A Multiple Access Layer and Signalling Simulator for a Ka-Band LEO Satellite System

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Abstract

Communication systems using Low Earth Orbit (LEO) constellations offer real communication with a real worldwide coverage thus being able to augment terrestrial communication systems in application areas where large scale mobility or mobility in areas not covered by terrestrial systems is required. The also offer an alternative to terrestrial systems where implementation of such systems is not going to happens soon because of the large distances that must be covered. LEO satellite communication systems however face a number of big challenges. First of all, as experience with the commercial implementation has shown, they must offer services beside the traditional voice communication-their first priority must be to support multimedia and data communication for a comparable price to be really useful for a large number of customers. Second are the technical challenges: multiple-access protocols, signaling, routing and management protocols that scale too a large number of customers and may be implemented in the rather small payloads of LEO satellites.

The goal of the ATMSat project sponsored by the German Bundesministerium für Bildung und Forschung is the development of an architecture for a LEO satellite multimedia communication system. They key technical features of the architecture are: on-board ATM switching, signaling and resource management, optical intersatellite links and direct Ka-Band access using a new MAC (multiple access protocol) to mobile terminals with active intelligent antennas. This paper describes the demonstrator that is developed in the project that is used to analyze the MAC protocol and some of the resource management and signaling functions. The paper first gives a short overview of the ATMSat system architecture. The it presents the architecture and implementation of this demonstrator and concludes with some of the results obtained with the demonstrator.

System Architecture

The ATMSat system consists of 70...100 LEO satellites at an altitude of approximately 1300 km. The inclination of the Walker orbits is between 45˚ and 55˚. The satellite visibility is in the order of 15 minutes. Table 1 and 2 provide the main system parameters and the planned capacity.

Table 1: Overall system parameters

Uplink bitrate	fixed and portable terminals: up to 2048 kbit/s mobile terminals: up to 384 kbit/s in steps of 16 kbit/s
Downlink bitrate	up to 32786 kbit/s in steps of 16 kbit/s
Modulation scheme	QPSK
Access scheme	uplink: MF-TDMA downlink: TDM
Bandwidth	500 MHz up and down
Terminal transmit BW	1.4MHz (fixed and portable terminals) 265 kHz (moble terminals)
Terminal receive BW	≥ 16 MHz per downlink carrier
Terminal transmit EIRP	35-50 dbW (fixed and portable), 30-40 dbW (mobile)
Terminal antenna gain	≥ 35 db (fixed and portable), ≥ 30 db (mobile)
Terminal G/T	10 db/K
Terminal RF power	up to 20W (fixed and portable), up to 5 W (mobile)
Terminal antenna diameter	40-50 cm (fixed and portable), laptop size (mobile)
Terminal antenna beams	steerable, 1 transmit 2 receive beams
Terminal pointing accuracy	±0.5° (at minimum elevation angle), ±0.5° (at minimum elevation angle)
Spotbeam diameter	50 km – 500 km

The capacity numbers allow for a total number of users per satellite between 2400 and 300000 depending on the data rate of the users.

Table 2: System capacity

Satellite switch capacity	5 Gbit/s - 10 Gbit/s
ISL capacity	7 Gbit/s - 10 Gbit/s
Downlink data rate per carrier	32 Mbit/s
Maximum number of downlink channels per carrier	32Mbit/s / 16kbit/s = 2000
Downlink carriers per satellite	150 – 300
Spotbeams per satellite	150 – 300
maximum number of carriers per spotbeam	20 % of total number of carriers: 30 – 60
Cluster size	3
carrier frequencies per footprint	90 – 180

The satellites are connected together by optical inter-orbit and intra-orbit links. The topology and the orbits are chosen so, that the links can be maintained all the time (but the distance between satellites for inter-orbit links changes periodically).

Users access the system by three different kinds of terminals: fixed terminals are used by gateways stations that provide interworking with terrestrial networks and large sites that need a lot of bandwidth. These terminals employ large antennas and allow for a higher data rate. Portable terminals use planar antennas of a size that allows their integration into cars, planes and other mobile equipment. And mobile terminals are of a size that allows to integrate them into laptops and other equipment of this size.

