Dynamic resource allocation with a novel handover procedure for application in a broadband system.

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Abstract

The present work investigates problems related to mobility of broadband users in a Wireless Local Area Network (WLAN), such as the MEDIAN environment [1]. One of the MEDIAN project main objectives is the implementation of a high speed wireless customer premises local area network for multimedia applications. The purpose of the present analysis is to investigate the intrinsic limitation introduced by mobility when high bit rate users compete among each other and with low bit rate users in sharing the same physical channel resource. Resource allocation management is analysed at the Medium Access Control (MAC) layer. A Time Division Duplex – Time Division Multiple Access – Orthogonal Frequency Division Multiplexing (TDD-TDMA-OFDM) access method is adopted in the model, in accordance to the MEDIAN MAC architecture. A novel resource allocation protocol referred to as PAMA (Priority Assignment Multiple Access) [2], which provides a different slot assignment to different types of services, is analysed. PAMA also allows a different priority to be dynamically obtained by the users according to the evolution of packet generation, and resulting in a larger number of slots assigned to high bit rate users. The users are allowed to make handover between cells, using a novel handover mechanism which takes advantage of the OFDM modulation scheme. Results obtained by simulation of the system for fixed and mobile users show that, surprinsingly, the introduction of mobility does not necessarily introduce a worsening of overall performance.

Introduction

The present work investigates the problem of dynamic resource allocation in a system in which broadband users compete among each other and with narrowband users in sharing the same physical channel resource. The system under study is based on the MEDIAN Wireless Local Area Network (WLAN) architecture [1] which adopts a Time Division Duplex – Time Division Multiple Access – Orthogonal Frequency Division Multiplexing (TDD-TDMA-OFDM) access method at the Medium Access Control (MAC) layer. The proposed model represents an extension of the MEDIAN architecture to include mobility; Thus it includes a proposal for the handover in order to control resource assignment when users move within a cluster, from one cell to the other. The proposed handover mechanism takes advantage of the OFDM-based modulation scheme.

The paper is organized as follows. In section 1, the resource allocation protocol, named PAMA [2] is described. In section 2, the handover procedure proposed is illustrated. Section 3 contains the results of simulation experiments of the proposed system obtained with video users (characterized by a bit rate of 3 Mbits/s) and with video+speech (GSM-like) users. Variations obtained as a function of the degree of mobility (represented by the probability of making handover) are also presented. Finally, section 4 contains the conclusions.

1. Priority Assignment Multiple Access: PAMA [2]

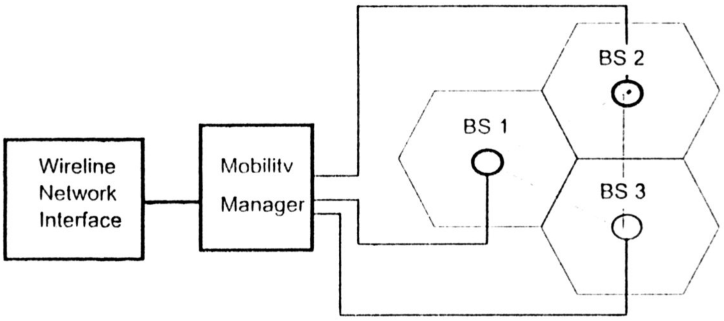

Figure 1 - Fixed Network Topology

We refer to a Wireless Local Area Network such as an office scenario. We consider a WLAN composed by a given number of clusters, each cluster containing seven Base Stations (BSs). In the same cluster, each BS uses a given channel in frequency. There is no frequency reuse in the same cluster. This scenario appears as an extension of MEDIAN [1] to a multicell environment. However, MEDIAN is based on the Asynchronous Transfer Mode (ATM) network architecture while in the present work reference is made to a more general fixed network topology, as shown in Fig. 1, with no condition imposed on the wireline network protocol. In the adopted scheme, each BS functions as a buffered switch connected to the other buffered switches (the other BSs) belonging to the same cluster. Packet exchanging between BSs is supposed to be instantaneous and users are supposed to move within one cluster. Moreover, we suppose inner communication between mobile users, and no connection to the outside world.

