Boriboon and Pongpadpinit *EURASIP Journal on Wireless Communications and Networking* (2016) 2016:120
DOI 10.1186/s13638-016-0616-2

EURASIP Journal on Wireless Communications and Networking

RESEARCH

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Optimized routing protocol for broadband hybrid satellite constellation communication IP network system

Anupon Boriboon[1*] and Siriwhaddhanah Pongpadpinit[2]

Abstract

Long delays and varying delays in triple-play services on a hybrid satellite network are constraints lead for quality of service in end-to-end delay; it is an origin of jitter to make obstacle such as motion freezes and block artifacts in the video. In this paper, the Optimized Routing Protocol for Hybrid Satellite Network (ORPHSN) algorithm is proposed in order to reduce end-to-end delay and determine the best path. The proposed algorithm applies to COMMStellation™ system where hybrid satellite network topology with triple-play services of traffic load applied. The algorithm consists of five metrics which are (1) propagation link delay, (2) queuing delay, (3) link hop count, (4) link utilization, and (5) link length. The simulation results show that the proposed routing algorithm can determine the best routing paths. As a result, link performance is improved due to lower transmission delay and shorter end-to-end delay.

Keywords: End-to-end delay, Hybrid satellite, ORPHSN, Routing metrics, Triple-play services

1 Introduction

A broadband satellite on a low Earth orbit (LEO) satellite network system provides connectivity to cover global users far beyond time and space limitations. To provide and respond to globalize customers, the broadband data satellite networks integrate terrestrial network, satellite network topology, link capacity, and routing which have major impacts on the cost of a network.

A satellite network does not only able to provide high bandwidth with global coverage but also able to support flexible network configuration expansion [1]. The network combines dynamic interconnected backbones of transport network in order to exchange transmitting information. In the telecommunication industry, triple-play encompasses the provisioning of three services: (1) Voice over Internet Protocol (VoIP) through the use of a broadband connection, (2) video on demand (VoD) to broadcasting television, and (3) high-speed Internet with high-performance data transfers. The triple-play service architecture are based on the most popular technology of each standard codec to evaluate performance over broadband hybrid satellite networks.

In order to improve the performance of a satellite network that combines dynamic interconnected backbone transport networks, a new routing protocol is designed [1]. This paper aims to evaluate the Quality of Service (QoS) parameters for triple-play service applications over Broadband Hybrid Satellite Constellation Communication System (BHSCCS) [2] using the non-geosynchronous Earth orbit satellite network system-based COMMStellation™ satellite system. The proposed technique based on metric costs to optimize the routing path. In order to a make more realistic simulation, a loss links on both wired and wireless connections are set in satellite links [3]. The triple-play service application is chosen as traffic load in the simulations. The Optimized Routing Protocol for Hybrid Satellite Network (ORPHSN) algorithm is implemented and compared with conventional routing techniques.

The remainder of this paper is organized as follows: Section 2 briefly presents the backgrounds and progresses on related research area. Section 3 presents the details of hybrid satellite over LEO constellation architecture and its simulation's parameters. Section 4 discusses the triple-play services application over a satellite network.

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Section 5 explains the details of the proposed routing technique with its metric cost. Section 6 discusses the simulation results and analysis. Finally, Section 7 presents the conclusion of this research.

2 Backgrounds

Hybrid networks have both wireless and wired components. A wide variety of networks can be treated according to this framework, including multisatellite constellation network with optical fiber crosslinks [4]. The interconnection to the global communication grid is needed to install a backhaul cable, fiber optics. Most infrastructure-based hybrid networks require significant effort, time, and capital to build and deploy. However, the tremendous adoption of some of these networks is a great testament to their usefulness and commercial viability. There are numerous other communication capabilities to serve such as temporary events, battlefield communications, remote sensing, and robotic networks [5].

A LEO satellite constellation consists of a set of satellites orbiting the Earth with a high constant speed at a relatively low altitude, using orbits much lower than the geostationary orbit, in order to give global coverage, more frequency reuse, and higher system capacity as a result of this frequency reuse. With the LEO satellite system, each satellite is equipped with a fixed number of antennas that allow it to communicate with terrestrial networks and with other satellites. Routing algorithms are needed to determine the best way to traverse the mesh; a flexible packet-based, rather than static circuit-based, routing approach can take advantage of the redundancy inherent in this mesh [6, 7].

The most straightforward hybrid architecture envisaged is based upon a high-speed forward link using a broadcast lower satellite, whereas the return link takes benefit of the already existing, high bandwidth network architectures such as the synchronous transport module connections. This also enables the seamless migration of broadband satellite constellation systems providing triple-play services into hybrid systems. Such hybrid systems already exist. One can quote, for instance, that the AstraNet system providing IP telecommunication services uses an ASTRA satellite in the forward link and a terrestrial telephone line in the return link. Satellite/terrestrial LTE networks are integrated for IP services delivery, for instance, in the SkyTerra/LightSquared with LTE/satellite network system [8].

3 Hybrid satellite constellation architecture

The COMMStellation™ satellite network [9, 10] is an orbit with an altitude range around 1000 km. It consists of six orbital planes with 12 satellites in each plane. Those planes have an additional two redundant satellites in every orbit. The spacing between the orbital planes is 30° apart. The Earth station is 10° in the minimum elevation angle to maximize the coverage area of satellites. This will improve the link quality by decreasing multipath fading and having positive impact on link quality when compared with lower elevation of the Earth station. Both the uplink and downlink of the satellite link bandwidth is 1.1 Gbps, and the capacity of the satellite node is 8.8 Gbps. There are two types of stations; they are (1) trunk station that always connects to the Internet backbone and (2) user station for individual client to connect to the satellite link. The available bandwidth of the Internet backbone of the trunk station has a setup link which is the STM-4 transmission and cross link communication which is the STM-1 transmission.

