Wireless Pers Commun (2013) 70:743–757
DOI 10.1007/s11277-012-0718-z

The Mobility Issue in Admission Controls and Available Bandwidth Measures in MANets

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Abstract This paper is focused on the QoS (Quality of Service) in IEEE 802.11 MANETs (Mobile Ad hoc Networks). The QoS support like resources allocation in any network is relied to the ability to estimate the availability of these resources. The bandwidth is main resource, which the estimation of its availability is an open issue to research in MANets. In order to improve the available bandwidth measurements, this paper proposes a new approach named **IBEM** (Improved Bandwidth Estimations through Mobility incorporation) in IEEE 802.11 MANets. Seen that the measurement failures in MANets are due to neglecting some features of such networks, and mobility is the principal characteristic. The mobility is neglected in all existing bandwidth measurement approaches. The proposed approach aims to incorporate the mobility criteria in the available bandwidth estimations with specific manner. The comparative results with bandwidth estimation methods in the literature testify the improvement brought by this approach.

Keywords IEEE 802.11 MANet · QoS · Available bandwidth · Mobility

1 Introduction

The standardization of new variant technologies of IEEE 802.11 [1] has become necessary due to the growing use of such networks and the applications requests. Knowing that, IEEE 802.11 networks are able to provide some QoS level through the service differentiation by IEEE 802.11(e) amendment. However, no solution has been standardized for resources

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allocation like bandwidth (which is necessary for some today flows). This lack is due to the absence of safe admission control, where, the problems of false admissions are still present with current solutions.

The available bandwidth between two neighbor nodes is the maximum throughput that can be achieved between these two peers without disrupting any already ongoing flow in the network. Thus, available bandwidth depends on the ongoing flows in network, whereas, the wireless link's capacity is the maximum throughput that flow can to achieve between two neighbor nodes regardless of any ongoing flow in network.

Consequently, the false admission means the admission of flows whose bandwidth consumption is beyond to which is available in network. The leading cause of false admissions is the inaccuracy of available bandwidth estimations. When this resource is over-estimated, it will cause the false admission.

In order to provide a safe admission control, we present in this paper a new approach that improves the available bandwidth estimations. By a thorough study of available bandwidth estimation methods and admission control solutions, we noticed that the estimation failures are due to the neglect of some network criteria. The mobility which is major criterion of MANets, is still not treated specifically by any existing solution of admission control and/or bandwidth measurements. So through this paper we will see how the neglect of mobility criteria makes the available bandwidth estimations erroneous and its affects in admission controls. The approach IBEM that we propose incorporates the mobility in available bandwidth measurements with specific manner, allowing more accuracy and a more safe admission control, where the comparative study with existing solutions has given a satisfy improvement results.

This paper is organized as follow: Sect. 2 presents related work on available bandwidth estimations and admission controls. In Sect. 3, we will present the motivation points and the mobility problematic that is still presents in current solutions. Section 4 introduces our measurement solution IBEM, which incorporates the mobility feature in the available bandwidth measurement to improve it in IEEE 802.11 MANETs and therefore the admission control. We will present in Sect. 5 some results obtained through simulations, which demonstrate the gain of our proposal against the recent solutions like ABE-AODV [2] and IAB [3]. Finally, we conclude in Sect. 7, and present some perspectives.

2 Related Work

The solutions of bandwidth allocation and admission control are loaded by methods of availability measurement of this resource. As well, the performances of these solutions are distinguished following the accuracy of methods that are used to estimate the available bandwidth. However, the measurements accuracy is linked to the network behavior and its features that are taken in consideration.

Given that MANets allow autonomy and independence of any fixed infrastructures or coordinating points, the network nodes must self organize to transfer data packets or any information by managing the mobility and wireless physical characteristics from source to destination. Therefore, the use of multi-hop communications is unavoidable. So, to estimate the end-to-end available bandwidth, some authors (like in SLoPS method [4]) proceed to send packets of equal size (probe packets) from a source to destination. The source increases gradually the emission rate of probe packets. Measurements of the characteristics of this particular flow are performed at the receiver's side and then converted into an estimation of the end-to-end available bandwidth. Such methods are considered as actives measurements, as additional packets (probe packets) are used for estimations. These methods type (actives measurements) are developed firstly for the wired networks, and then reused in wireless networks. The SLoPS approach is an example of reusing of the approach TOPP [5]; however, the actives measurements turn out less accurate in wireless networks, given the physical and topological features of such networks.

Globally in wireless networks, the metrology is reoriented to be passive. In other terms, the measurements are based-on the monitoring of node activities and networks behavior. One of these passive estimation techniques is used by RENESSE and his team in QoS-AODV [6]. The authors propose that each node computes a value named BWER (Bandwidth Efficiency Ratio), which is the ratio between the numbers of transmitted and received packets. After that, BWER is broadcasted to the one-hop neighborhood through "Hello" messages. And the available bandwidth is considered as the minimum of available bandwidths over a closed single-hop neighborhood.