In agreement with MEDIAN, in the proposed scheme a frame is divided into an uplink and a downlink channel, following a TDD-TDMA technique. The modulation adopted is OFDM. Each frame is formed by 64 time slots. The first (last) 32 time slots refer to the downlink (uplink) channel, resulting in a constant number of time slots per frame, as shown in Fig. 2. The last downlink slot, called Broadcast slot, is used by the BS to transmit, in the current frame, the Broadcast Cell which defines resource allocation in the following frame. The first uplink time slot is called Signalling slot and is used by Mobile Stations to forward a resource access request.

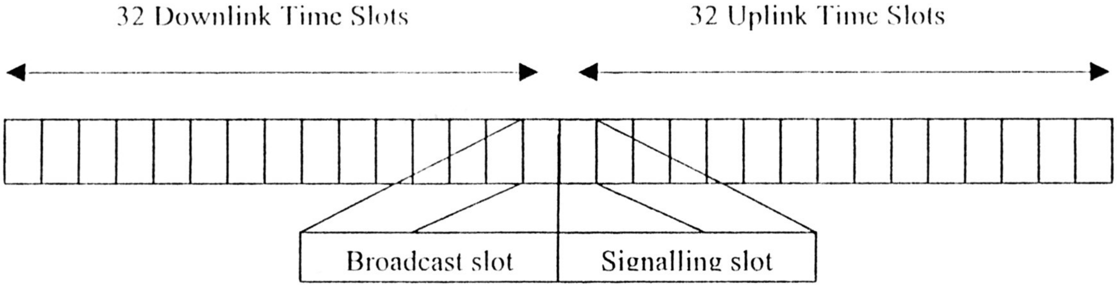

Figure 2 - Frame Structure in the PAMA scheme.

According to the OFDM modulation scheme, it is possible to assign different OFDM subcarriers to different active users. In standard OFDM, subcarriers are orthogonal, yielding to the possibility of transmitting more bits per subcarrier [3]. In the present model, the Signalling slot is shared among different active users. Suppose an assignment of a different subcarrier to each active user. Although it is impossible to obtain perfectly orthogonal subcarriers, it is possible to detect energy at a certain frequency. This solution allows each active user to send at least a two level flag per Signalling slot. This flag is used to inform the BS about a resource allocation request.

Considering an OFDM system which uses N subcarriers, the maximum number of users in the system is N. A more realistic assumption corresponds to limiting the number of subcarriers (users) to a number which is lower than the maximum allowed.

When a user enters the system, the BS assigns a Signalling flag to that user by sending an identifier of one of the available subcarriers. The user sets its Signalling flag to one every time it needs to send at least one packet.

As regards the position of the Broadcast and Signalling slots within a frame, by positioning the Broadcast cell at the end of the downlink channel one allows the BS to "defer" the decision about slot allocation as much as possible, in order to evaluate information in the previous Signalling slot.

Obviously, one flag per frame is not enough to inform the BS about the number of slots needed by a user. Therefore, an additional information message called Queue Signalling message (QS) is introduced. The possibility of sending one packet allows the user to send the QS formed by the value of two bits attached to the packet using a classic piggy-back mechanism. The QS can assume 3 values (-1, 0, +1). Sending a +1 value implies an increase in the length of the transmission buffer, while a –1 value indicates a decrease in the buffer length. A 0 value indicates that the buffer length is constant. The QS messages allow the BS to estimate the size of the transmission buffer of each user. The allocation algorithm, which is extensively described in [2], tends to assign a number of slots which follows as closely as possible the number of required slots. Compared to other non centralised schemes such as PRMA (Packet Reservation Multiple Access), it is intuitive that in the present case of a BS with some knowledge of the queue buffer length, a better resource assignment is obtained. In the PAMA scheme, slots are assigned according to delay requirements and number of packets in the transmission buffers. Therefore, global traffic conditions are considered.