In this research, the network topology consists of four user stations with triple-play service applications as illustrated in Fig. 1. The source nodes are assumed to be located in Bangkok, Thailand; Yangon, Myanmar; Vientiane, Laos; and Oil platform, Indian Ocean, while the destination nodes are located in North Boston, MA; Tallahassee, FL; Saint Paul, MN; and Lincoln, NE [2]. The reason for support to choose the located in Asia and North America is almost content in the world has location over there, and we selected Asia because this continent is growing internet usage statistics more than other continents from Internet users in the world by geographic regions. The error model produced two loss links on both wired and wireless network links [3].

The plot script [11] for this research shown in Fig. 2 illustrates the location of the satellite, trunk station, and user station of the COMMStellation™ satellite system [2, 12] which has NS-2 satellite plot scripts. In addition, our previous [2] research shows a constellation satellite layout, trunk station layout, and Internet backbone layout. Our Internet backbone traffic density model is similar to the model described in [13]. Table 1 summarizes the key properties of the presented COMMStellation™ satellite system which is used throughout the simulations.

4 Triple-play service application for traffic loads

There has been an exponential growth in multimedia applications over Internet due to the increasing demand of combining voice, video, and data services known as 'triple-play bundling' [14]. In order to support 'triple-play', a satellite system needs to be integrated with the Internet to provide appropriate performance across a range of applications that required capacity, minimum jitter, minimum delay, etc. It is a challenge to maintain the QoS for an IP-based satellite network that share communication channel's capacity among transmitting media. The voice is VoIP [12, 15] with codec G.711 over IPv6, the video is Internet Protocol television (IPTV) [12, 16–18] with codec H.264 part 10 (1920 × 1080 @24 fps) over Ipv6, and file transfer using the File Transfer Protocol (FTP) that

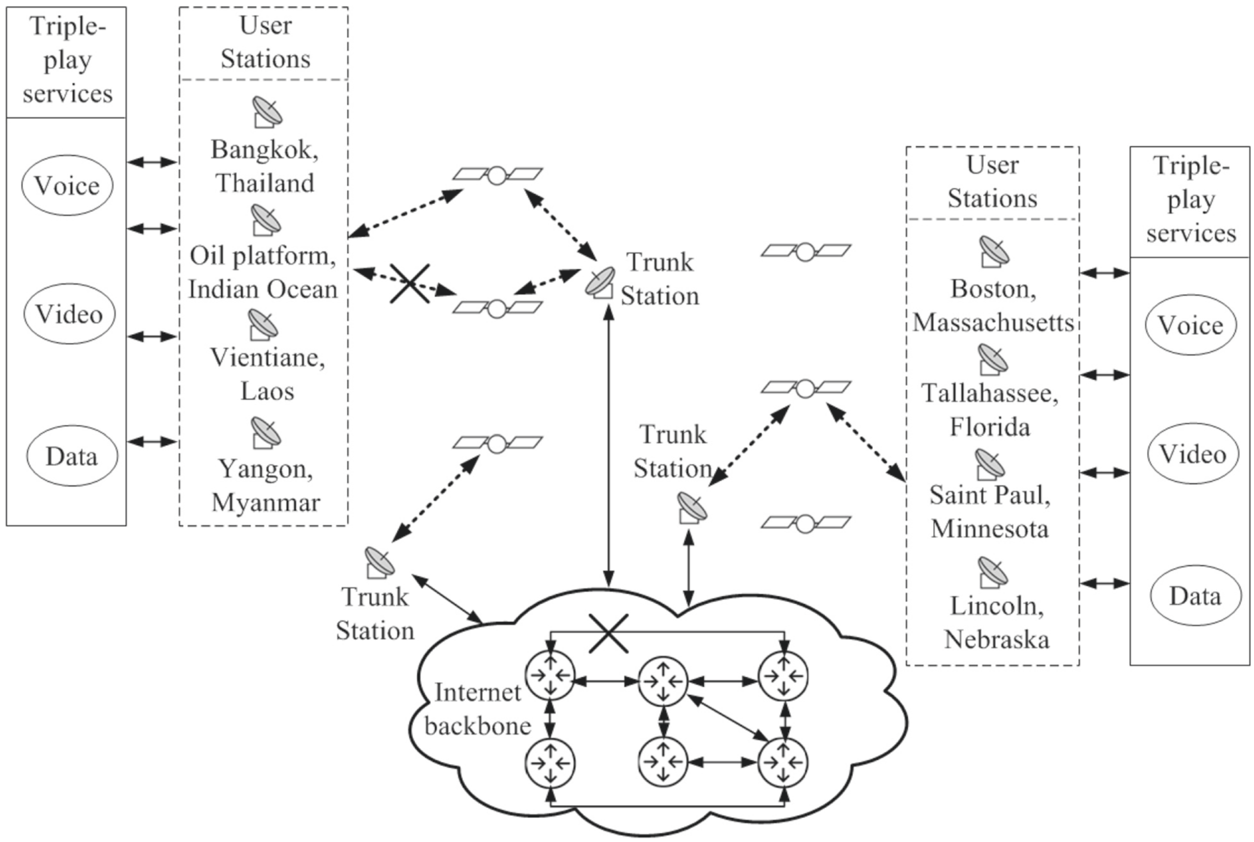

Fig. 1 Illustration of triple-play services for hybrid satellite network topology

