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A NEW EFFICIENT ACCESS PROTOCOL FOR INTEGRATING MULTIMEDIA SERVICES IN THE HOME ENVIRONMENT

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ABSTRACT

This paper presents a new dynamically adaptable medium access method that can be applied to home networks in order to create a distributed environment for multimedia and data processing services. The method uses a mechanism that detects silent periods in voice transmissions and dynamically allocates the available bandwidth between isochronous and asynchronous traffic.

Keywords - *Wireless LAN, Access protocol, Integrated voice-data communication, Wireless Personal Area Network (WPAN).*

I. INTRODUCTION

The key aspect of the telecommunications revolution is the ubiquitous access to information and services. Wireless communications give a new meaning to that concept. Cellular networks combined with the POTS infrastructure provide universal user access to voice-related services, while data-related services are still under development for this environment.

The IEEE 802.11 protocol [1] was accepted as a standard in 1997, and intends to ensure the development of interoperable products in order to facilitate the deployment of wireless LANs (WLANs). The IEEE 802.11 is limited in scope to the physical (PHY) and Medium Access Control (MAC) layers of the OSI model. It specifies a choice of three different PHY layers, any of which can underline a single MAC sublayer. Specifically, the IEEE 802.11 specifies an optical-based PHY that uses infrared light to transmit data, and two RF-based PHYs that use different types of spread spectrum radio communications (Frequency Hoping-FHSS and Direct Sequence-DSSS). FHSS systems use conventional narrow-band data transmission techniques but regularly change their operational frequency. DSSS systems artificially broaden the bandwidth needed to transmit a signal by modulating the data stream with a spreading code. The receiver can recover the originally transmitted data even if noise persists in portions of the transmission band.

The MAC layer of the IEEE 802.11 standard should provide the services of Authentication, Deauthentication, Privacy and MSDU Delivery. Within a wireless system, the medium is not exactly bounded as in wired systems and unauthorized users may access the transmitted information. In order to control the network access, new stations must first establish their identity with the other network stations. Finally, every station should provide the mechanism that ensures the information in the MAC service data unit is delivered between the MAC service access points (SAP).

The MAC protocol uses the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) algorithm which is similar to the CSMA/CD algorithm used in the wired LANs. CSMA/CA deals also with the problem of the hidden node. In this case, station A does not hear station C but both of them hear a third station B. If station A and station C try to send data to station B at the same time, the data will be corrupted. In the home environment, the hidden node problem does not exist when a centralized protocol is employed, since all stations are synchronized by the central station.

In this paper we present a new centralized Medium Access Control (MAC) protocol, called Centralized Access Protocol (CAP), designed to support isochronous and asynchronous traffic in the home environment. The protocol is based on a subset of the IEEE 802.11 functions with the addition of the necessary functionality to support

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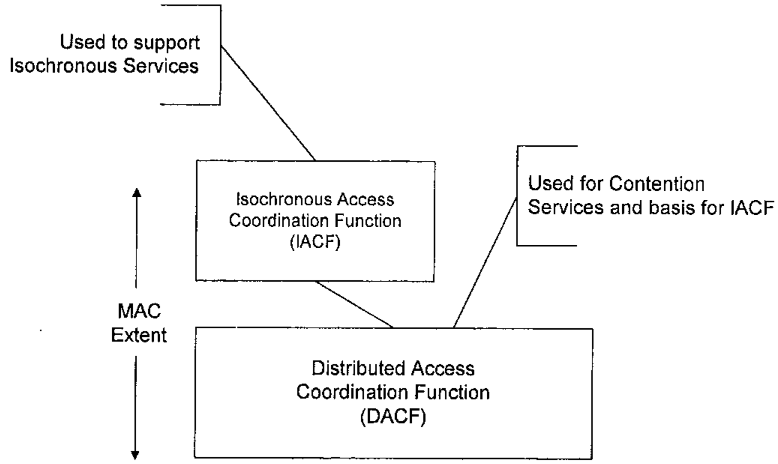


Fig. 1: The MAC layer architecture

isochronous services. As isochronous are considered the services which require bounded delay, thus guaranteed bandwidth must be provided. The Quality of Service (QoS) of isochronous services is negotiated during service set-up and remains constant as long as the service is provided. Such services are mainly voice and video related.

