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AMRA: Angle based Multicast Routing Algorithm for Wireless Mesh Networks

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Abstract

Objective: The main intent of this research is to improve the quality of service in Wireless Mesh Networks by reducing the number of hops and communication overhead generated in the network. **Methods:** In this manuscript, the Angle based Multicast Routing Algorithm (AMRA) is introduced for reducing communication overhead and thus improving performance in the wireless mesh networks. Every intermediate node towards the destination is selected based on the angle towards the forwarding nodes. The next intermediate node is selected in the forwarding direction, if the angle is within 60° of the current node. This method reduces the number of hops in transmitting data. **Results:** The Angle based Multicast Routing Algorithm (AMRA) show higher performance when compared to the existing CAMP method. If the number of nodes is 50, the packet delivery rate is comparatively better in AMRA and the throughput in AMRA is 70%. According to the comparison results, the proposed approach works better than the other existing schemes with high quality of service. **Conclusion:** The simulation results demonstrate that the Angle based Multicast Routing Algorithm (AMRA) has high quality of service compared to the existing CAMP.

Keywords: Angle, Multicast Routing, Quality-of-Service, Wireless Mesh Networks

1. Introduction

A Wireless Mesh Network (WMN) is made up of radio nodes organized in a mesh topology. WMN often consists of mesh clients, mesh routers and gateways. Coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. This mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network.

The multicast is more complex task in the wireless networks than the wired networks, due to mobility and interferences. Multicast is an effective communication and collaborative communication among all nodes. Flooding and tree-based protocols represent two-ends-of-multicast spectrums. The flooding model is a simple approach that generates more control message packets in the wireless network environments. On other hand, tree-based approach generates minimal data traffic in the network. Here, tree maintenance and updates require more number of control message packets over the network. Both models have a scalability problem. The multicast protocols for the MANETs vary in terms of route, state maintenance, reliance on unicast and other points. The problem of multicast in the MANET is mixed by the node mobility, which resulted in conflicting goals. Frequent updates require more amount of the bandwidth. It takes more control message packets, power and wastage of the bandwidth. The most common metric is the cost, which is used to determine a route in terms of shortest delay/least number of hops.

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In this paper, the AMRA: Angle based Multicasting Routing Algorithm for WMN is presented with guaranteed performance. The source node broadcasts the information. Each and every node checks for the angle and if the destination node is within the communicative angle range, the data is sent to the destination, else the data is sent to the next node of the routing process until the destination is found.

2. Previous Research

In[1] multicast routing Shortest Path Trees (SPTs) and Minimum Cost Trees (MCTs) concept is proposed. SPT algorithms minimize the distance from the sender to each receiver whereas the MCT algorithms minimize the overall cost of the multicast tree. The SPT approach is the more commonly used method for multicast routing in the internet, because it is easy to implement and gives minimum delay from the sender to each receiver. Contrasting wireless mesh network has a much smaller size, and its topology can be made known to all nodes in the network.

In[2] two algorithms are presented for dealing with multicast routing problem using the notion of virtual forces. Effective force exerted on a packet is checked and determined whether a node could be considered as a Steiner node. The nodes' location information is used to generate virtual circuits corresponding to the multicast route. QoS parameters are taken into consideration in the form of virtual dampening force. The virtual-force technique was applied for multicast routing in mobile ad-hoc networks.

Energy Efficient Throughput Maximization for Wireless Networks Using Piece Wise Linear Approximation is proposed in[3] with the objective to improve network outputs along with the wide energy consumed by the whole network. In this paper both network throughput and energy requirement were optimized through a multi criteria framework, which is optimized (i.e.) by optimizing the network output by reducing the maximum power consumption.

An efficient bandwidth utilization with congestion control for wireless mesh networks is proposed in[4] with the objective of efficient utilization of the bandwidth available so that it will result in reduced congestion in a network.

The authors in[5] proposed a multi-objective evolutionary QoS routing algorithm based on Genetic Algorithm (GA) optimization called Multi-constrained Genetic Algorithm for QoS routing (MGAQ). The new option of fitness base functions on result density was proposed to increase the ability to generate feasible routes. The principal disadvantage of MGAQ is that some MOEA's algorithm has a better efficiency to find the Pareto front, because its algorithm has an elite-preserving operator. Additionally it is not clear how the algorithm was implemented by using the bandwidth restriction.

