Simulation and Analysis of Satellite Mobile Systems

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Abstract: - Satellite communications system uses various satellites to transmit radio signals between earth terminals. A typical operational link includes an active satellite and two or more earth terminals. Satellite communication is one of the significant factors from the space programs and has made a major contribution to the international communication. There are various types of information that can be transmitted through satellite, such as voice (telephone), video (television) and digital data.

This paper gives modeling and simulation of satellite mobile systems using various tools such as Matlab, OPNET and Celplanner. Matlab results show that the losses don’t depend on a direction: from earth station to a satellite or vice versa. Moreover, power changes over the distance are identical for remote and for the central station. The OPNET simulated results show that changing in WAN protocols types don’t affect the performance of a network. Celplanner results show that the forward prediction has a better performance output than the reverse links. Decreasing the number of sites leads to performance and capacity changes. Also antenna high, antenna gain and power adjustments resulted better BER, less interferences and better reception.

Key-Words: - Satellite, Mobile, Simulation, Modelling, OPNET, Celplanner, Matlab.

1 Introduction
Satellite communication systems have limitations as other telecommunication systems. Two main limitations of the satellite communication systems are: Satellite transmitter power on the down links and receiver sensitivity on the up links. Satellites communications have been limited by low-gain antennas in early years [1]. None-the-less better quality of the service is relating to the characteristics of the propagation environment and channel modelling of mobile satellite communication systems [2].

In this paper, the channel impairments affecting the performance and an overview of the satellite channel models are presented. Section 2 gives background of satellite communication system simulations and modelling techniques and tools. The various modelling parameters are investigated and results are represented with use of Matlab software in the section 3.1. we have tested the satellite mobile system, particularly the channel models and the effect of the propagation environment, by using a simulation package such as OPNET and Celplanner softwares and presented results in section 3.2, 3.3 correspondently. Analysis of the results are explained in section 4 and conclusion in section 5.

2 Background
MATLAB has been used to analyse formulas with various parameters. It is an interactive environment for numerical computation, visualization, and programming [3]. Using MATLAB, we have analyse data, develop algorithms, and create models and applications. We have used this software for calculating the required distance between satellite and the earth station [4]. Moreover the loss changes over the distance for downstream and upstream links are represented, as well as the power changes through the distance for the central/remote stations.

OPNET IT Guru provides performance analysis of computer networks and applications. The main parameters for investigations involve traffic flow and performance such as: queuing delay, throughput, utilization, etc. [5]. These results can be represented in various graphs using different protocol types [6] [7].

For design, modelling, analysis and optimization purpose, the Cellplanner have been chosen as it is the one of the most complete and integrated suite of software engineering tools that enables to achieve
the highest levels of accuracy, integration and optimization. From Celplanner, Forward / reverse predictions and coverage areas of the telecommunication network can be simulated. Besides Bit Error Rate (BER), Best Server, interferences diagrams represents a full picture for future analysis [8]. Finally the link Budget summarizing all results and provides details [9].

3. Modelling and Simulation of the Satellite Communication Systems
Section 3.1 gives the simulation of satellite communication system using Matlab. Section 3.2 represents the simulation in OPNET. The Celplanner simulation is given in Section 3.3.

3.1 Matlab simulation
Satellite AziyaSat-2 (100.5 °E) has been used for calculations. This is a geostationary satellite, the beam is in the C-band covers China, Japan, Indonesia, India, the Middle East, the CIS countries. As an input data the websites sources have been used[10].

For the central station have chosen Beijing city (with coordinates - 39 N, 116 E) and for the remote –Shanghai (with coordinates - 31 N, 121 E)
The distance from the earth station to airborne repeater is calculated according to the formula (1.1) [11]:

\[ d = 42644 \sqrt{1 - 0.2954 \cdot \cos \phi} \]  

where \( \cos \phi = \cos \xi \cos \beta \)  

\( \xi \) - latitude earth station  
\( \beta \) - difference in longitude satellite and earth station  
\( d \) - distance from the earth station to the satellite, km.

- for Beijing \( d_{Beij} = 4.4223\times10^4 \) km  
- for Shanghai \( d_{Shan} = 4.5691\times10^4 \) km

Calculations of Azimuth is made with formula (1.3)

\[ \text{Azimuth} = 180^\circ - \arctg \left( \frac{tg \beta}{\sin \xi} \right) \]  

where  
\( \gamma \) - longitude of the subsatellite point, deg  
\( \delta \) - earth station longitude, deg  
\( \xi \) - earth station latitude, deg.

azimuth_Beij = 180.3024  
azimuth_Shan = 181.3122

Next, the attenuation of the signal energy in free space (in dB) is found using the formula (1.4):

\[ L = 20 \lg \left( \frac{4\pi d}{\lambda} \right) \]  

Loss at path Earth-satellite for Beijing:  
\( L_{Beij\_earth\_satt} = 200.7497 \)

Loss at path satellite-Earth for Beijing:  
\( L_{Beij\_satt\_earth} = 196.6244 \)

Loss at path Earth-satellite for Shanghai:  
\( L_{Shan\_earth\_satt} = 201.0333 \)

Loss at path satellite-Earth for Shanghai:  
\( L_{Shan\_satt\_earth} = 196.9080 \)

Antenna gain in the direction "to satellite":  
\( G_{Beij} = 19.6000 \)

Antenna gain in the direction "from satellite":  
\( G_{Shan} = 19.6000 \)