To provide seamless integration of data services, real-time and non-real-time multimedia traffic and voice traffic ATM is used at the lowest transport layer and a modified version of ATM signaling is used to manage user connections. The stacking of these protocols is shown in figure 1.

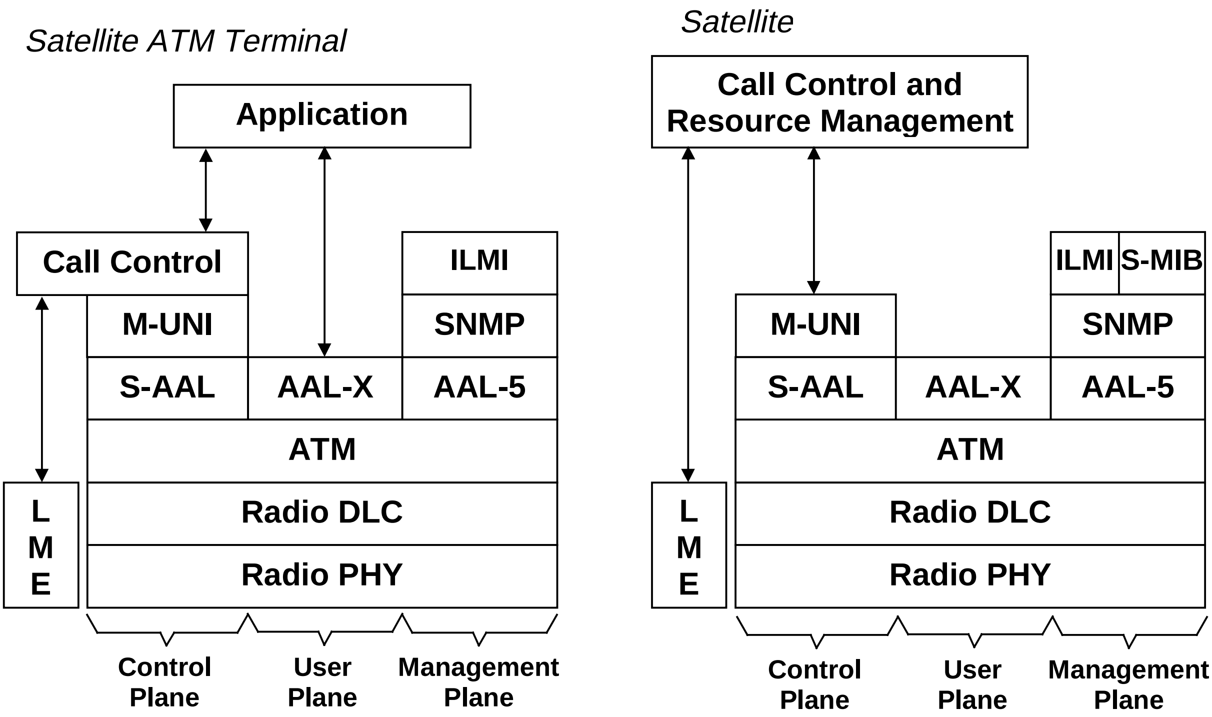

Figure 1: Protocol Architecture

Location management and access control is done by means of a terrestrial network management center. Performance of these processes is ensured by intelligent caching of relevant data on the satellites.

Demonstrator

The ATMSat demonstrator provides an environment to test and evaluate the DLC and signaling protocols. It is build based on standard PC and ATM equipment as shown in figure 2.

The demonstrator consists of four DLC systems, one wireless link system, two or three application terminals, one control station, and one ATM switch.

The ATM switch is the center of the demonstrator. It provides the cell switching functionality, but not the signaling. The signaling stack runs run on a workstation (control station) and and controls the switch via SNMP over CLIP (Classical IP over IP) from this control station.

