Multi-path QoS Routing Protocol for Load Balancing in MANET

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ABSTRACT

In Mobile Ad hoc Network (MANET), single path QoS routing is disadvantageous since it may cause fading, interference, collision and link failures. For QoS routing, load balancing is essential since it allows a router to take advantage of multiple best paths to a given destination. It can minimize the maximum utilization while supporting the same traffic demands. It reacts quickly to changes in traffic demands, link failures, and traffic spikes. It also avoids congestion within the network. So, considering the advantages of load balancing, a multi-path routing for load balancing (MQRLB) is proposed in this paper. Initially, Route Discovery is initiated when the source node attempts to discover disjoint routes to the destination. After multiple disjoint routes are established, the balancing function and the forwarding function for each path is calculated, based on which the load unbalance condition is checked. In case of load unbalance, load distribution is done by adding redundant codes along with the data and transmitting through multiple paths. Thus QoS routing can be processed through multiple successful paths using load balancing.

Keywords
Manet, QoS, Load Balancing, QoS routing, multipath

1. INTRODUCTION

1.1 Mobile Ad hoc Networks (MANETs)

A group of wireless nodes which is capable of developing a network without using existing network infrastructure is known as the mobile ad hoc network. When the node wishes to forward packets with each other, it communicates with other nodes by multi-hop. Since the host mobility can cause recurrent impulsive topology changes, the design of a Quality of Service (QoS) routing protocol is quite complicated compared to the conventional networks [1]. Due to instant formation of infrastructure less network, MANETs supports various services. Along with the usage of MANETs in emergency situations like natural disasters, military conflicts, medical facilities etc, it is also widely used in the multimedia communications currently. But it is difficult for maintaining real-time media traffics such as audio and video in presence of dynamic network topology due to high rate requirements and severe delay constraints. [2]

1.2 QoS Routing in MANETs

Satisfying the given QoS requirements of arriving communication requests and achieving global efficiency in resource utilization are the two main goals of QoS routing. Delay, jitter, bandwidth and loss rate are the typical routing metrics for providing QoS. The QoS aware services are mainly based upon the QoS routing in the wireless ad hoc networks. The network size, computation, communication and storage overhead are considered for designing routing protocol. Due to the network dynamics caused by node mobility, it is complex to guarantee an initial QoS contract with a session that has specific QoS requirements. Due to the path break or network partition, there exists a transient time if the required QoS is not guaranteed. The routing information inaccuracy should be efficiently absorbed by the designed protocol. It needs to prevent the QoS Traffic from starving best effort traffic [3]. Most of the established QoS routing algorithms are depended on the shortest path techniques. The shortest paths links often run out of capacity, since these paths passes through the middle of the network. The effect of the ad hoc networks is greatly amplified, where each path interferes with multiple links in its vicinity. As a result, low admission ratios exist in the QoS routing which uses shortest path. [4]

1.3 Multi-path Routing

Multiple routes between the source and the destination node are determined using Multi-path routing. These multiple paths support QoS and compensates for dynamic and unpredictable nature of MANET. Node disjoint, link disjoints or non-disjoint routes are discovered by the multi-path based routing. Node disjoint routes – no common nodes or links Link disjoint routes – no common links, common nodes. Non-disjoint routes – common links, common nodes. There are no restrictions in the non-disjoint routes whether the routes need to be a node or link disjoint and so it is more advantageous. A subset of paths which satisfies QoS requirements is selected in the QoS routing. [5]
The multi-path routing protocols for MANETs are as follows:
SMR: This protocol calculates link and node disjoint paths and the path is set to two. The source is conscious about the complete path towards the destination.

