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# Improving Broadcast System of Integrated Satellite-Terrestrial Network-based on Enhanced Ant colony Optimization

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**Abstract**

With the use of seamless high-speed worldwide network connectivity in future, it is anticipated that the integrated satellite-terrestrial network (ISTN) will be a possible option. Due to the inadequacy of topological data and the close coupling of data and control planes, deploying optimized rules on routers is difficult. The important factors in ISTN networks are routing rules and policies, link failure, and high-bandwidth communication. Software-defined networking (SDN) is an open innovation approach that enables programmability from a central location. The controller handles the complexity of the network, whereas the infrastructure layer devices relay the packets. Thus, we investigated the broadcast by dynamically adjusting routes for fault tolerance and energy efficiency of the ISTN using distance between nodes. In addition, using dynamic source routing, this study examines the competence functions of all managing nodes in a network. The routing design is distributed among all nodes to create numerous collective paths. For LEO satellite networks, the ant colony optimization-based routing algorithm is an improved version that considers the probability of faults and low-energy consumption. The proposed simulation ensures a seamless transition in the event of failures and avoids the requirement for an additional coordination service.

**Keywords:** ant colony optimization, broadcast, dynamic source routing, energy efficiency, fault tolerance, Integrated Satellite-Terrestrial Network (ISTN), Software-Defined Networking (SDN).

## 1 Introduction

In recent days, Integrated Satellite-Terrestrial Networks (ISTNs) [32] [31] have the ability to offer an immediate wireless networking solution in situations where no pre-deployed infrastructure is present.

The necessity for ISTNs arises from circumstances in which nodes, such as mobile phones and laptops, must group together to form a network capable of supporting services like messaging, resource sharing, and file-sharing. So, the main goal of ISTN routing is to build one (unicast) or more (multicast) reliable end-to-end channels (also called "routes") between the nodes as soon as possible so that they can communicate in a reliable or valid way.

Software-Defined Networking (SDN) [11] [13], with its centralized overview of the entire network, presents significant opportunities in the context of broadcast. The data plane, the control plane, and the application plane are the three regions in which broadcast can be considered in SDN. Failures of links or switches make up data plane concerns, whereas controller connections to switches or controller failures themselves fall within the control plane region. The application plane region is concerned with the failure of an application that may impact the northbound API, which may subsequently affect other applications over time. The southbound interface (SBI) is the communication between controller and networking elements at data layer. In this study, we concentrate on the SDN data plane's (LEO) fault tolerance.

By using dynamic source routing, two key strategies rehabilitation and protection for failure recovery in the LEO are made. To account for potential future failures, alternate rules for active flows are set for protection. New routing rules for impacted flows were computed during rehabilitation while considering the most recent network view. As shown in Figure 1, the GEO is the entity in charge of this procedure. The corresponding switch first notices a failure in the LEO, and the GEO (controller) [14] [28] then generates an event to start the path-calculating procedure. After the event has been dealt with in the northbound interface (NBI) application, a new route is determined. Based on the conduct of harvester ants looking for a connection between their territory and a foodstuff, an enhanced ant colony optimization protocol was created to find the best path in a network.

