PERFORMANCE EVALUATION OF ROUTING ALGORITHM FOR LEO SATELLITE NETWORK

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ABSTRACT: *The development and worth of the internet during the past few years has led to demand for and internet services everywhere. Satellite Network could be an important component for the future internet due to its ability to provide a wide geographic coverage. Internet traffic is required to be efficiently routed through these satellites in order to protect the quality of services (QoS) over internet. To study the performance of Satellite Network with reference to a routing algorithm, we carried out simulation based experiments in ns-2. Ns-2 provides centralized routing algorithm for routing in the satellite network. Centralized routing algorithm of ns recomputes routes for every packet received at every node in the network. This paper attempts to make routing efficient by avoiding unnecessary recomputation of routes. As a result, the end to end delay for packet transmission reduces. We compare the simulation results of end to end delay of both original and modified routing algorithms. The difference in the delay reflects in the performance of transport layer protocols.*

KEYWORDS: NS-2(Network Simulation - 2), Quality of Services (QoS) routing, LEO satellite networks.

1. INTRODUCTION

Satellites have been used to provide telecommunication services since the mid-1960s. Since then, key developments in satellite payload technology, transmission techniques, antennas and launch capabilities have enabled a new generation of services to be made available to the public and private sectors. For example, satellite television is currently available in both digital and analogue formats, while global positioning system (GPS) navigation reception is now being incorporated into new car systems.

There are several reasons why satellites play a key role in the NGI [1]. Two-thirds of the world does not have the infrastructure for the Internet. Satellite services can be provided over wide geographical areas including urban, rural, remote, hilly and inaccessible areas. Satellite communication systems have very flexible bandwidth on-demand capabilities. Alternative channels can be provided for connections that have unpredictable bandwidth demands and traffic characteristics, which may result in maximum resource utilization. Satellites can act as a safety valve for NGI. Fiber failure or network congestion problems can be recovered easily by routing traffic through a satellite channel. Satellite Applications i.e. tele-education, telemedicine.

In fact, wireless satellite channels are usually characterized by link-asymmetry and higher Round Trip Time and Bit Error Rate in comparison to wired links. It means that TCP, which was developed for wired channels, exhibits often poor performance in a Satellite Network [1]. Satellites also play important roles in military, meteorology, global positioning systems (GPS), observation of environments, private data and communication services, and future development of new services and applications for immediate global coverage such as broadband network, and new generations of mobile networks and digital broadcast services worldwide [2].

Teledesic is a limited license company comprised of Motorola, Boeing, Microsoft, and several other companies and venture capitalists. Their goal is to build a global, broadband Internet-in-the-Sky ™ network [3], which is targeted to begin in 2004. Using satellite technology, Teledesic is creating the world's first network to provide worldwide access to telecommunications services such as multimedia applications, computer networking, and broadband Internet access. It has the capability to transmit data via fast packet switching protocols from any one point on the Earth to any other point, fully independent of any ground-based, cable infrastructure. The current constellation calls for 288 satellites orbiting in a Low Earth Orbit (LEO). The orbits are polar, meaning they travel over the poles of the Earth. The logical structure is similar to a mesh network topology. In this research we focus on LEO satellite networks constructed by Iridium and Teledesic satellite constellations. These networks provide high capacity and have low traffic congestion.

2. CHARACTERISTICS SPECIFIC TO LEO SATELLITE

The Teledesic architecture requires the analysis of several characteristics that have never been a factor in conventional routing algorithms. The first is making the bridge from logical to physical addresses. In today's Internet, all devices are assigned an IP address, which is a logical number. With the proper routing configurations, two devices can be located halfway across the world from each other, yet have logical numbers that are practically neighbors. Teledesic routers, on the other hand, only have connectivity to a certain physical location on the Earth at any one time; therefore, we propose the use of physical addresses. An address corresponding to latitude and longitude would meet this requirement. Each ground station must have one such physical address. If the fidelity of the address were carried out to the tenths of a second (degree: minute: second: tenths), the possibility of several ground stations in the same "address space" would be likely. A solution would be to assign an identifying network number to each station in that space. An advantage to this addressing scheme is that anyone could very easily determine their address without going through a controlling authority (InterNIC) to obtain their address.

