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Survey on Routing Algorithms for LEO Constellations Network

Eman Adel Elbehiry[1,2], Heba A.TagElDien[1,3] , Ahmed Fares[4,1] , Basem M.ElHalawany[1,5*]

[1] Electrical engineering department, faculty of engineering at shoubra, Benha university, Cairo, Egypt,
[2]Giza Higher Institute for Engineering and Technology, Giza, Egypt.
[3]Communication Systems Engineering Department, Benha National University, ElObour city Egypt.
[4]Faculty of Engineering, the School of Electronics, Communication and Computer Engineering (ECCE), the Department of Computer Science and Engineering, The Egypt-Japan University for Science and Technology (E-JUST), New Borg El-Arab City, Egypt.
[5]Electronics and Communication Engineering Department, Kuwait College of Science and Technology, Doha District, Kuwait.

*Corresponding author: Basem M.ElHalawany[1] (basem.mamdoh@feng.bu.edu.eg).

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Abstract

The fast growth of communication technology has resulted from the desire for information globalization. Satellite communication systems, which have the benefits of extensive coverage and minimal requirements on the geographical environment as compared to terrestrial communication systems, are progressively becoming the principal competitive arena of next-generation communication. The low-orbit (LEO) communication satellite has a high data transmission rate, a short communication latency, and a near proximity to the earth. The conventional geostationary orbit communication market has worsened as a result of the fast expansion of terrestrial communication technology and Internet technology, and the development of low-orbit satellite communication has become a general trend. Satellites with the same tasks are getting smaller and smaller, and the cost is getting lower and cheaper, thanks to the rapid growth of the integrated circuit industry. Furthermore, the new technology represented by the reusable rocket can cut the cost of launching a LEO satellite even further, making the development of a LEO communication satellite network more affordable and viable. In comparison to the terrestrial communication network, the LEO satellite network can provide communication services that span the whole globe and can support communication in distant places, mountainous areas, and maritime areas at a reduced cost. At the same time, the LEO satellite network differs significantly from the terrestrial network in several ways. This research is a survey paper that focuses on routing protocols algorithms for LEO constellations networks, to the best of our knowledge.

Keywords

LEO, ISL, routing algorithm, satellite constellation

1. Introduction

One of the essential technologies for future communications is the satellite network. Traditional geostationary orbit (GEO) satellite systems, on the other hand, suffer from severe delay and high launch costs. As a result, low-earth orbit (LEO) satellites have emerged as a viable alternative to GEO satellites' inherent flaws. The inter-satellite connection (ISL) has been created to deliver increased system performance and more dependable service in tandem with the advancement of LEO technologies. Furthermore, because of its high data rate and compact terminal size, the optical ISL has been highlighted. Varied constellation designs will result in quite different satellite connection situations and topologies. The most basic need in terms of constellation design is to attain global coverage. There are two traditional topologies for regular constellations at the same altitude: the Walker star or polar [1,2], and the Walker or Rosette [3,4]. The Walker Delta constellation, which uses inclined orbits, and the Walker Star constellation, which uses polar orbits, are the two principal LEO satellite constellations. In this study, four areas of security technologies in contemporary satellite networks are evaluated based on the function features of satellite networks. Furthermore, we examine vulnerabilities to satellite networks based on routing processes and discover safe routing methods. We also compare and contrast the results, as well as outline future research areas and difficulties concentrating on secure routing issues based on many routing protocols. In a Walker Delta constellation, a group of co-rotating satellites that move in the same direction is called a "mesh". This type of SatCon has two meshes that cross each other in opposite directions (i.e., Ascending: from southwest to northeast, and Descending: from northwest to southeast). Consequently, an inter-mesh link denotes an ISL between two satellites in two different meshes, while an inter-plane ISL refers to an ISL between two satellites in adjacent orbits that lie in the same mesh. Due to the high relative speeds, inter-mesh links usually are not used. To reach one mesh from the other, traffic must travel over the highest latitudes using Intra-plane ISLs [4], which increases the communication's end-to-end delay. Even if inter-mesh links are established, they will be intermittent and lead to frequent topology change if not carefully designed, resulting in significant routing overhead and instability. This motivates a reliable and fast inter-mesh link design to support routing in LEO SatCon Networks. To the best of the authors' knowledge, there is a gap in the literature regarding the LEO SatCon routing techniques in general and specially exploiting inter-mesh linkages.

