# Cell Stay Time Prediction for Mobility Independent Predictive Services in Wireless Networks

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*Abstract*—**In the past few years, there has been much research in wireless adaptive networking and resource management, in order to examine how to efficiently handle wireless communications between mobile hosts and base stations. In this paper, we focus the attention on Mobile Independent Predictive (MIP) service class, which provides a passive reservation policy, with the goal of QoS guarantees during hand-off events. We analyzed MIP users' mobility along coverage areas, to obtain a system utilization improvement, by reducing passive resource reservations on cells that users will probably visit. A prediction technique is also proposed and calls are managed in a wireless system by an utility-based algorithm that takes into account the radio-link quality variability by a Markov channel model, based on IEEE802.11b standard. System performances are evaluated by varying users' speed and system utilization with prediction error percentages are shown. It is observed that the proposed prediction technique causes an increase in system utilization.**

***Keywords: Partial reservation, mobility management, MIP, wireless network, bandwidth allocation, admission control.***

## I. INTRODUCTION

With the rapid growth of mobile devices being employed, the demand for wireless communications has rapidly increased over the last several years and many multimedia data are being transmitted via wireless media; so, the adaptive multimedia networking paradigm can play an important role in mitigating the highly-varying resource availability in wireless/mobile networks, where users require different levels of QoS [6]. Wireless networking poses special problems, like limited bandwidth and high error rate, due to fading and mobility [1,2] effects. The non-ideality of wireless links (fading effects) between users and base stations must be taken in account, by introducing a channel model, like the one proposed in [3]. Users' mobility is another reason for the fluctuation in received QoS, because it has a high impact on QoS parameters (like packet-delay, delay-jitter and packet-loss rate); that is, when a mobile host changes its coverage cell (e.g. hand-off) with an active flow, the available bandwidth in the new base station may be scarce, so the congestion level suffered by user may vary and the perceived quality of service may fall below requested lower bounds; in the worst case, the connection can be dropped. Because of these problems, deterministic service guarantees, commonly used in wired networks, become inadequate in a wireless scenario and a flexible service model which allows variable QoS is needed. This work takes into consideration both fading and mobility effects. The fading has been considered through a Markov channel modeling, accounting for the slow fading effects, while the users' mobility has been taken into account through the management of hand-in (when a new flow enters in a cell for hand-off or for a new call request) and hand-out (when a flow leaves a cell) events among the visited cells. In order to offer an adaptive QoS to mobile hosts, an architecture capable of reserving bandwidth levels and of offering guaranteed services is used. This architecture is the Integrated Services Networks with mobile hosts; Mobile Resource Reservation Protocol (MRSVP) is used for exchanging the state information of wireless networks [5,12]. This protocol can offer soft QoS (adaptive QoS) for a class of services called Mobility Independent Predictive (MIP), which prevents mobility effects when a hand-off event occurs. In this paper, the MIP services that use a pre-reservation phase to reserve bandwidth for the mobile host in the current cell (active reservation) and in the cells that mobile host probably will visit (passive reservations) have been considered. According to an adaptive multimedia wireless framework [1,2], MIP flows can reserve a bandwidth level that can change during call holding time. A preservation policy with cell stay prediction and a utility-based algorithm are used in the resource management in order to improve the system utilization. This paper is organized as follows: section II gives an overview of MRSVP and the pre-reservation policy; in section III, the proposed prediction technique is treated; section IV shows simulation results; and section V concludes the paper.

## II. MRSVP, UTILITY-ORIENTED BANDWIDTH MANAGEMENT AND PRE-RESERVATION POLICY

As mentioned above, users' mobility must be properly managed in a wireless scenario, in order to offer guaranteed services (independent from mobility); for this reason, the Resource reSerVation Protocol [11] has been extended, with the MRSVP [5], so that hand-off events can be managed in an adequate manner and mobile users can make reservation requests over more than one cell (as we will see later) [12]. There have been different research groups that have tried to define some service models, in order to deal with applications variety in packet networks. Integrated Services networks and wireless adaptive networks are the results of such kind of works. In a real network, resource reservations can be made by protocols, in order to satisfy QoS requirements and to offer to mobile hosts a service "better than best-effort", accounting for the inherent time varying environmental conditions evident in radio communications (e.g. fading).