Calculation of earth station transmitter power is performed by the formula (1.5) [12]:

\[ P_s = L \uparrow + L_{add} + k + T_c + \Delta f_{nb} - G_s - G_{rec} \eta_v + \eta_v + \eta_{rec} + a + \left( \frac{P_s}{P_n} \right)^\Xi \]  

where  
\( L \uparrow \) - path attenuation, dB  
\( L_{add} \) - additional attenuation, dB  
\( k = -228.6 \) dB - the Boltzmann constant  
\( T_c \) - total noise temperature of the board, dB  
\( \Delta f_{nb} \) - noise bandwidth, dB  
\( G_s \) - gain on transmission, dB  
\( G_{rec} \) - gain on reception, dB  
\( \eta_v \) - attenuation in high-frequency part of the satellite at the transmission, dB  
\( \eta_{rec} \) - attenuation in high-frequency part of the satellite at the reception, dB  
\( a = 7 \) dB - the safety factor;  
\( (P_s/P_n) \) - the signal / noise ratio at the receiver input, dB.

All values are substituted in decibels. The matlab results are:
Transmitter power of the earth station (dB):
\[ P_{tr1} = 11.6697 \]

Transmitter power of the earth station (Watt)
\[ P_{tr\_1} = 14.6882 \]

Power required for using the remote station to the central station (dB):
\[ P_{tr2} = 6.6433 \]

Power required for using the remote station to the central station (Watt):
\[ P_{tr\_2} = 4.6167 \]

The graphs in Fig. 1 introduced how the loss and power changes over the distance:

![Graph 1: Loss/Power changes over the distance.](image1)

The Fig. 1 indicates that the losses don’t depend on a direction: from earth station to a satellite or vice versa. Also power changes over the distance are identical for remote and for the central station.

### 3.2 OPNET simulation

For this part of the paper the OPNET simulation is represented. There is a network that consists of 2 main branches in Melbourne and in Washington with up to 400 computers, also there is a small Moscow branch with 50 workstations. All networks connected through the Fame relay Cloud that we use as a Satellite connection [13]. Three routers are connected with each other as well. Mainly two configurations are used: App and FR PVC. The design is given in Fig.2.

![Fig. 2: Network design of the OPET simulation scenario.](image2)

The Melbourne Site includes Router, Hub, LAN and Branch as it is represented on a Fig.3:

![Fig. 3: Network design of the Melbourne Branch.](image3)

The above diagram has been simulated using OPNET and obtained the results as shown in Fig.4. Two following diagrams compare the network characteristics before and after adding the Moscow Branch.

![Fig. 4: Performance results before and after adding the Moscow Branch.](image4)
After adding the third network the throughput changes a lot - 50 times less for Melbourne and 25 times less for Washington branches. Utilization decreases for Washington and remain staidly for Melbourne. All other parameters slightly changes.

The next step was analysing of the Frame relay Cloud. For this reason 2 different models have been implemented. All results are demonstrated in the following Fig.5.

As we could see from the graphs changing in WAN protocols types (fr64 / atm8) don’t affect the performance.

3.3 Celplanner Simulation

With a help of a Celplanner software the simulation have been designed. Several parameters have been used for this part. Some of them are represented on figures below in Fig.6 and Fig.7. Most of them have been adjacent to be as close as possible to real word scenario.

The network design is represented as shown in Fig.8. Due to limitation of a Celplanner and no satellite options – the base station is used as a satellite. Other 16 mobile stations are connected to it [14]. The nearest points are connected in a star topology. For better performance further 10 points communicate with BS through other external nodes. All links are interconnecting in one network and the neighbour list is made automatically due the “shortest path” criteria [15].
Fig.8 Network design in Celplanner.

Reverse prediction (MS to BS):

Forward prediction (BS to MS):

Fig.9 The reverse/forward predictions for the current scenario.

Mainly the results form Celplanner simulation perform the service level and performance details. It can be shown with use of some diagrams such as Bit Error Rate (BER), Best server and Interferences graphs from Fig. 10.

For the future experiment some parameters such as number of sites, power, antenna azimuth, radius etc. have been changed to analyse the performance. Fig.12 provides more details about them.

Fig.11 Output graphs of Celplanner simulation: BER, Best Server, Co-channel / Composite interferences.

Fig.12 Changes in the input parameters.
Only two prediction diagrams changed greatly. The first one was a coverage area. Decreasing the number of sites from 3 to 1 changed performance and capacity, proving that the cell splitting and cell sectoring are the best option to increase capacity. Also antenna high, antenna gain and power increase performance level in term of better BER, less interferences and better reception in the end devices as it is represented in Fig.13.

4 Conclusion
From section 3.1 with use of Matlab have been found the optimum distance to a satellite for all types of a Base stations. Also the power required for using different types of links have been found. The graphical results show that the losses don’t depend on a direction: from earth station to a satellite or vise versa. Moreover, power changes over the distance are identical for remote and for the central station.

The OPNET simulated from Section 3.2 introduced the performance results such as utilization, throughput, delay, traffic load, etc. The results show that changing in WAN protocols types don’t affect the performance of a network. Section 3.3 prove that in a Celplanner simulations the forward prediction has a better performance output then the reverse links. Besides decreasing the number of sites from 3 to 1 changed performance and capacity. Also antenna high, antenna gain and power increase performance level in term of better BER, less interferences and better reception in the end devices. Future work will investigate the performance analysis of more sites coverage and optimum number of sites for good coverage.

References: