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Study and Implementation of Cross Layer Design Based Routing Algorithm for Leo Satellite Network

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Abstract: **Now a days Low earth orbit satellite networks are used to provide global coverage to users in remote areas. Since LEO's are continuously revolving, they traverse their orbits and thus cause frequent user handovers. So for providing better service to the user and improving the LEO satellite network performance a Cross-layer design and Ant-colony optimization based Load-balancing routing algorithm (CAL-LSN) is designed and implemented. In CAL-LSN mobile agents called ants are used. These mobile ants will collect information of nodes and help to find shortest path. In CAL-LSN cross layer architecture is used and network layer and physical layer are exchanging information in between. CAL-LSN will reduce network congestion and improves link utilization thus providing Quality Of Service to the user.**

Key words- **Ant-colony optimization; cross-layer design; LEO satellite networks; Quality of Service**

I. INTRODUCTION

Low earth orbits (LEO) are satellite systems used in telecommunication, which orbit between 400 and 1,000 miles above the earth's surface. They are used mainly for data communication such as email, video conferencing and paging. They move at extremely high speeds and are not fixed in space in relation to the earth. LEO-based telecommunication systems provide underdeveloped countries and territories with the ability to acquire satellite telephone service in areas where it otherwise would be too costly or even impossible to lay land lines. Low earth orbit is defined as an orbit within a locus extending from the earth's surface up to an altitude of 1,200 miles. Attributing to their high speeds, data transmitted through LEO is handed off from one satellite to another as satellites generally move in and out of the range of earth-bound transmitting stations. Due to low orbits, transmitting stations are not as powerful as those that transmit to satellites orbiting at greater distances from earth's surface. Most communication applications use LEO satellites because it takes less less energy to place the satellites into LEO. Moreover, they need less powerful amplifiers for successful transmission. As LEO orbits are not geostationary, a network of satellites is required to provide continuous coverage. However, as a result of the popularity of this type of satellite, studies reveal that the LEO environment is getting congested with space debris. NASA keeps track of the number of satellites in the orbit, and estimates that there are more than 8,000 objects larger than a softball circling the globe. Not all of these objects are not satellites, but rather pieces of metal from old rockets, frozen sewage and broken satellites.Due to the movement of the satellite footprint, the number of users in a cell and the traffic served by each satellite changes in time. A user is *handed over* from one satellite to another multiple times during the lifetime of a call. In terrestrial broadband networks, a route for a particular connection between two end-users is determined based on available bandwidth on various network links at the time of call set-up. This particular route is used for the entire call duration. In LEO satellite networks the traffic on the inter-satellite links (ISLs) also change with changes in the user-to-satellite traffic (which in turn changes due to the mobility of the satellites).Hence, traditional terrestrial routing protocols cannot be applied to broadband LEO satellite networks. Although sufficient bandwidth may be available on a particular route at call set-up for a particular call, the same route may become congested in time due to the changes in access traffic loads which in turn are changing due to the mobility of the satellites. In such a case CAL-LSN perform well as it uses Ant Colony Optimization technique because of which shortest path between nodes can be found out for packet transmission which in turn results in load balance. To satisfy the Quality of Service (QoS) requirements of multimedia applications, a distributed QoS routing scheme based on heuristic ant algorithm is proposed for satisfying delay bound and avoiding link congestion [10]. The cross layer architecture is used in which network layer collects information from physical layer. Information that network layer collects from physical layer is traffic load information and the wireless link quality as well as the transmission delay of each data packet.

II. LITERATURE SURVEY

The literature survey is to get the insight of the methods, their shortcomings which we can overcome while designing the new algorithms for LEO satellite network.The main reference is taken from, Cross-Layer Design and Ant-Colony Optimization Based Routing Algorithm for Low Earth Orbit Satellite Networks. WANG Houtian1, 2, ZHANG Qi1, 2, XIN Xiangjun1, 2, TAO Ying3, LIU Naijin3, China Communications • October 2013.Based on that advantages of CALLSN over existing algorithms are studied. First of all the various routing algorithms for LEO's are studied.