Another factor, moving routers, adds significant difficulty to the routing problem. Since the constellation is a low earth orbit (LEO), the satellites are constantly moving in reference to a single location on the Earth. This means that the satellite used to route traffic at the beginning of a transmission may soon move out of range of either ground station. The routing algorithm chosen must handle the possibility that gateway routers will change any number of times during a communication session. Fortunately, the physics to calculate the location of celestial objects based on time is quick, easy and widely available. The challenge is to handle the changes within a communication without having to reset the session every time a satellite moves out of ground station range.

3. IMPLEMENTATION ISSUES

The routing algorithm solution must meet the criteria listed below:

a. Find an optimal path from sender to receiver: This is true for every routing algorithm, today or in the future. However, the new algorithm must do this using a physical address instead of a logical address.

b. Allow a ground station to choose the optimal gateway satellite to begin transmission: This requirement can be met in a way similar to the methods cellular phones choose a cell tower while moving. The ground station would measure the signal strength of whichever Teledesic satellites were within visible azimuth and pick the strongest signal. A more advanced algorithm would calculate which satellite would remain usable for the longest amount of time.

c. Allow the receivers gateway satellite to be chosen at time of transmission: This case is a little harder to solve than the above case due to the "roaming" network. Orbital characteristics are static and do not change; therefore, they can be programmed into each computer. By using the above information, a gateway for the receiver can be located quickly. To save time, the gateways chosen upon initialization of transmission should be computed only when needed instead of every time a packet is sent.

d. Re-compute either a receiver or sender gateway dynamically: When a gateway satellite moves out of range of an end ground station, the communication path must remain persistent. In other words, the communications must not be interrupted when a gateway signal is lost.

4. MODIFIED ROUTING ALGORITHM

Each node re-computes the routes whenever packet comes to the node. So it requires the time for route computation, ultimately increases the end-to-end delay for the packet. Hence this chapter describes the modified routing algorithm for satellite network that reduces the time required for route computation and finally end-to-end delay for the packet.

Whenever satellite node receives the packet, first it calculates the network topology, and then creates the routing/lookup table. After that it generates the slot table for find-out the next hop for the current destination satellite node. Hence, when any intermediate node receives the packet, first repeats the above procedure. Instead of repeating whole above procedure, the modification creates only the slot table because the cause of change in the topology is handoff. If handoff is not occurred so it does not require computing topology again and again. Hence, the computation of topology at each and every time is avoided as well as generation of lookup table if there is no event of handoff. As we discussed previously, slot table is actual table which is helpful for finding the next hop. It is maintained by each node individually. Hence, generation of slot table is compulsory.

a. Code Implementation

Implementation of modified code required in function which finds the next hop and forwards the packet to that hop since node requires more time for finding the route towards the destination in original routing algorithm. Hence in modification we try to reduce this computation time.

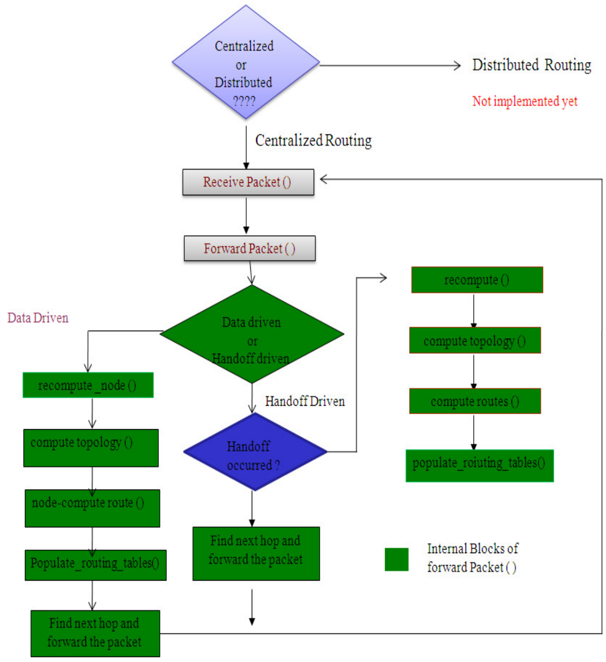
In modified routing algorithm, we compute the routes for first packet only. The rest of all packets follow the same path until handoff is occurred. Whenever the packet reaches to the intermediate node, that node used same code tree and lookup table which is generated previously by the source node because those information is shared by all the satellite nodes. From that lookup table it generates the slot table and from slot table it finds the next hop for the destination.

```
// when first packet comes to forward
if (firstpkt_recv )
{
// check topology, make populating table and
 node compute-route
re-computation ();
// increments the counter. Initially count = 0;
count++;
}
// When handoff is occurred, count is reset to zero
 if (! count)
{
  if (check_handoff_peer () )
   {
   re-computation ();
   count++;
   }
  }
// create lookup table and slot table
 if (!slot) create_slot ();
// find-out the next-hop from lookup table
 find_nexthop ();
forward_pkt_to_nexthop ();
 // forward the packet
```

