

Research Article

An Improved QoS Multipath Routing Using Bandwidth Estimation and Rate Adaptation

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Abstract: Mobile Adhoc Networks (MANETs) are composed of nodes which communicate with one another without network infrastructure. Their advantage being that they can be used in isolation or along with wired infrastructure, usually via a gateway node to ensure traffic relay for both networks. Quality of Service (QoS) is harder to ensure in ad hoc networks than in other network types, as wireless bandwidth is shared by adjacent nodes with network topology changing as nodes move. Most QoS protocols are implemented for specific scenarios and consider parameters such as network topologies, bandwidth, mobility, security and so on. This work proposes a novel multipath routing protocol which is an extension of AOMDV by discovering routes based on available bandwidth and rate adaptation. The method with Hello message box is used to calculate available bandwidth for a route. Relative Fairness and Optimized Throughput is an approach for rate adaptation in this paper which is to ensure fairness and allow nodes to adapt transmission rates and contention windows to channel quality. In sequence this is determined by calculating the access probability of a channel for each node in a distributed manner approximating successful and failed transmissions.

Keywords: Ad hoc On-demand Multipath Distance Vector (AOMDV), Mobile Adhoc Network (MANET), Quality of Service (QoS)

INTRODUCTION

A MANET is a self-configuring mobile devices network connected by wireless links. In other words, a MANET is a communication nodes collection that communicates with each other without fixed infrastructure and predetermined wireless links topology. Each MANET node moves freely in any direction and change links to other devices frequently. Individual nodes dynamically discover other nodes they directly communicate with. Due to a node's signal transmission range limitation all nodes cannot communicate directly with others. Each node moves forward traffic unrelated to own use and is hence a router also (Lee *et al.*, 1999).

Adhoc networks suit situations where infrastructure is not available or trusted, like Communication network for soldiers, mobile network of laptop computers in conference or campus settings, temporary offices in campaign headquarters, Wireless Sensor Networks (WSN) for biological research, mobile social networks like Facebook, MySpace and Twitter and mobile Wi-Fi devices mesh networks.

Adhoc On-demand Distance Vector (AODV) is an on-demand, single path, loop-free distance vector protocol combining Dynamic Source Routing's (DSR's) on-demand route discovery mechanism with Destination-Sequenced Distance-Vector's (DSDV's)

concept of destination sequence numbers. But, unlike source routing using DSR, AODV takes a hop-by-hop routing approach. Ad hoc On-demand Multipath Distance Vector (AOMDV) has many characteristics similar to AODV. It is based on distance vector concept and uses hop-by-hop routing. Also, AOMDV finds routes on demand using route discovery. The difference is in routes found with every route discovery. Route Request (RREQ) propagation from source to destination establishes multiple reverse paths at intermediate nodes and destination in AOMDV. Many RREPs traverse reverse paths to form many forward paths to destination at source/intermediate nodes. AOMDV also provides alternate paths to intermediate nodes as they reduce route discovery frequency (Fig. 1).

AOMDV's core protocol ensures that discovered multiple paths are loop-free and disjoint and find paths using flood-based route discovery. AOMDV route updates rules applied locally at nodes, plays a key role in maintaining loop-freedom and disjointness in properties (Marina and Das, 2002).

AOMDV calculates multiple paths during route discovery in dynamic ad hoc networks where link breakage is frequent due to vehicles high velocity. A route discovery procedure is needed after each link failure in AODV routing protocol. Performing this procedure leads to high overhead and latency and so

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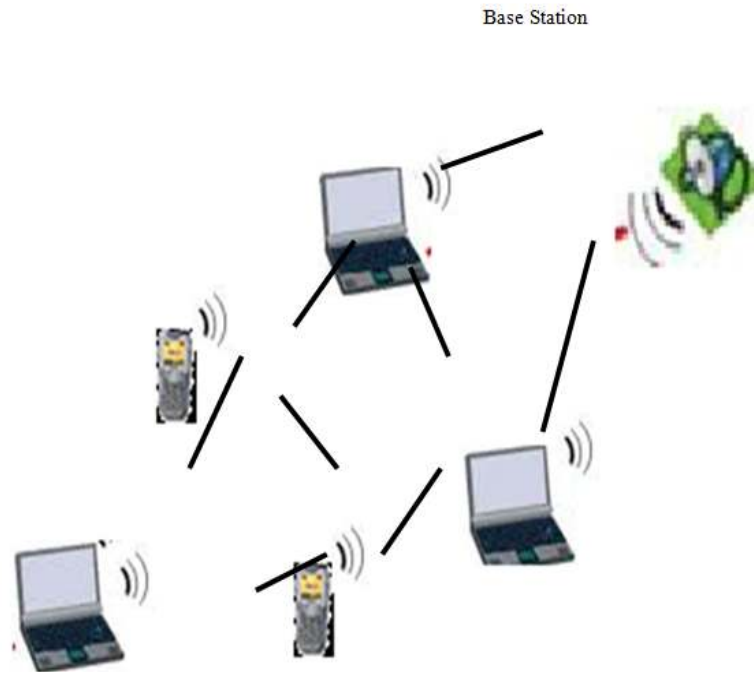


