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COMPARATIVE ANALYSIS OF MESH-BASED MULTICAST ROUTING PROTOCOLS ON QOS PARAMETERS USING ENERGY MODEL

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Abstract

Energy is a critical resource for mobile devices as it determines the stability of a network and affects the packet delivery ratio (PDR) in Mobile Ad-hoc Networks (MANETs). ODMRP and CAMP have been analyzed by only a few researchers earlier and most of the studies compare them using the Quality-of-Service parameters including throughput, PDR and latency, by varying the network size, number of senders and node speed. This paper adds a new dimension of energy utilization to the analysis by examining these two popular protocols using their energy efficiency and related parameters such as hop count and control overhead. The two protocols have been simulated and monitored here using NS3 tool which has not been used in previous researches for multicast routing protocols. The tool provides a scalable realistic environment with result analysis capability and it allows addition of modules for new protocol implementation. Secondly, the paper performs statistical comparison of the two protocols using non-parametric test for statistical confirmation of the simulation results. The outcomes of the analysis show CAMP to perform better in all dynamic scenarios for energy metric except in changing node speed. The results are derived after using an underlying demand based unicast routing protocol for CAMP implementation not used in earlier implementations. The analysis results of this research may be used by the network administrators to choose appropriate multicast routing mechanism where network stability cannot be compromised due to limited energy.

Keywords:

Multicast Routing, MANET, CAMP, ODMRP, Performance Analysis

1. INTRODUCTION

Multicast routing in MANETs involves some significant challenges as the nodes keep moving, often leading to link failures that make paths unavailable and packet drops by the originator nodes. This causes a low Packet Delivery Ratio (PDR) [1], [2]. Moreover, the nodes may join or leave a multicast group at any time that modifies the group structure. Yet, multicast transmission is preferred over unicast as the former saves the bandwidth of the ad hoc networks that are pressed by low battery power and bandwidth constraints. MANET's mesh multicast routing protocols perform better and are more robust than tree-based protocols as they provide alternative paths between originator and destination nodes [1]. ODMRP and CAMP are classical mesh-based protocols and differ in their working with respect to data forwarding; ODMRP has an on-demand (reactive) component, uses forwarding group and is immune to route failures under node mobility [3] [4]; CAMP uses core nodes and is known to avoid flooding to forward data packets [5]. The intention of this research is to emphasize on the benefits offered by these protocols from performance perspective and suggest their limitations for future improvements. Though comparative simulation studies have been done earlier also involving these protocols, the energy consumption-based comparison has not been described by the researchers for the ad hoc networks containing larger number of sources and receivers. In our study, we compute average energy consumption and average hop-count, apart from other simulation parameters such as PDR, control overhead and end-to-end delay for these two routing protocols. Furthermore, an on-off application has been used here for simulating different types of traffic.

The outline of the paper is given below: Section 2 describes related simulation based comparative studies done in the past. The working of ODMRP and CAMP is explained in Section 3. Section 4 states the simulation setup, followed by simulation results in Section 5. Section 6 describes the statistical analysis of the simulation results obtained, followed by discussion of the results in Section 7 and then Conclusion and Future Work in Section 8.

2. RELATED WORKS

The mesh multicast routing protocols where the sender starts the mesh formation process include On Demand Multicast Routing Protocol (ODMRP) [3], [4], Dynamic Core based Multicast routing Protocol (DCMP) [6] and Neighbour Supporting Multicast Protocol (NSMP) [7] along with their extended versions in [8]-[12]. The ones where receiver may begin the creation process of multicast mesh include Core-Assisted Mesh Protocol (CAMP) [5] and Forwarding Group Multicast Protocol (FGMP) [13]. MANET routing has been studied by researchers in differing scenarios using different simulation tools and environments such as in the works by Lee et al. [14], Kaushik et al. [15] and by Moustafa and Labiod [16]. Singal et al. [17] have considered signal strength as the QoS parameter to compute link stability for constructing route and compared ODMRP and E-ODMRP, under changing node speeds in Exata-Cyber v2.0. Omari et al. [18] have evaluated performance of MAODV and ODMRP to see the effect of changing traffic load models. Viswanath et al. [19] have used different scenarios to study ODMRP and showed that ODMRP offers high packet delivery ratio under high node mobility and heavy multicast traffic load. Alexandros V. et al. [14] have evaluated MAODV and ODMRP by altering the network traffic, area, mobility and antenna range in the simulation scenarios. ODMRP shows superior results for large areas and elevated node mobility but its performance degrades in case of small antenna ranges. MAODV has exhibited better results for dense traffic. Lee et al. [14] have compared AMRoute, ODMRP, AMRIS and CAMP in NS2 and have done the systematic comparison of ODMRP and CAMP, apart from the protocols' developers. Their results show that CAMP performance gets degraded under high traffic load as compared to ODMRP. ODMRP showed better results in most of their experiments, under the parameters of mobility and network traffic load. They evaluated PDR and metrics such as control bytes (including packet headers) transmitted per data byte, control overhead and total control overhead, recommended as a measure by MANET IETF working group [20]. No other studies have exclusively done analysis on these two protocols, on all the parameters together chosen in our study.

3. AN OVERVIEW OF PROTOCOLS UNDER STUDY

Multicast mesh may be created by a source or a receiver and link repair may be done in soft state or hard state. A few of these use core nodes that share the mesh.

3.1 ON DEMAND MULTICAST ROUTING PROTOCOL (ODMRP)

Source in the multicast group starts creation of the multicast mesh by sending the Join Request packets to all other nodes in the network periodically in the mesh creation stage. These are the intermediate nodes which take up the onus to form the mesh for relaying data between source-receiver pair. These relaying nodes have a message-cache utilized for identification of any redundant data plus JoinReq control packets [1] [21].

The receivers interested to get packets from the source remit the Join Reply, containing source node identifier and identifier of the immediate upstream node from which Join Request was received, via the reverse shortest path. As soon as originator gets Join Reply, a path is established.

