

# An Adaptive Rate Control based QoS Provisioning in Mobile Ad hoc Networks

S.Venkatasubramanian

Associate Professor, Computer Science Department,  
Saranathan college of Engineering,  
Trichy, India

**Abstract :** The Quality of Service in wireless Ad hoc network is the collective effect of service performance which determines the degree of satisfaction of a user of a service. QoS is achieved by the proper network traffic engineering such as traffic classes, connection admission control, using policy managers, etc., Prioritized flow control is a type of QoS provisioning in which each class is provided a different QoS by assigning priority to one class over another in terms of allocating resources. The objective is to achieve a desired level of service to high-priority flows so that the wireless medium is completely utilized using adaptive rate control. In this paper, we propose An Adaptive Rate Control based QoS Provisioning in Mobile Ad hoc Networks. Our 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.

**Keywords:** MANET, QOS, rate control, QoS routing.

## I. INTRODUCTION

A mobile ad hoc network includes a group of wireless nodes which develops a network without the deployment of existing network infrastructure. A node can communicate with the other nodes by multi-hop, when the nodes cooperate to forward packets with each other. In MANETs, the design of a Quality of Service (QoS) routing protocol is more difficult than the conventional networks because the host mobility can cause frequently unpredictable topology changes [1]. Since the last decade, MANETs are under the focus of the research community. It supports a variety of services by forming an infrastructure-less network immediately. Initially, MANETs are proposed for the emergency situations such as natural disasters, military conflicts, medical facilities etc but nowadays it is required to support the increasing demand for multimedia communications. Due to high rate requirements and severe delay constraints, maintaining real-time media traffics such as audio and video in presence of dynamic network topology is difficult [2].

### A. QoS Provisioning and Rate Control in MANETs

QoS provisioning in MANETs have attracted many studies by the potential commercial applications of MANETs. The existing QoS solutions for wired networks cannot be applied to mobile ad hoc networks without being adapted. There are two solutions for QoS provisioning on the Internet such as [3]: Integrated Services (IntServ) Differentiated Services (DiffServ). The objective of the Integrated Services (Intserv) is to provide applications with a guaranteed share of bandwidth. The requested QoS for a flow is either fully granted or rejected because the Intserv operates on a per-flow basis. DiffServ is a lightweight model and it is significantly proposed for the interior (core network) routers because the individual state flows are aggregated into a set of flows. It is not necessary to maintain the flow states within the core of the network because the service differentiation depends upon the per hop behaviors

Generally, the existing solutions for QoS provisioning in MANETs can be classified into two categories [3]:

- **Stateful Approach:** These approaches are based on resource reservation. Eg: INSIGNIA [13].
- **Stateless Approach:** These approaches do not rely on resource reservation, and try to provide a certain degree of service differentiation. Eg: SWAN [14].

### B. Priority of Traffic

Generally in QoS provisioning, the bandwidth is allocated first to the higher priority traffic in preference and then allocated to the lower priority traffic. The lower priority traffic can utilize the bandwidth only after the utilization of the higher priority traffic. If a high priority flow's traffic pattern satisfies the behavior described in the service agreement, its packets should be delivered in preference to other packets with lower priorities. On the other hand, flows with lower priorities should use as much bandwidth as possible after the transmission requirements of higher priority flows have been satisfied [6].

### C. Rate Control in MANET

Since the available bandwidth of the wireless channel is variable and unpredictable, rate control becomes more

complicated in MANETs than in the wired networks. When a source-based admission control mechanism uses rate measurements from aggregated real-time traffic as feedback, a rate control mechanism uses the per-hop MAC delay measurements from packet transmissions as feedback [4].

The rate control of TCP and UDP best effort traffic is performed locally at every mobile node in a fully distributed and decentralized manner to make sure that the bandwidth and delay requirements of real-time UDP traffic are met. In order to restrict the best effort traffic to produce the essential bandwidth required for supporting real time traffic, rate control is designed. It can also be used to allow the best effort traffic to efficiently utilize the bandwidth which is not currently utilized by the real-time traffic at any particular moment. In order to reduce the excessive delays, the total rate of all best effort and real-time traffic transported over each load shared media channel is maintained below a particular threshold rate [4].

#### D. QoS Provisioning Challenges in MANETs

Due to several problems, QoS provisioning in MANETs is much complicated when compared to wired networks. The following are some of the main QoS provisioning and maintenance problems in MANETs.