Fig. 1: Mobile ad hoc network

this is overcome by having many available paths. Route discovery procedure is undertaken after all paths to source/destination fail in AOMDV. Also, efforts are made to utilize routing information available in underlying AODV protocol. However, some modification is needed to calculate multiple paths. AOMDV protocol includes 2 sub-procedures.

Calculating multiple loop-free paths at each node:

Route discovery defines alternate path to source/destination in AODV routing protocol. Each RREQ packet copy received by a node, introduces an alternate path to source.

Finding link-disjoint paths by deploying distributed protocols:

Loop-free mechanism enables nodes establish many paths to destination conveying the next stage which is disjointness process (Moravejosharieh *et al.*, 2013).

The major disadvantages of AOMDV are:

- More message overheads are caused during the route discovery. This is because of increase in flooding.
- Since it is a multipath routing protocol, the results are with longer overhead (Balachandra *et al.*, 2012).
- AOMDV is affected more since it has the additional overhead of more RREPs per route discovery
- AOMDV's route maintenance mechanism requires known routes to be frequently purged. This results

in a new route discovery for every new data connection (Nithya and Maruthaveni, 2013).

In this study it is proposed to overcome these issues by proposing an improvement based on rate adaptation and bandwidth estimation.

Rate adaptation is challenging in MANETs, when considering fairness among competitive nodes. Existing rate adaptation solutions are designed for IEEE802.11-based Wireless Local Area Network (WLANs) and are unable to cope with relative fairness. Unlike these schemes, the objectives of the proposed approach, called Relative Fairness and Optimized Throughput (REFOT), is to ensure fairness and allow nodes to adapt transmission rates and contention windows to channel quality. In turn this is determined by calculating the access probability of a channel for each node in a distributed manner approximating successful and failed transmissions. REFOT allows reaching appropriate transmission rate level, without crossing intermediate levels. This helps to avoid scenarios where network capacity can be underutilized/overused, allowing a system to reach stability faster. Generally speaking, rate adaptation scheme effectiveness hinges on how it copes with transmission failures impact which is due to channel errors/packet collisions (Benslimane and Rachedi, 2013).

QoS is harder to ensure in ad hoc networks than in other network types, as wireless bandwidth is shared by adjacent nodes with network topology changing as nodes move. This needs inter node collaboration to establish routes and secure resources to provide QoS. The ability to provide QoS is dependent on how

resources are managed at Media Access Control (MAC) layer. Among QoS routing protocols proposed, some use generic QoS measures not tuned to a specific MAC layer. Code Division Multiple Access (CDMA) is also used to eliminate interference between different transmissions. Different MAC layers have varied requirements to ensure successful transmissions and QoS routing protocol developed for a MAC layer will not suit others easily. QoS routing needs to locate a route from source to destination with required bandwidth. This study also provides a method to calculate available bandwidth for a route. It is not a routing protocol and should be used along with a routing protocol to perform QoS routing (Zhu and Corson, 2002).

LITERATURE REVIEW

A QoS Aware Stable path Routing (QASR) Protocol for MANETs was proposed by Chauhan and Nandi (2008), where a QoS aware on demand routing protocol which used signal stability as routing criteria along with other QoS metrics was introduced. The proposed QASR was designed over SSA and planned to select stable QoS routes that survive longer. Using NS-2 simulator, it conducted extensive simulations to verify QASR effectiveness with various mobility patterns/network loads. A comprehensive QASR performance analysis and comparison with other QoS aware MANET routing was presented.