To mention a limitation of the PAMA algorithm, note that PAMA does not provide any slot allocation within the first 4 frames (after setting to one the allocation request flag). Thus, the algorithm does not apply to systems adopting a frame duration higher than about 5ms.

2. Handover procedure

According to the PAMA scheme, there is not any real channel assignment to users, resulting in an intrinsic continuous intracell Hand Over (HO). Therefore, the only HO procedure which must be implemented, if only one cluster is considered, is intercell HO.

Suppose that a user decides to change its serving BS which means that it wants to make an intercell HO. The user must obtain a new OFDM subcarrier from the new serving BS by forwarding a subcarrier request to the new BS. The request must specify the actual BS and OFDM subcarrier identifier. Thus, the HO procedure enables the new BS to automatically locate the originating BS and therefore to exchange user profile information with the originating BS.

It is assumed that the HO is a Mobile Controlled Handover (MCHO) combined with the Forward Handover (FHO) algorithm. In addition, Soft Handover (SHO) may be considered, although this choice depends on radio-channel characteristics and on radio-channel measurements carried out by the mobile terminal.

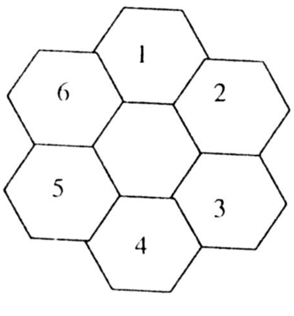

Figure 3 - Cluster of cells

In the system considered, a cluster is formed by seven hexagonal cells (see Fig. 3). Without loss of generality, referring to the central BS in the cluster, one can assign a number to adjacent BSs as shown in Fig. 3. In order to obtain a fast HO, the destination BS must know from which adjacent cell a new user is originating. By this way, the exchange of user profile information between the BSs involved and rerouting of packets to the new BS is made possible. The procedure is obtained as follows. The Signalling slot of every BS is divided into seven mini slots, each of which is referred to an adjacent BS. Each of the mini slots enables a BS to monitor the requests originating from users in adjacent cells who want to enter its cell. When a given BS is taken as the central reference, independently of which BS is taken as reference, one can derive the originating cell number of a mobile terminal. Moreover, an algorithm which allows users to recognize which mini slot is assigned in the destination BS can be implemented in the following manner: mini slots are numbered from 0 to 6, and a given mini slot refers to the corresponding numbered BS. In other words, mini slot#0 refers to the central BS, while mini slot number i (i=1,2,...,6) refers to an adjacent BS (see Fig. 3). When moving, a mobile terminal checks the different OFDM channels in order to detect which channel is characterized by the strongest energy. The identification of the channel with strongest energy allows the mobile terminal to identify the destination BS, and thus the direction of movement which is represented by the number of the destination BS. Consider for example a user who proceeds from cell#3 to the central BS. Centering on cell#3 (originating cell), the user appears as being in the central BS and moving towards cell#6, while centering on the central cell (destination cell) the user appears as being in cell#3. The above user must therefore forward its resource request to the destination BS (central BS in Fig. 3) using the mini slot#3 in the Signalling slot of the destination BS. The destination BS will know that this particular user is originating from cell#3 because it uses mini slot#3. The information about which user is entering the destination cell, is implicitely contained in the received Signalling flag, because each user transmits using a specific OFDM subcarrier.

We can summarize the procedure as follows: when a user decides to change its serving BS it searches in its map the identification of the destination BS consisting of the mini slot which must be used in the Signalling slot of the destination BS. Once the destination BS has received the HO flag contained in the mini slot, it can forward to the originating BS a user profile request and also the new OFDM subcarrier identifier. The serving BS sends to the "handovering" user the new identifier which enables the new user to forward an allocation request.

3. Simulation results

Simulations have been carried out using the channel parameters specified in Tab.I.