AOMDV: The maximum number of paths and the hop difference between the shortest path and an alternative path are configured in this protocol. It also calculates the link and node disjoint paths.
AODV Multipath: Only node disjoint paths are established by the protocol and there is no limitation on the maximum number of paths. [6]

1.4 Load Balancing in MANETs

The existing multi-paths forwards packets through mobile nodes which have enough capacity remaining, and this mechanism is called as Load balancing. So, the existing or potential local network congestion can be mitigated and rate of transmitting the dynamically changing load in the network can be increased. The overall network throughput can be increased and a better QoS can be provided for the network due to load balancing. [7]
The load balancing can be processed as per destination, per packet or per flow. When a router distributes the packets based on destination address then it is called as per-destination load balancing. Here when a network has two paths, all the packets for destination1 on the network go for the second path and vice-versa. Only upon the condition that both the paths have the same bandwidth, the router sends one packet for destination1 over the first path and second packet for destination1 over the second path. Else the traffic is sent as a function of the link bandwidth. Researches for minimization of the maximum utilization of traffic demands and also supporting the same traffic demands are focused in wired network. A multi-path routing with load balancing can satisfy this demand [8]

1.5 Problem Identification and Proposed Solution

In the previous paper [14], a QOS-based, Robust Multi-path Routing (QRMR) protocol for mobile ad hoc networks was developed. In that, individual links were alloted weights, depending on the metrics link quality, channel quality and end-to-end delay. The individual link weights are combined into a routing metric to validate the load balancing and interference between links using the same channel. The traffic is balanced and the network capacity is improved as the weight value assists the routing protocol to evade routing traffic through congested area.
In the next paper [15], an design idea of QoS architecture for Bandwidth Management and Rate Control in MANET was proposed. The proposed QoS architecture contains an adaptive bandwidth management technique which measures the available bandwidth at each node in real-time and it is then propagated on demand by the QoS routing protocol. The source nodes perform call admission control for different priority of flows based on the bandwidth information provided by the QoS routing. The network bandwidth utilization is monitored continuously and network congestion is detected in advance. Then a rate control mechanism is used to regulate best-effort traffic. But this QoS routing does not consider the load balancing mechanism. As an extension to the previous papers, the QoS routing was extended in order to overcome the disadvantages and to design an efficient load balancing technique using multi-path routing.

2. RELATED WORK

Fujian Qin et al [5] have presented a multipath source routing protocol with bandwidth and reliability guarantee is proposed. In routing discovery phase, the protocol selects several multiple alternate paths which meet the QoS requirements and the ideal number of multipath routing is achieved to compromise between load balancing and network overhead. In routing maintenance phase, it can effectively deal with route failures similar to DSR. Sujatha P Terdal et al [9] have proposed a paper which enhances upon multi-path routing by organizing group of nodes into clusters and designating high capability nodes as cluster heads. These cluster heads are later explored to generate multiple paths. This measure reduces interference among multiple paths. Joint entropy based selection of cluster heads is done to attain stable multiple paths using mobility and energy values.

Zhu Bin et al [10] have presented a paper which proposes a novel adaptive load balancing routing algorithm in Ad hoc networks based on a gossiping mechanism (ALBR-G). This algorithm combines gossip-based routing and the idea of load balancing effectively. It can adaptively adjust the forwarding probability of RREQ messages according to the distribution and load status of nodes in route discovery phase. Mohamed Tekaya et al [11] have presented a new multipath QoS routing protocol for MANET with load balancing mechanism. There are two main contributions in this work. One is load balancing mechanism to fairly distribute the traffic on different active routes, the other is the route discovery mechanism based on QoS parameters such as delay and throughput.

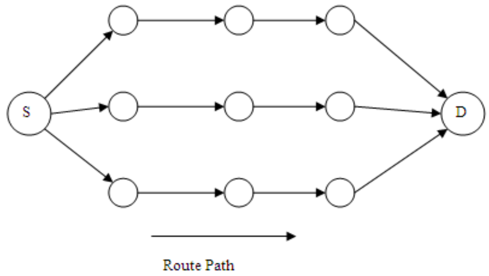
Dr. B.S Pradeep et al [12] have proposed some enhancements to the AODV protocol to provide QoS and load balancing features by adding two extensions to the messages used during route discovery. A detailed packet-layer simulation model with media access control (MAC) and physical layer models is used to study the performance of both the AODV and the QoS-AODV protocols. Important performance measures such as average delay, packet delivery fraction and normalized routing load are used in the comparison.
Chengyong Liu et al [13] have presented the ad hoc QoS routing protocol with load balancing scheme. For MANETs, load balancing can be advantageous for increasing reliability and network throughput. Their approach relies on modifications of AODV protocol, on which they make an extension to utilize the node's reservable bandwidth and load information to distribute the network loads, which can prevent network from getting into the sate of congestion, and avoid the power of congested node to be exhausted.

