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QoS Aware and Secure Dynamic Multipath Routing Protocol for MANET

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Abstract – *Now days the use of wireless networks such as Mobile Ad Hoc Networks (MANET) or Wireless Sensor Networks (WSNs) is common and widely used in day to day life. Mobile Ad Hoc networks (MANET) are dynamically formed by a group of mobile nodes that are connected via wireless links. MANETs are infrastructure-less and dynamic behavior networks. Due to this dynamic behavior and topology change of the network, QoS and security becomes challenging tasks in MANET. The proposed secure and QoS aware dynamic multipath routing protocol is used to improve the Security and QoS of MANET. This new protocol is named as QSAOMDV protocol for MANET. For quality improvement we are using dynamic multipath routing method which avoids stale routes by periodic maintenance, provides route switching prior to route breakage and achieving the security of communication by sharing secret key between the source and destination. This secret key is used for secure communication. With use of both these methods we can achieve better QoS and Security of routing prototcol.*

Keywords: MANET, security services, QoS aware, data integrity, data confidentiality.

1. INTRODUCTION

A Mobile Ad hoc Network is a collection of mobile nodes that are connected via wireless links. Mobile nodes could be laptop computers, mobile phones, PDAs or sensors. MANETs form infrastructure-less network without any centralized administration or control (routers, switches or base stations). So each node in the network can act as a host as well as a router. Nodes which are within the each other's radio range they can communicate directly and the nodes which are apart from each other's radio range any node act as a router for the other [10]. MANETs are self-configuring, self-administering and decentralized networks. With this dynamic behavior, topology change and lack of central control of the network, QoS and security provision become a more challenging task in MANET.

Due to the widespread use of MANET, QoS provisioning is very important. Applications of MANET are military / battlefield communication, disaster management, rescue operations, industries, healthcare and academic, real time applications such as audio and video communication [1, 4]. All these applications need QoS support and secure communication. QoS provisioning in wireless (MANET) is more challenging than wired networks because of node mobility, lack of central control, limited battery power, multi-hop communication and contention for accessing wireless channel [4]. Due to mobility and frequent link failures, throughput and end-to-end delay are low in MANET. This situation can be avoided by using multi-path routing means finding multiple paths in a single route discovery phase. If one of the path fails, another path is selected for further communication. The proposed method finds multiple node disjoint paths in a single route discovery and maintain these paths periodically based on QoS metrics such as Signal strength, remaining battery energy and link stability [13]. Along this, the proposed method also exchanges the shared/session key between the source and destination during the route discovery phase [1]. This secret key is used during data transfer phase for secure data transmission.

Following sections are as follows: Section II deals with the background while the section III provides a review of the related work. Section IV presents proposed method and Conclusion is presented in the section V.

2. BACKGROUND

2.1 QoS in MANET

The quality of service is a set of service requirements to be met by the network while transporting a flow. A flow is a packet stream from a source to a destination with an associated QoS. A network is expected to guarantee a set of measurable pre-specified service attributes to the users in terms of end-to-end performance such as delay, bandwidth, probability of packet loss, delay variance (jitter), processing power, buffer space etc. Quality of Service sometimes refers to the level of quality of service i.e. the guaranteed service quality [3, 4]. As different application have different service requirements so QoS parameters differ from application to application. In case

of multimedia applications, the data rate and delay are the key factors, whereas, in military use, security and reliability become more important. QoS metrics are designed to find most suitable path. The metrics determine packet routing or topology changes. For reaching the required QoS level it is necessary to consider the QoS metrics such as are battery charge, MAC delay, PLR, delay, jitter, throughput, link stability, node stability. The QoS metrics classified into four categories additive metrics, concave metrics, convex metrics and multiplicative metrics.

2.2 QoS Aware Routing in MANET

QoS aware Routing protocols are the routing protocols that use the QoS parameters for finding a path from source to destination. As the selection of is based on the desired QoS, the routing protocol is termed as QoS aware [3]. The parameters that can be considered for routing decisions are network throughput, packet delivery ratio, reliability, delay, delay jitter, packet loss rate, and bit error rate and path loss. Decisions on the level of QoS and the related parameters for services in ad hoc networks are application specific and are to be met by the underlying network.