Given that in wireless networks, the power of an emitted signal by node, it weakened along the traveled path. This weakness is mainly according to the traveled distance and the interferences. The power of receiving signal must be equal or upper than some threshold (that we note "$\mathbf{Th_C}$") to receive correctly the packets (theoretically, $\mathbf{Th_C}$ is accorded to the traveled distance $\boldsymbol{C_d}$, which is communication radius or communication distance). In wireless networks, we distinguish two area types for each node. The communication (or transmission) area, wherein the power of the transmitted signals by node, is upper than $\mathbf{Th_C}$. The second area, which is the carrier sensing area, the power of transmitted signals by node, is less than $\mathbf{Th_C}$ and equal or upper than some threshold that we note "$\mathbf{Th_S}$" (theoretically, $\mathbf{Th_S}$ is also accorded to the traveled distance $\boldsymbol{d_S}$, which is sensing radius, and $\boldsymbol{C_d} < \boldsymbol{d_S}$). In IEEE 802.11-based networks, the carrier sense radius is about twice the transmission range ($\boldsymbol{d_S \approx 2\, C_d}$).

The medium is also considered as busy on carrier sensing area when the signals are detected. This means that the medium as it is shared between nodes on transmission range; it is also shared on sensing range. Therefore, in BWER value where only the transmission areas are considered, it makes the solutions like QoS-AODV protocol not able to take an accurate medium availability rate and so the bandwidth availability at node.

For more accuracy, we adopt in our approach the method that is used in QoS-aware protocol, proposed by Chen in [7].

The QoS-aware routing protocol is dedicated to the admission control flow depending on throughput requested by applications and available bandwidth on the network to meet the requirements of QoS.

In this method, each node monitors all its physical activities. All times when node transmits any information are considered as busy periods (that we note $\boldsymbol{P_{busy}}$) of medium. Also times when the node receives any signal upper than $\boldsymbol{Th_S}$, are also considered as busy periods. The computed periods are updated periodically every $\boldsymbol{\Delta}$ time $\boldsymbol{\Delta}$ is called the measurement period). From that, the medium availability times $\boldsymbol{P_{idle}}$ are also computed and defined as: $\boldsymbol{P_{idle}} = 1 - \boldsymbol{P_{busy}}$. Then, the available bandwidth at node is computed by multiplying the medium availability rate during $\boldsymbol{\Delta}$ by the medium capacity $\boldsymbol{C}$:

$$\boldsymbol{AB_s = (P_{idle}/\Delta \cdot C)} \tag{1}$$

In multi-hops communications, the nodes contend among themselves (including nodes that are in carrier sensing range and participate in the communication). This leads to the contention intra-flow [8], where some authors aim this issue by predicting all path nodes in sensing range. In fact, Yaling and Kravets proposed in [9] the $\boldsymbol{CACP_{power}}$ variant, to increase the node transmission power during the "Hello" packet exchange (packets used by the routing protocol) in order to identify nodes that are in carrier sensing range and so predict the contention intra-flow.

Note that all existing solutions such as IAB, take the hypothesis that available bandwidth on the end-to-end path is defined as the minimal available bandwidths at among nodes in that path. Therefore, the available bandwidth on single wireless link is defined as the minimum of the available bandwidths on its both ends. For example, let the wireless link (s, r) built by the two neighbor nodes (s) and (**r**), whose the available bandwidth (computed through Eq. 1) $\boldsymbol{AB_s}$ and $\boldsymbol{AB_r}$ respectively, the available bandwidth on link (s, r), which note ***AB s,r*** is defined as:

$$\boldsymbol{AB_{s,r} = Min\{AB_s, AB_r\}} \tag{2}$$

This definition was valid until Sarr and his team present in [2] the new approach ABE-AODV. In [2], the authors present some scenarios in MANets where even bandwidth availability at both sides of single wireless link ($\boldsymbol{AB_s} > 0$ and $\boldsymbol{AB_r} > 0$), none-data can be transmitted for example from the sender (**s**) to the receiver (**r**). Scenarios where the medium is available at sender (**s**) to transmit data, but it is not available at receiver (**r**). In other terms, the medium idle periods on both sides of link do not overlap. Such problems are also called the idle periods synchronization. And such scenarios are very common in MANets.

Evaluating accurately the impact of this overlap requires a fine clock synchronization mechanism, and large information's exchange, which represents a huge overhead. Therefore, the authors propose to use the average of the overlap times to define the available bandwidth. So, on single wireless link, the available bandwidth is newly defined as (which is definition adopted in our approach IBEM):

$$\boldsymbol{AB_{s,r} = (Pr_{idle}/\Delta) \cdot (Ps_{idle}/\Delta) \cdot C} \tag{3}$$

- $\boldsymbol{Pr_{idle}}$ and $\boldsymbol{Ps_{idle}}$ are the medium idle periods at nodes (**r**) and (**s**) respectively.
- $\boldsymbol{Pr_{idle}\Delta)} \cdot \boldsymbol{(Ps_{idle}\Delta)}$ is the average of the medium availability on the wholly link.

As its name indicates, ABE-AODV is integrated into AODV protocol, the throughput desired by the applications is added in the RREQ (Route REQuest) packet. During the broadcast of the RREQ from a source node, the admission control is executed at each node receiving this packet by comparing the desired bandwidth to which is estimated on link as available. This mechanism will allow the circulation of QoS flows in the network without being disrupted by others (without QoS violations).