2. Methodologies

Satellite constellation networks in low earth orbit (LEO) have resurfaced in recent years as a result of their capacity to deliver ubiquitous broadband communication [5]. LEO satellite constellations are divided into Walker star and Walker delta constellations based on their orbit inclination. Many modern commercial constellations, like as Starlink and Kuiper, have chosen Walker-delta constellations because they give superior coverage in mid-latitudes, where the majority of the human population resides [6]. Existing LEO satellite constellations have either deployed or are proposing to install intersatellite connections (ISLs). ISLs can help the system become more self-sufficient and less reliant on terrestrial infrastructure. In addition, ISLs can assist improve system throughput and delay performance [7]. The LEO attitude is shown in the next figure.

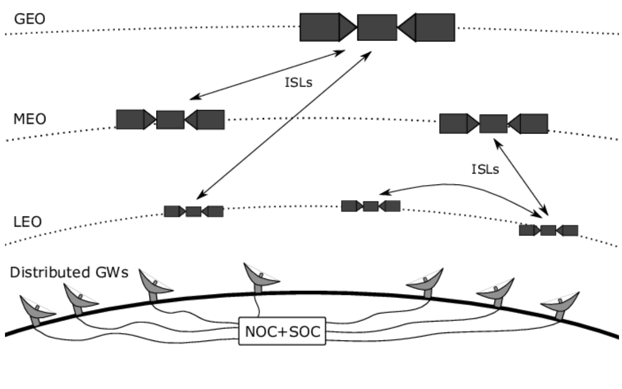

Figure 1: difference between LEO, MEO, GEO

In this paper [5], we investigate the prospect of striking a balance between overcoming the challenge of creating inter-mesh linkages in Walker delta constellations and enjoying the benefits of doing so. A technique for scheduling inter-mesh links is suggested that takes into account several limitations such as link distance, rotational velocity, link setup time, and link switching frequency. Simulations on the Starlink constellation demonstrate that with moderate system complexity, average end-to-end latency may be greatly reduced. Suddenly, For Walker delta constellations, we suggested an inter-mesh link scheduling mechanism. We showed how inter-mesh networks may dramatically reduce end-to-end delay while maintaining acceptable system overhead in terms of antenna required and topology update frequency. In future constellation networks, we expect that our technique will serve as a starting point for more complicated ISL pattern construction. Another project underway is the development of routing algorithms for the planned ISL pattern, with the goal of lowering storage overhead and jitter between snapshots.

Analysis of Inter-Satellite Link Paths for LEO Mega-Constellation Networks [9] is another study. The following is a list of the work's contributions: For MCNs, an explicit technique for estimating the ISL hop-count between any ground users is presented, providing a theoretical approach to hop-count analysis and routing design. The algorithm's correctness is confirmed by comparisons with simulation results. Based on the suggested approach, several connections and symmetries between hop-count and user pair placement are obtained. The theoretical study shows that the hop-count in a given constellation is governed solely by the users' latitudes and the absolute value of their longitude difference, but not by their relative orientation. The hop-count distribution properties of Star-link are explored, as well as the influence of constellation parameters on them. We show that by adjusting the phasing factor, the total average hop-count in Star-link may be efficiently reduced. Similar findings may be obtained in the regional example of the United States and Europe. When users switch to a neighboring access satellite, significant differences in hop-count and routing can be discovered. The hop-count discrepancy in Starlink can be up to 45 hops.

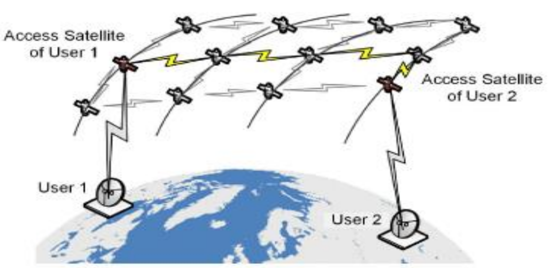

Figure 2: A multi-hop path connecting two ground users in MCNs [9].

Finally, The ISL hop-count is investigated in this work in relation to Walker Delta mega-constellations. The purpose is to use ISL relay analysis to get insight into the topology and routing architecture of MCNs. A simple and fast hop-count estimate method is given, which avoids the need for sophisticated and expensive simulations. The hop-symmetry counts and certain explicable features are then derived. It is discovered that the hop-count value in a particular constellation is solely defined by the users' latitudes and the absolute values of their longitude difference. Comparisons with high-resolution MCN simulations are used to validate the suggested technique. The ISL hop-count has been explored in various settings using our suggested technique and derived attributes.

