Asian Journal of Information Technology 15 (15): 2594-2601, 2016
ISSN: 1682-3915

Bandwidth and Delay Aware QoS Provisioning and Admission Control in MANET

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Abstract: In the study, we propose to develop a bandwidth and delay aware QoS provisioning and admission control in MANET. At first as a route repair mechanism Flow Aware Admission Control with Multiple Constraints (FAAC-MM) is used to enable intermediate node to carry out route repair locally without contacting the source node. This protocol maintains two routing paths for satisfying delay and throughput requirements. Here, if primary route fails due to either nodes mobility or congestion then the secondary route is selected as a primary route for data transmission. For backup route selection, apart from path bandwidth, the route delay and contention Difference are considered. Finally, for the slot allocation of each link in TDMA process for transmission we are using the Band Width Calculation-Forward Algorithm (BWC-FA) in admission control mechanism. Here, the best path is selected based upon the Path Bandwidth (PB) of each link.

Key words: Bandwidth, admission control, MANET with multiple, TDMA, PB

INTRODUCTION

MANET: Mobile ad hoc network consists of wireless mobile nodes that can communicate with other nodes through wireless links without any fixed infrastructure. MANET is a system of wireless mobile nodes that self-organizes itself in dynamic and temporary network topologies. MANETs are characterized by self-configured, dynamic changes of network topology, limited bandwidth, instability of link capacity and other resource constraints (Sridhar *et al*., 2013). The interest in MANETs was driven mainly by their ability to provide instant wireless networking solutions in situations where cellular infrastructures do not exist and are expensive or unfeasible to deploy such as: disaster relief efforts, battlefields and highway roads communications (Fahmy *et al*., 2010).

The nodes involved in this system should collaborate among themselves and can function as both hosts and routers. They work together only based on the mutual agreement without knowing about the network topology around them. Hence, maintenance of Quality of Service (QoS) in MANETs is a complex task due to the dynamic behaviour of the network topology.

Qos provisioning in MANET: Quality of Service (QoS) routing relies on selecting network paths that have sufficient resources to satisfy the QoS requirements of all admitted connections and achieving global efficiency in resource utilization. The QoS constraints that need to be met delay, bit error rate, bandwidth, route length, etc., along with MANET specific requirements like energy, route stability and route reliability (Rishiwal *et al*., 2009).

QoS provisioning in MANETs is importance in order to support real-time communications (such as audio and video) over MANETs. However, with the appearance of real-time communication such as voice over internet protocol and video streaming, e.g., video on demand, strict QoS requirements have been put on the Internet in terms of delay, jitter and throughput (Marwaha *et al*., 2008). There are two types of QoS provisioning models in the internet.

Integrated services (Intserv): The objective of the integrated services 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 which maintains per-flow reservation state at QoS network entities has a greater level of accuracy and a finer level of granularity.

Differentiated services (Diffserv): 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 flow. It is not necessary to maintain the flow states within the core of the network because the service differentiation depends upon the per hop behaviours (Venkatasubramanian, 2011; Marwaha *et al*., 2008).

But the QoS provisioning in MANET has some challenges due to the absence of a central point of organization resulting in complicated routing mechanisms

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and also a higher overhead (Fahmy *et al*., 2010) the mobility of nodes which causes the network topology to be changed dynamically and the shared wireless medium (Akhter and Sanguankotchakorn, 2010; Sanguankotchakorn and Maharjan, 2011).

Problem identification and solution: The study (Canales *et al*., 2009) is used to evaluate an adaptive cross layer architecture based cooperation between a QoS routing and MAC level. In BCH mode once an access is successful, the scheme slot also reserved only once so it no longer accessed also more possible to provide contention. Also, in point to point transmission, broadcast reservation are still reliable but not efficient to solve the exposed terminal. Due to preemption of terminal allocation high priority despite the lower priority one. If the bandwidth of each slot in a node is insufficient this will drop route request packet, so, more possible to loss weighted and shortest path for transmission. Also, if more than one neighbours transmit a same slot a collision will occur but here transmission one hop away are not sensed.

