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Fuzzy Logic Approaches in Reverse AD HOC on Demand Distance Vector Routing Protocol

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Abstract: Fuzzy logic is a strong and powerful tool that would make intelligent decisions if there exists inadequate data. Network lifetime is enhanced based on the routing path in a network. In this paper enhance the Reverse AODV routing protocol using fuzzy logic concepts. Fuzzy Logic control based on three variables like energy, Queue length and hop count. The optimal paths are selected based on these variables, used to enhance the process of Reverse AODV routing protocol and also improve the lifetime of the network. The result of the simulation which has been done in NS2 Simulator shows that Reverse AODV protocol based on fuzzy logic is more efficient and improves the lifetime of the network comparing with the existing Reverse AODV routing protocol. Packet delivery ratio, average energy, end to end delay, dropping ratio and throughput metrics are evaluated in Fuzzy logic RAODV and it has better result compared with RAODV.

Key words: Fuzzy Logic · Energy · Queue length · Hop count · Optimal paths · RAODV (Reverse Ad Hoc on Demand Distance Vector)

INTRODUCTION

Ad Hoc Network is a multi hop wireless network and also it has a dynamic nature in network. Ad Hoc Networks are used for many areas of applications like military, emergency, conferencing, sensor applications etc. The Quality of Service is varied based on the applications. Mobile Ad Hoc Networks (MANETs) is one of the types of Ad hoc network.

In MANET, each mobile node is acts like router and has energy and bandwidth constraints. Routing protocols have to be designed for dynamic; self configure ration characteristics for ad hoc networks. MANET routing is based on multi hop routing from source to destination and these networks have many constraints like bandwidth, battery energy, throughput etc. Traditional routing protocol of wired network is not suitable for wireless network. Generally routing protocol is divided into table-driven and on-demand routing protocols.

Table driven routing protocols have each node maintains up-to-date routing information to every other node in the network. In this routing protocol every node are well maintained routing table and each node has paths to every other node in the network and also stores routing information even before it is needed. Each node updates the routing information periodically whether the topology of the network is changed or not. The main drawback of proactive routing protocol is continually updating the routing table .whether needed or not

In the On-Demand routing protocol, when the source node is needed to transfer the data then only establish the path from source to destination. Reactive routing protocols are establishing path only when the source node wants to send data to destination node. When source node wants to send data to destination, it initiates a route discovery procedure to establish the path between source and destination. After the route discovery process over then only transfer the data packet from source node. One of the drawback is delay in reactive routing protocol because first to establish the path between source and destination and then transmits the data.

Fuzzy logic [1] was introduced by Lot Fi-Zadeh in the mod 1960s; it is a system design technique. Fuzzy logic approaches are used to improve the quality of service in wireless network. Fuzzy logic system has four components that are fuzzification, defuzzification, inference engine and a fuzzy rule base. In the fuzzification process, system inputs are converted into fuzzy sets. The

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inference engine is used fuzzified input to simulate human reasoning procedure. In the defuzzification module, fuzzy inference value into crisp value.

In this paper, Fuzzy logic control is used to enhance the performance of the Reverse AODV protocol and improve the lifetime of the network based on three variables like energy, queue length and hop count. The input variables of fuzzy logic are energy, queue length and hop count, destination node selects the optimal paths for data packet transmission. The rest of this paper is organized as follows, chapter 2 describes the related work, chapter 3 explains proposed work, chapter 4 indicates simulation results and parameters and the last chapter is the conclusion of this work.

Related Work: Ad hoc On-demand Distance Vector (AODV) [2] is one of the examples of on demand routing protocol which is the combination of DSR and DSDV protocol and it has single route reply along reverse path and also reduce routing overhead in a network. Many routing protocols are developed based on this protocol. In AODV, when the link failed in a network source node again to reroute the routing path to destination node and it takes more time and more power consumption is needed to transfer the data.