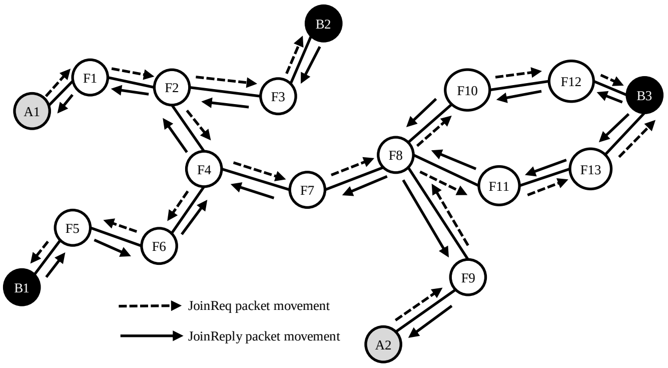

Fig.1. Forming a multicast group (Source: Author's own)

The Fig.1 shows the mesh formation process. B_1, B_2 and B_3 are receivers. When an intermediary node (F_1 to F_{13}) receives a JoinReq, it saves the ID of the immediate previous node from which JoinReq has been received. This helps the intermediate node to transmit reply packets back to the source node A_1 or A_2 and it also prevents the node from sending the JoinReq back to the source.

While JoinReq packets are broadcast by sources and intermediate nodes, the JoinReply packets are sent along the reverse path from which they received the JoinReq. The forwarding nodes discard any duplicate JoinReq packets.

On receiving the JoinReply from receiver node, the intermediate node takes up the role of a forwarding node of the multicast group. Passing on of JoinReply packets establishes the routes of the multicast group. JoinReply routes from B_3 are B_3-F_{12}-F_{10}-F_8-F_7-F_4-F_2-F_1-A_1 and B_3-F_{13}-F_{11}-F_8-F_9-A_2.

ODMRP uses soft state approach which does not make use of any separate route repair method when the path or link breaks between source and receiver. Source peri-odically keeps sending control packets of JoinReq to multicast mesh nodes so that route keeps getting refreshed, after refresh period. Soft state makes it robust, though at the expense of high number of control packets. The Fig.2 shows how the mesh recovers from link break and how alternate paths can be utilized in case of link break.

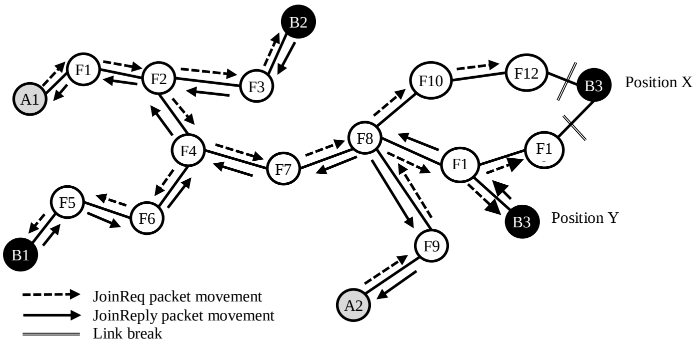

Fig.2. Recovering from a link break (Source: Author's own)

Under highly mobile conditions, when node speed in-creases, the ODMRP mesh safeguards multicast sessions from getting adversely affected because multiple routes are present and hence it gives high PDR. Apart from high control overhead, due to packets getting propagated via more than one path to destination, which means a lot of data re-transmissions happen and hence multicast efficiency is reduced, calculated as ratio of data packets delivered with respect to packets (control + data) transferred.

3.2 CORE-ASSISTED MESH PROTOCOL (CAMP)

The shared mesh-based protocol CAMP [5] overcomes the challenges that a tree-based algorithm faces such as substantial exchange of control packets due to change in topology, while also trying to address the inefficiency of loops in a mesh structure. Packets are not flooded and are rather transmitted over the reverse shortest paths. This controls the traffic in the network. High PDR is an advantage of CAMP since alternative paths let the packets get delivered from the senders to the receivers. It ex-tends the approach of Core-Based Tree (CBT) protocol. There are relay nodes, sender-receiver nodes and receiver nodes. Relay nodes have mappings of group to core nodes and set their forwarding flag when they are part of the mesh. Additionally, out of these relay nodes, there are one or more core nodes which maintain multicast routing tables.

There may be sender nodes which are in simplex mode. Any relay node directly linked to such nodes also joins the mesh in simplex mode and does not distribute messages from the group. This leads to a reduction in data traffic around sender-only nodes. CAMP doesn't use flooding until all core nodes become unreachable. To exit from a group, a relay node simply advertises its group information to its neighbours. Like in ODMRP, there is a packet cache in relay nodes that stores the received packets. The node forwards a new packet not al-ready in its cache. CAMP makes use of heartbeat messages when a node learns of a broken link. These are relayed along the reverse shortest path based on the unicast routing protocol. The nodes receiving heartbeat messages send push join packets that establish the new path to the source node through the core nodes. A node maintains a set of groups, and a set of anchor nodes. An anchor node of a node is that neighbour that falls in the reverse shortest path to a source. A node sends a multicast update whenever a topological change occurs due to nodes' movement leading to change in the routing tables and anchor node list.

4. PROTOCOL SIMULATION SET UP AND SCENARIOS

NS-3.25 has been used as a simulation tool to implement and analyse the performance of ODMRP and CAMP. CAMP is deployed using AODV unicast protocol to leverage its advantages. We assess the performance of the two mesh-based routing algorithms on a mobile network of $N = 50$ to 500 nodes covering a simulation area of 1000m×1000m. The simulation time considered is 200 seconds. Nodes move by using the Random Waypoint Model [22]. Packet size is 512 bytes. Traffic pattern is Constant Bit Rate. Node pause-time = 0 seconds. Each node moves in the 1000×1000m^2 space at a speed between 5 and 50 m/s. We have used the Energy Model of NS3 while implementing both the protocols. Related work on power consumption of MANETs has been done by Mariyappan and Karnan [23]. The network size or the speed of a node or number of senders or multicast group size (receiver count) is changed, in each scenario.

In each graph given in the next section, x-axis represents either the network size in terms of nodes or the transmission range or the speed of a node or number of senders or multicast group size. In a single simulation scenario, only one of these parameters is changed while other parameters are kept constant. Y-axis in a graph exhibits either Packet Delivery Ratio (PDR); Average Hop count; Average Delay; Average Energy Consumed or Average Control Overhead. The two curves in a graph show relative performance of the two protocols with respect to the selected parameter. The Table.1 shows the values of various simulation variables.