- ✓ It requires knowledge of the available bandwidth, which is difficult to be accurately estimated in a dynamic environment.
- ✓ Bandwidth reservation has to be made through negotiation between neighbors within two to three hops other than only the direct neighbors sharing the same channel, and this needs signaling message exchanges between them. Moreover, when the neighbor moves out of the reservation area of the node, the reserved bandwidth in a neighbor should be released through some mechanism. Hence, an extra control overhead will be introduced by these signaling messages and consumes limited bandwidth and energy.
- ✓ The reserved bandwidth over the entire duration of an active session cannot be guaranteed. Some of the reserved bandwidth might be stolen by the oncoming node, if a communicating node moves towards a node which has reserved some bandwidth for flow(s). The reserved bandwidth over the link between them might be unavailable or the link might be broken, if two nodes on the end of a link move away from each other.
- ✓ In MANETs, due to the dynamic topology, there is no clear definition of what is core, ingress or egress router. Since all the nodes in the network cooperate to provide services, there is no clear definition of a

Service Level Agreement (SLA). On the other hand, an infrastructured network where the services to the users in the network are provisioned by one or more service providers [3].

- ✓ Since the wireless bandwidth and capacity in MANETs are affected by interference, noise and multi-path fading, it is limited and the channel is not reliable. Moreover, the available bandwidth at a node cannot be estimated exactly because it involves in a large variations based on the mobility of the node and other wireless device transmitting in the vicinity etc [5].

In this paper, we propose to design a QoS architecture for resource provisioning and rate control of various traffic classes.

## II. RELATED WORK

R. Gunasekaran et al [7] have proposed a model called High-Privileged and Low-Privileged Architecture (HPLP) for the forthcoming Ad Hoc networks where the differentiated services can be achieved for different classes of users. They have considered only the bandwidth reservation among the various factors influencing the differentiated services and identified the different factors that can influence the efficiency of the bandwidth reservation. Claude Chaudet et al, [8] have proposed a distributed algorithm to allocate bandwidth to each mobile according to the topology of the network and the available bandwidth on each mobile for stable ad hoc networks. Their algorithm guarantees a non null minimum bandwidth to each mobile. With their algorithm, each mobile computes its bandwidth usage in order to avoid saturating its capacity or its neighbors and congestion is less likely to appear in the network.

M. Mirhakkak et al [9] have developed a prototype implementation of resource reservation, running as an extension to the Reservation Setup Protocol (RSVP) protocol. Their approach is to expand the semantics of the reservation, so that, instead of being a single value indicating the level of service needed by an application, it becomes a range of service levels in which the application can operate, together with the current reserved value within that range. Kumar Manoj et al [10] have proposed a bandwidth control management (BWCM) model to improve the QoS performance by minimized end-to-end delay. In addition to end-to-end delay, they have proposed an algorithm for end-to-end bandwidth calculation and allocation. They have considered different QoS traffic flows in the network to evaluate the performance of their proposed algorithm of BWCM model. Their algorithm includes a set of mechanisms: control management, co-ordination temporary resource reservation process.

Belkadi Malika et al [11] have proposed a new solution combining QoS (Quality of Service) routing protocol and flow control mechanism. This QoS routing protocol selects the routes with more resources in an intelligent manner rather than diffusion. It returns the best route offering a higher transmission rate, a less delay and a more stability. Their protocol uses a new metric to compute the most stable route. To reinforce the congestion avoidance, they have added a flow control mechanism to adjust the sender's transmission rate for each route.

Marek Hejmo et al [12] have proposed a distributed QoS signaling protocol which is an extension to the SWAN protocol. Their proposed DoS-resistant QoS (DRQoS) signaling scheme employs distributed rate control to manage the bandwidth resources of the network, but does not rely on the maintenance of per-flow state. Their signaling protocol provides QoS for real-time traffic and employs mechanisms at the medium access control (MAC) layer, which serve to avoid potential attacks on network resource usage. Their proposed signaling scheme achieves a compromise between signaling protocols that require the maintenance of per-flow state and those that are completely stateless.

### III. PROPOSED QOS ARCHITECTURE

#### A. Overview of the Architecture

In this paper, we propose to design a QoS architecture which has four basic components:

- Adaptive Bandwidth Management
- Routing
- Call Admission Control
- Rate Control.

