An adaptive Protocol for Wireless Asynchronous Transfer Mode Platform Network

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Abstract- A quality-of-service-oriented medium access control (MAC) protocol is suggested for delivering multimedia services through a stratospheric aeronautical platform wireless communication system. The invented protocol exploits the statistical multiplexing of Asynchronous Transfer Mode (ATM) technology. Combing the reservation- and contention-based access schemes in a single protocol allows the platform communication system at an altitude of 20 km to guarantee the service quality requirements for the diverse services. Exploiting the flexibility of the protocol as well as the low encountered propagation delay of the wireless link permit constant bit rate (CBR), variable bit rate (VBR) and available bit rate (ABR) services to be efficiently multiplexed without violating quality constraints. The effects of channel capacity and its associated limitations on the network performance are discussed and pragmatic solutions are suggested. Different service priority schemes are presented and numerical results are discussed. The obtained results dictate the wireless ATM platform communication as a promising means for the next-generation wireless communication system.

I. INTRODUCTION

The wireless market is witnessing unprecedented growth fueled by an information explosion and a technology revolution. Wireless communication networks should be able to support multimedia applications, such as voice, video, image and data transmission [1]. Due to its ability to flexibly support a wide range of services with quality of service (QoS) guarantees, Asynchronous Transfer Mode (ATM) is considered the most suitable transport technique for the future broadband integrated services digital network (B-ISDN) [2]. The combination of wireless communication and ATM approach can provide freedom of mobility with service advantages and QoS guarantees [3]. However, some inherent problems of the wireless link have to be resolved. Most of these problems stem from the fact that ATM was designed for supporting multimedia services in a reliable, noise-free and bandwidth-rich environment. In contrary, the wireless channel is a resource-limited channel with time-varying characteristics that is shared between contending users [1][4]. Consequently, the most important network design issue is the invention of an efficient medium access control (MAC) protocol for the radio interface of the wireless ATM (WATM) network. The protocol should be able to support multimedia applications with conflicting requirements, and guarantee the required QoS for each connection. It should also allocate the network resources efficiently and dynamically between the contending users using advanced traffic scheduling.

Wireless multimedia services can be provided by terrestrial-based cellular systems or space-based satellite systems [5]. An ambitious new trend is to deliver multimedia applications using telecommunication systems in the stratosphere [6]. These novel stratospheric telecommunication systems (STSs) exploit the best features and avoid the pitfalls of both terrestrial and satellite schemes. Besides, they have their special virtues [7]. The STSs is intended to replace the terrestrial base stations (BSs) network with a network of BSs in the stratosphere.

The current article proposes an efficient MAC protocol for the wireless stratospheric platform ATM networks. The BSs, onboard the platform, serve the roving users using one of two suggested traffic scheduling algorithms. The first is the first-input-first-output (FIFO) algorithm which gives the handling priority to the cells according to their arrival order. The second is first-dropped-first-output (FDFO) algorithm which gives the handling priority to the cell that is nearest to be dropped. The network performance is investigated with the two strategies. Numerical results are, then, presented and discussed. The paper, first, investigates the issues related to the development of WATM networks and the recommended solutions. The salient virtues and infrastructure of STSs are declared. Then, the performance of the proposed MAC protocol is discussed. Finally, the conclusions are drawn.

II. THE SALIENT ISSUES OF WATM NETWORK

The inherent nature of radio communications, in terms of transmitted power constrains and limited spectrum availability, imposes certain restrictions on the maximum data rate that is possible over the air interface [1]. Furthermore, the radio transmission is more error-prone than the wired link.

Some enhancements are, therefore, necessary to efficiently transport mixed media traffic over the wireless communications networks. The fixed ATM network infrastructure should be enhanced with ATM mobility in order to support connections with mobile users. It is primarily concerned with call handover, location management, routing, and network management. Furthermore, the radio access layer (RAL) of the air interface protocol of the wireless network should be modified in order to support the requirements of ATM. The RAL infrastructure has a MAC sub-layer to control the sharing of radio resources amongst the multiple terminals, a data link control (DLC) sub-layer to mitigate the effects of radio channel errors. The MAC layer and DLC layer are added between the wireless physical layer (WPHY) and the ATM layer in the protocol stack. The wireless physical layer is necessary for dealing with the actual radio transmission and reception protocol [4].

