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Intelligent Rule Based QoS Aware Routing Protocols for MANET

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Abstract: In this study, two intelligent routing protocols namely Intelligent Quality of Service (QoS) aware adhoc on demand distance vector routing scheme and a rule based QoS aware AODV protocol for effective routing in mobile ad hoc networks have been proposed and implemented. The first protocol which focuses on the improvement of QoS relies on the information it receives from the network and application layers to calculate the network bandwidth consumption and operates independently of the Media Access Control (MAC) layer. Using this proposed intelligent QoS based AODV scheme, the network layer provides feedback on network congestion to the application layer. Therefore, the source node adapts the real-time data transmission rate based on the network congestion feedback it receives through intelligent rules. In addition to this, researchers propose a new routing protocol which focuses on both QoS and rule based route management. The simulation results obtained from this work demonstrate that the schemes proposed in this work are effective for both QoS requirements and also for making intelligent routing decisions with multiple QoS constraints. The proposed schemes reduce the packet loss, network overload, optimizes the delivery path, packet overhead, packet delivery ratio and delay.

Key words: Quality of Service (QoS), mobile ad hoc networks, Intelligent Ad hoc on Demand distance Vector (I-AODV)

INTRODUCTION

Mobile Ad hoc Network (MANET) is a collection of networking devices such as nodes or routers that participate in the communication without a centralized access point (Song *et al*., 2004; Bai and Sighal, 2006). The nodes in MANET communicate and coordinate within themselves and hence each node is responsible for communicating with other nodes. Moreover, the nodes in MANETs move arbitrarily and they are configuring themselves to form a new topology. Therefore, it is necessary to find new routes every time since the topology changes rapidly (Li *et al*., 2010). Routing is an important problem in mobile ad hoc networks since it has to find an optimal route for sending data from one node to another. Since, Mobile Ad hoc Networks (MANETs) are characterized by a dynamic topology they must be handled through effective techniques. Such networks are capable of providing communication capabilities to remote areas in which no communication infrastructures exist. The main applications of MANET include war, earthquake and other emergency applications where communication infrastructures are lacking.

Currently, mobile ad hoc networks are receiving attention due to its potential military and civilian applications. The major challenges in designing a routing algorithm are the issues such as dynamic topologies, bandwidth-constrained links, energy constrained operations and limited physical security. Moreover, the routing protocols for wired networks cannot be directly used for wireless networks. A MANET uses multi-hop routing instead of a static network infrastructure to provide network connectivity. Several routing protocols have been proposed for mobile ad hoc networks (Li *et al*., 2010).

Routing in MANET: Routing is the process of selecting optimal paths in a network for sending the message traffic. Routing techniques are necessary in computer networks and separate routing algorithms are necessary for wired and wireless networks. However, all these routing algorithms try to find a shortest path in terms of the number of hops or it may aim at finding a route with less congestion. Therefore, it is necessary to consider not only the distance metrics but also other metrics such as mobility, network bandwidth, traffic and congestion in order to provide an effective routing technique. In the past, many routing algorithms including distance vector routing and link state routing algorithm have been proposed for routing in wired and wireless networks

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(Shurdi *et al*., 2011; Song *et al*., 2004; Bai and Sighal, 2006; Al-Qassas *et al*., 2003). However, these routing techniques are not considering the dynamic topology due to mobility constraint. Therefore, routing algorithms such as AODV, DSDV and DSR have been proposed for effective routing in MANETs. Moreover, intelligent agents have been proposed for performing registration, security checking and routing in wireless networks where the nodes roam freely. In spite of all these techniques, the performances of the routing algorithms are reduced due to security threats. Therefore, many researchers have proposed algorithms for secure routing. Another direction in the development of routing algorithms is the design and implementations of multipath routing algorithms. Even though, multipath routing algorithms are better choice for congestion control, the overheads involved in them reduces the routing performance (Li *et al*., 2010). The maintenance of routing tables or cache to maintain the routes must be revised and additional table structures must be introduced for making effective decisions in routing. Moreover, the performance of routing is depending upon the application. Therefore, it is necessary to consider the QoS requirements of the application and a suitable transport layer protocol must be considered in the implementation. The routing must reduce delay as well a jitter and at the same time, the packet delivery ratio must be improved.

Quality of service: Quality of Service (QoS) refers to a set of metrics that are to be considered while developing a network or networking applications. The QoS in networks can be measured in terms of time taken to deliver the packets, packet delivery ratio and jitter (Djenouri and Balasingham, 2011). These metrics are depending on network bandwidth and the traffic characteristics. Quality of service must be maintained in many critical applications where MANETs are used. In such a scenario, the routing algorithms must care about fast routing of packets and must avoid packet traffic (Iqbal *et al*., 2010). It must reduce the overheads occurring due to frequent update of routing tables and cache. Therefore, it is necessary to develop new routing algorithms that must provide QoS and also must provide effective security (Baolin and Layuan, 2006). It is possible to provide security through encryption and decryption of data in communication. In addition, efficient key management techniques and Intrusion Detection Systems can be used for providing security. However, in an intelligent secure routing environment, key computation and re-computation overheads can be reduced by using rules.

In this study, researchers propose two new routing algorithms called I-AODV and R-AODV which have been developed by enhancing the existing Ad hoc on Demand Distance Vector Routing Protocol (AODV). In this approach each node maintains two tables, i.e., neighbour table and routing table. It stores all information about the route and the neighbors in the coverage area of the node. Additionally, it stores the information about the available constraints that is maximum delay and minimum bandwidth. The main advantage of I-AODV is that it enhances the QoS metrics in networks. The second protocol called R-AODV not only enhances the QoS but also considers the neighbors for providing secure communication.

Literatue review: There are many researches in the literature that discuss about routing in MANET (Shurdi *et al*., 2011; Li *et al*., 2010; Song *et al*., 2004; Bai and Singhal, 2006; Al-Qassas *et al*., 2003; Garcia-Luna-Aceves and Menchaca-Mendez, 2011). In particular, many enhancements have been carried out to the existing AODV protocol. Wang and Cui (2008) proposed an enhanced AODV protocol, a scheme to make mobile nodes more aware of the local connectivity to its neighbours in the network. The new scheme extends the original HELLO message in AODV but with lower overhead. Their simulation results show that their scheme reduces the route load and hence provides better performance than AODV in the network with potential unidirectional links. They also proposed an enhanced AODV protocol, called EAODV. It is a scheme that can make mobile nodes more aware of the local connectivity to its neighbours. This EAODV has the capability to prevent the potential unidirectional links in the network.

Singh *et al*. (2010) proposed simulation based experiments to analyze the performance of On Demand Multicast Routing Protocol (ODMRP) by evaluating packet delivery ratio, end to end delay and average throughput. Their On-Demand Multicast Routing Protocol creates routes on demand which suffers from a route acquisition delay although, it helps to reduce network traffic. The authors have compared their results with AODV and (expansion) (FSR) routing protocols by varying number of nodes and mobility. Their comparison shows that ODMRP for ad hoc networks performs better as compared to AODV and FSR, packet delivery ratio for AODV is better than that of ODMRP and FSR with the changing number of nodes as well as with changing mobility and end to end delay for ODMRP is less than AODV and FSR with the varying number of nodes and mobility.

Zhong *et al*. (2011) proposed a new multicast routing protocol (NMP-MAODV) that improves the packet delivery ratio and average delay in highly mobile network using node mobility prediction and active-link switch. Their simulation results prove the feasibility and effectiveness of NMP-MAODV in ad hoc networks. Based on MAODV their study explained the NMP-MAODV multicast routing protocol for the link disconnection problem caused by node moving so that the node is out of its upstream node's signal range. They have proved that their protocol improves the packet delivery ratio and average delay in highly mobile network using node mobility prediction and active-link switch. Nagar *et al*. (2011) proposed the reliability and scalability of Network Sender Multicast Routing Protocol (NSMRP) where the effect of increasing the number of groups under different mobility scenarios on the data packet delivery ratio and the control packet overhead have been studied. The reliability and scalability of Network Sender Multicast Routing Protocol (NSMRP) were studied by finding the effect of increasing the number of groups under different mobility scenarios on the data packet delivery ratio and the control packet overhead. Their simulation results show that when the number of groups increases the data packet delivery ratio improves while the control packet overhead continues to decrease.

Sarma *et al*. (2008) proposed two efficient route recovery mechanisms for QoS routing based on an extension of the AODV routing protocol that deals with delay and bandwidth constraints. One is based on route maintenance by intermediate node using a special local route repair mechanism and the other one is route maintenance by the destination node. To support QoS routing with bandwidth and delay constraints, a QoS extension of AODV was proposed by them that uses an efficient route maintenance mechanism that aims at reducing control overhead reducing packet loss reducing connection reestablishment latency and QoS violation detection and recovery. However, if other QoS parameters are also considered then the performance of the network can be further enhanced. Dahal and Sanguankotchakorn (2011) proposed, the Modified Ad hoc on Demand Distance Vector routing based on Bit Error Rate (MAODV-BER) where the route discovery of AODV has been modified to achieve the stable route by obtaining Bit Ertror Rate (BER) information from physical layer through cross-layer approach. In their study, they proposed this routing algorithm based on the BER of the link from the physical layer which is provided to network layer as a parameter for calculating the reliable path.

Huang *et al*. (2010) proposed the design of a routing protocol with a single-source multicast operation. By modifying the MAODV protocol their work provided a multisource multicast routing and partition recovery scheme in MANETs. Their multisource routing scheme not only provides multisource routing but also avoids bottleneck problem. He *et al*. (2010) proposed a novel secure routing protocol called S-MAODV which is based on MAODV. S-MAODV takes full advantage of trusted computing technology, combined with the Secure Node Authentication and security indictor bit-set mechanism. SMAODV is an anonymous protocol without requirement of Trusted Third Party (TTP). Shurdi *et al*. (2011) presented a study on the performances of three multicast routing protocols for MANETs, notably MAODV, ODMRP and ADMR. Different performance aspects were investigated by them including throughput, link delay, transmission and control overhead. Tavli and Heinzelman (2011) presented Multicasting through Time Reservation using Adaptive Control for Energy efficiency (MC-TRACE), an energy-efficient real-time data multicasting architecture for mobile ad hoc networks. MC-TRACE is a cross-layer design where the medium access control layer functionality and the network layer functionality are performed by a single integrated layer. The basic design philosophy behind the multicast routing part of the architecture is to establish and maintain an active multicast tree surrounded by a passive mesh within a mobile ad hoc network.

Djenouri and Balasingham (2011) proposed a new localized routing protocol for wireless sensor networks. The proposed protocol takes into account the traffic diversity which is typical for many applications and it provides a differentiation routing using different quality of service metrics such as power, delay and reliability. Baolin and Layuan (2006) proposed QMRP-a new QoS-aware multicast routing protocol and showed its superior performance in terms of high success probability and low message overhead. QMRP-m increases the success ratio for finding a route by examining multiple paths that may be up to m hops longer than the shortest path. Chen *et al*. (2009) presented an Entropy-based long-life multicast routing protocol in MAODV (EMAODV). The key idea of EMAODV algorithm is to construct the new metric entropy to select the long-life multicast routing with the help of entropy metric to reduce the number of route reconstruction in MANET. Their simulation results demonstrated that their approach and parameters provide an accurate and efficient method of estimating and evaluating the route stability in dynamic mobile networks.

MATERIALS AND METHODS

Proposed approach: The AODV algorithms proposed in this study called I-AODV and R-MAODV provide QoS and rule based extensions to the existing AODV algorithm and improve the QoS metrics. This protocol is different from the existing AODV protocol due to the application of intelligent rules in decision making.

I-AODV: In I-AODV, researchers use a routing table and intelligent rules instead of HELLO messages. Moreover, this protocol uses the MAC layer information to determine available bandwidth and delay information. In this research, QoS is ensured by bandwidth reservation and in case of QoS violation the QoS lost message is generated and forwarded to the list of sources requesting QoS guarantees. The AODV control messages HELLO, RREQ and RREP are revised to carry and exchange the QoS information among the nodes. The routing table is extended to additionally store information about the available resources such as maximum delay and minimum available bandwidth.

In addition, researchers propose a new routing algorithm called R-AODV that has been developed by extending the AODV protocol to enhance QoS in communication using rules. It consists of two phases namely route discovery and route maintenance phases. In this new protocol, the existing route discovery policy is modified by extending with a neighbour table to reduce the connection set up delay. Moreover, each node maintains a neighbour table and decision rules which keep the list of the nodes to which it has a connection and the associated delay and bandwidth to reach that neighbour. A node exchanges HELLO packets containing the QoS requirement information, periodically with its neighbour to construct this table. This neighbour table is used in order to update the routing table periodically. Hence, each node has to maintain two tables namely neighbour table and routing table.

Algorithm steps for the I-AODV algorithm: Whenever, a source wants to send any packet, it first checks its routing table for the destination by applying rules. If it has a route to the destination satisfying the required QoS, it reserves the resource and starts packet transmission using that route after checking the all the members from the corresponding neighbor tables.

If it does not have a route or the route does not satisfy QoS requirements, it applies rules to check whether it needs a broadcast. If so, it sends a RREQ packet to its neighbors through all eligible links using flooding.

When any intermediate member node which satisfies the QoS requirements in the route receives the RREQ, it sends a RREP back to the source.

During the RREP packets routed back to the source, the intermediary nodes checks and compares the bandwidth which is available with the bandwidth field of the RREP message and chooses the minimum of these two values and forwards that packet to the source and hence the minimum available bandwidth value of the source/destination pair is stored in the routing table.

After receiving the RREP packet the source will compute the delay comparisons and discards the duplicate RREP packets that arrive in other paths.

If any node along the route moves, its upstream neighbor propagates a link failure notification message (by an RREP message with infinite value as a route metric) until the source node is reached. The source node may then choose to reinitiate route discovery for that destination if a route is still desired for communication.

R-AODV: In this study, researchers propose an additional routing protocol called R-AODV that has been developed by extending the AODV protocol with rules for decision making. This proposed R-AODV routing protocol performs better than traditional AODV and I-AODV during high mobility and high network load. As R-AODV always maintains a routing table for neighbours, most often it provides the optimal routes quickly. So, the average delay is reduced significantly in the route discovery process.

Moreover, the packet delivery ratio is improved in this proposed protocol as it maintains the QoS and node information and looks for a path satisfying the QoS requirements of the member nodes and applications. Moreover, it sends only smaller number of control packets to handle route discovery and route reply. As a result, the control overhead is also reduced. The steps of the proposed R-AODV algorithm are as follows:

- Whenever a source wants to send any packet, it first checks its routing table using rules. If it has a route to the destination satisfying the required QoS, it reserves the resource and starts packet transmission using that route after checking the rules
- If it does not have a route or the route does not satisfy QoS requirements, it apply rules to check whether it needs a broadcast. If so, it sends a RREQ packet to its neighbors through all eligible links using flooding
- When any intermediate member node which satisfies the QoS requirements in the route receives the RREQ, it sends a RREP back to the source

- When RREP is forwarded back to the source each node checks and compares its available bandwidth with the bandwidth field of the RREP message and puts the minimum of these two values in RREP and forwards towards the source. So, the minimum available bandwidth of the source destination pair is stored in the routing table
- On receiving the RREP, source will compare the delay and if it satisfies the QoS requirement, it starts sending data following that route and discard duplicate RREP packets received in other feasible paths
- If any node along the route moves, its upstream neighbour propagates a link failure notification message (by an RREP message with infinite value as a route metric) until the source node is reached. The source node may then choose to reinitiate route discovery for that destination if a route is still desired for communication

Implementation details: These proposed algorithms have been implemented using the NS2 simulator. Table 1 shows the simulation parameters used in the experiments carried out in this research.

RESULTS AND DISCUSSION

The comparative performance of AODV and proposed R-AODV are studied in different simulation scenarios based on the selected performance parameters. The performance parameters show the same manners for variable number of nodes and velocity under different data rate. Therefore, only the simulation results for 30 nodes with velocity of 3 m sec^{-1}, data rate of 10 packets/sec and 2 senders and 5 receiver for routing performance are shown.

Figure 1 shows the delay analysis. From Fig. 1, it can be observed that the average end to end delay rises gradually as number of nodes increases. The reason is that with increasing number of nodes, the total traffic load increases and the network becomes congested. So, more packets are kept waiting in the queues for long time which causes the delay to increase.

