Australian Journal of Basic and Applied Sciences, 9(27) August 2015, Pages: 687-695

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Scalable Optimized Heuristic Routing for Mobile Ad Hoc Network

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ARTICLE INFO

Article history:
Received 3 June 2015
Received in revised form 17 June 2015
Accepted 1 August 2015
Available online 15 October 2015

Keywords:
Multicast tree, Fitness function, chromosome, hop metric, Virtual Rate, Connectivity, Virtual Grids.

ABSTRACT

Wireless devices are fabricated to operate in a cooperative manner by using the mechanism of utilizing the shared channel to transmit and receive the data among other devices. In order to maintain the seamless and robust communication, the routing model must be designed with the consideration of the optimization process. This optimized routing strategy must have the capacity to improve the throughput and its related aspects such as good-put, and to reduce transmission cost and delay, and which needs to handle the dynamic network situations such as link unavailability, node failure and channel collision situations. In this work, Scalable Optimized Heuristic Routing (SOHR) strategy is proposed for large scale wireless network with the consideration of dynamic connectivity and channel availability among congested wireless devices. This solution improves the probability of seamless data forwarding which includes the link unavailable and node failure network situation. The simulation result shows that the proposed scheme achieves better performance compared to the existing multi-hop and multipath routing protocols in terms of successful packet delivery ratio, transmission delay, throughput and routing overheads.

To Cite This Article: A. Vijayalakshmi and Dr. P. Ramamoorthy., Scalable Optimized Heuristic Routing for Mobile Ad Hoc Network. ***Aust. J. Basic & Appl. Sci.***, *9(27): 687-695, 2015*

INTRODUCTION

A MANET is self-reconfigurable, autonomous devices which are connected by using the wireless channel, that is used to create and maintains the communication between these devices and can be used to share and exchange the data. In detail, the mobile devices can move anywhere in the deployment region, which causes the dynamic changes in the topology of the network, which requires re-route establishment by involving the route discovery process frequently. Computing the reliability metrics in heuristic routing for large scale, high devised wireless network is a critical task to complete. In high mobility, high network traffic congestion situation and in low resources available conditions, the devices cannot operate in normal mode. So, there is a need to design the protocol to work under high pressured network situations such as critical network situations including congestion, collision.

During the design of routing and scheduling protocol there is need to consider the congestion control algorithm with the effective scheduling approach to solve optimization problem. The route scheduling algorithm converges to an optimal close system which robustly increases the throughput. And an important characteristic is to carry out the successful network centric welfare operations with the reliability of routing protocol in the mobile ad-hoc environment. The MANET devices are deployed in several challenging situations which affect the packet related aspect and reduce the network performance such as high node mobility, bad channel condition, interference of nearest nodes and the physical barrier such as difficult terrain features. In order to design an application specific network centric routing protocol, it must have the capacity to overcome this problem with a robust solution which works under the highly pressured bottleneck situations and to take the necessary decision based on the current network situations.

Related Work:

The MANET devices are equipped with lower amount of resources such as energy in terms of battery power, connectivity in terms of transmission range, data buffer to store the data, memory which is used to maintain the topology routing table and other related aspects. Chen and Heinzeliven et al., provides a comparative study and survey on routing protocols that provide some kind of support for quality of

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services in the network. In this survey the routing protocols, including both table driven and on-demand protocol with QoS support. The QoS related metrics such as energy, bandwidth is considered in this survey. And this work clearly explains how the protocol handles the problem arises during the design considerations of QoS related metrics.

Emma et at., suggests, a solution for MANET to access the shared channel efficiently on "Distributes End to End Allocation of Time Slots for Real Time Traffic which is named as "DARE". This solution provides end to end reservation for the complete transmission path. The request-to-reserve message is used to perform the end to end reservation, which travels from the source to destination affect the establishment of a route. The route formation is done by using the traditional routing protocol, which executes in on-demand manner. At the time of receiving the request message by the destination, it replies with clear-to reserve message to source node which travels along the reverse path of the established route.