Along with the new trends in global telecommunications where the Internet traffic may hold a dominant share in the total network traffic, satellites may become more popular for IP networks. Especially for interactive internet applications, Low Earth Orbit (LEO) satellites may be utilized due to shorter round-trip delays and lower transmission power requirements as compared other satellite solutions; namely, Geostationary (GEO) and Medium Earth Orbit (MEO) satellite ones. Real-time communications services can be provided to the users regardless of the users' geographical location. Most of the LEO satellite constellations include direct inter-satellite links (ISLs) in order to provide communication paths among satellites. Routing is an important issue for efficient use of satellites and ISLs, increased throughput and decreased delay.

In LEO satellite networks the traffic on the inter-satellite links (ISLs) also change with changes in the user-to-satellite traffic (which in turn changes due to the mobility of the satellites). Hence, traditional terrestrial routing protocols cannot be applied to broadband LEO satellite networks. Although sufficient bandwidth may be available on a particular route at call set-up for a particular call, the same route may become congested in time due to the changes in access traffic loads which in turn are changing due to the mobility of the satellites. The focus in research in LEO satellite networks has been in providing successful handover to users as they transition from one satellite's coverage area to the coverage area of another.

The handovers between the satellites in adjacent orbital planes are also considered for a single hop scenario. However, multi-hop communications is necessary in mobile satellite networks since different users might be covered by different satellites. The multi-hop satellite routing problem has been addressed in [5] with an emphasis on setting up routes between pairs of satellites to minimize the re-routing frequency. Notice that, the need for rerouting arises from the fact that, often, no user pair can be serviced by the same satellite end nodes for the entire call duration.

As the LEO satellite moves along its orbit, it must service as many users that are in its coverage area, as possible. The effects of non-uniform geographical user traffic distributions in LEO satellite networks have not been investigated extensively. As explained in the previous sections, non-uniform user traffic load on the satellites may cause changes in the traffic on inter-satellite links, which may result in unexpected dropping of some of the user calls or packets. Which affects the delivery of guaranteed services to the users? Guaranteed services require that the packets of a call arrive within a pre-specified guaranteed delivery time and that the packets will not be discarded due to queue overflows.

So for load balancing and to improve the performance of LEO satellite network CAL-LSN makes use of a multi-objective optimization model. The performance of CAL-LSN is measured by the packet delivery rate, the end-to-end delay, the link utilization and delay jitter.

III. PROBLEM DEFINITION

Most existing routing protocols for LEO satellite networks are unable to handle handover to users as they transition from one satellite's coverage area to the coverage area of another. One of the challenges in Low Earth orbit satellite networks is development of specialized and efficient routing algorithm. Multi-objective QoS routing based on cross layer designs has not been addressed recently. If the connection has strict *Q*uality *of S*ervice (*QoS*) requirements, such as delay or delay jitter bounds, it may be blocked even if user-to-satellite channels are available due to the lack of a route with adequate resources from the satellite entry to the satellite egress point. However, multi-hop communications is necessary in mobile satellite networks since different users might be covered by different satellites. To satisfy the QoS requirements of multimedia applications, satellite routing protocols should consider handovers and minimize their effect on the active connections.

The constellation environment has a number of important impacts on routing. Three of these are related to fact that the network nodes are not fixed. First, distances between satellites and the corresponding propagation delays evolve as the constellation orbits the earth. This orbital movement also leads to handovers whenever an earth station exits a satellite footprint. Finally, in a satellite network, load conditions evolve more quickly than in the terrestrial case since they are determined by the *projection* of terrestrial conditions onto the rapidly moving network above it. An additional consideration stems from the relative inaccessibility of satellites as compared to earthbound nodes. The need for an autonomous routing algorithm is in this case all the more pronounced.

All satellites in the same orbit cover exactly the same orbital coverage area during a revolution. However, at a given time, each satellite handles traffic from a portion of this orbital coverage region. The user traffic might be non-uniform with respect to both time and location. As the satellite moves along its orbit, the number of users and thus the amount of traffic it serves changes. This change in the amount of user traffic served by a satellite may cause blocking of some of the handover calls due to either the non-availability of the ground user-to-satellite up/down wireless links, or insufficient capacity on ISLs on the route connecting the end users.

