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A Load-Based Multihop Routing Using Whitebox Routers in Backbone Network

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Abstract— White box routers are multi-hop networks. Clients and routers form this kind of network, with the routers serving as its backbone and including many radio interfaces. It is critical to distribute the load uniformly and prevent interference for Wireless Mesh Network (WMNs) to be able to provide backbone support. As a routing system for multi-radio backbone networks, we introduce Load-based Multihop-White Box Routing (L-MWBR). This protocol accounts for variations in transmit rates, packet loss ratios, intra- and interflow interference, and traffic volumes. In multi-radio networks, the L-MWBR measure is useful for locating pathways that are superior in terms of load balancing and lowering the amount of interference that occurs between multiple flows and within individual flows. There are various current routing measures in multi-radio backbone networks, and the results of the simulation reveal that the L-MWBR method works substantially better than other metrics.

Keywords— *Whitebox Routers, Backbone Network, Multihop Routing and Load*

I. Introduction

In high-speed switches and routers, a routing lookup is the fundamental component that determines how well packet forwarding works. Low Earth orbit constellation backbones need a tailored RL technique [1] to accommodate changes to network topology and constraints on aeronautical device resources. A better way to employ channel resources is to reassign them new jobs. Channel reassignment in the Internet of Things, which is based on software-defined networking, is one paradigm that shows promise for enhancing the performance of network communications. Because of this, software-defined routers may work with an SDN controller to properly arrange traffic loads, leading to improved transactions on matching channels on a single link. [2]. Despite the fact that almost every nation now has its own sophisticated network, very few businesses really make advantage of it. Sharing and contributing to initiatives in a collaborative manner is made possible via collaboration that connects certain sophisticated networks across the regional level. As a result, several Pacific nations are merging their educational and scientific systems. From 1 Gbps to 100 Gbps, Pacific Wave's backbone has seen a remarkable evolution, including high-performance technology [3]. Network design entails sizing IP capacities across an optical network's structure to fulfill a collection of requirements while adhering to reliability constraints. Problem of efficiently routing demands through every hose traffic matrices in the case of a certain failure state is our primary emphasis in the hose-based cross-layer network design. [4]. In order to facilitate the effective functioning of smart grids, distribution system owners are now establishing communications networks. Electrical substation connections to the centralized management system are a fundamental component of a DSO's communications network [5]. Broadband access for rural and outlying locations may be achieved using satellite backbone networks. Furthermore, aerial, marine, and disaster relief settings are ideal for satellite communication systems. Onboard regeneration with routing are now within the realm of possibility within the power envelope of spacecraft, thanks to ever-improving connection technologies [6]. Communication networks are the connective tissue of the Fourth Industrial Revolution. To solve the associated capacity and connectivity problems, transportation networks may look into the -unexplored- residual transmission frequency in the two as well as three low attenuation windows of the optical fiber, which avoid the C-band barrier [7]. It is well-known that optical communications are used to establish satellite communications in response to the increasing needs for big communication capacities and high data rates. The success of an optical backbone network in space depends on a well-designed protocol stack [8]. As a crucial part of the design process, network planning entails allocating resources to various nodes in the network. An essential component of network planning is the traffic demand for each pair of nodes in the network. Usually, a static traffic need matrix is used, which contains the average traffic values over a lengthy period of time for each pair of nodes. Nevertheless, the accuracy (specificity) of the traffic demand matrix evaluation can be lacking [9]. Intelligent Transportation Systems have made extensive use of the Internet of Vehicles, a subset of the Internet of Things, resulting in IoV backbone networks that are both complicated and diverse. Routing algorithms, network planning, anomaly and intrusion detection, and other network traffic prediction methods are vital for effective and safe network administration [10]. It is essential to implement load balancing in any static network, such as a multi-radio backbone network, in order to prevent hot spots and maximize network usage. Consequently, load balancing routing techniques in multi-radio backbone systems rely on building a routing measure that faithfully represents the traffic load. In this study, we provide a routing method called L-MWBR, which stands for load-based multihop white box routing. In multi-radio backbone networks, it considers not only the traffic load but also variations in transmission costs, packet loss proportion, intra-flow disruption, and inter-flow interference. The results show that L-MWBR metric might be much more effective than other routing metrics currently used in multi-radio backbone systems. After that, the other parts of this work are structured as follows: Next, Section III provides an explanation of the load measure known as L-MWBR. Section II provides a review of other relevant publications. Finally, a conclusion is presented in Section V, which follows the presentation of certain simulation findings in Section IV.