2.3 Security of MANET

MANETs are collection of mobile nodes without any centralized control and any fixed infrastructure. So nodes in network will not be under the control of their central authority and as a result physical security of the node becomes an important issue [11]. Due to the absence of infrastructure, it may prevent from key agreement between the two entities. MANETs have the dynamic topology because of mobility of the nodes means arrival and departure of nodes is not fixed, any time they can move to another network. Due to freely roaming of nodes, it difficult to identify or detect which are compromised nodes and which are trusted nodes [11]. These characteristics of MANET may be challenges for building a secure MANET.

There are various types of attacks are possible in MANET. Some attacks apply to general network, some apply to wireless network and some are specific to MANETs. Types of attacks are passive or active, internal or external [2, 11]. The attacks in MANET can roughly be classified into two major categories, namely passive attacks and active attacks [2] [11] [20]. A passive attack obtains data exchanged in the network without disrupting the operation of the communications, while an active attack involves information interruption, modification, or fabrication, thereby disrupting the normal functionality of a MANET. Examples of passive attacks are eavesdropping, traffic analysis, and traffic monitoring. Examples of active attacks include jamming, impersonating, modification, denial of service (DoS), and message replay. The attacks can also be classified into external attacks and internal attacks, according the domain of the attacks. External attacks are carried out by nodes that do not belong to the domain of the network. Internal attacks are from compromised nodes, which are actually part of the network. Internal attacks are more severe when compared with outside attacks since the insider knows valuable and secret information, and possesses privileged access rights.

3. RELATED WORK

The Route Stability-based Multipath Quality of Service Routing (SMQR) [15] supports routing stability along with throughput and delay in MANETs. This algorithm consists of: 1) Computing route stability based on received signal strengths for selecting QoS routes for longer duration. 2) A route stability-based QoS-aware multipath route discovery mechanism. 3) A hop-by-hop admission control and a soft resource reservation during the route discovery process. 4) A method to select three node disjoint paths in which one is the primary path and other two are secondary paths. 5) A route maintenance method which handle QoS violation and for the maintenance of secondary paths and 6) A path switching by the source, so that the highest stable route among the multiple paths is always selected for transporting data. If the stability value of the alternate route is higher than that of the primary route, then the primary route is switched to the alternate route. A new route discovery process is initiated only when all the paths in the multipath fail.

Route Stability and Energy Aware QoS (REAQ) Routing Protocol [16] computes the reliable path for data communication based on route stability and the residual energy of the intermediate node for the admission control. This algorithm consists of three phases as Route discovery like AODV, Route discovery at intermediate nodes and route selection at destination node. 1) In route discovery phase, route discovery is done same as AODV. RREQ packet contains few new fields such as Accumulated Path Stability (APST), Accumulated Energy Cost (AEC), minimum bandwidth and maximum delay. 2) If an intermediate node receives a RREQ packet from its neighbor, it measure the signal strength and energy of the receiving node. The calculated stability value is updated in the Neighbor Information Table (NIT). 3) When the destination node receives the first RREQ, it starts the timer. Then it calculates the reliability of path. This method selects only the highest reliable path for communication depending on route stability and energy of nodes.

QoS Aware Multipath Routing Protocol [14] computes multiple paths. The QMRP protocol establishes multiple node disjoint paths with low delay. This protocol consists

of two phases route discovery and route reply. 1) In this method route discovery is similar to AODV. QMRP introduces two additional fields to the RREQ as Expected Path delay and load field. 2) If a node receives an RREQ and it is the destination. Then this node only gives the reply back to source by unicasting RREP with EPD initialized to zero. Intermediate nodes that receive the RREP maintain their routing table and increment the EPD field of the RREP with their calculated delay and forward the RREP to the next hop towards the source node. When the source receives all RREPs back from the destination, it sorts the available paths based on minimum delay in its routing table. Only three paths are selected and uses the first path in the list as the primary path. Hence it select the path from multiple path based on delay calculations.

The QoS Enabled Ant Colony based Multipath Routing Protocol [18] based on Ant Colony Optimization for finding optimal path from multiple paths for data transmission. Depending on the path preference probability path is selected Path preference probability is calculated based on the QoS parameters such as delay, next hop availability (NHA) and bandwidth. The route establishment and communication between mobile nodes is carried by ant like agents such as forward ants (FANT) and backward ant (BANT). This method consists of two phases as route exploration and route safeguarding phase. 1) In Route discovery phase HELLO message is broadcasted to all nodes for neighbor discovery. The source node selects a path which has highest pheromone value. In route exploration phase most probable path is chosen from multiple paths. When link failure occurs then alternative path is chosen. 2) In Route safeguarding phase when link failure occurs because of node mobility then alternative path is selected and notification ant is transmitted to source to notify the source about route alteration.

