QOS Evaluation of Stable Energy Efficient Node Disjoint Adhoc Routing protocol

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Abstract - A mobile adhoc network (MANET) is a self-configuring infra- structure less network of mobile devices connected by wireless. The emergence of real-time applications such as multimedia services, disaster recovery etc., and the widespread use of wireless and mobile devices has generated the need to provide quality-of-service (QoS) support in MANET. But QoS provisioning in MANETs is a very challenging problem when compared to wired IP networks. This is because of wireless multi-hop communication, limited battery power, each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently, and range of mobile devices as well as the absence of a central coordination authority. So, the design of an efficient and reliable routing scheme providing QoS support for such applications is a very important. Therefore, an effort has been done to create a new QOS based Stable Energy Aware Ad hoc Routing protocol (QSEAAR) by adding quality of service to the Stable energy aware adhoc routing (SEAAR) protocol. The simulation of proposed protocol is carried out using network simulator ns-2.35 under Linux platform. The protocol considers not only the QoS requirement, but also the cost optimality of the routing path to improve the overall network performance**.** The evaluation results show that the performance of QSEAAR is comparable and outperforms the existing AOMDV and SEAAR.

Key terms: AOMDV, RREQ, RREP, MANET, ADHOC,QSEAAR, SEAAR

1. Introduction

MANET is a wireless infra structureless network having mobile nodes. Communication between these nodes can be achieved using multi hop wireless links. Each node will act as a router and forward data packets to other nodes. Since the nodes are independent to move in any direction, there may be frequent link breakage. AD HOC networking is becoming very popular nowadays and will emerge as an effective complement to wired or wireless LANs, and even to wide-area mobile networking services, such as Personal Communication Systems (PCS). The most important design criterion for any type of network is guaranteeing Quality of Service. QoS measures include bandwidth, delay and delivery guarantee. Different classes of traffic (e.g. voice, data, image, video, etc.) have different bandwidth and delay requirements. QoS-aware routing takes into consideration multiple QoS requirements, link dynamics, as well as the implication of the selected routes on network utilization, rendering QoS routing a particularly challenging problem. However, the unique features of MANETs, namely dynamically varying network topology, imprecise state information, lack of central coordination, error-prone shared radio channel, hidden terminal problem and time-varying capacity exacerbate the already complex routing problem. More importantly, node mobility causes frequent failure and reactivation of links, effecting a reaction to the changes in topology from the networks routing, thus increasing network control traffic and saturating the already congested links. Hence, all these aspects necessitate a cost-effective QoS-aware routing [1].

Most of the conventional routing protocols are designed either to minimize the data traffic in the network or to minimize the average hops for delivering a packet. Even some protocols such as Ad-hoc on demand Distance Vector (AODV), Dynamic Source Routing (DSR) and On-demand Multicast Routing Protocol (ODMRP) are designed without explicitly considering QoS. When QoS is considered, some protocols may be unsatisfactory or impractical due to the lack of resources and the excessive computation overhead. To support QoS, a service can be characterized by a set of measurable pre specified service requirements such as minimum bandwidth, maximum delay, maximum delay variance and maximum packet loss rate [2]. However, many other metrics are also used to quantify QoS and in this paper bandwidth, hop count and error count are used to calculate QOS requirements.

The main objective of this paper is to analyze AOMDV protocol for ways it could be improved. AOMDV is taken as base protocol and energy and link stability concept is added to get a stable energy aware adhoc routing protocol SEAAR[25].To further enhance the performance of SEAAR for use in multimedia network an attempt is made to include the QoS parameters in SEAAR protocol and propose a new protocol QSEAAR. The performance is analyzed using parameters like energy consumption, packet delivery ratio, latency and throughput. The evaluation results show that the performance of QSEAAR is comparable and outperforms the existing AOMDV and SEAAR

2 Related work

A fairly comprehensive overview of the state of the field of QoS in networking was provided by Chen in 1999 [3]. Chakrabarti and Mishra [4] later summarized the important QoS related issues in MANETs in 2001 and their conclusions highlighted several significant points in MANET research. It includes admission control policies and protocols, QoS robustness and QoS preservation under failure conditions. In 2004, Al-Karaki and Kamal published a detailed overview [5] and the development trends in the field of QoS routing. They highlighted some areas such as security and multicast routing requiring further research attention. They were categorized the QoS routing solutions into various types of approaches: Flat, Hierarchical, Position-based and power aware QoS routing. Reddy et al. [6] provided a thorough overview of the more widely accepted MAC and routing solutions for providing better QoS in MANETs. L. Chen et al. proposed QOS aware routing protocol [7]. The authors introduce the bandwidth estimation by disseminating bandwidth information through Hello messages. The authors compare two different methods of estimating bandwidth. The IEEE 802.11E [8] standard MAC (Medium Access Control) enhancements enables some QOS guarantees through MAC level service differentiation. The QOS routing protocol should respond quickly in case of path breaks and recompute the broken path or bypass the broken link without degrading the level of QOS. This is a complex and difficult issue because of the dynamic nature of the network topology and generally imprecise network state information [9].