The effects of non-uniform geographical user traffic distributions in LEO satellite networks have not been investigated extensively. Non-uniform user traffic load on the satellites may cause changes in the traffic on inter-satellite links, which may result in unexpected dropping of some of the user calls or packets.

Using CAL-LSN algorithm in our routing protocol we can achieve load balancing. So that user traffic load on the satellites get equally distributed and no particular satellite will be overloaded. In CAL-LSN, mobile agents called ants are used to gather routing information actively. CAL-LSN can utilize the information of the physical layer to make routing decision during the route construction phase

IV. EXISTING SYSTEM

In existing system, Routing is a complex issue because of high mobility of satellite and necessity of efficient connectivity information update for successful handover .On account of moving coverage region of individual satellite the terminal on ground may not stay in single coverage region of the satellite during communication .Thus LEO satellite needs to transfer ground terminal to other satellite whose coverage region contain the ground terminals. This event is called handover in LEO satellite system. If there is no channel available in destination cell or satellite the handover is unsuccessful and call is dropped. So satellite routing protocol should consider handovers and minimize their effect on active connection.

To tackle this issue there are existing two routing algorithms based on ant colony optimization

these are Improved Ant Colony System (IACO) and Distributed QoS-based Algorithm (DQA). IACO improves the original ant-colony algorithm; it does not consider the influence of the residual bandwidth on the QoS requirement. So when the number of users increases, the link utilization decreases. So when IACO is made use of in the network, the end-to-end delay and delay jitter performance are poorer. When the number of users increases, IACO always tends to select the optimal path. This will make the load of the optimal path heavy.

There is a algorithm Distributed QoS-based Algorithm (DQA) that focuses on multi-objective QoS routing based on heuristic ant algorithm it satisfy QoS parameters delay bound and avoid link congestion [10], it considers the handover between the satellite and the ground station so as to minimize the effect on the active connections. As compared to DQA, CAL-LSN has improved link utilization and throughput. CAL-LSN and DQA introduce minimum bandwidth constraint and this will balance traffic load and meets the basic requirement for video transmission

V. METHODOLOGY / APPROACH

In CALLSN Cross layer architecture is used where physical layer and network layer can communicate with each other. Network layer can perceive channel state information from physical layer and and calculates next hop using dealy and residual bandwidth .The following diagram shows cross layer architecture used by CALLSN.

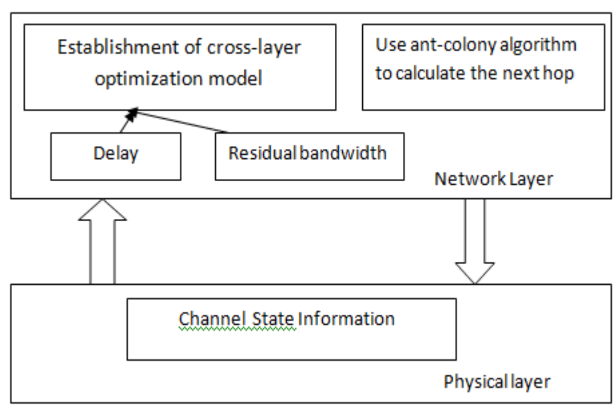

Fig: CALLSN Cross layer architecture

Every satellite node in LEO satellite network consists of five modules .

1. Ground link queue module: stores those packets interacting with the ground station.

2. Satellite link queue module: is in charge of storing packets that interact with other satellite nodes in the network.

***3. Pe* calculation module:** perceives channel state information and according to that calculates the error probability of each link.

4. Ant-colony algorithm module: the error probability of each link calculated by *Pe* calculation module is the input of ant-colony algorithm module. This module can calculate the probability of sending data packets to adjacent satellite nodes.