Section II of this paper introduces the technology trends for wireless applications in the home environment, while section III describes the architecture of the Centralized Access Protocol. Finally, section VI presents some simulation results that highlight the CAP performance.

II. TECHNOLOGY TRENDS

Along with the IEEE 802.11 protocol, two additional proposals are being considered for standardization, the HomeRF and the Bluetooth. The HomeRF Shared Wireless Access Protocol (SWAP-CA) [2] was designed to carry both voice and data and to interoperate with PSTN and the Internet. The Bluetooth communication architecture is a proposal for cable replacement with wireless links between portable and/or fixed electronic devices [3]. The medium access protocols of both specifications are expected to operate on top of FHSS physical layers with short-range transmission capabilities.

The HomeRF SWAP-CA MAC is a hybrid protocol, originating from the combination of the DECT (Digital Enhanced Cordless Telephone) medium access protocol and a lightweight variation of the IEEE 802.11 MAC. It can operate either as an ad-hoc or centrally managed network with data rates of up to 2Mbps and supports up to six full duplex voice connections (centralized network mode only). Four basic types of nodes are supported:

- A Connection Point (CP) that acts as the gateway between the personal computer, the PSTN, and the SWAP-compatible devices
- Isochronous data devices (I-nodes)
- Asynchronous data devices (A-nodes)
- Combined Asynchronous/Isochronous devices (AI-nodes)

Connection Points provide channel access and power management coordination for the whole network and interworking with personal computers and the external communication infrastructure (PSTN, Internet). Connection Points are present only in centrally managed configurations. In ad-hoc configurations, where no CP and I-nodes exist, the channel access arbitration is distributed among the A-nodes and there is no support for power saving.

Basically, SWAP/CA MAC permits upper layers to access the channel by dividing time in subsequent identical "superframes". Each superframe consists of slotted contention free periods (TDMA) and contention periods (CSMA/CA) during which A-nodes compete for the channel. The structure of the superframe as well as the protocol services are defined in such a way to allow the DECT higher layers (DLC, NWK and IWU) to be hosted on the SWAP-CA MAC without serious modifications.

On the other hand, the Bluetooth Baseband specification defines a purely centralized configuration for the network (piconet). Nodes operate in a master-slave mode, where the master is the base station. The master's clock is the main clock of the piconet and the slave stations access the medium in a timely manner on a per slot basis. There are no contention periods and strict timing restrictions apply to slave clock adjustments in order to preserve synchronicity with the piconet clock. Between master and slave(s), two different types of links can be established: synchronous connection-oriented (SCO) and asynchronous connection-less (ACL) links. According to the specification, the SCO link is a point-to-point link between a master and a single slave in the piconet. The master maintains the SCO link by using reserved slots at regular intervals. The ACL link is a point-to-multipoint link between the master and all the slaves participating on the piconet. In the slots not reserved for the SCO link(s), the master can establish an ACL link on a per slot basis to any slave, including the slave(s) already engaged in an SCO link.

Bluetooth masters can support simultaneously an asynchronous full-duplex data channel and up to three synchronous 64 kbps voice channels. The aggregate symbol rate of the protocol is 1 Mbit/sec.

The IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) is a newly-formed working group. Its responsibility is to provide a standard for short distance wireless networks with low complexity, low power consumption wireless connectivity to support interoperability among devices within or entering the Personal Operating Space (POS). Bluetooth, IEEE 802.11 and HomeRF are considered as the base for the development of this new standard. As it will be presented in the following sections, the protocol described in this paper has similar if not the same scope with the IEEE 802.15 standard.

III. PROTOCOL DESCRIPTION

The purpose of the Centralized Access Protocol (CAP) is to provide wireless connectivity to automatic machinery or equipment, which may be portable or hand-held, with non-portable devices, within the area of the home environment. Specifically, CAP describes the functions and services required by any device to operate within the home network. It also defines the MAC procedures to support the asynchronous MAC service data unit (MSDU) delivery services and adopts the IEEE 802.11 requirements and procedures to provide privacy of user information being transferred over the wireless medium (WM) and authentication of conformant devices.