When users swap access satellites, we saw a considerable change in hop counts. Furthermore, we discovered that the hop-count has a geographical distribution that is dependent not only on the spherical distance between users, but also on their latitudes. On ISL relays, the effects of constellation settings have also been investigated. The findings demonstrate that adjusting a phase factor is a potential method for lowering hop-count values without sacrificing other performance parameters. In specific US-to-Europe user scenarios, similar consequences have been discovered. Phase II's Star-link constellation will be far bigger than phase I's [10]. Although this research focuses on a single Star-link constellation layer, our suggested hop-count analysis method may be used to each layer of the future multiple-layer Star-link constellation. Based on this research, we want to do a follow-up study on the influence on routing design, in which not only hop count but also other factors such as route stability will be examined. A routing strategy that selects the route mode with the longest sustainable duration and the fewest hops will be an attractive field for further research. The research of latency for MCNs with routing in the sky will be addressed in this regard.

3. Routing algorithms:

Many satellites have recently been deployed to provide individual users with global internet broadband connectivity. As satellite networks become more widely used, security concerns become more prominent, particularly with regard to the satellite network routing protocol, which ensures the regular forwarding of network data. When the routing protocol is attacked, routing discovery and maintenance are not completed, resulting in communication disruption and data leakage.

3.1. Routing Geographically Asymmetric

The Asymmetric Geographical Routing (AGR) algorithm is a location-based algorithm extension [11]. The satellite uses location-based algorithms to identify the next hop depending on its position and the location of the destination terminal [12]. The method ignores satellite overlap and handover transitions, both of which might cause the final hop to be misrouted. Recent study suggests that each satellite will offer a list of terminals attached to it to its neighbors to overcome these issues. As a result of this need, the size of the satellite payload memory has been considerably expanded. AGR offers low-complexity access routing by assigning each terminal to a single GW. In the future load balancing method, the terminal might be allocated to different/multiple GWs. The assignment was created to help with routing and service planning. Current wire-line and satellite routing solutions use a static and symmetric addressing mechanism for endpoints. Asymmetric and partially dynamic addressing is used by AGR. The GW address is fixed and defined by the location of the GW.
The terminal address is made up of both static (unique ID) and dynamic components. The dynamic component contains the satellite ID and user beam number for which the terminal is logged on. Packets are transported from the terminal to the GW via geographic routing. Because the number of GWs is far fewer than the number of terminals, the last node's access routing may be handled via local routing, as described in [2], but at a significantly lower cost. Once a packet from the terminal has been received, packets from the GW to the terminal can be sent. This should not be an issue because most sessions are started through the terminal (client-server model). Once a packet is received from a terminal, the GW will record it and keep track of each terminal's satellite ID and user beam. Packets delivered from the GW to the terminal can be routed using any of the virtual node strategies. To account for handovers, AGR augments previous approaches by resolving the destination satellite ID and the beam ID (not handled by current work). Additionally, AGR is automatically updated to aid terminal handover between satellites. When the terminal connects to a rising satellite, it will change its source address.

3.2. Seam-Aware Geographical Routing

The parts that follow outline the problem of seam disconnection, model the impact of the seam on latency and routing, and compute the impact cycle as a function of the two end points' locations. Finally, a unique method for shortest path geographical routing is demonstrated using a pseudo code of the whole SAGRW routing algorithm. SAGRW calculates the seam location and maps the satellite and destination locations for each received packet. SAGRW employs the mapped coordinates of the destination and satellites to execute location-based routing, in which each satellite transmits traffic to the next satellite, minimizing the distance to the destination. In each phase, the algorithm moves horizontally or vertically toward the destination. In each phase, the algorithm moves horizontally or vertically toward the destination. The algorithm creates a lattice of shortest paths between the transmitter and the receiving. Load-based normal distribution random walks are used to improve the load distribution on the lattice.
Advantages of AGR include the ability to resolve the destination satellite ID and the beam ID to account for handovers, which complements previous approaches (not handled by current work). In order to facilitate terminal transfer between satellites, AGR is automatically updated. When the terminal connects to a rising satellite, it will change its source address. AGR handles access (satellite to terminal) routing, handover, and satellite identification, which are not addressed by conventional virtual node and location-based routing algorithms. It also simplifies geographical access routing and eliminates the need for end customers to declare their location.