The adaptive bandwidth management measures the available bandwidth at each node in real-time. This bandwidth information is then propagated proactively or retrieved on demand by the scalable QoS routing. The source nodes in the DiffServ model perform call admission control for real-time flows based on the bandwidth information provided by the QoS routing. The congestion control part is unique to mobile ad hoc networks. In a MANET, even though admission control is performed to guarantee enough available bandwidth before accepting any real-time flow, the network can still experience congestion due to mobility or connectivity changes. Thus, the fourth component, congestion control, is extremely important to our QoS architecture. It monitors the network bandwidth utilization continuously and detects network congestion in advance with the help of the adaptive bandwidth management component. A rate control is then used to regulate best-effort traffic and ensure that best-effort traffic coexist well with real-time traffic.

#### B. Adaptive Bandwidth Management

In our QoS architecture, each node will continuously estimate its available bandwidth. The bandwidth information will then be used for QoS capable routing protocols to provide support to admission control.

We compute the available bandwidth based on the channel status of the radio to determine the busy and idle periods of the share wireless media. By examining the channel usage of a node, we are able to take into account the activities of both the node itself and its surrounding neighbors and therefore obtain a good approximation of the bandwidth usage. The channel utilization ratio is defined as the fraction of time within which a node is sensing the channel as being utilized. An 802.11 wireless radio has four states:

1. Busy state (transmitting or receiving packets)
2. Carrier sensing channel busy (some other nodes within its neighborhood are transmitting packets)
3. Virtual carrier sensing busy (deferral to RTS or CTS packets)
4. Idle state (not in any of the above states).

Among the four states, the first three states can be treated as busy state and the fourth state as the idle state. Each node will constantly monitor the channel state changes (from busy to idle or from idle to busy) and record the time period that the radio is in each state.

For each time period  $T$ , we then calculate the channel utilization ratio  $CH_{util}$  as

$$CH_{util} = \frac{\text{channel-busy-period}}{T} \quad (1)$$

To smooth the channel utilization estimation, we define a smoothing constant  $\delta \in [0,1]$ . Suppose the last channel utilization ratio is  $CH_{util}(t-1)$  and the channel utilization ratio measured in the current sampling time window is  $CH_{util}$ . Then, the current channel utilization ratio is given as  $CH_{util}(t) = \delta CH_{util}(t-1) + (1-\delta) CH_{util}$ . The channel utilization ratio  $CH_{util}(t)$  is bounded between 0 and 1. After correctly estimating the channel utilization at time  $t$ , we then are able to calculate the available bandwidth of a node at time  $t$  as

$$ABW_t = CH_{BW}(1 - CH_{util}(t)). \quad (2)$$

Here,  $CH_{BW}$  is the raw channel bandwidth.

#### C. Bandwidth Reservation

In our scheme, we use a soft bandwidth reservation where each node in the network will periodically calculate its own available bandwidth, based on the bandwidth measurement technique discussed in the previous subsection. The available bandwidth calculation will be used by our call admission control component to determine if flows can be admitted for a particular service class. Once a flow is admitted and starts

sending data traffic, the bandwidth resource occupied by the flow will be automatically taken into consideration during the periodic available bandwidth measurement intervals. Therefore, resource reservation is done implicitly without the need to keep track of per flow information; only per class information is needed.

#### D. Routing

We use our previously designed QOS based multipath routing protocol intended for mobile ad hoc networks [15]. Enabling a QoS constrained route from source to destination is the objective of this routing protocol.

A QoS-based routing metric for MANETs should incorporate minimum available bandwidth and end-to-end latency along with congestion around a link. Congestion is related to channel quality, which depends on the MAC access contention and channel reliability. So our algorithm should rely on the following metrics to allocate weights to individual links.

- End-to-End Delay
- Channel Quality
- Link Quality

We now introduce the weight metric  $W$  which assigns a cost to each link in the network. The weight  $W$  combines the link quality  $L_q$ , channel quality  $C_{occ}$  and the average delay  $D_{avg}$ , to select maximum throughput paths, avoiding the most congested links.