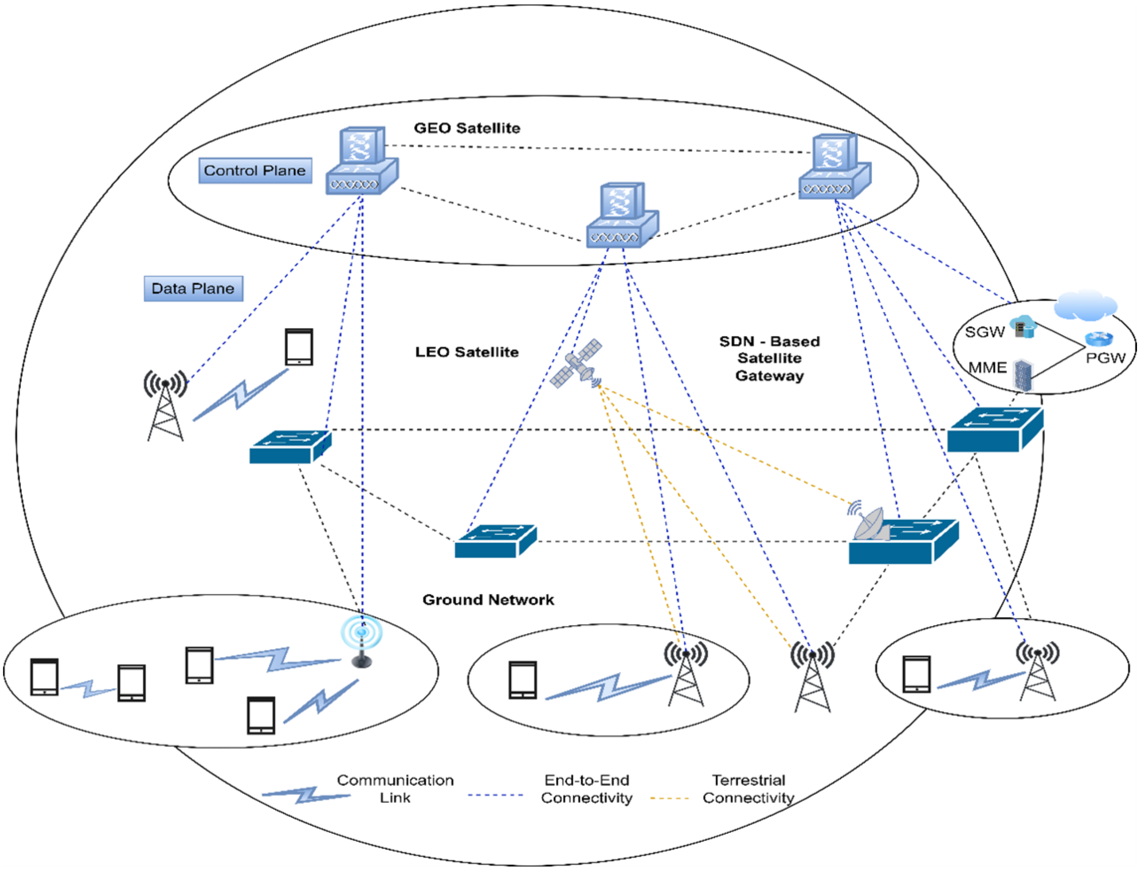



Figure 1: Architecture of Integrated Satellite-Terrestrial Network (ISTN)

The goal of incorporating Enhanced Ant Colony Optimization (Enhanced-ACO) into dynamic source (DS) routing is to identify and preserve the optimum paths between the nodes. The Enhanced-ACO can nevertheless provide an efficient route, despite requiring processing power [25] from individual nodes. This algorithm can reliably update the forwarding table according to the ACO's degree of self-organization and adaptation.

### 1.1 Features of the study

The features of the enhanced ACO framework are as follows:

- We suggest and improve a method to assess a link's and determine its congestion level.
- To provide a new route discovery technique that not only guarantees reduced end-to-end packet delivery delays but also resolves a number of conflicts, such as the looping conflict of earlier approaches.
- We detect congestion by determining the route based on the duration, traffic, and dependability of the method. In addition, explore the Enhanced-ACO of the pheromone decay method for maintaining routes and calculate the energy required for a node by analyzing the proposed scheme.
- To this aim, we make a design of congestion avoidance with time frame, fault-tolerant controller architecture and network lifetime is increasing by energy efficient.

### 1.2 Motivation

This study integrates technologies such as SDN, satellite networks, and virtualization to enhance network programmability, congestion, interoperability, and control dynamic network changes. Adopting SDN in satellite-terrestrial networks can improve throughput, packet loss, and delay in networking scenarios. With the help of SDN controllers, heterogeneous networks can use their resources together and set up custom services in a way that changes as the network structure varies.

The paper is organized as Section II, which impersonates the literature surveys related to the different methodologies incorporated for predicting fault tolerance. Section III includes data sources, proposed enhanced architectures, and rerouting mechanisms. Section IV discusses the performance metrics that are employed for testing the effectiveness and provides a comparative analysis between the proposed model and the conclusion, along with the future direction of this study, which is presented in Section V.

## 2 Related Study

The work related to the proposed broadcast and optimization-based routing algorithm is described as follows.

The broadcast networks have gained significant attention in recent years owing to their ability to optimize and manage complex networks. This review provides an overview of the different types of broadcast systems for satellite systems with a focus on minimum energy consumption. The theoretical exploration and development of ISTNs are currently in progress. Liu et al. [17] proposed a network architecture called space-air-ground integrated network (SAGIN) for ISTN, in which concerns with system implementation, protocol optimization, and resource management are also closely examined. An evaluation of exemplary ISTN architectures and a summary of pertinent studies that concentrate on wireless transmission, control and maintenance, resource allocation, and security can be found in Cao. et.al., [2] Key network functionalities to ensure Quality of Service (QoS) in ISTNs are outlined in [6] and is based on cross-section SDN controllers from the perspective of the varied requirements of future applications and the lengthy transmission delay of satellite-to-earth links.

Three groups of fault diagnosis (FD) methods: model, signal, knowledge based — can be distinguished. Since the innovative research by Jones [10], observer-based techniques have been widely studied and deployed in the field of well-known FD methods. Excellent references [18], [4], and [8] include a number of survey studies on fault diagnosis and the three fundamental tasks of fault identification, separation, and evaluation, which constitute fundamental fault isolation techniques.

Nevertheless, there is still a concern regarding how to combine the three tasks (fault diagnosis, fault isolation, and tolerance) into a single, well-thought-out plan.

### 2.1 Energy-Efficient Networks

There has been a lot of focus placed on finding ways to reduce the amount of energy that is used by networks that only use wireless connections. The fascinating achievements related to the issue of minimum-energy broadcasting in all-wireless networking [26], and notably the work of Wieselthier et al. [29], inspired us to pursue this line of research. They presented a node-based multicast model for wireless networks and served as the foundation for the numerous broadcast and multicast heuristics that they developed. The Broadcast Incremental Power (BIP) algorithm [5] is one of the most significant contributions of their work in the field. The primary goal of the BIP is to build a broadcast tree with the lowest possible energy consumption rooted at the source node. The tree is constructed by first identifying the node that the source can reach using the least amount of energy. In BIP, weights are dynamically changed at each step; however, in Prim's method [22] for the construction of minimum spanning trees, weights are only updated once.