Definitions	**Value**
Frame Duration	400μs
Slot Per Frame	64
Slot Duration	6.25μs
Mini Slot Duration	893ns
Net Packet Size	424 bit
Global ATM Channel Rate	68Mbps
Gross Packet Size	1024 bit
Global Channel Rate	163Mbps
User Information Payload	384 bit
User Information Global Channel Rate	61.44Mbps
ATM Channel Rate (One Slot Per Frame)	1.0625Mbps
User Payload Channel Rate	0.96Mbps

Table I: Channel Parameters

The multiple access scheme has been tested in a multimedia scenario in which video users, and video + speech users are present. Table II summarizes the users in terms of average bit rate. Users are modelled using Markov chains as extensively described, especially as regards video users, in [4].

User	**Average Bit Rate**
Voice (GSM)	22.8Kbps
Video (standard h.263)	3Mbps

Table II: Bit rate of the users

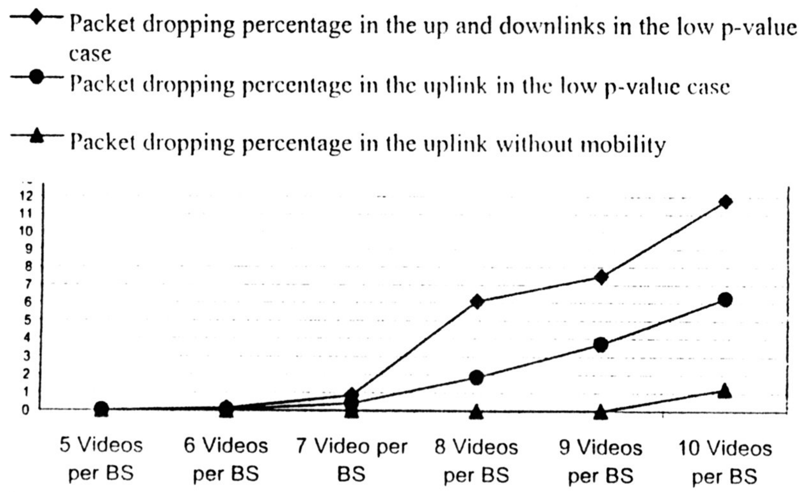

Figure 4 - Results of simulation for the low p-value case in terms of percentage of packet dropping vs. number of video users in a cell

In particular, for the video users analysis we have tested the access method under different degrees of mobility conditions. The degree of mobility is expressed by the Handover probability per user and per frame, which indicates that in each frame the generic user can decide to make HO with a probability value *p*. Simulations have been carried out at different *p* values: a low value case ($1.5\ 10^{-4}$), a medium value case ($1.5\ 10^{-3}$), and a high value ($1.5\ 10^{-2}$). We consider that a packet is dropped after a time delay of 30 ms, and we assume the maximum percentage of dropped packets be less than 1%, which is a generally agreed value of acceptable quality [5]. In the low p-value case, results show that (see Fig. 4), in comparison with the case of no mobility, the maximum number of video users per BS must be decreased from 9 to 7, in order to keep the packet dropping percentage to a value under the target of 1%. In Fig. 4 three cases are shown; the curve identified by triangles refer to the no mobility case, the circles to the low mobility case ($p=1.5\ 10^{-4}$) considering a delay caused only by the up-link, and the diamonds to the low mobility considering a delay caused by both the up and downlinks.

As regards the analysis of both speech and video users, we analyzed the low p-value case. Figure 5 shows the dropped packet percentage for video users as a function of the number of speech users in the cluster, in two cases of 6 and 7 video users in each cell. It can be noted that an increase in the number of speech users produce an oscillation in the average packet dropping for video users. Results of simulations also show (not in the Figure) that dropped packets for the speech users are largely lower than 1%.