In[6] authors proposed a modeling approach where the two conflicting objectives, deployment cost and channels interferences are simultaneously optimized. They used an Evolutionary Algorithm (Meta-Heuristic) based on particle swarm optimization. The overall work emphasizes in taking into account the different QoS goals as a whole complex problem of more than one criteria, even when the evaluation of the QoS includes security issues, the isolation of these different goal leads to a conflict on the results obtained and leads to the incapability of correctly planning the infrastructure for ensuring QoS goals and security goals at the same time.

The authors in[7] proposed a multi-objective evolutionary QoS routing algorithm based on Genetic Algorithm (GA) optimization called Multi-constrained Genetic Algorithm for QoS routing (MGAQ). The new options of fitness base functions on result density were proposed to increase the ability to generate feasible routes. The principal disadvantage of MGAQ is that some MOEA's algorithm has a better efficiency to find the Pareto front, because its algorithm has an elite-preserving operator. Additionally it is not clear how they implemented the algorithm and they only used the bandwidth restriction.

The authors in[8] proposed a multi-objective approach for the Round Weighting Problem (RWP) which solves a joint routing and scheduling problem to satisfy a given demand subjected to the multi-access interferences considering two objectives. The first one is to balance the load in the routers which increases the security in case of failure. The second objective is to minimize the communication time which corresponds to the time required to route all router demands. The problem takes into account the complete set of rounds, where a round is a collection of links that can be simultaneously activated in the network.

In[9] the multi-layer support based clustering for energy-hole prevention and routing in wireless sensor networks is proposed. This work has proposed a clustering protocol for an energy-hole preventive environment, called CLUE-HOPE, to provide energy-efficient routing. The grid formation and selection of CH in the distributed manner reduces the control overhead, and the rotation of CH role among the nodes in the grid improves energy conservation in the network. CLUE-HOPE substantially reduces cluster size variations without spending extra energy in the network.

In[10] a new multi-objective optimization model for planning WMNs has been proposed. It has two conflicting objectives, namely network deployment cost and network channels' interferences and is simultaneously minimized while guaranteeing end users' full coverage and robust topologies. A novel performance metric has also been proposed to evaluate the network interference level and a population-based optimization heuristic to solve our model, whereby many WMN planning solutions are provided to the end-planner. Realistic-size instances mesh nodes are used to test our multi-objective optimization model, and discuss the impact of the key parameters on the characteristics of the solutions. The future work is to investigate the issues of rate adaptation and scalability.

3. Proposed Work

A new angle based multicasting routing algorithm is proposed. The importance of this algorithm is to reduce the number of hops while multicasting in a wireless mesh network. The existing method of data transmission from source to destination using multicast scheme is given in

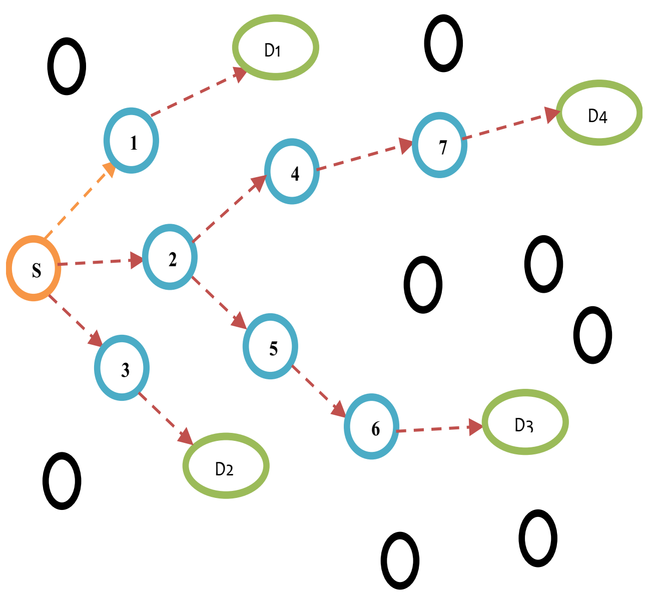

Figure 1. Existing data transmission scheme.