QoS Aware Stable Path Routing (QASR) [8] provides a scheme for dynamically constructing paths between mobile nodes. QASR uses signal stability along with QoS parameters as route selection criterion. Signal stability consists of signal strength and link stability. The signal strength criterion allows the protocol to differentiate between strong and weak channels. The link stability of the nodes allows the protocol to select a channel which has longer period for existence. Using signal strength and link stability, QASR selects the most stable QoS links which have stronger signals for maximum amount of time and hence selects the stable QoS routes.

QoS Aware Adaptive Multipath Routing Protocol [12] is an on demand multipath routing protocol used to find node disjoint routes and for periodic route maintenance prior to route breakage based on the QoS metrics. In this method when a source wants to communicate with the destination, source node broadcasts a RREQ message to all its neighbors. Then intermediate nodes forward this message with first hop information towards destination. Destination node replies to neighbors by uni-casting a RREP message. Hence source gets distinct routes with multiple next hops to destination. Dynamic route maintenance method which selects best routes from multiple routes and also switches to alternative route prior to route breakage based on QoS metric. QoS metrics are signal strength, link stability and remaining battery energy. Every node calculate its signal strength, link stability and remaining battery energy.

In [4] proposed node disjoint multipath routing method based on AODV. This method provide node disjoint paths in no node is common among all the paths. This method has the multiple paths so it reduces delay and control overhead. In [7] proposed a link stability based multicast routing protocol. Link stability between two nodes is affected by variation of these parameters such as distance between two nodes, congestion on link, bandwidth of link and node energy.

Table No-1: Comparison of QoS Aware routing schemes.

QoS Aware Routing Scheme	QoS Metrics	Base protocol	Multiple Path Support	Route Discovery
QASR	Bandwidth, End-to-end delay	AODV	No	Reactive
QMRP	End-to-end delay	AODV	Yes	Reactive
SMQR	Throughput, Delay	AOMDV	Yes	Reactive
QAMR	Delay, Bandwidth and Hop count	ACO	Yes	Reactive
REAQ	Throughput	AODV	No	Reactive

QAAMR	Signal strength, link stability, Remaining battery energy	AOMDV	Yes	Reactive

In [3] proposed survey of attacks and countermeasures in MANET. In this attacks on all layers are mentioned or surveyed. Network layer attacks include attacks at the routing discovery phase, attacks at the routing maintenance phase, and attacks at the data forwarding phase, attacks on particular routing protocols and other advanced attacks. Attacks at the routing discovery phase contains routing message flooding attacks, acknowledgement flooding, routing table overflow, routing cache poisoning and routing loops. Other advanced attacks are wormhole attack, Byzantine attack, black hole attack, rushing attack, resource consumption attack, location disclosure attack.

Security Enabled DSR [2] used to exchange a shared / session key between the source and destination during the route discovery process. In this algorithm various packets are generated based on presence or absence of route and key. Source and destination both store the path and key information in its routing table. Source generate the secret key based on path and key information, which is then shared between source and destination. After the path and key establishment between the source and destination, key is used for authentication, integrity and privacy for secure data transmission.

In [1] author presented a technique to provide the data security to network using node authentication and digital signature. This protocol provide the data integrity, confidentiality, non-repudiation and authentication security services with the help of AES and digital signature. AES is used for data confidentiality. Digital signature is created with the help of RSA and hash function MD5, which provide data integrity, non-repudiation and authentication. This method uses the combination of symmetric and asymmetric key algorithms and hash functions to achieve security goals.

In [14] author proposed a hybrid cryptosystem to secure data transfer in MANET. This cryptosystem is combination of symmetric key cryptosystem and public key cryptosystem. This hybrid cryptosystem is used to provide security services such as confidentiality and integrity. For encryption or to provide confidentiality AES algorithm is used. Symmetric key is generated through RSA algorithm. MD5 hash algorithm provides the data integrity.

In [22] author proposed a security scheme for MANET using HMAC. In this method security to MANET communication is given by keyed hash message authentication code. In HMAC, MAC is generated using a symmetric key. HMAC is used for authentication and data integrity.

In [23] author proposed a secure token by using cryptographic algorithm AES and hashing algorithm SHA-2. Secure token is used for authentication of two neighbor nodes based on secret key. Message is signed using SHA-2 and AES algorithm. Data confidentiality and integrity is achieved by AES algorithm. Authentication, non-repudiation and access control is achieved by digital signature.

