Utility-based Adaptivity and Partial Resource Reservation in Wireless/Mobile Multimedia Networks

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Abstract—**Recently there is a growing interest in the adaptive multimedia networking where the bandwidth of an ongoing multimedia flow can be dynamically adjusted. In this paper the attention is focused on the management of independent and dependent from mobility services. Two classes of services have been considered: MIP and MDP classes defined in Integrated Services for mobile wireless environment. These two classes have been managed in a wireless adaptive networks. A utility-based rate adaptation algorithm has been considered and an admission control has been proposed. Rate adaptation and admission control consider the channel conditions through a slow fading channel model for Wireless LAN 802.11b. The admission control can use the pre-reservation phase among the cells potentially visited from mobile hosts for MIP services and consider only the bandwidth availability on current cells for MDP services. A new way for estimating the cells visited by MIP services has been proposed and analyzed. The performance evaluations of the wireless system have been evaluated in terms of total bandwidth utilization for MIP and MDP services, average bandwidth assigned to mobile users, system outage probability and admitted flows.**

Keywords –Wireless network, partial reservation, bandwidth allocation, admission control, utility function.

I. INTRODUCTION

The adaptive multimedia networking paradigm can play an important role to mitigate the highly-varying resource availability in wireless/mobile networks. Compared to wired networks, the fluctuation in resource availability in wireless networks is much more severe and results from two inherent features of such networks: fading and mobility [1,2]. The fading in wireless channel is highly-varying with time and spatial dependencies and interference. The second reason for the fluctuation in resource availability is mobility (e.g. handoff). This work takes into consideration fading and mobility effects. The fading has been considered through the channel modelling accounting the slow fading effects. The mobility has been considered through the mobility of hosts and the *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) of calls among the visited cells.

In order to offer an adaptive QoS to mobile hosts or a service "better than best-effort" due to the inherent time varying environmental conditions evident in radio communications (e.g. fading), an architecture capable to reserve bandwidth levels and to offer guaranteed services is used. This last one is the Integrated Services Networks with mobile host and Mobile Resource Reservation Protocol (MRSVP) is used for exchanging state information of wireless networks. This protocol can offer soft QoS (adaptive QoS) for a class of services called *Mobility Indipendent Predictive* (MIP) and for services depending from mobility called *Mobility Dependent Predictive* (MDP). MIP and MDP services have two different management in terms of admission control and bandwidth assignments. In this paper the MIP services that use a pre-reservation phase to reserve bandwidth for mobile host in the current cell and in the cells that mobile host probably will visit (passive and active reservations) have been considered. The MDP services, instead, can reserve the bandwidth only on the current cell. For details to see [5]. According to adaptive multimedia wireless framework [1,2], MIP and MDP can reserve a bandwidth level that can change during call holding time. These behaviour can guarantee a more flexible resource management increasing the system utilization. This paper is organized as follows: in section II the MobileRSVP is described, in order to analyse the behaviour of mobile hosts during connections; section III describes the rate adaptation and call admission control employed in our work, while section IV shows simulations results; section V concludes the paper.

II. MOBILE RSVP

In order to handle users mobility and to offer guaranteed services (mobility independent) the ReSerVation Protocol [10] has been extended, with the MRSVP [5,11]; in this way, the hand-off events can be managed in an adequate manner and the mobile users can make reservation requests over more than one cell, by their *proxy agents*: there are *local proxy agents* (which handle the active reservations) and *remote proxy agents* (which deal with passive reservations). An active reservation is made by a user only on the current access point (for MDP class, as we see later), while passive reservations are made only on the remote cells that the user will visit during its connection (users belonging to MIP class requests passive reservations). A MRSVP connection starts with a *proxy-discovery protocol* phase, with which the user can know the addresses of its remote agents; then a resource request can be made, which will reach the net sender, in order to begin the data packets transmission.