Yuanyuan *et al*., nominates a solution based on the evaluation of the network stability metric of the nodes. This normalized method is widely used for the evaluation of network stability and which is based on the neighbor connectivity during the multicast tree merging traffic and is not supported for the unicast data transmission. It requires the GPS to identify the location of devices which reduces the link failures and improves the connectivity fraction. The solution is not suited for low energy devices. Since, it is operated with GPS devices which significantly increase the energy consumption.

Neng Chung Wang et al., proposes a solution to handle the dynamic time slot allocation for QoS multicast routing. The slot allocation is initiated after the construction of the multicast tree. The multicast tree is formed by taking the first node try to join in the tree as multicast root. The remaining nodes join a leaf node in the tree by selecting the appropriate node as the parent node. The slot assignment is performed by taking the availability of bandwidth during the data transmission. If the network is heavily congested by a large amount of traffic then the allocated time slot arc efficiently operated for the upstream and downstream nodes. This scheme identifies the low utilized link during the data transmission and allocated the required bandwidth for the corresponding link and repeats the same until all link gets a time slot allocated.

Sreeher et al., suggests a mechanism to avoid congestion in the wireless network. This solution is mainly designed for the multicast communication. The MAC layer congestion control algorithm is working by considering the cross layer parameters. It uses the point to point communication as well as group communication either in broadcasting or in the selected transmission of data. The CSMA mechanism avoids the ACK technique to deduce the congestion and instead of broadcasting procedure for multicasting. This solution has two phases, namely multicast tree formation and multicast transmission. During the transmission phase congestion control is achieved by selecting the appropriate time slots and allocation of bandwidth to the necessary links. The allocation process takes place for both unicast and multicast transmission to control the congestion. This will increase the quality of multicast routing process and data transmission throughput.

System Model & Assumptions:

The network setup has following assumptions are listed below. The network is composed of 'n' wireless devices which operate on battery power. These devices are highly mobile devices that can move anywhere in the deployment area. The device has homogenous connectivity in terms of transmission range or coverage. The devices use the IEEE 802.11 DCF MAC standard, which utilizes the shared channel. Nodes are aware of their location information both latitude and longitude.

The proposed solution develops a robust protocol, which consider the current statistics of node and network, which performs the scheduling process with routing process. The route discovery process is continued with the selection of the best available path is route reservation.

Scalable Optimized Heuristic Routing:

This solution is generated for both unicast and multicast data traffic by formatting the multicast tree and routing tree for unicast and multicast communication respectively. All nodes in the network are designed to work in a distributed manner and there is no centralized device to control or manage the devices. These devices periodically broadcast the neighbor message named as hello message as the single hop connection message. After maintaining the neighbor connectivity information, nodes try to form the unicast route as well as multicast tree based on the current data traffic

Route setup and Multicast tree formation:

The propose solution performs the route setup process in the hybrid route discovery method. In other words the routing setup is executed in both table-driven as well as on demand route establishment. In the table driven working procedure, each node maintains the topology timer to announce of presence to all nodes in the network. The timer is executed for large time interval compared to hello timer interval. Whenever this topology timer expires, nodes broadcast the topology message as the network wide broadcast message which is rebroadcasted by all other nodes. The nodes which are rebroadcast the topology message verify the hop metric of the path. The hop metric is estimated from the hop count of message, energy cost and message travel distance of the path.

The optimal low cost route is selected with the following constraints, they are listed below;

$$M_{hop}\ (i) = \frac{Max\ \ hopcount\ *(ETx+Emp*coverage\ \ ^{n})*\sqrt{x^2+y^2}}{Current\ \ hopcount\ *(ETx+Emp*d\ ^{n})*d} \quad (1)$$

where d – distance, ETx-Transmission Energy, Emp-Propagation energy Loss
(x, y) – location difference in both axis
Once the hop metric is estimated for the previous hop node, the complete path metric is estimated in equation (2),

$$M_{path} = \sum_{i=1}^{n} \frac{M_{hop}\ (i)}{n} \quad (2)$$

After estimating the path metric nodes store the value in the routing table. If the currently available path has the higher path metric, compared to existing route path metric, then the old route is discarded and the new route is updated in the routing table. If the older one has a better value than the time at which route is updated is considered in the selection process. The time value greater than the required time gap, then the older route is discarded and it is replaced by the newer route. This route setup may also maintain the multipath route to the corresponding node. During the data transmission node with highest hop metric is selected to forward the data packets. By this way the protocol forms the table driven route entry to perform the data forwarding process.