A QoS aware multicast routing in MANETs was proposed by Kakkasageri *et al.* (2008), which was simulated on network scenarios to test operation effectiveness regarding performance parameters like cluster formation time, QoS aware cluster heads number and network reconfiguration time. Simulation revealed that the new scheme reduced network overhead and took care of connectivity breakages caused by node mobility and node failures.

A QoS Aware Routing (QAR) and Admission Control (AC) in shadow-fading environments for multi-rate MANETs was proposed by Hanzo and Tafazolli (2011) which evaluated new solutions to improve performance of QAR and AC protocols due to mobility, shadowing and varying link Signal-to-Interference-plus-Noise Ratio (SINR). It was found that reliability of assured throughput services noticeably improved through proactive maintenance of backup routes for active sessions, adapting transmission rates and routing around temporarily low-SINR links.

A distributed architecture with control scheme and status-aware routing protocol for QoS support in MANETs was proposed by Li *et al.* (2008), which suggested distributed architecture to ensure QoS for mobile MANETs. The new architecture included two approaches distributed control scheme and status-aware

routing protocol, both being implemented in a fully distributed manner without resources allocation or reservation at intermediate nodes. Simulation showed the proposed architecture significantly improved end-to-end delay performance for real-time traffic and extended network life under various traffic loads.

A game theory approach to enhance QoS-aware routing in MANETs was proposed by Enneya *et al.* (2009) which proposed a cooperative game theory approach to extract a MANET core that was stable regarding mobility. This core was a MANET mobile nodes subset where mobility was less and stable. Path selection by QoS-aware routing protocols through extracted core ensured more timely QoS.

An agent based adaptive multicast routing with QoS guarantees in MANETs, was proposed by Santhi and Nachiappan (2010) where a QoS aware multicast routing scheme used static and mobile agents to ensure QoS guarantees regarding delay constraint, bandwidth reservation, delay-jitter constraint and packet loss to multicast session. Here mobile agents move in the network collecting routing information. Simulation showed that the new scheme performed better than MAODV and ODMRP regarding reducing network overhead, improving packet delivery ratio.

A bandwidth estimation based QoS-aware routing for MANETs was proposed by Chen and Heinzelman (2005) where a QoS-aware routing protocol incorporating an admission control and feedback schemes to meet QoS requirements of real-time applications was introduced. The QoS-aware routing protocol's novel part, was use of approximate bandwidth estimation to react to network traffic. This approach implemented schemes using two bandwidth estimation methods to find residual bandwidth available with every node to support new streams. Experiments showed that packet delivery ratio increased greatly, with packet delay and energy dissipation decreasing significantly while overall end-to-end throughput was not affected, compared to routing protocols without QoS support.

An adaptive multi-path QoS aware DSR protocol for MANETs was proposed by Hashim *et al.* (2006) where the method collected QoS metrics information during route discovery and used them to choose disjoint paths set, distributing QoS based data provided. Every node monitors links and adaptively added/removed paths to achieve required QoS. Simulation experiments were planned using Glomosim network simulator.

A QoS aware route selection mechanism using Analytic Hierarchy Process (AHP) for MANETs was proposed by Uddin *et al.* (2009). Here an on-demand source routing protocol for MANET which worked with 6 important QoS attributes by varying priority for various traffic flow categories reflecting this variation through incorporation of AHP.

A QoS-Aware Routing Protocol based on Entropy (QARPE) for MANET was proposed by Lian *et al.* (2008). QARPE ensures stable multi-path routing strategy. The strategy inhibited entropy metric to guarantee stability and selected routing QoS conditions. It adopted the following QoS conditions like delay, bandwidth and delay jitter. To reduce route reconstructions, QARPE ensured a standby route. Simulation revealed that QARPE provided accurate and efficient method with a stable multi-path satisfying MANETs QoS constrains.

QoS-aware routing protocol research with load balancing for MANETS was proposed by Liu *et al.* (2008), where multi-constraint QoS mechanism were combined with load balancing to locate a satisfying path between source and destination nodes. The aim was developing a load balancing strategy that monitored changes to neighbourhoods load status and could choose least loaded routes with surrounding load status knowledge. Simulation showed that proposed protocol improved packet delivery ratio with less transportation delay compared to on-demand routing algorithm. And in varied network load levels it reduced average end-to-end delay to achieve better network performance/efficiency.

A QoS Routing protocol supporting Unidirectional Links (QRULA) in MANETs was proposed by Wushi *et al.* (2008), in which it considered existing unidirectional network, used upper table between adjoining nodes to choose route with delays/bandwidths limitations. QRULA performed well in MANET scenarios with unidirectional links. QRULA was simulated and results showed that it not only worked well in ad hoc network environments with unidirectional links, but also was advantageous in route loads and package transmission rates.