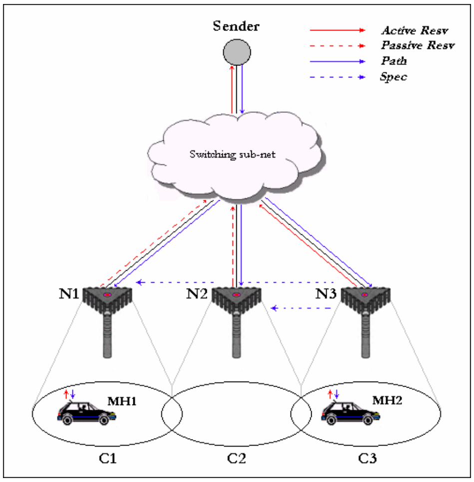


Figure 1. An example of wireless LAN with mobile hosts and some MRSVP messages.

After the proxy addresses are discovered, users send active_RESV messages to their local access points and passive_RESV messages to their remote access points, so the system must effect an admission control (as explained in section III), in order to accept or refuse users' requests. When a user moves from a coverage area to another one, the hand-off event is managed by making a new request (MDP class) or by a reservation switch (MIP class): the reserved resources in the old access point are released in both cases and, if the user belongs to MIP class, the passive resources can be assigned by switching to an active reservation. For more details about MRSVP to see [5,11]. Users' mobility has a considerable impact on QoS parameters (like packet-delay, delay-jitter and packet-loss rate): when a user moves between adjacent cells, congestion level may vary, so the assigned bit rate may fluctuate and the perceived quality of service may degrade below requested lower bounds; moreover, in adaptive networks, there are lots of bandwidth reallocations, so the users' assigned resources are frequently subject to variations and the offered service may be high degraded. In order to handle mobility effects and to offer mobility-independent services in an adaptive multimedia networking, different classes have been defined [11]; in this paper two classes are considered: Mobility Independent Predictive (users belonging to this class are not subject to mobility effects and the packet delay must be always respected; tollerant and real-time applications with a limited delay-bound belongs to this class) and Mobile Dependent Predictive (the offered service is subject to mobility effects and it may suffer several degradations, so the delay-bound is not always respected). As earlier discussed, with the MRSVP, mobility effects can be handled in adequate way for MIP users, by the passive reservations policy, while, for MDP users, only active reservations are made.

III. RATE ADAPTATION AND CALL ADMISSION CONTROL

We used an *utility-oriented* algorithm for rate-adaptation and admission control, which takes in account the time-varying nature of links, between hosts and access points [4] and the mobility effects (hand-in, hand-out).

A. Utility based Rate Adaptation

The bandwidth of a flow takes its discrete value from the set $B=\{l_1,l_2,\ldots,l_m\}$, where $l_i<l_{i+1}$ for $i=1, \ldots, n-1$. It is assumed that the calls can belong to MIP or MDP classes and all of them take (varying) bandwidth values from the same set B. Mobility and fading can change the system condition so it is necessary to use rate adaptations algorithms for varying bandwidth levels according to channel conditions and host mobility. There are different rate adaptation algorithms in literature [6-8] based on QoS index as degradation ratio, degradation degree, outage probability etc, but this case the considered rate adaptation algorithm is based on a *utility function* associated to two classes of services (MIP and MDP), and it tries to maximize the *user profile satisfaction* modelled by this target functions [4]. The *slow fading effect* of wireless channel has been considered in order to give more effectiveness to used rate adaptations algorithm and to reservation protocol (MRSVP). So the rate adaptation distributes the discrete bandwidth levels considering the channel state valued in terms of degradation state and the target utility function. The utility perceived by mobile user is $u_i = U_i\left(\left(1-D_{i,m}\right)\cdot r_i\right)$, where U_i is the utility function associated to user i, $D_{i,m}$ is the degradation state m associated to the channel i in a given time and r_i is the discrete bandwidth level given to mobile user. The channel modelling is based to Discrete Time Markov Model (DTMC) according to [3]. The rate adaptation algorithm is the Utility based Rate Adaptation Algorithm [4]. It is based on QoS target that is to guarantee the *minimum utility* $u_{\min} = U_i\left(\left(1-D_{i,m}\right)\cdot l_1\right)$ where the user utility can change between u_{min} and u_{max} and $u_{\max} = U_i\left(\left(1-D_{i,m}\right)\cdot l_n\right)$. Another characteristics of this algorithm is the fairness criteria. This last is based on a *normalized gap* associated to the user and defined as