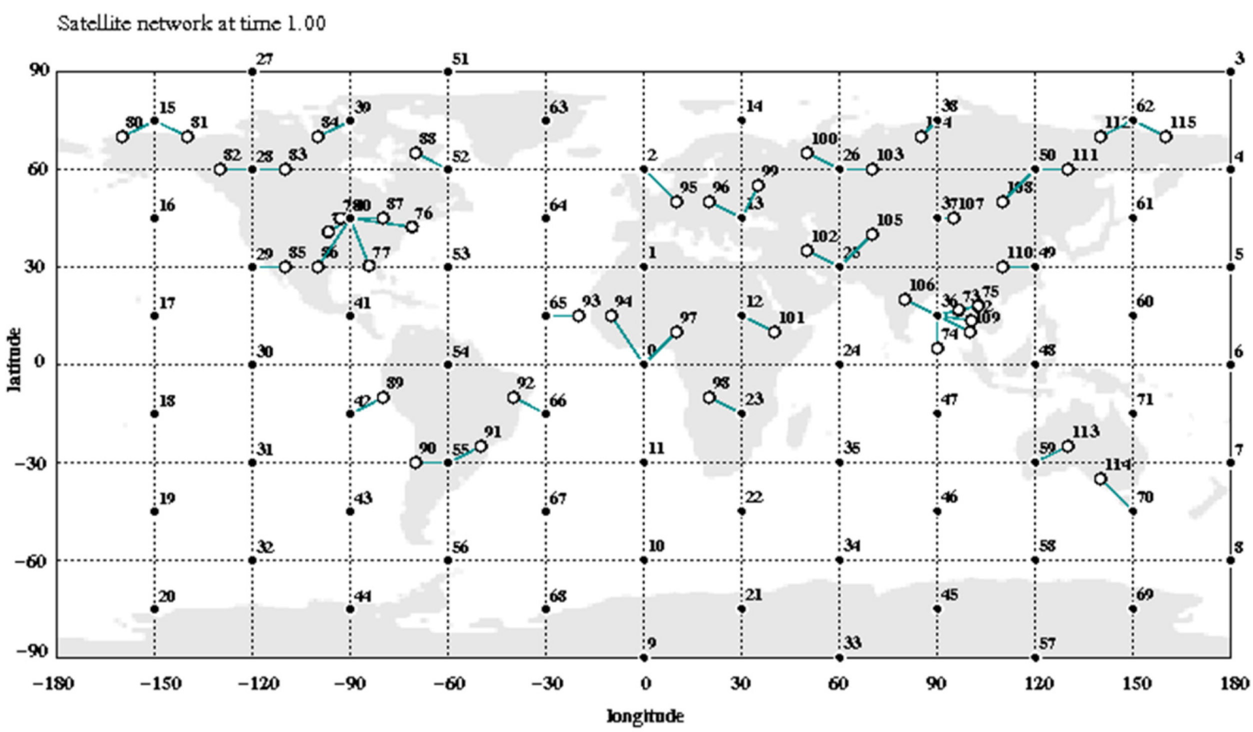

Fig. 2 Snapshot of COMMStellation™ LEO satellite constellation, trunk station, and user station

Table 1 Satellite constellation parameters

Parameters	Value
Satellite altitude	1000 km
Inclination	90°
Number of orbital plane	6
Number of satellite per orbital plane	12
The cutoff elevation angle	10°
Spacing between orbital plane	30°
Satellite bandwidth	8.8 Gbps
Link bandwidth	1.1 Gbps
Trunk stations	35
User stations	4

uses TCP Westwood [19] over Ipv6 (512 B payload). These are chosen as the traffic loads in the simulations.

5 Proposed routing technique

The routing algorithm for hybrid satellite networks is proposed based on a weighted graph model to solve the QoS routing problem in BHSCCS. The metric selection of the proposed technique based on optimization with the relationship ratio of QoS metric for triple-play services which have strict requirements on bandwidth, delay variations, and availability. Hence, five significant dynamic parameter functions are considered. The first metric is the propagation link delay, which is determined by an advanced propagation delay model from the source to the destination. The second metric is the queuing delay. It is affected by the traffic load on a particular satellite and its outgoing links, as the packet traverses varying traffic gateways. The third metric is link hop count. The fourth metric is link utilization in which the throughput part of all the next neighborhood nodes confirms the best path. The fifth metric is link length that chooses the shortest link between user/trunk stations to both satellites. The five matrices are used to reduce the end-to-end link delays, deteriorate the rerouting frequency, and chose the best route path in the routing table.

5.1 End-to-end delay metric

The metric that considers the end-to-end delay [20–22] measures the time taken for a message to journey from the source to the destination. In a network, variations of the end-to-end delay are bounded by the variations of the propagation, processing, and transmission delays. It also impacts the experience for triple-play services. Therefore, we will calculate all of the wired and wireless networks. Figure 3 illustrate the end-to-end delay metric of the simulation model. E_1 is the sum of a propagation delay for a source uplink into a satellite node. E_2 is the sum of a propagation delay for a source downlink into a trunk station. E_3 is the sum of a propagation delay for a high-speed Internet backbone. E_4 is the sum of a trunk station propagation delay for a destination uplink into a satellite node. E_5 is the sum of a propagation delay for a destination downlink into a destination node. Then, the advanced E2E propagation delay (P_d) can be calculated using the following Eq. (8). The goal of this metric is finding the lowest end-to-end delay in the network route.