The presented wireless LAN protocol integrates voice, video and data services in a unified environment with dynamically adaptable functionality. The CAP aims to provide the necessary mechanisms in order to support services which require the use of constant bandwidth, while the remaining bandwidth is used by stations with burst and asynchronous data traffic [4]. Priority of service is also supported by this access protocol.

The fundamental access method of this protocol is the Distributed Access Coordination Function (DACF), which implements the Carrier Sense Multiple Access algorithm with Collision Avoidance (CSMA/CA). The isochronous services are supported by the Isochronous Access Coordination Function (IACF).

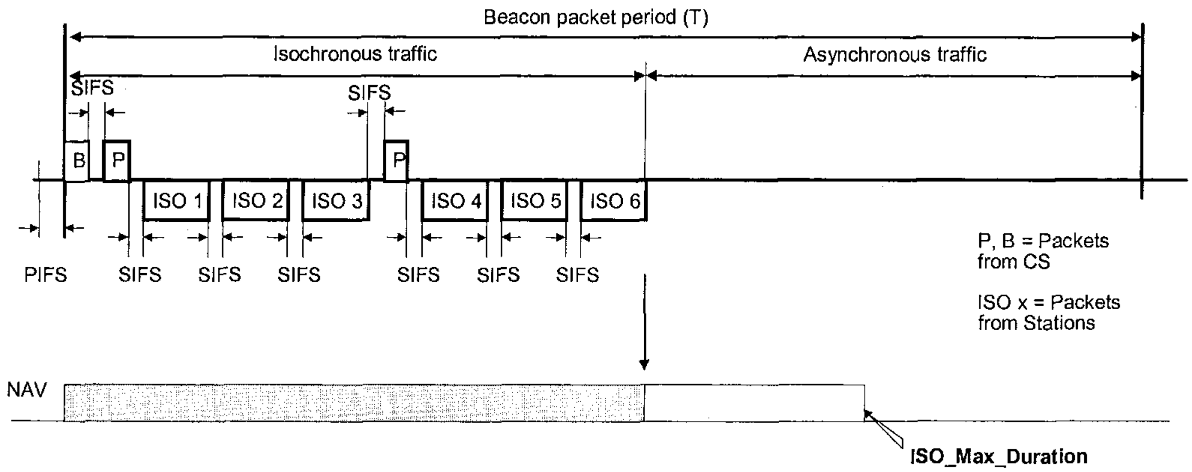
The design of the protocol is based on the concept of the IEEE 802.11 standard with some major changes. CAP operates in the home environment, so there is no hidden terminal problem and the extended service set functionality is not needed. On the other hand, the basic services that should be supported in this environment, i.e. wireless phone handsets, are the basic services that CAP should support with the proposed protocol. The main effort of this development is the best possible allocation of the channel resources.

In order to implement this protocol, a Central Station (CS) is required in order to manage the available bandwidth and to reserve part of it for the isochronous services. The CS transmits Beacon (B) management packets for synchronizing the network nodes. Every Beacon packet defines the timing of the isochronous traffic, that is, when packets of isochronous traffic have to be transmitted. Every station in the network buffers its data and postpones any pending transmission to the appropriate time instant, by setting its Network Allocation Vector (NAV) value. Every station implements the collision avoidance algorithm, and for accessing the medium uses also the NAV parameter. The station does not transmit while this vector is greater than zero.

