Enhancing QoS for Multimedia Services Using Mobility-Aware Bandwidth Estimation Algorithm in MANETs

Lokesh Sharma, Chhagan Lal, Devi Prasad Sharma and Pallavi Kaliyar

Abstract Over the years, a large array of multimedia services started using mobile ad hoc networks (MANETs) due to its attractive features such as low-cost quick deployment, node mobility, and distributed networking. However, multimedia applications also require provisioning of adequate quality of service (QoS) to enhance quality of experience (QoE) of end users. In order to provide QoS in a network, the accurate knowledge of the remaining network resources at any time is the key. But, due to the inherent characteristics of MANETs such as dynamic topology, high bit-error-rate communication channels, and decentralized control, estimating remaining network resources is a challenging task. In this paper, we propose a novel remaining bandwidth estimation algorithm which considers the node (or link) mobility into consideration while performing dynamic bandwidth estimation on a node. The estimated link bandwidth value is then used during the route discovery process to select routes with adequate bandwidth and thus increases the QoS of the data flow. The proposed algorithm is verified using real-time video traffic (i.e., H.264/SVC encoded video traces) using a industry standard simulator called Qualnet. The simulation results show that the proposed approach increases the decision accuracy of the soft admission control process and thus leads to the enhancement of the quality of the received video traffic.

Keywords Mobility · QoS · Bandwidth estimation · AODV

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1 Introduction

The IEEE 802.11-based networks provide QoS level using the service differentiation stated in the IEEE 802.11e amendment. However, still there is no solution defined as standard for estimation and allocation of the network resources. Bandwidth is one of the most critical network resources for real-time flows. Due to the absence of precise estimation of available bandwidth, it is difficult to provide safe admission control. The estimated available bandwidth can be defined as maximum throughput achieved between two adjacent nodes while keeping the existing ongoing ows in the network. Thus, the available bandwidth is influenced by the current ows in the network. Consequently, if the admission of ows whose bandwidth needs is more outstanding than the available bandwidth in network, leads to false admission control. Therefore, accuracy in the estimation of the usable bandwidth is a decisive and vital issue.

To provide true admission control without disturbing the existing flows, we proposed an improved approach for bandwidth estimation by considering the mobility of the nodes. Nodes mobility causes the frequent link failures and re-transmissions. The effects of the mobility are not considered in the existing solution for network resource estimations. Further, on the basis of true available bandwidth estimations, a reactive route discovery process proposed that discovering end-to-end path from source to destination node covering all the intermediate nodes satisfies the bandwidth requirement requested by the application to support desired QoS.

The remaining part of the paper is organized as follows: The next part is the review of the existing solutions and methodologies suggested for bandwidth estimations in the literature. Then, we present our proposed methodology. It is followed by the simulation results of the comparison of proposed new protocol with the existing solutions like BAND-MR [1], which is one of the closest QoS-aware reactive routing solutions suggested, and AODV routing protocol [2]. In the last section, we provide the conclusion and future scope of the proposed work.

2 Related Work

This section presents the existing solutions for bandwidth estimation and admission control to support QoS-enabled delivery of multimedia traffic in MANETs. Hanzo and Tafazolli [3] in their paper presented a survey of the main contributions to the group of QoS routing solutions for MANETs available in the period 1997–2006. They also presented the process and their communications with the medium access control (MAC) protocol. In another paper, Prasad et al. [4] explained the state-of-the-art bandwidth estimation techniques, metrics, and practices used, and tools that instrument with them.

Sarr et al. [5], in another paper, broadly categorized the bandwidth estimation approaches in two streams: (1) Active approaches: used for end-to-end estimation of the available bandwidth by sending the sequence of the probe packets along the route. (2) Passive approaches: uses the local information to estimate the bandwidth utilization. The estimation is based on the channel sensing (ideal and busy time of channel). In another paper, the authors [6] proposed new solutions for enhancing the performance of QOS-aware routing and admission control protocols in the presence of mobility, shadowing, and fluctuating link signal-to-interference-plus-noise ratio (SINR).

In another literature, Belbachir et al. [7] focused on the QoS enabling using resources allocation and estimation. They considered bandwidth as a key resource, and in order to estimate it, they proposed a new approach named Improved Bandwidth Estimations through Mobility incorporation (IBEM) MANETs. In another paper, Chaudhari and Biradar [8] proposed a scheme of estimating available bandwidth (ABW) in MANETs using the actual channel utilization and collision rate. They modified the existing collision probability model and dynamically computed separate Lagrange interpolation polynomial at each node according to node behavior.