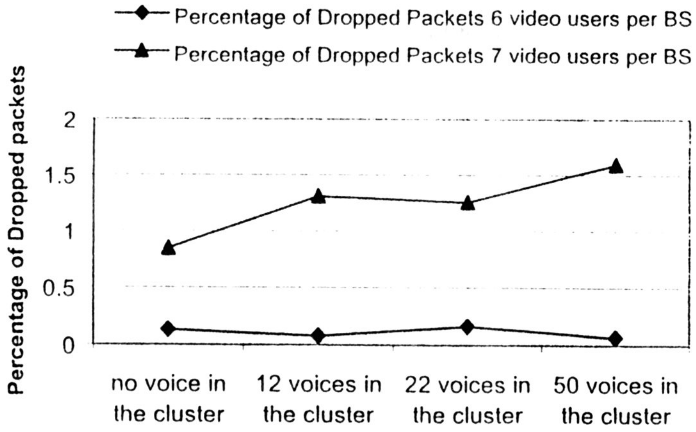

Figure 5 - Packet dropping percentage for video users in a multimedia scenario

Finally, we analyzed the case of only video users characterized by different HO probabilities (i.e. different degrees of mobility). As shown in Fig.6, when the HO probability increases, the average performance for each video user increases. When the HO probability is at a low value, the upper bound for the number of the video users imposed by the introduction of mobility is 7 users per BS. When the HO probability is set to the medium value ($1.5\ 10^{-3}$), the average dropped packets decrease. In this second case, the upper bound is still 7 users per BS, but a lower average percentage of dropped packets is obtained. In addition, the dropped packets for each video user does not rise above the

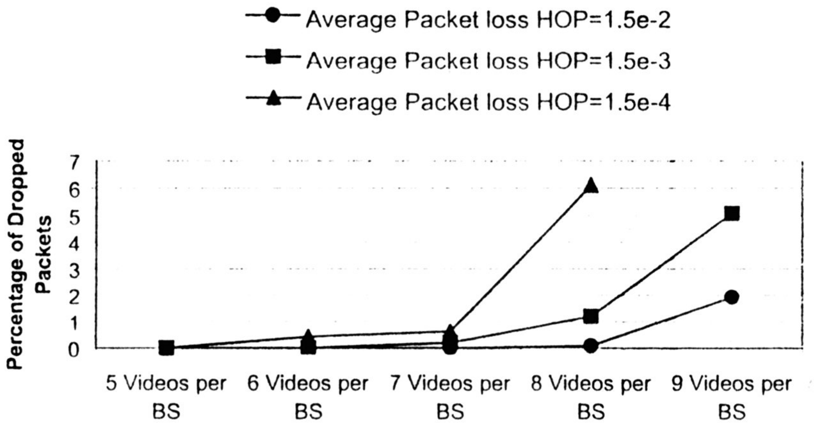

Figure 6 - Percentage of Packet dropping for different value of HO probability

maximum target of 1%. In the third case, when HO probability is at a high value (1.5 10^{-2}), the obtained upper bound rises to 8 users per BS, which is very close to the upper bound obtained without mobility (which is equal to 9 video per BS, as shown in Fig. 4). Furthermore, in the present case, the percentage of dropped packets for each user is much lower than 1% for 8 video in a cell, and goes to 0 as soon as the number of video is reduced to 7.

Conclusions

The present work investigated the problem of resource allocation to broadband users in a WLAN based on the MEDIAN architecture. The adopted scenario appears as an extension of MEDIAN (TDD-TDMA-OFDM) to a multicell environment in which users can make intercell handover.

The adopted resource allocation protocol, named PAMA, allows dynamic resource allocation by using a Signalling slot in the frame structure and a Queue Signalling message. By this way, the number of assigned slots tends to follow the number of the required slots and therefore provides a different slot assignment to different types of services.

The proposed intercell handover protocol exploits the OFDM-based transmission protocol and is a Mobile Controlled Handover combined with a Forward Handover algorithm.

Simulations of the proposed system were carried out by considering the presence of both video users and video+speech users. Results show that with the proposed mechanism, the number of allowed video users in a cell is about 7 at a packet dropped probability below 10^{-2}, compared to 9-10 allowed users when no mobility is present. Moreover, results show that the above limit of 7 video users can be increased to a higher number of allowed users when the degree of mobility is increased.

Reference

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