3. MULTI-PATH QOS ROUTING FOR LOAD BALANCING

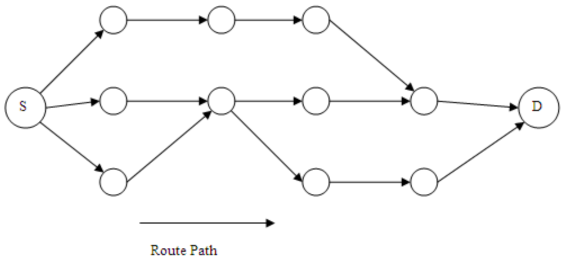
3.1 Multi-path Route Discovery

On flooding the request packets (RREQ), a route discovery can be initiated when source node endeavors to discover routes to the destination. The source address, destination address and a route record are present in the RREQ. The sequence of hops through which the RREQ has been propagated, and a sequence number which prevents the loops, are stored in the route record. Until the target host is reached the RREQ will be propagating.

Only disjoint routes are discovered in this scheme. Figure 1 shows the example of joint and disjoint routes. For each source-destination pair, the intermediate node forwards RREQ in order to discover disjoint routes. The RREQ received from each node is stored in the RREQ table for the disjoint routes discovery.



Disjoint Routes



Joint routes

Fig 1: Joint routes and Disjoint routes

	M_1	M_2	….	Mj	….	Mn
M_1	S_{11}	S_{12}		S_{1j}		S_{1n}
M_2	S_{21}	S_{22}	….	S_{2j}	….	S_{2n}
…						
Mi	S_{i1}	S_{i2}	….	S_{ij}	….	S_{in}
…						
Mn	S_{n1}	S_{n2}	….	S_{nj}	….	S_{nn}

Fig 2: RREQ Table

M_i (i = 1,2, n) denotes the mobile nodes in this table. The latest sequence number subsequent to the pair M_i and M_j is denoted by S_{ij}(i,j = 1,2,n). On receiving the RREQ, the mobile node compares the sequence number in the RREQ and the one cached in the RREQtable. The RREQ is forwarded and the cache gets updated when the cached RREQ is lesser than the sequence number in the RREQ. If the sequence number of the RREQ is higher then the RREQ gets discarded. Consider v as the maximum number of disjoint routes which reverses the sequence of hops in the route record of the RREQ to discover routes. On a first-come-first-served basis, the destination replies v RREP packets for the first v RREQ packets. During the second route discovery, the possibility of overheads can be avoided by this route reversal method.

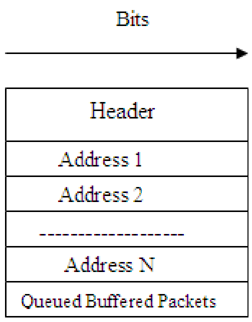


Fig 3: Route Reply Packet Format

Figure 3 shows the route reply packet format. The total number of buffered packets on the path is stored in each RREP which contains a 32-bit field "Buffered packets". The number of buffered packets on the "Buffer field" is recorded by the destination on the "Buffered Packet" before sending the RREP. The intermediate nodes revise their buffered packets from their "Buffer field" to " Buffered Packet" after receiving the RREP. The route path information is segregated and according to the specified route the RREP packets are forwarded. A maximum of v disjoint paths are discovered at the end of the route discovery. Besides, the total number of buffered packets on these routes is known.

In summary, the algorithm for the route discovery is shown below:

1. Routes are discovered to the destination by flooding RREQs.
2. On receiving RREQ, it compares sequence number in the RREQ table.
3. If sequence number of RREQ < Received RREQ

   . Discards the RREQ

   Else

   Node forwards RREQ.