Literature review: Ghosh *et al*. (2010) have proposed to describe a communication middleware system of QoS-aware Adaptive Middleware (QAM) that shields distributed application developers from the complexities of tactical MANET. QAM resolves the problem of bandwidth contention between multi-priority applications by providing an adaptive, priority aware, middleware layer that acts as an intermediary between an application and the network protocols. QAM adapts to current network conditions by providing a reliable data transfer mechanism that is capable of adapting data transfer rates in response to changing network conditions. The adaptations performed by QAM attempt to limit the use of network bandwidth by applications when network bandwidth is diminished.

Miao *et al*. (2012) have proposed an optimal resource allocation algorithm for multi-access in heterogeneous networks which supports mixed uplink service traffic. This algorithm was distinguished these services traffic into two classes: Delay-Constraint (DC) and Best-Effort (BE). Also the paper formulated a mathematical optimal model to support heterogeneous service requirements in multi-radio access scenario. Then, it achieved the goal of maximizing the total system throughput in heterogeneous networks which efficiently satisfying the QoS requirement for DC services traffic and fairness for BE services traffic. However, each level of channel per MMT may differ from one another also which increased the computational complexity.

Zafar *et al*. (2011) have proposed a new capacity-constrained QoS-aware routing scheme. This scheme is to estimate residual capacity in IEEE 802.11-based ad hoc networks. This residual capacity estimation technique has less dependence on the window size. The scheme proposed the use of a ‘forgiveness’ factor to weight these previous measurements to provide appropriate utilizations estimation and improved available capacity based admission control. However, if the bottleneck capacity increases through the path selection, the route will be break.

Asif *et al*. (2011) have presented a paper for an extension of FAAC protocol to improve the provisioning of multiple QoS metrics in many mobile scenarios. The designed FAAC-Multipath protocol with multiple constraints (FAAC-MM) is equipped with the intermediate route repair mechanism to enable the intermediate node to carry out route repair locally without contacting the source node. With an effective QoS violation detection and route maintenance mechanism, the protocol reduces the frequency of route discovery thus leading to a significant reduction in QoS disruption. The protocol have illustrated the effectiveness of FAAC-MM with the state of the art admission control protocols. But if the route is failed, it select another backup path on successful transmission of testing path. If the backup path does not satisfy the disjoint condition, then it drops all multipath packets.

Canales *et al*. (2009) have proposed an adaptive admission procedure based cross-layer QoS routing supported by an efficient end-to-end available bandwidth estimation. This article allowed to perform a distributed admission procedure with a flexible reallocation that responds to the different grades of mobility of the environment, triggering accordingly the appropriate configuration mode. The proposed scheme has been designed to perform a flexible parameters configuration that allows to adapt the system response to the observed grade of mobility in the environment.

Calafate *et al*. (2009) have proposed a novel QoS architecture that is able to support applications with the bandwidth, delay and jitter requirements in MANET environments. The proposed architecture is modular, allowing the plugging in of different protocols which offers great flexibility. The proposed optimizations based on interactions between the Media Access Control (MAC), routing and admission control layers which offer important performance improvements. This will validate the proposal in scenarios where different network loads, node mobility degrees and routing algorithms are tested in order to quantify the benefits offered by QoS proposal.

MATERIALS AND METHODS

Proposed solution

Overview: In this study, we propose to develop a Bandwidth and Delay aware QoS Provisioning and Admission Control in MANET. The Band Width

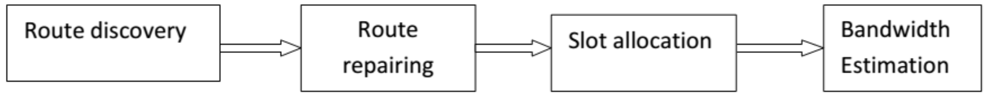

Fig. 1: Block diagram

Calculation-Forward Algorithm (BWC-FA) (Canales *et al*., 2009) in admission control mechanism is used to calculate slot allocation of each link in TDMA process for transmission. Also the best path selected depends upon the Path Bandwidth (PB) of each link.