The end-to-end delay (P_d) can be calculated as

$$E_1 = \frac{d_{\text{ts\_src}}}{c} + \frac{L}{B_1} + P \tag{1}$$

$$d_{\text{ts\_src}} = \sqrt{(x_{\text{sat}} - x_{\text{term}})^2 + (y_{\text{sat}} - y_{\text{term}})^2 + (z_{\text{sat}} - z_{\text{term}})^2} \tag{2}$$

$$E_2 = \frac{d_{\text{st\_src}}}{c} + D + \frac{L}{B_1} + P \tag{3}$$

$$d_{\text{st\_src}} = \sqrt{(x_{\text{term}} - x_{\text{sat}})^2 + (y_{\text{term}} - y_{\text{sat}})^2 + (z_{\text{term}} - z_{\text{sat}})^2} \tag{4}$$

$$E_3 = ((N-1).T_{\text{cross}}) + \left(N.D + \frac{L}{B_2} + P\right) \tag{5}$$

$$E_4 = \frac{d_{\text{ts\_dst}}}{c} + \frac{L}{B_1} + P \tag{6}$$

$$E_5 = \frac{d_{\text{st\_dst}}}{c} + D + \frac{L}{B_1} + P \tag{7}$$

$$P_d = (E_1 + E_2 + E_3 + E_4 + E_5) \tag{8}$$

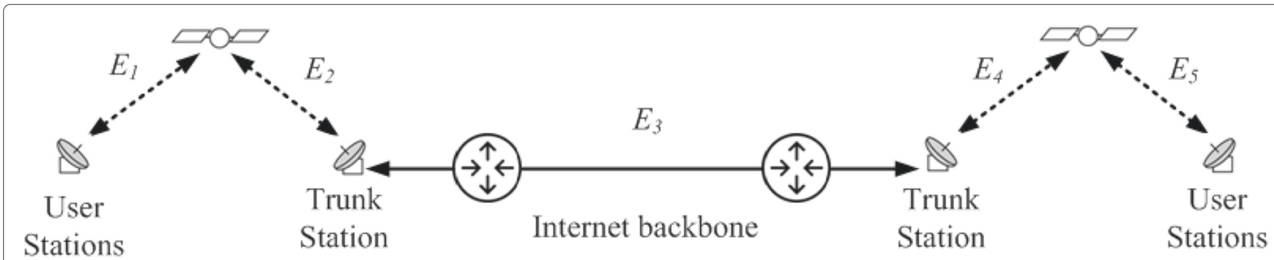

Fig. 3 Demonstrate E_1 to E_5

where:

$x_{sat} = (R + h). \cos\theta_{sat}. \cos\emptyset_{sat}$

$y_{sat} = (R + h). \cos\theta_{sat}. \sin\emptyset_{sat}$

$z_{sat} = (R + h). \sin\theta_{sat}$

$\theta =$ latitude $\quad \emptyset =$ longitude

$c = 299792$ Km/s (light speed)

$D = 2$ ms (processing delay of node)

$P = 1$ ms (deviation delay)

$B_1 =$ bit ratio of satellite link

$T_{cross} = 5$ ms (propagation delay of Internet backbone)

$d_{ts\_dst} =$ uplink of destination following with equation 2

$d_{st\_dst} =$ downlink of destination following with equation 4

$x_{term} = R. \cos\theta_{term}. \cos\emptyset_{term}$

$y_{term} = R. \cos\theta_{term}. \sin\emptyset_{term}$

$z_{term} = R. \cos\theta_{term}$

$R = 6378.137$ Km (earth radius)

$h = 1000$ Km

$L =$ length of data

$N =$ number of nodes in the path

$B_2 =$ bit ratio of Internet backbone

5.2 Queuing delay metric

Based on the queuing theory and the Little's equation [23, 24], the queuing delay and some parameters of node link state information can be deduced from the open Jackson queuing [23] network which is used as the queuing delay model. Hence, the average service rate of node i can be written as (9). For realistic traffic density in the Internet backbone in each continent, we adopt the generated traffic load which depends upon the statistics regarding user's traffic density levels per zone [13, 25]. Thus, all the traffic user nodes will be sent fitting with a traffic generating module built on each node to simulate the traffic generated by users. Therefore, this metric will avoid heavy network traffic from the source to the destination.

$$\mu_i = \frac{C_o}{L} \tag{9}$$

The service delay, t_s, is calculated by

$$t_s = \frac{1}{\mu_i} \tag{10}$$

The pending delay, t_p, in a queue is given by

$$t_p = \frac{\lambda_i}{\mu_i(\mu_i - \lambda_i)} \tag{11}$$

Finally, the queuing delay of a node link, E_q, can be obtained as

$$E_q = t_s + t_p = \frac{1}{\mu_i - \lambda_i} = \frac{L}{C_o - L * \lambda_i} \tag{12}$$

where

$\lambda =$ arrival rate $\quad \mu =$ service rate

$L =$ average packet size $\quad C_o =$ node link capacity

$t_s =$ average time spending packets in server per packet

$t_p =$ average time spending packets in queue per packet

In the queuing delay metric, the queuing delay metric over BHSCCS, P_q, can be calculated using

$$P_q = \Sigma_{i=1}^{m} E_q \tag{13}$$

5.3 Hop count metric

This metric provides the routing minimum hop count. Link quality for this metric is a binary term, which means that the link does either exist or does not exist. The primary advantage of this metric is its simplicity. Hence, the metric is less complicated when compared with other metrics. In wireless sensor networks, less hop count reducestransmission power of forwarded packet and prolongs the network life [20]. The hop count metric is

$$P_h = \Sigma_{i=1}^{\text{hop}_n - 2} E_h \tag{14}$$

where E_h is the total amount of link hop count on the reachable path.