   3.2.1 Destination records number of queued packets

   3.2.2 RREP is sent to the intermediate nodes.

   3.2.3 Intermediate nodes extract route path information and forwards RREP

4. Multiple disjoint routes are determined accordingly.

In the same way, many disjoint routes are discovered and we calculate the load on each path using a balancing function which is described in the next section.

3.2 Balancing Function

The load balance is characterized by (i) the destination oriented Directed acyclic graph (DAG),d, and (ii) the forwarding strategy used to forward the traffic, denoted by Ud. The forwarding strategy governs that how a node distributes the incoming load to the outgoing links of the DAG.

The traffic (bits/sec) forwarded on a link l of DAG, d for the forwarding strategy U_d is denoted by xUd(l). The set of outgoing links at node i in a DAG d is denoted by $U_d(i)$.

Thus for a given DAG and forward strategy, the total traffic forwarded by node i,

G(d, $U_d(i)$, is given by:

$$G_{d,Ud(i)} = \sum_{l€Od(i)} x\ U_d(i) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Two metrics for characterizing the load balance, called balance function and Forwarding function are defined here:

Balance Function (B_f): Let G_d;U_d denote the mean traffic load handled by a node in the network. The BF for a given d and U_d, denoted by Bf(d; U_d), is defined as

$$B_f\ (d,U_d) = (\ 1/N \sum_{i€v} (G_{d,Ud(i)} - G'_{d,Ud})^2\ )^{-1} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Forwarding function (F_f): The Ff for a given d and U_d, denoted by Ff(d, U_d) is defined as

$$F_f\ (d,U_d) = \sum_{i€v} G^2_{d,Ud(i)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

After calculating the B_f and the F_f, we need to analyze whether load distribution is necessary or not. For this, we consider two threshold values, Balance function threshold T_{Bf} and Forwarding function threshold T_{Ff}.

If the calculated B_f is lesser than its threshold value and the calculated F_f is greater than its threshold value, then it indicates load unbalance and hence load distribution has to be performed.

(i.e) $B_f < T_{Bf}$ …(4) and $F_f > T_{Ff}$ …..(5)

On satisfying these two conditions, we distribute the load using an optimization algorithm which is described in the following section 3.3.

3.3 Distribution of Load

Let us assume T_{max} paths for the data transmission from the source to the destination. Due to mutually disjoint paths, no common nodes are present. When a path i is down at the time of transmission, each path assigns a probability of failure Fi. We consider the paths as a pure erasure channel. Probability Fi is denoted, when no information is reached at the destination for each path i. Probability Si is denoted when all the information is received correctly.

- The success or failure of one path doesn't encage in the success or failure of all other paths. The failure probabilities of the available paths are organized as probability vector F = [Fi] , i = 1……..T_{max} such that $F_i \leq F_{i+1.}$ Starting from the best to the worst ones we order the paths.

Knowing F, the success probability S = [Si], Si = 1 – Fi, i = 1…….T_{max} has been defined.

Without the consideration of node mobility patterns, the failure probability vector F reveals the network topology and the quality of the available routes.

We propose to develop a method for the fast calculation of the optimal solution, so that it can respond to rapid changes in F (i.e) changes in the network topology.

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- Let us assume that a packet of P information bits utilizing the set of available independent paths in such a way as to maximize the probability that these bits are successfully communicated to the destination and this probability is denoted as Ds.

- We add Q extra bits as overhead. The network layer packet is the resultant R = P + Q. These extra bits are considered as a function of the information bits. Given any subset of these blocks with a total size of P or more bits, we can reconstruct the initial P bit packet, while spitting the R bit packet into multiple equal size non-overlapping blocks.

- First we define the overhead factor v = R / P = r / p, where r and p take integer values and the fraction r/p cannot be further simplified, (i.e) the greatest common divisor of r and p is 1.

- In order to find how the R bits are distributed over the available paths, we define the vector $\underline{b}$ = [bi], where bi is the number of equal size blocks that is allocated to path i.

- The paths which have a very poor performance may not be used at all. Only some of the available paths are used and so we require using only some available paths.

