nodes only if they have less traffic load. Traffic load of a node is determined by its queue size.

$$TLF(n) = 0.5 * NTL(n)_t + 0.3 * NTL(n)_{t-1} + 0.2 * NTL(n)_{t-2}$$

where $NTL(n)_t$ is the normalized traffic load of n at time 't' and it is given by

$$NTL(n)_t = \begin{cases} 1 \; if \; routing \; queue \; size \; is \; full \; at \; any \; moment \; in \; time \; interval \; t \\ MQL(n)/CQ(n) \quad otherwise \end{cases}$$

where MQL(n) is maximum queue length of node 'n' and CQ(n) is the current queue size of node 'n' at time 't'

4. Performance Analysis

The performance of MPR-Dupe Group is analyzed using widely used network simulator NS2.35 [27] and the simulation output of MPR-Dupe Group is analyzed in contrast to the AOMDV protocol [39] as MPR-Dupe Group protocol is based on AODV.

Simulation Setup

The wireless multimedia sensor network simulation environment is set up with the parameter values as shown in Table 1.

Table 1: Simulation Parameters

Simulation Parameter	Value
Sensing area size	2550 X 100 m^2
Propagation model	Two-ray ground model
Antenna	Omnidirectional antenna
MAC protocol	802.11
Simulation time	300 seconds
Number of sensor nodes	26
Sensor Mobility	Random Way Point Mobility Model
Transmission range	250 meters
Transmission rate	0.5 Mb
Initial energy	1000 units
Idle power	1.0 units
Receiving power	1.0 units
Transmission power	2.0 units
Packet size	1000 Kbits

Results Analysis:

As shown in Fig.5, average end-to-end delay of MPR-Dupe Group is improved comparatively than AOMDV as MPR-Dupe Group considers traffic load factor of intermediate nodes while setting up the paths between source and sink node.

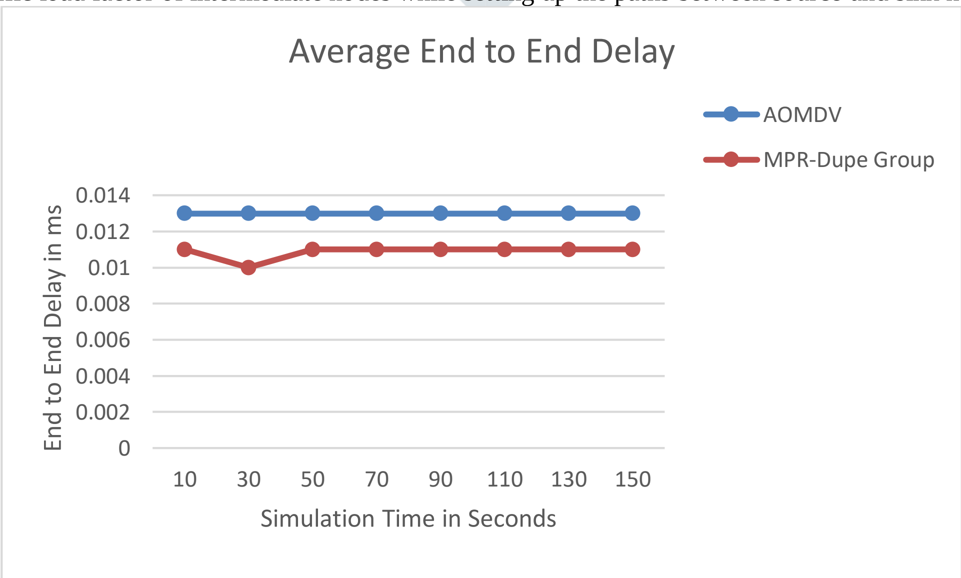

Figure 5 Average End to End Delay

As shown in Fig.6, overall network performance of MPR-Dupe Group seems to be high compared to AOMDV as the MPR-Dupe Group protocol selects most reliable, stable and energy efficient routing paths from sender to receiver nodes.