5. Routing table module The routing table structure is maintained by each node. The forward agents in CAL-LSN travels through the satellite networks and collect routing information and the backward agent updates the routing table

5.1.1 Routing procedure using CALLSN algorithm in LEO satellite network

Working of CLLSN is as shown in figure below.

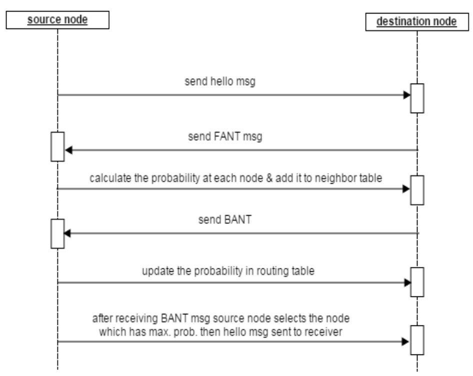

Fig: Working of CLLSN

The source node data packet to transfer sends hello message to destination node.Destination node then sends forward ant to collect the information of the nodes. Forward ant then calculates probability at each node and adds it to neighbor table. Destination node then sends backward ant which updates the probability in routing table. After receiving backward ant message, source node selects the node which has maximum probability. Then hello message is sent to the receiver.

5.1.2 CALLSN algorithm

Main motive of CALLSN is to avoid network congestion thus causing maximum link utilization. So first step in CALLSN algorithm is to calculate the cost of each link from source to destination.the cost of each link is calculated according to following formula.

$$cost_{ij} = \omega_1 \times \frac{PD_{min}}{PD_{ij}} + \omega_2 \times \frac{RB_{ij}}{RB_{max}} \quad (1)$$

For simplification delay constraint and the residual bandwidth constraint are considered equally important indications of link cost.

so $\omega 1 = \omega 2 = 0.5$

PDij is the propagation delay of link (*i*, *j*), where the propagation delay of intra-satellite links and inter-satellite links is about 13.47 ms and 11.58×cos*j*° ms respectively and *j* *here* is the value of satellite latitude. The value of *PD*min can be derived According to the latitude threshold for Polar Regions. *RB*max is the bandwidth of satellite links and *RB*max= *BW*.

When packet *P*(src, des) travels from source satellite to destination satellite it should satisfy the following constraints for an application to begin and progress.

$$\max \sum_{(i,j)\in P(src,des)}^{des} cost_{ij}$$
$$\max \sum_{(i,j)\in P(src,des)}^{des} TD_{ij} \le De$$
$$min_{(i,j)\in P(src,des)} \quad RB_{ij} \ge B \quad (2)$$
$$\forall\, link(i,j) \; (i,j) \in P(src,des) \quad Pe_{ij} \le 10^{-6}$$

In Eq(2) I,j stands for two satellite nodes in path *P*(src, des). According to Ref. [15], *for* reliable data transmission, the error probability *Pe* should be $\le 10^{-6}$. *TDij* stands for the transmission delay of link (*i*, *j*). *De is* the maximum delay that can be tolerated by LEO satellite networks. *B is the* the minimum bandwidth constraints. *TDij* and *RBij* can be calculated according to Eqs. (3) and (4).

$$TD_{ij} = PD_{ij} + QD_{ij} \quad (3)$$
$$RB_{ij} = BW - Q_{ij} \quad (4)$$

At the regular interval Δ*t*, a forward agent F*s*→*d* is launched at source satellite node *s* toward destination satellite node *d*. For node *s*, the probability to choose the next hop *j* is calculated according to Eq. (5).

$$(P_{sjd})_{agent} = \frac{1/Hop_{jd}}{\sum_{j\in M} 1/Hop_{jd}} \; (j \ne d) \quad (5)$$

HOP*jd is* the minimum number of hops from node *j* to node *d* and *M* is the set of satellite nodes that are adjacent to satellite node *s*. Each forward agent maintains two lists, list V and list T. List V maintain the number of satellite nodes the forward agent passes and list T maintains the time forward agent visits each node. According to reference [17] the forward agent uses the pseudo-random proportional selection rule based on strategy of deterministic rules combined with random selection. The forward agent *k* which is located at node *i* will choose the next node *j* through the following formula.