For an intermediate node  $i$  with established transmission with several of its neighbors, the  $W$  for the link from node  $i$  to a particular neighboring node is given by

$$W = Lq / (C_{occ} + D_{avg}) \quad (3)$$

During the route discovery phase of the protocol, each intermediate node uses an admission control scheme to check whether the flow can be accepted or not. If accepted, a Flow Table (FT) entry for that particular flow is created. The FT contains the fields Source (Src), Destination (Dst), Reserved Bandwidth (BWres), Minimum bandwidth (BWmin). Each node collects the bandwidth reserved at its one hop neighbors (piggybacked on periodic HELLO packets) and stores it in its Neighbor Table (NT). The Neighbor Table contains fields Destination (Dst), Reserved Bandwidth (BWres), No. of Hello Packets (No Hello).

Let us consider the route

S -- R1 -- R2 -- R3 -- D

To initiate QoS-aware routing discovery, the source host S sends a RREQ. When the intermediate host R1 receives the RREQ packet, it first estimates all the metrics as described in the previous section.

The host R1 then calculates its weight  $W_{R1}$  using (3).

$$\text{RREQ}_{R1} \xrightarrow{W_{R1}} R2$$

R2 then calculates its weight  $W_{R2}$  in the same way and adds it to the weight of R1. R2 then forward the RREQ packet with this added weight.

$$\text{RREQ}_{R2} \xrightarrow{W_{R1+} W_{R2}} R3$$

Finally the RREQ reaches the destination node D with the sum of node weights

$$\text{RREQ}_{R3} \xrightarrow{W_{R1+} W_{R2+} W_{R3}} D$$

The Destination node D sends the route reply packet RREP along with the total node weight to the immediate upstream node R3.

$$\text{RREP} \xrightarrow{W_{R1+} W_{R2+} W_{R3}} R3$$

Now R3 calculates its cost C based on the information from RREP as

$$C_{R3} = (W_{R1+} W_{R2+} W_{R3}) - (W_{R1+} W_{R2}) \quad (4)$$

By proceeding in the same way, all the intermediate hosts calculate its cost.

On receiving the RREP from all the routes, the source selects the route with minimum cost value.

#### E. Call Admission Control

With the support from the above described QoS routing, the source node can then decide whether to admit a new real-time flow. This is usually referred to as call admission control (CAC). When a new request with certain bandwidth requirement comes, the source will perform admission control following the procedure described below.

- The source node first consults the local routing table. If the destination is within the local scope and the available bandwidth is enough, then the flow is accepted. If the destination is within scope, but bandwidth is not enough, then, reject the flow.
- If the destination is not within the local scope, the source node then consults the landmark routing table. It first examines whether it has enough bandwidth to

the corresponding landmark node of the destination. If not enough, the flow is rejected.

- If bandwidth to the landmark node is enough, the source node then has to further check the minimal and maximal bandwidth propagated by that landmark. If the requested bandwidth is smaller than  $BW_{min}$ , the flow can be admitted. If the requested bandwidth is larger than  $BW_{max}$ , the flow is rejected.
- If, however, the requested bandwidth falls between  $BW_{min}$  and  $BW_{max}$ , the bandwidth information in the landmark routing table is not enough to make an admission decision. A probing packet is then sent by the source node to the corresponding landmark to collect the exact available bandwidth to the destination node. After getting the reply back, if the available bandwidth can meet the requirement, then accept the flow. Otherwise, the flow is rejected.

#### F. Adaptive Rate Control

The Consumed Bandwidth usually increases, as the Network Load increases. When the network load reaches a certain level, the bandwidth does not increase any more. We call the bandwidth at this stage as *Critical Bandwidth*.

Channel busy ratio (ChBR) is the channel busyness ratio which represents the interference level. It is defined as the ratio of time intervals when the channel is busy due to successful transmission or collision to the total time [16].

We use the current Channel Busy ratio (ChBR), and channel utilization ( $CH_{util}$ ) to estimate Critical Bandwidth (CB).

$$CB = CChBR * CH_{util} / ChBR \quad (5)$$

Where, CChBR is the Critical Channel Busy Ratio.

Predicted rate  $\mu$  is given by the difference between Critical Bandwidth CB and Data Receiving Rate ( $D_R$ ).

$$\mu = CB - D_R \quad (6)$$

For rate control, we use the well-known additive increase multiplicative decrease (AIMD) rate control mechanism. The difference between the conventional AIMD and our technique is that the initial value of predicted Rate  $\mu$  is estimated using (6).