Lei Chen et al. [10] proposed network architecture to support QOS in Manet. Heni Kaaniche et al. [11] suggest an approach to estimate available resources which is based on the estimation of the busy ratio of the shared canal. Anelise Munaretto, Mauro Fonseca [12] proposed the QOLSR protocol which includes quality parameters to the standard OLSR. Muhammad Ibrahim et al. [13] discussed some problems that may occur in providing QoS to Mobile nodes in Mobile Adhoc networks and solution for managing those problems, like dynamic topologies that change continuously and unpredictable at any time. L.Hanzo (II.), R. Tafazolli [14] include a thorough overview of QoS routing metrics, resources, and factors affecting performance and described their interactions with the medium access control (MAC) protocol. CH. V. Raghavendran [19] describes the challenges and approaches for QoS aware routing techniques. Bhagyashri. R. Hanji et al. [20] gives detailed survey of strength, weakness and applicability of existing QoS routing protocols. N. Sarma and S. Nandi[21] presents a route stability-based multipath QoS routing protocol for mobile ad hoc networks to support throughput and delay sensitive real-time applications in these networks.V.Banumathi et al [27] aims to find an optimal path to prolong the network lifetime and to find energy efficient routes for MANET. Routing involves path discovery based on Received Signal Strength (RSS) and residual energy and selection based on an optimized biobjective model.

3. Issues and challenges while providing QoS in ad-hoc networks

QoS provision will lead to an increase in computational and communication cost. In other words, it requires more time to setup a connection and maintains more state information per connection. The improvement in network utilization counterbalances the increase in state information and the associated complexity and various issues are needed to be faced while providing QoS for MANETS [10].

The IEEE 802.11E standard MAC (Medium Access Control) enhancements enable some QoS guarantees through MAC level service differentiation. However, its throughput is expected to degrade at high traffic load. To assist QoS routing, the topology information can be maintained at the nodes of ad hoc wireless networks. The topology information needs to be refreshed frequently by sending link state update messages, which consume precious network resources such as bandwidth and battery power. Otherwise, the dynamically varying network topology may cause the topology information to become imprecise. This trade-off affects the performance of the QOS routing protocol. As path breaks occur frequently in ad hoc wireless networks, compared to wired networks where a link goes down very rarely, the path satisfying the QOS requirements need to be recomputed every time the current path gets broken. The QOS routing protocol should respond quickly in case of path breaks and recompute the broken path or bypass the broken link without degrading the level of QOS. This is a complex and difficult issue because of the dynamic nature of the network topology and generally imprecise network state information [16].

3.1 Bandwidth reservation

Multimedia applications such as digital audio and video have much more stringent QoS requirements than traditional data-gram applications. For a network to deliver QoS guarantees, it must reserve and control resources. A major challenge in multi-hop, multimedia networks is the ability to account for resources so that bandwidth reservations (in a deterministic or statistical sense) can be placed on them. In cellular (single hop) networks, such accountability is made easily by the fact that all stations learn of each other's requirements, either directly or through a control station (e.g., the base station in cellular systems). However, this solution cannot be extended to the multi-hop environment. To support QoS for real-time applications, we need to know not only the minimal delay path to the destination, but also the available bandwidth on it [17].

With bandwidth constraint as QoS metric, it is reasonable to view the bandwidth as available bandwidth. Most probably, the devices in the adhoc network will be configured with the same wireless card, which means that all nodes in the network have the same maximum bandwidth [18]. So we are only interested in how much of the remaining bandwidth is available for new traffic. However, in real networks, bandwidth computation is a complex issue. Many papers such as [17] discuss how to compute bandwidth in adhoc networks. Here simple and straightforward approach is used: measuring how much time a node monitors an idle channel and thus is available to transmit new messages over a link (node's idle time). MAC protocols such as IEEE 802.11 are based on a carrier-sense capability of each node. This capability is exploited to determine, locally at each node, for what percentage of time the medium has been busy in the recent past. A busy medium may indicate that a neighbor is transmitting data over the shared wireless channel. However, it may also indicate that nodes even further away, but still within interference range, are using the media. A node can only successfully transmit during times when neither its immediate neighbors nor other nodes in its interference range are transmitting.