Figure 1. The existing method uses different routes for sending the same information to multiple destinations. The source 's' wishes to send information to destinations 'd1', 'd2', 'd3' and 'd4'. The source finds separate routes to different destinations as (s->1->d1), (s->3->d2), (s->2->5->6->d3) and (s->2->4->7->d4). The above way of sending data to destination requires more time and it uses more number of hops. For each and every route, separate route request and route reply is required before data transmission. This results in overhead among the nodes in the communication network. Also redundant path makes the communication more complex which results in lesser efficiency.

To overcome the above disadvantages, the new angle based algorithm is proposed. The idea behind reducing the number of hops is the usage of an important metric: angle in multicasting scheme. This can be obtained by forming multicast meshes with the nodes participating in the multicasting operations.

The angle is calculated between two nodes with the corresponding co-ordinates (x1,y1) and (x2,y2) and is given in equations (1) and (2),

$$\begin{aligned} dx &= x_2 - x_1 \\ dy &= y_2 - y_1 \end{aligned} \quad (1)$$

$$angle = \text{Atan}\,2(dy, dx) \times \frac{180}{\pi} \quad (2)$$

where

Atan = Arc tangent.

If the node has angle within 60° in the forwarding direction, then that node is selected otherwise the node is unselected.

Steps involved in optimizing the route to destination

- Source broadcasts data in the network, where the neighbor node receives it.
- The intermediate node checks the angle for the nodes in its communication range to check the nearest destination.
- If the node is destination, the data is transmitted, else move on the next hop and find the angle.
- If a single destination is found, find the other destinations to send data.
- Same process is continued till data is transmitted to all the destinations.

In the proposed method, the same source's' sends data to the destinations d1, d2, d3 and d4 through the same path. For different destinations there will be different paths for the source to send the data. To avoid using more number of hops, common path in the network is selected from the source to destination. When the source sends the data and when the first intermediate node is reached, it checks whether any destination is there within angle 60°. If it finds the destination, then the route is changed to the destination else the data is moved to the next forwarding node.

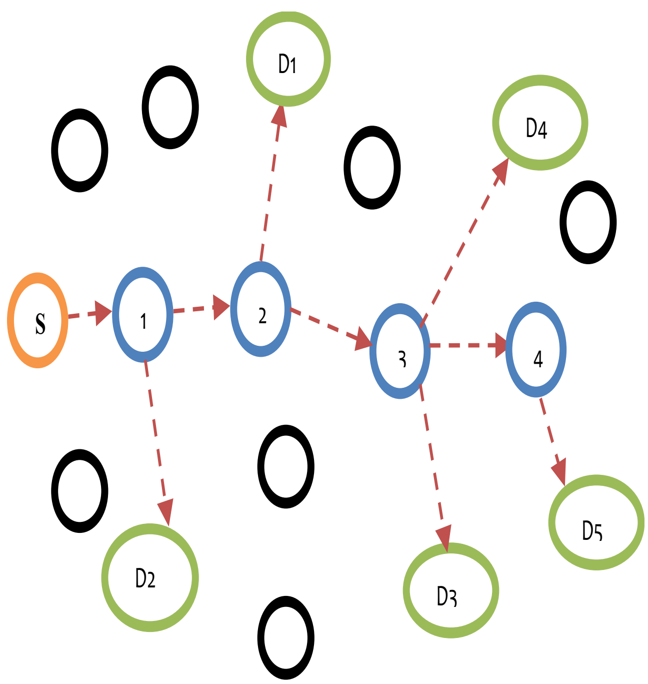

Figure 2. Angle Based Multicasting Routing.

In Figure 2, when's' reaches intermediate node '1', while it calculates the angle, it finds the destination d2. So data is transferred to d2. And from node '1' data is forwarded to '2'. In intermediate node 2, it finds the destination d1. So data is transferred to d1. The same process is continued till the data is send to all destinations in the network.