There are two proposals for forming the WATM cell. The first approach encapsulates the conventional ATM cell with two headers for mobility-enabling and error check. Although this method is simple, the bandwidth is used inefficiently. The second scheme replaces the conventional header of the ATM cell with a wireless one [1]. This enables best utilization of the bandwidth. Accordingly, it is recommended despite its complexity.

III. Configuration Of The Stratospheric Platform Communication System

A potential solution to the problems of terrestrial [8] and satellite systems [9] is to deploy a network of aeronautical platforms in the stratospheric zone between 18-24 km [6]. The configuration of the system is depicted in “Fig. 1,”. The stratospheric platform systems have many advantages that cannot be offered by other existing or announced technology. SkyStation Inc. and the HALO Network (High Altitude Long Operation) provide STSs using two approaches. The former plans to set up a 250 unmanned airship network [10], whereas the latter employs conventional manned aircraft operating 24 hours a day over the supported metropolitan area [11]. There are also many other announced projects [7].

The stratospheric platform communication system consists of a quasi-stationary platform in the stratosphere (including airship that carries a station-keeping system, integrated solar arrays and fuel cells, and communication payload which include the ATM switch), user terminals, several gateways, and the ground facilities for TT&C(Telemetry, Tracking, and Command) [12][13]. For connections between different users within the service area of a single platform, the ATM switches are used. High altitude platforms (HAPs) can be used either as a stand-alone-regional system, or they can be interconnected (using optical or radio links) to form a network of platforms [14].

IV. Quality-of-Service-Oriented MAC Protocol

The MAC protocol is a set of rules that control the sharing of radio resources among a number of competing mobile stations (MSs) [15]. An intelligent MAC protocol is proposed in order to enable efficient transmission of different ATM traffic types with guaranteed QoS. The allocated frequency spectrum is divided into uplink and downlink channels on a frequency division duplex (FDD) basis. The channel is divided into minislots used for requesting access (RA channel) followed by a slot for transmission (transmission channel tx_ch). The duration of the transmission slot is designed to accommodate the WATM air interface cell.

In the proposed protocol, mobile terminals (MTs) send transmission requests to the serving point (SP) (e.g. BS located onboard the stratospheric platform) by contention on the RA channel. The request packet includes the identity of the user as well as its service descriptors and traffic descriptors. The service descriptors refer to the QoS parameters that are specified by bit error rate (BER), cell loss rate and sustainable delay. The traffic descriptors specify the traffic characteristics of the source such as the mean and peak bit rates and the duration at which the peak rate can be sustained. Using these descriptors and based on the current channel load, the connection admission control (CAC) at the SP decides whether to reject or establish the new connection. If the connection is denied, the user can try again. If the connection is accepted, a positive acknowledgment is sent to the requested MT along the downlink channel while the user identity and the cell arrival time are saved in a request table (RT) at the SP. The SP allows transmission to those users registered in the RT according to one of two proposed strategies namely, FIFO and FDFO. The applied strategy determines the user identity that will transmit a cell in the next time slot. The FIFO algorithm searches for that cell with the minimum arrival time, i.e., that enters the RT first irrespective of the service type (audio, videophone, video, or data) to be served first. In the FDFO strategy, the service tolerable delay time is taken into account by looking for the cell that is nearest to be dropped. The SP sends transmission permission to that user along the downlink channel. If the user buffer is empty, its identity will be cleared from the RT; otherwise it will continue transmission according to the selected strategy.

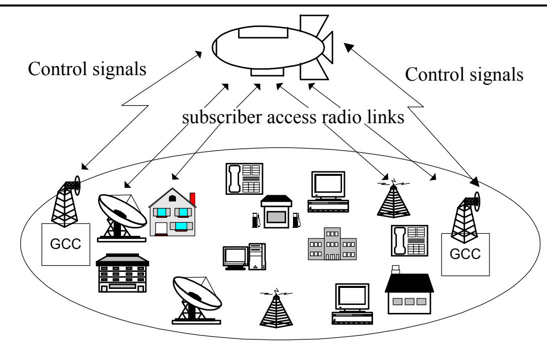

Figure 1. The configuration of the stratospheric platform communication system.