In [15], an intelligent spectrum management architecture that makes use of SDN to turn heterogeneous satellite and terrestrial networks into an ISTN that is capable of reconfigurability and interoperability was presented. AI can predict environmental perceptions and further configure the ISTN for the best use of spectrum resources. The author [24] established a multi-layer space information network (SIN) that utilizes the advent of space-based internet providers to provide persistent broadband connectivity. In particular, the difficulties associated with radio access and networking are investigated in depth inside the suggested multi-layer SIN, with an emphasis placed on rigorous technological constraints and needs.

### 2.2 Optimization-based Routing Algorithm

Because of its extensive network reach, high degree of adaptability, and ability to provide seamless communication services, software-defined networking (SDN) is an essential component of the Next Generation Internet (NGI). Here, users who are unable to connect directly via terrestrial networks are provided with communication services through a portion of the ISTN. Since, the typical LEO satellite network does not consider the delay caused by connections in routing, it provides an accurate estimate of the performance of the satellite network. Na et al. [1] proposed a distributed routing strategy based on machine learning for a low-Earth orbit satellite network, and the traffic load on the ground was analyzed and quantified using an Extreme Learning Machine to forecast the traffic load of the satellite nodes. The author [20] designed a state-aware and load-balanced routing model for LEO satellite networks, which consider various situations, including link/node failure and recovery, to reduce end-to-end delay under the premise of load balancing.

To minimize the congestion of LEO satellites and maximize the storage space of GEO satellites, [12] proposed a Stackelberg game model based on the congestion level of LEO satellites, where the non-convex problem is transformed into a convex optimization problem using a threshold function, which is a strictly monotonic function. Ant colony algorithms are currently utilized in a variety of network applications at the present time. Examples of these applications include avoiding interflow and intraflow interference or balancing the loads in backbone networks [19], calculating the best route for vehicle networks, designing a dynamic source routing algorithm that meets high QoS requirements in ad hoc networks [24] [23], and balancing energy efficiency for WSNs and IPv6 networks [16].

Wang et al. came up with a load balancing technique called LBRA-CP, which was based on the algorithm for ant colonies. In LBRA-CP (load balancing scheme based on the ant colony algorithm) [21], the satellites actively searched out regions of congestion and communicated the information about their locations in order to accurately forecast congestion. Moreover, the ant colony algorithm was used in order to locate the most efficient route for each and every connection request [3].

In this paper, we consider the functions of managing nodes with dynamic source routing and the mechanism of ant colony optimization-based routing algorithm to measure the path distance, low packet delivery ratio, low routing end-to-end delay, and low energy consumption.

### 2.3 Problem Statement

It is possible to model a satellite broadcast system consisting of satellites ($i \subseteq$ I), a terminal unit ($j$ $\subseteq$ J), and a timeframe ($k \subseteq$ K). The unit time that a satellite "$i$" needs to connect to a terminal unit "$j$" is represented by the timeframe "$k$". The timeframe specifies the time window for satellite and terminal unit communications. The route choice and reliability of the satellite link can be illustrated as "*L= [l1, l2, l3,. . . . li]*". The connectivity between satellites and terminal units during the specific timeframe can be represented by an associative learning property of "A" (*binary value: i, j, k*) matrix.

In the event if "$A_{i,j,k} = 1$", satellite "$i$" can transfer the data to terminal unit "$j$" with time frame "$k$" or else it is "*0*". A schedule can be represented by $I\ X\ J\ X\ K$ form of $A$ is $A_{i,j,k}$ . In Figure 2. a sample of the associative learning property of matrix is given for route choosing with 3 satellites, 2 terminal unit, and 5 time frame. The dark box displays the unavailable timeslots as "0", whereas the white box indicates available timeslots as "1". For illustration, at time frames 2,4, and 5, the satellite 2' can link to terminal unit 2. The fault tolerance problem can be expressed as:

$$\max \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{k} A(i,j,k) \tag{1}$$

where,

$\max \sum_{i=1}^{I} \sum_{k=1}^{k} A(i,j,k) > \ l1 \iff \sum_{i=1}^{I} \sum_{k=1}^{k} A(i,j,k) > \ l2\ \forall\ l1,\ \forall\ l2,\ l1 \neq l2$