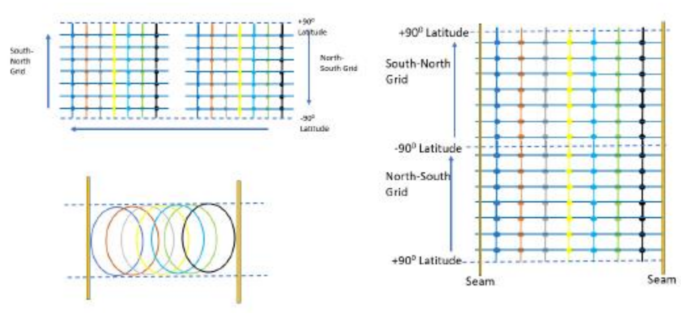

Figure 3: seam modeling [11]

SAGRW and AGR, which provide a unique constellation routing strategy in LEO, are discussed. These protocols don't rely on precise timing techniques and instead employ low-complexity algorithms to transport data from one terminal to another (or a GW) (which are implicitly necessary in current virtual node and virtual topology research). Both approaches allow access routing, simplify handover, reduce last hop routing complexity, and eliminate privacy issues [11], [13]. SAGRW uses random walk to generate a geographical shortest path lattice and disperse the load on it. While keeping the terminal location concealed, it handles handovers, seam disconnections, and any-to-any routing.

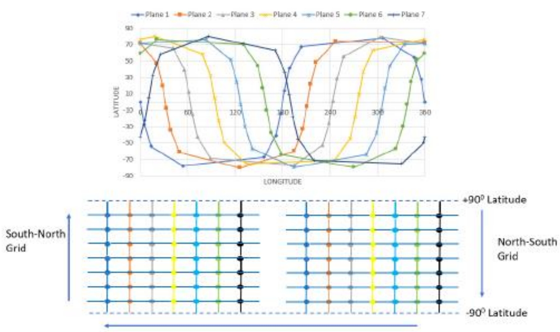

Figure 4: LEO Constellation Seam Satellite Grids [11].

3.3. The SCSA Algorithm

The Function of Super Satellites is Proposed [14] the super satellite is distinct from conventional satellites in that it may store or fuse information that has to be conveyed, as well as combine the wavelength requirements of the edge with it as the vertex. As a result, super satellites may be able to play a larger role in satellite communication. It's the foundation for calculating the satellite node's important coefficient.

The following are the features of super satellites:

I) the super satellites can filter and determine the information sent to the same destination node and combine it, reducing the use of wavelength;

ii) The super satellites can filter and determine the information sent to the same destination node and merge it, reducing the use of wavelength.

iii) Information already stored in the super satellite can be delivered immediately to the target satellite, eliminating the need to collect information from the source satellite and thereby reducing communication costs.

The SCSA algorithm's first three phases have been accomplished. The steps for determining the ISL topology of a satellite optical network, finding the matching optical path and calculating its cost, and ultimately assigning wavelengths are described below.

1) Define the ISL Topology of the Satellite Optical Network: This paper defines a parameter to describe the active state of a node in the satellite optical network link topology, which is the percentage of active laser link terminals in the network link topology, which can also reflect the physical connection state. This study also defines the satellite node pair connectivity metric in order to better understand the network's connection and blocking rate.

2) Determine the cost of an optical path and the rules for assigning wavelengths: This study addresses the data storage and computation capabilities of super satellites in depth, based on the RWA technique in [15], and presents the particular changes to the algorithm flow as follows: The super satellite we propose can only function as the beginning point satellite S of the light path or the end point satellite ID of the light path in the process of constructing an ideal light path set and a sub-optimal light path set. Because the super satellite can store, calculate, and re-forward data, communication via it necessitates the re-establishment of the optical route for relaying.

This paper considers an optical satellite network of super satellite nodes, in which we developed a mathematical model for the NeLS and SpacePro constellations, predicted and analyzed network topology and ISL characteristics over time, and proposed the SCSA algorithm to solve the inter-satellite RWA problem. For all-optical routing in the satellite network, we calculated the number of wavelengths necessary for complete interconnectivity without wavelength conversions. In comparison to [15], simulation results reveal that the SCSA method can save up to 50% in wavelength needs. SpacePro can save the number of super satellites to obtain a better result than NeLS, lowering the OBPs cost of the system. However, there is a trade-off between satellite optical network node connection and wavelength demand. Under the same limitation, the SpacePro constellation proposed in this article may save a certain amount of wavelength, and the choice of super satellites can save the maximum wavelength need without surrendering. Walker-SpacePro Star's constellation, as seen above, is excellent for constructing satellite optical networks. Super satellite capacity is connected to job complexity, and it is a vital stage in the later deployment of multi-satellite cooperative networking. The study presented in this paper aims to reduce the cost of on-board lasers, their related modulators, and the cost of creating ISLs for future inter-satellite optical/laser communication. It has significant reference relevance for the big satellite constellation network operator from this standpoint.