Figure 3 representation of Angle based Multicasting Routing Algorithm is shown in flowchart 1. The enhancement made reduction in overhead as there is minimal number of hops involved in routing. Also as an additional advantage the packet loss and delay will also be minimized since the shortest routes are obtained. Simulation analysis provides the actual comparison between the existing and proposed protocols in terms of the evaluation metrics considered.

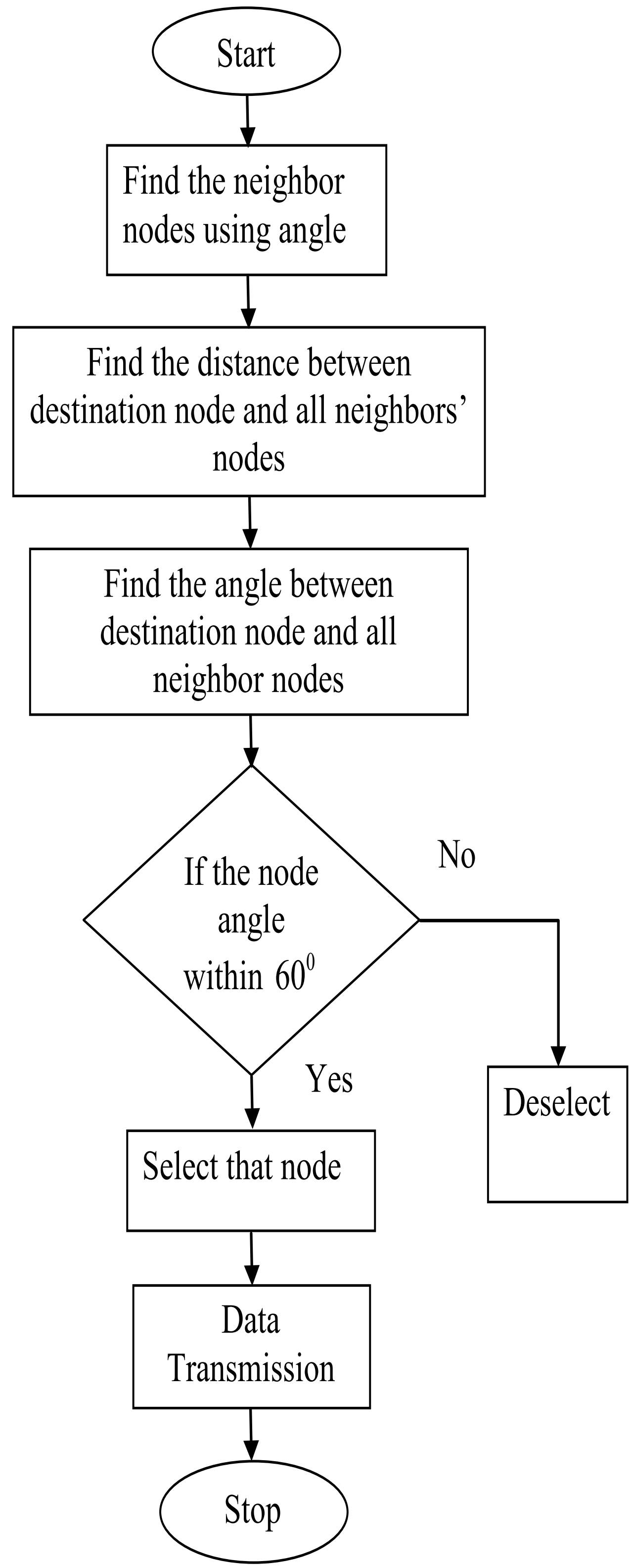

Figure 3. Flowchart of Angle based method.

4. Performance Evaluation

The performance of the proposed scheme is analyzed by using the Network Simulator (NS2). The NS2 is an open source programming language written in C++ and OTCL (Object Oriented Tool Command Language). NS2 is a discrete event time driven simulator which is used to mainly model the network protocols. The parameters used for the simulation of the proposed scheme are tabulated below.