### A. Mobile Resource Reservation Protocol (MRSVP)

In IS networks for mobile hosts, each flow can receive different QoS levels that must be negotiated at the beginning of sessions, between flows and net, by the MRSVP protocol in mobile scenarios [5]. The Mobility Independent Predictive (MIP) class is provided in ISPNs and it deals with tolerant real-time applications that can suffer limited bounds on packet delays. Other classes (like Mobility Dependent Predictive MDP and Mobility Independent Guarantee MIG) are provided in ISPN, but, in this paper, the attention is focused only on MIP services that use a pre-reservation phase for QoS guarantees. With MRSVP, an *active reservation* is made by a user only sending protocol request messages to the current access point, while *passive reservations* are made only on the remote cells that the user will visit during its connection (remote cells receive hosts' passive requests by a switching subnet). With passive-reservation policy, MIP mobile hosts can ensure themselves the needed QoS guarantees during hand-off events: when the user arrives in the new cell, passive bandwidth, reserved in the new coverage base station, is switched to an active resource that can be assigned to the flow, which then can continue receiving service. For more details about MRSVP, see [5,12]. Figure 1 shows the passive reservation policy for mobile users belonging to the MIP class.

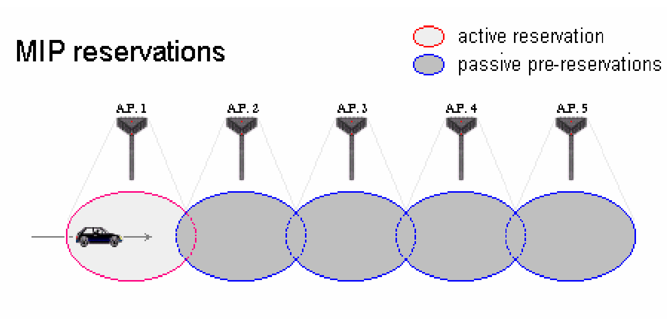


Figure 1. Active and Passive reservation for MIP flows in Integrated Service Networks for mobile hosts.

### B. Utility-Oriented Bandwidth Management

There are different rate adaptation schemes proposed in literature based on max-min fairness criteria or on QoS degradation parameters [6,7,8]. These schemes do not account the wireless channel state as in [9] and do not consider the integration between the rate adaptation scheme and the admission control in a unified wireless adaptive framework. We used an *utility-oriented* algorithm for rate-adaptation and admission control, which takes into account the time-varying nature of links between hosts and access points [4] and the mobility effects (hand-in, hand-out). The bandwidth of a MIP flow takes its discrete value from the set $B=\{l_1,l_2,\ldots,l_m\}$, where $l_i<l_{i+1}$ for $i=1, .., n-1$. Mobility and fading can change system conditions, so it is necessary to use the rate adaptation algorithm for varying bandwidth levels according to channel conditions and host mobility. In our case, the considered rate adaptation algorithm is based on a *utility function* associated with MIP class, and it tries to maximize the *user profile satisfaction* modelled by this utility target functions [4]. An example of utility function is showed in figure.2. The *slow fading effect* of a wireless channel has been considered in order to give more effectiveness to the used rate adaptation algorithm and to reservation protocol. So the rate adaptation distributes the discrete bandwidth levels while considering the channel state valued in terms of degradation state and the target utility function. The utility perceived by the mobile user is

$$u_i = U_i\left(\left(1-D_{i,m}\right)\cdot r_i\right) \qquad (1)$$

where $U_i$ is the utility function associated with user $i$, $D_{i,m}$ is the degradation state $m$ associated with the channel $i$ in a given time and $r_i$ is the discrete bandwidth level given to the mobile user.

One of the objectives of the bandwidth allocation scheme is to guarantee the minimum utility level for each user $i$; if we define *utility outage* as the event when user $i$'s instant utility level falls below the minimum, the scheme should guarantee that the probability of an utility outage is smaller than a certain threshold $p_{outage}$. In addition, the fairness criterion should also be based on utility; in fact, considering users $i$ and $j$ with average utility $u_{i,avg}$ and $u_{j,avg}$ respectively, we can define the *normalized gap* of the average utility received and the minimum level $u_{*,\min}$ as:

$$G_i = \frac{u_{i,avg} - u_{i,\min}}{u_{i,\min}} \qquad (2)$$

so we want all users to have the same normalized gap in the long run ($G_i \approx G_j$, $\forall i,j$).