3.4. The Media Access Control (MAC) protocol, in conjunction with the routing protocol, uses the Time Division Multiple Access (TDMA)

Micro-satellites have bright prospects in the fields of commerce, navigation, communication, detection, and military because of their small size, low cost, short development cycle, strong flexibility, and survivability [16]. Another research with LEO Micro-Satellite Network Routing Protocol based on virtual topology with the development of informatization and the increasement of various demands, micro-satellites have bright prospects in the fields of commerce, navigation, communication, detection, and military because of their small size, low cost Microsatellites, which usually function in constellations or networks, may coordinate and share network resources, giving satellite networks a high degree of flexibility and reach, as well as being free of environmental restrictions and simple to set up. As a result, microsatellite networks have emerged as the primary way of obtaining and processing geographical data resources [17,18]. The low-orbit satellite network is expected to become a research trend in the future communication domain [19]. However, due to the high-speed movement of satellites, inter-satellite linkages are continually altering. The constellation network topology changes relatively often in comparison to the ground static network. Furthermore, because unexpected link and node failures are more common in space, inter-satellite networks require frequent link switching and a certain degree of convergence [20]. Because the performance of the satellite routing algorithm has such a direct impact on the whole communication system's capabilities, it's critical to create a routing algorithm tailored to a certain low-orbit constellation network [21]. Traditional satellite routing favors static routing, which takes use of the satellite network's regularity [22], is simple and efficient, but requires a lot of storage, and has a poor reaction to node changes and connection outages. By acquiring the routing table through its own computations, the dynamic routing method eliminates the need to save a huge quantity of topological connection data in advance [23,24]. At the same time, it is better at dealing with connection changes, but the downside is that it consumes some processing resources and adds to the cost of sending data.

The following things must be considered while creating an acceptable and successful routing algorithm based on the properties of the above unique Walker constellation:

(1) Because the constellation's topology evolves over time, the routing algorithm must adapt to the changing topology.

(2) The inter-satellite connectivity circumstances are difficult. To guarantee efficacy, inter satellites should be able to get the most recent link information and then compute the best path for data forwarding; (

3) The routing algorithm should be convergent and capable of reacting to crises, such as link failure or satellite posture changes.

THE DESIGN OF A SATELLITE ROUTING PROTOCOL FOR LOW EARTH ORBIT

Because the micro-nano satellite constellation network explored in this research is meant to be dependable and low latency, and because micro nano satellites have limited resources, a virtual topology-based routing strategy was chosen.

On the one hand, a routing scheme based on virtual topology will pre-store the required topology table and routing table on the satellite, eliminating the need to calculate the routing path during data transmission, saving computing resources on the satellite and ensuring lower cost and time delay; on the other hand, the network cycle is relatively short, and the topology change is relatively small, Simultaneously, in order to simplify control of the whole operation process of the low-orbit constellation, the Media Access Control (MAC) protocol, in conjunction with the routing protocol, uses the Time Division Multiple Access (TDMA) approach to enhance network operation.

THE Publication Views, it can develop a typical satellite constellation configuration model in STK based on the low-orbit remote sensing Walker constellation design and study the changes of same and different orbit connections. Then we propose and refine a virtual topology-based satellite routing technique that can automatically update in response to topology changes. It works for satellites in the same orbit as well as satellites in separate orbits. The protocol is modelled using OPNET software, and we may collect associated indicators such as network node latency and average network performance at various coding rates. The routing scheme's rationale and practicality are confirmed by the simulation results.