Table 1. Simulation parameters of AMRA

Parameter	Value
Channel Type	Wireless Channel
Simulation Time	30 s
Number of nodes	50
MAC type	802.11
Traffic model	CBR
Simulation Area	1000×1000
Transmission range	250m
Mobility speed	0 to15m/s

The simulation of the proposed scheme has 50 nodes deployed in the simulation area 1000×1000. The nodes are moved randomly within the simulation area by using the mobility model Random waypoint as shown in Table 1. The nodes are communicated with each other by using the communication protocol User Datagram Protocol (UDP). The traffic is handled using the traffic model CBR. The radio waves are propagated by using the propagation model two ray ground. All the nodes receive the signal from all direction by using the Omni directional antenna. The performance of the proposed scheme is evaluated by the parameters packet delivery ratio, packet loss ratio, delay and throughput.

4.1 Packet Delivery Rate

Packet Delivery Rate (PDR) is the ratio of number of packets delivered to all receivers to the number of data packets sent by the source node. The packet delivery rate is calculated by the following formula.

$$PDR = \frac{Total\ Packets\ \mathrm{Re}ceived}{Total\ Packets\ Send} \tag{3}$$

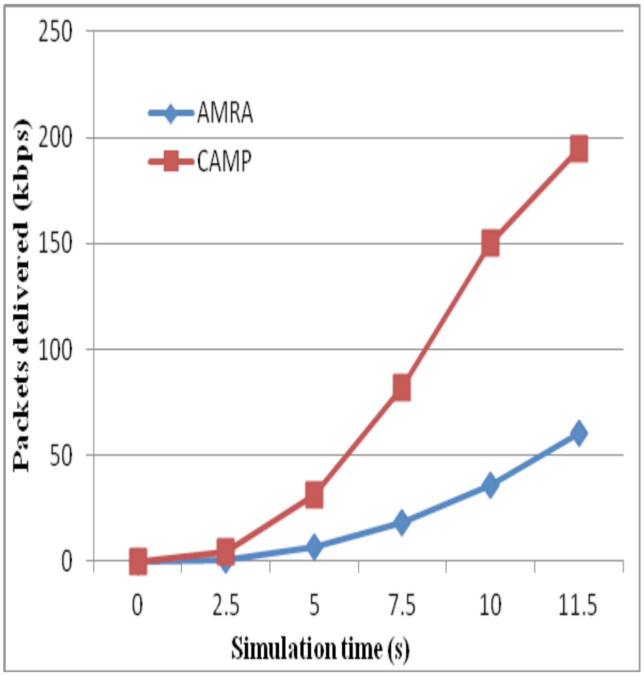

Figure 4. Packet Delivery Rate.

The packet delivery rate of the proposed scheme is higher than the packet delivery rate of the existing method. The greater value of packet delivery rate means the better performance of the protocol.

4.2 Original Packet Delivery Rate

Original packet delivery ratio represents the actual packet delivered in Wireless Mesh Networks. Figure 5 shows that there is increase in original packet delivery ratio in AMRA when compared to that of CAMP.

4.3 Packet Loss Rate

Packet Loss Rate (PLR) is the ratio of the number of packets dropped to the number of data packets sent. The formula used to calculate the packet loss rate is as follows.

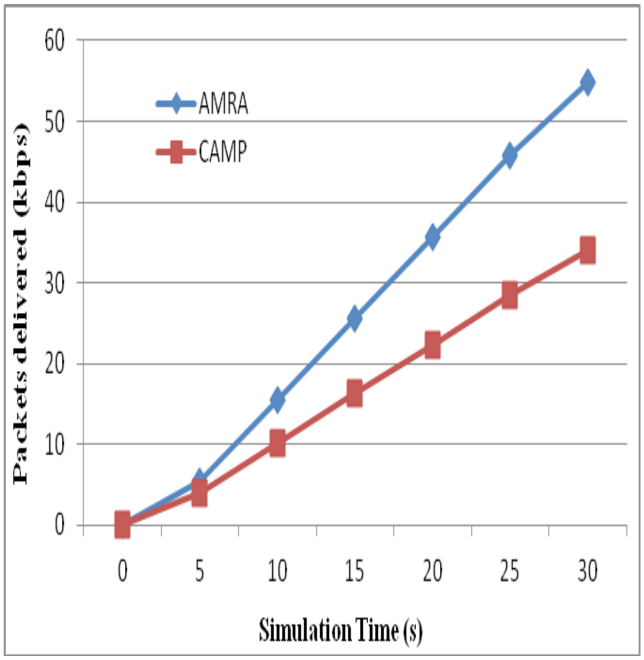

Figure 5. Original Packet Delivery Rates of AMRA and CAMP.