The available bandwidth over a link connecting nodes A and B is proportional to the minimum of A's idle time and B's idle time since both nodes have to be available for a successful transmission. Since the number of nodes and the traffic between them in each node's interference range is different, the idle times of two adjacent nodes may well be substantially different. However, due to the shared nature of the wireless medium, it is always the case that the link bandwidth between two adjacent nodes A and B is always equal to or better than the bandwidth over any 2-hop connection between A and B (i.e., via some intermediate node C). Depending on the underlying MAC protocol, a node may not be able to use the whole idle time. In IEEE 802.11 networks, for example, a node will wait for a random back off time after it detects that the link is idle. However, as such back off times are deliberately kept short. Because of the unstable nature of adhoc networks, it is also important to decide how the idle time, which reflects the network traffic condition, should be maintained and updated.

3.2 Quality of service routing

Based on the discussion in Section 3.1, the following revisions are made to develop the QoS node model.

3.2.1 Idle time calculation

If the node is sending packets, its transmitter becomes busy. If there are other nodes beginning transmission within the interference range of the current node, its receiver senses the busy media and sends a media busy signal. As ns-2 model already defines functionalities to capture changes of the media, the media idle time is computed as follows:
In a 0.5 second time period, how long the transmitter or receiver is busy (the time between the transmitter or receiver becomes busy and then returns to idle again is recorded. Then, the percentage of idle time is calculated, which is (0.5-busy time)/0.5. This is a sample of the idle time in this interval. The idle time of 10 such 0.5-second-periods in a row is calculated, obtain 10 samples of idle time over 5 seconds, arrange these samples into a sliding window, and calculate its average value.

4. Stable energy aware routing protocol (SEAAR)

In this section, the SEAAR protocol which selects the optimal paths using power aware metric and link stability which optimizes the power consumption, delay, packet delivery ratio, packet loss and throughput as proposed in the previous work [25] is reviewed.

4.1 Path stability model

Route P is said to be broken if any one of the following cases occur. First, any one of the nodes in the route dies because of limited battery energy. Second, any one of the connections is broken because the corresponding two adjacent nodes move out of each other's communication range. Thus, the lifetime of route P is expressed as the minimum value of the lifetime of both nodes and connections involved in route P [26]. Thus, the lifetime Tp of route P can be expressed as

$$Tp = \min(TNi, TCi) \qquad (1)$$

4.2 Node life time (TNi)

Node life time can be evaluated based on it's current residual energy and its past activity. The term REi represents the current residual energy of node i, and dr_i is the rate of energy depletion. REi can simply be obtained online from a battery management instrument. Every time interval T, node i reads the instantaneous residual energy value RE_i^0 , RE_i^{2T} , RE_i^{3T} , ….$RE_i^{(n-1)T}$, RE_i^{nT}…. and the corresponding estimated energy drain rate dr_i is obtained as

$$dr_i^{\,n} = \alpha(RE_i^{(n-1)T} - RE_i^{nT}) / T + (1-\alpha)\, dr_i^{\,n-1} \qquad (2)$$

where dr_i^n is the estimated energy drain rate in the nth period, and dr_i^{n-1} is the estimated energy drain rate in the previous $(n-1)^{th}$ period. α denotes the coefficient that reflects the relation between dr_i^n and dr_i^{n-1}, and it is a constant value with a range of [0, 1]. At time t, we can obtain the estimated node lifetime as follows:

$$T_{Ni} = RE_i^{nT} / dr_i^n \quad (3)$$

4.3 Connection life time (TCi)

The connection time TCi depends on the relative motion between Ni and Ni−1, the definition of link stability is provided in what follows:

Definition 1. A link between two nodes i and j with transmission range R is established at time instant t_1 when the distance between both nodes is such that d(i,j) < R.

Definition 2. A link between two nodes i and j with transmission range R is broken at instant time t when the distance between both nodes verify the condition d(i,j) > R.

Definition 3. A link age **a** or connection lifetime between two nodes i and j is the duration a(i, j)= TCi = t –t_1 (4)

4.4 Path life time

The intermediate nodes updates the PLT value in the common header of the RREP packet with a local Min (NLT or LLT) value, if Min (NLT or LLT) < PLT, before forwarding this RREP packet. When the RREP packet reaches the source node, the PLT becomes the minimum value of the estimated lifetime of all nodes and links through the route from the source node to the destination node. In the persistent data forwarding period, a source node tends to select the path with the longest lifetime (the path with the maximum PLT value) from multiple paths as a source route for data forwarding.

5. QoS based SEAAR (QSEAAR)

In this section SEAAR protocol with power aware and stability concept in [25] is extended by including QoS parameters and new protocol QSEAAR is proposed. In QSEAAR protocol, IEEE 802.11 MAC layer is taken and the same MAC layer bandwidth is considered for the transmission. With this, available bandwidth estimations are done. The parameters considered for QOS are explained below.

1. Error Count (EC) -The EC is the maximum value between set of node error counts (linkage break and node failure) for the feasible path. The smaller EC represents the more reliable routing path.

2. Hop Count (HC)-The HC is the number of hops for the feasible path. The smaller HC represents the more reliable and less cost of routing path.