Hence in modification, we first check that the first packet is received for a particular destination by routing layer of source node or not. If it is, it follows the complete procedure to find the next hop for that destination. We use one variable *count* which performs the two tasks. First, if its value is zero means that first packet is arrived so node has to calculate the complete route after that its value is incremented by one. Second, when handoff is occurred, it is again reset to zero means we need to compute the route again and after recalculation of route it is again incremented by one. Next we check the value of *slot* variable, if it is zero means slot table of node is empty so it has to generate it from lookup table. After that, it finds next hop from slot table. This task is common for all nodes either it is source node or intermediate router.

b. Routing Algorithm for LEO Satellite Constellation in NS-2

Centralized routing algorithm is one of the most popular algorithms which are used for satellite constellation. So in this section we discuss the centralized routing for satellite constellation in *ns-2*. In centralized routing, route computation is performed centrally and this information is provided to each and every satellite node. Whenever any node receives the packet, there are three possibilities. One is node sender node, if it is sender so it finds the next appropriate nodes towards the destination. Second node is destination node, packets is simply received by destination node. When node is intermediate node, it has to first find out next hop towards the destination and forwards the packet to that next appropriate node. In Satellite networks, for forwarding the packet to the appropriate next hop following algorithm is used. Figure 1 shows the centralized routing algorithm.



This algorithm is operated in two modes. One is Handoff driven routing and second is data-driven.

- **Handoff -Driven**

With handoff-driven computations, routes are computed for an all-pairs irrespective their needs. For route computation it uses the shortest path algorithm. Hence, the mode of centralized routing algorithm will produce a very slow runtime because it executes an all-pair shortest path algorithm upon each topology change even if there is no data currently being sent.

- **Data-Driven**

With data-driven computations, routes are computed only when there is a packet to send, and furthermore, a single-source shortest-path algorithm (only for the node with a packet to send) is executed. So it will faster compare to handoff driven mode. Both modes follow the same procedure to find the appropriate route towards the destination. In handoff driven, first it computes the network topology, creates the routing table and then routes are calculated using the shortest path routing algorithms. In data-driven routing, when packet comes at that time it checks the network topology, creates the routing table and find the routes using shortest path algorithm. In Handoff-driven, when handoff is occurred network topology is changes and recalculated. Hence, new routes are re-calculated.

- **Compute Topology:**

In this step, it first checks the connectivity between the nodes. Then it calculates the delay of each and every possible link and that delay is used for finding the appropriates route for a particular destination.

- **Routing Table Generation:**

Each source node creates first route tree from topology information which is generated in previous step. Then it builds up the lookup table for all possible destinations from generated route tree. Lookup Table contains information like source address, next hop and cost. Lookup table is shared by all nodes.

The next step is generation of slot table. It is the actual table that is used for finding the appropriate route. Slot Table contains the information about next hop for all possible destinations. Slot table is maintained by each node.

5. CONCLUSION

The performance of routing for (LEO) satellite network depends on the different satellite parameters. Delay is the most important parameter of the routing in satellite. Efficient routing is only obtained, when satellite network parameters such as delay, elevation mask, inclination are minimized for iridium and teledisc satellite constellation. Inter-satellite links delay for each node is measured. ISLs delay in iridium is observed higher than teledisc constellation because number of satellite nodes. As ISL delay increases the end-to-end delay also increases. End to end delay variation is more in iridium than the teledisc constellation.

We compare the simulation results of original and modified routing algorithm for end to end delay, average end to end delay and throughput in both iridium and teledisc. In iridium constellation, there is more variation on the end to end delay as compared to teledisc constellation. Iridium has more difference in the average end to end delay for different user terminal of the ground than teledisc because in teledisc more handoffs occurred. We also measured the throughput performance of original and modified routing algorithm. Throughput with modified routing algorithm is almost same as original, when handoff occurs.

TABLE I.

Average ISLs Delay for Iridium and Teledisc Constellations

ISL Delay (Iridium) ms	ISL Delay (Teledisc) ms
13.45	6.75

TABLE II.