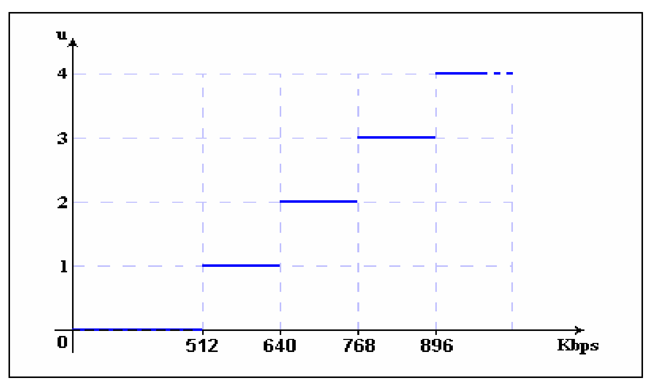


Figure 2. Utility function used for the utility-based rate adaptation algorithm

The channel modelling is based on the Discrete Time Markov Model (DTMC) according to [3, 13]. Let $S = \{s_0, s_1, \ldots, s_{K-1}\}$ denote a finite set of states and $\{S_n\}$, n=0,1,2,… be a constant Markov process, with the property of stationary transitions, then the transition probability is independent of the time index $n$ and can be written as

$$t_{j,k} = P_r(S_{n+1} = s_k \mid S_n = s_j), \qquad (3)$$

for all $n$ = 0,1,2,… and $j,k \in \{0,1,2,\ldots,K\text{-}1\}$; we can define a $KxK$ state transition probability matrix $\mathbf{T}$, with elements $t_{j,k}$. Moreover, with the stationary transition property, the probability of state $k$ without any state information at other time indices can also be defined as $p_k = \Pr(S_n = s_k)$, where $k \in \{0,1,2,\ldots,K\text{-}1\}$, so a $Kx1$ steady probability vector $\mathbf{p}$ can be defined with its element $p_k$. To complete the description of the chain model, we require additional information on the channel quality for each state, so we can define a $Kx1$ crossover probability vector $\mathbf{e}$ with its elements $e_k$, $k\in \{0,1,2,\ldots,K\text{-}1\}$. Now the FSMC is completely defined by $\mathbf{T}$, $\mathbf{p}$ and $\mathbf{e}$. Let $0 = A_0 < A_1 < A_2 < \ldots < A_k = \infty$ be the thresholds of the received signal to noise ratio, then the Rayleigh fading channel is said to be in state $s_k$, $k = 0,1,2,\ldots,K\text{-}1$ if the received SNR is in the interval $[A_k,A_{k+1})$. Associated with each state there is a crossover probability $e_k$ and, given a specific digital modulation scheme, the average error probability is a function of the received signal to noise ratio (the value of $e_k$ is the average error probability on transmitting a bit when the received SNR falls in the k-th interval). The elements of $\mathbf{p}$ and $\mathbf{e}$ can be written as follows:

$$p_k = \int_{A_k}^{A_{k+1}} \frac{1}{\rho} e^{-\frac{a}{\rho}} da, \tag{4}$$

$$e_k = \left[ \int_{A_k}^{A_{k+1}} \frac{1}{\rho} e^{-\frac{a}{\rho}} P_e(a) da \right] / p_k, \tag{5}$$

where $P_e(a)$ depends on the digital modulation scheme chosen. In our simulations we considered the CCK modulation with the BER represented in figure.4 (as in the standard IEEE802.11b) [10], and

$$P_{e(CCK)}(a) = 12Q\left(2\sqrt{a}\right) \tag{6}$$

To guarantee users' minimum utility level, an admission control policy should be enforced to limit the number of users in the system. Recalling that when a user's instant utility falls below its minimum utility level, there is a utility *outage* for the user; the probability $p_0$ of such event at any time is:

$$p_0 = P_r \left\{ \sum_{i=1}^{n} \frac{r_{i,\min}}{1 - D_{i,m_i}} > R \right\}, \tag{7}$$