3. BandWidth(BW)-Bandwidth estimation is a basic function that is required to provide QOS in MANETs. It is a way to determine the data rate available on a network route. It is of interest to users wishing to optimize end-to-end transport performance, overlay network routing, and peer-to-peer file distribution

Techniques for accurate bandwidth estimation are also necessary for traffic engineering and capacity planning support. QOS is calculated using equation given below,

$$QOS = C_1 \times \frac{EC}{Max(EC)} + C_2 \times \frac{HC}{Max(HC)} + C_3 \times \frac{BW}{MAX(BW)} \quad (5)$$

Where |C1|+|C2|+|C3|=1, EC=error count, HC= hop count, BW=bandwidth, C1, C2, C3 are the values which can be chosen according to the system needs. For example, bandwidth is very important in MANETs, thus the weight of C3 factor can be made larger. C1, C2 factor related to path error and hop count reduce the weight of path so C1 and C2 factor can be made smaller [19]. In QSEAAR protocol, the value of C1, C2 & C3 are chosen as C1=0.10, C2=0.10 & C3=0.80.

QOS values are calculated for the selected path as described in the section 4.4 and the source node tends to select the path with the high QoS value from multiple paths and data is forwarded in that path .

6. Results and discussion

Mobile ad hoc networks (MANETs) have been widely studied in the literature. Due to the nature of self-organization, the dynamic topology caused by mobility and transmission power control, and the multiple-hop routing in MANETs, it is difficult to build a complete analytical model to study the network performance. On the other hand, a real test bed is expensive. Therefore, the simulation study of MANETs is important. Different simulation tools such as ns-2 with CMU monarch extension, GloMoSim and its commercial successor QualNet, OPNET, and SWANS have been developed for MANET evaluation. The simulation study presented in this paper is based on ns-2 (NS2.34) under LINUX platform because it is open source and is widely used in both academia and industry [22].

Ns-2 has following features [22]:

1) For radio propagation, the Friss-space model is used for short distances and the approximated two-ray-ground model is used for long distances. The shadowing model is employed to characterize the probabilistic multiple path fading during radio propagation. There are some other extensions to ns-2, for example, Ricean fading and accurate physical layer modeling.
2) At MAC layer, the IEEE 802.11 distributed coordination function (DCF)is implemented, including Request-to-Send (RTS) / Clear-to-Send (CTS) / DATA / ACK four-way handshake for unicasting packets.
3) At network layer, major ad hoc routing protocols, such as Destination Sequence Distance Vector (DSDV), Ad hoc On-demand Distance Vector (AODV), and Dynamic Source Routing (DSR), Adhoc on demand multipath distance vector routing (AOMDV) are implemented.
4) At transport and application layers, random connections of Constant Bit Rate (CBR) and TCP data traffics can be generated by a traffic-scenario generator.
5) The random way-point mobility model is developed, which is specified by the maximum speed of movements, the pause time between movements, and the direction of the movements.

Using a simulator written in C++, topologies are randomly generated, and perform the computations on these fixed graphs, which represent snapshots of the Ad-Hoc network state.

6.1 Network Scenario

Table 1: Simulation Environment

Simulation Time	100s
Topology Size	500m x 500m
MAC Type	MAC 802.11
Radio Propagation Model	Two Ray Model
Radio Propagation Range	150m
Pause Time	25s
Initial Energy	100J
Transmit Power	0.4W
Receive Power	0.1W
Traffic Type	CBR
Packet size	1000bytes
Bandwidth	Based on the analysis in this section, the available link bandwidth is computed as follows: Each node is randomly assigned an “idle time” ranging from 0 to 1. The available link bandwidth between two nodes is equal to the minimum of their idle time x maximum bandwidth. Here, we consider that in the Ad-Hoc network, each link has the same maximum bandwidth, 2 Mbps. For example, if node a’s idle time is 0.5 and node b’s idle time is 0.3, then the available bandwidth over link ab is: 0.3 x 2Mbps = 600 kbps.
Routing Protocol	AOMDV

The table 1 shows the important parameters chosen for the NS2 simulation. An effort has been done to create a new protocol QSEAAR by adding quality of service with the concept of SEAAR protocol which provides path stability, residual energy consumption. QSEAAR protocol was also analyzed in terms of packet delivery ratio, energy consumption, packet loss, throughput and end to end delay. The performance of QSEAAR protocol was compared with existing protocol AOMDV and SEAAR which shows that QSEAAR outperforms than other protocol in most of the case.