V. Numerical Results And Discussion

A software package has been developed to investigate the performance of the wireless ATM stratospheric platform communication network. The package implements the object oriented programming technique. Using Microsoft Foundation Class library, friendly graphical user interface (GUI) has been designed and implemented. "Fig. 2," shows a view for the GUI of the developed package. The effects of the two proposed buffering algorithms, namely, FIFO and FDFO, on the network performance are gauged using this package. The service quality guarantees for multimedia connections is evaluated in terms of cell dropping ratio, average transmission delay, and average buffer size. A number of constant bit rate (CBR), real-time variable bit rate (VBRrt) and non-real-time variable bit rate (VBRnrt) applications are simulated and the network performance is examined when adopting the proposed MAC protocol with such algorithms. The traffic characteristics and QoS parameters of these applications are listed in Table 1.

A system with audio and videophone services is examined first. The channel rate is set to be 5 Mbps. The number of videophone users is selected to be 16 such that videophone service is the most dominant traffic. "Fig. 6," shows, for FDFO and FIFO strategies, the variations of the cell dropping ratio of audio and videophone services as functions of the number of audio users. When using FDFO strategy, the cell-dropping ratio of audio is greater than that for videophone users. This is because FDFO chooses to send the cell that is nearest to be dropped. This cell is expected to be the videophone one due to its strict delay time as its tolerable delay is only 20 ms in comparison with 40 ms for audio. In addition, the videophone-encoding rate (256 kbps) is much greater than audio encoding rate (16 kbps). Also, the videophone service is CBR where the audio service is VBR (silence period of about 58% of the time). The number of audio users that can be tolerated while satisfying the constraint of less than 1% cell loss probability is 65.

On the other hand, when using FIFO strategy, the cell dropping ratio of audio service is approximately zero. The FIFO discipline arranges the cells in a queue according to their arrival times. As audio has more tolerable delay than videophone and videophone has more encoding rate, the drop probability of audio cells is much smaller than that of videophone. The number of audio users that can be tolerated without violating the quality constraint is 68.

The variations of the audio and videophone average transmission delay (ms) as functions of the number of audio users is displayed in "Fig. 4,". The average transmission delay of the audio service is greater than that of the videophone service when the FDFO discipline is adopted. As videophone cells are the nearest to be dropped due to its small tolerable delay, these cells are privileged transmission first. This results in more transmission delay for audio cells as compared to videophone cells. In contrary, the FIFO algorithm results in an audio average transmission delay that is slightly greater than that of videophone.

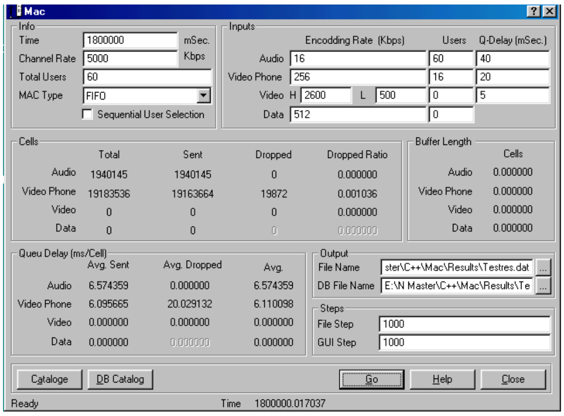

Figure 2. The GUI of the developed package.

TABLE 1

Traffic Characteristics And Quality Of Service Parameters

Traffic class	CBR	VBRrt		VBRnrt
Application	video-phone	video	audio	data
Encoding rate (Kbps)	256	1500	16	512
Max. delay (ms)	20	5	40	
Max. rate (Kbps)	256	2600 (33.3% of time)	16 (42% of time)	512 (10% of time)
Min. rate (Kbps)	256	500 (66.6% of time)	0 (58% of time)	

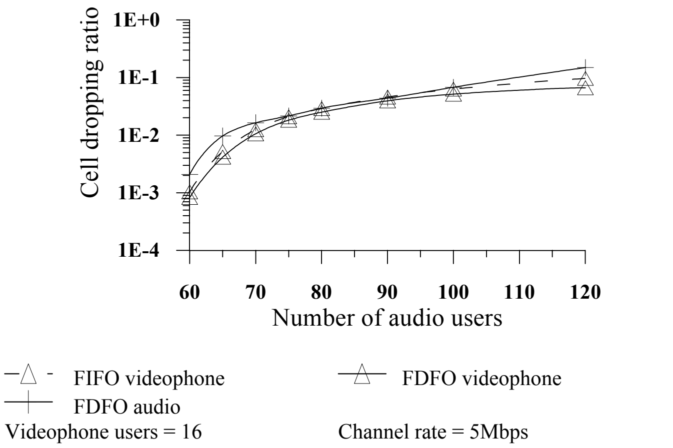

Figure 3. Audio and videophone cell dropping ratio as functions of the number of audio users.