$$G_i = \frac{u_{i,avg} - u_{i,\min}}{u_{i,\min}} \qquad (1)$$

where $u_{i,avg}$ is the average utility perceived by mobile user i. Algorithm try to maximize user perceived utility function maintaining $G_i \approx G_j$, $\forall i, j$, where i, j are two generic users admitted in the wireless network. This task is obtained through the management of the flows list ordered for increasing G_i values. When a rate adaptation occurs for bandwidth deficit or channel degradation the bandwidth is taken from flows with lower G_i, while when the bandwidth is released by a terminated call, the available bandwidth is given to the flows with higher G_i values. For details on this algorithm and optimisation criteria refer to [4].

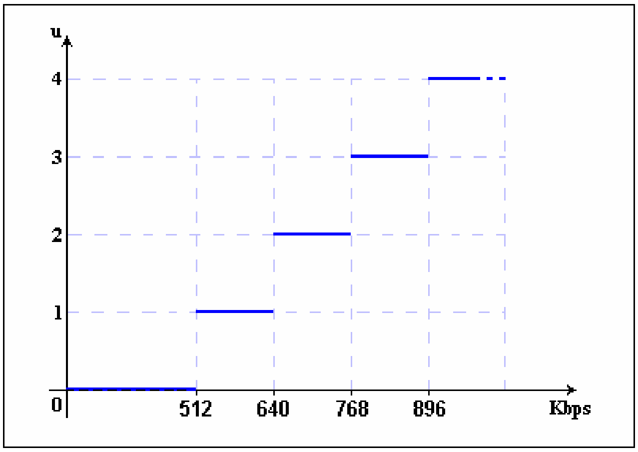


Figure 2. Utility function used for users belonging to MIP and MDP services

B. *Call Admission Control*

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. It is used the same algorithm proposed in [4] but some variations have been added. If a user is admitted in the wireless network, a bandwidth $R_u = \frac{l_{j,\min}}{(1-D_{j,q})}$ is assigned to the user, where $D_{j,q}$ is current degradation q of wireless link j. The outage probability is defined in the following way: $p_{o,c} = P_r\{\sum \frac{l_{i,\min}}{1-D_{i,m_i}} > R\}$, with R representing the bandwidth associated to 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 to change degradation state, it is possible to know the probability of the link to being in the state i : $p_i = \frac{\pi_i t_i}{\sum_{i=1}^{k} \pi_i t_i}$, with π_i representing the steady state probability associated to channel state i, and t_i representing the i's average holding time. Through p_i it is possible calculate in the worst case p_0 accounting the channel state conditions in the following way

$$p_0 = \sum_{A} \prod_{1 \le i \le n} p_{m_i} \qquad (2)$$

where

$$A = \{m_1, m_2, ..., m_n \mid 1 \le m_1, ..., m_n \le k, \sum \frac{r_{l,1}}{1 - D_{l,m_l}} > R\},$$

with m_i representing the user i's link state at the time instance. For details to see [4]. The admission control algorithm works differently for two classes of service. For MIP, the flow is admitted if:

$$\sum_{c=1}^{C} p_{0,c} \le C \cdot p_{outage} \qquad (3)$$

where C is the number of cells that mobile host will visit and p_{outage} is the outage probability of the wireless system. The verified condition is that for each cell m, $p_{0,c} \le p_{outage}$ 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. For MDP, the flow is admitted if $p_{0,c} \le p_{outage}$ where $p_{0,c}$ represents the current cell in which mobile host is found. The MIP services can under-utilize the system resource for passive reservation, so it can be permitted to MDP flows to use the *passive bandwidth* of MIP flows. When a flow needs of its passive bandwidth (e.g. for handoff), the passive bandwidth is switched in active reservation and the MDP is pre-empted. For avoiding the increasing of MIP flows cut, rate adaptation is used for MDP. So the available bandwidth obtained by rate adaptation algorithm is assigned to a flow MDP that used passive bandwidth. If there is no availability of bandwidth, the MDP flow is cut.