Performance metrics used for evaluation of the two protocols are: PDR, which is the number of packets delivered upon number of packets transmitted; control overhead which is number of control packets sent per data packet delivered; total control overhead which is number of control and data packets sent per data packet received; average delay which is the time difference between time taken by sender in sending a data packet and time taken by a multicast receiver in getting it, averaged over all packets; average energy consumed which is the energy consumed per packet transmitted between a source and receiver pair, averaged over all packets; and average hop count which is the number of hops required per packet transmitted between a source and receiver pair, averaged over all packets. Many of the metrics are recommended by the IETF MANET working group [24].

Table.1. Simulation Criteria

Parameter	Simulated Values
Number of Nodes	50, 100, 150, 200, 250, 300, 350, 400, 450, 500
Number of Senders	5, 10, 15, 20, 25, 30, 35, 40, 45, 50
Number of receivers	5, 10, 15, 20, 25, 30, 35, 40, 45, 50
Speed (m/s)	5, 10, 15, 20, 25, 30, 35, 40, 45, 50
Antenna Range (m)	250
Simulation Area (m^2)	1000×1000

4.1 SIMULATION BASED - COMPARATIVE ANALYSIS AND RESULTS

The aim of any routing protocol is to achieve delivery of data in minimal average number of hops. Similarly, higher packet delivery, lower average overhead, lower energy consumption and lower delay are required of a protocol. These parameters have been therefore critically evaluated for varied scenarios including increase in the network size that is rise in the total nodes or sender nodes or receiver nodes or increase in the node speed.

The Fig.3 to Fig.8 show that CAMP performs better than ODMRP when number of nodes increases because CAMP configures the reverse shortest paths from receivers to originators. Using receiver-initiated method, any network node can become a member of multicast group. Here, ODMRP exhibits exponential generation of control packets with augmented network size due to the inherent broadcasting nature of the protocol.

The Fig.9 to Fig.14 show that CAMP gives better results than ODMRP when number of sources increases and hence is a more scalable protocol, because of limited forwarding of packets to decrease the control overhead and increase reliability. Only core nodes take up the role of message forwarding. ODMRP wastes network bandwidth by relaying redundant control packets. Average delay is also higher for ODMRP.

The Fig.15 to Fig.20 show that ODMRP performs better in PDR, Control and Total Control Overhead as well as Energy consumed than CAMP under highly mobile node conditions, due to frequent refreshing of paths and dynamic construction of better forwarding routes, in case of faulty paths. It helps to keep the network connected in spite of high node movement.

The Fig.21 to Fig.26 show that CAMP achieves much higher PDR than ODMRP when multicast group size increases ie when number of receiver surges because the mesh becomes bigger, and number of core nodes rises, thereby more redundant paths get created, leading to a better functioning.