6.2 Simulation Parameters

RFC 2501 describes a number of quantitative metrics that can be used for evaluating the performance of a routing protocol for mobile wireless ad-hoc networks. Some of these quantitative metrics [23] are defined as follows:

1. Packet delivery ratio

The packet delivery ratio is defined as the ratio of number of data packets received at the destinations over the number of data packets sent by the sources as given in equation (6). This performance metric is used to determine the efficiency and accuracy of MANET's routing protocols.

$$Packet\ Delivery\ ratio = \frac{Total\ data\ packets\ received}{Total\ data\ packets\ Sent} x100 \quad (6)$$

2. Energy consumption

This is the ratio of the average energy consumed in each node to total energy as given in the equation (7).

$$Energy\ consumption = \frac{Energy\ remaining\ in\ the\ node}{Total\ energy} \quad (7)$$

3. End to end delay

This is the average time involved in delivery of data packets from the source node to the destination node. To compute the average end-to-end delay, add every delay for each successful data packet delivery and divide that sum by the number of successfully received data packets as given in equation (8). This metric is important in delay sensitive applications such as video and voice transmission [24].

$$Average\ End\ to\ end\ delay = \Sigma \frac{(Time\ received - time\ sent)}{Total\ data\ packets\ received} \quad (8)$$

4. Throughput

The throughput metric measures how well the network can constantly provide data to the sink. Throughput is the number of packet arriving at the sink per ms. A network throughput is the average rate at which message is successfully delivered between a destination node (receiver) and source node (sender). It is also referred to as the ratio of the amount of data received from its sender to the time the last packet reaches its destination. Throughput can be measured as bits per second (bps), packets per second or packet per time slot. For a network, it is required that the throughput is at high level. Some factors that affect MANET's throughput are unreliable communication, changes in topology, limited energy and bandwidth.

5. Number of Packets dropped

This is the number of data packets that are not successfully sent to the destination during the transmission. In this study the time versus number of packets dropped have been calculated. Packet loss occurs when one or more packets being transmitted across the network fail to arrive at the destination. It is defined as the number of packets dropped by the routers during transmission. It can be shown by equations (9) to (11).

Packet Loss = Total Data Packets Dropped (9)

Packet Loss = Total Data Packets Sent – Total Data Packets Received (10)

$$Packet\ loss(\%) = \frac{Total\ data\ packets\ dropped}{Total\ data\ packets\ Sent} x100 \quad (11)$$

6.3 Simulation Results

The performance of the following protocols is compared and applied them to the randomly generated network snapshots:

1) Adhoc on demand multipath routing protocol (AOMDV)

2) Stable Energy aware adhoc routing protocol (SEAAR)

3) QoS based SEAAR (QSEAAR)

The performance of SEAAR and QSEAAR is compared with the existing protocol AOMDV and the results are shown below.

Figure 1 shows the comparison of packet loss ratio versus nodes for AOMDV, SEAAR and QSEAAR protocols in terms of packet loss.

The observation is that at 60 nodes, the packet loss is less in QSEAAR and more in SEAAR. But at 120 nodes packet loss is same as AOMDV. Higher the packet loss, less efficient is routing protocol and in this figure, AOMDV gives high packet loss than QSEAAR and SEAAR.

Figure 2 shows the comparison of end to end delay versus nodes for AOMDV, SEAAR and QSEAAR protocols. It shows that the end to end delay of network using QSEAAR is minimum as compared to SEAAR and AOMDV with 60, 80 and 100 nodes. At 120 nodes QSEAAR has slightly more delay as compared to AOMDV. On an average performance of QSEAAR is better.

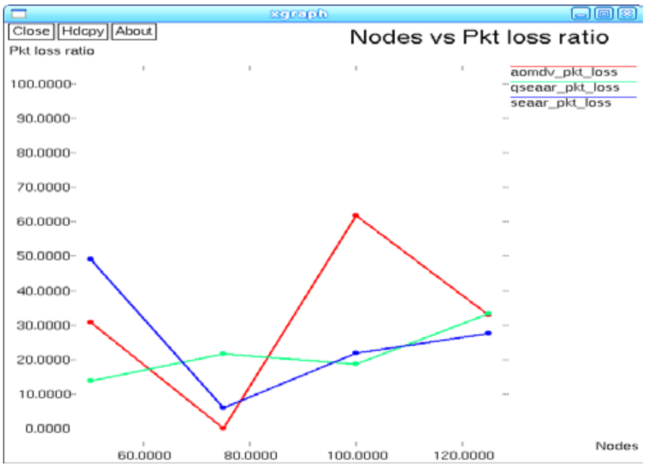

Fig 1 Comparison of packet loss ratio versus nodes.