3.5. Demand Island Split Routing

Advanced Routing Algorithms for Low Orbit Satellite Constellations is the subject of yet another research. Broadcast services with wide coverage and high aggregated throughput are provided by telecom broadband satellites [23]. The majority of today's broadband satellites are GEO satellites, which orbit the earth at a height of 36,000 kilometres. Low Orbit (LEO) constellations attempt to provide the same advantages as GEO satellites while reducing satellite-to-ground delay. Several LEO constellations are being developed and planned as of 2018. SpaceX, OneWeb, LeoSat, Telesat, and others are among them. Inter-Satellite Links (ISL) communication during the first or second phase, as well as on-board processing capabilities, are included in several of these constellations. The LEO constellations form a network that includes satellites connected via ISLs (as routing nodes) and satellite terminals that dynamically connect to one or more satellites. The terminals are forced to switch beams and/or satellites due to satellite grid movements vs. the earth and ground nodes (terminals). The transition of beams and satellites (also known as handover) necessitates a change in the satellites' routing information. Depending on the geographical distribution of the terminals, the rate of change might be extremely high, while the delay to propagate these changes to all satellites is on the order of 100 mSecs. These changes are frequent (a LEO terminal may switch satellites every few minutes) and can result in high-rate transients (for densely populated service areas). The combination of rapid high-rate fluctuations and high latency poses a unique problem when it comes to building a routing system that can handle frequent changes without packet failures. Another unique difficulty is service design to ensure CIR (Committed Information Rate) and latency.

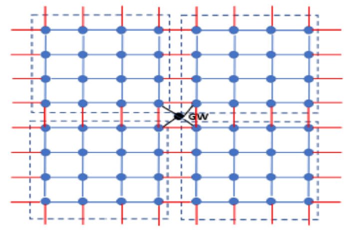

Figure 5. Demand Island Autonomous Architecture [23].

A demand flow is characterized by two end points and a bandwidth. The way the traffic is routed on the satellite grid will alter if one of the end points is handed over. The bandwidth mapped on the ISLs changes when the flow is rerouted on the grid, which may have an influence on how the bandwidth is allotted for the service and the service latency. Terminals may be linked to numerous satellites in some constellations (each satellite link may have different capabilities that change dynamically). In this situation, the routing method should allow the terminal to make dynamic load balancing decisions while preserving the SLA for all terminals. This paper tackles the challenge of routing traffic from a source terminal to a destination terminal (linked to many satellites) while ensuring and enabling service metrics/quality of service planning (bandwidth and latency). Current methods are computationally intensive and do not take into account factors like access routing and service planning. A new LEO architecture and routing algorithm are presented (Demand Island Split Routing).

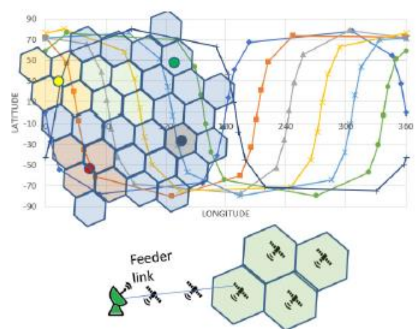

Figure 6: Demand Island with 4 Satellites in the GW FoV [23].

-Virtual topology routing models
the network's dynamic nature as a collection of static fixed configurations or snapshots, the satellite topology, terminals, and Gate Ways (GWs) connections are all fixed in each snapshot. Routing or circuit planning can be done for each

snapshot utilizing older networking methods. The algorithm determines the time window for each photo. One method is to set the time frame duration for each photo to be short enough that the topology inside it does not change. Virtual topology routing has several flaws: terminals may only be supplied by a single satellite, dynamic real-time functionalities such as QoS, and connection failure events are not handled. Computation and capacity planning for each snapshot are required for approving new service demand needs and ensuring latency and BW requirements for each new service that will be maintained during the service's lifecycle. The constellation of satellites is replaced by a virtual constellation with set placements for the virtual satellites in the virtual node technique. Each real satellite is allocated to a virtual satellite at any given time. The coupling varies when the satellite constellation moves, depending on the identification of the satellite nearest to the virtual location. A routing database exists on each virtual satellite that shows the next hop for each destination satellite. When a physical satellite is allocated to a virtual node, it will use the virtual node routing table until the constellation moves it to a different virtual node. The destination satellite identity is identified based on the target terminal address, but the virtual node algorithms do not explain how this is done. Capacity and service planning are not supported by the virtual node concept. The distances between the destination terminals and the current satellite for each next hop satellite are calculated using location-based algorithms, which use the terminals' geographical position as an extra characteristic. Each routing step aims to reduce the physical distance between the starting point and the final terminal. Current location-based methods do not consider how the packet will be routed to the correct user beam by the final satellite on the way. Because the traffic mapping on top of the grid is dynamic, location-based routing does not allow for traffic load balancing (all traffic to a particular geographical place would travel on the same path) or service planning. Another problem may be privacy, since many clients (and even laws) may prohibit sharing the specific geographical position of the terminal (customer).