In Reverse Ad hoc On-demand Distance Vector [3] is also an on demand routing protocol which is the extension of AODV protocol. This protocol is helpful to reduce the loss of Route Reply Packet and improve the performance of the network. In the route discovery process, source node initiate the routing path, it broadcast the RREQ packet to the next neighbor node which forward to the next intermediate nodes and these process continues to reach the destination node. If the first RREQ packet reaches to destination node again it broadcasts the R-RREQ packet to the nearest neighbor nodes and this process continues finally R-RREQ packet reach to the source node. Source node immediately transfers the data packet when it receives the first R-RREQ packet from the destination node, remaining R-RREQ packet is collected in the routing table. When the link is failed in a network, source node chooses another feasible path in the routing table. RAODV has multiple route reply to the source node and it has better result in packet delivery ratio, power consumption and communication delay compared to AODV.

Randomized RAODV [4] is based on Reverse AODV routing protocol. In this protocol, source node collects the various routing paths to reach destination node in the routing table and it selects the path randomly in the routing table for security purposes. Authors [5] analyzed Randomized RAODV protocol to produce better result in packet delivery ratio, end to end delay and control packet overhead based on number of nodes and speed.

In [6], authors select multiple routing paths for data packet transmission, at a certain time, only one path is used for data transmission and remaining path has probability to be selected. This protocol has energy aware source routing with a disjoint multipath selection schema. In this protocol, the paths are not overlapped and overhearing effect cannot be occurred. Lee *et al.* [7] describes intermediate nodes forward the duplicate packet to establish disjoint multipath from source to destination, but the energy of the node is wasted due to overhearing. Ze Li *et al.* [8] using QoS oriented distributed routing protocol to enhance the QoS of hybrid networks. In this protocol source node selects nearby neighbor that can provide QoS services to forward the data packets to base station based on their queuing condition, channel condition and mobility.

Author proposes [9] efficient power aware routing protocol to increase the lifetime of the network. It selects the path that has largest packet capacity at the smallest residual packet transmission capacity. Mohammad Saraireh *et al.* [10] improve the average Quality of Service in audio and video applications using fuzzy logic and access QoS provided by wireless networks. Inference engine inputs are the mean values of delay, jitter and throughput and packet loss. SEPFL routing protocol [11] based on fuzzy logic using three fuzzy logic variables like distance of node from base station, density of nodes and the battery level of nodes is helpful to improve the lifetime and throughput of the wireless sensor network. In [12], the algorithm uses three fuzzy variables like energy; centrality and concentrations of a node for selection of cluster head and the base station select the cluster head based on the fuzzy logic rules. Authors [13] proposes the new routing method for wireless sensor networks to prolong the lifetime of the network using a combination of fuzzy approach and an A-Star algorithm and this one is help to select the optimal routing path based on highest remaining battery power, minimum number of hops and traffic loads. The main drawback is each node has a certain amount of traffic pending in node’s queue. Jin-Shyan Lee *et al.* [14] proposes a fuzzy logic based clustering approach with an extension to the energy prediction helpful to improve the lifetime of wireless sensor networks by evenly distributing the workloads. In the cluster head election, each sensor node generate a random number between o and 1, If the random number for a node is greater than a predefined threshold, then the node calculates the chance using the fuzzy inference system and broadcasts a candidate message with the chance. If the chance is more than the chance value from the other nodes, then this sensor node is elected as the cluster head. The main drawback is not to handle mobile sensor nodes.

Authors [15] propose fuzzy – based on-demand routing protocol for MANETs. This protocol uses fuzzy logic system based on remained energies of the nodes on the path, bandwidth and node mobility to select a stable route to enhance system performance. Goswami *et al.* [16] proposed a fuzzy based routing protocol for MANET and multiple optimal paths are selected based on the fuzzy logic variables hop count, battery power and signal strength. In [17], fuzzy logic based decision method is adopted for queue scheduling and three queues are defined like low, medium and high priority queues. Anno *et al.* [18] select cluster head based on remaining battery power, number of neighbor nodes, distance from cluster head and network traffic. Authors [19] propose fuzzy logic based relay selection algorithm, it can transmit a large amount of data during network lifetime. OD-PRRP protocol [20] enhances the network life time, low delay, high packet delivery ratio, low overhead and balanced load distribution using fuzzy logic and ant colony optimization. Geetam Singth Tomar *et al.* [21] proposes a fuzzy logic approach to elect cluster head election.