$$(P_{sjd})_{agent} = \begin{cases} \frac{(P_{ijd})_{data}}{\sum_{j\in table_k}(P_{ijd})_{data}} & if\,(q \le q_0) \\ 1/N & if\,(q > q_0) \end{cases} \quad (6)$$

Here *q* is a random number which is even distribution in (0, 1), and *q*0 is a parameter (0<*q*0<1) whose size reflects the relative importance of using prior knowledge and exploring the new path. Table *k* represents the set of the next node which ant *k* can choose and *N* is the number of elements in table*k*. The function of table*k* is avoiding routing loops. Once the forward agent *Fs*→*d* reaches the destination satellite, it is terminated and the backward agent *Bd*→*s* is created. *Bd*→*s* copies the two lists from *Fs*→*d* and follows the identical path in the reverse direction. At each satellite node *Bd*→*s* passes, the probability for data packets to choose the next hop is updated.Suppose that *r* is an arbitrary satellite node that is adjacent to satellite node *i* and *M*1 is the set of satellite nodes that are adjacent to satellite node *i*. The set *K* in CAL-LSN is defined as

$$K=\left\{r, (P_{e)}_{ir} < 10^{-6}, r \neq j, r \in M_1\right\} \quad (7)$$

That is, *K* is the set of satellite nodes that satisfies (*Pe*)*ir*<10-6 except node *j*. *l* is one element of set *K* and *l* satisfies:

$$l \in K \cap cost_{il} = max\{cost_{ir}, r \in K\} \quad (8)$$

The probability for data packets to choose the next hop is calculated according to Eqs. (9) and (11). Suppose that *T*update stands for the routing table update cycle. *h* is the number of backward ants one satellite node receives during this update interval. The value of *h* in Eqs. (9) and (11) returns to zero every fixed time interval.

$$(P_{ijd)}{}_{data}|_{h+1} = \begin{cases} \rho \times (P_{ijd)}{}_{data}|_h + (1-\rho) & (P_{e)}{}_{ij}|_h < 10^{-6} \\ \rho \times (P_{ijd)}{}_{data}|_h & (P_{e)}{}_{ij}|_h \geq 10^{-6} \end{cases} \quad (9)$$

$$(P_{ijd)}{}_{data}|_{h=0} = \frac{1/Hop_{jd}}{\sum_{j \in M1} 1/Hop_{jd}} \; (j \neq d) \quad (10)$$

$$\binom{P_{ird}}{r \neq j}_{data}|_{h+1} = \begin{cases} \rho \times (P_{ird)}{}_{data}|_h + (1-\rho) & (P_{e)}{}_{ij}|_{h+1} \geq 10^{-6} \cap r = l \\ \rho \times (P_{ird)}{}_{data}|_h & (P_{e)}{}_{ij}|_{h+1} \geq 10^{-6} \cap r \in K \cap r \neq l \\ \rho \times (P_{ird)}{}_{data}|_h & (P_{e)}{}_{ij}|_h \geq 10^{-6} \cap r \notin K \\ \rho \times (P_{ird)}{}_{data}|_h & (P_{e)}{}_{ij}|_h < 10^{-6} \end{cases} \quad (11)$$

In Eqs. (9) and (11), ρ is the pheromone evaporation coefficient. In order to ensure that data packets will choose the link that its probability is strengthen, the value of ρ is discussed in this paper. Suppose that at the time satellite node *i* receives the *h*-th backward agent, the probability for data packets to choose link (*i*, *j*) and link (*i*, *l*) is *P*1 and *P*2 respectively. When node *i* receives the (*h*+1)-th backward agent, the value of (*pijd*) data is strengthen, so according to Eqs. (9) and (11)

$$(P_{ijd)}{}_{data}|_{h+1} = \rho \times P_1 + (1-\rho) \quad (13)$$

$$(P_{ild)}{}_{data}|_{h+1} = \rho \times P_2 \quad (14)$$

In order to ensure that data packets will choose the link that its probability is strengthen,
the following conditions should be satisfied.