A Flow Aware Admission Control Multipath Protocol with Multiple Constraints (FAAC-MM) (Asif *et al*., 2011) is used to enable the intermediate node and route repair mechanism. This protocol maintains two routing paths for satisfying delay and throughput requirements. Initially multiple paths are established using AOMDV routing protocol. The primary path is selected based on the path bandwidth (Canales *et al*., 2009) and delay metrics. Secondary route is selected as a backup path for the data session. Here, if primary route fails due to either nodes mobility or congestion then the secondary route is selected as a primary route for data transmission. For backup route selection, apart from path bandwidth, the route delay and contention difference are considered (Fig. 1).

FAAC-MM protocol: Here the source node is designed to maintain more than a single path to each destination with the reliability of the routes maintained through nodes disjointness. Flow-Aware Admission Control Multipath (FAAC-MM) protocol is equipped with the intermediate route repair mechanism to enable intermediate node to carry out route repair locally without contacting the source node. The process of FAAC-MM is described as follows. Route discovery (Asif *et al*., 2011):

- Initially the application agent indicates the conditions of the data session in the form of Session Request (SReq) packet and then passes on this SReq packet from application layer to the network layer
- The source node stores this information and examines its local capacity against the requested requirement of the data session
- The source node initiates and propagates Route Request (RReq) on satisfying the conditions as well as it rejects the data session admission
- The RReq propagate till the destination and destination replies with Route Reply (RRep) to all routes found between source and destination
- Initially multiple paths (Asif *et al*., 2011) are established using AOMDV routing protocol. The protocol selects two routes for each data session all the time which satisfies the throughput and delay requirements. One of the routes with adequate capacity and less delay is selected as primary and the other one is selected as secondary route
- While the primary route is selected for data transmission, a secondary route is selected as a backup path for the data session. If primary route fails due to either mobility or congestion then it is removed from the route cache and secondary route is selected for data transmission

Primary route selection: The primary route is selected based on the Path Bandwidth (PB) (Canales *et al*., 2009) and the delay metrics. Here the route with adequate capacity and less delay of data transmission is selected as the primary route.

Estimation of path bandwidth: The PB can be determined from the set of available slots. Each intermediate node defines the available slots to transmit without colliding the neighbor reception. The aspects of the measured bandwidth in the partial path P^k from the source to that node defines the desired bandwidth metric BW (P^k). From this the PB can be estimated as:

$$BW\left(P^k\right) = \left|PB^k_{k+1}\right| \quad (1)$$

where, Pb^k_{k+1} the set calculated in node k naming the available slots to transmit from node k+1-node k.

Estimation of delay: The routes with less delay capacity are selected for the primary routes. The delay metrics can be estimated as:

$$\text{Delay} = N/R \text{ second} \quad (2)$$

Where:

N = Number of bits

R = Rate of transmission (bits per second)

Secondary route selection: Secondary route is selected as a backup path for the data session (Asif *et al*., 2011). The intermediate nodes are used to recover the route repair by themselves. If the primary route fails due to either

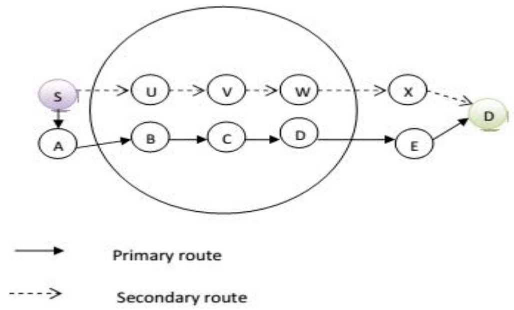

Fig. 2: Primary and secondary route selection

nodes mobility or congestion then the secondary route is selected as a primary route for data transmission (Fig. 2).