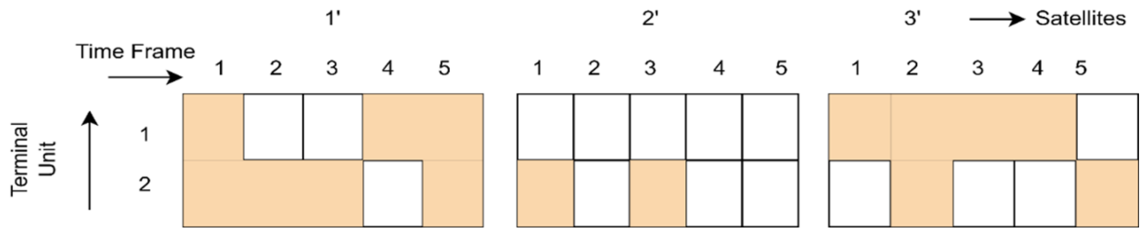



Figure 2: A sample of Associative Learning Property of Matrix

# 3 Network Routing Deployment Phases

### 3.1 Proposed Enhanced-Ant Colony Optimization-DS Routing

An auto-configuring, multipath unicast routing protocol called the enhanced ant colony optimization (DS) algorithm for ISTN is used to solve combinatorial or NP-optimization problems. This represents the route with pheromones for the search of food to follow the shortest path between the source of food and the colony. Ants leave pheromones on their trajectories to help their fellow ants recognize leftover food and reinforce the pheromone on the trail. In this approach, numerous routes exist from the nest to food. Because of the shorter end-to-end transit time, reinforcing shorter tracks is typically more desirable. However, alternate short routes become stronger with increased pheromone content when a previously short route is obstructed or lengthened as a result of route obstruction. However, the pheromone on this path progressively dissipates over time. As a result, when food is consumed, the ants stop leaving new trails and the pheromone level gradually drops. Such stigmatizing activity aids ants in adjusting to environmental changes.

For each time frame k, the Requisition Ant and Reply Ant hold the source s and destination d addresses of the node connecting to the $i$ and $j$ respectively. The parameter of $s$ is set to 0 by the sender node when it sends the Requisition Ant. Here, before the packet arrives at the destination field $d$, each intermediary node adds one to the Hop Count field as the packet moves through the network, and the method employs various combinations of pheromone intensification weights $W$. The satellite link field records the congruence of the route's intermediate link and the congestion measure records the route's congestion value. During the premature process, to steer clear old pheromones, the decay ranges from *0-1* is equal to mean of the window size in network.

As shown in Figure 3. the Enhanced-Ant Colony Optimization-DS algorithm for ISTN first generates

$r$ random ants assesses at iteration $T$. Each ant's fitness in accordance with an even-handed function, and then uses formula (2) to update the pheromone concentration of each potential trail. The pheromone evaporation technique, which involves evaporating the pheromone from every cell is the initial step,

$$\tau_{i,j,k}(T) = \rho\ \tau_{i,j,k}(T-1) + \Delta\tau_{i,j,k} \tag{2}$$

subject to, $\tau_{i,j,k}(T)$ – revised concentration of pheromone correlated with link $l_i$, $\rho$ – pheromone decay (evaporation) with value $0-1$, $\tau_{i,j,k}(T-1)$ – absorption of pheromone at previous iteration, $\Delta\tau_{i,j,k}$ - with iteration T and link $l_i$ results in sum of the confine of all ants Each ant must modify its route in accordance with pheromone concentration and certain heuristic preferences in accordance with the following probabilities using formula (3) once the pheromone has been updated:

$$P_{i,j,k}(rT) = \frac{\tau_{i,j,k}\ (r,T)}{\sum_{i=1}^{I} \tau_{i,j,k}(r,T)} \tag{3}$$

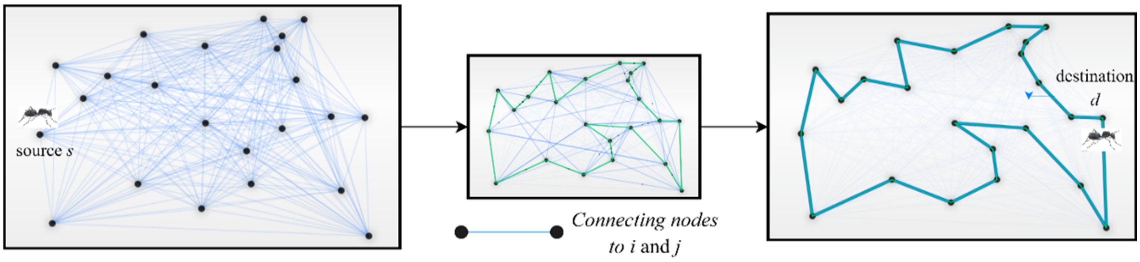



Figure 3: Ant-colony improvised Network structure for achieving optimal path (with less pheromone

Now, the pheromone values are associated with an improvement phase for direct ants in subsequent rounds to search in a more successful region. The convergence factor of iterative method ($cf_{ir}$) is the pheromone reward and K fitness value is the objective function defined by (4) and specifying the effect of path and attractiveness, respectively, and taking values larger than 0,

$$cf_{ir} = \frac{\sum_{k=1}^{K} (\tau_{i,j,k}\ max_{\forall\ i,j}\ ) - \ (\tau_{i,j,k}\ min_{\forall\ i,j}\ )}{K} \tag{4}$$

After the coverage range, following the broadcast step of wavelength, the transmitting power and nearest node are known to the receiving node with an echo message. As a result, it is quite simple to determine the threshold value of each nearest node with minimal computation time. It is evident that various neighbors have different threshold values because they have varied specifications, and the threshold value for a given neighbor node is fixed, as it is independent of the node placement.

## 3.2 Route Prolongation

As shown in Figure 4. the network is constantly developing and routes that are good during discovery may become problematic owing to congestion or intermediary link failure. Here, route maintenance is crucial in the ISTN. Ants passing through an established route deposit pheromones there, increasing the route's pheromone concentration. The pheromone intensifies or reinforces in a scenario involving harvesting ants, illustrating how effective a route is, and the pheromone level of abandoned ineffective routes gradually decrease because there is no pheromone accumulation on them.

