

# Towards a New Approach in Available Bandwidth Measures on Mobile Ad Hoc Networks

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*Abstract: Given the development of multimedia applications with intensive consumption of network resources by the traffic generated, and the emergent use of mobile ad hoc networks, the guarantee of the quality of service (QoS) has become essential. The available bandwidth is the crucial resource, particularly in mobile ad hoc networks, since it is very limited; this is why it must be optimally managed and accurately estimated. Several projects have been conducted to provide new techniques for measuring the available bandwidth in mobile ad hoc networks. But mobility, which is the basic criterion of this type of network, is neglected and isn't processed by any measurement technique proposed. In this paper we disclose the importance of the taking into account this criterion and we will unveil a novel measurement technique ABE\_MM (Available Bandwidth Estimation with Mobility Management) which is an extension of other robust existing measurement methods and which treats mobility in a specific manner.*

*Keywords: ad hoc networks; mobility; estimation; bandwidth; ABE\_MM*

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## 1 Introduction

In Wireless networks, the IEEE 802.11 norm is most frequently used. It provides ad hoc configuration that operates with fundamental mechanism to access on medium, which is called *Distributed Coordination Function* DCF mode [1]. It allows a more flexible communication model than others networks since the user is not limited to a fixed physical location. Mobile ad hoc networks allow autonomy and independence of any fixed infrastructures or coordinating points. Considering topology changes due to the mobility of hosts, these last must self organize to transfer data packets or any information with mobility and wireless physical characteristics management.

Observing the use of multi-hop communication because of limiting the communication range and the traffic diversity transiting the mobile ad hoc networks, the quality of service (QoS) became the subject in art. However, the term QoS is so vague that it has been extensively studied and QoS solutions are increasingly being proposed. The QoS solutions take different concepts to ensure the meeting of criteria required by applications (like bandwidth, delay transmission and others).

Most QoS solutions proposed are interested in particular resources in the network. These solutions are usually embedded with measurement methods of these resources which are the object of their interest. Available bandwidth is a fundamental one of these resources, especially in the 802.11 ad hoc networks, since it is limited and shared by all neighboring nodes; its optimal management is indispensable.

In this paper we focus on the optimal management of bandwidth in 802.11-base ad hoc networks to provide better QoS. This requires prior knowledge of the availability of this resource, where an accurate estimate of available bandwidth is essential. The estimation of available bandwidth is such a delicate operation because of the dynamic topologies of ad hoc networks, where links between nodes may dispartate at any time which has the effect of very frequent disconnection paths.

The available bandwidth estimation techniques in mobile ad hoc networks have experienced real progress in accuracy terms. After a thorough study of these techniques and QoS solutions in ad hoc networks, we noticed that the mobility problem is still persistent. So through this paper we present a new approach, ABE\_MM, which is an extension of the ABE [2] technique (which made the evidence in terms of accuracy, which is why we chose it) to manage mobility specifically in bandwidth measurement. The particularity of this approach is that it can be combined with any other measurement technique of bandwidth on dynamic topologies. A collaboration is used in this paper between the MAC, physical and network layers to respond to our approach. Knowing different methods could be used to respond to our approach.

This paper is organized as follows: In Section 2, Existing Work on Bandwidth in Mobile Ad hoc Networks, we provide an overview on techniques to measure bandwidth and look especially at the technical ABE. In Section 3, we will give motivation points for our approach to managing mobility in bandwidth measurement. In Section 4, we explain the concept of our approach, the protocol extensions and the changes necessary to achieve the ABE\_MM technique, and finally in Section 5, in order to evaluate our approach, a comparison is made between ABE\_MM, ABE techniques and AODV through a network simulator.

## 2 Existing Work on Bandwidth in Mobile Ad hoc Networks

There have been significant changes in the types of traffic types transiting networks, led by the development of different applications. The request for the transmission of multimedia applications in wireless networks has increased significantly. Consequently, the quality of service management has created strong interest. Note that the issues raised in the specific context of wireless networks are different and more complex than those encountered in wired networks.

