LAN interconnection systems using LEO and GEO Satellites - A Simulation Study

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Abstract

There is an increasing demand for interconnecting LAN's at high data rates, e.g. remote X-Applications. Due to the lack of B-ISDN before the second decade of the next century, satellite systems are the only alternative. We compare the End-to-End cell delay of a geostationary satellite system with a low earth orbit satellite system by means of simulation. The comparison shows that the use of LEO satellites is suitible to LAN interconnection.

1 Introduction

Today users are demanding standard applications and protocols to be supported by wide area communication networks. Ideally, the user must not be aware of any difference whether his data are carried over a LAN, some wide area ground network or via satellites. Currently, the TCP/IP protocol family is the widely used in the world and is used for a large set of applications such as file-transfer, database access, remote login and e-mail.

Unfortunately TCP/IP has been designed for terrestrial networks which are characterized by low delays and error rates. Experimental systems [11] have shown that the applications mentioned above can be supported well on existing geostationary satellite links. The situation is more complex when highly interactive applications shall be supported like

- client-server applications using X-Windows
- real-time interactive voice
- World Wide Web
- video-applications

which will be established on a companies campus site before the next century. To migrate these applications to companies subsideries, one have to interconnect these LAN's by means of high-speed WAN's.

Currently, in the WAN market there is only the opportunity to lease 2 Mbit/s links. More capacity will not be available in the next years because the CCITT does not have much interest to introduce B-ISDN in the next decade[1]. Exceptions are the SMDS [3] from Bellcore and the ETSI-MAN [2] in Europe. But these DQDB based systems are not available by all PTT's or other providers.

One alternative to terrestrial lines is the use of VSAT systems. These VSAT systems are today limited by the employed satellite technology, i.e., todays satellites are only signal amplifiers without signal regeneration or switching capabilities.

2 Proposed Satellite Systems in the Ka-Band

Broadband satellite communications systems need much bandwith. So one is looking for higher frequency bands. The Ka-Band (23-30 GHz) is not very crowded today and will be allocated during the WARC-Conference at the end of 1995. The Ka-Band offers the bandwith needed for high-speed satellite networks.

Another force driving the developement of high speed satellite networks stems from the successful implementation of NASA's ACTS program. This satellite is equiped with an On-Board processing facility an is operated in the Ka-Band [4]. The effects of rain loss can be eliminated by the use of Reed-Solomon coding [12].

For the Ka-Band WARC-Conference there are a lot of high-speed satellite systems propsed offering fixed communication services. There are for example:

- AT&T
- Hughes
- Loral
- Motorola
- General Electric
- Teledesic

All systems except of Teledesic use a constellation of geostationary satellites while Teledesic is using a LEO constellation consisting of 840 satellites. Loral and Motorola are plannin additional systems to their L-Band mobile systems Globalstar and Iridium respectivily. The question is what system will be best for futur multimedia applications concerning end-to-end delay, bit error rates, and complexity of the earth-station equipment .