Initially, $T = 0$ current time in seconds, $ACK(K) = 1$ for the Reply Ant message, when the destination node indicates the successful delivery to the sender network $ACK(K)$ increments by 1. When the pheromone value of a route is reduced below a E-predetermined threshold, it is automatically deleted from the route table. The timer begins when a route is found. $ACK(K)$ represents the number of $ACK$ messages that have been received up to the current time and $V$ represents the average of the top speed limits of the ISTN nodes.

$$E = E * e^{\frac{-TV_{avg}}{ACK(K)}} \tag{5}$$

The fault detection in equation (5) principles produced by ant colony fault diagnosis and classification are used to determine if the network is defective and, if so, what sort of system fault occurred. When a defect is detected, the system first updates the fault sign and determines whether it is capable of in-orbit autonomous maintenance. If so, the system's operating mode would change to enter the fault-handling mode [19] in four distinct ways:

- The minor fault-$mf$ system changes the working state to fault handling and converts the working mode into entering fault handling mode.
- The general fault-$gf$ system would spin to the NULL point; therefore, it would remain still for return fault handling and awaits commands from the ground.
- The system would attain the serious fault-$sf$ when changing the working state to fault handling failure and turns the working mode into entering fault handling mode and wait for commands from the ground
- Incorrect fault handling-$if$ results, after experiencing a minor or general failure, if the servo system is unable to rotate to a given position within a predetermined timeframe, it will change the functioning status to fault handling failure. The mechanism would shut the engine off after that and hold back for instructions from the ground.

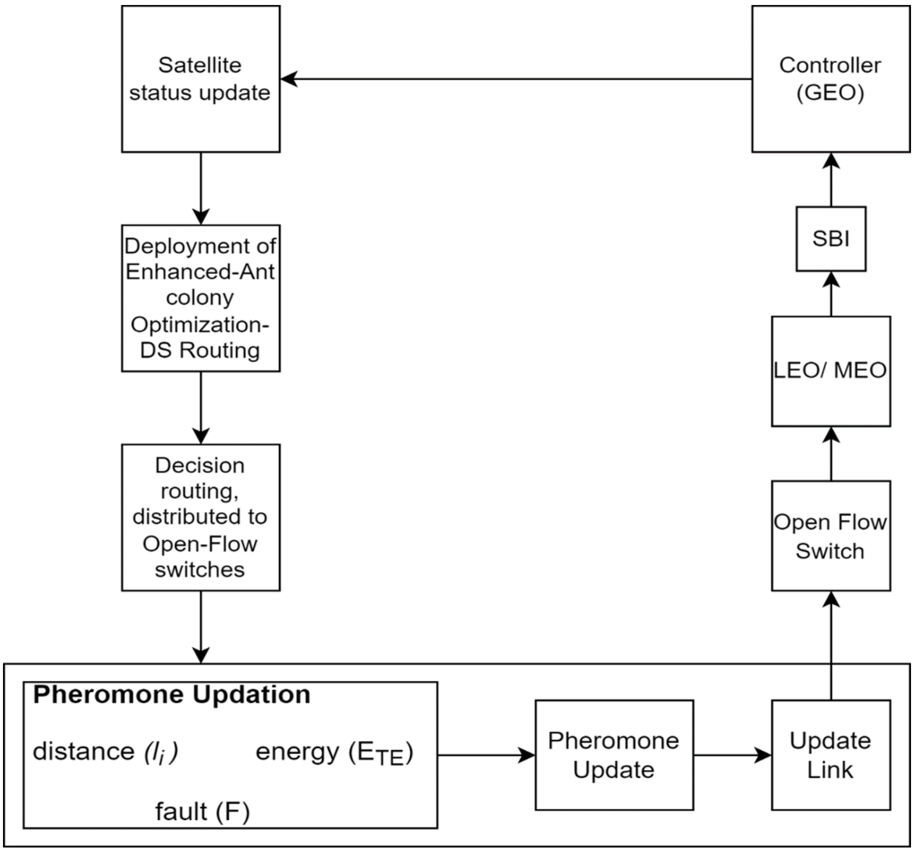



Figure 4: Proposed Method of Enhanced-Ant Colony Optimization-DS Routing

### 3.3 Congestion Avoidance with time frame

The pheromone algorithm requires considering the overall transmission quality of entire path from source node to destination node, without promptly addressing local conditions. After the execution of the ant colony algorithm for a certain duration, a phenomenon known as stagnation occurs. This phenomenon $\tau_{i,j,k}(T)$ is characterized by all individuals within the algorithm converging to the same solution, resulting in the search space reaching a state of convergence. Consequently, the algorithm is unable to discover any superior solutions. The occurrence of stagnation has the potential to result in congestion at specific nodes within a given locality. In order to address this issue, we propose the utilization of a congestion-avoidance time frame. This time frame aims to estimate the level of congestion on a given link by taking into account the cache occupancy of said link. The variability in length of intersatellite links necessitates consideration of the fluctuations in communication links ($l_i$). We design the associative learning property of time frame *"A" (binary value: i, j, k)* matrix of link *(i, j)* at time t.