Proposed Work: Fuzzy logic has been used to enhance the lifetime of R-AODV. The routing path is selected to transfer data according to some criteria in order to maximize network life time. A good routing method in MANET involves finding the optimal transmission paths from source through intermediate nodes to the destination in order to prolong the network life time. Three metrics like energy, queue length and hop count are used to select the optimal paths to transfer the data packets. The focus is on the total energy capacity of the intermediate nodes on the paths. Minimum Hop count is one of the most common criteria used in routing protocols. This routing protocol is used to find the minimum hop count to reach destination node that requires the smallest number of intermediate nodes. When the smallest number of intermediate nodes involve, low end-to-end delay, low resource consumption has occurred. If Queue length is high means, traffic load is automatically reduced otherwise loss of important information. Fuzzy structure is represented in the Figure 1.

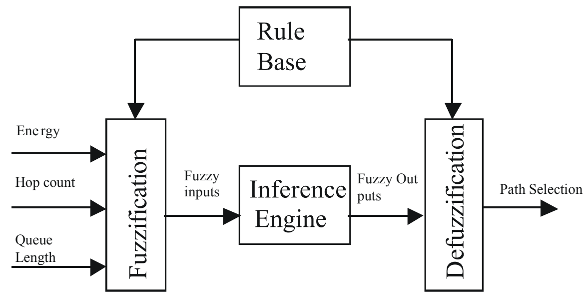

Fig. 1: Fuzzy Structure with three inputs

Table 1: Fuzzy logic Rules

Hop count	Energy	Queue Length	Probability
Low	Low	Low	Low
Low	Medium	Low	Medium
Low	Low	Medium	Low
Medium	Medium	Medium	Medium
Medium	Medium	Low	Medium
Medium	Low	Medium	Low
High	High	High	High
High	Low	Medium	Low
High	Medium	Low	Medium

Life time of each node in MANETs depends on energy consumption, it is used to preserve residual energy of those nodes in such a way that overall network life time is extended. Fuzzy approaches are used to access and improve the Quality of Service in simulated wireless networks. Fuzzy logic analysis information using fuzzy sets, each of which is represented by a linguistics term such as “low”, “Medium” and “High”. Life time of each node in the network depends on energy consumption, the overall lifetime of the network is increased when the residual energy of the network is high. Fuzzified values are processed by the inference engine which consists of a rule base that is a series of IF-THEN rule and it is represented in the Table 1.

In the fuzzy logic approaches in RAODV routing protocol, the neighbor nodes are selected based on the fuzzy logic variables of energy, queue length and hop count. It follows the same procedure to find the route discovery in RAODV protocol. Source node broadcasts the RREQ packet to find the path to destination node. The destination node select the two optimal paths based on the fuzzy variables like hop count, queue length and energy. Two optimal paths are selected based on highest energy, minimum number of hops and queue length is high in the intermediate nodes in the network. One path is used by the source node to forward the data packets and the remaining one is used for back off. If the primary path fails then secondary path is activated.

MATERIALS AND METHODS

Simulations are helpful to evaluate the performance of Fuzzy logic in Randomized RAODV and also compare with and without applying fuzzy logic in Reverse Ad hoc on demand Distance Vector routing protocol. Detailed performance analysis of fuzzy logic in RAODV is carried out using the parameters like Packet delivery ratio, Average end-to-end delay, Average energy, Dropping ratio, jitter control and Throughput, Packet loss, Control packet overhead. Two different scenarios are used to evaluate the above parameters. One scenario is varying the number of nodes but speed is constant and other is varying speed but node is constant.

The simulation environment for performance analysis is shown in Table 2.

Detailed performance analysis of RAODV and Fuzzy based RAODV using the parameters like Packet delivery ratio, Average end-to-end delay, Throughput, Dropping ratio, Control packet overhead. Two different scenarios are used to evaluate the above parameters. One scenario is varying the number of nodes but speed is constant and other is varying speed but node is constant.

Scenario 1 – Network with Varying Number of Nodes: In scenario 1, RAODV and fuzzy logic in RAODV are analyzed using the parameters like packet delivery ratio, end to end delay, throughput, Dropping ratio and average energy consumption using varying the number of nodes (60, 70, 80, 90 and 100) and the speed of the nodes is constant (40m/s).