The wireless link system is used to emulate the wireless link. It consists of a PC with a four-port 100Mbit/s full duplex Ethernet card. Each DLC system is connected to one port of this Ethernet card. The wireless link emulation merges the received data, manipulates the data, and forwards the data.

The DLC layer is implemented on the DLC system (standard PC) which can be configured to run either S-DLC (satellite DLC) or T-DLC (terminal DLC). So the DLC implementation is separated and independent from the terminal platform. The DLC system is connected with the terminal over ATM and with the satellite over the Ethernet.

The application terminal (terminal) represents an endsystem which communicates over the satellite with an other endsystem. The terminal can be any platform (e.g. FreeBSD, Solaris, Windows, Linux) with an ATM interface. The terminal runs different applications depending on the test scenario.

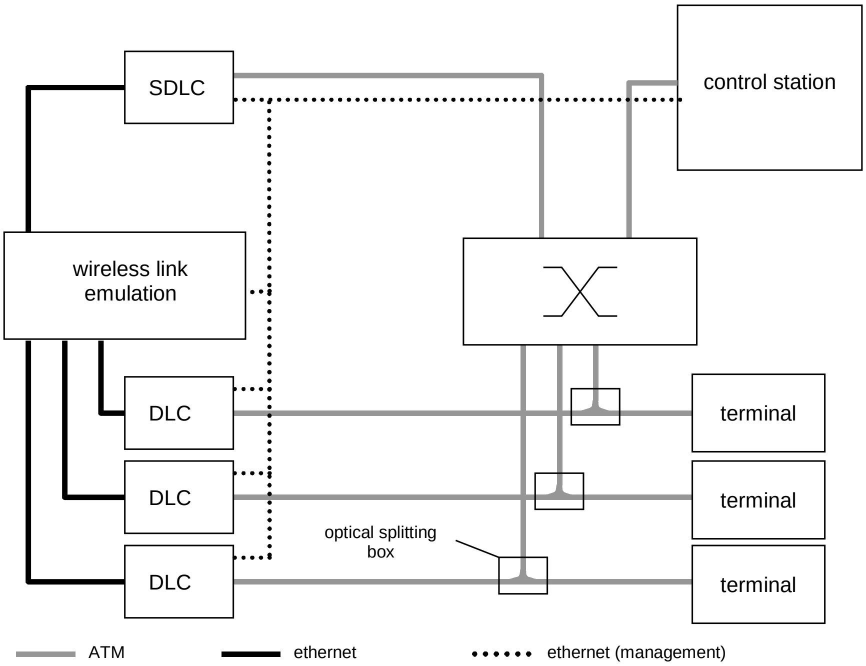

Figure 2: Demonstrator architecture

Wireless Link Emulation

To demonstrate the functionality of the DLC layer, it is necessary to emulate the characteristics of the wireless transmission channel. This will be done with a channel emulation system. The modular architecture of the demonstrator give the flexibility to replace the channel emulation system without any changes of the DLC layer. The link emulation system has one interface for each user terminal and one interface for each coverage area of each S-DLC instance. For the actual implementation a high end PC with a four port full-duplex 100MBit/sec Ethernet card is used. This allows to simulate a system with up to four end user terminals or satellite ports.

Ethernet, in general, is a multiple access system, like a wireless link. To handle collisions two mechanisms are used:

1. Prior to sending, the receiver listens on the wire, whether it hears another station sending. If there is another station, the sender is blocked, until the wire is free.
2. While sending, the receiver checks the link, whether another station is also sending (this is named a collision). This may happen because of the transmission delay on the link, if both stations decide at almost the same moment, that the link is free. In this case, the packet is retransmitted after a (more or less) random period.

Within the demonstrator, the wireless link (including collisions) will be emulated with the channel emulation system and a dedicated Ethernet segment will be used for transmitting the data between the DLC systems and the channel emulation system. Therefore, no collisions on the Ethernet take place-the Ethernet is simply used as a full-duplex point-to-point connection. Bandwidth is also an issue because 100Mbit/s are far more than the bandwidth that is to be emulated.

