Mobile Satellite Communication with Cross Layer Architecture

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Abstract

Background/Objectives: The objective is to develop algorithms for improving Quality of Service with minimum delay and higher throughput using intelligent networking with cross layer architecture. **Methods/Statistical analysis**: For Mobile satellite communication Low Earth Orbit (LEO) satellites are used. Mobile satellite networks using LEO satellites provides less delay and high bandwidth. The cross-layer design is the method used to allow optimized operation in the modern heterogeneous wireless environment. **Findings**: The throughput improves with speed of transmission of information with cross layer design compared to the existing OSI model. The packet ratio increases with increasing transmission rate in comparison with the existing model. The overall delay is minimized in the proposed system with increase in number of packets. Simulation developed establishes that better QOS can be obtained with minimum delay and improved throughput in MSC networks using intelligent networking with cross layer architecture. **Application/Improvements**: The various applications of mobile satellite communication includes TV broadcasting, digital processing and point to point communication. The throughput is improved by 30% with speed of transmission of information. Packet ratio increases by 20% with increasing transmission rate. The overall delay is reduced by 17% with the help of cross layer design which is the optimized level compared to the existing model.

Keywords: Cross Layer Architecture, Cross Layer Optimization, Intelligent Network, Low Earth Orbit, Mobile Satellite Network, Quality of Service

1. Introduction

Satellite communications plays an important role in communication system. It provides services for point-to- point data communication³. The advantages of mobile satellite communication includes coverage, bandwidth flexibility, multi point connectivity for various applications such as TV broadcasting, digital processing point to point and data communication.

A communication satellite orbits the Earth in three important ways. One of these orbits is called Geo synchronous orbit (GEO), which is 19,300 miles from Earth's surface. The Medium Earth Orbit (MEO) ranges from 500-1200 miles above earth surface³. Below MEO, closer to earth, Low Earth Orbits (LEO) are present and is about 200 miles above Earth. Moreover LEO satellites are employed for mobile communication environment to minimize delay towards the acceptable value. There is a tremendous demand for mobile communication with required QoS. This has improved heavy traffic over long distance in the network.

LEO satellite orbit times are much less than for many other forms of orbit. LEO satellites velocities are nearly around 8 km/s. The Round Trip Time (RTT) for the radio signals is generally less than that experienced by geostationary orbit satellites. The actual time is depending on the altitude of the orbit and user position, relative to satellite. Radiation levels are lesser than present at higher altitudes.

LEO satellites are used for both aeronautical as well as military purpose. Military rocketry and missiles takes the advantage of launching missiles and rockets over long distances¹⁰. This is done in three steps. First it is launched into a suborbital path using its engine. Second step is to allow the missile to reach cruising speeds. In third step, the influence of gravity brings it back to Earth towards its target. Low Earth Orbit is used for mobile satellite communication⁸.

A Mobile Satellite Communication (MSC) system is as shown in Figure 1. It consists of three segments. They are

- 1. Space Segment in which the satellites placed into orbit
- 2. Control Segment having equipment and facilities responsible for the control of satellite for the desired operation
- User Segment having equipment and facilities that use the capabilities provided by the satellite³.

The network architecture is capable of queuing the information sources for classifying the packets and scheduling them appropriately. Measuring, conditioning and monitoring the flow of packet steam is carried out. Cross layer interaction is deployed to achieve the above processes in an adaptive manner by involving all layers in contributing the final Quality of Service³.

For example, in the physical layer, coding techniques and bandwidth efficient modulation are to be used for improving the Bit Error Rate (BER) and power level performance to compensate the varying Quality of Service.



GSL- Gateway Switching Link ML - Mobile Link ISL - Inter Satellite Link Figure 1. Mobile Satellite Communication System.

2. Exiting Work

The Open Systems Interconnection (OSI) reference model provides a hierarchical architecture which logically divides the functions required to provide system-to-system communication. The OSI model consists of seven layers. Every layer has its own well defined function.

2.1 Application Layer

The functions of application layer includes security checking and information validation and provides a set of interfaces for applications to obtain access to networked services and access to network.

2.2 Presentation Layer

It is responsible for formatting data, encryption, text compression, and reformatting. Data compression and cryptography techniques are often used.

2.3 Session Layer

It provides a session across a network. It has the responsibility to setup session, data or message exchanges, tear down when the session ends, dialogue control, token management and synchronization.

2.4 Transport Layer

This layer accepts the data from the session layer, split it up into smaller units, pass it to the network layer, and check the bits delivered are the same as that of the bits transmitted without modification, loss or duplication.

2.5 Network Layer

The network layer provides routing, controls the operation of a sub-net, congestion control and accounting. The network layer is used to provide connectionless and connection-oriented services.

2.6 Data Link Layer

The data link layer is used to take a raw transmission and transform it into a line that appears free of transmission errors in the network layer. The sender breaks the input data up into data frames, transmit the frames sequentially, and process the acknowledgment frames.

2.7 Physical Layer

The physical layer is used to transmit raw bits over a communication channel. The design issues deal largely with mechanical, electrical, functional, and procedural interface and also describe the network topology.

In the existing work, the routing and satellite coverage algorithms are less reliable. The parameter variations of the channel are not considered. Since there is no communication between non adjacent layers, the parameter variations of one layer are not known to others. Environmental factors are ignored. The changes in the environmental condition affect the system during transmission. As a result optimized QoS is not achieved. Hence Cross Layer Design (CLD) is involved in order to get the optimized result in terms of higher throughput and lower delay[§].

3. Proposed Work

An Intelligent Network conceptisproposed work with Cross Layer Optimization (CLO) for Mobile Satellite Networks. The Intelligent Network (IN) is the network architecture identified by International Telecommunication Union (ITU). It provides value-added services such as PSTN, ISDN and GSM on mobile phones⁸.