where $m_i$ is user $i$'s link state at time instance, $p_{mi}$ is the probability of the user $i$'s link of being in state $m$ at a particular time, $n$ is the total number of users including the new one and $R$ represents the bandwidth associated with the wireless cell $c$. Modelling the wireless channel through the Finite State Markov chain (FSMC) where the state of the chain represents the channel degradation, the transition probabilities represent the probability of changing the degradation state. It is possible to know the probability of the link to being in state $i$ :

$$p_i = \frac{\pi_i t_i}{\sum_{i=1}^{k} \pi_i t_i}, \tag{8}$$

with $\pi_i$ representing the steady state probability associated with the channel state $i$, and $t_i$ representing $i$'s average holding time. Through $p_i$ it is possible calculate the worst case $p_0$. For details on this algorithm, optimisation criteria and on the $p_0$ calculation, refer to [4].

### C. Prereservation Policy for MIP services

In order to guarantee the outage probability $p_0$ (where an outage event takes place when a user utility falls below the minimum value), an appropriate admission control has to be considered for mobile users belonging to MIP class. In this case the flow is admitted if:

$$\sum_{c=1}^{C} p_{0,c} \leq C \cdot p_{outage} \tag{9}$$

where C is the number of cells that the mobile host will visit, $p_{outage}$ is the outage probability of the wireless system, and $p_{0,c}$ is the outage probability for cell $c$. The verified condition is that for each cell $m$, $p_{0,c} \leq p_{outage}$ and it is satisfied by utilized call admission control. So it is possible to fix $p_{outage}$ to guarantee the outage probability for MIP services, limiting the acceptance of other flows. MIP services under-utilize system resources for pre-reservation, because of a certain passive amount of bandwidth $P_c$ is reserved for "future" connections at time instance $t$ in cell c; if $Q$ is the total capacity of the access point (the same for every cell $c$), the active MIP flows in the current cell can use only $U_c=Q\text{-}P_c$ amount of bandwidth; in addition, only $U_c$ amount of bandwidth for each access point $c$ can compete for admission control at time instance $t$. So it is obvious that $P_c(t)$ ensures QoS guarantees, but it causes a bandwidth utilization wastage ($P_c$ is unused by other MIP flows) and it limits the number of admitted flows, because new service requests can only compete for $U_c$ amount of bandwidth, lower than access point capacity $Q$. In the next section, a prediction technique, based on users' mobility analysis, is proposed, with the goal of reducing system utilization wastage.

## III. Bandwidth Partial Reservation Technique Based on Cell Stay Time Prediction

As explained in previous sections, passive reservations represent a good way to guarantee and maintain QoS to MIP users during hand-off events; this policy is based on "in-advance making" bandwidth reservations over all the cells in the network, without evaluating either average host's speed or call holding time. In this section, we propose a new criteria for increasing system utilization, while maintaining pre-reservation policy, and improving the performances of WLANs system. This time, passive reservations are made after evaluating average hosts' speed and call duration, so if the host moves in the cells with extremely slow speed, pre-reserving over all system base stations is not necessary, because the user will probably never visit all of them. Moreover, if two mobile hosts have the same speed, the number of visited cells may vary in function of call duration (full reservation is often not necessary). A model for estimating the Cell Stay Time (C.S.T.) has been evaluated by many simulations and this information has been used to calculate the number of cells visited by mobile hosts. This information can be used to make passive reservations only on the cells that a host will effectively visit, leaving bandwidth availability in other cells. For deriving this model, a Poisson arrival time distribution and an exponentially distributed call holding time have been considered for any mobile host.

### A. Constant speed

In the first campaign of simulations, user's speed has been fixed to a constant value $v_{avg}$; that is to say all users move along coverage areas with the same speed, so they only have different connection times; the call holding time is exponentially distributed with an average $T_{cht}$. This kind of simulation has been employed in order to evaluate the model validity under simplified conditions (constant speed); as shown in the next section, in this case, low prediction errors result.

### B. Variable speed

In the second campaign of simulations, average speed has been uniformly selected in a range of $[v_{avg} - \alpha, v_{avg} + \alpha]$, where $\alpha$ is a variable percentage of $v_{avg}$, from 5% to 50%; as shown in the next section, estimation error increases for high values of $\alpha$, but the error is maintained within acceptable bounds.