The majority of QoS solutions are loaded with techniques for measuring the delay, jitter, available bandwidth or other criteria. Consequently, computing the available bandwidth with as much precision as possible must also consider the existing traffic and topology. The available bandwidth of one link (between two neighbor nodes) can be defined as the maximum throughput that can be transmitted without influence on any existing flow in the network. Contrary to this is capacity, which is the maximum throughput that flow can achieve in one idle link on an idle network. The most bandwidth reservation solutions designed to 802.11 based ad hoc networks use passives estimations for available bandwidth. Passives estimations are based on monitoring of the networks activities which corresponds to the radio channel activities (transmissions, receptions, and idle periods) or data transmission quantities. One of these passive estimation techniques used is the QoS-aware protocol, proposed by Lei Chen in [3].

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 QoS-aware, there are two methods used to estimates the residual available bandwidth. In the first method, each node estimates its residual bandwidth by monitoring the free times on radio channel every  $\Delta$  time interval. Monitoring is done at the MAC layer, which detects that the channel is free if three conditions are met:

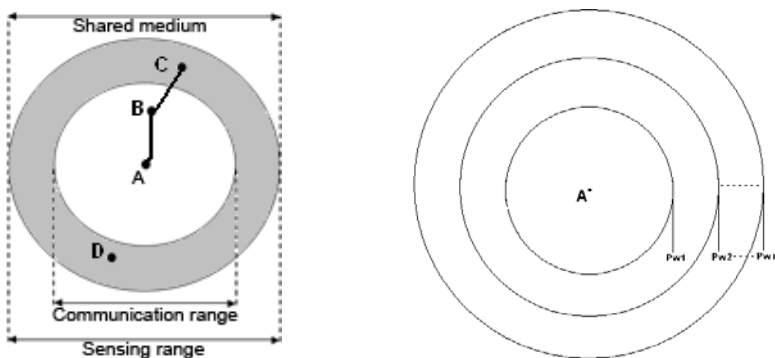
- The NAV's value is less than the current time;
- The receive state is idle;
- The send state is idle.

Then the residual available bandwidth of a node is computed from multiplying the rate of free times on  $\Delta$  interval by the capacity.

Observing that the bandwidth is shared among neighboring nodes, in the second method of available bandwidth measurement in QoS-aware routing protocol, each node broadcasts its current bandwidth consumption value on "Hello" standard message to its one-hop neighbor, and each node estimates its residual available bandwidth from its consumption and the information received from neighbors nodes.

Always keeping the same idea, to transmit the value of bandwidth through “Hello” standard message, RENESSE and his team use in QoS-AODV [4] the BWER (Bandwidth Efficiency Ratio) measurement method, which broadcasts to the one-hop neighborhood by “Hello” messages the ratio value between the number of transmitted and received packets. And the available bandwidth is computed as the minimum of available bandwidth over a closed single-hop neighborhood.

It is known that in wireless networks the power of a signal emitted by a node is weakened along the path mainly according to the traveled distance (particularly on free space). The power of this signal at reception must exceed a certain threshold in order for it to be decoded. The communication zone is the area in which the receiver nodes can decode the signal. But the sensing zone is where the signal strength is below the threshold, and where the nodes detect the signals (then medium activity) and cannot decode it. This means that the medium (Figure 1(a), the medium (then the bandwidth) is also shared between the node A and D) is not shared only on the communication area but also on the sensing area; and solutions like BWER, of which the QoS-aware protocol is one, are not able to take into consideration this phenomenon in bandwidth measurement (because the node A cannot exchange information with node C directly, as depicted on Figure 1(a)).



(a) Sensing and Communication ranges of node A (b) the communication areas changing according to the signals strength

Figure 1  
Sensing and Communication ranges of node A

In order to solve the problem of estimating available bandwidth with taking into consideration the communication and sensing areas, firstly the authors of [5] present a modelling in a theoretical study of the interferences on the carrier sensing zones, and then in [6], they propose the BRuIT protocol which approximates this zone by using the neighborhood, where each node broadcasts to all its neighbors (on communication zone) the bandwidth rate which it uses and also information from all its one-hop neighbors, propagating this information at a two-hop distance. (The information are exchanged by using the Hello packets).