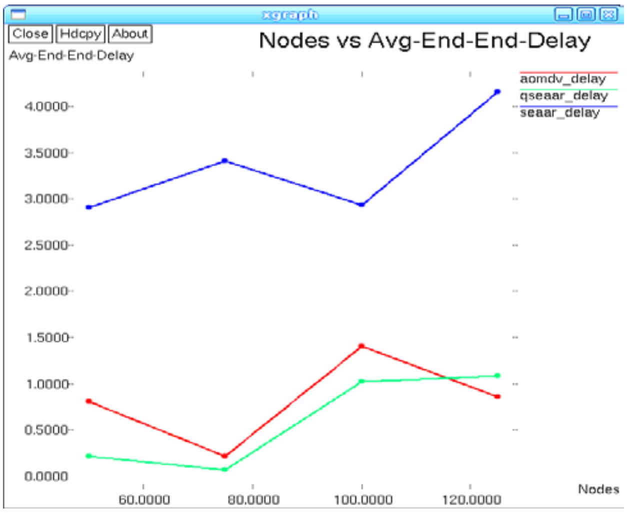

Fig 2 Comparison of end to end delay versus nodes.

Figure 3 shows the comparison of residual energy versus nodes for AOMDV, SEAAR and QSEAAR protocols. It shows that the residual energy of network ie the energy remaining in the node using SEAAR is maximum compared to AOMDV and QSEAAR. Energy remaining in QSEAAR is better when number of nodes is less and energy decreases as number of nodes increases. On an average QSEAAR is better as compared to existing AOMDV and slightly inferior as compared to SEAAR.

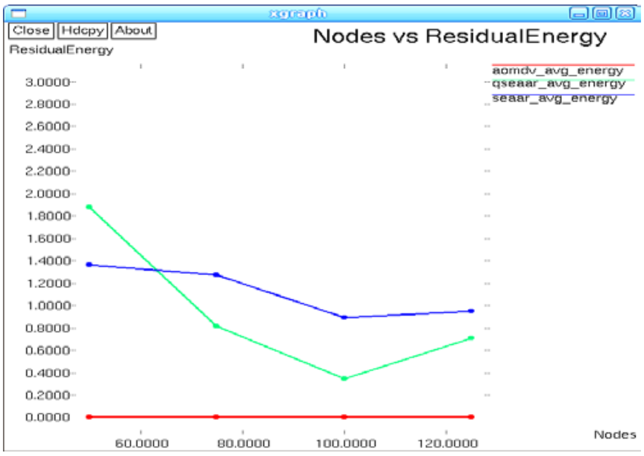

Fig 3 Comparison of residual energy versus nodes.

Figure 4 shows the comparison of throughput versus nodes for AOMDV, SEAAR and QSEAAR protocols. It shows that the throughput of network using SEAAR and QSEAAR is maximum compared to AOMDV. The protocol having high network throughput is more efficient and in this figure, SEAAR and gives high throughput than AOMDV.

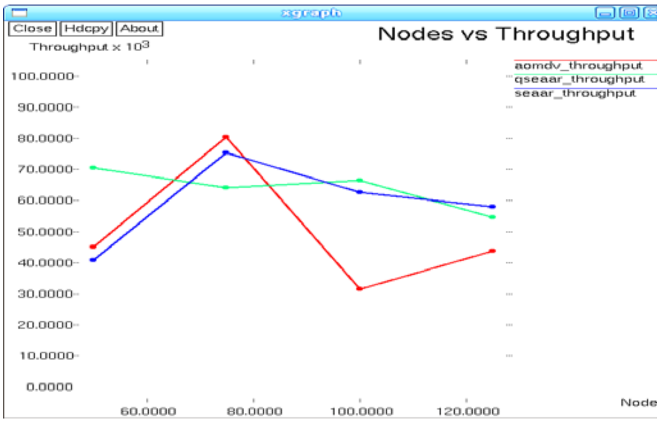

Fig 4 Comparison of throughput versus nodes.

Figure 5 shows the comparison of packet delivery ratio versus nodes for AOMDV, SEAAR and QSEAAR protocols. It shows that the packet delivery ratio of network using SEAAR and QSEAAR is maximum compared to AOMDV.

Therefore QSEAAR outperforms AOMDV in terms of throughput, delay, energy remaining, pack loss and packet delivery ratio.

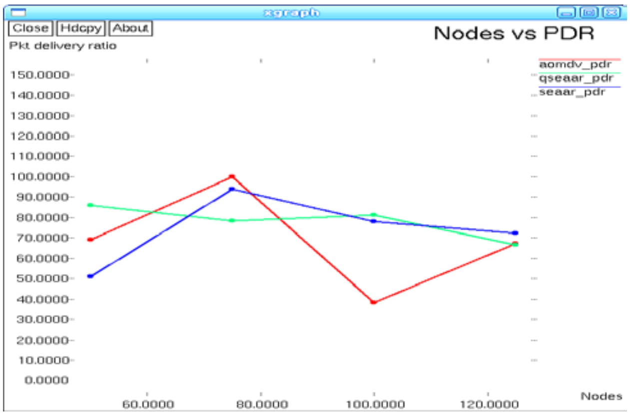

Fig 5 Comparison of packet delivery ratio versus nodes.

The performance of the protocol is analysed with different types of mobility of the nodes.