Let the Data Sending Rate be DS, Packet Delay be PD and the threshold be Th,

While  $DS = \mu$  and  $PD \leq Th$

$\mu = \mu + f$ , where f is the increment factor.

$CChBR = ChBR$

End While

Update the value of CB with CChBR using (5)

In this manner, the Adaptive Rate Controller has the ability of updating the previous critical bandwidth for  $\mu$  estimations, and adapting itself according to network state.

## IV. SIMULATION RESULTS

### A.. Simulation Model and Parameters

The Network Simulator (NS2) [17], is used to simulate the proposed architecture. The simulation settings and parameters are summarized in table

<i>B.</i>	No. of Nodes	50
	Area Size	1000 X 1000
	Mac	802.11
	Radio Range	250m
	Simulation Time	100 sec
	Traffic Source	CBR
	Packet Size	512
	Speed	10m/s
	Flows	2,4,6,8 and 10
	Rate	0.5,1.0,1.5 and 2Mb

### Performance Metrics

The proposed QoS Architecture for Resource Provisioning and Rate Control (ARCQP) is compared with the that of the scheme without applying Rate control. The performance is evaluated mainly, according to the following metrics.

- i. **Average End-to-End delay:** The end-to-end delay is averaged over all surviving data packets from the sources to the destinations.
- ii. **Aggregated Throughput:** We measure aggregated throughput in terms of no. of packets received.
- iii. **Fairness:** For each CBR flow, we measure the fairness as the ratio of throughput of each flow and total no. of flows.
- iv. **Packet Loss:** We measure the packet loss, which is the no. of packets lost per unit time.

### C. Results

#### 1). Effect of Varying Rate

In the first experiment, the transmission rate is varied as 0.5, 1.0, 1.5 and 2Mb and the above metrics are measured.

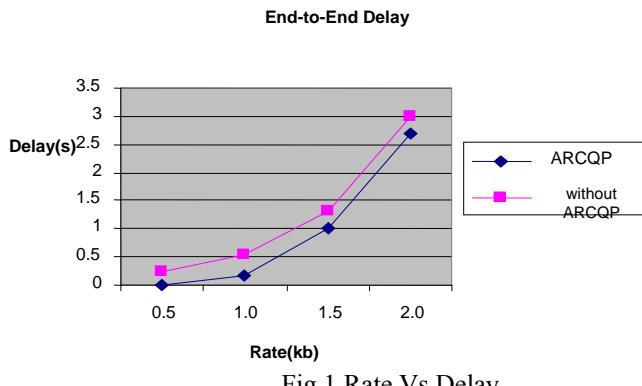


Fig.1 Rate Vs Delay

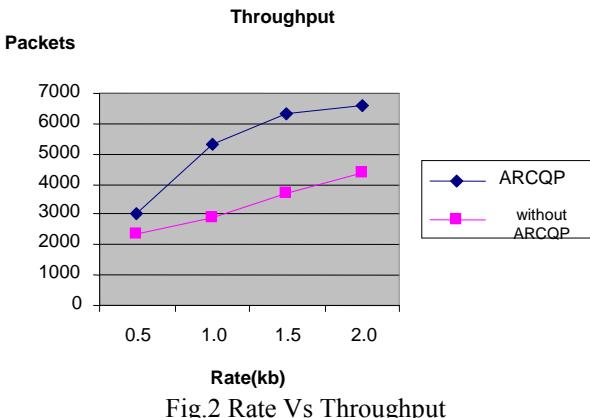


Fig.2 Rate Vs Throughput

Fig. 4 presents the packets loss for both the schemes. Because of QoS routing and rate control policies, ARCQP has less packet loss than DRQoS. Fig.5 shows the blocking probability when the rate is increased. From the figure it is clear that ARCQP attains less blocking probability than the DRQoS, since it has the effective call admission control mechanism.

## 2). Effect of Varying Flows

In the second experiment, we vary the number of data flows as 2,4,6,8 and 10.