5.4 Link utilization metric

The link utilization metric denotes the number of bytes transported from the source to the destination per unit of time. It depends on the throughput offered by the least capable link [20]. Suppose the source node is m_1, the destination node is m_k, (m_1, m_k) represents the reachable path from m_1 to m_k. Between the two nodes, they are n reachable paths existing, such as $(m_1, m_{11}, m_{12}, \ldots, m_{1j}, \ldots, m_k)$, $(m_1, m_{21}, m_{22}, \ldots, m_{2j}, \ldots, m_k), \ldots, (m_1, m_{n1}, m_{n2}, \ldots, m_{nj}, \ldots, m_k)$.

m_{nj} means the no. j hop node of the no. n reachable path. Among the n path, the optimal path must exist and can be achieved from (15). It represents the minimum availability link utilization among hops from the source to the destination including the total amount of hops on the no. n, hop_n, reachable path [1].

Also, the link utilization has related with realistic traffic density. Hence, the statistics regarding user's traffic density levels per zone [13, 25] on the above metric will come back to use in this metric again. All the Internet backbone nodes have a traffic load on each node to simulate the traffic generated.

The performance of link utilization is measured as defined in [26]. The goal of this metric is to maximize the efficiency link utilization from m_1 to m_k.

Link utilization from node i to k, $P_u(m_1, m_k)$, is defined as [1, 27].

$$\begin{aligned} P_u(m_1, m_k) \, &= \, min\{uz(m_1, m_{n1}), \\ &\quad uz(m_{ni}, m_{n(i+1)}, uz(m_{n(i+1)}, m_k)\}, \\ &\quad i \in [1, \text{hop}_n - 2] \, , n = 1, 2, 3 \ldots \end{aligned} \quad (15)$$

where uz is the utilization of hop_n computed as the billing efficiency of data that can be sent between nodes.

5.5 Link length metric

A COMMStellation™ model is used in this research. The orbit parameters of every satellite in the COMMStellation™ system at a time point are obtained in a snapshot of the COMMStellation™ satellite constellation at one time point via NS-2 [2, 28]. The differences of a snapshot of the satellite constellation are chosen at different time points. In the snapshot, we notice the satellite orbital parameters, which will be used to calculate the link parameters [28–30].

From the satellite orbit parameters, the required topology parameter can be calculated from the link length metric to find the best path between trunk/user stations and satellite nodes. For the three dimensional coordinates of satellite orbit, to calculate the link length between the satellite node A and satellite node B, the latitude and longitude of COMMStellation™ satellite orbit parameters are known by a snapshot of the satellite constellation. It is only needed to find the central angle, α. Figure 4 illustrates the three-dimensional coordination of a satellite orbit. With the equation of distance between two nodes in three-dimensional geometry, the following (16) can be derived. Hence, this metric will find the shortest link length between satellite and ground station.

$$\sin^2 \frac{\alpha}{2} = \sin^2 \frac{\varphi_1 - \varphi_2}{2} + \sin^2 \frac{\delta_1 - \delta_2}{2} \cos \varphi_1 \cos \varphi_2 \quad (16)$$

where

φ_1 and φ_2 are the latitudes of satellite A and B, respectively
δ_1 and δ_2 are the longitudes of satellite A and B, respectively

From Eq. (16), the value of α can be obtained. So the link distance between satellite nodes A and B, P_l, is

$$P_l = AB = 2R \sin \frac{\alpha}{2} \quad (17)$$

where R is assumed to be the distance between the core of the earth and the satellite.

5.6 Apply the proposed routing technique to a hybrid satellite

In this paper, the performance of the proposed algorithm is evaluated based on the weight graph model. The routes are optimized against end-to-end delay or any other linear costs in the deterministic case. Some of these techniques come from the transport optimization field. For non-deterministic networks, most of the early routing algorithms target delivery ratio as the premier objective, metrics such as delay, message size, or network load are secondary. Hence, the best performance indicator is delivery ratio instead of end-to-end delay [18]. In this paper, the best routing path from the source to the destination is

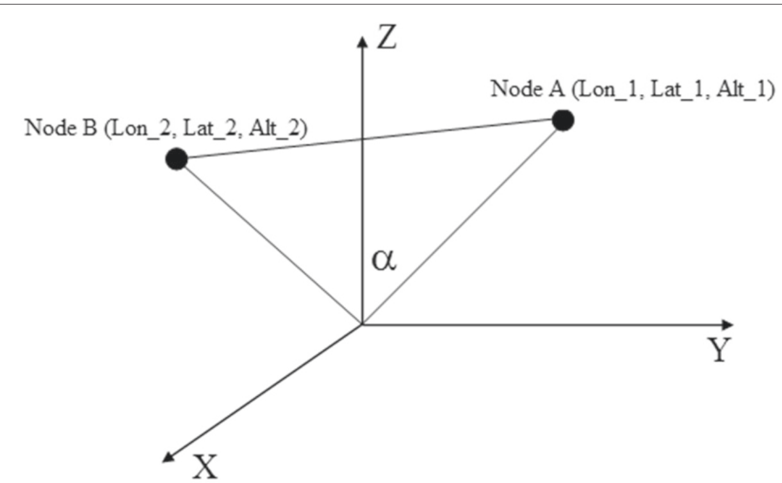

Fig. 4 A three-dimensional coordinate of a satellite orbit [1, 27]

chosen using the proposed five metrics which are complicated due to the number of metrics that have been taken into account.