In [6] author proposed a key derivation function based on HMAC-SHA-256. Key derivation function is used to generate security keys in the network. HMAC-SHA-256 is a secure cryptographic hash function based message and shared key authentication algorithm. It is used to prevent any modification, interception of data. It helps to maintain data integrity, reliability and security.

Table-2: Comparison of methods that provide security services.

Method	Cryptosystem	Security Services	Algorithm Used
Authentication and digital signature method	Hybrid	DC, AU, DI, NR	RSA, MD5, AES
Enhanced key derivation function	Symmetric	DI, Reliability	HMAC-SHA-256
Security scheme using HMAC	Symmetric	DI	HMAC
Secure Token for secure routing of packets	Hybrid	AU, DI, NR, DC, AC	HMAC-SHA-256
Secure data transfer	Hybrid	DI, DC	RSA, MD5, AES
Security Enabled DSR	Symmetric	AU, DI, DC	HMAC-SHA1, SHA1, AES

4. PROPOSED SYSTEM

The proposed method is based on AOMDV routing protocol. It is an on-demand multipath routing protocol. It establishes route only when needed. When source S wants to communicate with the destination D, then only route discovery is initiated by source. The proposed method consists of four phases: Route Discovery, Key Generation, Secure Data Transmission and Route Maintenance. Fig. 1 shows the phases in proposed method QSAOMDV, which are discussed below.

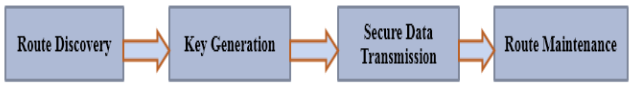


Fig. 1- Phases in QSAOMDV

4.1 Route Discovery

a. When a source node S needs a route to destination node D, it checks the availability of route in its routing table. If it finds, it select the next hop and starts forwarding packets. Otherwise a route discovery process is initiated by broadcasting a RREQ packet.
b. In this method different kinds of packets to be generated based on different situations which will depend on the presence or absence of route and shared key between the source and destination node.
c. If both route and key are unavailable then the source will generate and broadcasts KRREQ (Key and Route Request) packet for route as well as the key establishment. Fig.2 shows the propagation of request message. 'S' is the source node, it broadcasts request message to neighbor nodes A, C and B. 'D' is the destination node.

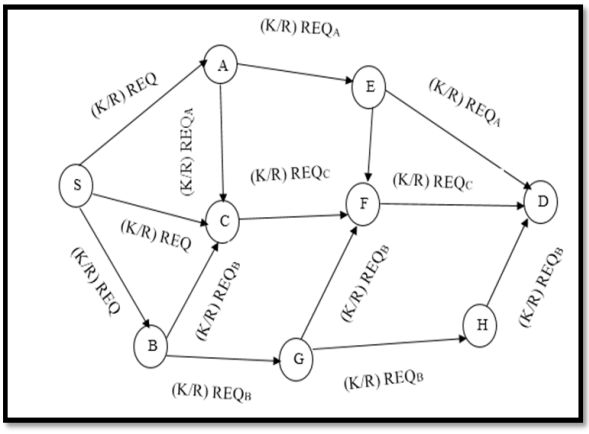


Fig. 2 -Propagation of Route request

d. If route already exists and the source needs a secret key between itself and the destination, it can only generate and broadcast a KREQ (Key Request) packet.
e. If the source needs only route to destination then RREQ (Route Request) packet will be generated and broadcasted to all neighboring nodes.
f. Then all (K/R) REQ with different first hop information (neighbor of the source) are forwarded towards the destination by intermediate nodes. Hence intermediate nodes forward only one (K/R) REQ towards the destination.
g. Destination node replies to more than one (K/R) REQ message by sending (K/R) REP to distinct neighbors of the source. Thus REP message sets the path from source to destination. Fig.3 shows the propagation of reply message. Destination 'D' reply to distinct neighbors of the source.