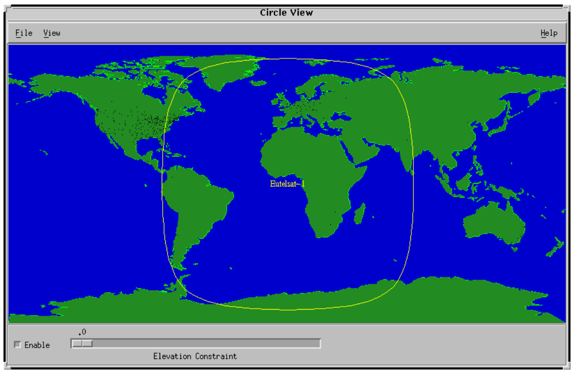

Figure 1: The geometric coverage of the Eutelsat GEO satellite

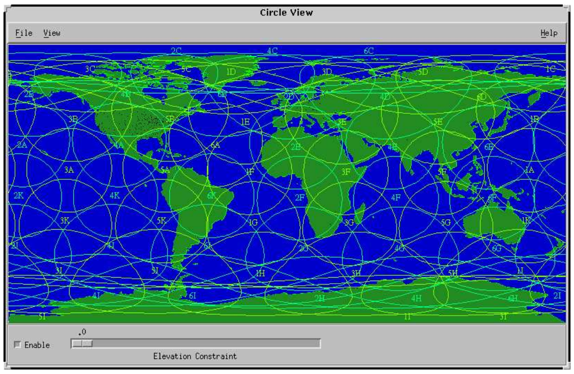

Figure 2: The geometric coverage of the Iridium LEO constellation

3 LEO-Satellites vs. GEO-Satellites

Despite the fact that for the moment only GEO satellites are used for communication, constellations of LEO satellites have several advantages over GEO satellites. The main advantage is the significant lower round-trip delay. The delay is about 10-20 ms for a one hop LEO link vs. 250 ms for a GEO link. A multihop LEO-link will have Delays up to 100 ms which are also fine value for undersea lightwave cables. But the LEO systems are introducing new problems on the physical layer:

1. They need steerable antennas because the satellites are moving at high speeds relative to the earth station.
2. The high relative speed is leading to a big doppler shift.
3. There is a necessity for handover management between satellites.

Probably the first commercial LEO satellite system will be launched by the *Iridium*^{TM} consortium lead by Motorola. The system will use 66 Satellites in a polar inclined constellation. The main purpose of this system is to supply voice services to mobile subscribers using handheld telephones. Low-bitrate data services (2.400 bit/s) will also be offered according to the Iridium [8] plans. The system will be operating in a small part of the L-Band (1.610 - 1.6525 Ghz) [8].

4 The LEO-WAN - a first feasibility study

To give the whole world access to the Infohighway, one has to use satellites. LEO satellites are ideal for worldwide coverage because of the implication of Keppler's laws: in order to see one satellite at one point anywhere in the world the whole time one has to cover the world[5]. A LEO satellite system used for LAN interconnection with world-wide coverage is called a **LEO-WAN**. It acts like an internet in the sky.

LEO satellites are changing their positions relativ to the earth stations. So the satellite delay depends on the distance of the satellite to the earth station. Figure 3 shows the distance of earth-stations located in Berlin and San Francisco to the next satellite.

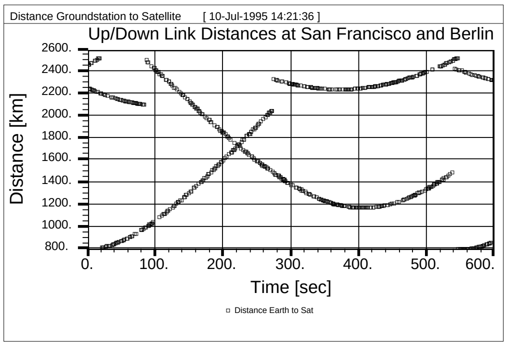

Figure 3: Uplink distance to nearest visible satellite

The distance variations leads to variations in the satellite systems delay. To show this, we investigated a simple study using the SatCom library of BONeS-Designer. Packets are sent through a satellite network using the iridium constellation. There is no protocol overhead or error correction so that the pure transmission delay can be seen in figure 4.

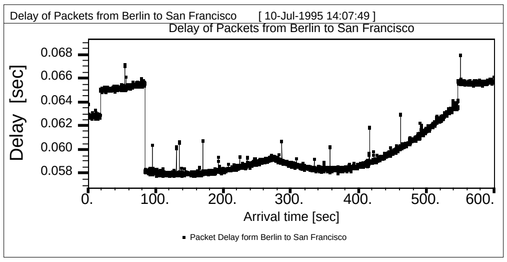

Figure 4: Satellite system delay variation

To investigate the contribution of the protocol overhead to the end-to-end delay in a satellite based ATM-Network, we carried out a simulation study comparing a LEO satellite network using the Iridium constellation with one GEO satellite using the Eutelsat coordinates. As earth stations we are assuming VSAT-Terminals installed at the following sites:

1. Rome
2. Amsterdam
3. Budapest

For the data communication an ATM network is used. It consists of 5 ATM switches. The ATM switches are assigned to earth stations in the following constellation:

- 2 Switches are assigned to Rome and Amsterdam
- 1 Switch is located in Budapest

Every ATM switch serves an Ethernet and a Video-Source. Data is split into cells and cells are transmitted via the LEO-WAN via encapsulation in a satellite frame.