Intelligent network involves Cross Layer Design (CLD) for effective mobile satellite communication¹. CLD approaches which refer to the protocol designs that actively exploit the dependence between protocol layers to obtain performance gains⁴. The new requirement for network architecture design is the Ambient Intelligence. The new network architecture with Ambient Intelligence emphasizes user-centric and personalized design principles.

4. Cross Layer Design

TCP is a point-to-point protocol which helps to achieve the Intelligence which sets up a connection between two endpoints using control signals called handshake signal. Information sharing among all the layers is done in order to obtain highest possible adaptability of any network² with CLD. This is needed to meet out the requirements such as challenging data rates, higher performance gains and Quality of Services requirements for various real time and non real time applications.

In Figure 2 Inter-layer signaling pipe makes use of IP data packets as in-band message carriers. There is no



Figure 2. a) Packet headers. b) ICMP messages.

need to use a dedicated message protocol. A message is transferred by these holes rather than a pipe used as in Method I.

The messages are transmitted over the layers using the Internet Control Message Protocol (ICMP)² which is more flexible and efficient method. But, ICMP encapsulated message have to pass by network layer even if the signaling is requires between link and application layer.

Cross layer information is extracted from related layer and stored in separate profiles within a Mobile Host (MH) as shown in Figure 3. Channel and link information from physical layer and link layer are gathered, abstracted and managed by Wireless channel Information Servers (WCI).

The processing overhead is increased by Checksum calculation, and other procedures which motivates a "lightweight" version of signaling protocol CLASS. It is used only for destination layer identification, type of event, and related to the event data fields as shown in Figure 4.

5. Cross Layer Design for MSC

The intelligent network based satellite network architecture that includes lower layers is defined by European Telecommunication Standard Institute Technical Committee (ETSITC). Teledesic is the satellite constellation⁶.

The constellation Teledesic is planned to meet the demand using constellation of LEO satellites operating in Ka-band (30/20 GHz). The Teledesic network provides



MH - Mobile Host WCI -Wireless Channel Information **Figure 3.** Network Services.



Figure 4. Local Profiles.

service quality, low transmission delay, high data rates and low bit error rates to fixed and mobile users.

The cross layer design provides interfaces between non- adjacent layers. Each layer should have all the information about other layers so that the information can be exchanged between lower layer to higher layer and vice versa. Exchange of information through send and receive parameters have been done only at the adjacent layers in existing model³.

There are two basic cross layer approaches. They are Implicit cross layer design and explicit cross layer design. The exchange of information between layers is done during design process in case of implicit design. In explicit design, interactions among non-adjacent layers are done in order to perform dynamic adaptation. In Figure 5 cross layer manager is used in to share the information between adjacent and non-adjacent layers.

Without disturbing the information that flows from lower to higher layer or higher to lower layer, the cross layer manager helps in performing the function. The



RTP - Real-time Transport Protocol UDP - User Datagram Protocol TCP-Transmission Control Protocol **Figure 5.** Cross Layer Design for MSC.

main layers involved are MAC/PHY layer, network layer, transport layer and application layer¹⁰. The information about cross layer manager is known to all other layers so that it communicates with all layers and shares the required information to the particular layer².

The parameter variations are considered and the environmental changes are also informed to the required layer. Adaptive techniques are deployed for communication. Hence the QoS is achieved in terms of less delay and higher throughput.

For example, transport layer should know about the channel capacity for data transmission⁶. The channel capacity information is present in physical layer. The cross layer manger transfers such information to the transport layers for further communication. This is how the cross layer design involves in mobile satellite communication and exchanges information and improves the QOS.

6. Challenges in Deploying the Technique

Cross-layer design is mainly used to improve the performance of LEO based MSN. It provides the improved results which are not an easy work, as co-operation among protocol layers should be coordinated without leading to clashes¹⁰. One of the challenges is the lack of a systematic approach for cross-layer design. The optimizations run across the layer disturbing the architecture principles for shortsighted performance gains. Cross layer interactions in a controlled way through a common optimization interaction interface is not simple task to do². The satellite network consists of a number of interfering links. This leads to power control problem and rate maximization. The problem of allocating the transmitting power is intertwined with determining the links on which receivers can perform Interference Cancellation. The major challenge of satellite network is to allocate power for new links.

7. Simulation Results

This section describes the Quality of Service (QoS) parameters such as throughput, delay and packet ratio used in cross layer design for mobile satellite communication.

Figure 6 shows Throughput comparison graph with and without cross layer. The throughput increases with speed of transmission of information by 30% with the help of cross layer design in comparison with the existing OSI model.

Figure 7 shows the simulation output for achieving QOS in terms of packet ratio. The packet ratio increases



Figure 6. Throughput Comparison With and Without Cross Layer.



Figure 7. Packet Ratio Comparison With and Without Cross Layer.



Figure 8. Delay Comparison With and Without Cross Layer.

by 20% with increasing transmission rate when compared with the existing model.

Figure 8 shows the simulation output for delay. In this overall delay with the help of CLO is reduced by 17% as the number of packets increases which is in optimized level when compared to the existing OSI model.

8. Summary and Conclusion

To assure the improvement in QOS in terms of higher throughput and minimum delay, Cross Laver Optimization is used in Mobile Satellite Networks which has cooperation and state information sharing among all layers. First, Mobile Satellite Network with LEO satellite communication has been addressed. The intelligent network plays an important role and its application with the help of cross layer design for mobile satellite network has been addressed. The cross layer manger function for QoS improvement also been discussed. The challenges of applying cross layer design have been discussed. Finally the comparison of throughput, delay and packet ratio with and without cross layer have been addressed. The possible future work includes implementation of various power control methods to solve the power problem for more users.

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