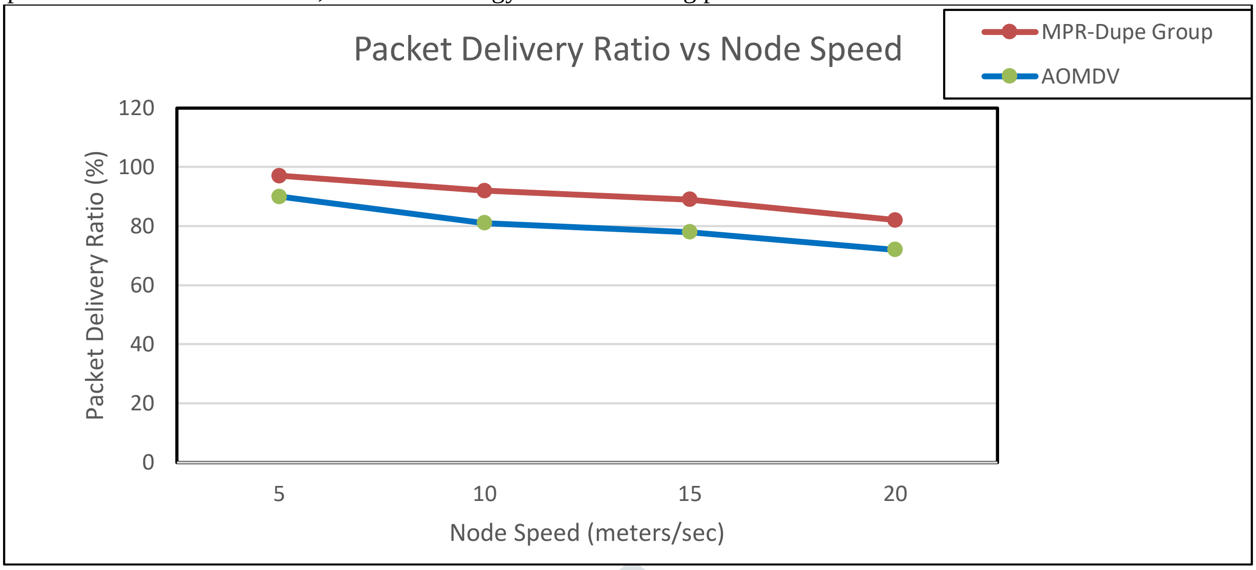

Figure 6. Packet Delivery Ratio vs Node Speed

As shown in Fig 7, network life time is more when MPR-Dupe Group protocol is used to select energy efficient nodes in the path. AOMDV protocol simply establishes multiple node-disjoint paths that are shortest from source to destination.

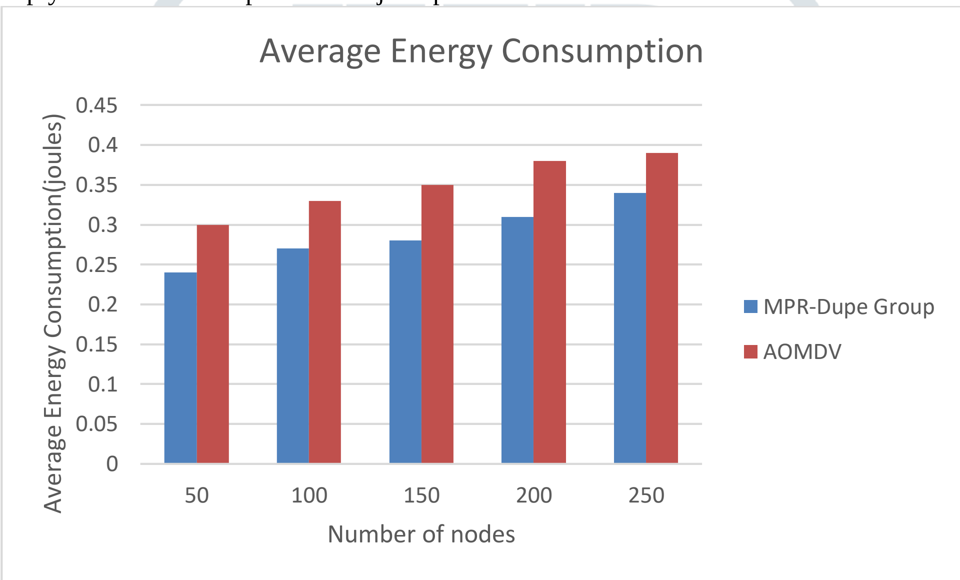

Figure 7. Average Energy Consumption

Even when the sensor nodes are moving, MPR-Dupe Group protocol outperforms the AOMDV protocol because MPR-Dupe Group protocol considers node mobility factor as decision parameter to setting up multiple paths between source and sink nodes.

5. Conclusion

Wireless Multimedia Sensor Networks have most widely used multimedia applications such as visual target monitoring, smart surveillance etc. These applications need QoS guaranteed performance. This paper proposed a novel and unique node-disjoint multipath routing protocol called MPR-Dupe Group based on AODV protocol. This protocol is simple to implement and highly effective in improving network life time, delivering multimedia content with the predefined delay threshold and also handles moving sensor nodes. Simulation results showed that MPR-Dupe protocol achieves significant improvement in network performance.

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