$$\rho \times P_1 + (1-\rho) > \rho \times P_2 \quad (15)$$

That is

$$\left(\frac{1-\rho}{\rho}\right) > |P_2 - P_1| \quad (16)$$

If $\frac{1-\rho}{\rho}$ satisfies $\frac{1-\rho}{\rho} \geq 1$ Eq. (16) can be tenable regardless of the value of *P*1 and *P*2. $\frac{1-\rho}{\rho} \geq 1$ is equivalent to $\rho \leq 0.5$ So we can conclude that data packets will choose the link that its probability is strengthen if the value of ρ satisfies $\rho \leq 0.5$ On the basis of Ref. [12], we define an interval [min, max]. *x* satisfies even distribution in [min, max]. The relationship between *Pe* and *x* is as follows,

$$P_e = \lambda \times e^{-\lambda x} \quad \textbf{(17)}$$

where λ=1. Value of *Pe* is made as the external input. a=ln$\frac{1}{10^{-6}}$ ∈ [min, max]. Considering satellite constellation characteristic the interval [min, max] is defined. In the light of the latitude of the satellite at time *t*, we define three areas. Let λ*u* reflects the probability of *Pe* larger than $10^{-6.}$ in each area and lat*u*(*t*) denote the latitude of the satellite at time *t*, the definition of λ*u* is shown in Eqs. (18) and (19).

Inter-plane satellite links:

$$\lambda_u = \frac{max-a}{max-min}$$

$$\begin{cases} 0.05 & -90^0 < lat_u(t) \leq -60^0 \\ 0.1 & -60^0 < lat_u(t) \leq -30^0 \\ & \vee\, 30^0 < lat_u(t) \leq -60^0 \\ 0.15 & 60^0 < lat_u(t) \leq 90^0 \end{cases} \quad (18)$$

Intra-plane satellite links

$$\lambda_u = \frac{max-a}{max-min} = 0.15 \quad (19)$$

The average link utilization is calculated according to Eq. (20).

$$Link\_uti = \frac{\sum_{i=1}^{H}\sum_{j=1}^{4} s_{ij}}{4 \times H \times 1 \times 10^7}$$

(20)

Where *Sij* is the *j*-th port's actual transmission rate of satellite node *i*. *H* is the number of satellites over the whole constellation. An Iridium-like satellite constellation is considered for our study, so the value of *H* is 66.

RESULTS/DISCUSSION

Simulation parameters

Parameters Value

The type of service =Video conference

The bit rate of service =256 Kb/s

The bandwidth of inter-satellite links= 10 Mb/s
The bandwidth of intra-satellite links =10 Mb/s
The bandwidth of the links between satellite and the ground terminal = 8 Mb/s
ρ= 0.5
Minimum bandwidth required = 200 Kb/s
Delay bounds= 300 ms
Software Used: NS2

ns is an object oriented simulator, written in C++, with an OTcl interpreter as a frontend. The simulator supports a class hierarchy in C++ (also called the compiled hierarchy in this document), and a similar class hierarchy within the OTcl interpreter (also called the interpreted hierarchy in this document). The two hierarchies are closely related to each other; from the user's perspective, there is a one-to-one crrespondence between a class in the interpreted hierarchy and one in the compiled hierarchy. The root of this hierarchy is the class TclObject. Users create new simulator objects through the interpreter; these objects are instantiated within the interpreter, and are closely mirrored by a corresponding object in the compiled hierarchy.The interpreted class hierarchy is automatically established through methods defined in the class TclClass. User instantiated
objects are mirrored through methods defined in the class TclObject. There are other hierarchies in the C++ code and OTcl scripts; these other hierarchies are not mirrored in the manner of TclObject.
In this section, the performance of CAL-LSN is studied. All the simulations were performed with the simulation tool NS2 on core I3 processor (3.3 GHz clock). NS2 simulator has three logical levels: network level (a LEO satellite system has been considered, together with satellite terminals), node level (consisting of all the algorithms of the protocol stack), and process level developed in *C++* that implement the proposed algorithms).Figure 3 shows the simulation scenarios. In this paper, an iridium-like satellite constellation is considered for our study. There are two intra-plane ISLs
Traffic inserted into the network was generated by earth stations which were distributed according to the hot spot scenario described in Ref. [18]. The