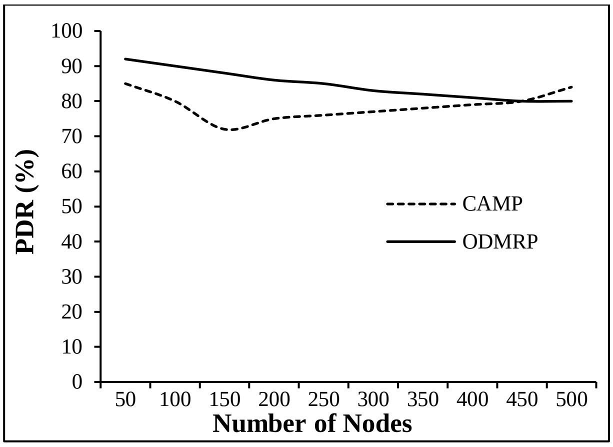

Fig.3. PDR obtained on Varying nodes

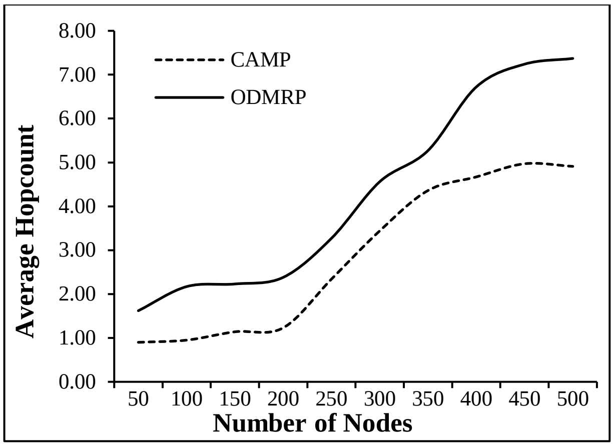

Fig.4. Hop count obtained on Varying nodes

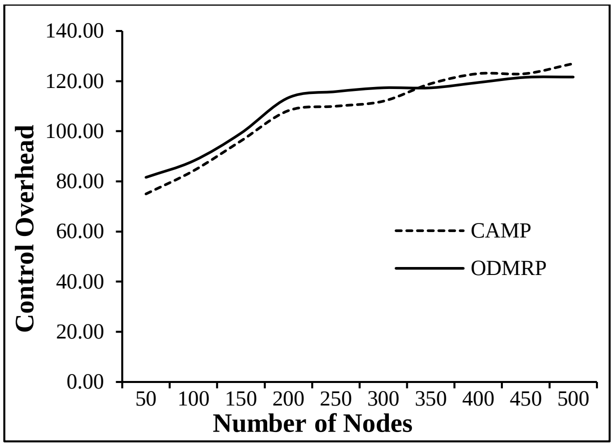

Fig.5. Control overhead obtained on Varying nodes

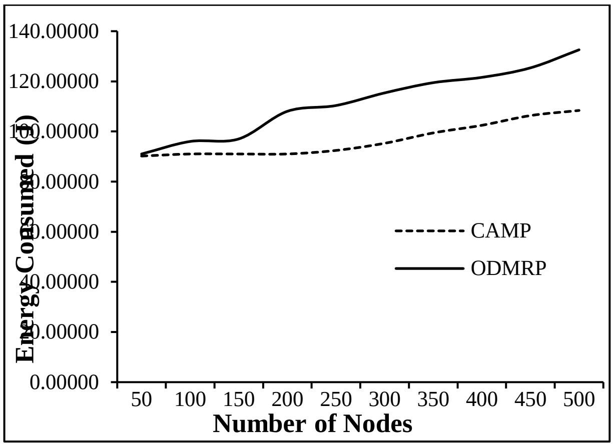

Fig.6. Energy consumed obtained on Varying Nodes

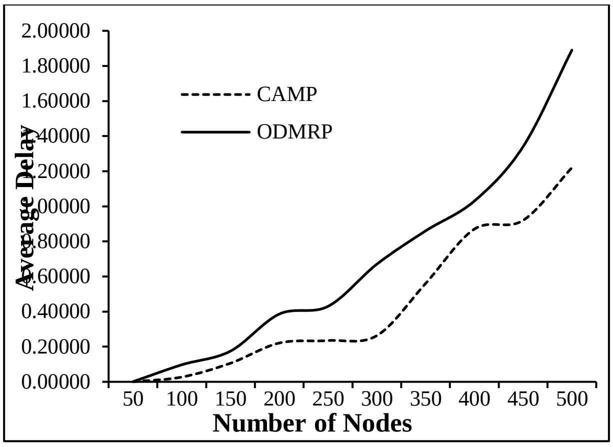

Fig.7. Average Delay obtained on Varying nodes

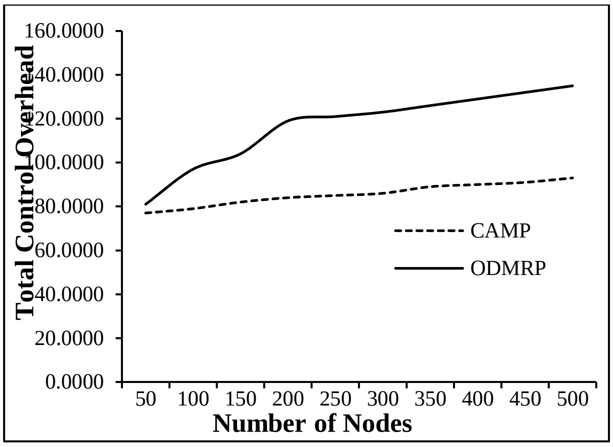

Fig.8. Total Control overhead obtained on Varying nodes

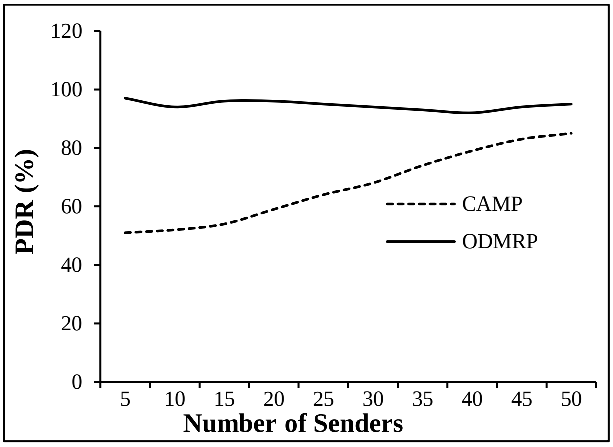

Fig.9. PDR obtained on Varying Senders

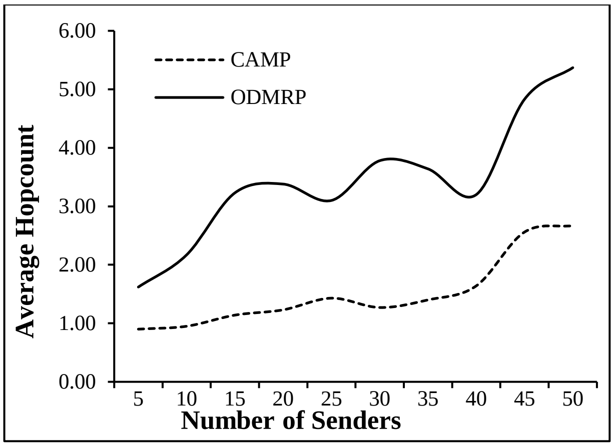

Fig.10. Average Hop count obtained on Varying Senders

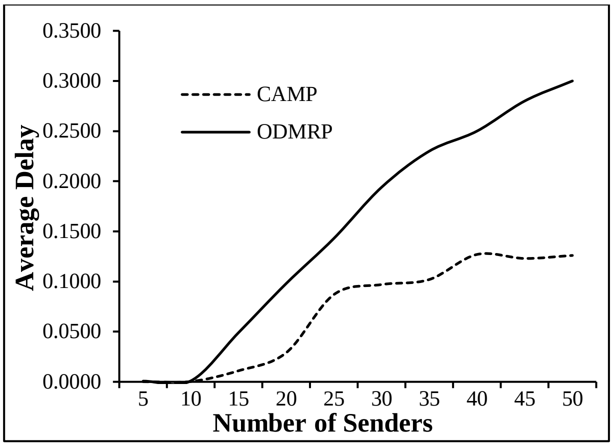

Fig.13. Average Delay obtained on Varying Senders

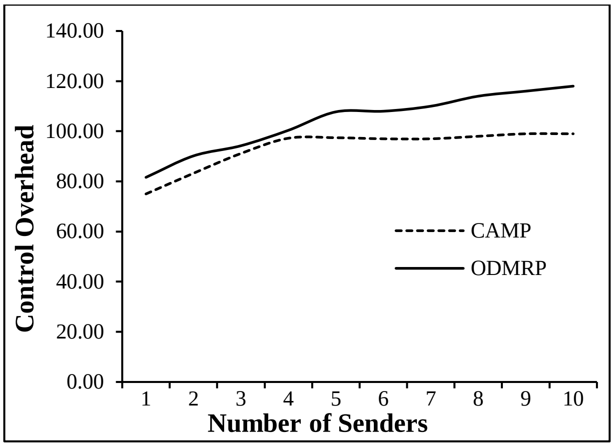

Fig.11. Control overhead obtained on Varying Senders

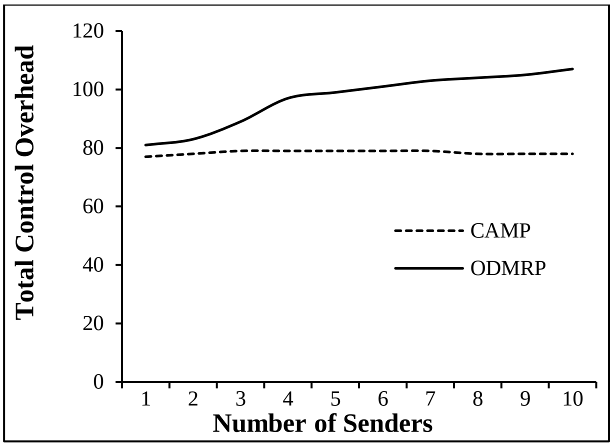

Fig.14. Total Control overhead obtained on Varying Senders

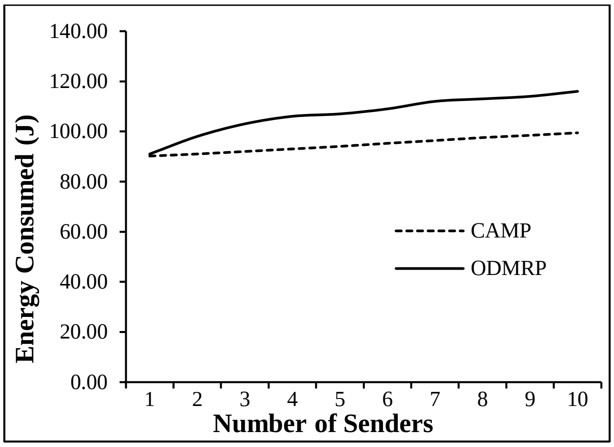

Fig.12. Energy consumed obtained on Varying Senders

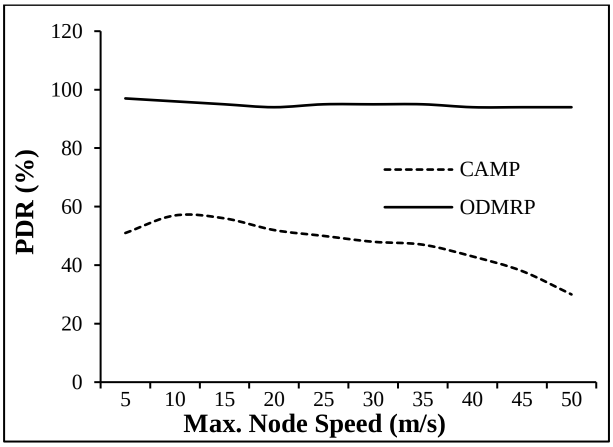

Fig.15. PDR obtained Vs Max. Node Speed

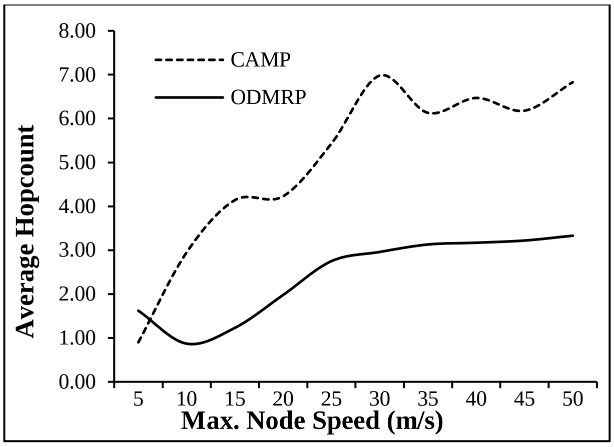

Fig.16. Average Hop count obtained Vs Max. Node Speed

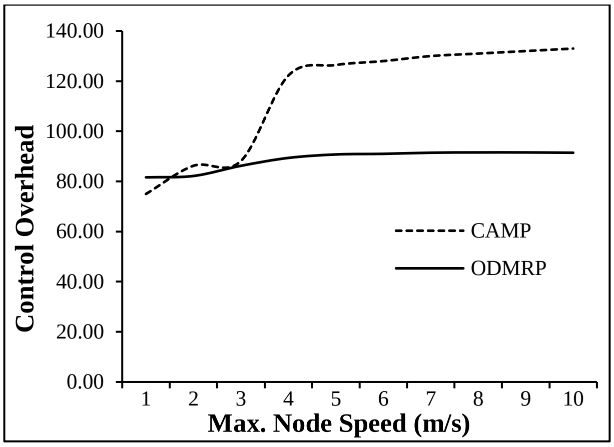

Fig.17. Control overhead obtained Vs Max. Node Speed

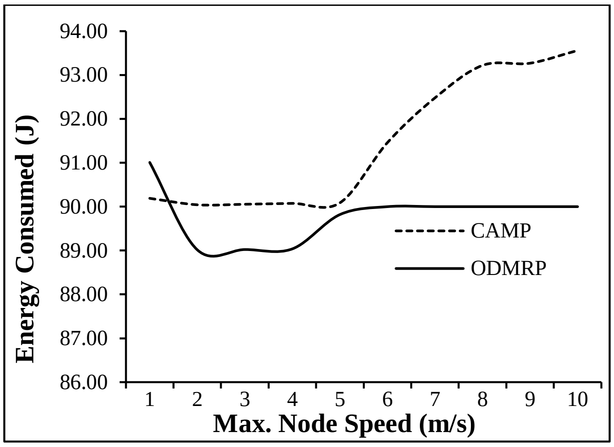

Fig.18. Energy Consumed vs Max. Node Speed

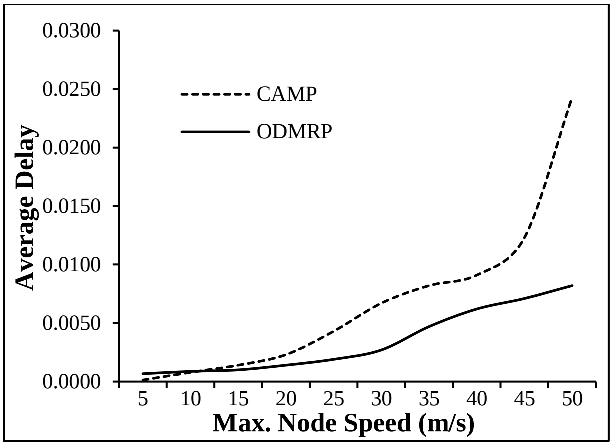

Fig.19. Average Delay vs Max. Node Speed

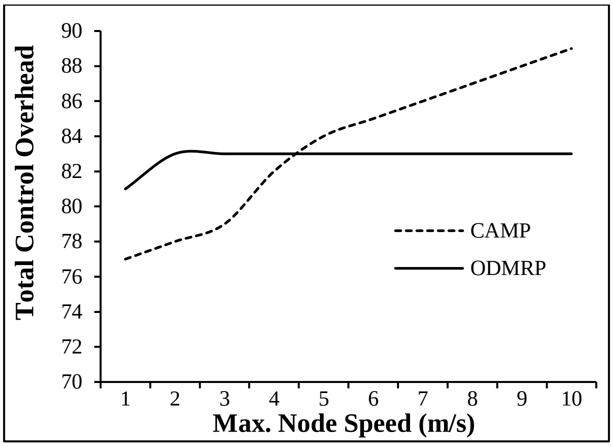

Fig.20. Total Control overhead vs Max. Node Speed

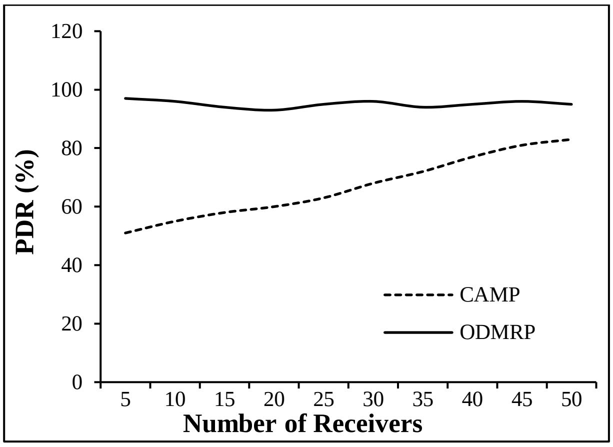

Fig.21. PDR obtained on increasing Receivers

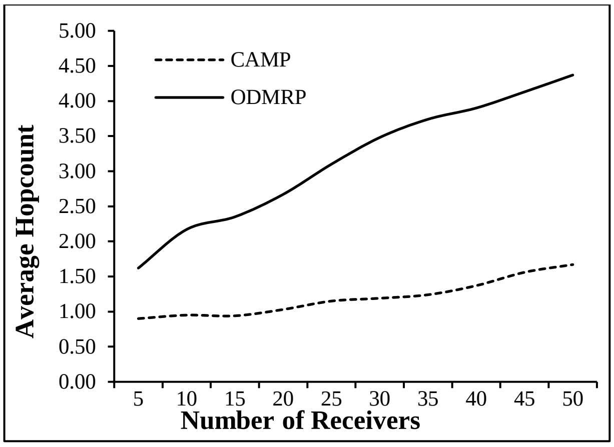

Fig.22. Average Hop count obtained on increasing Receivers

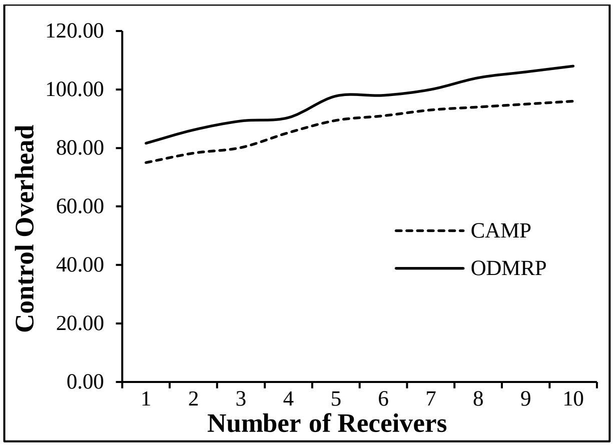

Fig.23. Control overhead on increasing Receivers

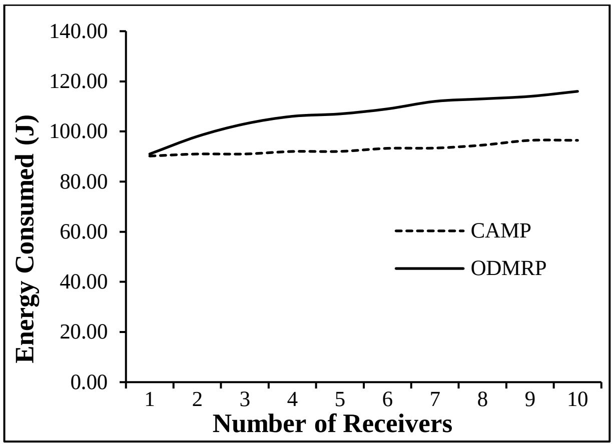

Fig.24. Energy consumed on increasing Receivers