-Demand Island Split Routing Algorithm (DSR algorithm)

The sub-grid has certain qualities that make demand and route planning easier:

• All ISLs have the same capacity C. (or edges).

• The total capacity that may be processed for each sub-grid matches the number of satellites linked to the GW in that sub-grid. • The number of edges (or latency) on a path between a node and a GW is the same for all potential pathways between the node and the GW. Because each sub-grid is connected to the GW through two ISLs in the instance of GW4, the total capacity that may be routed and processed is 2 C. The following definitions apply to Demand Split Routing (DSR):

• The node's total demand is the sum of traffic received via satellite user beams (i.e. its FoV hexagon) and traffic received on its ISL.

• The access network terminals divide the demand for each node into vertical and horizontal dimensions.

• We treat terminals with multiple satellite connections as numerous sub-terminals (one per satellite), and the terminal can dynamically distribute its assigned demand across its sub-terminals (terminals and sub-terminals are referred to as terminals)

• The overall demand, both vertically and horizontally, must not exceed C.

• The satellite receives demand (IP packets) from terminals or ISLs and passes the packets vertically or horizontally depending on the kind of demand.

Review of The Demand Island paradigm allows traffic to be routed from a terminal to a GW using a low-complexity algorithm that achieves the same utilization as Virtual Topology routing (using multi path circuits). The hexagon-based DSR method allows for a dynamic demand split across terminals (and sub-terminals) without affecting overall throughput. This enables terminals to balance their allotted demand among their serving satellites based on connection circumstances without having to re-plan or re-allocate the service circuit. The Demand Island strategy is the first to provide tight service (CIR and latency) planning for terminals connected to many satellites, and it can simply be modified to accommodate beam hopping. The self-contained one-to-many Demand Island combines the advantages of GEO satellite design with the reduced latency of LEO satellites. Demand Island provides one-to-one service redundancy.

3.6. GomHop Algorithm

GomHop is a connectionless LEO satellite constellation routing solution that does not require routing databases. It's ideal for dense MC, because any pair of satellites generally has many pathways to connect them. The routing decisions are made per-packet, which means that each satellite analyses each incoming packet separately. Even though the constellation is moving, it is moving at a far slower rate than the network layer's time scale [25]. We follow the standard strategy in related research, which is to use fixed length time intervals with a static topology. The GSL is not mentioned in the explanation for clarity's sake, although it is an integral aspect of the routing process. In the paper's formulation, the end destination d is a spacecraft, but in fact, it might be either a space segment satellite or a ground station/user terminal. There will be a last leg to download the packet to the ground, as well as a mapping procedure to find satellite(s) with ground coverage, i.e., presently covering the region where the ground terminal is located [26]. The approach presupposes that each satellite has geometry awareness, or knowledge of the network's topology, geometry, and dynamics, and hence the set of possible links at any given time instant. This is not a strong assumption: other spacecraft subsystems, such as the Attitude and Determination and Control (ADCS) subsystem, rely on geometry awareness to point to nearby satellites or ground stations at a particular moment, even in tiny satellites with low processing capability. As a result, the ground station is not required to send this information. When certain connections (or whole nodes) fail, the network (which is launched by the ground station) is believed to broadcast the information to the rest of the constellation's nodes, avoiding the use of non-functional links. It's worth noting that, unlike Dijkstra's shortest path method, GomHop's complexity is not proportional to N. Instead, it is affected by the geometry, link budget, and RF characteristics, as well as the maximum number of accessible satellites, which is substantially smaller than N as shown on next figure.

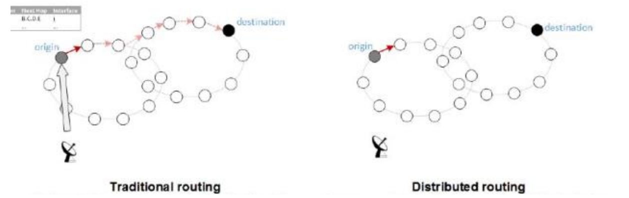

Figure. 6: comparison between traditional and distributed routing [25]

The suggested GomHop algorithm's key benefit is its simplicity, which makes it suited for use in tiny satellites in dense constellations. There's no requirement for the ground segment to store and disseminate updated routing tables, and there's no need for spacecrafts to communicate periodic control information. The idea is to determine the optimum next-hop from a list of available links autonomously, with the goal of getting closer to the end destination while reducing the number of inter-plane hops. Despite its simplicity, simulation results reveal that GomHop performs extremely close to the best solution, which uses Dijkstra to find the shortest path for all source-destination pairings. The global usage of inter-satellite linkages is particularly close, but inter-plane hops are utilized less frequently with GomHop. Because of the relative motion between planes and the misalignment, RF inter-plane hops are substantially more difficult than intraplane hops, which is particularly intriguing for practical solutions. QoS limitations and heterogeneous traffic can be added to the algorithm. Another intriguing generalization is to consider several hops rather than a single one when making a choice. The balance between the number of decision hops, complexity, and performance will be investigated further. Both of these things come at the expense of more control data. These enhancements might then be compared to current QoS-aware systems.