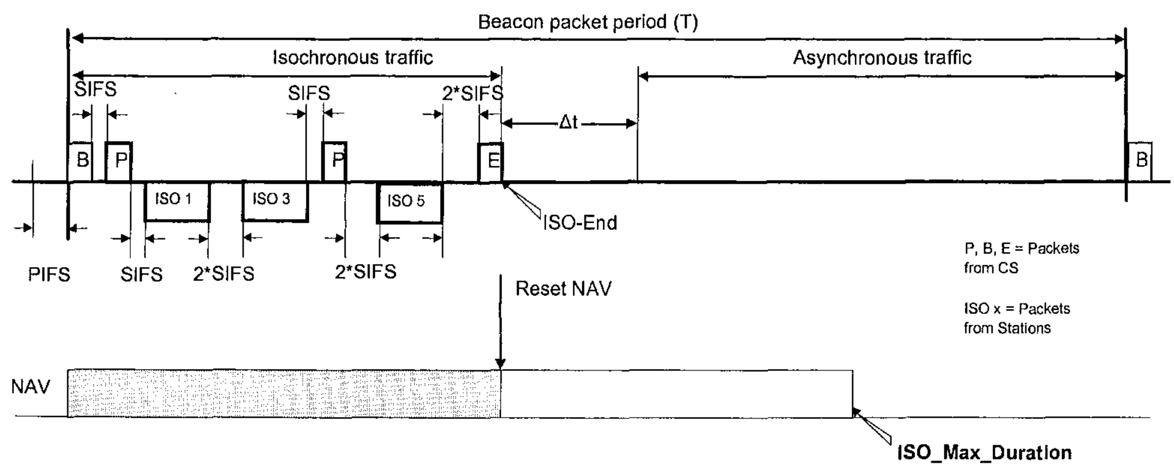
Each Beacon packet contains also the duration of the time until the next Beacon packet. The time between the end of the isochronous traffic and the next Beacon is used for asynchronous traffic. During that period, every station should content with other stations to gain access to the medium. Within the Beacon packet a time stamp is provided in order all stations to synchronize their clocks to the central station.

During the isochronous traffic, every station transmits using the Short InterFrame Space (SIFS) time-gap between successive packets. Figure 2.a shows the operation of a typical system where two conferences are settled and three stations participate in each conference. The first Poll (P) packet, transmitted just after the Beacon, informs stations 1 2 and 3, which participate in the first conference that it's their turn to transmit and it also informs the how to do that. At the end of the transmission of the third station, the Central Station sends a second Poll packet to synchronize stations 4, 5 and 6, which participate in the second conference.

Figure 3.b shows the same scenario within CAP but with its updated version. In this case, only stations having useful information are allowed to transmit, thus achieving better bandwidth utilization. In this scenario, a station without useful information postpones its transmission. All the stations in the conference know that if a station has data to transmit, it has to start its transmission SIFS-time after the end of transmission of the previous station. If at the end of this time the medium is still idle, the next station participating in the conference starts transmitting its data, no later than SIFS-time after it senses that the previous station postponed its transmission.



(a)



(b)

Fig. 2. Bandwidth allocation to isochronous and asynchronous traffic

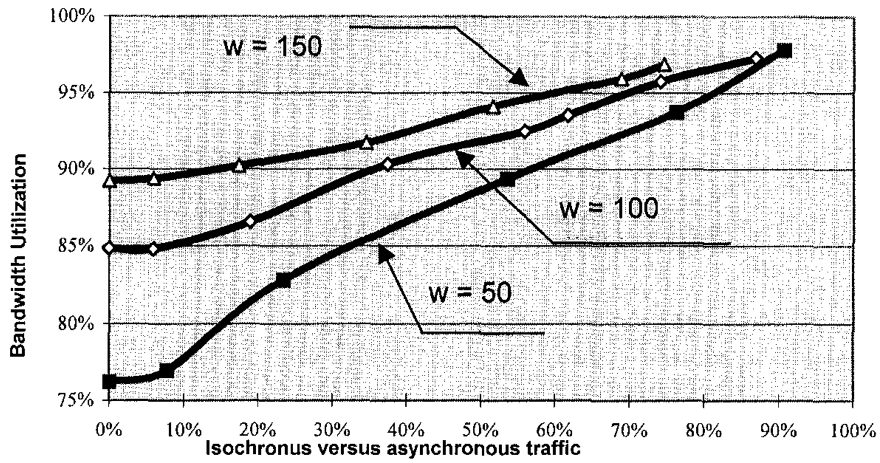


Fig. 3: CAP Channel Utilization

According to the CAP protocol, the ISO-END packet signals the early end of the isochronous traffic allowing stations with asynchronous traffic to reset their NAV and to start contenting for the medium using the backoff mechanism.