### 3.4 Managing Existing Fault

In addition, three working states are used to show how the system is currently treating faults. These states are fault handling failure, fault handling completion, and continued fault handling. It is difficult for the ground to monitor and regulate the servo system's operational state and mode in real time, because in-orbit activities are handled remotely. Two working modes: entering fault handling mode and leaving fault handling mode, are used to regulate the expert system's in-orbit fault handling. Regardless of the fault-handling stage currently being used, the system enters the mode designated for quitting fault-handling and clearing all fault signals.

### 3.5 Energy Efficiency

Here, we construct a measure of individual nodes to derive the energy [7] used throughout the route identification $E_{RI}$ procedure where is the sum of the energy used during the dissemination of Requisition Ant, broadcast, Reply Ant and data transmission $E_{DT}$ is determined. It also tracks the energy used to transmit $E_{Echo}$ message. Therefore, the total energy $E_{TE}$ may be expressed as,

$$E_{TE} = E_{RI} + E_{DT} + E_{Echo} \tag{6}$$

$$E_{TE} = E_{Echo} + (E_{Disseminate} + E_{Broadcast} + E_{reply}) + E_{DT} \tag{7}$$

where, $E_{RI} = E_{Disseminate} + E_{Broadcast} + E_{reply}$. As a result, the sender node broadcasts by Requisition Ant are equivalent to number of neighbor nodes has around 0.9 $R_N$, where $R_N$ is the transmission satellite range of the node.

## 4 Performance Metrics

### 4.1 Datasets

It is required to take into account the ground stations (LEO), in order to determine end-to-end route characteristics. The ground stations (LEO) include stationary facilities used by the constellation's controller and user terminals, such as ship trucks, airplanes, and automobiles. In order to determine the suggested method performance, the process of solving a total of 7 benchmarks taken from [12]. Table 1 presents information on the characteristics of the benchmark dataset.

Table 1: Characteristics of Benchmark's dataset

| Test Benchmark(BM) | Satellites ($i$) | Terminal ($j$) | Timeframe ($k$) | Location distance($l_i$) | Requested $k$ : Assigned $i$ |
|---|---|---|---|---|---|
| BM1 (Newport Univ. – Sydney) | 52 | 42 | 104 | 15,733 | 2284:3000 |
| BM2 (Newport Univ. – Cape Town) | 40 | 30 | 80 | 12,592 | 1508:2570 |
| BM3 (Newport Univ. – Tokyo) | 33 | 23 | 66 | 11,132 | 914:1336 |
| BM4 (Newport Univ. – Moscow) | 25 | 15 | 50 | 7,956 | 367:623 |
| BM5 (Newport Univ. – London) | 7 | 6 | 16 | 5,985 | 43:72 |
| BM6 (Newport Univ. – Los Angeles) | 5 | 4 | 8 | 3,787 | 32:16 |
| BM7 (Newport Univ. – Chicago) | 5 | 4 | 8 | 1,117 | 7:16 |

Assuming that satellites($i$) and ground stations (LEO) can support a limitless number of connections, the optimal architecture of a network would compute each link that is physically feasible at each step time. When a satellite($i$) is at an altitude that is greater than or equal to a certain threshold over the horizon, it is possible for ground stations (LEO) to communicate with it. The inter-satellite connections are considered to be operational, provided that the achieve is known as a minimum user-defined distance or communication altitude above the surface of the Earth. The number of connections in the network may rapidly reach millions when dealing with large constellations located at high altitudes. In order to precisely take into account, the rotation of the Earth, the linkages between satellites and ground stations (LEO) must be computed at each and every step time. The value of $cf_{ir}$ is considered by the algorithm when determining whether a pheromone should be re-considered. Depending on the current condition of $cf_{ir}$, the pheromone intensification approach will implement one of the five available pheromone update processes. The intensify or reinforce weights W for faults $F_{mf}$,$F_{gf}$,$F_{sf}$,$F_{if}$, respectively, are denoted by $W_{mf}$ $W_{gf}$,$W_{sf}$,$W_{if}$, (Table 2). The threshold values for the partition of the five phases were as follows: $cf_{ir}$ = [0.2, 0.4, 0.6, 0.8, 0.85] for broadcast requests r = 1,..., 5.

Table 2: Reinforce Weights (W)

| $W$ | $cf_{ir} < cf_{i1}$ | $cf_{ir} \in (cf_{i1}, cf_{i2})$ | $cf_{ir} \in (cf_{i2}, cf_{i3})$ | $cf_{ir} \in (cf_{i3}, cf_{i4})$ | $cf_{ir} \in (cf_{i4}, cf_{i5})$ |
|---|---|---|---|---|---|
| $W_{mf}$ | 1 | 0.667 | 0.333 | 0 | 0 |
| $W_{gf}$ | 0 | 0.333 | 0.667 | 1 | 0 |
| $W_{sf}$ | 0 | 0 | 0.333 | 0.667 | 1 |
| $W_{gf}$ | 0 | 0 | 0 | 0 | 1 |

When $cf_{ir}$ is greater than or equal to $cf_{i5}$, the proposed algorithm performs the pheromone reconsideration procedure. During this procedure, all pheromone are set to the initial values $\tau_{i,j,k}(T = 0)$. This is immediately followed by the pheromone update procedure, which uses $W_{mf}$ as the intensification solution. The algorithm continues to search for the most important fields in subsequent iterations. The iteration loop $T$ continues until one of its termination criteria is fulfilled. These requirements may include reaching the maximum number of possible iterations or finding a satisfactory solution.

## 4.2 Simulation

The simulator would simply generate massive amounts of location data and linkages if it did not include the important and highly useful capability of creating a 3D picture of a satellite network circling Earth. This is a crucial and extremely practical feature, and visualization is performed using

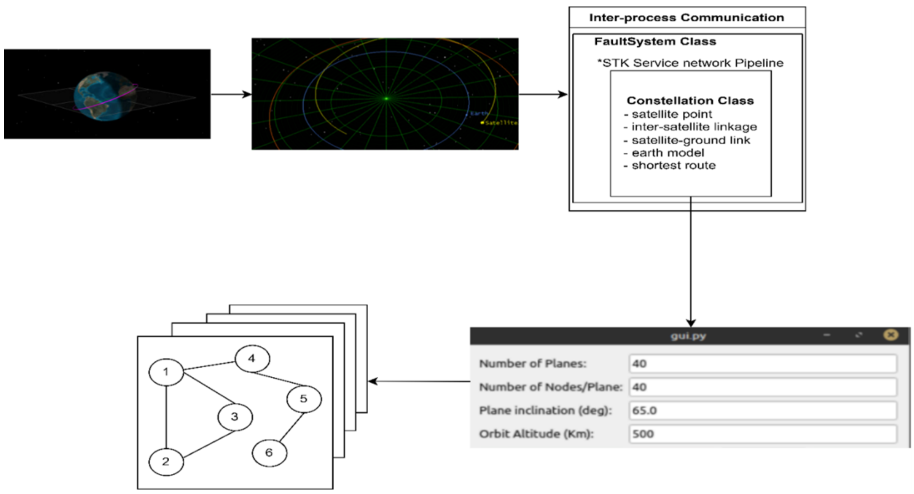



Figure 5: 3D picture of a satellite network

the Systems Tool Kit (STK) [30] library, which is an application programming interface for OpenGL. The simulation environment parameters are shown in Table 3. Upon setup, the FaultSystem class creates the STK service network pipelines. These network pipelines include the satellite point, inter-satellite linkages, satellite-ground links, ground stations, Earth model, and shortest route.

As shown in Figure 5., each pipeline may have its own color, the other properties (no. of planes, links, earth model), and various layers such as links, ground stations (LEO), satellites ($i$), and so on,

Table 3: Simulation Parameters

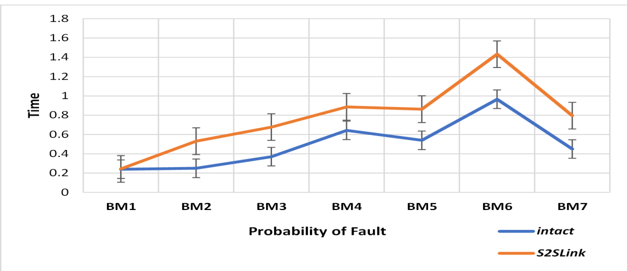
| Parameter | Value |
|---|---|
| Number of nodes | [30-60] |
| Speed of the nodes | 0-100 m/s |
| Area Size | 1000m X 1000m |
| Packet Size | 512 bytes |
| Transmit power | 2.0 mW |
| Receiver power | 2.0 mW |
| Initial energy | 1000J |
| Routing Protocol | Dynamic Source Routing (DSR) |
| *ACO Parameters* | |
| No. of iterations (T) | 45 |
| No. of Ants | 85 |
| Pheromone decay (evaporation rate) | 0.2 |
| Initial crossover threshold | 1 |
| reinforce weights | W |

can have their visibility activated or disabled independently. The FaultSystem class also uses a method that exports a PNG file that shows the rendered model at each time step. This PNG file can then be merged with other animations to produce a GIF or any other type of moving image. All evaluations were simulated using the Systems Tool Kit (STK) of the space terrestrial platform to share the results on the integrated Mininet SDN platform [9] and executed on an Intel Xeon processor at 3.6GHz.

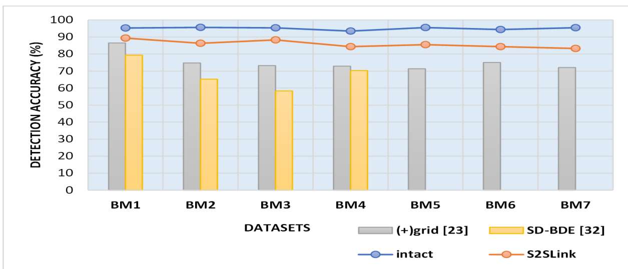
The proposed enhanced ant colony optimization (Enhanced-ACO) into a dynamic source (DS) routing algorithm in large LEO networks concentrates on a select group of source-destination pairings that have been spatially mapped to the sites of major cities, as shown in Table 1. The simulator is used to perform a fault analysis of link congestion and energy consumption increases by considering a wide variety of constellation configurations and finding the shortest path from the hop count.