II. Related Work

First introduced as the ideal hash-based RL in [11], this approach compresses metarule storage and allows for random access to the output interface. An approach based on satellite optimal hashes function is proposed as a storage-efficient hash value generator. With 538 kilobytes of storage space, the SPHF method can generate 50,000 randomly generated keys in 3.05 milliseconds. Afterwards, authors combine the ideal hash with RL to create the routing-oriented hashing function algorithm, which authors then optimize for hardware implementation. No matter the RL situation, the RHF algorithm can handle it. The field programmable gate array (xc7k70t-fbv900-1) test, which makes use of 10,000 32-bit matrix gates with four output interfaces, can look up each packet in 13.2 ns at a 312.5 MHz clock frequency using 1429 equivalent look-up-tables. An architecture that combines multi-channel reassignment and traffic management is proposed by the authors of [12] for the SDN-IoT core backbone network. They maximize throughput and minimize delay by sending data to the most suitable routes inside a single connection, while also decreasing packet loss rate and other conventional performance metrics. They devised a method using Multi-Agent Deep Deterministic Policy Gradients, TCCA-MADDPG, to optimize the objection function, control traffic, and reassign channels. As a piece of channel status information, they employ the traffic forecast result to confront the complexity and dynamism of the main backbone network. In that experiment, they augment the neural network with an LSTM layer to better capture the channel's timing information, allowing us to make greater use of the channel state's temporal continuity. They may evaluate the problems with the new methods of transport planning for the passenger transport network or the structure of urban traffic in the article [13] that discusses the location of accident and route halting locations. The related suggestions for the placement of stop points and their configuration in the intersection areas are provided. Using that topic as an example, researchers show how to use and enhance the traditional Benders decomposition technique in [14] and talk about the practical aspects of implementing it. Authors demonstrate a distributed framework that can be expanded horizontally, which allows us to take advantage of the decomposable nature of the issue as well as solve millions of linear applications simultaneously, thereby reducing the difficulty of the network design problem. Using all traffic matrices as well as failure situations simultaneously, the Benders algorithm produces global optimum designs, as opposed to the traditional method of planning them sequentially. That allows for the construction of hyper-scale networks in hours, with enhanced solution reliability and quality, reduced IP capacity with spectrum usage of 20-30%, reduced link augments of 50%, and runtimes up to 20 times quicker. The development of a GIS-based tool for the layout of the backbone optical networks, which was implemented to meet the DSO's communications needs, is detailed in [15]. Authors developed all the necessary geospatial tools on top of the efficient heuristic algorithms in the open-source QGIS software. The goal was to find the most cost-effective routes that could still reach all the electrical substations from the central management structure. The DSO's present implementation of intelligent energy distribution systems with enhanced functionality relies on that topological architecture of its telecommunications network. Read the [16] article for details on how to build and test a space-based router using an FPGA. To protect chip circuitry from space radiation, FPGAs, which can be reconfigured during runtime, are an essential tool. They tested the latest generation of field-programmable gate array (FPGA) chips for scalability and bandwidth requirements, like 100 Gbps intersatellite communications with 10 Gbps satellite-to-ground connections. After putting modern FPGA technology through its paces, the authors confirm that space routers with extraordinarily high data throughput are feasible. Researchers have developed a novel routing engine for use in planning that employs a Physical Layer Conscious, Routing, with Modulation and Spectral Assignment algorithm [17]. The idea of employing band-specific fiber amplifiers for unrepeated transmission was considered. They computed the impact for the most negative impacts in multi-band transmission, including ASE accumulation, FWM, and SRS, taking into account the abilities of fiber amplifier circuits that are approaching commercialization. They demonstrate that that design tool may

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be used by multi-band systems to increase network capacity, despite the fact that they may cause extra physical layer problems, all while maintaining connection between Core nodes. The need to install more C-band fibers may be lessened, however, due to the fact that multi-band devices provide greater operating flexibility. Not only that, but they proved that these multi-band devices could be deployed in stages, which would lower the initial investment. The authors of [18] proposed a protocol stack for a space-based optical backbone network. Next, they built a hardware platform for evaluating the stack, then used software to run simulations and evaluate the results. The results proved that the proposed protocol stack was well-thought-out to provide efficient management and command of the space-based optical backbone network. It has the potential to improve management efficiency by automatically collecting resources and determining and creating routes. Information transfer at intermediate satellite nodes with limited resources may be improved by using an advanced orbiting network frame switching technique to avoid unnecessary activities such as unpacking, upper-layer processing, as well as repacking for passing applications. Unidirectional connections may also be enabled by the protocol stack to improve the use of link resources. Transparent transmission may ultimately provide more services as well. In order to alleviate congestion, the authors of [19] provide an optimization approach for a wavelength-routed wavelength-division multiplexed optical backbone network based on these anticipated traffic demands. Limited network resources provide a constraint on the modeling of such a network, which may be generally expressed as an optimization problem including fuzzy logic. Additionally, in the presence of an estimated traffic demand matrix, decision makers may choose to loosen the aim of reducing congestion by a tiny margin in order to achieve some desired level, rather than missing the precise target by a very little amount. To decrease traffic congestion and reach an ideal level, they apply the network planning model. Authors investigate an optimization model based on mixed-integer linear programming that incorporates fuzzified constraints with objective function by use of Zimmermann's fuzzy programming approach. They analyze all relevant limitations, including those for traffic along with lightpath routing, frequency selection, average propagation delay restrictions, lightpath degree, and maximum hop count. In [20], the authors propose a smart city Internet of Things (IoT) solution that uses IEEE 802.15.4 6LoWPAN mesh networks and the right routing proto-col to achieve low latency and good energy efficiency. That approach is ideal for applications that use smart meters and need moderate to slow data processing in close proximity to real-time. The adoption of an open-source modulated technique in that study aims to reduce early implementation costs and increase interoperability. The recommended solution is trustworthy, efficient, and cost-effective when it comes to upgrading the street lighting systems of smart cities and backbone infrastructure.