We note that all existing approaches including ABE-AODV use an exchange of "Hello" packets periodically in order to reduce the mobility impact on the admission controls. Therefore, the detection of link expiry for ABE-AODV (as example) is made according to the method used in AODV.

3 Motivations

Although the measurement approaches were reoriented to be passive in IEEE 802.11 MANets, but some reliability in accuracy terms is still not reached in order to provide a safe admission control. And to reach this reliability, we must consider all the networks features in measurements, which is not the case for existing approaches. In [2], we could see the efficiency of ABE-AODV against other older methods by taking into consideration the random synchronization of the idle periods. However, the main element, which is the mobility that characterizes especially the MANets, is not treated whatsoever by ABE-AODV or any

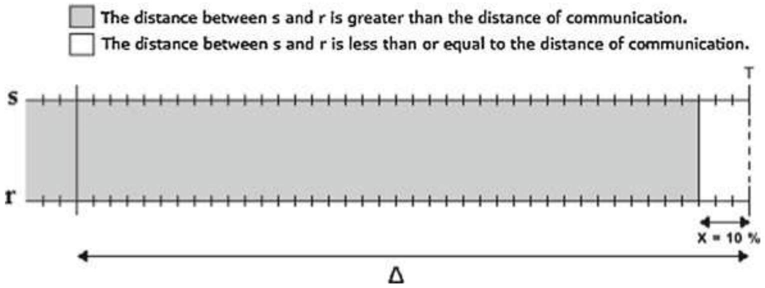


Fig. 1 Link status during a **Δ** measurement period

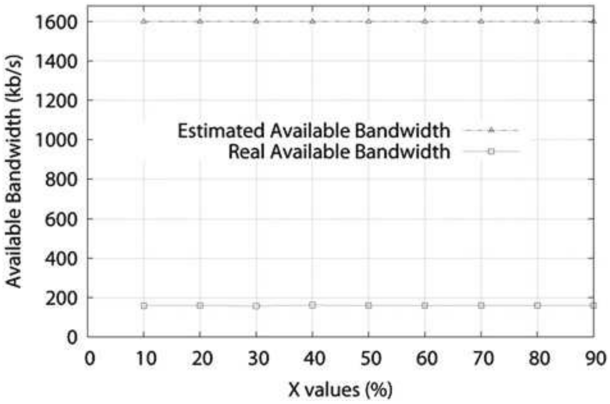


Fig. 2 Available bandwidth estimation results with ABE Technique

other measurement approach or admission control solution. Increasing the rate exchange of "Hello" packets is the solution most used in order to reduce the mobility impact.

Let us consider that there is a link (s, r) in IEEE 802.11 MANet with a high level of mobility. This high mobility leads to an instability of the (s, r) link because of a distance changing between the two nodes (**s**) and (**r**). Suppose there is no traffic on the network and the distance between the two nodes is larger than the distance of communication (each node is outside of the communication area of the other). At the time T the distance between the two nodes (**s**) and (**r**) is enough for a communication (each one is inside the communication area of the other).

Figure 1 shows the (s,r) link state during the measurement period **Δ**. We remark that this link exists only during X = 10 % of **Δ** measurement (X value represents the percentage of the link existence during the period **Δ**). At the T instant, all measurement approaches can be applied (as ABE-AODV), where the link is built and information between both link peers through "Hello" packets is possible.

We intend to compute the available bandwidth on the link (s, r) (the scenario depicted on Fig. 1) with the measurement method that is used by ABE-AODV at time T, with different and several values of X. These measurements are made by using the simulator NS-2. The simulated medium capacity is set to 2 Mbps, resulting, in a 1.6 Mbps maximum application-layer throughput. The estimations of ABE-AODV and all existing approaches give same results in such scenario. The results are showed in Fig. 2 through "Estimated Available Bandwidth" graph that we compare to the real available bandwidth (green graph).

Following the estimations results of ABE-AODV (where $\boldsymbol{\Delta} = 1$), we understand that 1.6 Mbps of bandwidth was available during the period [(T − 1)…T], regardless the existence rate (X) of the link (s, r) during this period $\boldsymbol{\Delta}$. So up to 1.6 Mb of traffic could be transmitted during that period even if the link (s, r) exists only for X = 10 % of the period. However, the estimations results are false, because 10 % of $\boldsymbol{\Delta}$ is 0.1 s and 1.6 Mb of traffic cannot be transmitted in 0.1 s with 1.6 Mbps of bandwidth. Therefore, the available bandwidth is largely over-estimated. So this error on estimations is due to neglecting the mobility, and we will see that this error can affect the traffic circulation in MANets by penalizing some applications through the false admission controls and the QoS violations.

4 Available Bandwidth Estimation with Mobility Management

Firstly, to solve the accuracy problem in available bandwidth estimations in the scenario of the previous section (Fig. 1), and avoid the over-estimations, we add the mobility criterion $\boldsymbol{M}$ to the Eq. 3. For now, we consider that this mobility criterion is the rate of the link existence during the last measurement period (the value of X in Fig. 2 at T). Hence, we obtain the new equation with the criterion of mobility:

$$\boldsymbol{AB_{s,r} = AB_{Expected} \cdot M} \tag{4}$$

- $\boldsymbol{AB}_{\textbf{Expected}}$ is the available bandwidth obtained by Eq. 3.