## 4.3 Analysis

In the proposed transitions, consider *the extent of Ants* = *80*, $\rho$ = *0.2*, *T (iterations)* = *45*, *intact* configuration (the set of links recalculated at each time step), and *S2SLink* (the satellite-satellite linkages remain static and are used only when necessary). Here, the experimental results show that the *intact* network design provides the least number of faults feasible along all links, and the *S2SLink* design for a network provides higher faults along all possible pathways, and there is often more variation. Figure 6(a). illustrates the statistics for an LEO constellation *(40, 40)*, which occurs at an altitude of *500 km* and an inclination of *65°*. The connection may only travel between orbital planes by relaying through a ground station, so the greater faults caused by *S2Slink* network are most evident in east-west connections such as BM6 (Newport University – Los Angeles).




(a) Probability of Fault Vs Time




(b) Percentage of Fault Detection Accuracy

Figure 6: Analysis of Fault

Figure 6(b) shows the percentage of fault detection accuracy, and it is evident that the intact accuracy rate is 3.898% higher than the *S2Slink*. It represents the failure accuracy rate of existing methods (+) *grid* [12] and Stochastic Diffusion search method hybridized with Differential Evolution ($SD-BDE$) [27], which reported the lowest accuracy percentage and also failed with respect to time.

The energy efficiency for the same set of network architectures is shown graphically in Figure 7. with a series of charts. The optimal architecture of a network would result in fewer hops, with the exception of the direct route from Newport University to London. This is because the intact and *S2SLink* network designs allow connections to be made between neighboring satellites. If the architecture is perfect, the connections will be able to "skip" several nearby satellites, which will result in reduced overall energy efficiency, especially for long-distance connections. In addition, periodic variations in energy efficiency for the intact and *S2SLink* network designs occur for the same reason as the periodic abrupt transitions in faults. These variations were caused by periodic changes in the amount of time required for each hop. When ground stations (data plane) transition between the first and last hop satellites, a drastic change in route length frequently results in a change in the hop count. This is because the hop count is determined by the number of satellites passed. However, in an ideal network architecture, periodic fluctuations in hop count are less noticeable than would otherwise be because longer connections are better able to rapidly absorb changes in route length.


Figure 7: Energy efficiency vs Number of iteration

In BM5 (Newport Univ. to London), has energy efficiency and fewer hops than other BM, comparatively the other ideal network architecture suffers from poor route stability. In this regard, the *intact* design provides noticeably improved stability in comparison to the *S2SLink* network designs with an average of 35.6 seconds passing between route modifications. Experimental results show that the optimum design of *intact* has a duration between change intervals that are 0.05 seconds on average, whereas the *S2SLink* design has 0.45 seconds.

### 4.4 Results comparing Enhanced-Ant Colony Optimization-DS Routing to the existing techniques

In previous studies, [27] used benchmarks BM1-BM4 for Fast and scalable algorithm based on the meta-heuristic Stochastic Diffusion search method hybridized with Differential Evolution (SD-BDE) and [12] used BM1-BM7 were able to reach optimal solutions. In Table 4. the computation times are compared with [12] and [27] to show the proposed Enhanced-Ant Colony Optimization-DS Routing is promising to achieve maximum possible assignments within termination criteria.

Table 4: Comparison of proposed Enhanced-Ant Colony Optimization-DS Routing to existing techniques

| Test Benchmark (BM) | Execution Time in [27] seconds SD-BDE | Execution Time in [12] seconds (+) grid | Computation time for 45 iterations (seconds) with proposed algorithm | |
|---|---|---|---|---|
| | | | *intact* | *S2SLink* |
| BM1 (Newport Univ. – Sydney) | 316.5 | 261.4 | 212.99 | 221.6 |
| BM2 (Newport Univ. – Cape Town) | 165.26 | 144.2 | 113.67 | 138.54 |
| BM3 (Newport Univ. – Tokyo) | 102.29 | 99.78 | 85.44 | 90.1 |
| BM4 (Newport Univ. – Moscow) | 81.24 | 70.12 | 55.32 | 68.98 |
| BM5 (Newport Univ. – London) | - | 50.6 | 35.6 | 44.05 |
| BM6 (Newport Univ. – Los Angeles) | - | 74.45 | 56.7 | 65.31 |
| BM7 (Newport Univ. – Chicago) | - | 56.62 | 43.29 | 50.45 |

# 5 Conclusion and Future Work

In this study, the proposed enhanced ant colony optimization-DS routing offers a means of improving the performance of dynamic routing inside an SDN architecture. Simulation tools allow for the development of a satellite constellation of arbitrary size and structure. The tool's current implementation provides distinct network architectures from which users can choose. It is possible to add ground stations or user terminals to the network, which will then track Earth's rotation. A dynamic 3D model can be used to depict the simulated networks. This model can include network connections, satellites, ground locations, and a simplified representation of Earth. The user has the ability to configure the simulation of export pictures and GML files of the network, making it simple to gather big datasets. This proposed algorithm adds a new feature that creates a new table containing all associative learning matrices for problems owing to congestion or intermediary link failure in ISTN. In addition, the algorithm minimizes the faults in each router and improves stability for low energy consumption. In the future, efforts may involve the creation of more datasets, application of statistical methods to the process of parameter setting, development of more efficient local search algorithms, and formulation of metaheuristic approaches.

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## Author contributions

The authors contributed equally to this work.

## Conflict of interest

The authors declare no conflict of interest.

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