Packet Delivery Ratio: It is the ratio of packets reaching the destination node to the total packets generated at the source node that means ratio between number of packets originated by source node and number of packets received at their destination. Average rate of packet delivery ratio in RAODV is 85.38% but in FRAODV has 95.45%. FRAODV chooses the paths based on the fuzzy logic, so Packet delivery ratio is also increased and the lifetime of the network is enhanced because Destination node selects the optimal paths based on high energy, queue length and low hop count. Figure 2 represents packet delivery raio.

End to End Delay: The interval time between sending by the source node and receiving by the destination node, which includes the processing time and queuing time. It is represented in Figure 3.

Table 2: Simulation Parameters

Parameter	Value
Simulator	ns-2.34
Protocols	RAODV, FRAODV
Number of nodes	60, 70, 80, 90, 100
Simulation Area	1000m X 1000m
MAC Layer	IEEE 802.11
Simulation Times	100s
Radio Transmission range	250m
Movement Model	RWP (Random Way Point Model)
Traffic type	CBR
Mobility	10ms
Propagation	Two ray ground
Agent	UDP agent
Data Payload	512 bytes/packet
Transmission Power(TxPower)	0.02
Receiving Power(RXpower)	0.01

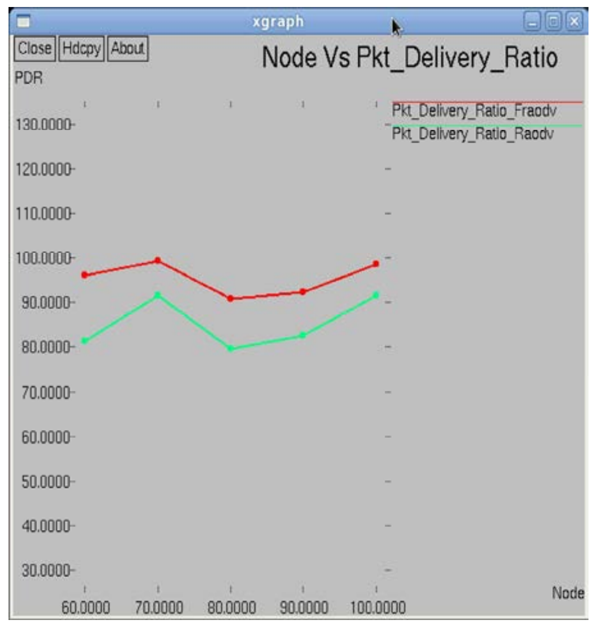

Fig. 2: Packet delivery ratio Vs number of nodes

Average delay is calculated as follows,

$$Average\ Delay = \frac{1}{n}\sum_{i=1}^{n} r_i - S_i$$

where n is the number of packets received, r_i is the time stamp of the arrival of the i^{th} packet and s_i is the time stamp of the departure of the i^{th} packet. Delay time is less in FRAODV compare to RAODV. In FRAODV, source node sends data packets to destination using feasible path and the path selection is based on high queue length, high energy and less hop count, so the lifetime of the network is increased and the path is also an optimal path. Fuzzy logic approach has helpful to improve the Quality of Service in the wireless network.

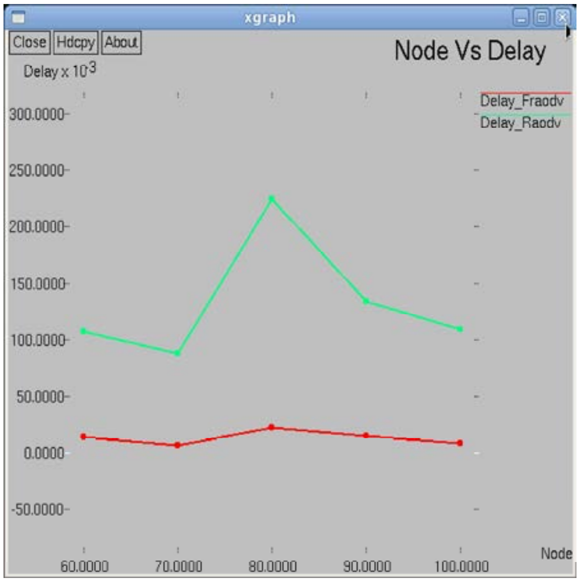

Fig. 3: End to End Delay Vs number of nodes

Dropping Ratio: Dropping ratio is measured as a percentage of packets lost with respect to packet sent. It is measured by the total number of packets sent by the source node minus total number of packets received by the destination node. Dropping ratio is represented in Figure 4.