When there is no service with demand for isochronous traffic all the bandwidth is available to stations that want to transmit asynchronous data. Isochronous services should not occupy the whole time between two successive Beacon packet transmissions. The ISO_Max_Duration parameter is used to control the percentage of the bandwidth that is assigned to the two types of traffic.

The isochronous traffic should be limited to allow coexistence between contention and contention-free traffic. A station with synchronous traffic should content for the channel, in order to signal the central station its need for a new service setup. The central station will check for the available resources and if there are enough resources available, it will allow the service setup. At the same time, a station with asynchronous data traffic should have the chance to access the channel during the contention period with the priorities provided from the access mechanism.

The transmission period (T) of Beacon packets may be redefined within each Beacon, so better adaptation to traffic requirements is achieved. For instance the round trip delay of voice packets in any network affects the perceived quality of the connection [5]. According to ITU-T Recommendation G.114 [5], round trip delays of less than 300 msec, with no echo, are imperceptible to even the most sensitive users and applications. This value gives an upper limit to the Beacon period when a service with voice transmission is active.

In video transmission, the Beacon period can be settled according to the frame rate. When there is no active isochronous service, the Beacon period should have the minimum value in order to keep synchronized to the Central Station any devices that are in power save mode. Values close to 1 sec are considered acceptable for most of the cases.

The selected Beacon period affects the channel utilization, and more data are transmitted since the interframe space remains constant. Using the proposed access method, channel utilization up to 95% and payload up to 75% of the channel bandwidth can be achieved as it is shown in Fig. 3.

The term useful information depends on the supported service. In a telephone conference call for example, the signal has to be transmitted only during speech activity intervals. Speech activity can be detected using several methods, although here a noise gate was used. Noise gates are devices that mute their output when the signal energy is below a predefined threshold. In this sense a NG can be used as an indicator to whether speech signal is present or not in a certain time interval. NG can be applied to both time and Frequency domains. Time domain NGs are easier to implement and less computational expensive. For better speech signal detection however psychoacoustical-based methods can be used [7]. In this work a time domain NG was implemented. The algorithm is applied in blocks of data. In every block the rms value is calculated. If this value is less than a predefined threshold, no data are transmitted to the network. Changing the attack and decay parameters of the Noise Gate we can achieve smoother transition from the ON state to the OFF state (Fig. 4). A linear slope was chosen for the transition between the ON and OFF states. The attack time and decay time parameters are calculated with the following equations:

$$attack\_step = block\_time / attack\_time$$
$$decay\_step = -block\_time / decay\_time$$

where *block_time* is the duration of the block.

The function *Thr(i)* changes with every block of data according to the folowing equation:

$$thr(i) = thr(i) + step$$

where,

$$step = ATTACK\_STEP, if(rms(i) >= THR)$$
$$step = DECAY\_STEP, if(rms(i) < THR)$$

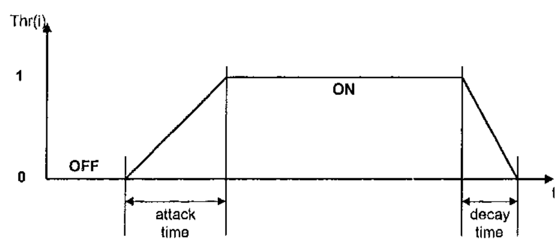


Fig. 4. Transition state in a Noise Gate

In case of a video conference as useful information could be considered the pictures of the speaking person at any moment. The Central Station can handle the diferent types of applications with the use of higher layer protocols.

IV. CONCLUSION

The proposed method can be applied to home networks in order to create a distributed environment for multimedia and data processing services. The main advantage of the proposed method is its dynamic bandwidth allocation according to the bandwidth requirements of the supported isochronous services. The CAP protocol exploits the silence detection capability during voice calls and conferences to decrease the bandwidth allocated to isochronous devices. A Central Station is required to interface the external world (PSTN, Internet etc) with the residential environment and to support the CAP coordination functions. Using such a network, various services can be supported efficiently, such as voice, videoconference, Internet access, utility control, security systems etc.