In both cases (constant or variable average speed), for any fixed value of $v_{avg}$, a probability density function (p.d.f.) of average cell stay time of mobile hosts has been derived in order to make a predictive evaluation of visited cells. The obtained p.d.f., as shown in figure 5, can be approximated by a normal distribution:

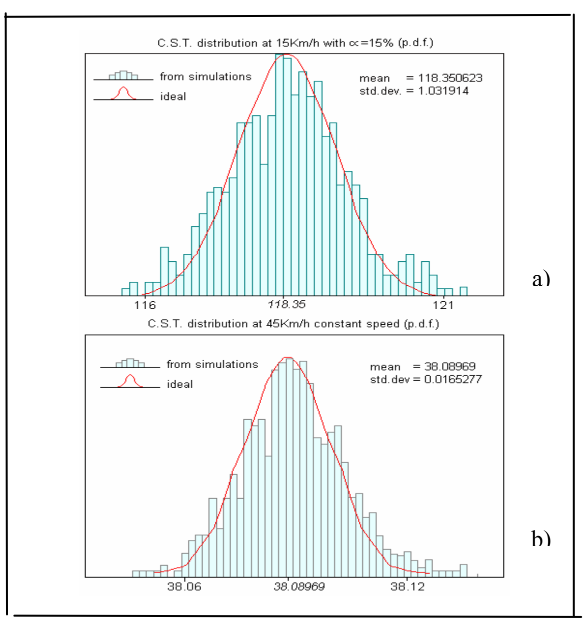


Figure 3. P.d.f. of the cell stay time of the mobile host for variable (a) and constant speed (b).

So it is possible to express the p.d.f. of the cell stay time in the following way:

$$f(x) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)} \qquad (10)$$

where $\mu$ and $\sigma$ are the obtained values of mean and standard deviation respectively.

So it is possible to evaluate the error of considered C.S.T. and to make a cell stay time prediction based on confidence intervals and confidence levels, considering the worst case *cell outage probability* (COP). It is possible to select a cell stay time $T_{cst}$ for a mobile host so that $Prob(X< T_{cst}) <1\text{-}COP$, where X is normally distributed. $T_{cst}$ is called a (1-COP)*100% upper confidence bound for X. If the average call holding time $T_{cht}$ is known, it is possible to consider the term C called $C_p$ (C partial) as

$$C_p = \frac{T_{cht}}{T_{cst}} \qquad (11)$$

So it is possible to use the $C_p$ value represented in eq. 11 to make the pre-reservation of MIP flows in order to leave more bandwidth availability in the not visited cells for new MIP flows. The bandwidth preservation on all the cells of the system using $C_t$ (C total) and the partial reservation using $C_p$ is shown in figure 6.

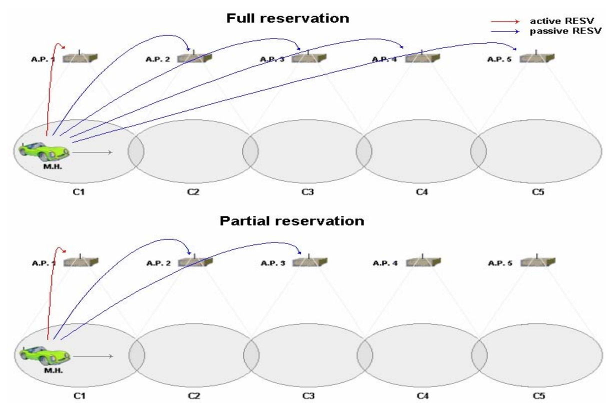


Figure 4. Full and Partial Reservation for passive reservation in the next wireless cells.

## IV. SIMULATIONS

Our simulated net consists of five wireless cells with a coverage radius of 250 meters; each access-point has a bandwidth capacity of 5.5Mbps, as specified in IEEE802.11b standards and it is wired, connected by a switching subnet, to the net-sender. In our model, each mobile host moves ahead in a circular way (a user that is receiving data in the last cell will visit the first cell after a hand-off). The $T_{cht}$ is three minutes and the COP is 5%. Each wireless link is described by a 4-states Markov chain, with the following parameters (derived by the partition method proposed in [3]):

| | $p_i$ | $e_i$ | $D_i$ (%) | $t_{mi}$ (s) |
|---|---|---|---|---|
| 0 | 0.30233 | 0.150588 | 41.8 | 0.1 |
| 1 | 0.095 | 0.0670038 | 24.58 | 0.1 |
| 2 | 0.25267 | 0.016459 | 9.5 | 0.1 |
| 3 | 0.35 | 5.92112e-5 | 0 | 0.1 |

TABLE I. VALUES FOR THE MARKOV CHAIN MODEL where $D_i$ is the wireless degradation state associated to the Markov state *i*.