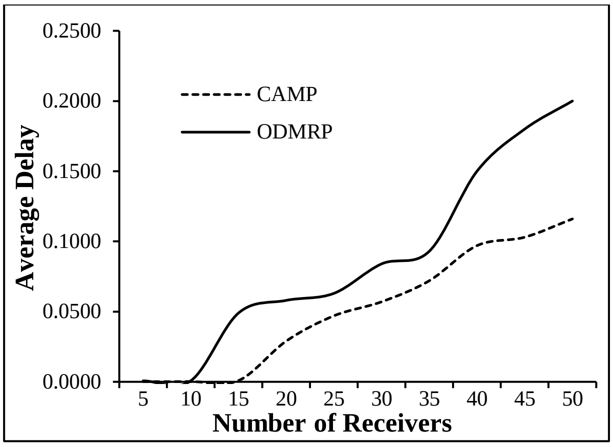

Fig.25. Average Delay obtained on increasing Receivers

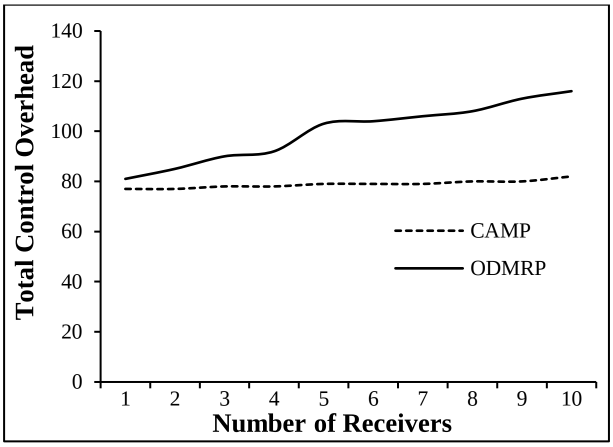

Fig.26. Total Control Overhead on increasing Receivers

4.2 STATISTICAL ANALYSIS AND INTERPRETATION

This section performs the statistical analysis of the two protocols to validate the results that we have obtained through simulation tests for four dynamic scenarios. Since the assumptions of normality and homogeneity of variances were not fulfilled, therefore, non-parametric Mann Whitney U rank sum test was run for each scenario at 5% significance level (two-tailed) to compare the performance of the protocols (n_1=n_2=10) based on the selected metrics, viz. Packet Delivery Ratio (PDR), Average Hop count (HOP), Control Overhead (COH), Average Energy Consumed (ENG), Average Delay (DLY), and Total Control Overhead (TCH).

The Table.2 to Table.5 summarize the U values, p-values and z values along with the group mean ranks, for various scenarios. The median values of the metrics are depicted in Table.6 for differing conditions.

Table.2. Test Statistics for Scenario-1: Increasing Number of Nodes

Test	PDR	HOP	COH	ENG	DLY	TCH
U	.000	31.000	49.000	18.000	39.000	8.000
Z	-3.801	-1.436	-.076	-2.419	-.832	-3.175
P	.000	.151	.940	.016	.406	.001
CAMP Mean Rank	5.50	8.60	10.40	7.30	9.40	6.30
ODMRP Mean Rank	15.50	12.40	10.60	13.70	11.60	14.70

Under Scenario 1, where we increased number of nodes, Mann Whitney U test indicated, on average, that packet delivery ratio in multicast routing through ODMRP Protocol significantly exceeded the PDR using CAMP proto-col. The average energy consumed and total control overhead were however, also significantly higher in ODMRP than in CAMP.

In case of ODMRP, with more nodes entering a network, there is an increase in the number of packets duplicated and forwarded by them along various interfaces. So, the packet delivery ratio increases rapidly.

Number of data and control packets transmitted per packet delivered by intermediary nodes also increases. In case of a network using CAMP protocol, PDR improves though not as much due to shorter paths and less link breaks.