$\boldsymbol{AB_{s,r}}$ obtained by Eq. 4 is the available bandwidth that we use in our measurement approach IBEM, but the value of $\boldsymbol{M}$ will be different and in what follows we'll see the new value of $\boldsymbol{M}$ and why.

4.1 Link Expiration in Bandwidth Measurement

Figure 3 shows a link (s, r) during two consecutive measurement periods $\boldsymbol{\Delta}$, with two [(a) and (b)] identical activities scenarios (the same bandwidth consumption), but in different states:

- Stable (Fig. 3a): the distance $\boldsymbol{d}$ between the two nodes of this link is less than or equal to the distance of communication $\boldsymbol{C_d}$ at any time (and any $\boldsymbol{\Delta}$), we note: $\forall \boldsymbol{t_k / k} \in \boldsymbol{[0..n]}, \boldsymbol{d} \le \boldsymbol{C_d}$ (where $\boldsymbol{t_k}$ is time unit of calculus in $\boldsymbol{\Delta}$ period, and $\boldsymbol{n} \in \boldsymbol{N^*}$).
  We found this type of links in wireless networks with stable topologies. Note that the stable links are the only scenarios discussed in the existing approaches of available bandwidth measurements.
- Unstable (Fig. 3b): We say that a link is dynamic or unstable, if there are some moments when the distance $\boldsymbol{d}$ between the two nodes is largest than communication distance $\boldsymbol{C_d}$ (which can be observed at $\boldsymbol{t_j}$ instant in Fig. 3b), and we note: $\exists \boldsymbol{t_k / k} \in \boldsymbol{[0..n]}, \boldsymbol{d > C_d}$.

The absence of mobility criterion in the existing measurement methods such as used by ABE-AODV has bad consequences, particularly in the admission control. It is clear that the available bandwidth $\boldsymbol{\alpha_1}$ (figure 3 (a) at $\boldsymbol{t_{n-1}}$) estimated by ABE-AODV measurements or even through equation 3 (with that represents $\boldsymbol{M}$ value) will have the same value as $\boldsymbol{\alpha_2}$ (Fig. 3(b) at $\boldsymbol{t_{n-1}}$). So if ($\boldsymbol{\alpha}_1 = \boldsymbol{\alpha}_2$), regardless the admitted bandwidth for allocation at $\boldsymbol{t_{n-1}}$ on Fig. 3 (a) whichever $\boldsymbol{\alpha_1}$, it can be admitted also whichever $\boldsymbol{\alpha_2}$in second scenario (Fig. 3 (b) at $\boldsymbol{t_{n-1}}$), while the (s, r) link in this second scenario will be available just during ($\boldsymbol{t_{n-1}}$ to $\boldsymbol{t_j}$) time (during (Y) fragment). Hence the available bandwidth that will be used at $\boldsymbol{t_{n-1}}$ depends also on the probability that link will exist. Therefore, for an accurate value of $\boldsymbol{\alpha_2}$, we must take into

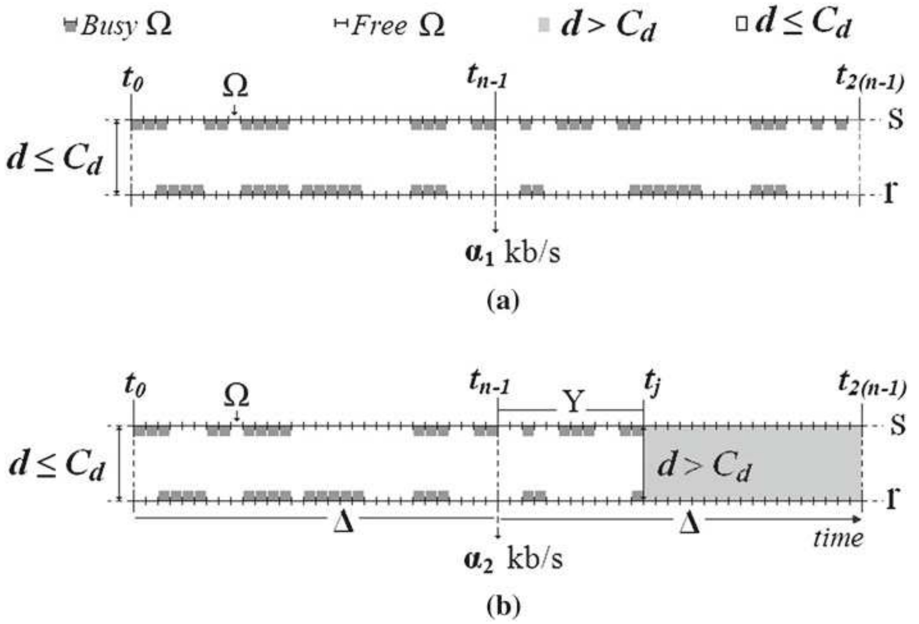


Fig. 3 Expiration link during the available bandwidth estimations. **a** Link (s, r) (stable). **b** Link (s, r) (instable)

account the fragment (Y), and the mobility criterion $\boldsymbol{M}$ is newly defined as the probability of the link existence in the next $\boldsymbol{\Delta}$ measurement period.

$$\boldsymbol{M = (t_j - t_{n-1})/\Delta} \tag{5}$$

- $\boldsymbol{t_j}$ is the moment where the link disparate ($\boldsymbol{d} > \boldsymbol{C_d}$).