3 Proposed Methodology

For efficient admission control in MANET, information about the available bandwidth at each node as well as its neighbors is required. The available bandwidth of any node can be calculated at its physical layer by passively monitoring the network activities. In [9], the authors suggested a method to measure available bandwidth of a node based on the busy and ideal time of the channel. When a node transmits and receives information from the neighbor node, the channel will be considered as busy period (denoted as Pr_{busy}). Let the busy/ideal period of the medium get updated in every T time known as the computational/measurement time period. Then, the ideal time of the channel can be expressed by $Pr_{idle} = (1 - Pr_{busy})$. The available bandwidth at any node on the basis of ideal time can be defined as

$$\mathbf{BW} = \frac{Pr_{idle}}{T} \cdot C \tag{1}$$

where C is the channel capacity. However, the expresses mentioned in Eq. 1 are not correct as different nodes have different contention ratio and sensing range. Let us assume two nodes V_1 and V_2 create a wireless link as shown in Fig. 1. The available bandwidth at the node V_1 and V_2 will be different. Therefore, the available bandwidth of the link between V_1 and V_2 is defined as

$$\mathbf{BW}_{\{V_1,V_2\}} = min\{\mathbf{BW}_{V_1}, \mathbf{BW}_{V_2}\} \tag{2}$$

Fig. 1 Wireless link connecting 2 nodes

Therefore, the available bandwidth of the link will be the minimum of the bandwidths available at two nodes connecting through the wireless link. However, as per the authors [5], the expression written in Eq. 2 is only valid when the computation period T of nodes V_1 and V_2 does not overlap, and hence, ideal period of channel in both communicating nodes is synchronized. This requires strict clock synchronization of the communication nodes. If the ideal period of channel in the nodes is not synchronized, it is suggested to use the average of the overlap times to evaluate the available bandwidth [2]. So, on single wireless link between nodes V_1 and V_2, the available bandwidth is newly defined as being different. Therefore, the available bandwidth of the link between V_1 and V_2 is defined as

$$\mathbf{BW}_{\{V_1,V_2\}} = \left(\frac{Pr_{idle}^{V_1}}{T}\right)\cdot\left(\frac{Pr_{idle}^{V_2}}{T}\right)\cdot C \tag{3}$$

where $Pr_{idle}^{V_1}$ and $Pr_{idle}^{V_2}$ are the ideal periods of channel at nodes V_1 and V_2, respectively, and $(\frac{Pr_{idle}^{V_1}}{T})\cdot(\frac{Pr_{idle}^{V_2}}{T})$ is the average of the channel availability on the entire link.

For more reliability and accuracy in the measurement of bandwidth, we need to consider more network features. Mobility is the vital issue in MANETs. Mobility leads to frequent topology change and link failures because of the change in the distance between the communicating nodes. Let us take an example for mobility as shown in Fig. 2. At the time instance t_1, the two nodes V_1 and V_2 are not in the communication range of each other. That is, the distance d between the two nodes is larger than communication distance $D_{comm}(d > D_{comm})$. Thereafter, at time instance

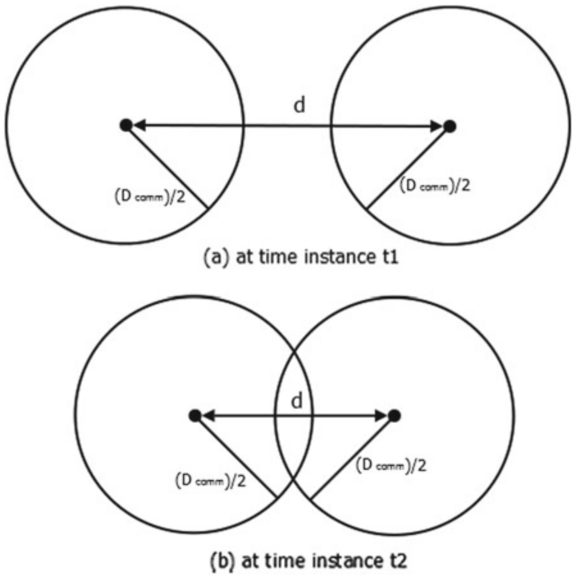

Fig. 2 Example of mobility of two modes

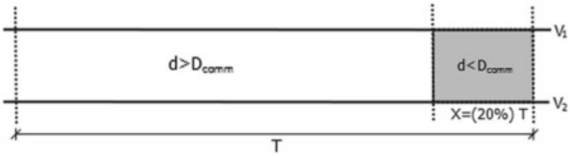

Fig. 3 Link status during T measurement period

t_2 both the nodes come into the communication range of each other. The distance d between the two nodes is smaller than communication distance $D_{comm}(d < D_{comm})$.