Number of hops per packet also decline a bit for CAMP due to shorter distances to the destination nodes. The average hop count increases with rising count of forwarding nodes in ODMRP that also leads to increased energy consumption. However, the statistical test did not support the difference between the two protocols on based on hop count, control overhead and delay.

Table.3. Test Statistics for Scenario-2: Increasing Number of Senders

Test	PDR	HOP	COH	ENG	DLY	TCH
U	.000	5.000	24.000	11.000	26.000	.000
Z	-3.788	-3.402	-1.967	-2.948	-1.814	-3.823
P	.000	.001	.049	.003	.070	.000
CAMP Mean Rank	5.50	6.00	7.90	6.60	8.10	5.50
ODMRP Mean Rank	15.50	15.00	13.10	14.40	12.90	15.50

Under Scenario 2, where we increased the number of senders, the packet delivery ratio using ODMRP Protocol significantly exceeded the PDR using CAMP protocol. Average Hop count per packet, control overhead, energy consumed and total control overhead were significantly higher in ODMRP than CAMP while interestingly, the delay in packets in both the protocols couldn’t be differentiated statistically using the tests. Performance of an ad hoc network using CAMP is better in this scenario since the increase in number of packets transmitted also increases the control packets to create source driven meshes in ODMRP while CAMP shows a constant behaviour. The nodes in CAMP do not need to always send requests to join when they are next to core nodes. Additionally, the Heartbeat messages in CAMP are sent to the receiving nodes periodically for shortest route establishment. As senders increase, CAMP allows the senders to operate in simplex mode preventing excess traffic and less congestion. ODMRP floods data leading to loops, congestion, longer queuing, buffering, and more retransmissions.

Table.4. Test Statistics for Scenario-3: Increasing Maximum Speed

Test	PDR	HOP	COH	ENG	DLY	TCH
U	.000	14.000	24.000	5.000	37.000	39.000