Figure 6 shows the comparison of packet loss ratio versus speed for AOMDV, SEAAR and QSEAAR protocols. It shows that the packet loss of network using QSEAAR is minimum as compared to AOMDV and SEAAR when nodes are moving with more speed and in low mobility environment it is comparable with AOMDV.

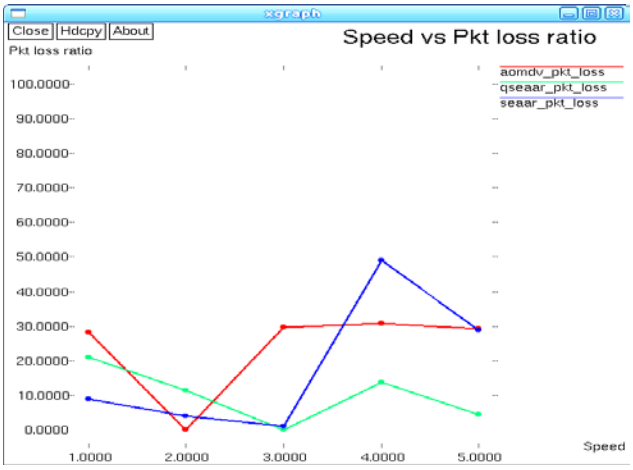

Fig 6 Comparison of packet loss ratio versus speed.

Figure 7 shows the comparison of end to end delay versus speed for AOMDV, SEAAR and QSEAAR protocols. It is observed that the end to end delay of network using QSEAAR is minimum as compared to AOMDV and SEAAR when nodes are moving with more speed and in low mobility environment it is higher than AOMDV and less than SEAAR.

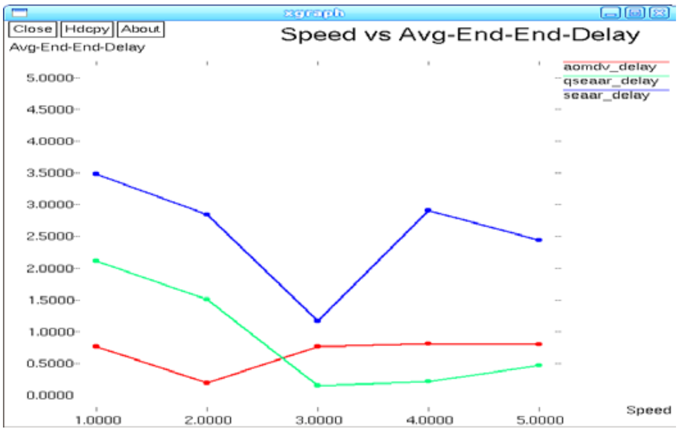

Fig.7 Comparison of end to end delay versus speed.

Figure 8 shows the comparison of residual energy versus speed for AOMDV, SEAAR and QSEAAR protocols. It shows that the energy remaining in the nodes using QSEAAR is more as compared to AOMDV and SEAAR when nodes are moving with more speed and in low mobility environment it is higher than AOMDV and less than SEAAR.

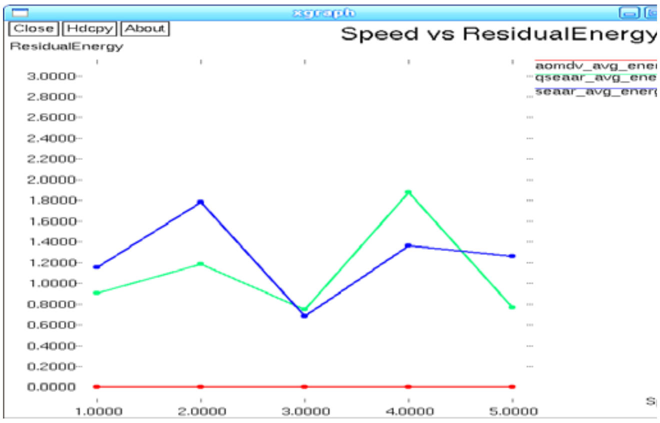

Fig 8 Comparison of residual energy versus speed.

Figure 9 shows the comparison of throughput versus speed for AOMDV, SEAAR and QSEAAR protocols. It shows that the throughput of network using QSEAAR is maximum compared to AOMDV and SEAAR and slightly inferior to SEAAR when nodes are moving with less speed.

Figure 10 shows the comparison of packet delivery ratio versus speed for AOMDV, SEAAR and QSEAAR protocols. It shows that the packet delivery ratio of network using QSEAAR is maximum compared to AOMDV and SEAAR slightly inferior to SEAAR when nodes are moving with less speed.