Let us take an example shown in Fig. 3, the wireless link state between nodes V_1 and V_2 during the measurement period T. Here, it is mentioned that this link exists only during $X = 20\%$ of T (X value denotes the percentage of the link presence during the period T). We intend to compute the available bandwidth on the link available between the nodes V_1 and V_2 (the scenario depicted in Fig. 3) with the measurement method defined in Eq. 3. As per the author [main paper ref], this method largely overestimates the available bandwidth. This is due to the negligence of the mobility and leads to false admission control and QoS violation. Now, the expression to evaluate the bandwidth can be defined as including the effect of mobility

$$\overbrace{\mathbf{BW}}_{\{V_1,V_2\}} = \mathbf{BW}_{\{V_1,V_2\}} \cdot MC \tag{4}$$

where $\mathbf{BW}_{\{V_1,V_2\}}$ is mentioned in Eq. 3 and MC is the mobility criteria. With the predicted value of MC, let us consider the scenario depicted in Fig. 4. It illustrates a link between nodes V_1 and V_2 during consecutive measurement period T, with two [(a) and (b)] alike activities scenarios (the same bandwidth consumption), but in different states:

- *Stable Link* (Fig. 4a): the communication distance D_{comm} between the two nodes of this link is greater than the distance d of at any time; we note: $\forall t_i / i \in [0, \ldots, n]$,

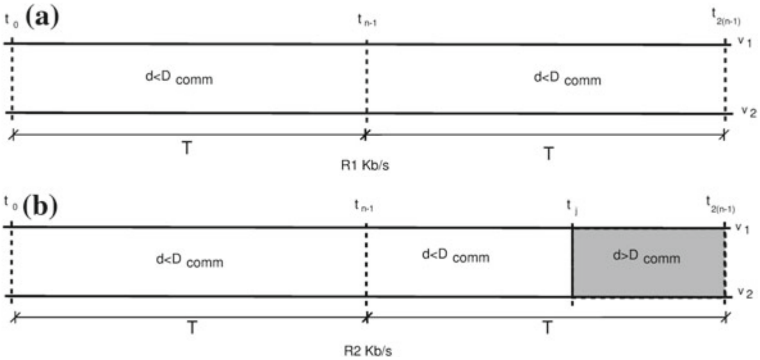

Fig. 4 Link expiration during bandwidth estimations. **a** Stable link. **b** Unstable link

$D_{comm} > d$ (where t_i is time unit of calculus in T period, and $n \in N^*$). This type of links in wireless networks is considered as stable. Most of the authors till now measure the available bandwidth on the stable links.

- *Unstable Link* (Fig. 4b): When we consider a link between two nodes is dynamic or unstable, at some instance, the communication distance D_{comm} between the two nodes of this link is less than the distance d, $D_{comm} < d$ (which can be observed at t_j instant in Fig. 4b), and we note: $\forall t_i / i \in [0, \ldots, n]$.

Algorithm 1 Mobility-aware QoS route discovery process

// Variables used in algorithms
N = Node, S = Source Node, D = Destination Node, I = Intermediate Node
BW_{req} = Bandwidth required for admission control, BW_{est} = Estimated Bandwidth
if Node S has data flow for Node D **then**
    S estimate the BW_{est} using the Eq. 1
    if S(BW_{est}) > (BW_{req}) **then**
        Accept the data flow and generate RREQ
    else
        discard the data flow
    end if
end if
if Node I receives a non-duplicate *RREQ* message **then**
    I calculates BW_{est} using Eq. 7
    if I(BW_{est}) > (BW_{req}) **then**
        Node I update the info in RREQ Packet and
        broadcast further RREQ packet
    else
        generate RERR packet and send to Node S
    end if
end if
if D receives a non-duplicate RREQ message and BW_{req} satisfied **then**
    Node D sent a unicast RREP to Node S
end if