Z	-3.808	-2.721	-1.966	-3.428	-.983	-.843
P	.000	.007	.049	.001	.325	.399
CAMP Mean Rank	5.50	14.10	13.10	15.00	11.80	11.60
ODMRP Mean Rank	15.50	6.90	7.90	6.00	9.20	9.40

Under Scenario 3, where we increased mobility speed, Mann Whitney U test confirmed significantly better performance of ODMRP protocol in terms of PDR as well as control overhead. Additionally, average hop count and energy consumed per packet were also higher in CAMP than in ODMRP. This is because of the link breaks between the core nodes and receivers incurring large overhead and energy consumption in the recovery of the routing paths. The statistical tests however showed insignificant difference between the two protocols on the basis of delay and total overhead.

Under Scenario 4, where we increased the number of receivers, packet delivery ratio in ODMRP Protocol significantly exceeded the PDR using CAMP protocol. Average Hop count per packet, control overhead, Energy consumed and Total control overhead were also significantly higher in ODMRP than CAMP. The test did not support the difference between the two protocols on the basis of delay.

CAMP is performing better in this case since a lower number of packets are flowing in the mesh as compared to ODMRP where flooding is used to create mesh. Receiver join requests are also less in case of CAMP since the anchor nodes do not need join requests from neighbouring nodes that want to be a part of the mesh. Also, the receiver nodes are on the shortest routes to the source nodes while joining the group.

Table.5. Test Statistics for Scenario-4: Increasing Number of Receivers

Test	PDR	HOP	COH	ENG	DLY	TCH
U	.000	1.000	24.000	8.000	35.000	1.000
Z	-3.792	-3.704	-1.965	-3.175	-1.134	-3.714
P	.000	.000	.049	.001	.257	.000

CAMP Mean Rank	5.50	5.60	7.90	6.30	9.00	5.60
ODMRP Mean Rank	15.50	15.40	13.10	14.70	12.00	15.40

The statistical results affirm the simulation outcomes for most of the metrics. In Table.6, the columns A to E represent the same metrics as described for Table.2 to Table.5 above.