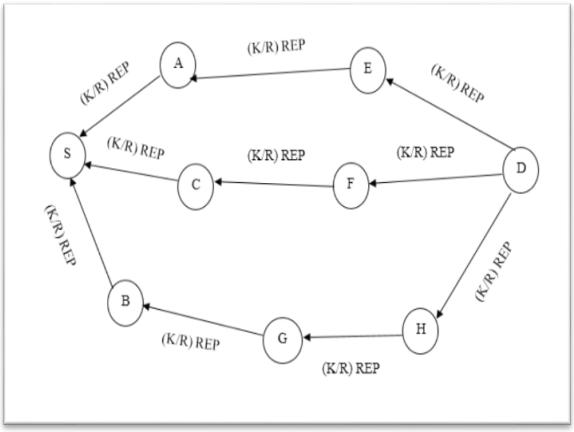


Fig.3- Propagation of Route Reply

h. The source node gets distinct key and route replies from its neighbors and keep these in its routing table.
i. Finally both the source and destination store the path and key information in its routing table.

4.2 Key Generation

The source combines all paths and keys to generate a secret key.

$$K_{SD} = \int (P_1, P_2, P_3, \ldots\ldots P_N; K_1, K_2, K_3 \ldots\ldots K_N)$$

$$E_{ID} = E_{KSD}\ (SourceID)$$

Where,

P_i - the path from source to the destination found in i^{th} RREP packet.

K_i - the key provided by the destination with i^{th} RREP packet.

E_{ID} - encryption of SourceID using K_{SD}.

∫ - cryptographic key generation function. Then the source sends a key exchange (KEX) packet to the destination

< Source_ID, Destnation_ID, Path, TTL, EID >

Then the destination perform the following operations

$$K_{SDi} = \int (p_1, p_2, p_3, \ldots\ldots p_n; k_1, k_2, k_3, \ldots\ldots k_n)$$

$$D_{IDi} = D_{KSDi} (E_{ID})$$

Where,

P_i - the path from source to destination sent in i^{th} (K/R) REP packet.

K_i - the key provided by the destination sent in i^{th} (K/R) REP packet.

∫ - cryptographic key generation function.

K_{SDi} - key generated in i^{th} iteration.

D_{IDi} - Decryption of E_{ID} using K_{SDi}.

4.3 Secure Data Transmission

The route and the key are established between the source S and the destination D, now the key is used to achieve security goals like: authentication, integrity, and privacy, while transmitting the data packets. Threats on data packets include interruption, interception, modification and fabrication [1]. For secure data transmission this method provides security services such as authentication, confidentiality and integrity of data.
QSAOMDV provides the following security services:

1. Authentication: HMAC-SHA1 is used to create Message Authentication Code (MAC) containing routing information and time stamp. So source authentication, any modification to route information and replay attack is verified by the destination.
2. Confidentiality: Advanced Encryption Standard is used for encrypting the message i.e., EKSD (M). This will ensure the privacy of the message.
3. Integrity: Hash function SHA1 is used to create hash of the message i.e., H(M). This is used to check integrity of the message.

4.4 Route Maintenance

There are frequent route failures in MANET due to the mobility, limited battery energy of the nodes and instability of the nodes. For route maintenance RERR message is sent. In many multipath routing methods multiple paths are discovered but alternative paths are not maintained properly. So to avoid this dynamic route maintenance method is proposed which periodically maintain alternative routes and switches in advance to an alternative route before the breakage of the primary route. The alternative route is selected based on the calculated values of QoS metrics. The QoS metrics are Signal strength, remaining battery energy and link stability.

Each source node periodically sends a special control message called update message (UPD) towards the destination through all the calculated routes and the message is travelled back through the same path to reach the sour ce. The UPD message has three fields, namely, signal strength (x), remaining battery energy (y) and stability metric (z). Source node calculates the cost along all the routes from the UPD packet.

$$Ci = (axi + byi + czi) / (a + b + c)$$

Where,
xi, yi, zi are x, y and z values from the UPD packet received through the path i. Symbols a, b and c are coefficients (weights) and their values can be selected according to the QoS requirements. The source node selects the path which has maximum C value as the primary path and the alternative paths are arranged in the descending order of C values. Whenever the C value of the current primary path becomes lower than the next alternative path, the primary path is switched. So at any point of time our method routes packets through the best available path. Since this method selects the best path based on quality, durability and stability, the overall throughput of the MANET can be increased considerably.

5. IMPLEMENTATION

The implementation of proposed method QSAOMDV is performed using ns3 simulator under ubuntu-14.04 Linux environment.

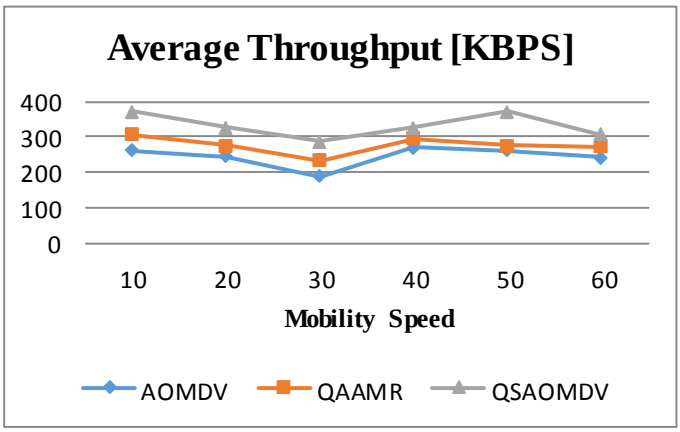
The parameters used for simulation are:

- Simulation Area : 1000m X 1000m
- Simulation Time : 50 sec
- Transmission Range : 250m
- Traffic Pattern : Constant Bit Rate (CBR)
- No. of nodes : 10, 20, 30, 40, 50, 60
- Pause Time : 10 sec
- MAC Protocol : 802.11

- Maximum No. of paths cached : 3
- Node speed : 0-25 m/s

6. RESULT AND GRAPHICAL ANALYSIS

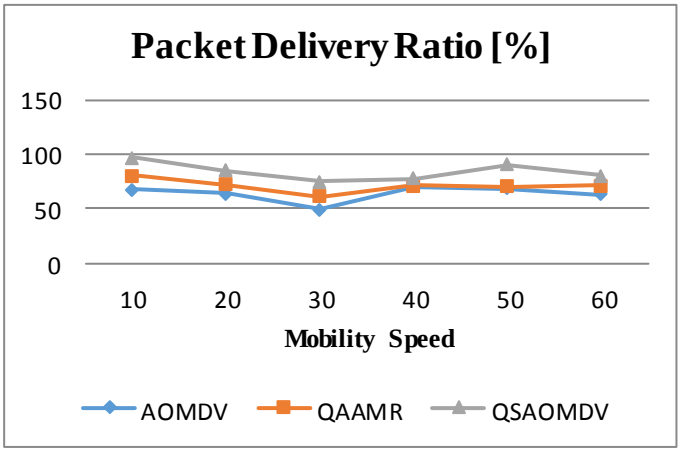
1. Average Throughput: It represents the number of packets sent or received in network in per unit of time. It means the throughput represents the successful delivery or reception of packets with respect to time.



Graph-1: Average Throughput

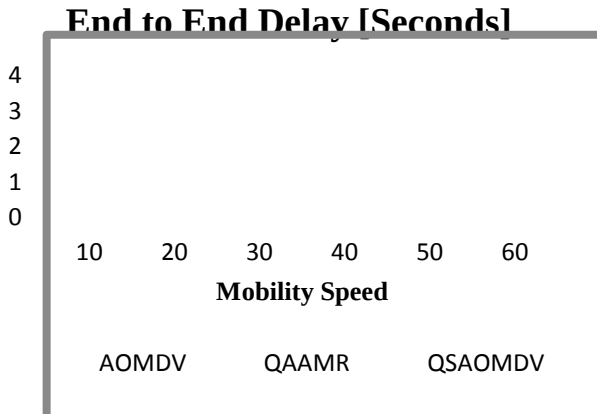
The above graph represents the comparison of AOMDV, QAAMR and QSAOMDV protocols w.r.t average throughput.

2. Packet Delivery Ratio: Packet Delivery Ratio is the ratio of the number of packets received by the destination to the number of packets sent by the source.



Graph-2: Packet delivery Ratio

3. Average end-to-end delay: It is the sum of the transmission delay, buffering delay after link failure, retransmission delay and link layer delay.



Graph-3: End-to-end delay

Due to the security and QoS, throughput and packet delivery ratio will increase as compared to other protocols in the QSAOMDV. End to end delay will be less because of multiple paths and switching of alternate path before the breakage of the primary path.

7. CONCLUSION

MANET is consisting of a collection of mobile nodes that are connected via wireless links. MANETs have the dynamic topology and dynamic behavior of the network. MANETs are self-organizing and decentralized networks. Due to the dynamic behavior and lack of central control QoS provisioning and security becomes a challenging task. In this project work try to improve the QoS and security of communication. This is achieved by using node disjoint and secure route discovery by secret key sharing between source and destination, periodic route maintenance by using QoS metrics and then secure communication in which Authentication, Confidentiality and Integrity services are provided.

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