- In order to increase Ds, we need to use block allocation vector $\underline{b}$ as a vector with a variable size n, instead of fixing its size to the number of available paths. The probability vector is ordered from the best path to the worst one, a decision to use T paths implies that these paths will be the first T paths.

The allocation vector is denoted as follows:

$\underline{b} = (b_1, b_2 \ldots b_n),\ T \le T_{max}$ ………… (6)

If the block size is z then:

$z. \sum_{i=1}^{n} b_i = R = v\,P$ ………. (7)

The total number of blocks that the R bit packet is fragmented to is:

$c = \sum_{i=1}^{n} b_i = \frac{v\,P}{z}$ ………….. (8)

- A path with higher failure probability need to be assigned more blocks while a path with a lower failure probability can be assigned with fewer blocks.

- The following diagram shows the R bit packet and its relation to the original P bit packet. The R bit packet is fragmented into equal size non-overlapping blocks of size z. We fragment the P bit packets into A z-size blocks, $l_1, l_2, \ldots l_n$, and the R bit overhead packet into B z-size blocks, $m_1, m_2 \ldots m_n$.

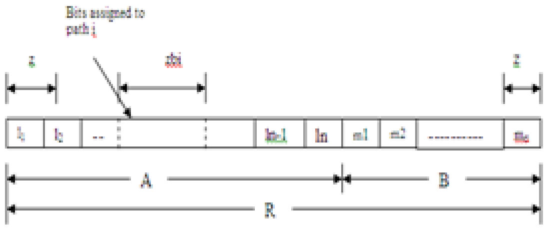


Fig 4: information and overhead packet fragmentation

- The first b1 blocks of the R- bit sequence are assigned for path 1, and then the next b2 blocks are assigned to the path 2 and so on. Thus bi blocks are assigned for path i with each block of size z.

The expressions for A and B are derived as follows:
A = P / z = c / v, ………. (9)
B = Q / z = (v-1)c / v …………… (10)

Here we need to distribute the loads in the multi-path. It is possible to recover the original A information blocks, if B or less blocks are lost out of all A + B total data and overhead blocks.

We calculate the overhead blocks m_i, i= 1….B as a linear transformation of the information blocks l_i, i = 1 ……. A.

The following equation has to be satisfied in order to recover the original information.

$z \geq [\log_2(A+B+1)] \geq \log_2(c+1)]$ ………………. (11)

The R bit packet is split into number of blocks according to the equation

$R \geq a \log_2(c+1) \equiv R_{min}$ ………………….. (12)

The optimal number of paths and the optimal allocation vector are determined by the optimization algorithm when the path probability vectors $\underline{S}$ and the overhead factor v. The optimization algorithm maximizes the Ds. The definition is given here.

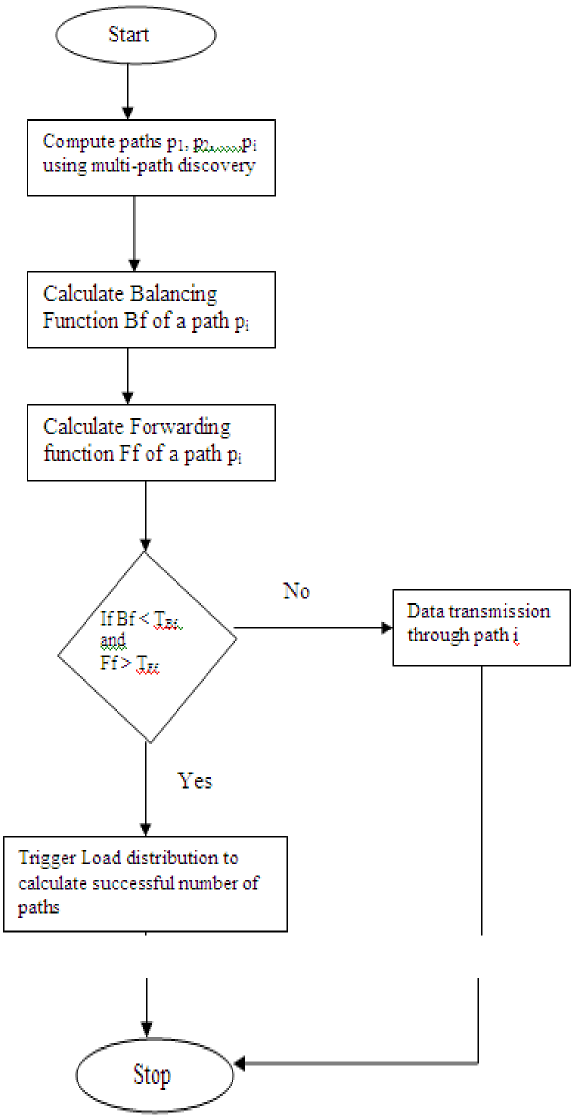
- $P\{z_i = b_i\} = S_i$
- $P\{z_i = 0\} = F_i$