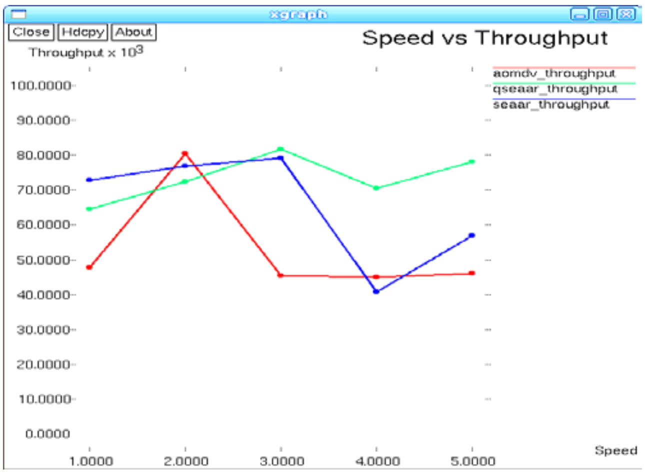

Fig 9 Comparison of throughput versus speed.

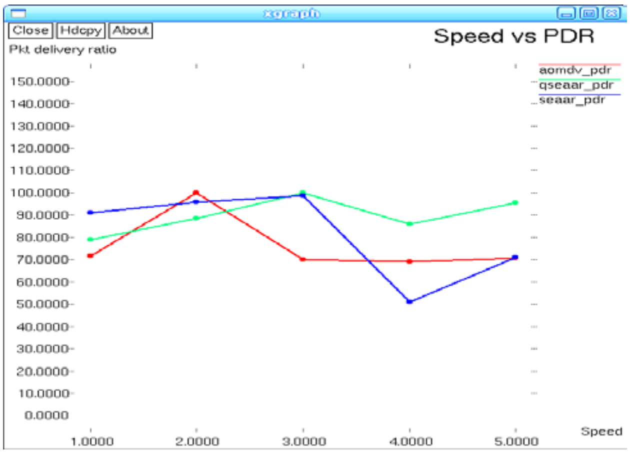

Fig 10 Comparison of packet delivery ratio versus speed.

6.4 Trace file analysis

C++ coding is written to include all the above concepts. This is linked with Tcl script written in ns-2. When the simulation is started, the working of the protocol is displayed in terminal window and the same is stored in a trace file. Some part of the output is given below. Here 50 nodes are used and each node calculate Node lifetime (NLT) and link lifetime(LLT) for all the neighbour nodes. Here sample output for node 0 is given. Node 0 calculates LLT &NLT for its neighbours 13, 11, 16

Node: 0 NLT
13 0.00079145613 node_lifetime: 126313
11 0.00077532311 node_lifetime: 128868
16 0.0013526916 node_lifetime: 73892.8
Node: 0 LLT
13 link_lifetime 65.3779
11 link_lifetime 104.393
16 link_lifetime 55.3369

The source node is taken as 39 and destination is taken as 10. Node 39 want to establish a path to 10 and it sends rote request to 10 through nodes 2,6,0,21 and 10. During that time the value of cost, bandwidth, hop count and error count are updated as shown below

Node: 39 send Route req to 10 at 29.8
Path:39 2 6 0 21 10
Path_bw:1.19993e+07
cost:500.753
Error_count:6

Node 10 sends route reply via the reverse path as shown below.

Node: 10 send Route reply
10 21 0 6 2 39
Reply Forward to : 21 dst: 39
Received route reply 21 from 10
Forward to : 0

Once route is established each node will have path table with updated next hop, bandwidth, cost and QOS values. Then data transfer starts. During that time node send data via path with higher QOS value. For example node source 39 forwards data via node 2 to the destination 10. Node 2's immediate neighbors are 41 & 6. Node 41 is having higher QOS so node 2 selects node 41 to transfer the data.

Node: 39 Forward data to : 2
Path_table
Dst:10 nhop:41 bw:1.3999e+07 cost:420.102 qos:0.927523
Dst:10 nhop:6 bw:1.19993e+07 cost:500.753 qos:0.664288
Node: 2 Forward data to : 41

7. Conclusion

An on-demand QoS routing protocol based on AOMDV is developed for mobile ad hoc networks. In the persistent data forwarding period, a source node tends to select the path with the high QOS value from multiple paths as a source route for data forwarding. Its performance is compared with that of the original AOMDV protocol with simulations. In the simulations the QoS routing protocol can produce higher throughput, less power consumption, better packet delivery ratio, lower delay and packet loss than AOMDV and SEAAR. It works the best in large networks under high network mobility. This work proposes further research into more efficient protocols or variants of existing protocols and network topologies. Emphasis is on protocols that could be suitable for the implementation of scalable system in high node density environments such as in manufacturing or product distribution industries. In the future, there is a scope to decrease ad hoc or sensor network's energy consumption by using MAC layer power-control techniques. Also the evaluation of QSEAAR protocol is also tested in terms of mobility models such as Random Way point Mobility (RWM), Reference Point Group Mobility (RPGM), Manhattan Grid Mobility (MGM).

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