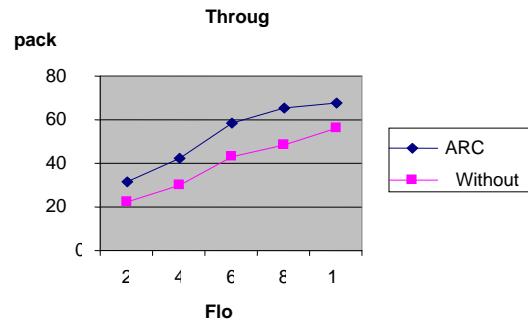


Fig.4 Flow Vs Throughput

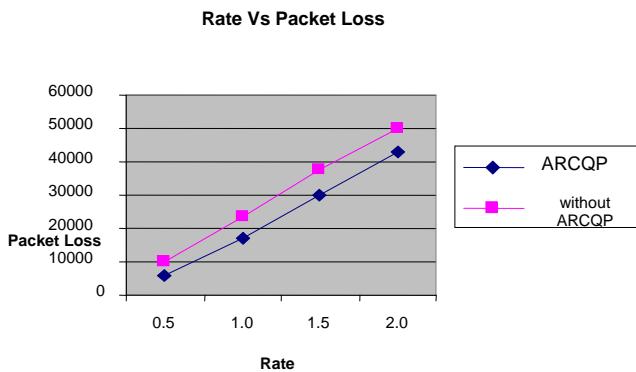


Fig.3 Rate Vs Packets Loss

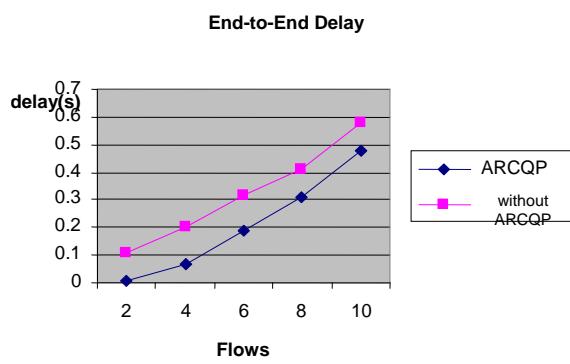


Fig.5 Delay vs. Flows

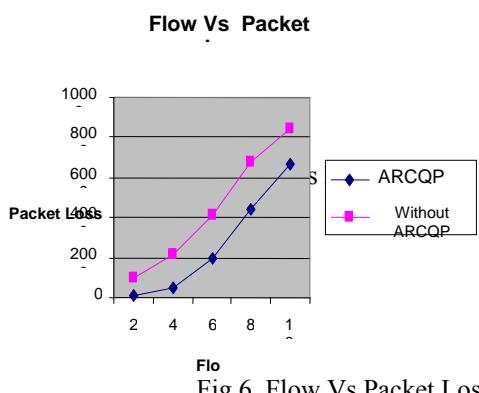


Fig.6 Flow Vs Packet Loss

Fig 1 shows the end-to-end delay values when the rate is increased. It is clear that ARCQP has less delay when compared to DRQoS, since it has the QoS routing protocol which selects best path.

Fig 2 and 3 show the result of throughput and fairness when the rate is increased. From the figures, it can be seen that the throughput and fairness are more in the case of ARCQP scheme than DRQoS, because of the adaptive bandwidth management and rate control schemes of OARCQP.

When the flows are increased, the cumulative delay is increased. Fig. 6 shows the end-to-end delay values when the flow is increased. It is clear that ARCQP has less delay when compared to DRQoS, since it has the QoS routing protocol which selects best path.

Fig. 7 and 8 show the result of throughput and fairness when the flows are increased. From the figures, it can be seen that the throughput and fairness are more in the case of ARCQP scheme outperforming non-ARCQP, because of the adaptive bandwidth management and rate control schemes of OARCQP.

Fig. 9 presents the packets loss for both the schemes. Because of the QoS routing and rate control policies, ARCQP has less packet loss than DRQoS.

When the flows are increased, the resulting blocking probability is also increased. Fig.10 shows the blocking probability when the flow is increased. From the figure it is clear that ARCQP attains less blocking probability than the DRQoS, since it has the effective call admission control mechanism.

## 5. CONCLUSION

In this paper, we propose to design QoS architecture for Bandwidth Management and Rate Control in MANETs. In our QoS architecture, each node will continuously estimate its available bandwidth. The bandwidth information will then be used for QoS capable routing protocols to provide support to admission control. For this, we have used our previous Robust Multipath Routing (QRMR) protocol. It allocates weights to individual links on the basis of the metrics link quality, channel quality and end-to-end delay. 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. The source nodes then perform call admission control for different priority of flows based on the bandwidth information provided by the QoS routing. In addition to this, a rate control mechanism is used to regulate best-effort traffic, whenever network congestion is detected. In this mechanism, the packet generation rate of the low-priority traffic is adjusted to incorporate the high-priority traffic.