Multicast Tree Formation:

Multicast data transmission begins with the multicast tree formation phase. Before entering into this stage all nodes are in the state of initial node. If any nodes want to join in the multicast group then it tries to search for the available group by checking its group id on its group list table. Initially this table will be empty before constructing the multicast group tree. This table has the following fields, group id, head node, connector node. If the requested group is not listed in this table, then the current node tries to create the group with corresponding group id. For this purpose, node broadcast a group formation message to complete network. This message is a network wide broadcast message which is used to inform the construction of the multicast group tree to all nodes in the network. This message has the following fields, group id, source id, visited path, path hop count, number of links connected in each hop, location of the sender, location of the previous hop forwarder, the energy of the node. Each and every field is updated in each transmission hop. And the transmission takes place as a model of broadcasting communication.

Once this message broadcasted over the wireless medium by the source, sender node, neighbor of these nodes receive the tree message. The Neighbor node performs stage verification which includes, routing loop, freshness of packet, least hop count verification. For this purpose, the verification process which is done during the route set up for unicast communication is reused. Once the packet is filtered after this verification, nodes estimate the hop for the multicast forwarding tree node. This multicast parameter estimation includes the same metric related to the unicast hop parameter of each hop count and reliability of the node with bandwidth availability. Equation (3) represents the multicast parameter which includes the (4), (5) & (6).

$$Multicast\ (param) = Mhop(param) * connectivity * Reliability * BW\ availiability \quad (3)$$

$$Connectivity = \frac{Number\ \ of\ nbr}{Number\ \ of\ nodes\ \ in\ network} \quad (4)$$

$$Reliability = \frac{Number\ \ of\ successful\ \ transmission}{Numb\ er\ of\ attempted\ \ transmission} \quad (5)$$

$$BW\ availability = \frac{Initial\ \ BW - Consumed\ \ BW}{Total\ \ BW} \quad (6)$$

Virtual Rate Estimation:

The next phase begins with the estimation of virtual rate, which is required to complete the data transmission /multicast transmission to all stream nodes. The rate or bandwidth refers the total number of bits transmitted in a unit time. The name itself explains the virtual rate is required rate value, but not an actual value of the rate.

The virtual rate is estimated in a periodical manner with the time interval “t”. If a node a data packet need to send to data to all of child as well as its parent node except the previous hop forwarder. If it is a source node then it has forward the data to all children and to its parent node. Let a node has “m” child and “1” parent node. So, the total number of transmissions will be (m+1) for the source node.

If it is intermediate forwarder than the total number of transmissions will be (m), the size of the data packet is denoted by “s”. If a node has “n” number of data to transmit in time interval “t”. Then the virtual rate for the first slot will be calculated as follows,
For Source node,

$$VR = \frac{n*s*(m+1)*8}{t}$$

For intermediate node,

$$VR = \frac{n*s*m*8}{t}$$

$$W_{VR} = \alpha * VR + (1-\alpha)VR(avg) \quad (7)$$

where VR=Current virtual rate;
VR_{avg} Average of previous history

By using the weighted value of the virtual rate value is estimated based on the equation (7), (8) and (9). To identify the rate accurately the weighted virtual rate is calculated by the real rate of the transmission as an average value.

$$Rate = \frac{W_{VR} + Current\ \ rate}{2} \quad (8)$$

$$Currentrate = \left[\frac{\sum_{i=1}^{n} controlpacketsize\ \ (i)}{t} + \frac{\sum_{i=1}^{n} Datapacketsize\ \ (i)}{t} \right] * 8 \quad (9)$$