3.7. The New Load Balancing Routing Algorithm Based on Extended Localized Link

Another avenue for Load Balancing Routing Adaptation to Flow Dynamics in LEO Constellation Networks research. Due to the contradiction between the un-uniform traffic distribution and the regular constellation architecture, load balancing routing is a critical challenge for LEO constellation networks [27]. Most load balancing routing algorithms would search for alternative circuitous pathways based on the connection state and load level assessed by various metrics, which are generally gathered in local regions [28]. The status information may be slow or erroneous at times due to the rapid change of data flow. The impact of this uncertain dynamic characteristic on load balancing routing in LEO constellation networks is investigated in depth in this article. First, a unique load balancing routing based on extended link states (LB-ELS) is suggested, and the adaptation to flow dynamics is addressed, along with comparisons to other common methods. The results of simulations demonstrate that this method not only increases network performance but also adjusts effectively to flow dynamics. In this research, a new load balancing routing based on extended link states (LB-ELS) is developed to address the local optimization problem, and the influence of unpredictable data flow dynamics on load balancing routing for LEO constellation networks is investigated in depth. The results of simulations reveal that this method is capable of not only improving network performance but also adapting to flow dynamics. STATES Because most distributed load balancing routing algorithms in LEO constellation networks only employ limited local information, packets may not be able to be detoured around high-demand locations to prevent congestion, as previously stated. Routing algorithms, on the other hand, will be susceptible to traffic variations, resulting in performance fluctuations. The LB-ELS algorithm is introduced to deal with the local optimization problem. It will identify optimal pathways based on more specific connection state information, decreasing link congestion and spreading traffic more equally. The data-driven route calculation method is used by the LB-ELS algorithm. It will only calculate pathways for sources that want to transfer data based on topological information known ahead of time within a snapshot. When data has to be delivered, K available pathways ri=(e1,e2,e3,...,el),(i=0,1,...,K, el is the link on path ri, l is the path length.) will be determined first. Meanwhile, these pathways must meet the following criteria ah shown in next figure.

As a result, OH-delay LB's mean value and variance are larger than those of other algorithms. The delay of the TH-LB method, on the other hand, is more stable and comparable to DSP since it redirects packets using the next two top link states, increasing the likelihood of avoiding congested connections. In addition, LB-ELS has a little larger mean value and variance in delay than TH-LB. This is because, in order to avoid congestion, the non-congestion path used by LB-ELS frequently involves more hops than TH-LB. And the non-congestion path chosen may experience greater changes than pathways picked solely on the basis of localized connection conditions.

4. Conclusion

Since of their ability to supply ubiquitous broadband connectivity, satellite constellation networks in low earth orbit (LEO) have revived in recent years. Based on their orbit inclination, LEO satellite constellations are split into Walker star and Walker delta constellations. Walker-delta constellations have been selected by many current commercial constellations, such as Star-link, because they provide improved coverage in mid-latitudes, where the bulk of the human population dwells. Intersatellite links have been implemented or are being proposed by existing LEO satellite constellations (ISLs). ISLs can aid the system's self-sufficiency and reduce its reliance on terrestrial infrastructure. ISLs can also help increase throughput and delay performance in systems. Since of their ability to supply ubiquitous broadband connectivity, satellite constellation networks in low earth orbit (LEO) have revived in recent years. Based on their orbit inclination, LEO satellite constellations are split into Walker star and Walker delta constellations. Walker-delta constellations have been selected by many current commercial constellations, such as Starlink and Kuiper, because they provide improved coverage in mid-latitudes, where the bulk of the human population dwells. Intersatellite links have been implemented or are being proposed by existing LEO satellite constellations (ISLs). ISLs can aid the system's self-sufficiency and reduce its reliance on terrestrial infrastructure. ISLs can also help increase throughput and delay performance in system.

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