C. *Partial Resource Reservation*

A further criteria for improving the performance of WLANs system has been proposed. A model for estimating the cell stay time has been evaluated and this information has been used to calculate the number of cells visited by mobile host. This information can be used to reserve in the pre-reservation phase the passive reservations only on the cells effectively visited and leave the bandwidth availability in other cells. For deriving this model, a *poisson arrival time distribution* and a *exponentially distributed call holding time* have been considered for any mobile hosts, and the mobile host speed has been uniformly selected in a range of [$v_{avg} - \alpha$, $v_{avg} + \alpha$], where α=10%* v_{avg}. For any fixed v_{avg} a cumulative distribution function (c.d.f.) of average cell stay time of mobile host has been derived in order to make a predictive evaluation of visited cells. The distribution, as shown in figure 3, follows a normal distribution, so it is possible to evaluate the error of considered cell stay time and to make a cell stay time prediction based on confidence intervals and confidence levels considering the worst case cell outage probability (COP).

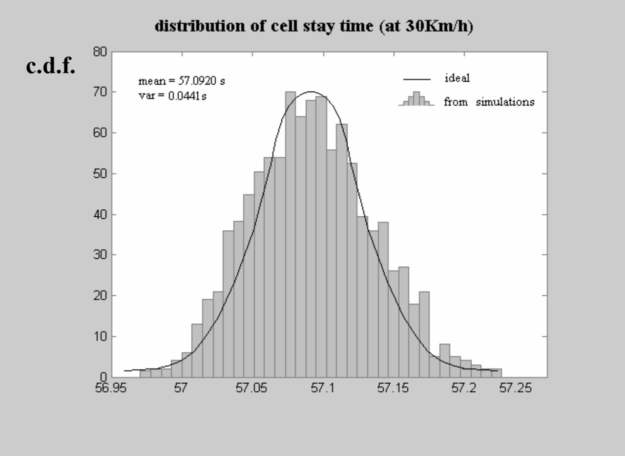
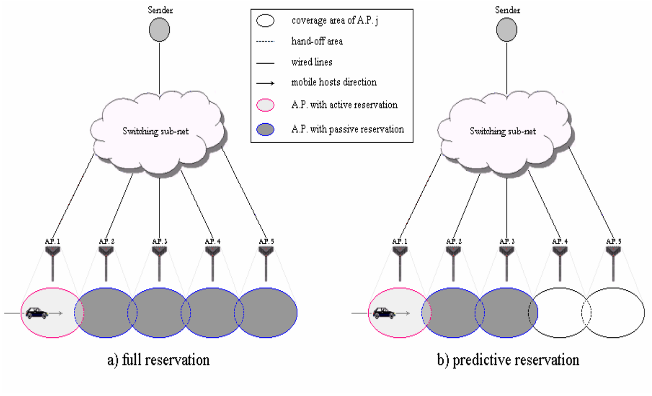


Figure 3. Cell Stay Time distribution with v_{avg}=35Km/h.

It is possible to select a cell stay time T_{cst} for a mobile so that $Prob(X< T_{cst})$ <1-COP, where X is normally distributed. This 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

$$C_p=T_{cht}/T_{cst} \qquad (4).$$

So it is possible to use the C_p value represented in eq. 4 to make the pre-reservation of MIP flows in order to leave more bandwidth availability in the not visited cells for new MIP or MDP flows. The bandwidth preservation on all the cells of system using C_t (C total) and the partial reservation using C_p is showed in figure 4.



a) full reservation

b) predictive reservation

Figure 4. a) A mobile host requesting MIP services makes a passive reservation over all cells of the system; b) Partial reservation over estimated number of potentially visited cells.