Virtual Grid Formation:

The deployed network nodes are more scalable as well as it is easier sparsely deployed or densely deployed in the deployment area. In order to handle the network, if it is highly scalable, the network must be partitioned into a small number of networks based on some criteria. Here the consideration is based on the deployment of the node and hence the whole network is partitioned into small equal sized partitions based on the region at which the nodes are deployed. To form this partition, virtual grids are introduced which is equally sized in the network. Each grid is identified by using unique identity that is calculated based on the location of the grid. The deployment area is subdivided into grids based on the size of the grid. The virtual grid is represented by its boundary points. The nodes which enclosed within the particular grid boundary points belong to the virtual grid. These nodes store the identity of its own grid. The grid id of the node is identified using the following equation (10)

$$Number\ of\ grid\ (x) = \frac{\text{Topology}}{\text{Grid Size}}$$

$$xid = \frac{x\ point}{grid\ \ size}$$

$$yid = \frac{y\ point}{grid\ \ size}$$

$$grid\ id = x_{id} * Number\ of\ grid(x) + y_{id} \quad (10)$$

Each node identifies its grid id, and broadcast the grid information to neighbor nodes. Neighbor nodes receive the grid information message from the node and store it in the grid information table with expiring time. For this purpose each node maintains the grid-update timer with the hello interval value as the interval value of this timer. Whenever this timer expired, the node calculates its new grid id based on the current location for each and every node is in mobility and it can move anywhere in the deployment area in a random manner. And the grid-information table is updated/ removed the expired entries by verifying the running time and expired time of the stored entry. The node with higher node parameter is becoming the relay nodes or forwarder nodes, which is otherwise known connector nodes.

$$Node\ Param = \alpha_1 * \frac{Current\ Energy}{Initial\ Energy} + \alpha_2 * \frac{No.of\ grid\ member\ in\ nbr}{No.of\ nbr} + \alpha_3 * \frac{Availabel\ BW}{Total\ BW} + \alpha_4 * \frac{RRR}{Max(RRR)} + \alpha_5 * \frac{No.of\ nbr\ updated\ \ in\ last\ observation}{Total\ \ no.of\ \ nbr\ \ changes} \quad (11)$$

$$where\ \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 = 1$$

RRR-Required Reduction Ratio in rate:

The selected connector nodes are periodically broadcast the connectivity message to its neighbor with the following field, node id, grid id, updated time, sequence number, Node-Parameter. The receiver node updates the connectivity of the nodes to reach the nodes which is belonging to the particular grid.

If the node has more number of neighbor nodes with the maximum connectivity node parameter, then the node selection process is done by using the optimization algorithm. This optimization model is the combination of genetic algorithm (GA) and particle swarm optimization algorithm. Genetic algorithm takes the significant amount of time to complete operation, but the particle swarm optimization took a small amount of time to terminate the operation, DSO takes the initial solution is the random particle. But GA generates the initial solution based on current/initial encoded information. By combining these two merits of these algorithms is the combined optimization algorithm produces the best result. That is the initial solution formation and encoding operation is done by using the genetic algorithm with first set of iterative solution, then the solution is converted into a PSO solution to generate and select the best combinations of solution to decide the nodes which are best connector node to connect with the neighboring grids.

The fitness function is used here to identify the objective value of the chromosomes, which is used in the selection process. The fitness value is purely related to the node parameter which is used to connect the other grids in the network. The metrics considered in the fitness evaluation are as follows, own grid connectivity ratio, distance to reach the own grid connection nodes, global grid connectivity ratio, bandwidth required to complete the transmission in both own grids as well as other grids. These terms are expressed and explained in the following equations (12), (13), (14) and (15).