The parameters evaluated in the simulation are:

- System utilization: it represents the bandwidth utilization calculated as the reserved *active bandwidth* over the total capacity of the cell *C*.
- Utility: it is the utility perceived by the users. The values accounted for the utility function are represented in figure 2.
- Error: it is calculated as $e = \frac{t_p - t_r}{t_r}$, where $t_p$ is the predicted time in which the flow crosses the cell, and $t_r$ is the instant in which the flow really cross the cell.
- Flow percentage: it expresses the percentage value of the flows that go over the last predicted visited cell over the number of totally managed flows. This gives an idea on how many flows cannot find the resource available because any passive reservation has been reserved.

First of all, a campaign of "monitor simulations" has been executed, observing users' mobility, and many samples have been collected in order to evaluate statistical prediction model parameters, by varying hosts' average speed. The obtained results are shown in tables II and tables III.

| | α=0 (constant speed) | | α=5% (var. speed) | |
|---|---|---|---|---|
| Speed (km/h) | μ | σ | μ | σ |
| 5 | 342.0313 | 1.1756 | 378.1067 | 9.4682 |
| 15 | 114.0886 | 0.0956 | 118.0354 | 0.2275 |
| 25 | 68.4953 | 0.0413 | 69.9256 | 0.1519 |
| 35 | 48.9498 | 0.0239 | 49.6754 | 0.0630 |
| 45 | 38.0896 | 0.0165 | 38.5444 | 0.0548 |
| 55 | 31.1784 | 0.0123 | 31.4821 | 0.0338 |
| 65 | 26.3942 | 0.0092 | 26.6176 | 0.0292 |
| 75 | 22.8851 | 0.0078 | 23.0509 | 0.0203 |

TABLE II. STATISTICAL PARAMETERS FOR α=0 AND α=5%;

| | α=15% (var. speed) | | α=25% (var. speed) | |
|---|---|---|---|---|
| Speed (km/h) | μ | σ | μ | σ |
| 5 | 378.1067 | 9.4682 | 358.2162 | 28.6616 |
| 15 | 118.3506 | 1.0319 | 118.6269 | 1.5311 |
| 25 | 70.0943 | 0.3691 | 70.7524 | 0.6918 |
| 35 | 49.9474 | 0.2260 | 50.3163 | 0.3695 |
| 45 | 38.7056 | 0.1456 | 39.1330 | 0.2483 |
| 55 | 31.6585 | 0.1030 | 31.9389 | 0.1807 |
| 65 | 26.7419 | 0.0785 | 27.0538 | 0.1334 |
| 75 | 23.1851 | 0.0642 | 23.4080 | 0.1091 |

TABLE III. STATISTICAL PARAMETERS FOR α=15% AND α=25%;

From the tables above, it can be observed that the standard deviation σ (and, so, the variance $\sigma^2$) increases for higher values of α; this reflects larger variations in the considered speed interval, which becomes wider, for high values of α. It is possible to observe as the average μ remains stable and the standard deviation σ is low for speed higher than 15 km/h and α>15%.

### A. Performance Evaluation

After the parameters have been obtained, other simulations have been made, in order to evaluate system utilization improvements, by introducing the proposed prediction model. Figure 5 shows the obtained results for the average system utilization, for different values of outage probability $p_{outage}$: $4 \cdot 10^{-1}$, $4 \cdot 10^{-2}$, $4 \cdot 10^{-3}$ and α fixed to 10%. Decreasing course for high speed depends on the higher number of bandwidth reallocations, which becomes more evident for higher values of outage probability (larger number of admitted MIP flows). An improvement near 75% can be reached, as figure 5 shows for $4 \cdot 10^{-2}$ outage value.
Partial reservation in the predictive class (MIP) permit to better manage the system resource in the not visited cells. The free bandwidth not used for the passive reservation can be used for other flows entering in the system.