But the solution proposed with BRult fails in some scenarios, as depicted in Figure 1(a), where the node D, which is inside the carrier sensing of node A, can't be reached. The authors of CACP-power [7] propose using a physical layer to increase the transmission power signals when neighboring nodes exchange the information of bandwidth in order to reach the nodes which are inside sensing range and outside the communication range (Increasing the transmission power of signals will increase the communication range Figure 1(b)).

Note that all these solutions take the hypothesis that the available bandwidth on the end-to-end path is defined as a minimal residual available bandwidth among the hosts in that path, as in [10] (The available bandwidth of one link is defined as the minimum between the two residual available bandwidths of the two nodes forming this link). Then such techniques are interested only by a residual available bandwidth of nodes, and constitute a class that is named "node by node" measurement techniques. The other class includes techniques oriented toward the estimation of available bandwidth especially at the links, as in ABE [2] and QOLSR [8]; this class is named "link by link" measurement techniques.

With the goal of moving towards the standardization of available bandwidth measurement techniques, Sarr and his team present in [2] the ABE technique. ABE treats QoS-based bandwidth in ad hoc networks through admission control of new flows in order to avoid any degradation of the existing traffic on the network, and so it requires the most accurate estimate possible. In [2], considering that the random changing of the topology on mobile ad hoc networks is the source of typical scenarios, the authors showed in first time that the hypothesis of "node by node" techniques is not always true because there are some scenarios where the available bandwidth of one link is less than the minimum residual available bandwidth of the two nodes forming this link. These scenarios are very common because of the random synchronization of the idle times between the sender and receiver nodes, for example in Figure 1(a), when the node (A) is in position to send data to the node (B), but this latter at this time is occupied; therefore, despite the availability of bandwidth at the two nodes, the traffic cannot be forwarded because of the non-synchronization of availabilities between the transmitter and receiver.

To address this problem, the authors have used probabilistic methods to define the available bandwidth on the link. For example on the (s,r) link, each node (s and r) monitors the medium at the MAC layer, as has been described with the first method of estimation in QoS-aware. Every  $\Delta$  time (set to 1 second) the ratios of the idle times of each of the two nodes are computed, and the available bandwidth of this link is calculated as follows<sup>1</sup>.

$$b_{(s,r)} = (t_s \cdot t_r) \cdot C \quad (1)$$

<sup>1</sup> The proof of formula (1) and collision probability calculating, are given in [2].

- $b_{(s,r)}$  is the available bandwidth of the link (s,r).
- $t_s$  (resp.  $t_r$ ) is the ratios of idle times on MAC layer of node s (resp. r).
- $C$  is the capacity of the medium.

Collision rates are high in the mobile ad hoc networks; ABE has taken into consideration this problem by adding the probability of nonexistence of collision  $(1-P)$ , where  $P$  is the probability of collision<sup>1</sup>. IEEE 802.11 defines the *backoff* system in order to reduce collision phenomenon. ABE also took into consideration the proportion of bandwidth “ $K$ ” consumed by the *backoff* system, through the average of *backoff* time. So the formula (1) became:

$$ABE_{(s,r)} = (1-K) \cdot (1-P) \cdot b_{(s,r)} \quad (2)$$

- $ABE_{(s,r)}$  is the finale available bandwidth of the link (s,r).

ABE is integrated into the AODV [9] protocol; the throughput desired by the applications will be added in the RREQ packet. During the broadcast of the RREQ from a source node, the admission control will be executed by each node receiving this packet using the equation (2). This mechanism will allow for the movement of traffic in the network without being perturbed by others.

We note that all these techniques use an exchange of “Hello” standard messages periodically (for ABE, it's every  $\Delta$  seconds) for mobility management. Because the protocol design of ABE is an extension of the AODV protocol, the detection of a link expiry is made according to the technique used in AODV. ABE also uses this exchange of “Hello” packets to exchange the bandwidth information between neighboring nodes; i.e. the Node  $r$  will need the  $t_s$  value to run the equation (2).

### 3 Motivations

Passive techniques are best suited for measuring available bandwidth in IEEE 802.11-based Ad Hoc networks. But reliability in accuracy terms is still not reached. And for reaching this reliability, we must consider all the essential criteria of the environment studied. This is not the case for the techniques presented previously. ABE proved the evidence against other technical in accuracy by taking into account a random synchronization mechanism. But the main element, the mobility that characterizes particularly the ad hoc mobile networks, is not treated in a specific manner whatsoever by ABE or any other measurement technique. Increasing the rate of packet “Hello” exchange is the solution most used.