## REFERENCES

- [1]. Yuh-Shyan Chen, Shin-Jr Jan and Ming-Chin Chuang, "A Shoelace-Based QoS Routing Protocol for Mobile Ad Hoc Networks Using Directional Antenna", Wireless Personal Communications, SpringerLink, 2009.
- [2]. A.N. Al-Khwildi, S. Khan, K.K. Loo and H.S. Al-Raweshidy, "Adaptive Link-Weight Routing Protocol using Cross-Layer Communication for MANET", WSEAS Transactions on Communications, 2007.
- [3]. Bosheng Zhou, Alan Marshall and Tsung-Han Lee, "A Cross-Layer Architecture for DiffServ in Mobile Ad-hoc Networks", International Conference on Wireless Networks, Communications and Mobile Computing, WIRELESSCOM 2005
- [4]. Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres and Li-Hsiang Sun, "Supporting Service Differentiation for Real-Time and Best-Effort Traffic in Stateless Wireless Ad Hoc Networks (SWAN)", IEEE Transactions on Mobile Computing, 2002.
- [5]. Shivanajay Marwaha, Jadwiga Indulska and Marius Portmann, "Challenges and Recent Advances in QoS Provisioning, Signaling, Routing and MAC protocols for MANETs", Australasian Telecommunication Networks and Applications Conference, 2008.
- [6]. Xue Yang and Nitin H.Vaidya, "Priority Scheduling in Wireless Ad Hoc Networks", Proceedings of the 3rd ACM international symposium on Mobile ad hoc networking & computing, 2002.
- [7]. R. Gunasekaran and V. Rhymend Uthariaraj, "Differentiated Bandwidth Allocation in Mobile Ad Hoc Networks (MANET) – A Profile Based Approach", Asian Journal of Information Technology, 2007.
- [8]. Claude Chaudet —Isabelle Guerin Lassous and Janez Zerovnik, "A Distributed Algorithm for Bandwidth Allocation in Stable Ad Hoc Networks", International Conference on Wireless On-Demand Network Systems, WONS 2004.
- [9]. M. Mirhakkak, N. Schult and D. Thomson, "A New Approach for Providing Quality-Of-Service In A Dynamic Network Environment", In the IEEE Proceedings of 21st Century Military Communications Conference, MILCOM 2000.
- [10]. Kumar Manoj, S. C. Sharma and S.P. Singh, "Dynamic Behavior of Bandwidth Control Management in Mobile Ad-Hoc Network", Proceedings of the World Congress on Engineering and Computer Science 2009.
- [11]. Belkadi Malika, Lalam Mustapha, M'zoughi Abdelaziz, Tamani Nordine, Daoui Mehammed and Aoudjit Rachida, "Intelligent Routing and Flow Control In MANETs", Journal of Computing and Information Technology, 2010.
- [12]. Marek Hejmo, Brian L. Mark, Charikleia Zouridakis and Roshan K. Thomas, "Design and Analysis of a Denial-of-Service-Resistant Quality-of-Service Signaling Protocol for MANETs", IEEE Transactions on Vehicular Technology, 2006.
- [13]. Seoung-Bum Lee, Gahng-Seop Ahn, Xiaowei Zhang, and Andrew T. Campbell, "INSIGNIA: An IP-Based Quality of Service Framework for Mobile ad Hoc Networks", Journal of Parallel and Distributed Computing, 2000.
- [14]. Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres and Li-Hsiang Sun, "SWAN: Service Differentiation in Stateless Wireless Ad Hoc Networks", In the Proceedings of the 21st Annual Joint Conference of the IEEE Computer and Communications Societies, INFOCOM 2002.
- [15]. S.Venkatasubramanian and N.P.Gopalan, "QOS based Robust multipath routing protocol for mobile adhoc networks", IACSIT International Journal of Engineering and Technology Vol.1, No.5, December, 2009
- [16]. K. Saravanan, and T. Ravichandran "A Cross-Layer Based High Throughput MAC Protocol for 802.11 Multi-hop Adhoc Networks" European Journal of Scientific Research 2009.
- [17]. Network Simulator: [www.isi.edu/nsnam/ns](http://www.isi.edu/nsnam/ns)