This system manipulates and forwards the receiving data (duplicates in downlink direction). It is possible to configure the system to emulate different channel conditions. The following channel characteristics are anticipated:

- add variable propagation delay
- add bit-errors based on a channel model for RS on and off
- emulate collisions within random access slots

Each ATM-Sat slot is encapsulated within one Ethernet frame as depicted in figure 3. This solution has the disadvantage of additional overhead. But a it turns out that this is not a problem. There is a maximum load of 8.3 MBit/s at the DLC system and 33.2 MBit/s at the channel emulation system in the worst case. Considering the channel access protocol, we obtain a much lower system load because the terminals have only around 5 random access slots in which they can send simultaneously.

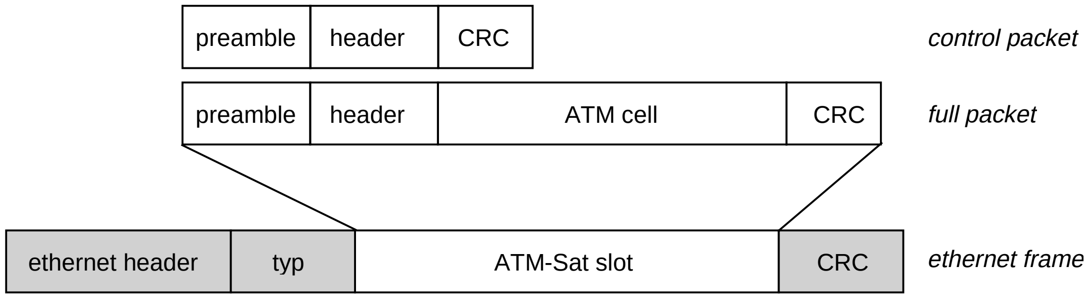

Figure 3: ATM-Sat Slot Encapsulation

Due to the absence of a real physical medium, we need a mechanism to synchronize the systems. This is done by means of special synchronization packets periodically broadcasted by the link emulation system to the DLC systems. An advantage of this solution is the ability to vary the simulation time base and the explicit knowledge of the time when all stations have sent their packet.

Simulation Scenarios

Based on the demonstrator several scenarios can be built with different number of satellites and terminals. Figure 4 shows an example scenario.

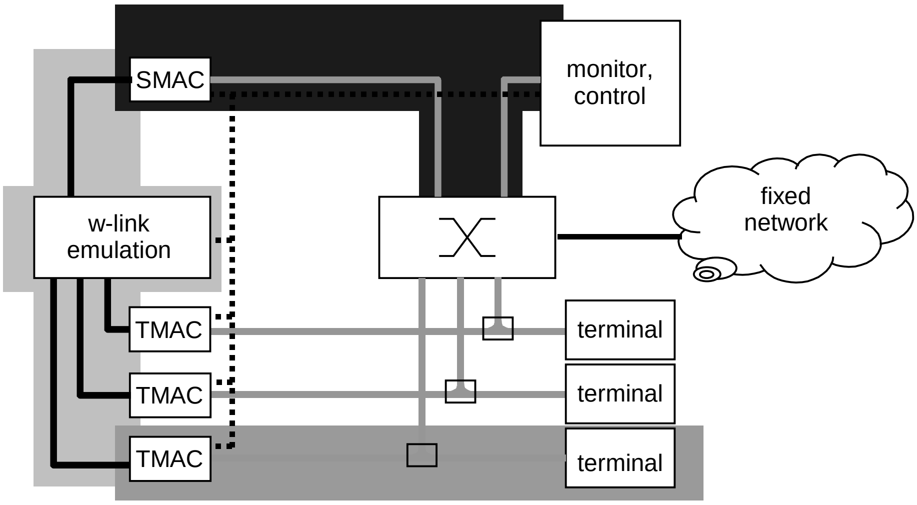

Figure 4: Three terminals and one satellite scenario