Let us consider that there is a link (s,r) in the 802.11 ad hoc network with a high level of mobility. This high mobility leads to 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. At the time  $T$  the distance between the two nodes ( $s$  and  $r$ ) is enough for a communication (each of them is in the communication area of the other).

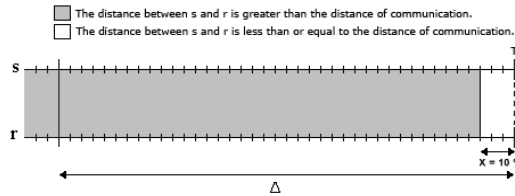


Figure 2

Link status during a  $\Delta$  measurement period

Figure 2 shows the  $(s,r)$  link state during the measurement period  $\Delta$ . We remark that this link exists only on  $X=10\%$  of  $\Delta$  measurement ( $X$  value represents the percentage of the existence of the link on the  $\Delta$  period). At the  $T$  instant, the ABE technique can be executed because of exchanging possibility of available residual bandwidth on “Hello” packets.

We intend to compute the available bandwidth on the link  $(s,r)$  (the scenario depicted on Figure 2) with the ABE technique at time  $T$  with several  $X$  values, by using the NS-2 simulator with 2 Mb/s of medium capacity, which corresponds to 1.6 Mb/s application layer achievable throughput. The ABE estimations results are showed in graph of Figure 3.

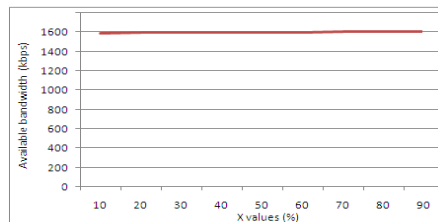


Figure 3

Available bandwidth estimation results with ABE Technique

Following the estimation results of the technical ABE (where  $\Delta = 1$ ), 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. 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; but this is false, because 10% of  $\Delta$  is 0.1 second and 1.6 Mb of traffic cannot be transmitted in 0.1 seconds with 1.6 Mbps of capacity. So this error on estimation is due to bad mobility management, and we will see that this error can affect the traffic circulation in mobile ad hoc networks with a penalization of certain applications, particularly in the admission control of QoS flows.

## 4 The Mobility in Available Bandwidth Measurement

Based on the physical quality of a link in wireless networks and considering how the IEEE 802.11 protocol operates, we can point out a few characteristics that we consider in our mobility management:

- Two nodes are separated by a distance  $d$ . A dynamic topology means that the distance  $d$  is variable.
- Two nodes can communicate if they are separated at most by a distance  $C_d$  (communication area).
- A node sends the signals with SSS strength, and these signals are received with RSS strength.

In this section, we will examine mobility by using these three points, and we describe how we can effectively take these phenomena into account.

Firstly, to solve the accuracy problem in available bandwidth estimation in the scenario of the previous section (Figure 2), we add the mobility criterion “ $M$ ” in formula (2). Now, we consider this mobility criterion the rate of the link existence during the last measurement period (the value of  $X$  in Figure 2). Hence, we obtain the new formula with the criterion of mobility:

$$ABE\_MM_{(s,r)} = (1-K) \cdot (1-P) \cdot b_{(s,r)} \cdot M \quad (3)$$

where  $ABE\_MM_{(s,r)}$  is the available bandwidth that we use in our measurement approach  $ABE\_MM$ , but the value of “ $M$ ” will be different, and in what follows we will see the new value of “ $M$ ” and why.

### 4.1 Link Expiration in Bandwidth Measurement

Figure 4 shows a link (s, r) for two consecutive measurement periods ( $\Delta$ ), with two ((a) and (b)) identical activities scenarios (the same bandwidth consumption), but in different states: stable (a) and unstable (b), which we can observe at  $t_j$  instant on (b).