The ORPHSN algorithm is implemented on BHSCCS [2, 26]. The ORPHSN algorithm incorporates both inherent dynamics of hybrid satellite network topology and triple-play services of traffic load in a COMMStellation™ system. Moreover, it applies perfectly to the contribution of the defined five metrics for characterizing routes in a hybrid network in order to reduce end-to-end delay and determine the best path, while at the same time satisfying the QoS requirements.

Finally, the link cost metrics can be calculated as:

$$Link_{cost} = P_{\rm d} + P_{\rm q} + P_{\rm h} + P_{\rm u} + P_l \tag{18}$$

where $P_{\rm d}$ denotes the propagation end-to-end delay, $P_{\rm q}$ denotes a predicted value of the queuing delay, $P_{\rm h}$ denotes the hop count in a path, $P_{\rm u}$ denotes the link utilization value for each link delay, and $P_{\rm l}$ denotes the link length between satellite and ground.

5.7 Weighted graphs methodology with QoS routing metric

This algorithm is based on the Dijkstra's algorithm [31]. In the ORPHSN algorithm, the shortest part is defined as the minimum-delay path. The grid-like network graph structure is used to represent the physical network topology. It is modeled on the directed graph

$$G(V,E) \tag{19}$$

where V represents the comprising set of nodes and E represents the set of all existing connection links (edges) [32, 33]. Also, it is clear that the size of V is

$$|V| = NM \tag{20}$$

where M is the number of the route for packet pass throughout plane that the system is comprised of and N is the number of nodes per route plane.

By numbering the route planes and the nodes within a system, we can define a pair of numbers (v_x, v_y), called virtual coordinates that uniquely identified a node. Clearly, $v_x \in (0, N)$ identifies the position of a node within a route plane, while $v_y \in (0, M)$ identifies the route plane.

Based on the system model described on the weight graph methodology, [34] an efficient method to route a packet from a source node, $v^s = \left(v_x^s, v_y^s\right)$, to a destination node, $v^d = \left(v_x^d, v_y^d\right)$, is the hop-by-hop approach [34]. The possible next hop is chosen if the $Link_{cost}$ between the end-to-end delay of the virtual node in vertical and horizontal directions, approaches 1. A neighboring node v^j will be selected as the possible next hop if

$$|v_x^d - v_x^j| < |v_x^d - v_x^i| \; or \; |v_y^d - v_y^j| < |v_y^d - v_y^i|, Link_{cost} \approx 1 \tag{21}$$

This process guarantees that the chosen paths are in the set of the optimization paths. It is used for a specific identification method into the $\text{Link}_{\text{cost}}$ value to the nearest one. Each metric has different cost value. Also, the Graph Topology Representation (GTR) is described as follows:

1) Construct a directed graph $G(V, E)$ and arrange the vertices to form a grid-like structure with n rows and m columns. The following (19) and (20) can be derived.
2) Use the initial link assignment in a routing table. In topological estimation stage, all nodes and links in the network will be traversed; it has to gain cumulative cost values from nodes.
3) Process each metric by Eqs. (8), (13), (14), (15), and (17) into a mapping table of each according metric value.
4) Process $Link_{cost}$ following (21) with all the paths in a routing table. Then, compare the cost of the link in the routing table value to the nearest one to set a path list for traveler information.

After the source node had all paths listed from the source to the destination, the process of five metrics is calculated into the mapping table for each metric. For instance, in link utilization, the metric is considered the maximum utilization based on end-to-end nodes which process by (15) and take the $P_{\rm u}$ into a mapping table of $P_{\rm u}$ according link utilization. After that, the process will have mapping tables of each metric. To complete, Eq. (21) makes a calculation for all path lists in the routing table. Then, each path has $\text{Link}_{\text{cost}}$ of itself.

The ORPHSN algorithm follows up the calculation into a routing table. In every call request from the source to the destination, the $G(V, E)$ will be constructed in order to find the feasible path. The ORPHSN algorithm considers a feasible path as the path that satisfies bounded requirements for each cost metric. Here, the optimized weight path from the source to the destination in the graph made by GTR corresponds to the optimized cost path in the network graph.

6 Results and discussion

In this research, in order to investigate the performance of the routing algorithm in a broadband hybrid satellite constellation communication system, the proposed ORPHSN algorithm was built on a NS-2 version 2.34 simulation platform.

We implemented five metrics which are (1) end-to-end delay, (2) queuing delay, (3) hop count, (4) link utilization, and (5) link length. These metrics consist routing techniques based on the described network topology and the traffic model given above. The network performance of study routing algorithms is evaluated based on the end-to-end delay between the source and the destination. The source and destination nodes in this experiment are respectively assumed to be located at Bangkok, Thailand, and Boston, MA, with an independent user type.