IV. PERFORMANCE EVALUATION

In order to evaluate the performance of rate adaptation scheme, call admission control for MIP and MDP and the conformance to QoS parameters (outage probability, minimum utility function and an high system utilization), different simulations have been lead out. The considered parameters for bandwidth levels have been similar to [5,6,7] but with the following values {512, 640, 768, 896 kbit/sec.}; for guaranteeing the slow fading conditions, the degradation states of channel have been fixed to (1%, 10%, 25%, 42%), the utility function has been considered according to figure 2. The outage probabilities considered for MIP and MDP services have the same values and the following values have been considered (0.004, 0.04 and 0.4). The same utility functions have been considered for MIP and MDP flows and a radio coverage of 250m has been assumed with a five cells disposed in a circular manner (if a mobile host leaves the last cells it go inside the first cell and go on). The mobile host can move with a speed selected uniformly in range [v_{avg} - α, v_{avg} + α], where α=10%* v_{avg} and the simulated average speeds are {5, 15, 25, 35, 45, 55, 65, 75 Km/h}. The simulated net is the same as in figure 4. Continuous curves represent the simulation results with the described prediction model based on C.S.T. evaluation, while the dotted ones are obtained in absence of prediction technique. Two are the considered policies for bandwidth management: *disjunctive* policy, in which two outage thresholds are defined, in order to distinguish MIP and MDP admission ratios and *conjunctive* policy, in which only one outage threshold is used and MIP flows can pre-empt MDP ones. Continuous and dotted curves are also obtained by varying the outage threshold (for disjunctive bandwidth policy the threshold is varied only for MDP users) as illustrated in the captions. Figures 5 and 6 are obtained by a *disjunctive* policy; for figure 5 the traffic percentage is 20%MIP, 80%MDP, while for fig. 6 it is 80%MIP, 20%MDP (reuse of passive bandwidth for MDP flows is *denied* in both cases); From fig. 5, introducing a prediction model, it can be observed that the system utilization goes from low values (below 3%) to higher values (between 16% and 37%); so, although the MIP percentage is low (20%), many improvements can be obtained by introducing the described technique. In spite of the MIP threshold is not varied, the curves decrease by increasing the MDP threshold: the system can offer less resources to MIP users, because the number of MDP flows that enter the system is higher, for higher values of their threshold. In figure 6 higher improvements are observed under the same conditions, by increasing MIP traffic percentage (80%): an utilization from 53% to 75% (depending on the chosen threshold) can be reached, versus the 10% value of full reservation.

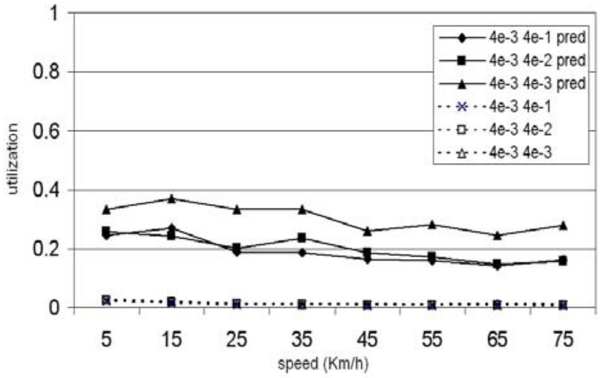


Figure 5. System utilization by MIP users (low MIP traffic).

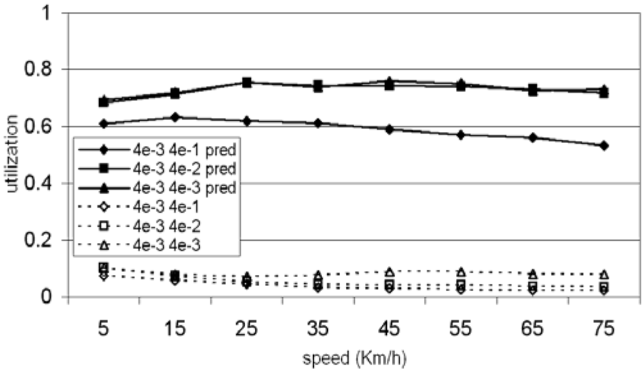


Figure 6. System utilization by MIP users (high MIP traffic).

Figure 7 is obtained by a *disjunctive* bandwidth management policy and a traffic percentage of 80%MIP, 20%MDP (reuse of passive bandwidth is *denied*); a decrease in assigned bandwidth is observed by introducing the prediction model: there are more users sharing resources (bandwidth) in the access points, so the system must decrease the amounts of bandwidth assigned to each user; the downturn values are in the range (2;26) Kbps depending on the chosen MDP threshold.