We say that a link is stable if the distance ( $d$ ) between the two nodes of this link is less than or equal to the distance of communication  $C_d$  at any time on  $\Delta$ . We note:

$$\forall t_k / k \in [0...n], d \leq C_d \text{ (where } t_k \text{ is the time unit of calculus in } \Delta \text{ period, and } n \in$$

$\mathbb{N}^*$ ); this is the link which we find in wireless networks with stable topologies. Note that the stable links are the only scenarios discussed in the measurement formulas of bandwidth measurement.



We say that a link is dynamic or unstable, if there are some moments when the distance  $d$  between the two nodes of this link becomes larger than communication distance  $C_d$ , and we note:  $\exists t_k / k \in [0..n], d > C_d$ .

The absence of mobility criterion in the classical "link by link" measurement techniques such as ABE has negative consequences, particularly in the admission control process. It is clear that the available bandwidth  $\alpha_1$  (Figure 4 (a) at  $t_{n-1}$ ) calculated by the ABE technique or even the formula (3) ( $M$  value as it is) will have the same value as  $\alpha_2$  (Figure 4(b) at  $t_{n-1}$ ). So if  $(\alpha_1 = \alpha_2)$ , regardless the throughput admitted to reservation at  $t_{n-1}$  of Figure 4 (a) whichever  $\alpha_1$ , also can be admitted, whichever  $\alpha_2$  in second scenario (Figure 4 (b) at  $t_{n-1}$ ), while the (s, r) link in this second scenario will be available just in  $(t_j - t_{n-1})$  time (during (Y) fragment). Hence the available bandwidth to be used at  $t_{n-1}$  depends also on the probability of future existence of the link; therefore, for the accurate value of  $\alpha_2$ , we must take into account (Y) fragment, and the mobility criterion "M" is newly defined as the probability of the link existence in the next  $\Delta$  measurement period time.

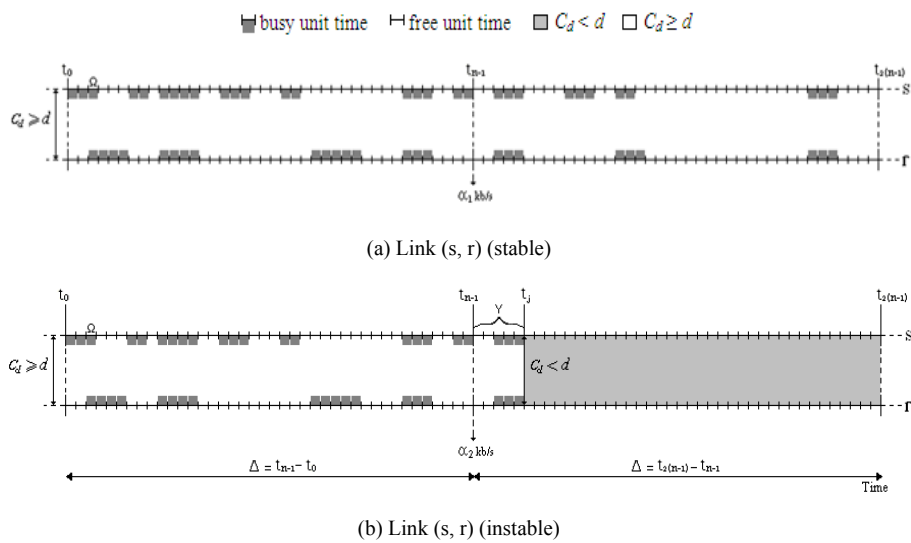


Figure 4  
Expiration link on available bandwidth estimation

$$M = (t_j - t_{n-1}) / \Delta \tag{4}$$

- $t_j$  is the moment where the link dispartate ( $d > C_d$ ).

Now the problem that arises is to know at the instant  $t_{n-1}$  or before the value of  $t_j$ . In this paper we propose the calculation through the prediction of the link expiration, in order to predict the  $t_j$  value.

## 4.2 Predicting Link Expiration

Several studies have been conducted in the field of the prediction of nodes movement. In [11] the authors present a summary of mobility prediction methods in mobile ad hoc networks and in [12] a fairly comprehensive method is proposed which could be used in our approach in order to calculate the  $t_j$  value.

To predict the link expiration time, we based on the location of nodes as in [13], but for simplicity reasons, we use a simple method that uses mainly a physical layer. Here we propose a scheme which depends of the mobility speed of nodes, by using the received signal strength (RSS). In our prediction method, we assume a free-space propagation model [14], where the RSS solely depends on its distance to the transmitter and the  $SSS$ . We assume that all nodes transmit their signals with the same strength  $SSS$ .

The intended receiving node measures the signal strength received, which holds the following relationship for free-space propagation model.

$$RSS = SSS (\lambda / 4 \pi d)^2 G_T G_R \quad (5)$$

where  $\lambda$  is wavelength of carrier,  $G_T$  and  $G_R$  are the unity gain of the transmitting and receiving antennas, respectively. The effects of noise and fading are not considered. The receiver node can calculate  $d$  from  $RSS$ , as illustrated in Figure 5, crossing  $d$  value calculated on Phy to the MAC layer.

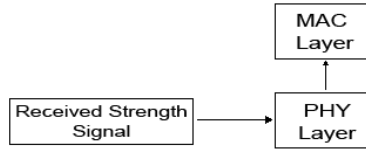


Figure 5

Crossing the distance value from physical layer to MAC layer

Receiving two signals with two different powers in free space involves two different distances ( $RSS_1 \neq RSS_2 \rightarrow d_1 \neq d_2$ ).

If a node detects a distance  $d_1$  at time  $t_1$  from its neighbor and at  $t_2$  detects a distance  $d_2$  different to  $d_1$  from the same neighbor, and  $d_2$  is larger than  $d_1$  (in linear motion) the node concludes that it is moving away from its neighbor with a speed of:  $SP = (d_2 - d_1) / (t_2 - t_1)$ . Assuming that each node can know at what speed it is moving away from its neighbor. So each node can know at what point the distance from its neighbor reaches the distance of communication  $C_d$ , and the expiration of the link with its neighbor. So to calculate the mobility criterion “ $M$ ” of the formula (4), the  $t_j$  value is no longer unknown and is calculated by:

$$t_j = (C_d - d) / SP \quad (5)$$

- where  $d$  is the last distance the moving neighbor node (in  $SP$  formula,  $d$  is  $d_2$ ).

### 4.3 The Protocol Design

For the protocol version of ABE\_MM, it is the same version that is used in the ABE technique [2] aiming to examine the mobility criterion in the formula (3). Certainly, there are some changes that has been found necessary. So there are some steps that we have deleted and other new steps added, and it gives the following:

In the admission control, an extension of the RREQ packet to insert a new field where the source indicates the throughput requested (described in previous sections). But now, each mobile which receives a RREQ, performs an admission control by comparing the throughput requirement carried in the RREQ packet by the estimated available bandwidth with the equation (3) on the link where it received the RREQ. If this request is admitted, the node adds its own address to the route and forwards the RREQ; otherwise it discards it. When the destination receives a first RREQ, following the AODV protocol after a control admission, it sends a unicast route reply (RREP) to the initiator of the request along the reverse path. The resources are then reserved and the new QoS flow can be sent.

We have added a new step of sending the route error (RERR) packets by nodes which discover that available bandwidth is no longer sufficient on the reserved link, as in Figure 4 (b) at  $t_{n-1}$ . (Then the RERR packets are sent because of available bandwidth failure). This step is caused particularly by the mobility phenomena and the changing of the “ $M$ ” value, where the senders of these RERR packets are the nodes which have predicted the breaking of the link. And another RERR will be sent after the failure of the link by nodes which detect it but the available bandwidth is sufficient.

**Note:** In ABE\_MM, the prediction of link expiration does not reject the QoS flow automatically, but it can be admitted if will be satisfied in the duration of existence.

## 5 Performances Evaluation

### 5.1 Evaluation Method

To evaluate the effectiveness of the proposed mobility management approach in bandwidth measurement, we conducted a comparative experiment using Network Simulator 2 (NS2.34) and the IEEE 802.11 implementation provided with the simulator. The scheme used was (CSMA/CA) without (RTS/CTS) Mechanism. Five constant bit rate (CBR) flows (Flow1, Flow2, Flow3, Flow4, Flow5) are generated with 1000 bytes of data packet size. A free space propagation model is

adopted in our experiment, with the radio propagation range length for each node being 250 meters (d) and the channel capacity being 2Mbits/sec.