The formula for calculating dropping ratio is as follows,

$$Dropping\ ratio = \left(1 - \frac{R_i}{S_i}\right) X100$$

where R_i is the total number of received packets in the i^{th} interval and S_i is the total number of transmitted packets in the i^{th} interval. Dropping ratio is less in FRAODV than RAODV. When the number of node is 60, packet loss is 18.58 in RAODV but 3.87 in FRAODV at the same time the number of node is 100, packet loss in RAODV is 8.4 and FRAODV is 1.36. In the fuzzy logic approach, neighbor nodes are selected based on the fuzzy logic, so increased the life time of the data path.

Throughput: Throughput is the rate of successful message delivery over a communication channel. It is measured in bits per second.

Throughput is calculated as follows,

$$Throughput = \frac{Total\ Number\ of\ bits\ received\ in\ t\ seconds}{t\ Seconds}$$

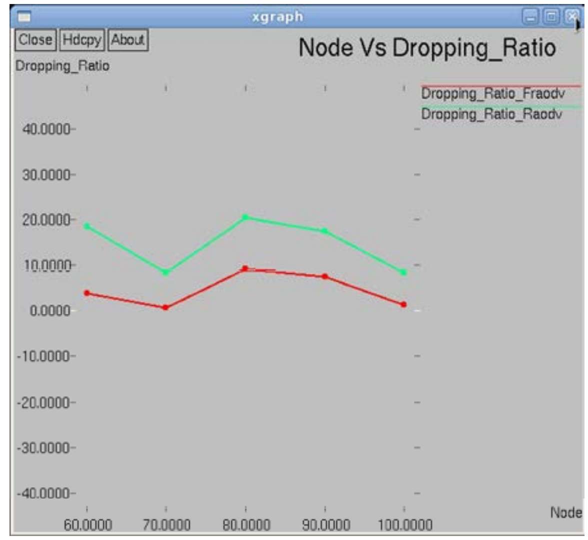

Fig. 4: Dropping ratio Vs number of nodes

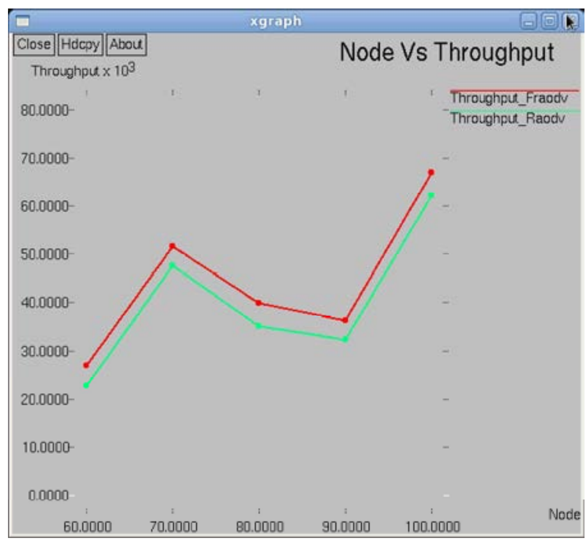

Fig. 5: Throughput Vs number of nodes

Throughput is also high in Fuzzy based RAODV, because the successful delivery of data packet is high and packet loss is low. Source node sends data only in the feasible path, the data packet forwarded path is not easily dead, it is in Figure 5.

Average Energy: Lifetime of the network is based on energy, in the fuzzy logic approach RAODV is also mainly focused on the energy consumption of the network. The destination selects the feasible paths based on energy which is one of the important fuzzy logic variables in wireless networks. Intermediate nodes in the network has more energy are only participate in the data packet sent to destination node. FRAODV has consumed less energy for data packet transmission. Energy consumption of FRAODV and RAODV based on number of nodes is represented in Figure 6.

Scenario 2 – Network with Varying Speed of Nodes: In scenario 2, RAODV and Fuzzy based RAODV are analyzed using the parameters like packet delivery ratio, end to end delay, throughput, Dropping ratio and Average energy consumption using varying the speed of nodes (10m/s, 20m/s, 30m/s, 40m/s and 50m/s) with the number of nodes is constant (50).