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Biographies

Stelios P. Koutroubinas was born in Ioannina, Greece in 1965. He received the B.Eng. degree in Electrical Engineering from the University of Patras, Greece, in 1989 and the Ph.D. degree in Wireless Networks from the Dept. of Electrical Engineering and Computer Technology, University of Patras, Greece, in 1999. He has more than eight years of work experience in networking protocols with his evolvement in R&D projects for the Greek Government and the European Community, initially as a research staff member and subsequently as a project leader within the Laboratory of Electromagnetics, University of Patras, Greece. Currently he is the Managing Director of ATMEL Hellas S.A., part of the Multimedia & Communications group of ATMEL. Dr. Koutroubinas is a member of the Technical Chamber of Greece.

Theodore Antonakopoulos was born in Patras, Greece in 1962. He received the Engineering Diploma degree in 1985, and his Ph.D. degree in 1989 from the School of Electrical Engineering at the University of Patras, Patras, Greece. In September 1985, he joined the Laboratory of Electromagnetics at the University of Patras in R&D projects for the Greek Government and the European Economic Community, initially as a research staff member and subsequently as the senior researcher of Communications Group. Since 1991 he has been on the faculty of the Electrical Engineering Department at the University of Patras, where he is currently an Assistant Professor. His Research interests are in the areas of data communication networks, LANs, B-ISDN and wireless networks, with emphasis on efficient hardware implementation and rapid prototyping. He has over 35 publications in the above areas and is actively participating in several ESPRIT and RACE projects of the EEC. Dr Antonakopoulos serves in the Program Committee of the IEEE International Workshop on Rapid System Prototyping, is a member of the Communications and Computer Societies of the IEEE, and a member of the Technical Chamber of Greece.

Vassilios Makios was born in Kavala, Greece. He received his Electrical Engineering degree (Dipl.Ing) from the Technical University in Munich, Germany in 1962 and his Ph.D degree (Dr. Ing.) from the Max Planck Institute for Plasmaphysics and the Technical University in Munich in 1966. From 1962-67 he was a Research Associate in the Max Planck Institute for Plasmaphisics in Munich, where he was associated with microwave interaction studies of plasmas. He served as Assistant Professor in 1967-70, Associate Professor in 1970-73 and Full Professor in 1973-77 in the Department of Electronics, Carleton University of Ottawa, Canada, where he was involved with teaching and research in microwave and optical communications radar technology, remote sensing and Co2 laser development.

From 1977 he is an honorary Research Professor of Carleton University. Since 1976 he has been Professor of Engineering and Director of Electromagnetics Laboratory in the Electrical Engineering Department Of the University of Patras Greece, where he is involved in teaching and research in microwave and optical communications, data communications networks, LANs, MANs, and B-ISDN with emphasis on efficient hardware implementations and rapid prototyping. He is also involved in research in photovoltaic systems. He has published over 140 papers and holds numerous patents in the above fields. He has participated in the organizing committees of numerous IEEE and European Conferences and was the Technical Program Chairman of the 5th Photovoltaic European Community Conference in Athens 1983 and Co-Chairman of the EUR-INFO 1988 Conference of the European Community. He is the recipient of the silver medal of the German Electrical Engineering Society (VDE). He is a senior member of the IEEE, member of the Canadian Association of Physicist, the German Physical Society and the VDE, Profession Engineer of the Province of Ontario and the Greek Technical Chamber.

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ABSTRACT

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INTRODUCTION

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In this paper we present a new centralized Medium Access Control (MAC) protocol, called Centralized Access Protocol (CAP), designed to support isochronous and asynchronous traffic in the home environment. The protocol is based on a subset of the IEEE 802.11 functions with the addition of the necessary functionality to support isochronous services. As isochronous are considered the services which require guaranteed bandwidth in order to achieve bounded delay. Quality of Service (QoS) of isochronous services is negotiated during service set-up and remains constant as long as the service is provided. Such services are mainly voice and video related.