"Fig. 5," shows the average buffer length (in terms of the number of cells) at the serving point as a function of the number of audio users. It is found that FDFO requires an average buffer length that is slightly greater than that required for the FIFO discipline. This is due to the methodology of service mechanisms of FIFO and FDFO algorithms. If the average buffer length is the necessary design constraint criterion, the FIFO strategy is recommended.

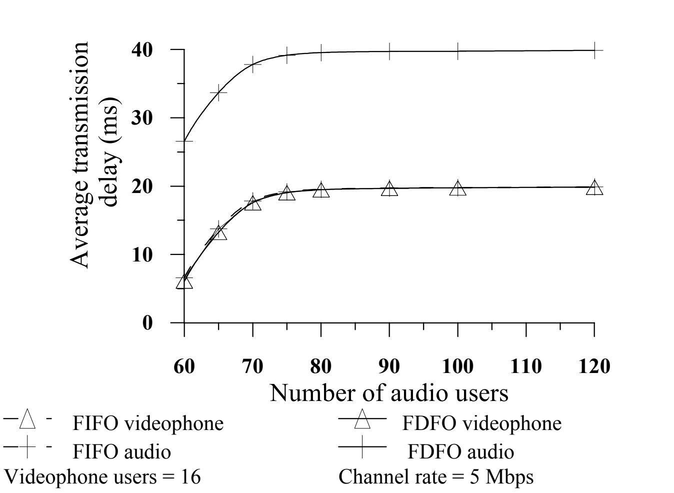

Figure 4. Audio and videophone average transmission delay as functions of the number of audio users.

We proceed in investigating the system performance when audio service is the most dominant. For this case, the number of videophone users is chosen to be 4. The channel rate of 5 Mbps is also considered. “Fig. 6,” displays the relation between cell dropping ratio of audio and videophone services and the number of audio users. It is found that FDFO can serve 508 audio user, whereas FIFO tolerates only 492 audio user. The variation of the audio and videophone average transmission delay (ms) as functions of the number of audio users is displayed in “Fig. 7,” and the two algorithms FIFO and FDFO are adopted. The system performance is the same as the previous case. “Fig. 8,” depicts the average buffer length at the serving point as a function of the number of audio users. The system behavior is identical to the former case.

In similar way, the performance of a system with audio, videophone, video, and data services is examined when FIFO and FDFO algorithms are employed. It was found that, for a system with audio, videophone, video, and data services, the FIFO algorithm is recommended for a better performance in terms of cell dropping ratio, average transmission delay, and average buffer length.

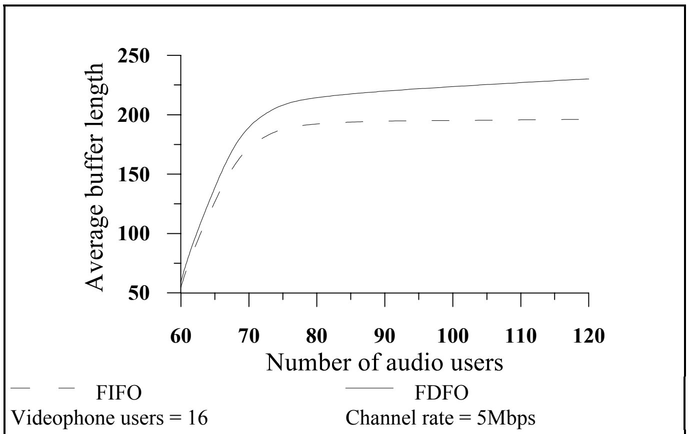

Figure 5. The average buffer length as a function of the number of audio users.