III. Proposed Work

A multi-graph may be used to depict a multi-radio backbone system, in which every white box router has numerous radio interfaces $G = (V, E)$, E is the set of unorganized pairs of different vertices, termed edges, and V is the collection of White Box Routers (Fig. 1).

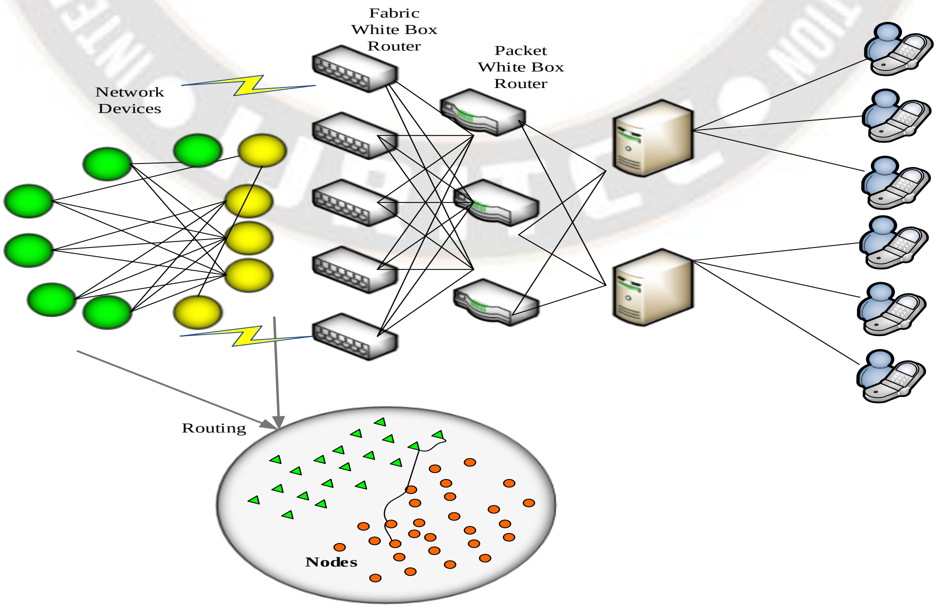

Fig. 1. Multi-radio backbone network and logical topology

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Due to the shared nature of the wireless medium, each node wishing to broadcast data must first check its range for other transmissions. Only if no other nodes are already transmitting or receiving can it access the channel. Consequently, packet delay may be caused by both the present node's traffic load and the traffic load of nearby nodes, which is referred to as interference traffic load.

Let l^i use channel i to connect neighboring nodes u and v; the load of the connection is the interference traffic l^i in which neighboring nodes vie for access to channel i in order to route traffic, depending on the load among nodes v and u:

$$Q(l^i) = \sum_{k \in N^i(u) \cup N^i(v)} Q_k^i$$

where $N^i(u), N^i(v)$ consist of all the nodes on channel i whose neighbors u and v cause interference, and Q_k^i is the mean amount of packets held in buffer at node k's interface that is associated with channel i. What follows is the definition of the link load of connection l^i.:

$$LL(l^i) = ETT(l^i) \times Q(l^i)$$

where $ETT(l^i)$ is how long it is anticipated for a packet to be sent over a connection l^iIn addition to measuring transmission rate with loss ratio differences, our link measure also accounts for traffic load at White Box Routers and inter-flow interference.