The presented WLAN protocol integrates voice, video and data services in a unified environment with dynamically adaptable functionality. The Centralized Access Protocol (CAP) aims to provide the necessary mechanisms in order to support services which require constant bandwidth, while the remaining bandwidth is allocated to stations with data traffic [3]. Priority of service is also supported through the access method of the protocol. The fundamental access method of this protocol is the Distributed Access Coordination Function (DACF) which implements the Carrier Sense Multiple Access algo200rithm with Collision Avoidance (CSMA/CA). The isochronous services are suported with the Isochronous Access Coordination Function (IACF).

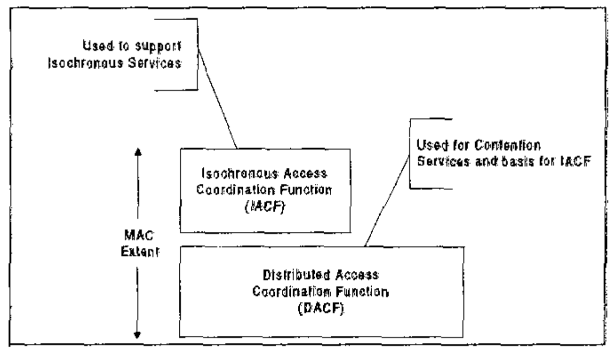

Figure 1. MAC layer architecture

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The ISO_Max_Duration is zero when there is no service with demand for isochronous traffic. The isochronous traffic should be limited to allow coexistence between contention and contention-free traffic. A station with synchronous traffic should content for the channel, in order to signal the central station, its need for a new service setup. The central station will check for the available resources and if there are enough available, it will allow the service setup. At the same time a station with normal traffic should have the chance to access the channel during the contention period with the priorities provided from the access mechanism.

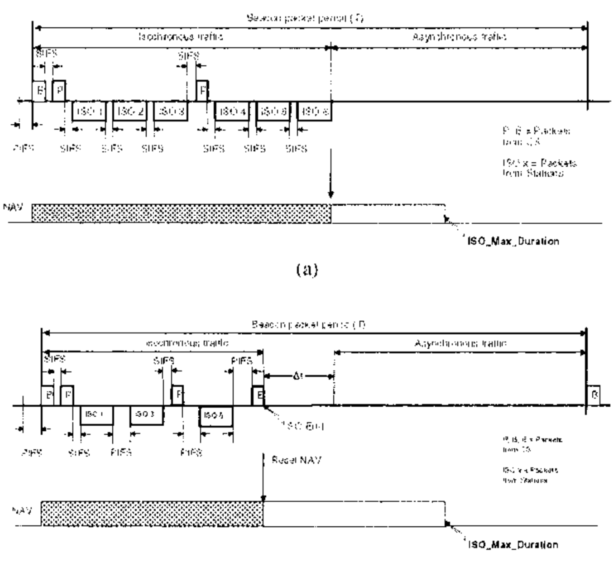

Figure 1. Bandwidth allocation to isochronous and asynchronous traffic

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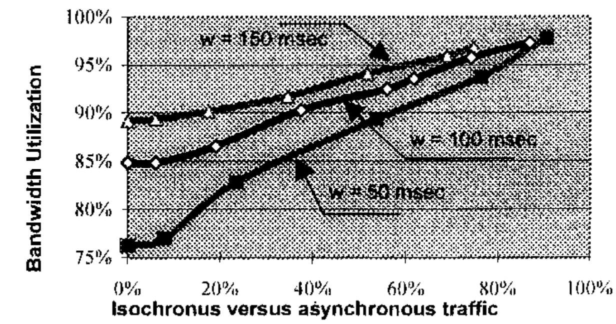

Figure 3: Channel Utilization

CONCLUSION

The proposed method can be applied to home networks in order to create a distributed environment for multimedia and data processing services. A Central Station is required to interface the external world (PSTN, Internet etc) with the residential environment and to support the CAP coordination functions. Using such a network, various services can be supported efficiently, such as voice, videoconference, Internet access, utilities control, security systems etc.

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