The simulation results are compared with the conventional algorithms. We managed to simulate the proposed ORPHSN, fixed adaptive routing (FAR) [13, 35], and random adaptive routing (RAR) [13, 35] algorithms with triple-play services load in BHSCCS model network topology.

The instantaneous end-to-end delay associated with a route length regarding hops count of the proposed OPRHSN is illustrated in Fig. 5. The algorithm optimizes paths in a routing table. Thus, all neighboring nodes know each other. When a packet is received by one of these neighboring nodes and is destined to fail, it is deflected to another direction.

The measurement of end-to-end delay of triple-play services traffic between two user terminals in Bangkok and Boston is also calculated. The most important metric of the satellite network is propagation delay. Figure 5 illustrates the simulation results of the proposed ORPHSN, FAR, and RAR algorithms. It plots end-to-end delay versus the route length from the source to the destination. The end-to-end propagation delay for the proposed ORPHSN is 81.66 ms for 10 hops, whereas it is 86.66 and 91.66 for FAR and RAR, respectively. This is because the proposed ORPHSN in BHSCCS is compared during route intervals in a routing table with a hybrid network system. The results show that the proposed technique chose the optimized route by having the least number of hops when compared with the conventional techniques.

In order to see fair results in terms of the end-to-end delay ratio of the proposed ORPHSN algorithm, we have performed simulations for three different traffic loads which are triple-play services, bulk transfer data 2048 kbps, and reliable messaging data 512 kbps. The results of these simulations are presented in Fig. 6. The highest number of the end-to-end propagation delay is triple-play services in the proposed ORPHSN, 81.66 ms in the triple-play services, whereas it is 72.02 and 64.46 for bulk transfer and reliable messaging, respectively. It is also observed that the proposed ORPHSN has the optimized performance for triple-play services, in terms of the propagation delay in the hybrid network system.

As shown in Fig. 7, the proposed ORPHSN has lower end-to-end delay when compared with the FAR and the RAR algorithms. Thus, the probability of packet traversing the whole BHSCCS network is lower. Figure 7 illustrates the comparison of user station bitrate versus end-to-end delay. This figure shows the user station capability of bandwidth started from 100 Mbps until a maximum bitrate at 1.1 Gbps. It is reflex that the user station has more uplink and downlink bandwidth, so the end-to-end delay in networks is lower. Although this is achieved with an occasional terminal bitrate increasing, with a rate of 10 % during intervals, these algorithms reduce end-to-end propagation delay by handling the statistical fluctuations more effectively. When we compared these algorithms for

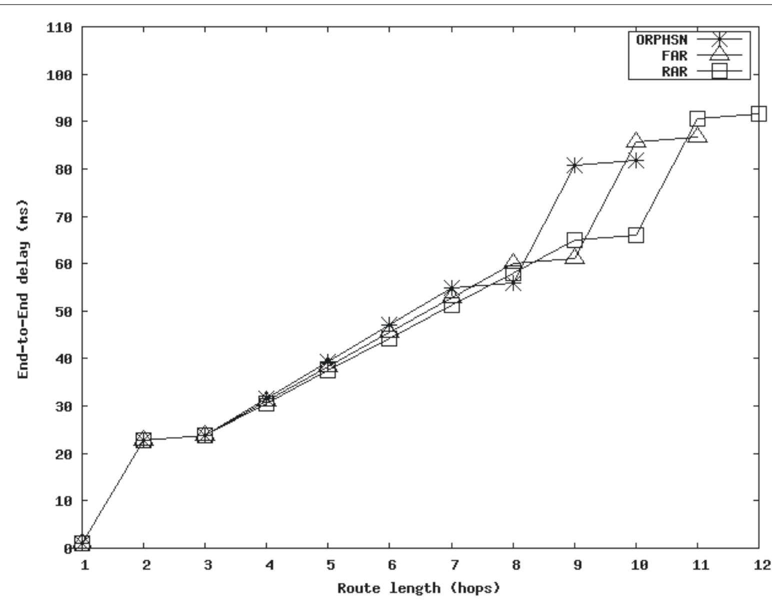

Fig. 5 End-to-end delay against a route length allowed

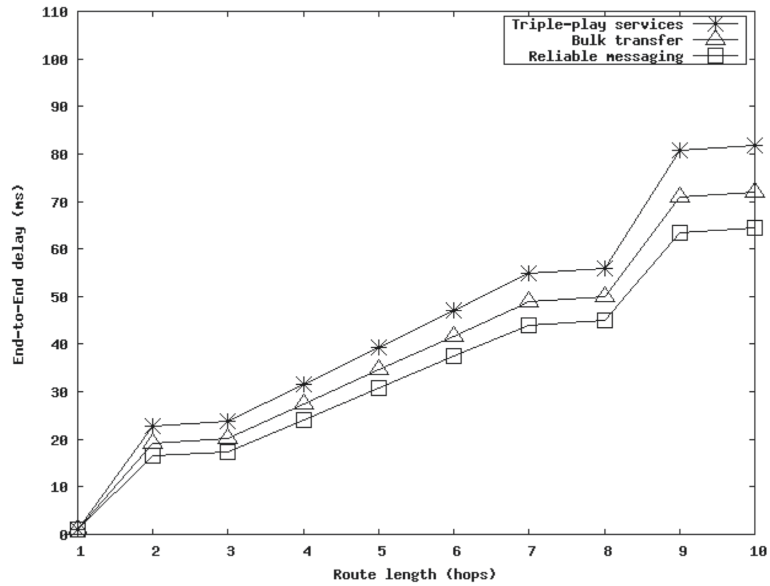

Fig. 6 End-to-end delay against a route length allowed with different application loads

triple-play services presented in Fig. 7, we observe that they are close to each other and have relations in the same direction. However, the proposed ORPHSN outperforms the end-to-end propagation delay in the BHSCCS environment, while FAR and RAR suffer in more propagation delay.