It has been assumed that if a path fails, all the blocks sent over the path are lost. If at least A blocks reach the destination the original Q bit information packets are reconstructed. Therefore, we define Ds in terms of the number of paths that are actually used and the corresponding allocation vector.

$Ds(n,\underline{b}) = P\ \{ \sum_{i=1}^{n} b_i \geq \underline{c} / v\}$ ………….. (13)

Thus we calculate the successful number of paths which are used for data transmission.

The entire step involved in the protocol is depicted in the flowchart.



4. SIMULATION RESULTS

4.1 Simulation Model and Parameters

We use NS2 [16] to simulate our proposed protocol. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. Our simulation settings and parameters are summarized in table 1

Table: 1 Simulation parameters

No.of Nodes	25,50,75 and 100
Area Size	1000 X 1000
MAC	802.11
Radio Range	250m
Simulation Time	50s
Traffic Source	CBR
Packet Size	512
Mobility Model	Random Way Point
Speed	5 m/s
Pause Time	5 sec
Rate	250Kb to 1000Kb

4.2 Performance Metrics

We compare our Multi-path QoS Routing for Load Balancing (MQRLB) protocol with the AQRL [13] protocol. We evaluate mainly the performance according to the following metrics, by varying the nodes and rate.
Drop: It is the number of packets dropped during the data transmission.
Average end-to end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.
Average Packet Delivery Ratio: It is the ratio of the No. f packets received successfully and the total no. of packets sent.
Throughput: It is the total number of packets received by the receiver.
Bandwidth: It is the received bandwidth in Mb/s.

4.3 RESULTS

4.3.1. Varying No. Of Nodes

In the first experiment, we measure the performance of the protocols by varying the no. of nodes as 25, 50, 75 and 100.