Packet Delivery Ratio: Figureure 7 shows the packet delivery ratio Vs Speed of RAODV and FRAODV. When the speed of the node is increased, packet delivery ratio is high in FRAODV compare to RAODV. FRAODV has 11% over RAODV. Packet delivery ratio is high in FRAODV when the speed of the network is increased.

End to End Delay: In Figure 8, End to End delay is very low in Fuzzy logic based RAODV compared to RAODV. If the speed is increased then delay is decreased in FRAODV. End to End delay of Fuzzy based RAODV has around 47% than RAODV.

Dropping Ratio: Figure 9 shows packet loss of each protocol. When the speed of the node is varied from 10m/s to 50m/s, packet loss in FRAODV is reduced by 51% over RAODV. When the speed is increased, dropping ratio is gradually decreased.

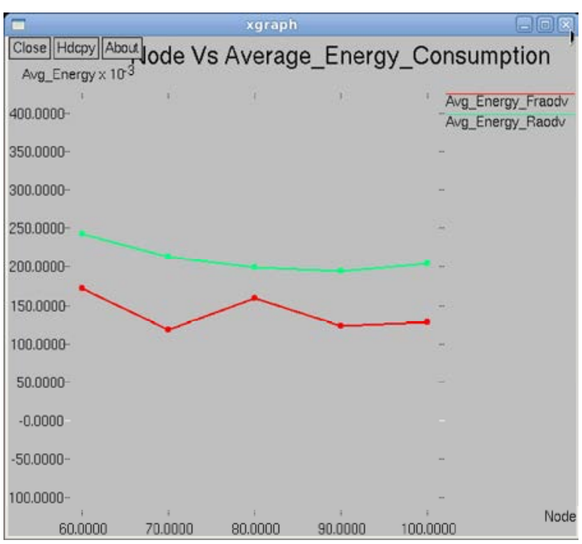

Fig. 6: Energy Consumption Vs number of nodes

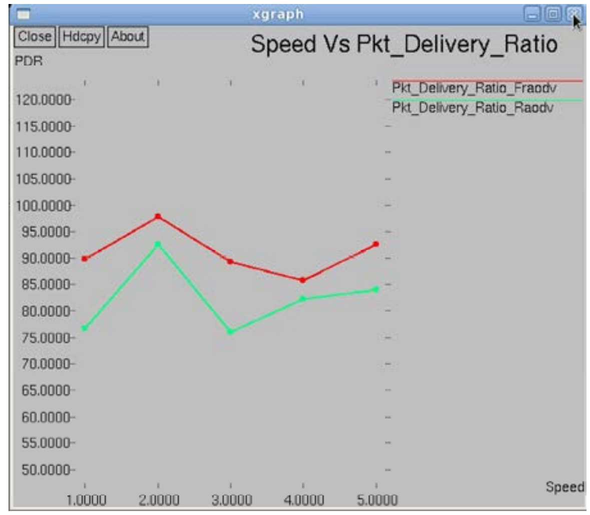

Fig. 7: Packet delivery ratio VS Speed

Fig. 8: End to End Delay VS Speed

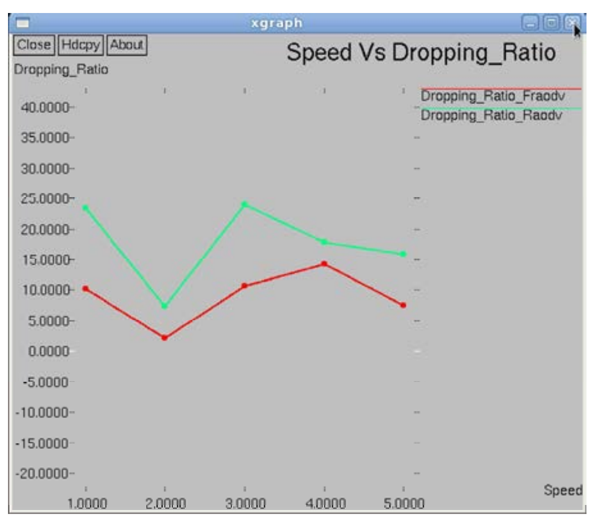

Fig. 9: Dropping ratio VS Speed

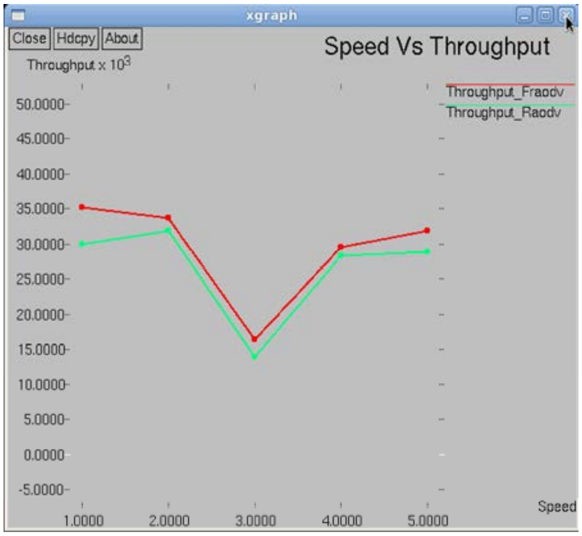

Fig. 10: Throughput VS Speed

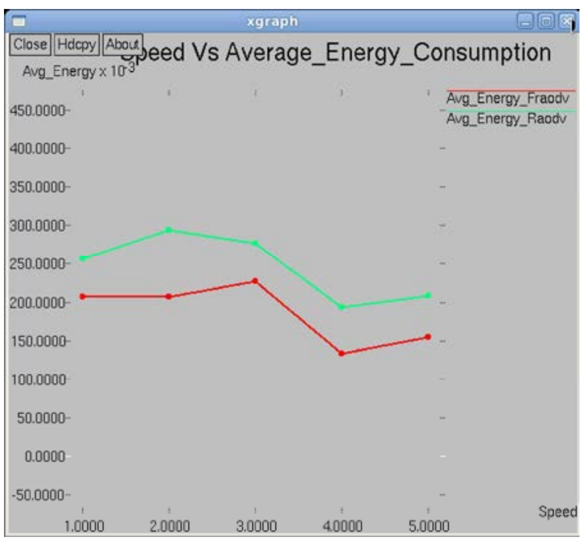

Fig. 11: Average energy VS Speed