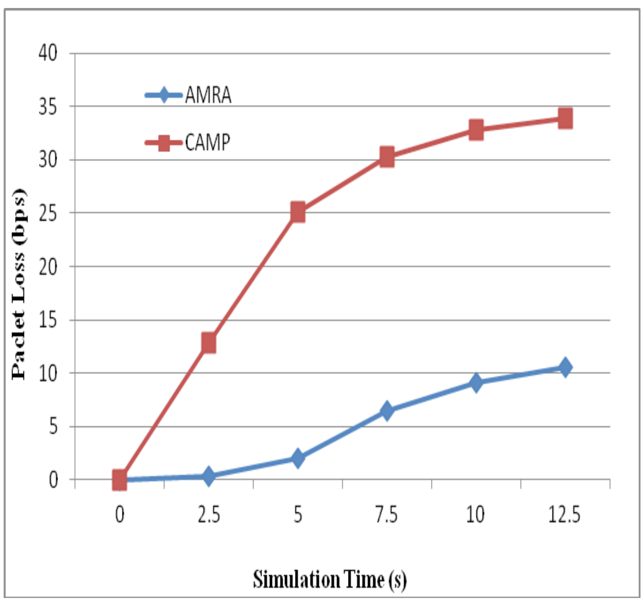

Figure 6. Packet Loss Rate.

$$PLR = \frac{Total\ packets\ Dropped}{Total\ Packets\ Send} \quad (4)$$

The packet loss rate of the proposed scheme is lower than the existing scheme in Figure 6. Lower the packet loss rate indicates that higher performance of the network.

4.4 Average Delay

The average delay is defined as the time difference between the current packets received and the previous packet received. It is measured by the equation 5 below.

$$Delay = \frac{\sum_{0}^{n} Pkt\ Send\ Time - Pkt\ \mathrm{Re}cvd\ Time}{Time} \quad (5)$$

Figure 7 shows that, the delay value is low for the proposed scheme than the existing scheme. The minimum value of delay means that higher value of the throughput of the network.

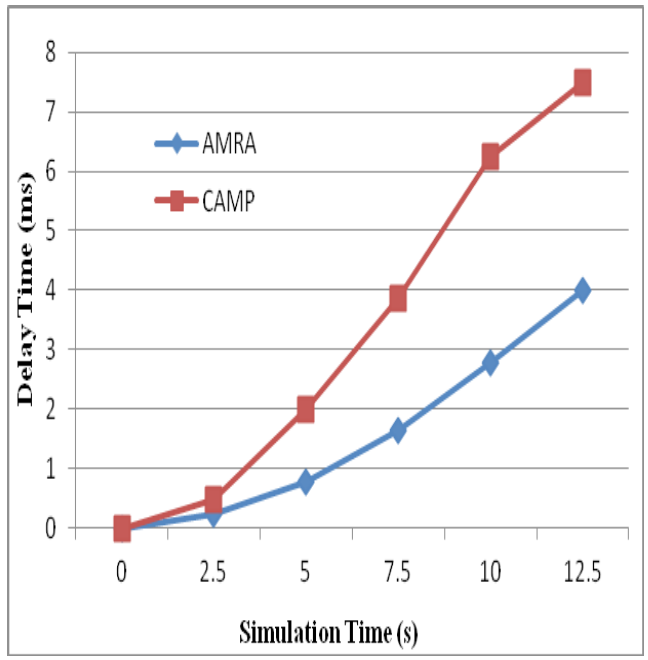

Figure 7. Average Delay.