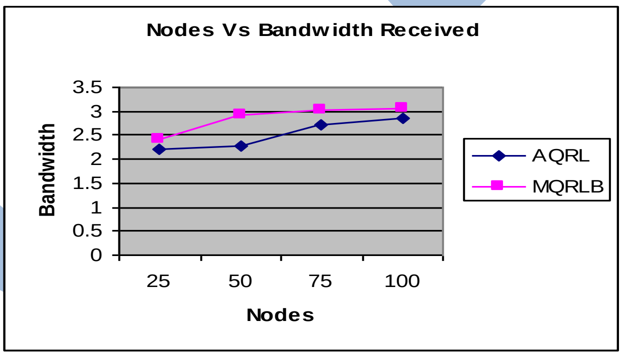


Fig 6: Nodes Vs Bandwidth Received

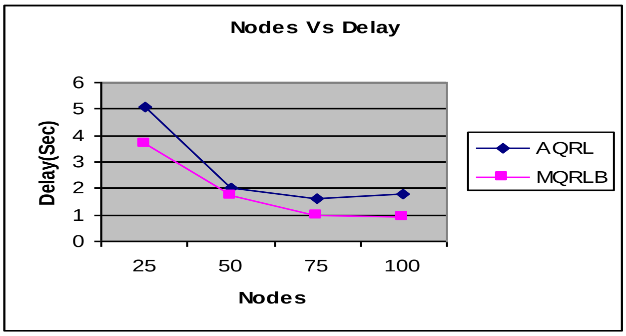


Fig 7: Nodes Vs Delay

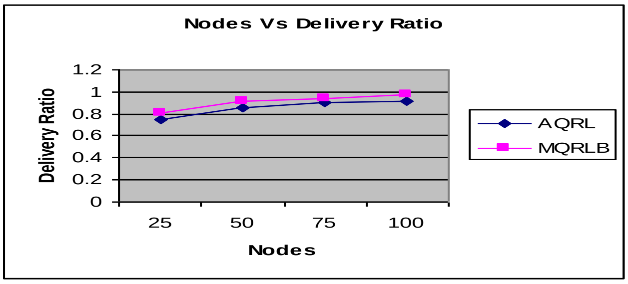


Fig 8: Nodes Vs Delivery Ratio

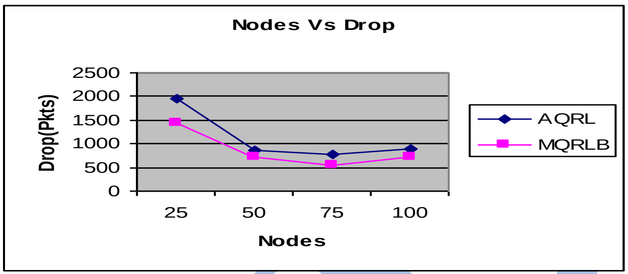


Fig 9: Nodes Vs Drop

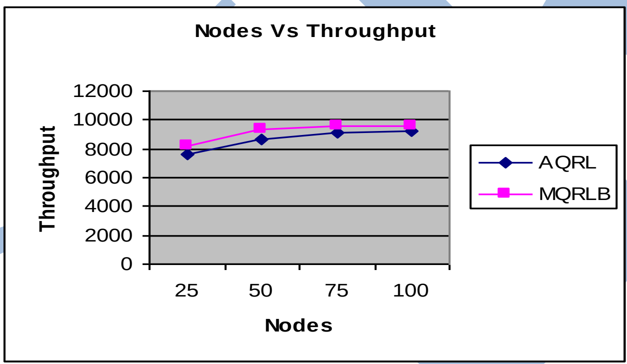


Fig 10: Nodes Vs Throughput

From fig.6 we can see that the received bandwidth for our proposed MQRLB is higher than the existing AQRL. From fig.7 we can see that the delay for our proposed MQRLB is less than the existing AQRL.
From fig.8 we can see that the Delivery Ratio of our proposed MQRLB is higher than the existing AQRL. From fig.9 we can see that the Drop of the proposed MQRLB is less than the existing AQRL.
From fig.10 we can see that the throughput of the proposed MQRLB is higher than the Existing AQRL.

4.3.2. Varying the Rate

In the second experiment, we measure the performance of the protocols by varying the rate as 250, 500, 750 and 1000Kb.