The generated initial chromosomes are sorted based on the fitness value in descending order. After sorting these values, average fitness boundary is compared with the fitness value of the each chromosome.

$$Own\ Grid\ Connectivity\ Ratio\ (OGCR) = \frac{Number\ of\ nodes\ covered\ in\ own\ grid}{Total\ number\ of\ nodes\ present\ in\ own\ grid} \quad (12)$$

$$NormalizedDistance\ to\ Reach\ the\ Nodes\ (NDRN) = \frac{\sum_{i=0}^{n} distance\ (curernt\ node, node\ i), i \in N, nodes\ in\ the\ same\ grid}{n * Transmission\ range.} \quad (13)$$

$$Global\ Grid\ Connectivity\ Ratio\ (GGCR) = \frac{No.of\ nodes\ covered\ in\ other\ grids}{Total\ number\ of\ present\ in\ other\ grids.} \quad (14)$$

$$BW\ Requirement\ Rate\ (BRR) = \frac{Bit\ transmitted\ same\ grid * Bits\ transmitted\ in\ other\ grids.}{Total\ Bandwidth} \quad (15)$$

From these expressions the objective value of the chromosome is estimates in equation (16).

$$fiteness\ value = \alpha_1 * (OGCR) + \alpha_2 * \frac{1}{NDRN} + \alpha_3 * (GGCR) + \alpha_4 * \frac{1}{BRR} \quad (16)$$

Where α_1, $\alpha 2$, $\alpha 3$, $\alpha 4$ are having parameter

$$\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$$

The chromosomes which have greater value compared to the average fitness value are selected for the crossover, mutation operation in the consecutive iterations. The chromosomes with the least value are discarded for the remaining steps. After completing the selection operations, genetic reproduction operators such as crossover, mutation and replacement is invoked to generate the new populations.

The crossover operator takes the two selected chromosomes as input and the input chromosomes must be unique to produce the new combination. These two chromosomes are merged and two new chromosomes are generated uniquely by exchanging the chromosome bits with each other. After the formation of new chromosomes by using a crossover operator, mutation operation is executed on these two chromosomes. These two chromosomes are processed independently in the mutation operation. Once the operation of the reproduction of chromosome gets completed, then fitness evaluation is done for the newly generated chromosomes.

If the newly generated chromosome has better fitness compared to the older one, then the old chromosome is replaced by the newer one in the population of the solution. And the iterative process of selection, crossover, mutation, fitness evaluation is done for the population until the maximum iteration count is reached in the particle swarm optimization space. This technique is invoked after completing the first iteration in the GA space. Then the solutions are converted into particles in the PSO space. The particle has location and velocity. Here, the nodes are marked as particles with the location, including the connectivity as the velocity of the particle. The crossover, mutation operation is replaced by the estimation of the new velocity and new location of the particles. Then the fitness evaluation is expected as same as in the GA fitness evaluation.

If the new particle has replaced the old one if it has greater fitness value. These steps are repeated until the best combination of solution is generated as well as the maximum iteration is reached. Once the optimization is terminated with the best solution, then the final best solution is decoded into node identity, which represents the node id of the currently selected connector nodes in the grid. The transmission of data and the data forwarding operation is completed by using the selected connector node.

Performance Evaluation:

The simulation is conducted using the ns-2 simulator, which is a discrete event simulator. This simulator is used to test the performance of the existing protocols as well as newly derived protocols. Here, the simulation is conducted to test the quality of the proposed protocol, which is designed to improve the scalability network protocols. The system is compared with unicast and AODV and multicast AODV with unicast and multicast respectively. The performance evaluation is conducted to validate the execution of the proposed scalable optimized routing in terms of packet related metrics such as PDR, delay, throughput, Goodput, Overhead, Normalized routing overhead, jitter and link utilization. The results are taken with varying the number of nodes in the network, packet generation interval and time of execution. Finally the results are compared with MAODV and GA based optimized routing. The table shows that the parameters used to perform the network simulation.

Performance evaluation for MAODV, STORM and Proposed routing protocol is conducted and result in terms of Packet delivery ratio is shown in Figure 1. Multicast AODV produces the performance from 72% to 83%. STORM achieves 70% to 86% and the proposed SOHR protocol achieves 83% to 95%. SOHR produces 9.47219% improvement compare to

STORM and 13.53175% improvement while comparing with MAODV protocol.