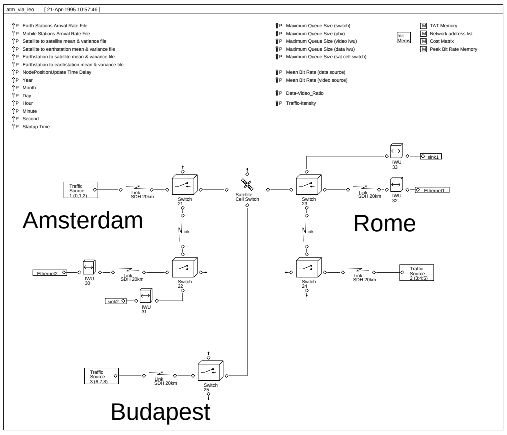

Figure 5: The simulation Model

5 The modified SatCom and ATM-Library

5.1 SatCom-Libray-Modell

We used BONeS-Designer in conjunction with SatLab to run the simulations. The latter is used for constellation modeling of the satellite networks. The basis for our model was the shipped SatCom-Library[6]. The shipped modell consists of mobile nodes. A mobile node can be an earth station, a satellite or a mobile user. The latter may be used to simulate a moving LAN, interesting for off-shore engineers. A distance table maintains the distances between all Nodes N. Its size is N^2. This *Distance Table Memory* is updated in periodics according to the orbital revolution of the LEO-System.

Cells arriving from a source are encapsulated into a satellite packet. The encapsulation of one cell into a satellite packet is appropriate by using access schemes like Symbol-Synchronous-TDMA [10] (SS-TDMA). This access scheme is designed for GEO satellites, but the orbit predictability of nongeostationary permits an adaption to LEO satellites. With SS-TDMA the access delay depends on the number of earth-stations. For this simulation we consider only three Earth-Stations, therefore we neglect the SS-TDMA-access delay.

Encapsulated cells are sent to the first node of the satellite subsystem (i.e the earth station), which is using its own addressing scheme. In our model the node is a queue, the service time is taken from a predefined file. After the processing delay the packet is routed to the nearest next node, normally a satellite.

The link length to the next satellite is taken from *Distance Table Memory* . The delay is calculated according to the link length. All delays are cumulated in the appropriate data structure representing the simulated packet. After the transmission delay the packet is queued in the next node. This procedure is repeated until the destination node is reached.

5.2 ATM-Library

For the ATM network we used the building blocks from the BONeS-ATM-Library [7]. This library contains LAN's as Ethernet and Video-Sources. Network components are switches, IWU's and B-NT1 and B-NT2 using the leaky-bucket algorithm[1]. The building blocks have no functionality for call setup and call release simulation.

To realize the integration of the libraries [6] and [7] we had to modify the earth station model of [6]. We created a new satellite data structure, in which an ATM cell is encapsulated.

The routing setup of the ATM-Library works as follows:

- Before the start of the simulation 'Hello' cells are sent between the network nodes.
- These values are stored in the global memory *Router Address List*.
- During the simulation, the routes are considered as fixed.
- Routing is obtained by using *Source Routing*.

5.3 The Ethernet Source Model

The Ethernets are representing an aggregated Poisson arrival process. The packet lengths are according to a bimodal distribution. The following parameters are used to form the process.

- L: packet length
- P_{sb}: Probability of a small burst = 0.4
- LB: length of a long burst = 3936 bit
- SB: lenth of a small burst = 24 bit
- L_{min} minimum packet length = 396 bit
- L_{max} maximum packet length = 12000 bit
- AC: aggregate LAN capacity
- ST: silence time
- N: number of Ethernets
- EC: Ethernet capacity = 10 Mbit/s
- ML: mean packet lenght = 5386 bit
- MB: mean bit rate
- MS: mean silence time
- TT: mean transmitting time