Now the problem that arises is to identify the value of $\boldsymbol{t_j}$ at the instant $\boldsymbol{t_{n\text{-}1}}$ or before. In this paper, we propose to compute it through the mobility prediction in order to identify the link expiration, and so to predict $\boldsymbol{t_j}$ value.

4.2 Prediction of Link Expiration

Several studies have been conducted in the field of the prediction of movement nodes in MANets. In [8], the authors present a fairly comprehensive approach that a similar we adopt in IBEM, which allow to estimate the $\boldsymbol{t_j}$ value accurately and that is also suitable for the any channel environment (free and/or shadowing spaces) and any mobility model.

The nodes motion is defined through the two following criteria: the motion velocity and the motion direction. We ensure in this paper that a geographical map (on which the network nodes are in motion, as depicted in Fig. 4, where nodes (**s**) and (**r**) are on two different positions) is embedded on each node in network. And each node may have its geographical coordinates through GPS (Global Position System) [10]. Therefore, each mobile node in network is able to identify the coordinates of its position, the coordinates of its motion beginning and the destination coordinates of its motion.

Each node that would like to change position (the motion beginning) should be able to inform its neighbourhood (see the protocol design section) about its motion criteria (velocity and direction). Considering that node **s** (respectively **r**) moves with velocity V_S (respectively

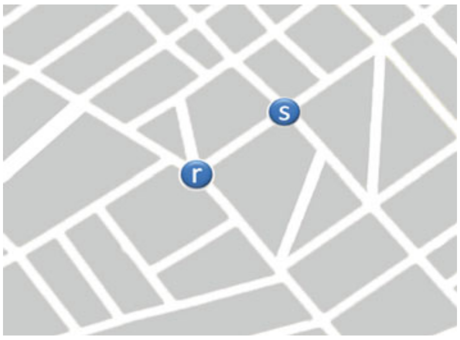


Fig. 4 Motion map embedded on each mobile node

$\mathrm{V_r}$), and following direction α (respectively β). $\boldsymbol{t}_j$ value is calculated as (for example at node **s**):

$$t_j = \begin{cases} \infty \quad \text{if} \quad (V_s = V_r \quad \text{and} \quad \alpha = \beta) \\ \frac{-(ef+gh)+\sqrt{(e^2+g^2)\cdot C_d^2-(eh-gf)^2}}{(e^2+g^2)} \text{ else} \end{cases}$$

By considering:

$$\begin{aligned} e &= V_s \cdot \cos(\alpha) - V_r \cdot \cos(\beta) \\ f &= x_s - x_r \\ g &= V_s \cdot \sin(\alpha) - V_r \cdot \sin(\beta) \\ h &= y_s - y_r \end{aligned}$$

4.3 Collisions and the Available Bandwidth Measurements

Above, we have saw about effects of the nodes state of wireless link on available bandwidth. However, as described in Fig. 5, the nodes of wireless link (for example **s** and **r**) are not alone in network, there are other nodes (noted in Fig. 5 by **N**) on neighbourhood. So there are others transmission activities that have effects on the data transmissions on the studied wireless link (**s**, **r**). Especially, the effects of collisions, knowing that, IEEE 802.11 networks

Fig. 5 The collisions in available bandwidth measurements

are subject of such problems. When data packet collides, it will trigger the process of *backoff* at the sender. The *backoff* process aims to reduce during some period the possibility to access to the medium (transmission). Although the sum of the medium idle periods $\boldsymbol{P_{idle}}$ is different to zero, but some of these idle periods are considered as busy. Therefore, there is a proportion of available bandwidth that is lost.

Indeed, the collisions problems have to be considered accurately, otherwise it conducts to biased estimates. In [11], we present an approach that estimates accurately the losses of available bandwidth due to collisions. For simplicity raisons and in order to conduct comparative study (that aims the mobility feature), we rather integrated the collisions in measurement equation in a manner that looks a bit to which is used in [2], the collision probability ($\boldsymbol{P}$) and the average of times (***backoff***) taken by the backoff process.

$$\boldsymbol{IBEM_{s,r} = (Pr_{idle}/\Delta) \cdot (Ps_{idle}/\Delta) \cdot C \cdot M \cdot (1 - P) \cdot (1 - backoff)} \tag{6}$$

- In [2], the collision probability is based on the rate of "Hello" packets collisions. In IBEM, $\boldsymbol{P}$ is defined as the conditional collision probability[12].

5 Protocol Design

Aiming specially examine the mobility criterion and for comparison purposes, we have chosen that the protocol design of IBEM will similar to the protocol version of ABE-AODV. So, IBEM is also incorporated in protocol. Therefore, we take the advantage of the "Hello" packets exchange in order to exchange the parameters of mobility between neighbour nodes. Each mobile node indicates on its "Hello" packets the velocity of its movement, and also the coordinates of starting and ending of its motion (from these two last parameters, the motion direction is computed).