Figure 2 shows throughput evaluation between MAODV, STORM and proposed protocol. Multicast AODV produces the performance from 120000 to 130000 bits transmission. STORM achieves 115000 to 140000 bits transmission and the proposed SOHR protocol attains 130000 to 150000 bits transmission in unit second. SOHR produces 9.472667% betterment compare to STORM and 13.53195% betterment while comparing with MAODV protocol.

Simulation parameters:

Parameter	Value
Number of nodes	50,100,150,200,250
Transmission Range	250m
Deployment area	1000x1000
Packet interval	0.1, 0.2, 0.3, 0.4, 0.5
Packet size	1000bytes
Maximum Speed	4m/s
Mobility Model	Random waypoint
Simulation time	200s
Mac layer	802.11 DCF
Queue type	Priority queue
Antenna type	Omnidirectional
Propagation model	FreeSpace and MultiPath
Connection & Traffic type	UDP & CBR traffic

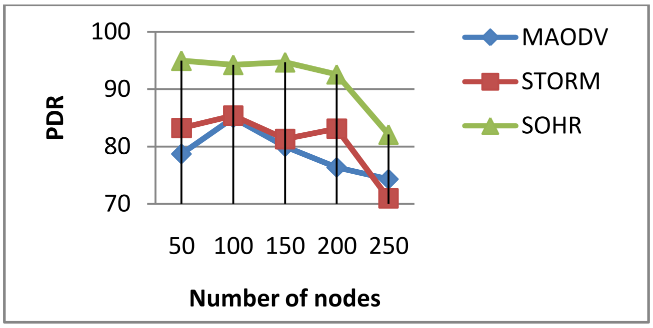

Fig. 1: Number of Nodes Vs PDR.

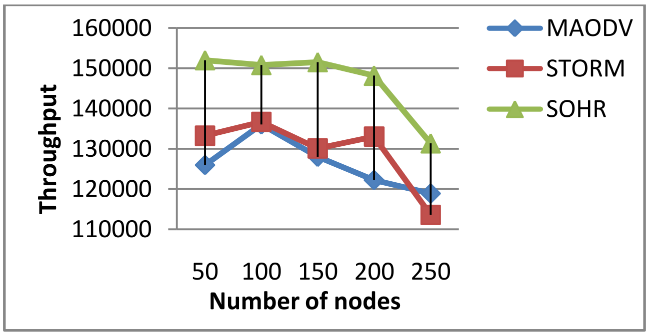

Fig. 2: Number of nodes Vs Throughput.

Link utilization parameter is estimated for MAODV, STORM and proposed routing protocol which is taken by varying the number of nodes from 50 to 250 nodes. SOHR accomplishes 0.149 as utilization ratio whereas MAODV and STORM achieves 0.049 and 0.098 respectively. The results in figure 3 clearly describes proposed solution produces 13.53195% and 9.472667% improvement while compare with MAODV and STORM protocol is shown in figure 3.

Figure 4 depicts Jitter comparison between MAODV, STORM and proposed SOHR protocol. Multicast AODV produces the jitter value from 0.12 to 0.14, STORM achieves 0.12 to 0.13 and the proposed SOHR protocol attains 0.105 to 0.12 seconds. SOHR produces 8.639256% betterment compare to STORM and 12.47272% betterment while comparing with MAODV protocol.

Performance evaluation for MAODV, STORM and Proposed routing protocol is conducted by varying the packet generation rate from 1 to 5 mbps

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and result in terms of Packet delivery ratio is shown in Figure 5. Multicast AODV produces the performance from 72% to 80%. STORM achieves 81% to 84% and the proposed SOHR protocol achieves 92% to 95%. SOHR produces 17.13456% improvement compare to STORM and 12.33927% improvement while comparing with MAODV protocol.