For backup route three metrics are used, the route delay is checked with the transmission of dummy packet, the local capacity is tested using Channel Idle Time Ratio (CITR) mechanism and the neighbour's capacity is tested passively while using lower carrier sensing threshold.

Estimation of contention difference: For backup route selection (Asif *et al*., 2011) apart from path bandwidth, the route delay and Contention Difference (CD) are considered. The CD of a node is the number of those carrier sensing neighbours excluding destination node which are on backup path but not on the current path of the data flow. CD is estimated as:

$$CD = |C_{count}| - |CSN \cap R_{curr} / \{D\}| \quad (3)$$

$$C_{count} = |(\text{Path}) \cap (\text{ActiveNodeSet})| \quad (4)$$

Where:

C_{count} = Contention count
CSN = Carrier Sensing Neighbour
R_{curr} = Current flow of the data traffic
D = Destination of the data traffic which is excluded in CD calculation (Yang and Kravets, 2005)

From the Fig. 3 the small circles represent nodes and larger circle represents carrier sensing range of node "R". According to formula of contention count (C_{count}), node "R" C_{count} is 6 but in these 6 nodes the three nodes {W, X, Y} are part of the current data traffic route. So, the CD of the node R becomes 3.

The reliability of the backup route is estimated by comparing the available bandwidth with the required bandwidth of the data flow which is given by:

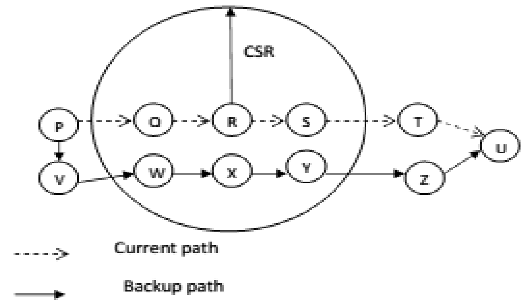

Fig. 3: Calculation of Contention Difference (CD)

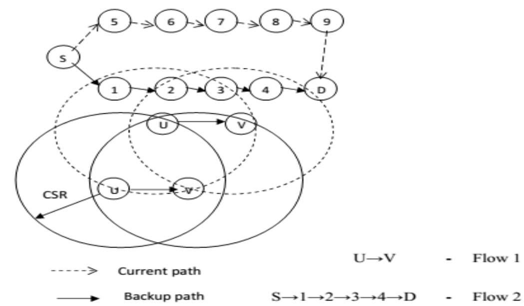

Fig. 4: Route changing

$$B_{avil} - B_{rsv} \geq CD.B_{req} \quad (5)$$

Where:

B_{avil} = Available capacity at node
B_{rsv} = Reserve capacity of the node
B_{req} = Required capacity of the data session

Route repair mechanism: In FAAC-Multipath protocol (Asif *et al*., 2011) if the primary path fails then the flow is switched to the secondary path by the intermediate nodes without pausing the data session. When route failure occurs at any node then the intermediate node attempts to recover the route locally. By local repairing, the error finding source node will search for the alternate route which can fulfil the requirements of that flow. From the Fig. 4, the small circle represents the nodes, large circle represent the carrier sensing range of the nodes.

Algorithm for route repair mechanism:

- At the beginning flow 1 use the route U→V and flow 2 uses the route S→1→2→3→4→D
- Therefore at the start, the nodes participating in the transmission of flows are out of carrier sensing range of each other. When the nodes of flow 1 and 2 come in the carrier sensing range of each other then both the route will fail to satisfy the QoS requirements
- So, the source of flow 2 switches the flow to alternate route S→5→6→7→8→9→D so it can satisfy the requirements