Our simulation models a network of 5 sources and 5 destinations (for each flow) in 20 mobile nodes that move to a common and constant velocity equal to 12 m/s. The movement of nodes is random, following the model of Manhattan [15] without buildings (without obstacles, to ensure a free space environment) on an area of 1000 m X 1000 m. The street length on this Manhattan model is 100m where nodes move through. At each arrival in a corner, a node can stay where it is, continue its movement in the same direction, or change it. For this simulation we used the prediction model that is explained in the previous section, where nodes predict with accuracy when they move away each from other on a straight line (other prediction models more efficient, such as in [12], can be used). The efficiency of our approach is evaluated through comparison between ABE\_MM, ABE and AODV without any QoS guarantee with the following criteria:

- The throughput on destination nodes of each flow obtained along the simulations.
- Average loss ratio: The average of the sent data packets but not received on destinations over the total number of data packets sent.
- Data packet delivery: The total number of data packets delivered to each destination along simulations.

## 5.2 Simulation Results

After several simulations of random scenarios, we chose one of them, and the results are as follows:

### 5.2.1 Throughput

Following the simulation logs (movement of nodes, routing flow and control packets) we noted the following:

To show the importance of the QoS guarantees, we also provided results obtained with the AODV routing protocol, where no admission control is applied. Figure 6 shows the throughput on destination nodes of the five flows when AODV is used. Since no admission control is performed in AODV and no QoS guarantee, each new requesting flow which reaches the desired destination is admitted automatically; therefore all five flows are admitted despite the lack of available bandwidth, and the network is congested as new flows are added, resulting in a dramatically decreasing in throughput of the flows.

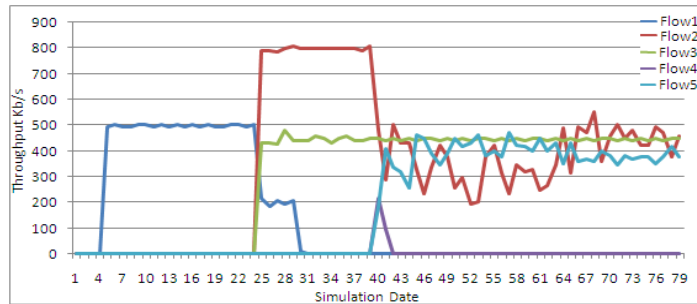


Figure 6

Throughput of each flow using AODV

Figure 7 shows the throughput of the five flows along simulation time when the ABE is enabled for path reservation. We remark that the number of admitted flows are limited compared to the AODV results, and there is no throughput degradation of the accepted flows. But 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 other flows (2) and (3), given the slow process of detecting the link failure. We also note that the absence of a mobility criterion in the ABE measurement formula has allowed flow (4) a reservation path (A false admission control) which contains a link being missing, which caused delays in the admission of the flow(2) and (3).

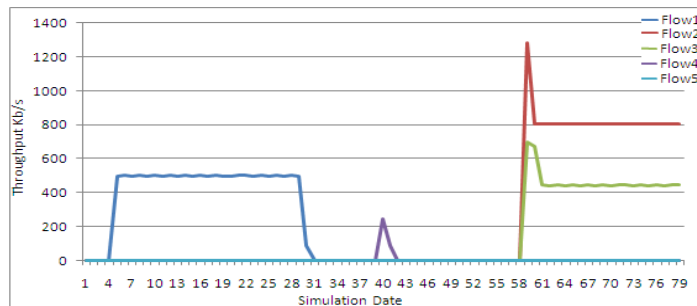


Figure 7

Throughput of each flow using ABE

Figure 8 shows the throughput of the five flows when the path reservation is activated with ABE\_MM. We observe that the consumption of bandwidth on the network is much more optimal compared to ABE. 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-related admission of flows (2) and (3). Also, eliminating unemployment times in the network caused by a flow (4) with ABE technique (the interconnection zone of flow (2) and (4) paths for [31 ... 58] seconds).