Constellation Parameters for the Iridium and Teledisc System

Constellation Parameters	Iridium	Teledisc
Altitude	780km	1375 km
Number of plane	6	12
Number of satellite per plane	11	24
Orbital period	6026.9 sec	6794 sec
ISL bandwidth	155Mbps	25Mbps
Uplink\Downlink	1.5Mbps	1.5Mbps
Inclination (deg)	86.4	84.7
Intersatellite separation (deg)	360/11 = 32.72 deg	360/24 = 15 deg
Interplane separation (deg)	31.6 deg	15 deg
Cross-seam ISLs	No	Yes
ISL latitude threshold (deg)	60	60
Elevation mask (deg)	8.2	40

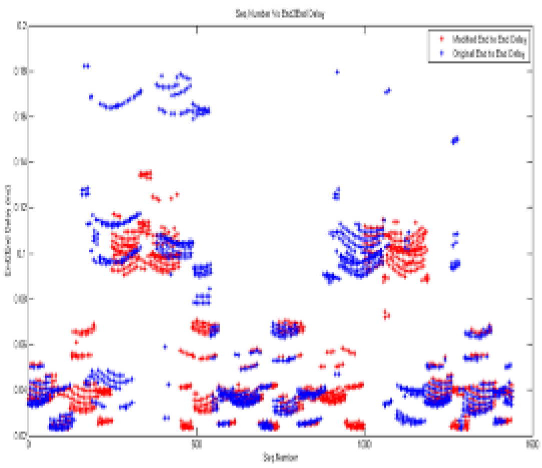


Fig.1 End-to-End Delay Comparision (Iridium)

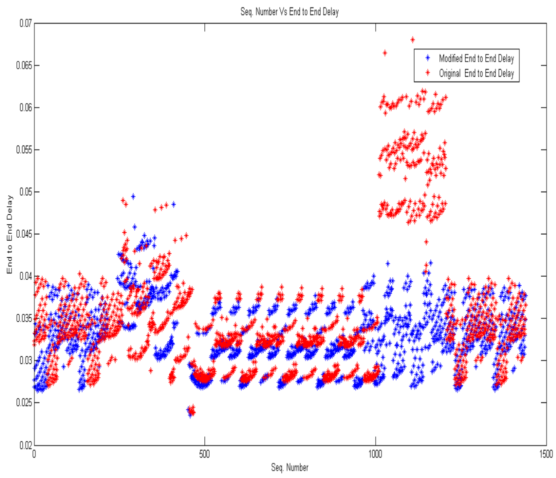


Fig.2 End-to-End Delay Comparision (Teledisc)

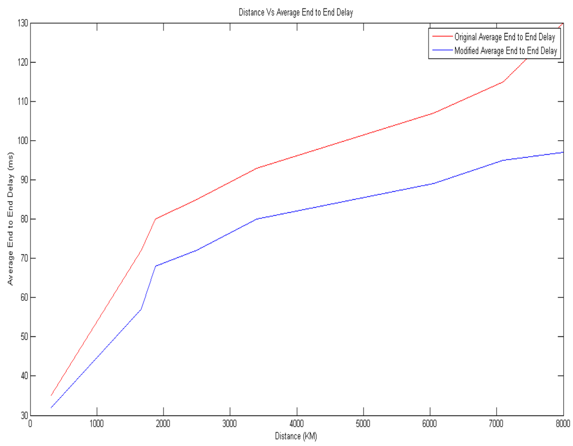


Fig.3 Distance v/s End-to-End Delay (Iridium)

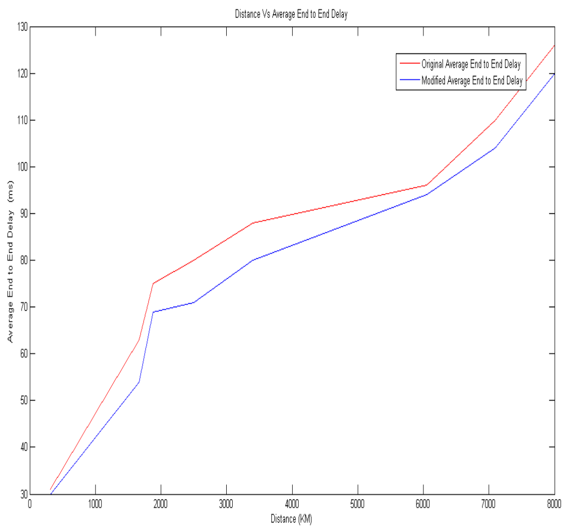


Fig.4 Distance v/s End-to-End Delay (Teledisc)

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