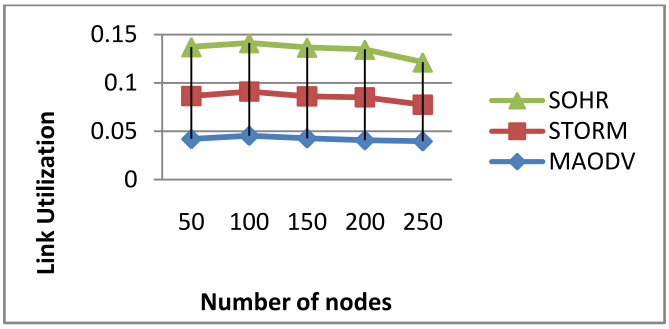

Fig. 3: Number of nodes Vs Link utilization.

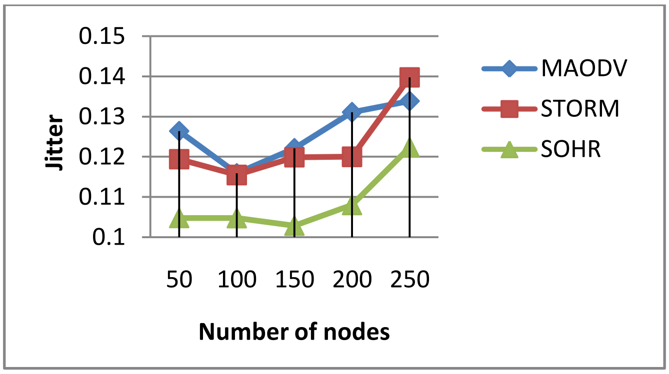

Fig. 4: Number of nodes Vs Jitter.

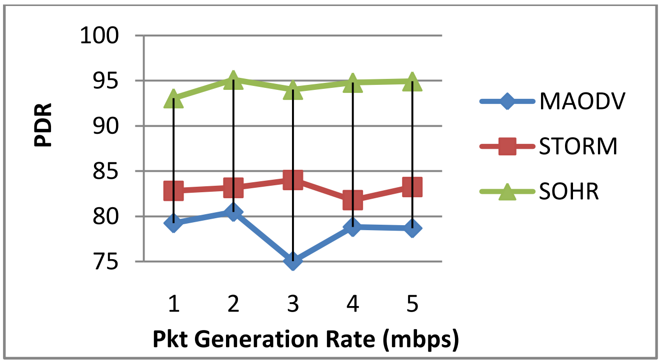

Fig. 5: Packet generation rate Vs PDR.

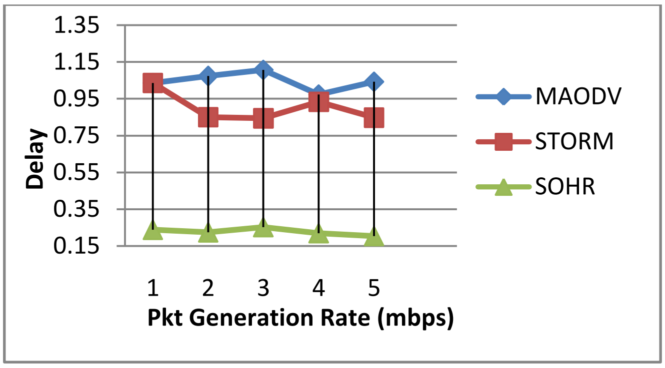

Fig. 6: Packet generation rate Vs Delay.

Figure 6 depicts Delay comparison between MAODV, STORM and proposed SOHR protocol. Multicast AODV produces the delay from 1.1 to 1.14, STORM achieves 0.9 to 1.11 and the proposed SOHR protocol attains 0.17 to 0.25 seconds to complete the transmission. This evaluation is performed by varying the packet generation rate. SOHR produces 80.4458% improvement compare to STORM and75.94676% better performance while comparing with MAODV protocol.

Goodput is estimated by varying the packet generation rate for MAODV, STORM and proposed routing protocol and it is displayed in figure 7. SOHR accomplishes 40mbps as utilization ratio, whereas MAODV and STORM achieves 8 Mbps and 9 Mbps respectively. The results clearly describe proposed solution produces 83.79631% and 78.91473% improvement while comparing with MAODV and STORM protocol in terms of Goodput.