The aggregate LAN capacity is calculated as follows:

$$AC = N * EC$$

The mean silence time is:

$$MS = \frac{ML}{MB} - \frac{ML}{AC}$$

The interarrival time of the process is:

$$P(ST) = \frac{1}{MS} e^{-\frac{t}{MS}}$$

The packet length distribution obeys:

$$P(L) = \frac{P_{sb}}{SB} e^{-\frac{(L-L_{min})}{SB}} + \frac{1-P_{sb}}{LB} e^{-\frac{(L_{max}-L)}{LB}}$$

The transmitting time for a burst is:

$$TT = \frac{L}{AC}$$

5.4 The Video-Source

The Video-Source is modelled as a Variable Bit Rate (VBR) video COder DECoder (CODEC). Every 1/30 of a second the next frame is generated. The lenghts of the actual frame Y_n is given by the following formula:

$$Y_n = 0.8781 Y_{n-1} + 0.213 w_n M \frac{bit}{s}$$

where M is the mean bit rate of the video source. w_n is a Gaussian random variable with N(0.573,1). Values of w_n which are lower than 0 are rejected.

5.5 Modifications in the SatCom-Library

The satellite model has its own routing system and addressing scheme. Therefore we had to introduce a mapping between the ATM addressing and the satellite scheme. This mapping is done in the modified earth station module.

Before the start of simulation incoming 'Hello' cells are monitored. During this process earth station addresses of the satellite addressing scheme are assigned to the ATM router addresses. These values are stored in the *Earth Station Address* memory. The satellite system is bypassed while the simulation is setting up. After the start-up time the model acts as follows: The actual station number of the cell data structure is used to index the earth stations.

6 Results

6.1 Parameters

The load was iterated from 5 to 10 Mbit/s on every earth station. 20% of the offered load was given to the Ethernet, the rest was produced by the video stations. The ATM switches are using central queueing and are capable to store 1000 cells. The memory on the satellite nodes has a capacity of 10000 cells. The satellite systems have been examined for the following transmission speeds:

1. LEO: 34 Mbit/s up- and downlink, 155 Mbit/s crosslink
2. GEO-1: 34 Mbit/s up- and downlink
3. GEO-2: 155 Mbit/s up- and downlink

6.2 End-to-End Cell Delay

The cell delay was monitored from the source adaption layer (IWU) to the sink adaption layer. The following chart shows the delay iterated over the load: The result confirms our expectation. The End-to-End delay of the LEO system is much shorter than the GEO system, according to the higher altitudes of the GEO satellites. Almost no difference was found in the comparison of the 34 Mbit/s GEO vs. the 155 Mbit/s GEO, see fig. 7.

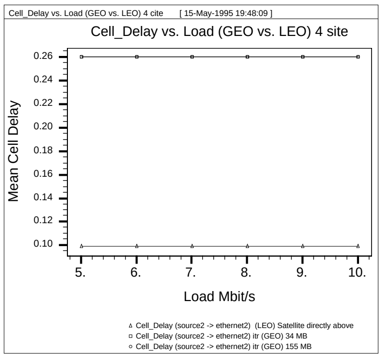

Figure 6: Cell-Delay vs. Load

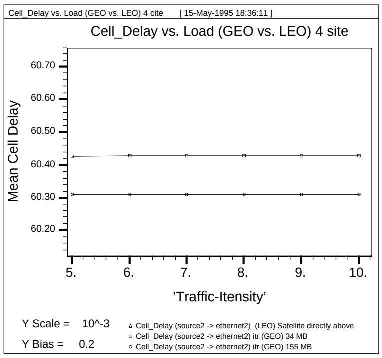

Figure 7: 34 MBit/s GEO and 155 Mbit/s GEO vs. Load

7 Conclusions

This simulation showed that the use of LEO satellite constellations is suitible to high-speed mulit-media communications. The greatest advantage of the LEO systems is the little altitude resulting low latences for interactive applications.

Further studies have to cover the following aspects:

- Is ATM the best transmission scheme?
- Are datagram techniques better than the concept of virtual channels?
- How can virtual channels be realized in a moving switching-node environment?
- Can the low round-trip delay of LEO satellites permit the design of better access-schemes?

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