A revised AODV protocol with QoS for MANETs was proposed by Ping and Ying (2009), where AODV routing protocol was revised by calculating corresponding QoS provision values to locate best routes applying carrier sense mechanism in IEEE 802.11b to get available band width. Simulation revealed that use of QoS parameters in route discovery significantly reduced end-to-end delay and increased packet delivery ratio under high load and moderate to high mobility conditions, though AODV routing load was slightly less than the new protocol. Comparison between original routing protocol and improved algorithm was through NS-2.

Yang *et al.* (2012) proposed a Network Coding-based AOMDV (NC-AOMDV) routing algorithm in MANET. It is typically proposed in order to increase the reliability of data transmission or to provide load balancing. In the simulation, NC-AOMDV routing protocol is compared with AODVM routing protocol, in terms of the packet delivery ratio, packet overhead and average end-to-end delay when a packet is transmitted. The simulations results showed that the NC-AOMDV

routing protocol provide an accurate and efficient method of estimating and evaluating the route stability in dynamic MANETs.

An improved AOMDV to increase path stability utilizing MANETs node mobility information was proposed by Park *et al.* (2013) where an algorithm which excludes nodes with high mobility from path construction by collecting/managing mobility information was suggested. Hence, the new algorithm provided stable paths. This algorithm appends M Record Field and Relieve Field in routing table to collect/manage mobility information through extension of current AOMDV. Additionally, Mbl Field is added to RREP message to adapt collected information for path configuration. The proposed protocol's performance is analyzed and is compared to existing AOMDV using ns-2 simulator.

METHODOLOGY

The Hello message of AOMDV is modified for bandwidth estimation (Chen and Heinzelman, 2005). Similarly RREQ message is modified for rate adaptation. Figure 2 shows the flow chart of proposed algorithm.

This study proposes a QoS aware routing for AOMDV. QoS is improved by Bandwidth estimation and Rate adaptation. The steps are as follows.

“Hello” bandwidth estimation: In “Hello” bandwidth estimation, sender's current bandwidth use and sender's one-hop neighbours' current bandwidth use piggyback onto standard “Hello” message. Each host estimates available bandwidth based on information in “Hello” messages and frequency reuse pattern knowledge. This avoids creation of extra control messages using “Hello” messages to disseminate bandwidth information.

The underlying IEEE 802.11 MAC is studied to know frequency reuse pattern. As defined in IEEE 802.11 MAC, hosts can access wireless channel as seen in Fig. 2 Hello structure. The bold item in first row is the host's information. Following rows are host's neighbors' information. Media is free and continues to be so when no hosts transmit packets within interference range. Interference range is usually twice transmission range, based on settings of 914 MHz Lucent WaveLAN card. Sol frequency is reused outside second neighboring hosts' range. The bandwidth's actual upper bound in two-hop circle varies with topology and traffic, but raw channel bandwidth is total bandwidth's soft upper bound. The soft upper bound bandwidth is used to estimate approximate bandwidth use. With this frequency reuse pattern, bandwidth calculation to determine residual bandwidth in a two-hop neighbourhood range is simplified. Hence, every host approximates its residual bandwidth information based on information from hosts in two-hops (interference range). First neighbouring hosts'

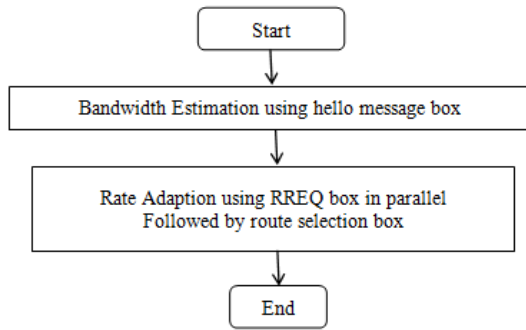


Fig. 2: Flowchart of proposed algorithm

Table 1: Hello structure

ID	Bandwidth spent	Time stamp
Neighbor ID	Consumed bandwidth	Time stamp
-	-	-
-	-	-
Neighbor ID	Consumed bandwidth	Time stamp

information is got directly, without any chance of getting second neighbouring hosts'2 information. There are ways to get second neighbouring hosts' information, like disseminating host bandwidth information using higher transmission power to reach two-hop neighborhood and setting up separate signalling channel to broadcast bandwidth information.