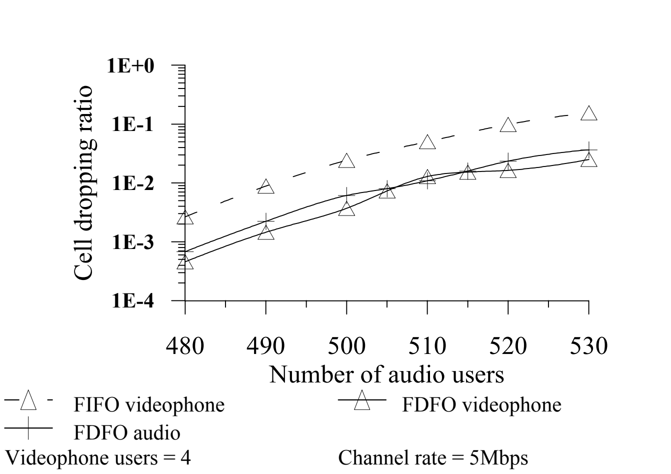

Figure 6. Audio and videophone cell dropping ratio as functions of the number of audio users.

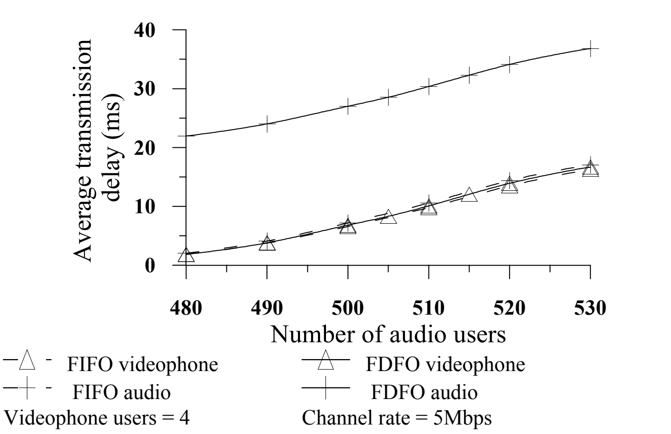

Figure 10. Audio and videophone average transmission delay as functions of the number of audio users.

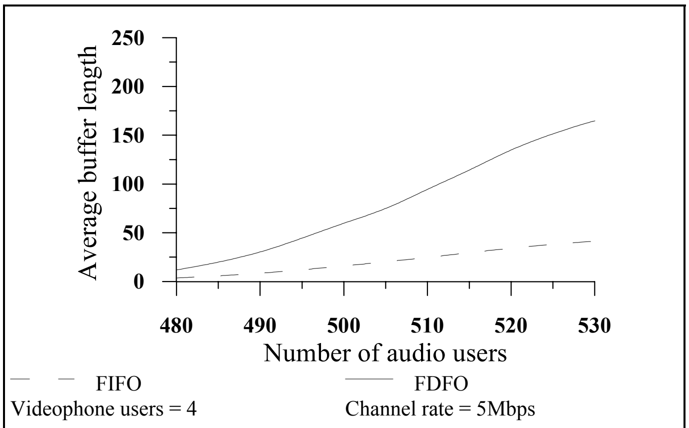

Figure 8. The average buffer length as a function of the number of audio users.

VI. Conclusion

A stratospheric platform wireless ATM network was presented. The most important design issue is the medium access control protocol for the radio interface. A quality-of-service-oriented protocol is devised in order to provide efficient use of the scarce radio spectrum as well as maintain QoS guarantees. To evaluate the performance of the proposed protocol, a computer simulation model was developed. The network performance is gauged in terms of cell dropping ratio, average transmission delay, and average buffer length when adopting FDFO and FIFO scheduling algorithms. For a system, which provides audio and videophone services. Whenever one or all of the following performance parameters is most significant: audio cell dropping, audio average transmission delay and average buffer length, the FIFO algorithm is recommended. Otherwise the FDFO algorithm is recommended. Regarding the allowable number of audio users, the FIFO algorithm is recommended when videophone service is the most dominant traffic and FDFO algorithm is recommended when audio service is the most dominant traffic. For a system with audio, videophone, video, and data services, the FIFO algorithm is recommended for a better performance in terms of cell dropping ratio, average transmission delay, and average buffer length.

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