Throughput: Throughput is high in FRAODV compare to RAODV. Throughput is related to packet delivery ratio, FRAODV has 11% over RAODV. The comparative result is shown in Figure 10. Successful delivery of data packet is high in FRAODV which select the optimal paths then only transfer data packets.

Average Energy: Energy consumption is less in FRAODV compare to RAODV. High energy rate of intermediate nodes selected to forward data packets, so energy consumption is less in FRAODV. Energy consumption of RAODV and FRAODV is represented in Figure 11.

RESULTS AND DISCUSSION

Performance analysis of RAODV and FRAODV based on number of nodes is represented in Table 3. In this table, packet delivery ratio and throughput of FRAODV is 12% over RAODV, delay time is reduced very less comapre to RAODV ie 90% over RAODV. Loss of packets is controlled in FRAODV, data packets are travel through efficent and optimal path only. Dropping ratio is 73% over RAODV. Average energy consumption is 34% over FRAODV.

In Scenario I, performance of the RAODV and Fuzzy based RAODV is analyzed based on the Number of nodes and the result is shown in Table 4. Based on the result, FRAODV has better performance in packet delivery ratio, throughput, end to end delay, dropping ratio and energy consumption on the number of the node is 60, 70, 80, 90, 100. In the number of node is 60, the performance of FRAODV is slightly reduced.