The proposed ORPHSN is implemented on the BHSCCS model, each node connection in network topology is assumed traffic loads constrained with an increasing traffic load until 20 %. The simulation assumes that the connections are of identical traffic characteristic. Figure 8 shows the comparison of the end-to-end delay from the source to the destination when different percentages of traffic loads are applied. Moreover, the average traffic loads in hybrid network system values for this simulation are around 1 % during intervals, which are due to the initially assigned traffic loads. The impact of traffic load rates on the hybrid network system for the proposed ORPHSN, FAR, and RAR algorithms are increasing the end-to-end propagation delay. The figure shows

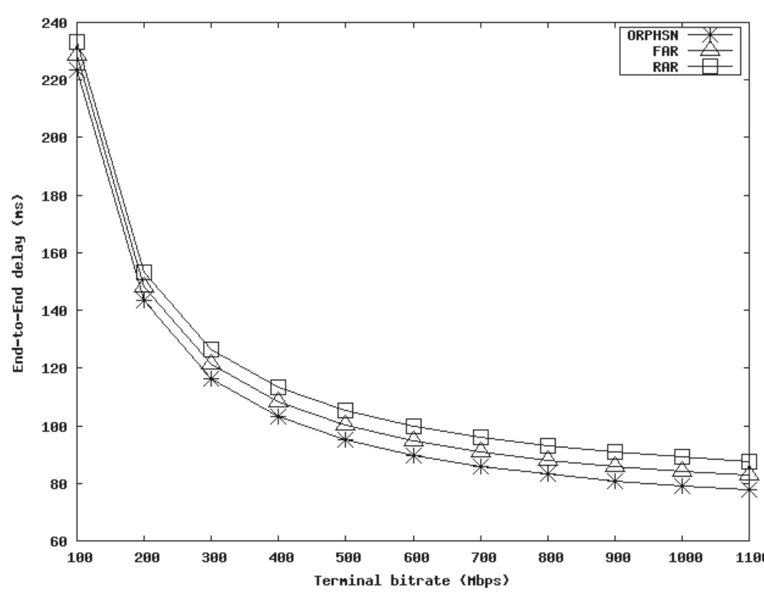

Fig. 7 End-to-end delay against terminal bitrate

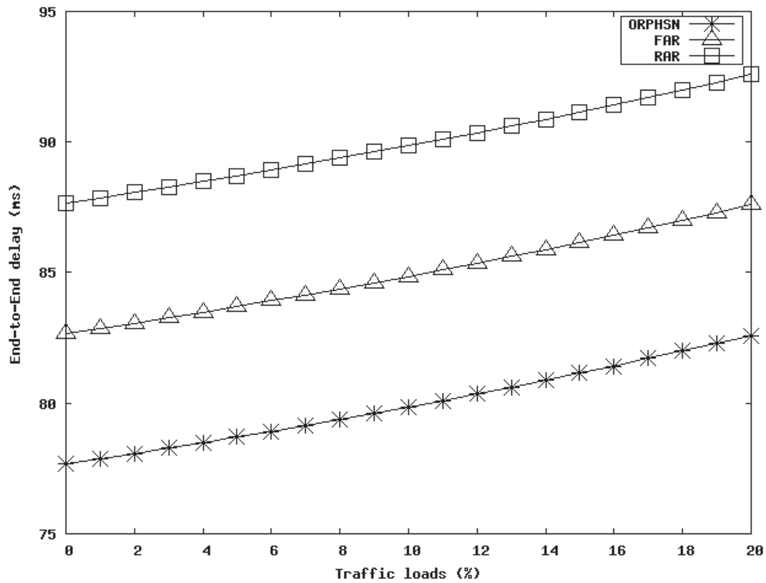

Fig. 8 End-to-end delay against traffic loads in a network

that ORPHSN outperforms with the lowest delay. This is because the proposed algorithm used multimetrics to optimize in that period of lifetime satellite connection for more information in the hybrid network system optimization.

The satellite routing algorithm based on the optimized path always considers many factors, such as the minimum propagation end-to-end delay, the minimum queuing delay, and the optimal link utilization. This article puts forward an ORPHSN routing technique which optimizes metric cost.

7 Conclusions

This paper proposed the ORPHSN algorithm over the BHSCCS network. The simulation results show that the performance of the proposed algorithm is better than other conventional algorithms. The ORPHSN algorithm proved contribution has investigated different routing metrics that impact route computation in a hybrid satellite network. Especially, this paper has presented simulation research to compare routing protocols between the hybrid satellite systems within triple-play service application for the end-to-end QoS performance evaluation. The ORPHSN algorithm has a lower transmission delay between end-to-end delays that is the most important for satellite links. Moreover, the research has found out that ORPHSN algorithm has the most optimization end-to-end QoS performance for triple-play service application compared to previous algorithms. Finally, the ORPHSN algorithm can influence the performance of the whole communication network and the quality of communication for BHSCCS network.

Competing interests

The authors declare that they have no competing interests.

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Received: 29 February 2016 Accepted: 19 April 2016
Published online: 03 May 2016

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