The performance in Fig. 2 shows the same trend as with fixed QoS requirements. With increasing mobility, route failure occurs more frequently. So, the number of successful packets decreases which causes reduces in average delay. As the nodes moving speed increases, more routes become unreachable which creates increasing packet drop. More control messages are generated to perform the route recovery operation which causes control overhead to increase. From Fig. 3,

Table 1: Simulation parameters

Parameters	Values
Protocols	AODV, I-AODV
Simulation environment	NS 2
Simulation time	500 sec
No. of nodes (connections)	10 (5), 20 (10), 30 (15), 40 (20), 50 (25) nodes
Simulation area	670×670 m
Mobility model	Random way point
Traffic type	CBR
CBR data rate	5, 10. 15, 20 packets/sec
Packet size	512 bytes
Transmission range	250 m
Link capacity	2 Mbps
Velocity	1, 2, 3, 5, 10 m sec^{-1}
Pause time	0 sec
No. of executions/scenario	10
MAC	802.11

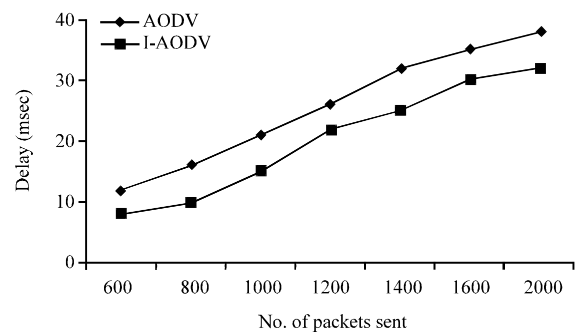

Fig. 1: Average end to end delay comparisons

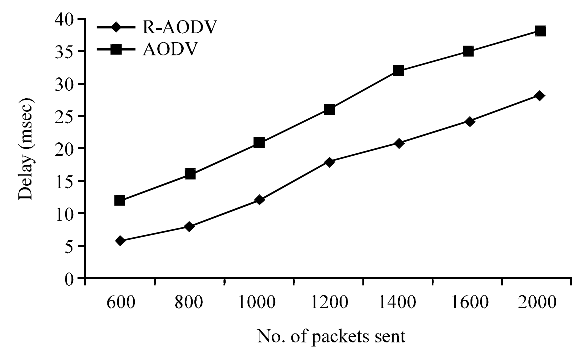

Fig. 2: Delay comparison

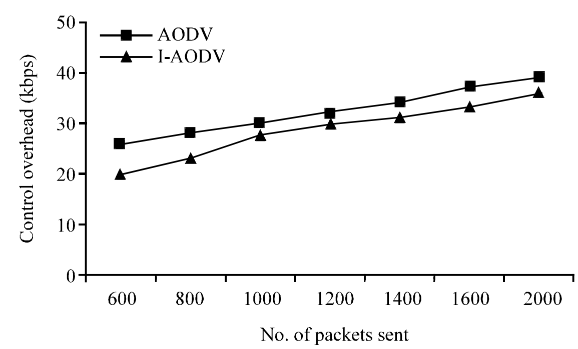

Fig. 3: Control overhead

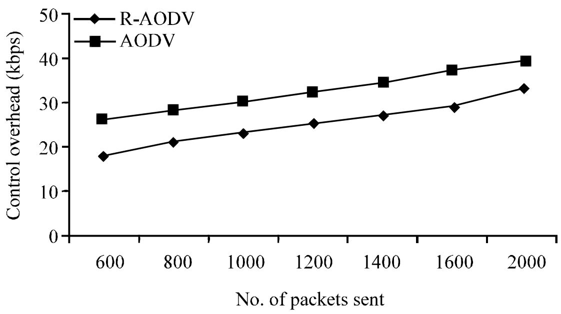

Fig. 4: Control overhead

it can be observed that the control overhead is reduced in the proposed I-AODV when it is compared with AODV.

From Fig. 4, it can be observed that the control overhead is reduced in the proposed R-AODV when it is compared with AODV.

CONCLUSION

In this research, researchers proposed two routing protocols called I-AODV and R-AODV for effective routing in ad hoc networks. The first protocol provides effective QoS. Therefore, it increases the packet delivery ratio and reduces the delay. The second protocol has been developed by enhancing the first protocol with rule based extensions. This extended protocol performs better in wireless communications by maintaining neighbour table. The main advantage of this second algorithm is that it is not only behaves intelligently for communication but also increases the QoS. Further researches in this direction can be the inclusion of trust factors to provide a secure routing algorithm.

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