Table 3: Performance analysis of RAODV and Fuzzy based RAODV With respect to Number of Nodes

Speed = 40 m/s (Constant)			
Packet Delivery Ratio (%) VS No. of Nodes			
Number of nodes	RAODV	Fuzzy Logic RAODV	Average Efficiency of Fuzzy Logic RAODV
60	81.4235	96.1294	12 % over RAODV
70	91.6941	99.2118	
80	79.6353	90.8	
90	82.5529	92.4588	
100	91.6	98.6353	
End to End Delay (ms) VS No. of Nodes			
Number of nodes	RAODV	Fuzzy Logic RAODV	90% over RAODV
60	0.107346	0.0140024	
70	0.0880679	0.0067912	
80	0.224491	0.0218273	
90	0.133883	0.0144234	
100	0.108707	0.00838412	

Table 3: Continued

Dropping ratio (Bytes/s) VS No. of Nodes			
Number of nodes	RAODV	Fuzzy Logic RAODV	73% over RAODV
60	18.5765	3.87059	
70	8.30588	0.788235	
80	20.3647	9.2	
90	17.4471	7.54118	
100	8.4	1.36471	
Throughput (Bytes) VS No. of Nodes			
Number of nodes	RAODV	Fuzzy Logic RAODV	12% over RAODV
60	22801.3	26919.4	
70	47686.6	51596.2	
80	35043.7	39956.7	
90	32364.6	36248.1	
100	62295.3	67079.9	
Average Energy VS No. of Nodes			
Number of nodes	RAODV	Fuzzy Logic RAODV	34% over RAODV
60	0.242448	0.171717	
70	0.213385	0.118803	
80	0.199767	0.159217	
90	0.194283	0.12333	
100	0.204456	0.127998	

Table 4: Performance analysis of RAODV and Fuzzy based RAODV With respect to speeds

Number of Node = 50 (Constant)			
Packet Delivery Ratio (%) VS Speed (m/s)			
Speed	RAODV	Fuzzy Logic RAODV	Average Efficiency of Fuzzy Logic RAODV
10	76.6235	89.7882	11% over RAODV
20	92.6706	97.8706	
30	76.0471	89.3647	
40	82.2118	85.7765	
50	84.0824	92.5412	
End to End Delay (ms) VS Speed (m/s)			
Speed	RAODV	Fuzzy Logic RAODV	47% over RAODV
10	0.125598	0.036678	
20	0.0891653	0.0133849	
30	0.160221	0.0277147	
40	0.165028	0.0809429	
50	0.0932146	0.14628	
Dropping Ratio (Bytes/s) VS Speed (m/s)			
Speed	RAODV	Fuzzy Logic RAODV	51% over RAODV
10	23.3765	10.2118	
20	7.32941	2.1294	
30	23.9529	10.6353	
40	17.7882	14.2235	
50	15.9176	7.45882	
Throughput (Bytes) VS Speed (m/s)			
Speed	RAODV	Fuzzy Logic RAODV	11% over RAODV
10	30040	35201.1	
20	31882.4	33671.4	
30	13994.3	16445	
40	28284.2	29510.6	
50	28927.7	31837.9	
Average Energy VS Speed (m/s)			
Speed	RAODV	Fuzzy Logic RAODV	25% over RAODV
10	0.256956	0.207272	
20	0.294491	0.2065	
30	0.276692	0.227416	
40	0.193441	0.133219	
50	0.207979	0.154421	

Performance analysis of RAODV and FRAODV with respect to speed is represented in Table 4. Packet delivery ratio of RAODV and FRAODV is 11 % over RAODV with respect to speed. Delay time is reduced in FRAODV compare to RAODV, FRAODV selects the optimal path for data packet transmission which has 47% over RAODV. Packet loss is also reduced in FRAODV i.e. 51% over RAODV. Energy consumption is 25% over RAODV based on speed.

In Scenario II, performance of the RAODV and Fuzzy based RAODV is analyzed based on the speed and the result is shown in Table III. Based on the result, FRAODV has better performance in packet delivery ratio, throughput, end to end delay, dropping ratio and energy consumption on the speed of the node is 10m/s, 20m/s, 40m/s, 50m/s. In the speed is 30m/s, the performance of FRAODV is slightly reduced.

CONCLUSION

This work is the enhancement of RAODV protocol and this protocol is helpful to select the feasible and optimal paths in the network. Applying fuzzy logic in RAODV protocol, consider the fuzzy logic variables like hop count, energy and hop count are applied in the RAODV protocol and the optimal paths are selected by the destination node based on these fuzzy variables. This optimal path is helpful to increase the lifetime of the network. It has better result in packet delivery ratio, throughput, end to end delay, dropping ratio and energy consumption in each round compare to RAODV. In future, applying some security mechanism used in this protocol to increase the security of the network.

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