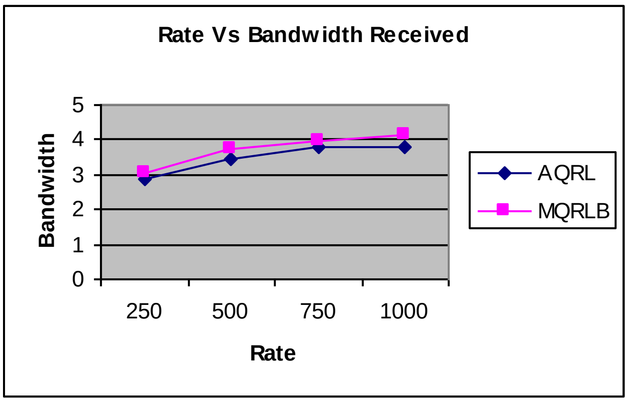


Fig 11: Rate Vs Bandwidth Received

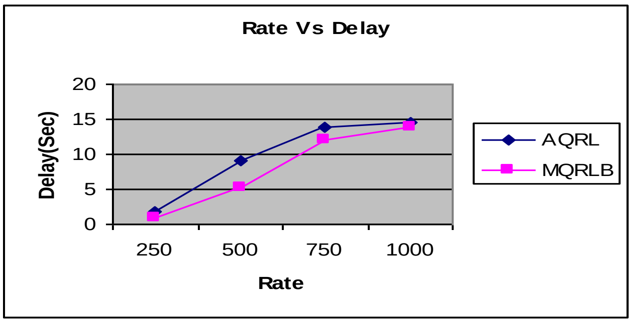


Fig 12: Rate Vs Delay

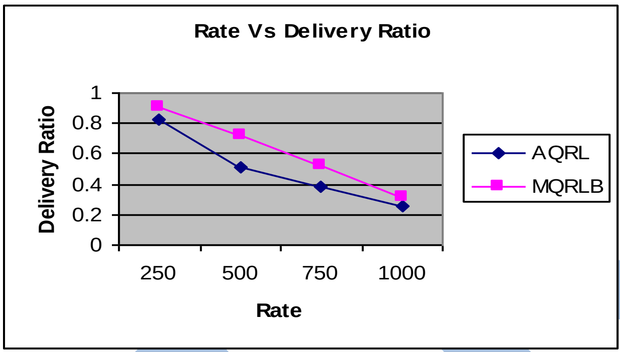


Fig 13: Rate Vs Delivery ratio

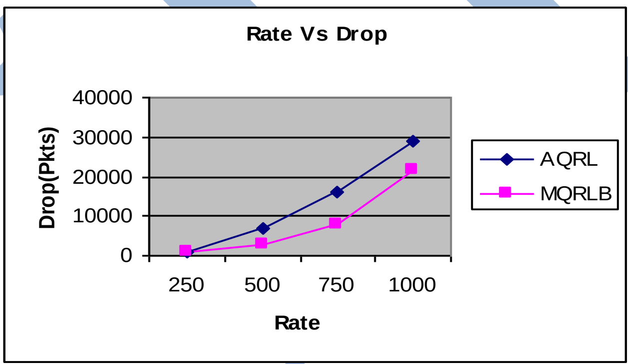


Fig 14: Rate Vs Drop

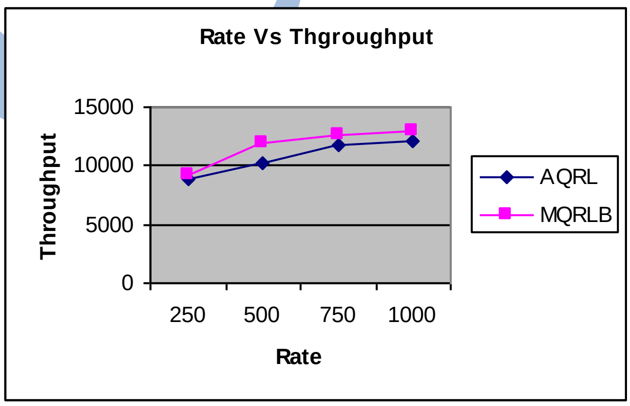


Fig 15: Rate Vs Throughput

From fig.11 we can see that the received bandwidth for our proposed MQRLB is higher than the existing AQRL.
From fig.12 we can see that the delay for our proposed MQRLB is less than the existing AQRL.
From fig.13 we can see that the Delivery Ratio of our proposed MQRLB is higher than the existing AQRL.
From fig.14 we can see that the Drop of the proposed MQRLB is less than the existing AQRL.
From fig.15 we can see that the throughput of the proposed MQRLB is higher than the Existing AQRL.

5. Conclusion

In this paper, we propose a multi-path routing for load balancing since it minimizes the maximum utilization while supporting the same traffic demands. Initially, a Route Discovery is initiated when the source node attempts to discover routes to the destination by flooding request packets (RREQs). The RREP are sent on the basis of first come first served basis. Upon receiving the RREPs, intermediate nodes extract the route path information and forward the RREPs according to the specified route. Then the balancing function and the forwarding function for each path is calculated. We consider a threshold value for the balancing function and the forwarding function and only if the threshold values are satisfied accordingly the load distribution is processed. Else the same path is used for data transmission. In the load distribution process, the success probability and the failure probability are calculated. Then an optimization algorithm is used for determining the successful number of paths for data transmission. Thus QoS routing can be processed through multiple successful paths using load balancing.

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