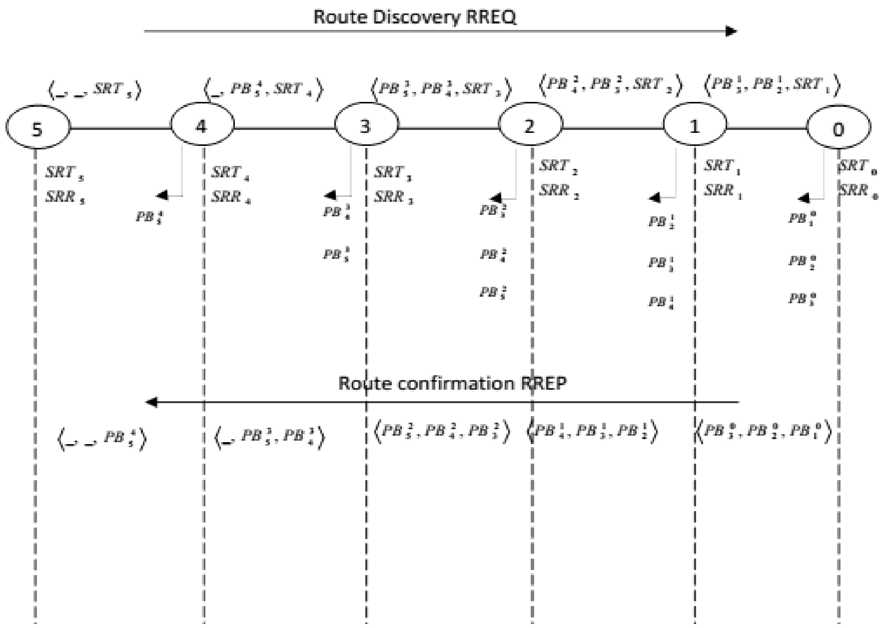

Fig. 5: QoS metric evaluated during discovery and resource reservation during reply phase

- If the backup route is cached at the source during the route discovery of primary route which is similar to the Session Request (SReq) packet process, then the protocol conducts the testing of nodes resources on the stated route
- Next to this local resources are tested using CITR, after the successful completion of the resource testing on that path the source stores the backup path. If the testing fails then the route is removed from untested backup route cache
- When all the cached backup routes are removed, then the source set off new route discovery for the same data session because if the current route fails then there should be a tested backup/secondary path in the cache, there will be no need to stop the data traffic but just switch to tested backup route
- The source node initiates the backup route discovery by transmitting route request multipath (RReq-Multipath) packet which is similar to the primary route discovery
- To avoid the fully flooding of the RReq-Multipath packet, the disjointness condition is applied
- If the backup route does not satisfy the disjoint condition or the available capacity is not sufficient for the data session then the Admission Request Multipath (Ad-Multipath) packet is dropped

Slot allocation: Figure 5 For slot allocation we are using Bandwidth Calculation Forward Algorithm (BWC-FA) (Canales *et al*., 2009). Using BWC-FA available TDMA slots could be found, that can be used for transmitting in every link along the path. So, if these slots are reserved it would be interference-free. The maximum available bandwidth in the whole path can be calculated from the final value in the destination node which is given by:

$$P = \{n_m \rightarrow ... \rightarrow n_{k+1} \rightarrow n_k \rightarrow ... \rightarrow n_0\} \quad (6)$$

- Initially during the route discovery process the set of each available slot is calculated. The set calculated in node k to transmit from node k + 1 to node k is given by PB^{k}_{k+1}
- From the slot status information at the MAC level each intermediate node defines the Slots Ready to Transmit (SRT) without colliding with Slots Ready to Receive (SRR) without suffering interference. The received routing information contains the SRT availability set along with the two previously calculated Path Bandwidth (PB) sets
- Therefore, with the SRR restriction, the terminal recalculates the path bandwidth PBs by calculating the PB^{k}_{k+1}
- Next the above metric is updated in each intermediate node. If the BW is insufficient, it drops a RREQ message
- In the route discovery process the availability sets for every link are recalculated and stored in the downstream neighbors

- Next for the three-hop disjoint sets, each node recalculates the sets for the three previous links. During the reply phase, these sets are attached to the RREP message, allowing the corresponding transmitter to finally reserve the selected slots based on more updated information
- Among these only the necessary slots are chosen to cover the QoS demand which defines the Transmission Schedule (TS) given by:

$$TS = BW_l\left(PB_k^n, R\right) \tag{7}$$

Overall algorithm:
- Initially using the FAAC-MM protocol the route discovery is made
- For this the paths are selected from the routes
- Here we are selecting two types of paths named as primary and secondary
- The intermediate node carries the route repair locally without contacting the source node
- Next to this route repair mechanism is enabled by which if the primary route fails the intermediate node switches the path to the secondary node
- The secondary route acts as a backup route
- Finally slot allocation is done by using the BWC-FA, here each slots are reserved in order to make the path interference free
- And the best path is selected by using the path bandwidth
- In order to provide QoS demand the necessary slots are selected and the transmission scheduling is defined for each slots

RESULTS AND DISCUSSION

Simulation model and parameters: The Network Simulator (NS2) is used to simulate the proposed architecture. In the simulation, 50 mobile nodes move in a 1000×1000 m region for 50 sec of simulation time. All nodes have the same transmission range of 250 m. The simulated traffic is Constant Bit Rate (CBR). The simulation setting and parameters are summarized in Table 1.

Performance metrics: The proposed Bandwidth and Delay aware QoS Provisioning and Admission Control (BDQPAC) is compared with the FAACMM technique (Asif *et al*., 2011). The performance is evaluated mainly, according to the following metrics.

Packet delivery ratio: It is the ratio between the number of packets received and the number of packets sent.

Table 1: Simulation parameters

Parameters	Values
No. of nodes	50
Area size	1000×1000
Mac	Tdma
Transmission range	250 m
Simulation time	50 sec
Traffic source	CBR
Packet size	512
Rate	250, 500, 750, 1000 and 1250 kb
Flows	2, 4, 6, 8 and 10

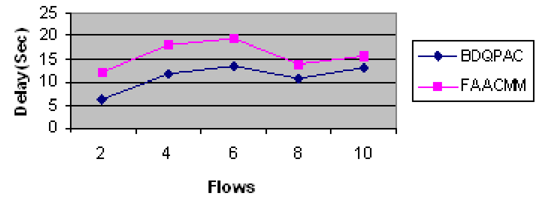

Fig. 6: Flows vs. delay

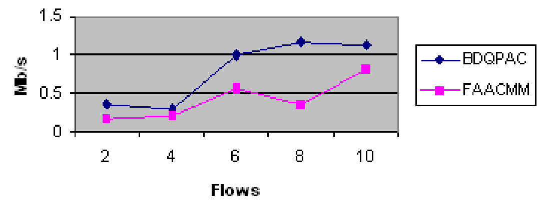

Fig. 7: Flows vs. received bandwidth

Packet lost: It refers the average number of packets dropped during the transmission.

Received bandwidth: It is the number of mega bits transferred per second.

Delay: It is the amount of time taken by the nodes to transmit the data packets.

Based on flows: In our first experiment we vary the number of flows as 2, 4, 6, 8 and 10. Figure 6 shows the delay of BDQPAC and FAACMM techniques for different number of flows scenario. We can conclude that the delay of our proposed BDQPAC approach has 30% of higher than FAACMM approach.

Figure 7 shows the received bandwidth of BDQPAC and FAACMM techniques for different number of flows scenario. We can conclude that the bandwidth of our proposed BDQPAC approach has 45% of higher than FAACMM approach.

Figure 8 shows the delivery ratio of BDQPAC and FAACMM techniques for different number of flows scenario. We can conclude that the delivery ratio of our proposed BDQPAC approach has 40% of higher than FAACMM approach.