As the scenario depicted in Fig. 4a, b, in the first measurement period T (from t_0 to t_{n-1}), the estimated bandwidths R_1(Kb/s) and R_2(Kb/s) between nodes V_1 and V_2 will be equal as there is no link breakage due to the nodes mobility ($D_{comm} > d$). But in the next measurement period T (from t_{n-1} to $t2_{n-1}$), the estimated bandwidths R_1(Kb/s) and R_2(Kb/s) between nodes V_1 and V_2 will be different as link breakage occurs because of the node mobility ($D_{comm} < d$) at time instance t_j, where $t_{n-1} < t_j < t2_{n-1}$. Therefore, in second scenario (Fig. 4b), the link is only available from t_{n-1} to t_j time instance of T. The estimated bandwidth will depend on the probability of link availability. Therefore, to estimate the available bandwidth R_2(Kb/s) scenario (Fig. 4b), we have to take into account the fragment (Y) and the mobility criteria M (defined as link existence probability) during the measurement period T

$$MC = \frac{t_j - t_{n-1}}{T} \tag{5}$$

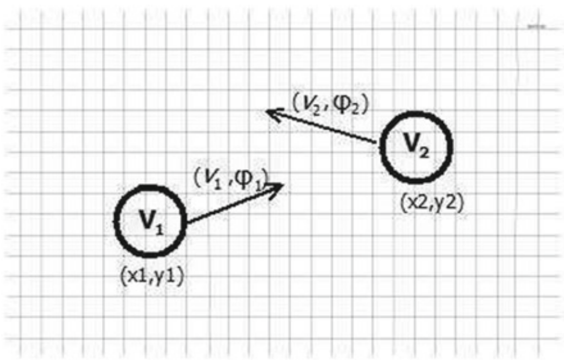

Fig. 5 Mobility of the nodes (coordinates, velocity, and direction)

t_j is the time instance ($t_{n-1} < t_j < t2_{n-1}$) when the $D_{comm} < d$ and link failure occurs.

To identify the value of t_j, authors [10] suggested fairly comprehensive approach based on the motion velocity (v) and the motion direction (φ). According to [11], each node has its geographical coordinates provided with global positioning system (GPS). Consequently, as shown in Fig. 5, each mobile node in network is able to identify the coordinates of its position, the initial coordinates, and the destination coordinates of its motion. Each node informs its neighbor nodes about its coordinates and motion parameters (direction and velocity). Consider that node V_1 (respectively V_2) moves with velocity v_1 (respectively the velocity of node V_2 (v_2)) and follows direction φ_1 (respectively the direction of node V_2 (φ_2)). t_j value is calculated as (e.g., at node V_1):

$$t_j = \begin{cases} \infty & if(v_1 = v_2) \wedge (\varphi_1 = \varphi_2) \\ \frac{-(pq+rs)+\sqrt{(p^2+q^2)d^2-(ps-rq)^2}}{(p^2+r^2)} & \text{otherwise} \end{cases} \tag{6}$$

where $p = v_1 \cdot \cos(\varphi_1) - v_2 \cdot \cos(\varphi_2)$, $q = (x_1 - x_2)$, $r = v_1 \cdot \sin(\varphi_1) - v_2 \cdot \sin(\varphi_2)$, $s = (y_1 - y_2)$.

The objective of the back-off process is to reduce the probability of channel access for some time period. During the back-off time period, channel may be ideal, but it will be considered as interfering (busy). Because of this, a portion of bandwidth is lost during the back-off time period. Hence, we also consider the collision probability of the measurement to be more realistic, and final accurate bandwidth is given in Eq. 7

$$\overbrace{\mathbf{BW}}_{\{V_1,V_2\}} = \left(\frac{Pr_{idle}^{V_1}}{T}\right) \cdot \left(\frac{Pr_{idle}^{V_2}}{T}\right) \cdot C \cdot MC \cdot (1 - Pr_c) \cdot (1 - backoff) \tag{7}$$

4 Algorithms Design

AODV HELLO packets are being used for exchanging the mobility parameters between the neighbor nodes. Modified HELLO packets carry the movement velocity and the coordinates of the beginning and ending of its motion. Using these beginning and ending coordinates, nodes calculate the direction of the motion respectively using Eq. 1. When network layer receives data from upper layers that to be delivered at destination node, it estimates the available bandwidth using the equation. If the available bandwidth is greater than the bandwidth requisite of the application to support QoS delivery of the traffic, the source node broadcasts the RREQ packet to initiate the route discovery process. We have modified the RREQ packets as shown in figure to carry the requisite bandwidth and the medium availability rate.