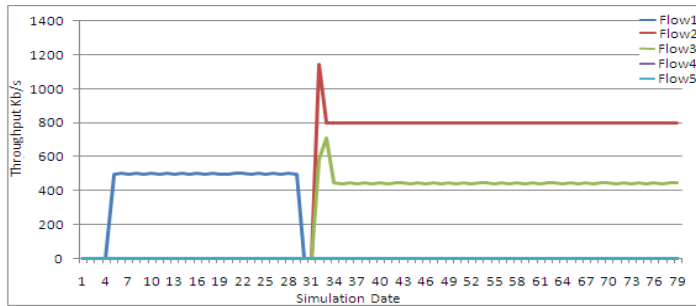


Figure 8  
Throughput of each flow using ABE\_MM

### 5.2.2 Average Loss Ratio

The average loss ratio along the simulation is shown in the diagram in Figure 9. We note that the absence of the QoS guaranteed in AODV protocol has not only caused catastrophic degradation on throughput (Figure 6), but also significant loss rates for all flows, particularly flow (4) where almost all data sent are lost. When applying the reservation beforehand of bandwidth with ABE, we notice an improvement in the results compared to AODV, but the absence of the mobility management in the ABE estimations has caused a false admission control of flow (4) resulting in a loss total data. As well, the absence of mobility criterion has caused significant losses in flow 1, because of late detection by the source of the path failure. ABE\_MM, with the criterion of mobility, has prevented the loss of data flow by stopping the source of flow 1 at the right time through the predictive detection of path failure. In addition, the admission control of flow 4 has been corrected with respect to ABE, which has helped prevent the loss of data of this flow.

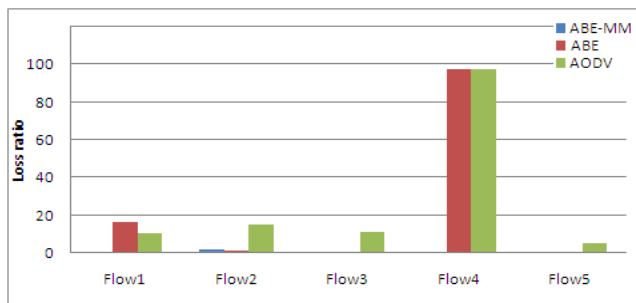


Figure 9  
Average loss ratio diagram using ABE\_MM, ABE and AODV

### 5.2.3 Data Packet Delivery

The total data packet delivery to each destination is shown in the diagram of Figure 10. Given that the goal of AODV is to deliver the greatest possible amount of data without taking into consideration any QoS criterion, this is why we find some delivery on large number of flows (quantitatively and not qualitatively). Enabling ABE has reduced the number of deliveries seen the bandwidth guarantees, but this reduction was significant where delivery of flow (2) and flow (3) were low, given their late admissions. With ABE\_MM we notice the mobility management has improved the delivery of flows (2) and (3) with admissions at the right time.

**Note:** The loss ratio and the number of data packets delivery of flow (1) by using ABE confirms that the source of flow (1) continued the transmission after the 31 seconds (Figure 7).

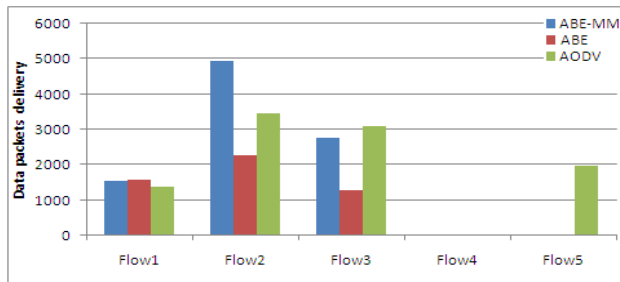


Figure 10

Data packets delivery diagram using ABE\_MM, ABE and AODV

### Conclusion

In this paper, we present the importance of taking into consideration the mobility phenomenon in available bandwidth measurement, especially during the path reservations. Our solution is based on the distances changing between neighboring nodes which are linked together. ABE\_MM was the result of the extension of the ABE technique with our approach.

The results obtained from a comparison between ABE and ABE\_MM are satisfactory in terms of the consumption optimality of bandwidth in the network. We have noticed an improvement of flow circulation where the density of traffic has increased over the network while decreasing loss rates.

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