On the other hand, usage of high power to disseminate information consumes more power and destroys frequency reuse pattern leading to more interference. Use of a separate channel to disseminate bandwidth information needs additional control which is burdensome for ad hoc networks regarding bandwidth consumption and hardware support. Hence, it is proposed to use hop relay to disseminate second neighboring hosts' information. AOMDV uses "Hello" messages to update neighbor caches. "Hello" message in AOMDV keeps host's address as it is, which initiates the message. "Hello" messages are modified to include two fields. The first includes host address, consumed bandwidth, timestamp and second field the neighbors' addresses, consumed bandwidth and timestamp, as seen in Table 1. Every host determines consumed bandwidth by monitoring packets it feeds a network. This value is recorded in a host's bandwidth-consumption register and updated regularly (Perkins and Royer, 1999).

PATH-CENTRIC ON-DEMAND RATE ADAPTATION FOR MANETS

Path-centric on-demand Rate Adaptation for MANETs (PRAM) is a multi-rate adaptation algorithm where a source node floods a RREQ to locate a routing path as in on-demand routing protocols like DSR, AODV and AOMDV. PRAM dictates a data rate for RREQ and forces intermediate nodes to use same rate when forwarding RREQ. It discovers suboptimal routing paths with simplicity and lower control

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/* When a data packet is ready */
If route is found in routing table [at data rate r1],
    Use it to send the packet h lifetime [at data rate r1];
[If the path lifetime is longer than a threshold r1 < Tmaz,
    callroute_discovery (pRREQ) procedure with ri+1;]
else, [determine initial data rate [with r1];
    Call route_discovery (RREQ) procedure [with r1];
/* When a RREQ is received [at data rate r1] */
Update routing table (back forward link) [with data rate];
If self-destination, prepare and send RREP [at r1];
Else forward RREQ [at r1];
/* When a RREP is received [at data rate r1] * \
Update routing table (forward link) [with data rate];
If self-source,
[If it is reply for pRREQ,
    Compare PST metric to choose ri;
    send the packet(s) [at ri];
Else, [extract, update and piggyback PT;]
    forward RREP [at ri];
/* When a RREP is received [at data rate r1] * \
Update routing table (eliminate routes)
    [with data rate r1]
Compute the set of unreachable due to the broken links;
If the set is empty, stop;
else, Drop the packet (s) destined to one of
    unreachable;
    Forward RERR [at r1];
/* route_discovery procedure [at data rate r1] * \
TTL = initial TTL;
While TTL < network diameter;
    Send RREQ [or pRREQ at data rate r1] with TTL;
    If no RREP within timeout, increment TTL;
    else, stop (RREP received)
    While retry_count < retry_limit;
    Send RREP [or pRREQ at data rate r1] with TTL;
    If no RREP within time out,
        [decrease data rate;]
        Increment retry_count;
    Else, stop (RREP received)
        Drop the Packet (s);
    