When the source has a data flow, it verifies firstly its availability of bandwidth estimated through Eq. 1, if the check is positive, it broadcasts the Route REQuest packet (RREQ). An extension is applied to the RREQ packet with a new field, allowing the source to indicate the bandwidth which asks, and the medium availability rate on its side. When a node receives a RREQ, it performs the admission control by comparing the bandwidth requirement to the estimated available bandwidth on the link, which is calculated by using the Eq. 6. If this check is positive, the node substitutes the informations of its predecessor by its own informations on RREQ, and forwards it; otherwise, the node discards the RREQ. When the destination node receives the RREQ and the admission control is positive, the node generates a Route REPlay (RREP) packet that sends it back to source node on reverse path.

When a node discovers that available bandwidth is no longer sufficient on the reserved link, as in Fig. 3b at $tn - 1$, then it generates a Route ERRor (RERR) packet and sends it to the data flow source (order that source takes decision to stop its transmissions and that it finds another path). Also, when the node predicts a link failure due to mobility, then it sends also the RERR indicating on the predicted time.

Note: In IBEM, predicting the link expiration doesn't reject the flow automatically, but it can be admitted if it will be satisfied in the duration of link existence.

6 Evaluation

We perform an evaluation through simulations by using NS2. An comparative study is presented in this section, between the simulations results when IBEM, AODV, ABE-AODV and

IAB solutions are enabled. The medium access scheme used is CSMA, the medium capacity is set to 2 Mbps, and 1,000 bytes of data packet's size are used. The below graphs are the average results of several simulations, where different parameters are considered as traffic load, transmission times and the mobility models. The length of the radio propagation range for each node is 250 m ($\boldsymbol{C_d}$).

6.1 Evaluation in Manhattan Mobility Model

This first simulation includes 20 mobile nodes, which are randomly positioned. Five CBR flows are generated, and the required bandwidths are chosen randomly. The simulation lasts 80 s and one flow is started every maximally 4 s. Nodes move according to Manhattan mobility model, where each one moves by random speed, which is about 20 m/s at maximum. The street length on this Manhattan model is 100 m where nodes move through. At each arrival in a corner, the node can stay where it is, continue its movement in the same direction, or change it.

To show the importance of the admission controls, we also provided results obtained with AODV routing protocol. Figure 6a shows the throughputs of the five flows when AODV is used. Since no admission control is performed in AODV and no QoS guarantee exists, each new requesting flow which reaches the desired destination is transmitted automatically. Therefore, the five flows are in transmission despite the lack of the available bandwidth. As it is depicted, while the network is congested, the new flows are added, resulting in a dramatically decreasing in throughputs of the flows.

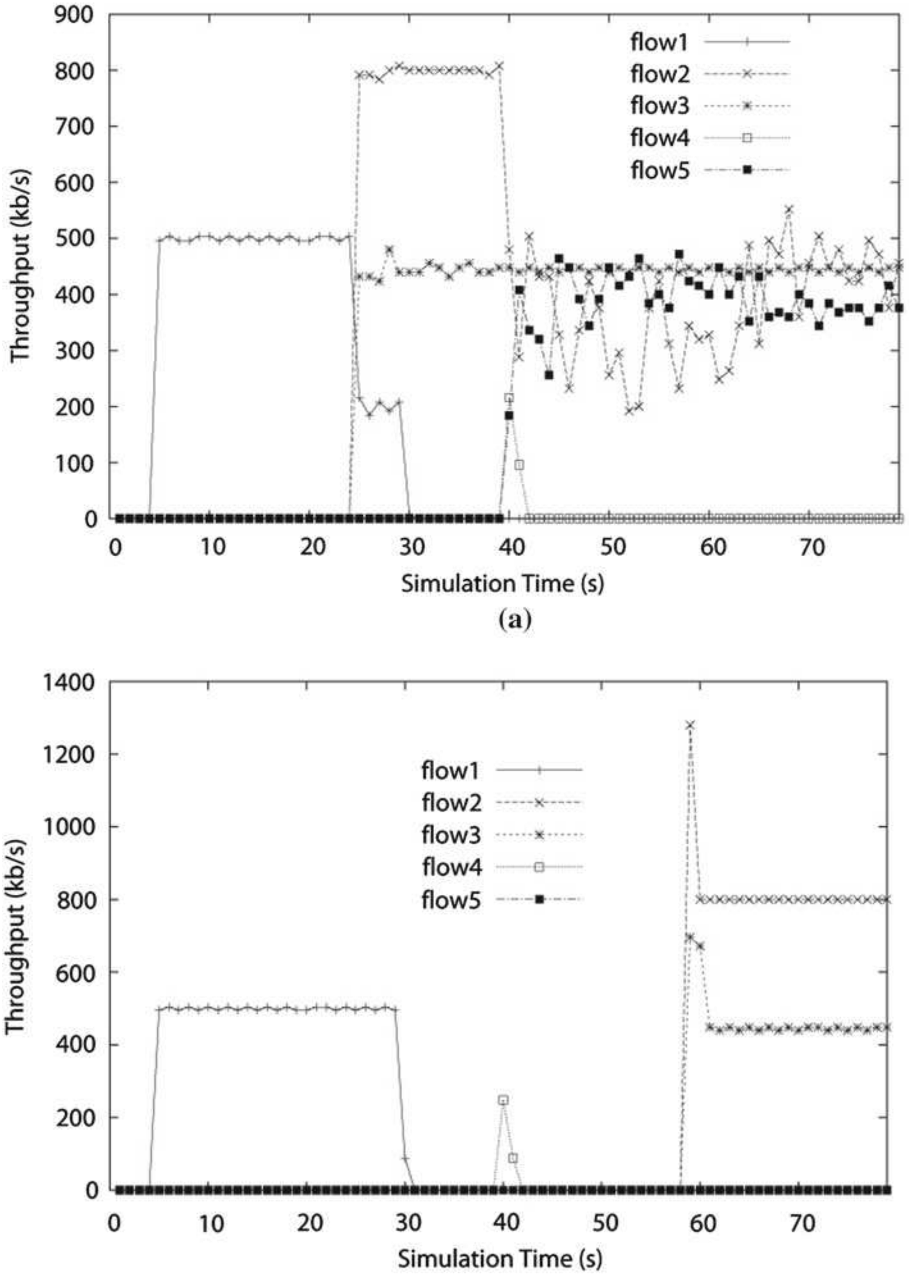
Figure 6b shows the throughput of the five flows along simulation time when ABE-AODV is enabled. In the absence of a subsequent monitoring of the bandwidth evolution depending on the mobility, the flow 1 continues to consume bandwidth while the path is in failure, penalizing the admission of flow 2 and flow 3, given the slow process of detecting the link failure. We also note that the absence of mobility criterion in ABE-AODV computation, has allowed flow 4 to be admitted on path which contains a link being missing, which results to losing it, as depicted in the diagram of Fig. 6d and without any delivery as depicted on diagram of Fig. 6e.