performance of CAL-LSN is studied. In this paper, the value of *Pe* is made as the external input of the simulation environment. According to Ref. [12], the distance is the dominating element of the error probability in space that no obstacle stands on the path. In Ref. [12], *Pe* was calculated using exponential distribution probability density function. Fig.3 shows the simulation scenario. It shows LEO satellite nodes, access points, LANS, Internet, GLO-PARA

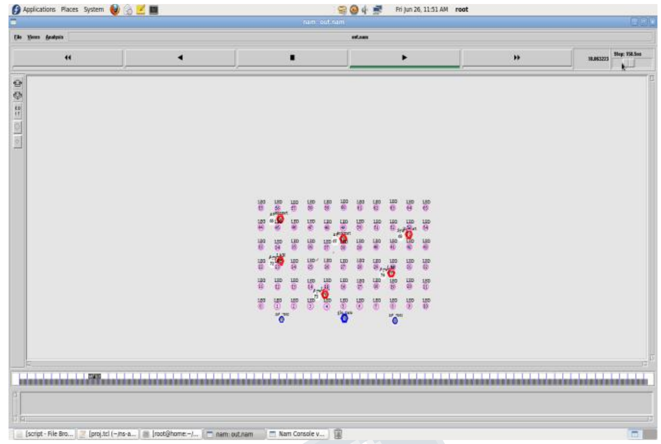

Fig.3 *The simulation scenarios*

Tcl file in NS2 is executed and the results are traced in Tr file. According to that Delay, Throughput, Delay jitter and Link utilization are calculated and graphs are plotted. The graphs are as follows.