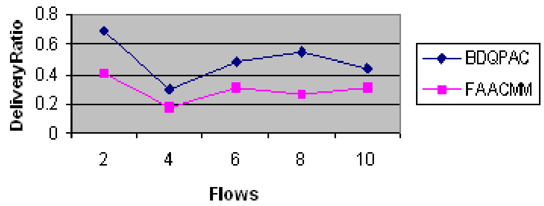

Fig. 8: Flows vs. delivery ratio

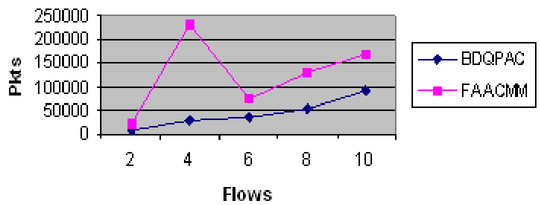

Fig. 9: Flows vs. packet lost

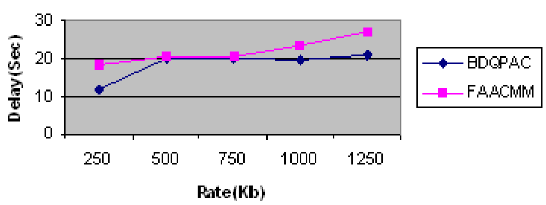

Fig. 10: Rate vs. Delay

Figure 9 shows the Packet lost of BDQPAC and FAACMM techniques for different number of flows scenario. We can conclude that the Packet lost of our proposed BDQPAC approach has 64% of higher than FAACMM approach.

Based on rate: In our second experiment we vary the transmission rate as 250, 500, 750, 1000 and 1250 Kb. Figure 10 shows the delay of BDQPAC and FAACMM techniques for different rate scenario. We can conclude that the delay of our proposed BDQPAC approach has 16% of higher than FAACMM approach.

Figure 11 shows the received bandwidth of BDQPAC and FAACMM techniques for different rate scenario. We can conclude that the bandwidth of our proposed BDQPAC approach has 54% of higher than FAACMM approach.

Figure 12 shows the delivery ratio of BDQPAC and FAACMM techniques for different rate scenario. We can conclude that the delivery ratio of our proposed BDQPAC approach has 63% of higher than FAACMM approach.

Figure 13 shows the packet lost of BDQPAC and FAACMM techniques for different rate scenario. We can conclude that the Packet lost of our proposed BDQPAC approach has 61% of higher than FAACMM approach.

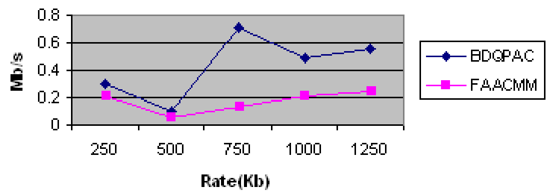

Fig. 11: Rate vs. received bandwidth

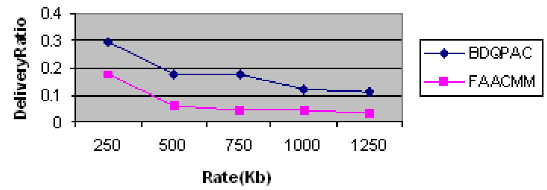

Fig. 12: Rate vs. delivery ratio

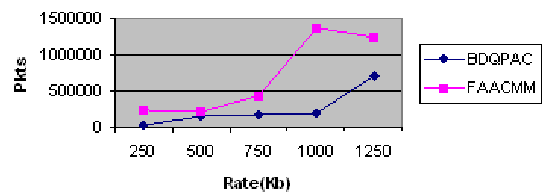

Fig. 13: Flows vs. packet lost

CONCLUSION

In this study, we have proposed a bandwidth and delay aware QoS provisioning and admission control in MANET. As a route repair mechanism Flow Aware Admission Control Multipath Protocol with Multiple Constraints (FAAC-MM) is used to enable intermediate node to carry out route repair locally without contacting the source node. This protocol maintains two routing paths for satisfying delay and throughput requirements. For backup route selection, apart from path bandwidth, the route delay and contention Difference are considered. Finally, the slot allocation of each link in TDMA process for transmission is provided by using the Band Width Calculation-Forward Algorithm (BWC-FA) in admission control mechanism. The best path is selected based upon the Path Bandwidth (PB) of each link.

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