Figure 6c shows the throughput of the five flows when the admission controls are activated through IBEM. We observe that the bandwidth resource on the network is more exploited (by increasing the bandwidth consumption where the packets delivery has been improved) in comparison to ABE-AODV results. Through the equitable utilization of this resource, flow 1 is stopped because of the mobility that has reduced the available bandwidth with which it was admitted, allowing a non-belated admission of flow 2 and flow 3. Also, the periods of network unemployment due to the admission of flow 4 by ABE-AODV, are erased in IBEM results.

6.2 Evaluation in Random Way Point Mobility Model

The simulations include 30 nodes, randomly positioned. Five CBR flows are generated using packets of 1,000 bytes, and the required bandwidths are chosen randomly between 500 and 550 kbps. The simulation lasts 100 s and one flow is started every maximally 5 s. Nodes move according to a random way point mobility model, where each one moves by random speed, which is about 20 m/s at maximum (as in first scenario).

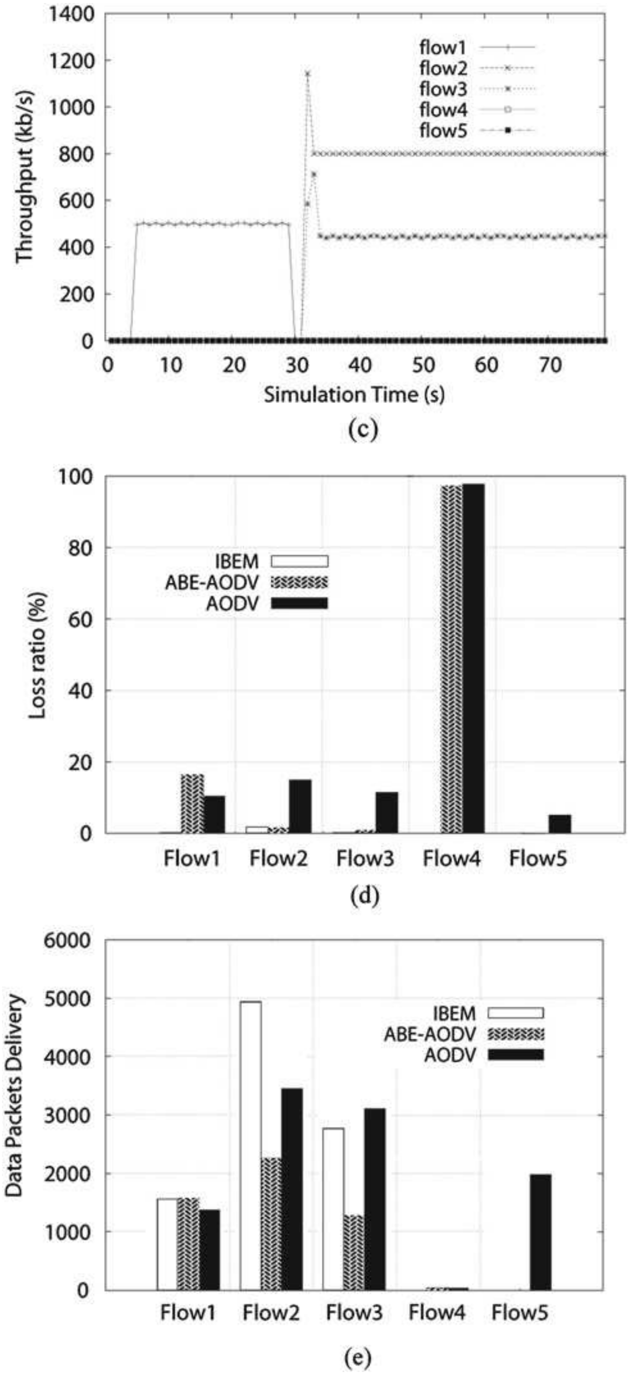
In Fig. 7a appears the throughputs evolution when IAB is enabled. Flow 1, flow 2 and flow 4 are admitted in a stable situation without any disruption. This stability stays until



(a)

(b)

Fig. 6 Throughput, Average loss ratio (**d**), and data packets delivery (**e**) of each flow using **a** AODV, **b** ABE-AODV and **c** IBEM

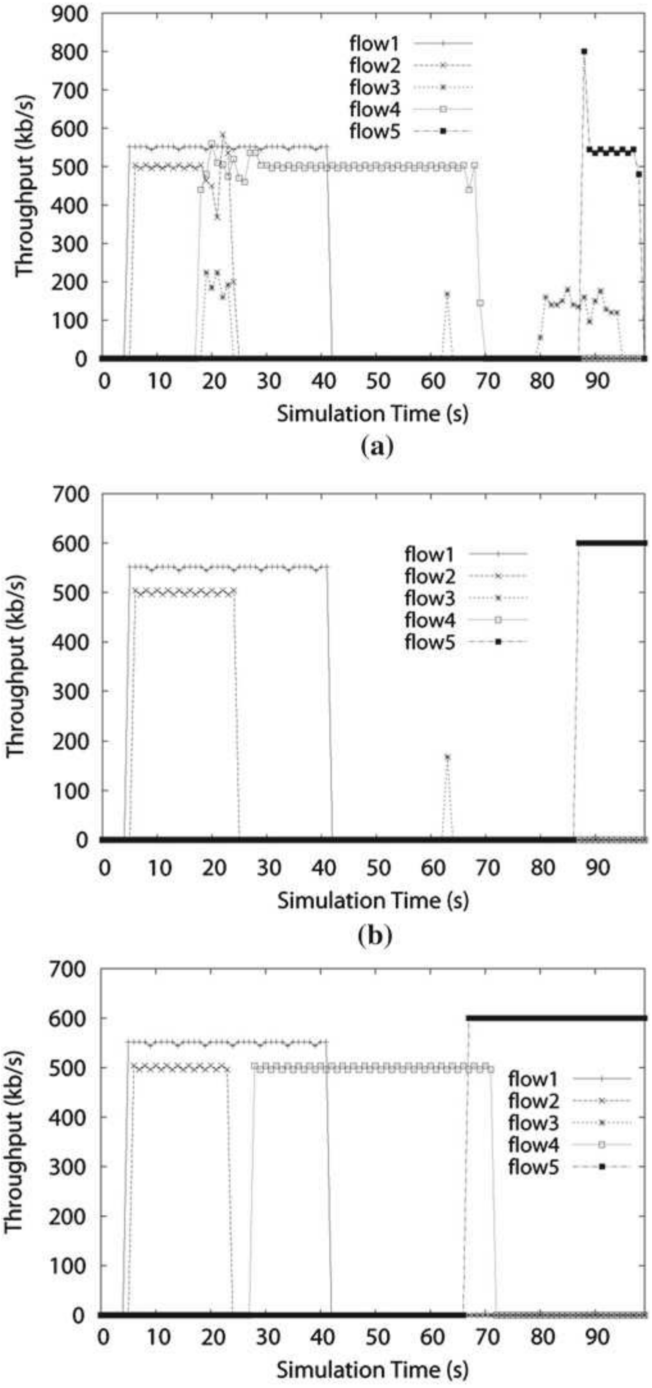


(c)

(d)

(e)

Fig. 6 continued



(c)

Fig. 7 Throughput of each flow using **a** IAB, **b** ABE-AODV and **c** IBEM the admission of flow 3 at 18th seconds (the time where its path is built). At 80th seconds, appears congestion by throughputs instability of the admitted flows.

In opposite, Fig. 7b shows that ABE-AODV was too severe, and fails to perform an accurate admission control, where flow 4 is rejected and the admission of flow 5 is delayed. Since, the absence of subsequent monitoring of the network mobility, flow 3 is admitted despite that its path is broken. Besides, the delayed admission of flow 5 has caused an under-consumption of bandwidth during the first times of its transmission.

However, as shown in Fig. 7c, with IBEM, in first time, all flows are admitted except the flow 3 and flow 5 are rejected. As throughputs are stable, all admitted flows are able to fit into the network. By rejecting the flow 3 through the incorporation of mobility criteria in measurements, the flow 5 is admitted without delaying, which has allowed more bandwidth resource exploitation and reducing the unemployment time.

7 Conclusion

In this paper, we present the importance of the taking into consideration the mobility phenomenon in available bandwidth measurements, especially during the admission control. Our solution is based on the prediction of the wireless link expirations. IBEM could be considered as an improvement of the ABE-AODV approach.

The results obtained from a comparison between ABE-AODV and IBEM are satisfactory in terms of the bandwidth consumption and the admission control decisions. We have noticed an improvement of flow circulation where the packets delivery has increased over the network while loss rates have decreased.

As future works, we plan to focus bandwidth allocation activities in multi-hop communications, and also improve the policy trading of QoS on single wireless link.

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