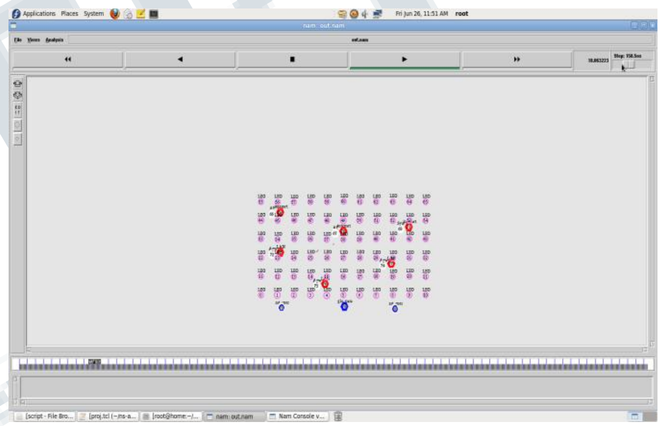

Fig.3 The simulation scenarios

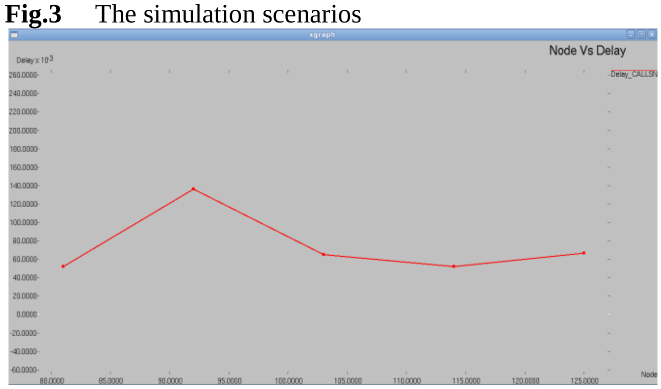

Fig 4: Comparison of Delay when nodes are increased

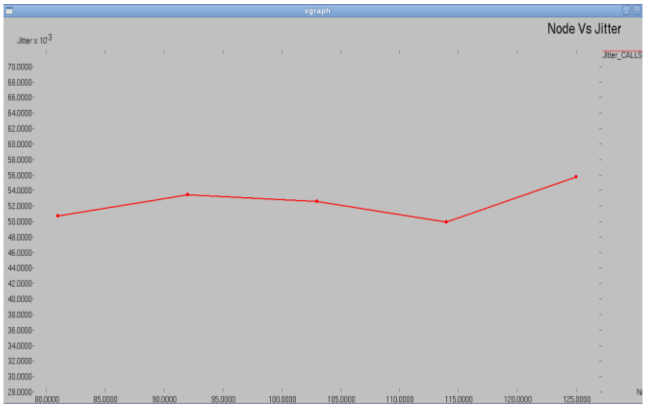

Fig: Comparison of Jitter when nodes are increased

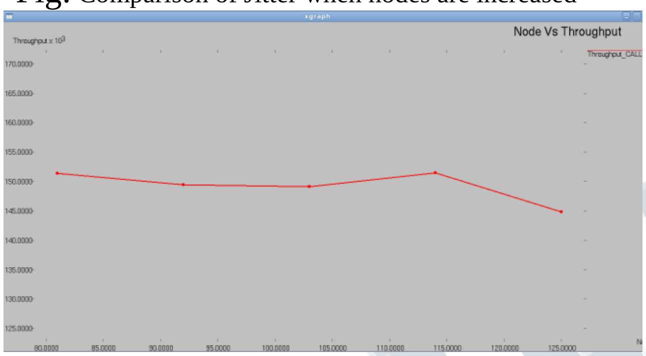

Fig: Comparison of Throughput when nodes are increased

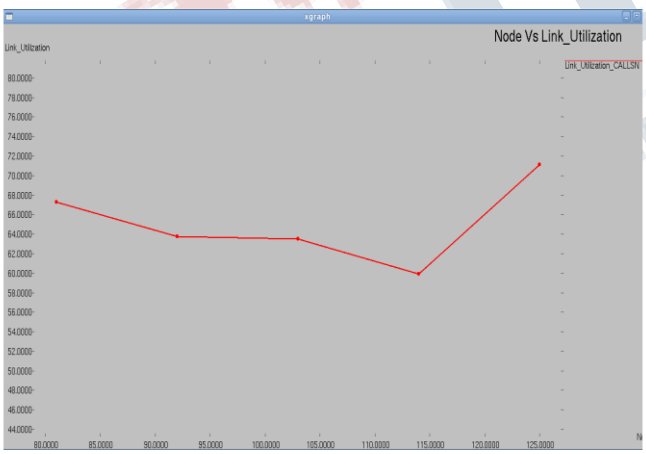

Fig: Comparison of Link-utilization when nodes are increased

CONCLUSION

In this paper We have studied the characteristics of the satellite links and thus proposed CALLSN algorithm for time-varying satellite channel. In CALLSN mobile agents called ants travel from one node to other and helps to find shortest path thus improving network performance. The network layer can make routing decisions based on link quality. Then, the optimization model was given. The model considered the minimum bandwidth constraint and the maximum delay the LEO satellite networks can tolerant as well as the error probability of the link. Thirdly, In order to make sure that data packets will choose the link on which the probability was strengthen, we are giving the update formula of the probability when data packets transmitted and discussed its key parameters. Finally, CAL-LSN can be compared with IACO and DQA. The simulation tool NS2 will be used. The performance of packet delivery, link utilization, the end-to-end delay of the network and delay jitter was compared respectively.

FUTURE SCOPE

We looked at CLD as a design principle involving state information sharing between two or more layers. This approach is bound by the strict layering found in traditional implementations, and needs to rely on extending the existing layered structure to maintain compatibility. Although different literature show many advantages with CLD, previous work has mostly focused on joint design of two or three layers only, such as the PHY, MAC and routing layers. It is however necessary to think CLD that involves cooperation and state information sharing between all layers. This brings us to the revolutionary approach. Here the CLD principles are applied to systems where strict layering or backwards compatibility is no longer necessary.

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