4.5 Throughput

Throughput is one factor similar to that of the packet delivery rate. Throughput is the average of successful messages delivered to the destination. The average throughput is estimated using equation 6.

$$Throughput = \frac{\sum_{0}^{n} Pkts\ \mathrm{Re}ceived\ (n)\ Pkt\ \ Size}{1000} \quad (6)$$

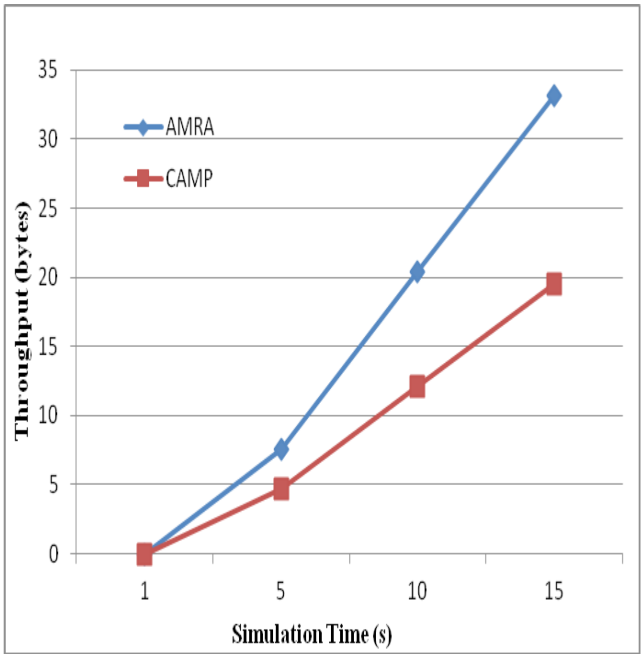

Figure 8. Throughput.

Figure 8 shows that the proposed scheme has greater average throughput when compared to the existing scheme.

4.6 Normalized Routing Load

The overhead generated for communication is calculated by using awk scripts over the trace file obtained from the simulations in the network simulator. Normalized Routing Load (NLR) is estimated from the equation 5 in[11]. The total packets received contain the sum of the routing packets and the control packets. Hence, the ratio of the routing packets to the total received packets implies the difference in overhead observed.

$$NLR = \frac{Routing\ Pkts}{Total\ Delivered\ Pkts} \tag{7}$$

Figure 9 shows the normalized routing load at various node mobility scenarios. The normalized routing loads show that the proposed mechanism performs better than the existing system. OCAMP has low overhead when compared to AMRA.

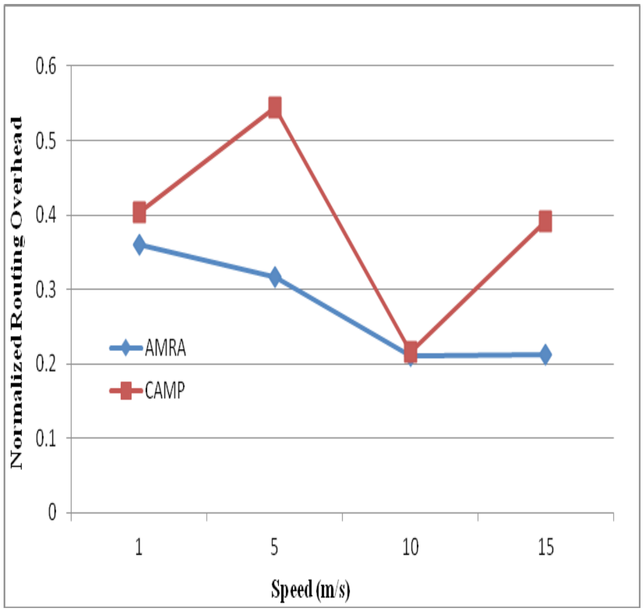

Figure 9. Routing Overhead.

5. Conclusion

The CAMP protocol provided a solution to transmit data to the multicast destinations by formation of multicast groups. In this paper, we have proposed a new angle based multicasting routing algorithm for wireless mesh network. In this algorithm the number of hops while multicasting in a wireless mesh network is reduced. The benefit of this method is that the overhead generated during the communication process between the networks is reduced. Simulation results show that the proposed method has low packet loss ratio, packet delay and better packet delivery ratio and throughput.

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