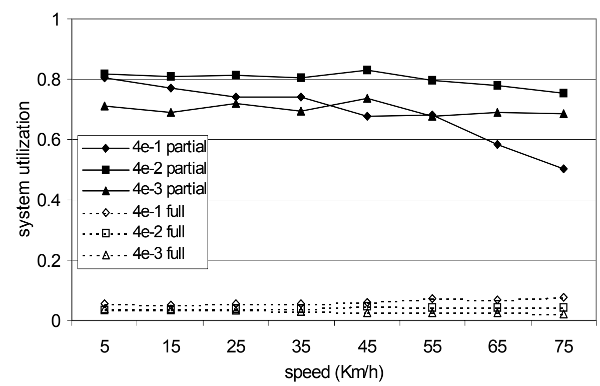

Figure 5. System bandwidth utilization against average speed of the mobile host with *full* and *partial* resource reservation for different values of outage probabilities.

### B. Accuracy of the proposed model

Other simulations have been made in order to estimate prediction errors introduced by our model. Different values of α have been considered, in order to estimate the effects of an increase in mobile speed variance of each host. Figure 6 and figure 7 show the difference (in seconds) between real and predicted hand-off time instances, for first and second hand-off events. It can be observed how the error increases as the allowed speed interval becomes wider (the variance increases because of the higher difference between average and real speeds) and how it decreases for higher average speeds (as the mobile hosts become faster, the average C.S.T. decreases, so there is less time for speed fluctuation around the average value). Obviously, the minimum error occurs in the constant speed case (α=0). In every case, for the second hand-off event (figure 7) the error is slightly higher (from 0.1 second up to 3 or 4 seconds) than the one in figure 6 (first hand-off event), because the statistical error committed in the previous prediction is added onto the second one.

Figure 8 shows that the percentage of admitted MIP flows that go over the number of predicted cells. It increases for higher average speeds (more flows are admitted for higher average speed); however, these error values are acceptable, if we think that only a negligible percentage (under 3%) of admitted flows arrive in a cell where there are no pre-reserved resources (these connections can continue receiving service or can be dropped out from the net).

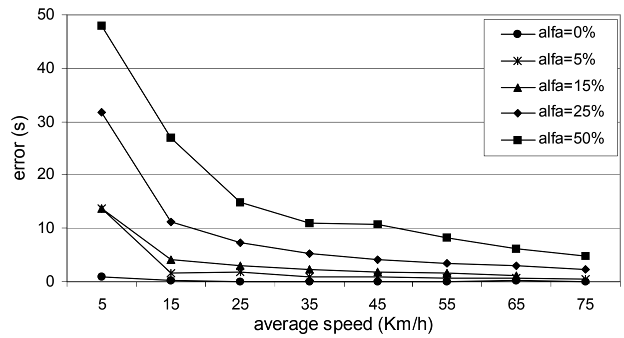


Figure 6. Prediction error (in seconds) for the first hand-off event in the crossing of the second cell.

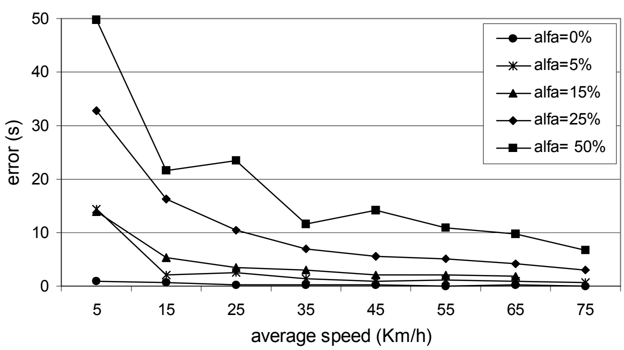


Figure 7. Prediction error (in seconds) for the second hand-off event in the crossing of the third cell.