Figure 8 is obtained by a *conjunctive* bandwidth management policy and a traffic percentage of 20%MIP, 80%MDP (reuse of passive bandwidth is *denied*); figure 8 shows that the number of admitted users increases because each flow can observe a less selective admission control: by the prediction tecnique, entering the system for MIP users is easier, beacause they have to obtain the access from a lower number of access points, wich are in the prediction list.

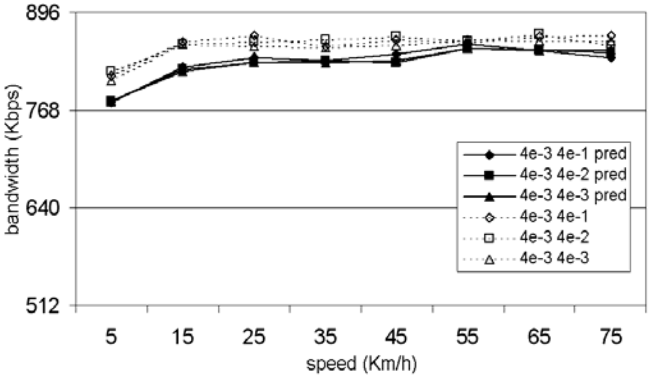


Figure 7. Assigned bandwidth to MIP users.

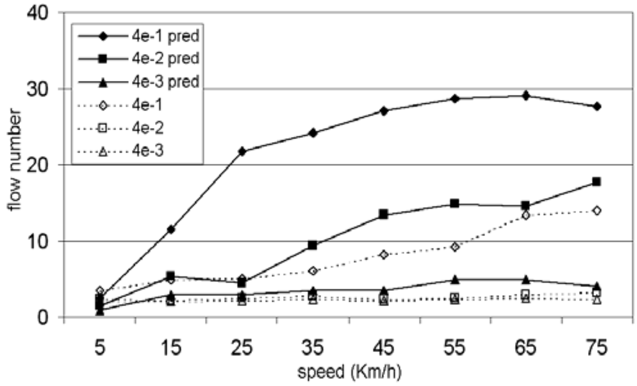


Figure 8. Admitted MIP flows.

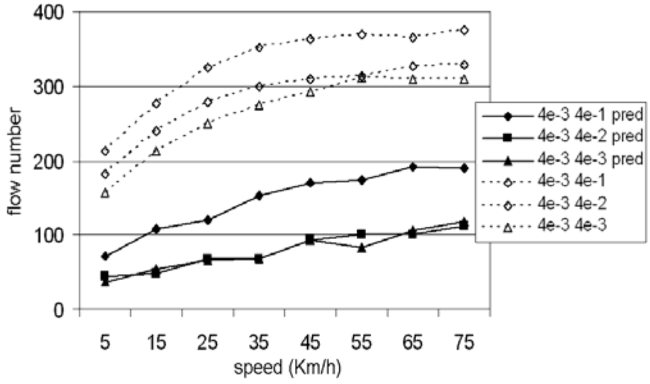


Figure 9. Admitted MDP flows.

Figure 9 is obtained by a *disjunctive* bandwidth management policy and a traffic percentage of 80%MIP, 20%MDP (reuse of passive bandwidth is *granted*); by introducing the prediction model, a decrease in admitted MDP flows can be observed, because there are more MIP users which can enter the system. In every case, the number of admitted flows increases by increasing users' average speed, because each user spends less time in coverage areas if it increases its average speed.

V. CONCLUSIONS

In this paper we proposed a new prediction model to estimate the average time spent in a cell by a mobile user. The obtained model has been employed and integrated with the utility-algorithm discussed in section III and the MRSVP, in order to value the number of cells that MIP users will visit during wireless connections. From simulation results it can be observed that the partial reservation gives more benefits than total reservation in terms of total bandwidth utilization of the system and it allows a higher ratio of MIP flows admission, independently from traffic percentages or bandwidth policy employed. In particular, for conjunctive policy a higher number of pre-empted MDP flows is observed. Both MIP and MDP respects the outage probability fixed by call admission control.

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