When a RREQ packet reaches an intermediate node, the node estimates the available bandwidth of the link using Eq. 7. The bandwidth requirement is being validated against the estimated available bandwidth as per the admission control constraints and QOS support. If the validation is true, the node replaces the information passed by the predecessor node in RREQ packet by its own information and broadcasts it further; else, the node discards the RREQ packet.

When the RREQ packet reaches the destination node and the admission control requirements found acceptable, the node generates the RREP packet and acknowledges it back to the source node on the reserve route. When a node finds that the available bandwidth is not sufficient to support the requisite QOS and admission control requirements or link failure occurs due to nodes mobility, then it generates a RERR packet and forwards it to the source node. On receiving this REER packet, the source node pauses the transmission of the data and initiates new route discovery process.

5 Simulation and Result Analysis

In this section, we present the details of the simulation setup used to test the effectiveness of our proposed approach and analysis of the results obtained. We use the Qualnet simulator to create the target MANET scenario which consists of the following main parameters: (i) Simulation time is set to 500 s; (ii) random waypoint mobility model with constant node mobility of 10 m/s is configured; (iii) routing protocols used are AODV [2], BAND-MR [1], and MBA-AODV (i.e., our proposed); (iv) the network consists of 60 nodes deployed randomly in an area of $1000 \times 1000\,\mathrm{m}^2$; and (v) video trace file generated from a real-time video stream with variable bit rates per second (i.e., from 33 bytes to 37,318 bytes) are used to model the source nodes.

5.1 Result Evaluation

The network is stressed with the increase in network load in each simulation round by introducing two new data sessions in the network. The source–destination pairs are selected randomly in the network. Each simulation result is the average of ten simulation runs done on different seed values.

As shown in Fig. 6, the ACR (i.e., the ratio of the total admitted to the total requested data sessions) of the AODV is 100% as no admission control scheme is running on it, while the ACR of BAND-MR and MBA-AODV starts dropping as the number of sessions increases beyond four. This is because as the number of sessions increases the network is not able to accommodate new data sessions due to the lack of bandwidth on discovered routes. However, the accurate and mobility-aware nature of our proposed MBA-AODV is able to accommodate more number of data sessions in the network and thus increases the network throughput without decreasing the network performance.

Figure 7 shows the QSR (i.e., percentage for which an admitted data session gets the requested bandwidth) for all the comparing protocols. As shown in Fig. 7, the AODV performs worse due to the un-availability of any admission control method, while the BAND-MR protocol's QSR decreases with increase in the number of data flows in the network. This is because the BAND-MR is unable to accurately estimate the remaining bandwidth of links during its route discovery process as it does not consider the node mobility which is addressed in MBA-AODV. This metric also shows that the MBA-AODV protocol is able to provide QoS guarantees for the whole duration of the data flow and thus increases the QoE for the end user.

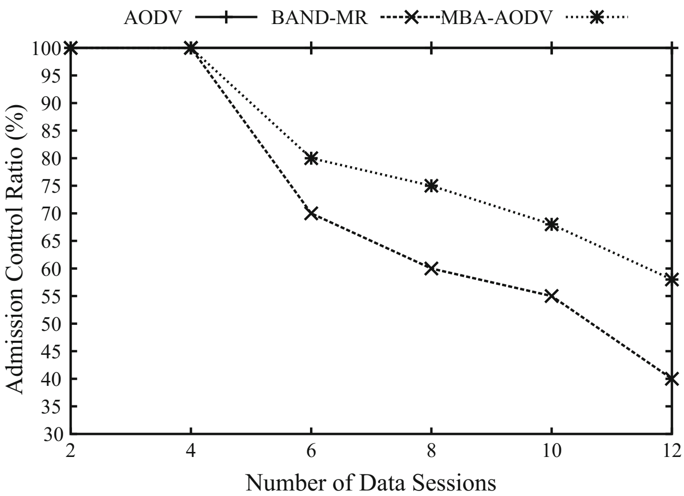

Fig. 6 Admission control ratio with increased network load

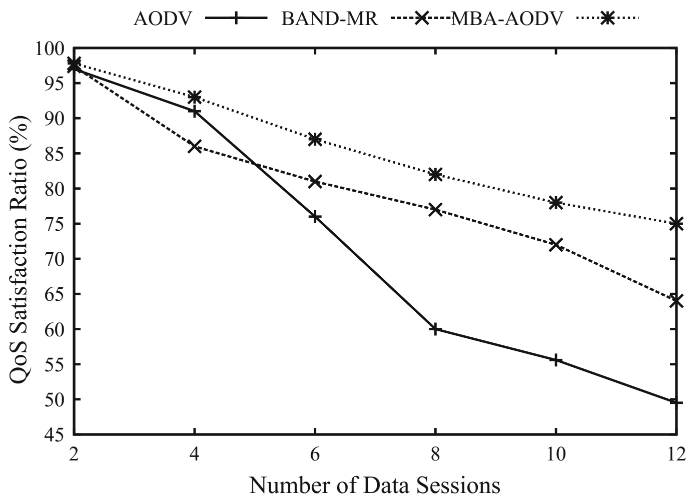

Fig. 7 QoS satisfaction ratio with increased network load

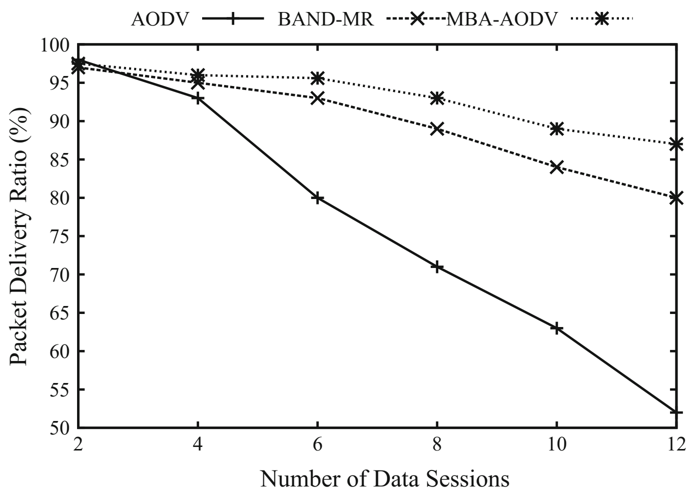

Fig. 8 Packet delivery ratio with increased network load

Figures 8 and 9 show the effect on PDR and EED of the increase in network load for all the three comparing protocols. As shown in Fig. 8, the PDR of all the protocols decreases with increase in network load because the contention and intermediate routes queue overflows. However, the PDR is high for MBA-AODV as it includes only the data sessions for which the required bandwidth is available on the discovered routes, and the accuracy in the estimation method is the reason behind its higher PDR when compared with the BAND-MR protocol. Similarly, the EED of

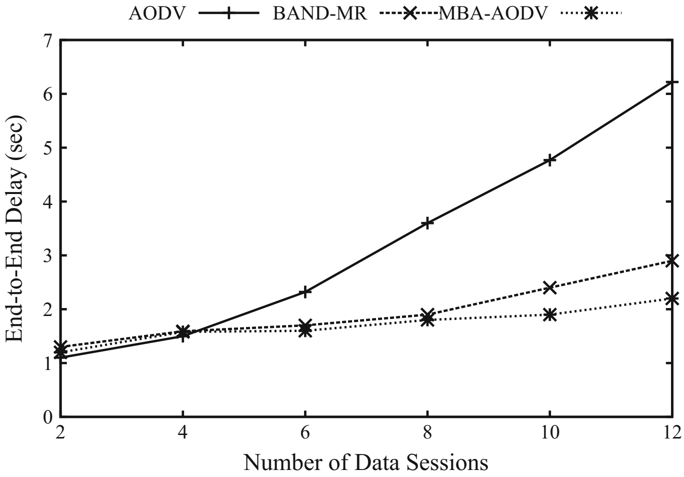

Fig. 9 End-to-end delay with increased network load

MBA-AODV is lower than the BAND-MR because the number of re-routing is lower in case of MBA-AODV due to the selection of high-bandwidth routes for data flow transmission. Also, the lower contention in MBA-AODV leads to the lower number of MAC layer re-transmissions, which leads to the lower EED.

6 Conclusion

In this paper, we presented a bandwidth-aware routing protocol that uses node mobility as an additional metric during its route discovery process. The simulation results clearly show the effectiveness of proposed approach along with the admission control ratio and QoS satisfaction ratio. It can be concluded from the theoretical and simulation analysis that using the mobility and admission control techniques into account during the route discovery greatly enhances the QoE of the received video traffic for the end user as its increases the packet delivery ratio and decreases the end-to-end delay for the received packets. In future, we are planning to emulate our proposed approach with real-time video streaming to evaluate its effectiveness in real-world scenarios.

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