Figure 8 depicts Control Overhead evaluation between MAODV, STORM and proposed SOHR protocol. Multicast AODV produces the Control Overhead value from 7000 to 30000, STORM achieves 6000 to 17000 and the proposed SOHR protocol attains 2000 to 10000.

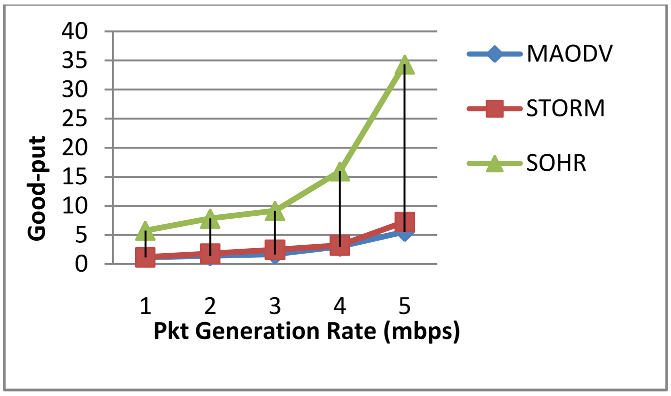

Fig. 7: Packet generation rate Vs Goodput.

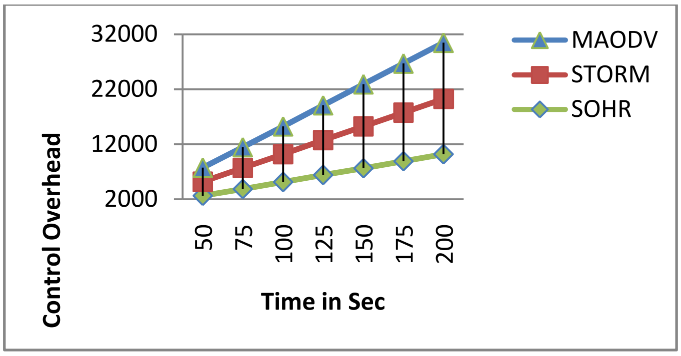

Fig. 8: Time Vs Control Overhead.

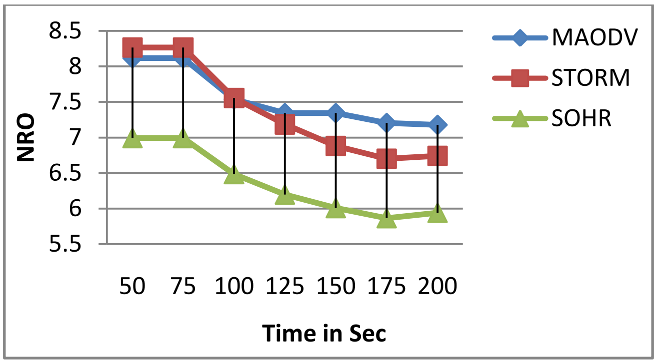

Fig. 9: Time Vs Normalized routing overhead.

Figure 9 displays normalized routing overhead comparison between MAODV, STORM and proposed SOHR protocol. Multicast AODV produces the Control Overhead value from 7.25 to 8.3, STORM achieves 6.8 to 8.4 and the proposed SOHR protocol achieves 5.9 to 7. Performance evaluation clearly shows that the proposed SOHR protocol produces the better significance while comparing with the MAODV and STORM protocol.

Conclusion:

In this work, Scalable Optimized Heuristic Routing (SOHR) strategy is proposed for wireless network to improve the Goodput and throughput and to reduce the transmission cost and delay. The proposed solution solves the multi-hop multicast routing problem by handling the dynamic network situation such as link unavailability, node failure and bad channel conditions. This solution purely optimized and which is based on dynamic connectivity and channel availability among congested wireless devices to increase the scalability of the network. The simulation is conducted using ns2 and the performance evaluation is done for the multicast transmission. The comparison result shows that the proposed SOHR scheme attains better performance compared to the MAODV and STORM protocol in terms of PDR, Goodput, delay, link utilization, throughput and routing overheads.

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