```

Fig. 3: Overview of the PRAM protocol

overhead. Key PRAM design issues are determining data rate for RREQ and when and how to increase/decrease it.

Multi-rate adaptation in PRAM: On-demand multipath routing algorithms, AOMDV use RREQs to locate routing paths. So it is necessary to use appropriate data rate when broadcasting RREQ i.e., RREQ's data rate in essence limits maximum feasible data rate for discovered routing paths links. An alternative is allowing each intermediate node to use a different rate when forwarding a RREQ. Every node maintains best data rate for every link considering local neighbourhood communication environment. It is not correct for nodes to determine best rate for a broadcast packet like RREQ.

Optimal data rate for node pair: PRAM is a path-centric adaptation scheme where a source node determines data rate for destination path and broadcasts RREQ at that rate. Intermediate nodes use same data

rate when forwarding RREQ. When data rate is too high, it leads to connectivity issues. However, when data rate is too low, network cannot use the allowed maximum capacity by radio hardware. So, it is essential for PRAM protocol to have a source node to determine destination-specific data rate.

Figure 3 shows PRAM protocol overview (Kamerman and Monteban, 1997). Changes to original AOMDV include:

- Routing table entries augmented by data rates
- New control packet, pRREQ, sent to discover new routes at higher data rate
- RREP packet piggybacking with PST to determine best routing path data rate

All data and control packets are transmitted at source-dictated data rate, but source dynamically adapts it based on path life. Another important PRAM protocol consideration is decision of destination unreachability. In original AOMDV, when network-wide RREQ broadcasting fails four times consecutively, destination is considered unreachable and source drops packets. In PRAM, when source fails to receive RREP for a network-wide RREQ flood, it decreases data rate of next RREQ broadcasting till it reaches lowest data rate available (6 Mbps). This is due to the fact that destination may not be reachable at higher rates. Changes in the 802.11 MAC protocol to implement PRAM protocol are:

- When a MAC layer passing a received packet to network layer, it informs the received data rate.
- When network (routing) layer passes packet to MAC for transmission, it specifies packet transmission rate.
- To ensure implementation of localized link rate optimization, nodes maintain links status to communicating neighbours. Similar to ARF, it increases/decreases data rate depending on recent history of communication successes/failures over specific links.

QoS parameter estimation is through normalized average of both techniques.

RESULTS AND DISCUSSION

In this study, a QoS aware routing for AOMDV is proposed. The QoS is enhanced using Bandwidth estimation and Rate adaptation. Simulations are conducted to evaluate the proposed AOMDV and are compared with AOMDV and AOMDV with bandwidth estimation. Size of network is used in the simulation is 2500 by 2500 m with 50 nodes. Transmission power of each node: 0.005 watt. The results obtained are as shown in Fig. 4 to 6.

From Fig. 3, it is shown that AOMDV with Proposed technique produces high packet delivery ratio

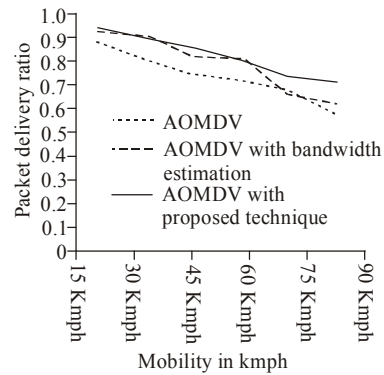


Fig. 4: Packet delivery ratio

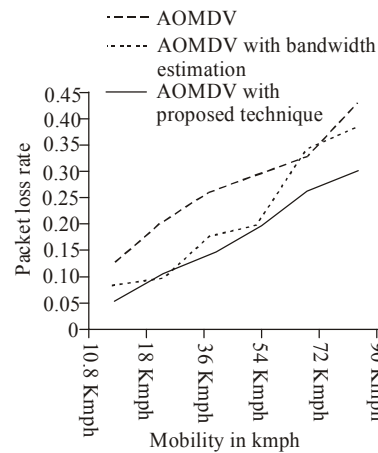


Fig. 5: Packet loss rate

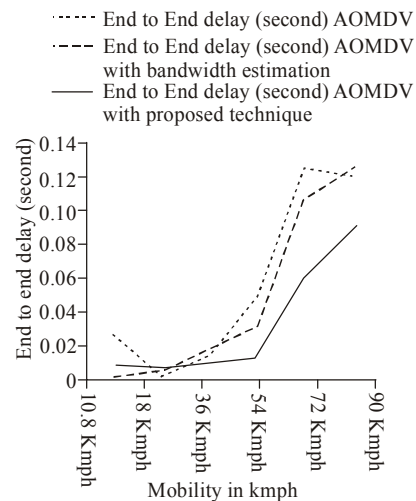


Fig. 6: End to end delay

of 4.75 and 12.99% compared to AOMDV and AOMDV with Bandwidth Estimation, respectively.

From Fig. 4, it is shown that the proposed AOMDV with Proposed technique produces low Packet

Loss Rate of 17.61 and 35.14% compared to AOMDV and AOMDV with Bandwidth Estimation, respectively.

From Fig. 5, it is shown that the proposed AOMDV with Proposed technique produces low End to End Delay of 36.25 and 44.16% compared to AOMDV and AOMDV with Bandwidth Estimation respectively.

CONCLUSION

This study proposes a QoS aware routing for AOMDV. QoS routing needs to locate a route from source to destination with required bandwidth. Bandwidth calculation developed provides a method to calculate available bandwidth for a route. QoS in the proposed method is enhanced using bandwidth estimation and Rate adaptation. The study reveals that the proposed AOMDV with planned technique results in high packet delivery ratio of 4.75 and 12.99% and lowering end to end delay by 36.25 and 44.16% compared to AOMDV and AOMDV with Bandwidth Estimation, respectively.

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