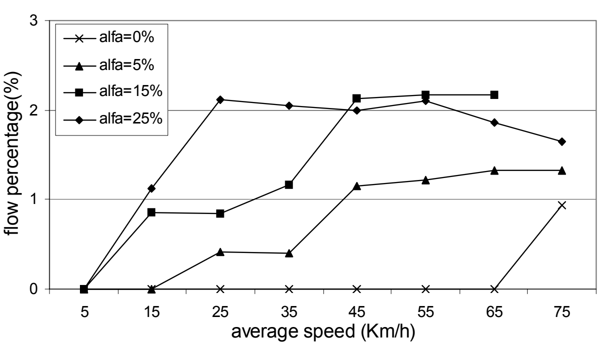


Figure 8. Dropped flow percentage against average speed of the mobile nodes for different $\alpha$ values

## V. Conclusions

In this paper, a new approach for network improvements is proposed and integrated with the MRSVP; in particular, through simulation results, it is shown that a partial pre-reservation policy can ensure either wireless QoS during hand-off events or higher system utilization than a full pre-reservation policy; we also show that our model presents a prediction error (more evident for low speed values and high values of $\alpha$) that causes negligible effects on QoS guarantees that MIP users require for their connections. A future issue can be the evaluation of the minimum bandwidth requirements after the hand-offs events, predicting the degradation state introduced by the wireless channel.

## References


[1] V.Bharghavan, K-W.Lee, S.Lu, S.Ha, J-R.Li, D.Dwyer, "The TIMELY Adaptive Resource Management Architecture," *IEEE Personal Communications Mag.*, pp.20-31, Aug.1998.

[2] A.Alwan, R.Bagrodia, N.Bambos, M.Gerla, L.Kleinrock, J.Short, and J.Villasenor, "Adaptive Mobile Multimedia Networks", IEEE Personal Comm. Magazine, Apr.1996, pp.34-51.

[3] H.S.Wang, N.Moayeri, "Finite-State Markov Channel-A Useful Model for Radio Communication Channels," *IEEE Trans. On Vehicular Technology*, vol.44, no.1, pp.163-171, Feb.1995.

[4] Y.Cao, Victor O.K.Li, "Utility-oriented Adaptive QoS and Bandwidth Allocation in Wireless Networks," *IEEE Int. Conf. On Communications (ICC2002)*.

[5] A.K.Talukdar, B.R.Badrinath, A.Acharya, "MRSVP: A Resource Reservation Protocol for an Integrated Services Network with Mobile Hosts," *Wireless Networks Kluwer Journal*, pp.5-19, 2001.

[6] A.K.Talukdar, B.R.Badrinath, A.Acharya, "Rate Adaptation Schemes in Networks with Mobile Hosts", *Proc. Of ACM/IEEE MOBICOM*,1998.

[7] F. De Rango, G. Aloi, S.Marano, "A Fair Rate Adaptation Algorithm based on the Degradation Factor for Integrated Wireless Networks with Mobile Nodes," *13th IEEE Workshop on Local and Metropolitan Area Networks (LANMAN 2004)*, CA, USA, April 2004

[8] F. De Rango, G. Aloi, S. Marano, "An Efficient Rate Adaptation Scheme in Wireless Mobile Networks," *Wireless Telecommunications Symposium (WTS2004)*, Pomona, California, USA, May 2004.

[9] F. De Rango, P.Fazio, S.Marano, "Mobility Indipendent and Dependent Predictive Services Management in Wireless/Mobile Multimedia Network," IEEE Vehicular Technology Conference 2004 Fall (VTC Fall 2004), Los Angeles, CA, USA, Sept.2004.

[10] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Layer Extension in the 2.4GHz Band", IEEE Std 802.11b-1999.

[11] [RFC2208] A. Mankin, Ed., F. Baker, B. Braden, S. Bradner, M. O`Dell, A. Romanow, A. Weinrib, L. Zhang, "Resource ReSerVation Protocol (RSVP) -- Version 1 Applicability Statement Some Guidelines on Deployment", September '97.

[12] Talukdar A. K., Badrinath B.R. and Acharya A., "On Accomodating Mobile Hosts in an Integrated Services Packet Network", In the Proceedings of the IEEE INFOCOM '97, April.

[13] F.De Rango, P.Fazio, S.Marano, "Resource Reservation and Utility based Rate Adaptation in Wireless LAN with Slow Fading Channels," *7th International Symposium on Wireless Personal Multimedia Communications (WPMC'04)*, Albano Terme, Italy, Sept.2004.