Table.6. Medians for Different Scenarios

Scenario	Protocol	PDR	HOP	COH	ENG	DLY	TCH
Increasing number of nodes	CAMP	65.50	2.890	111.00	93.85	.249	85.50
	ODMRP	95.00	3.915	116.58	112.85	.550	122.00
Increasing number of senders	CAMP	66.00	1.335	97.11	94.65	.09200	78.50
	ODMRP	94.50	3.305	107.87	108.00	.16850	100.00
Increasing node maximum. Speed	CAMP	49.00	5.780	127.21	90.82	.00550	84.50
	ODMRP	95.00	2.855	90.87	90.00	.00230	83.00
Increasing number of receivers	CAMP	65.50	1.170	90.21	92.65	.05200	79.00
	ODMRP	95.00	3.290	97.87	108.00	.07350	103.50

5. DISCUSSION

A protocol's performance is critical to understand its preferred use under varying applications, situations and for meeting minimal requirements of a specific parameter such as the packet delivery ratio and energy consumption. Our analysis of both CAMP and ODMRP protocols through simulation as well as statistical methods have shown that ODMRP is a high performing protocol in MANETs when assurance of data delivery is needed but energy consumption is not a concern owing to most of the forwarding nodes having large power backups. Unlike the previous works by prominent researchers in this area, Lee and PUMA, the underlying unicast protocol used by us with CAMP is AODV. Despite this modification, the packet delivery ratio of CAMP remains low as compared to ODMRP.

However, with diminishing energy, the networks are prone to instability and excessive exchange of control packets. In such situations, CAMP is a better performing protocol in comparison to ODMRP with respect to the number of hops a packet takes to arrive at a multicast group member, as well as the number of total data and control messages exchanged during data delivery reducing overall control overhead. This saves the energy consumed by a node in the network that deploys CAMP protocol. This is true for all dynamic environments of a mobile ad hoc network such as changing numbers of receiver nodes, source nodes as well as with increasing number of all network nodes. This protocol however is not a good choice in terms of energy preservation when nodes start moving faster such as in high-speed travel. This was also observed by Lee et.al. [25] and Biradar and Manvi [26].

Overall performance of CAMP protocol vs ODMRP protocol is shown through the radar graphs in Fig.27 to Fig.30 on a scale of 1, 2 and 3 representing relatively low performance, relative undifferentiated performance and relatively high performance respectively.

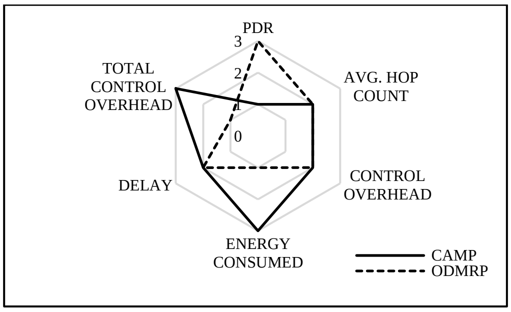

Fig.27. Radar Graph for increasing number of nodes

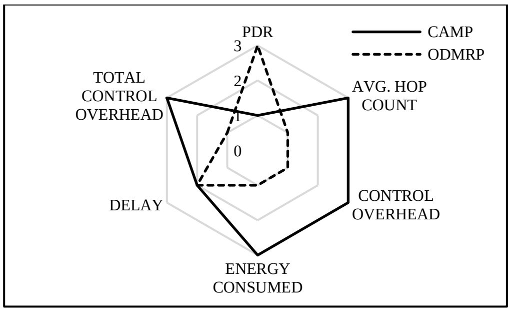

Fig.28. Radar Graph for increasing number of senders

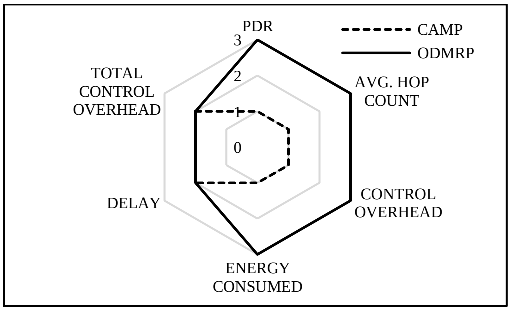

Fig.29. Radar Graph for increasing node mobility

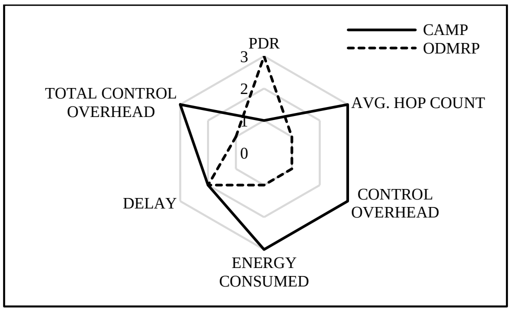

Fig.30. Radar Graph for increasing number of receivers

6. CONCLUSION AND FUTURE WORK

Mesh based protocols are designed to perform well in mobile ad hoc scenarios. But choosing a specific protocol to setup and maintain routes for multicast traffic in MANETs is subjective to the application scenario and the criticality of a specific parameter. The simulation results have shown that CAMP protocol is scalable and it per-forms better as compared to ODMRP in all scenarios except when the nodes move too fast leading to link breaks and unreachability of the core nodes. Additionally, since flooding is limited in CAMP, control packets are also kept relatively low except when node speed increases. ODMRP is able to utilise the bandwidth in a better manner when the node mobility and speed are high. If energy consumption is a criterion for protocol selection, CAMP saves on the nodes' energy since it has some nodes in simplex mode and consumes less energy. The study and analysis of these two multicast protocols presented in the paper brings out that normally ODMRP may be preferred for its robustness and reliability in case of fast-moving nodes. It is better suited with regard to packet delivery ratio in high mobility requirements scenario. In future, enhancements can be done in terms of efficiency and performance of multicast routing protocols that includes working upon areas of scalability (when the network expands or the number of nodes surges, the routing protocol must reconfigure its structure and provide reliable performance), residual energy (reducing nodes energy consumption and saving on the battery power can extend the lifetime of nodes), mobility (i.e. node speed), traffic load (which leads to a possibility for increased packet loss and collisions) and transmission range (some fault tolerance mechanism should be devised to keep the communication going even if nodes move out of each other's transmission range).

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