Suppose $p = \{l_1^{i_1}, l_2^{i_2}, \ldots, l_n^{i_n}\}$ serve as a path from one place to another, where $l_k^{l_k}$ is the k^{th} connect via route p with channel i_k. A channel's load (CL) on a routing route p is the total load of connections that use that channel; this allows us to take advantage of channel diversity and identify the path with the least amount of intra-flow interference:

$$CL(j) = \sum_{k=1}^{n} LL(l_k^j)$$

The Load-Aware Routing Metric (LARM) has been defined as the weighted average of the cumulative and bottlenecked channel loads on the routing route. It captures all the features of the backbone network:

$$LARM = (1 - \alpha) \times \sum_{j=1}^{m} CL(j) + \alpha \times \max_{1 \le j \le m} \{CL(j)\}$$

where m is the quantity of channels used throughout the routing route, while α is a variable that may be adjusted between 0 and 1

A routing path's cumulative load of occupied channel is the first term in Equation (4). Total resource use affects routing route latency, and this reflects that. On the other hand, channel diversity affects overall route throughput, as shown by the second term. Thus, the LARM statistic represents a compromise between the routing path's latency and throughput.

IV. Results & Discussion

Several of our own routing metrics are used by the NS-3 simulator in this investigation. This routing protocol is part of the AODV-MR suite of products. We compare the efficiency of the hop-count with WCETT routing measures to that of our suggested routing metric, L-MWBR.

Through the use of randomly dispersed static White Box Routers, a wireless backbone network was constructed, which encompassed an area of 1000x1000 square meters. Each white box router was outfitted with a number of IEEE 802.11a wireless interfaces that were configured to channels that did not overlap with one another. There was no difference in the number of interfaces between any of the White Box Routers, and they all used the identical channel allocation technique. All of the traffic flows among the White Box Routers with the gateway nodes are CBR traffic using UDP as a transport protocol so that we can test how well the routing protocol works. The goal of using the α parameter is to calculate the L-MWBR and WCETT measurements. To make comparing L-MWBR and WCETT's performance easier, we set this parameter to 0.1.

In order to measure the connection load, all interfaces are periodically broadcast with HELLO messages (every one second according to our implementation). By sending a HELLO message over a channel, every node updates its average buffered packet count at its interface. Upon receiving this message, the neighbors are prompted to update the related node's load information in the neighbor database. At this point, the impact on traffic load is determined by consulting the neighbor database for load statistics.

In order to determine how well L-MWBR works with respect to the amount of radios and the amount of traffic on the system, two simulations were run.

- Scenario 1: White Box Router with a variable number of radios. In the first scenario, the number of radios on each white box router was changed. In this scenario, a traffic load consisting of 50CBR flows and a packet rate of 4 packets per second was injected from the White Box Routers.
- Scenario 2: adjusting the amount of heavy traffic: In the second scenario, the traffic load was modified, and it comprised 50CBR flows. This resulted in a packet rate in the wireless backbone network that ranged from 4 to 20 packets per second.

The efficiency of the routing metrics was significantly improved by increasing the total amount of radios on a white

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box router, as shown in Figure 3. Based on the simulation findings, L-MWBR outperformed hop-count as well as WCETT in many metrics, including total throughput, average delay from start to end, and % of packets delivered. Despite the fact that White Box Routers had a restricted number of radio ports, this remained true. L-MWBR prioritized low-load routes, which allowed it to provide a lower delay than competing routing measures. Because of this, queue wait times, collision rates, and packet loss caused by buffer overflow were all reduced. In contrast, traffic load and interference between flows are not included in the hop-count and WCETT metrics.

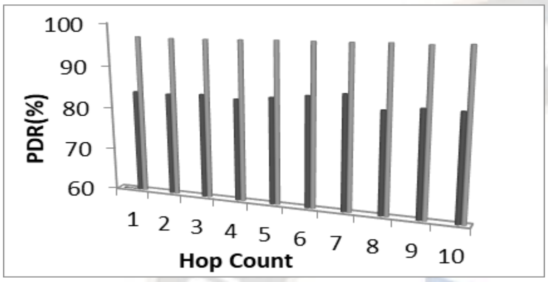

Fig.2. PDR vs. Hop Count (Scenario 1)

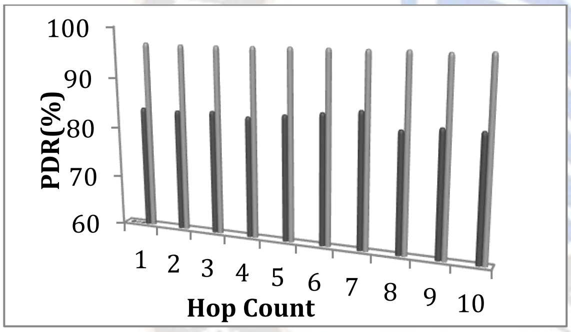

Fig.3. PDR vs. Hop Count (Scenario 3)

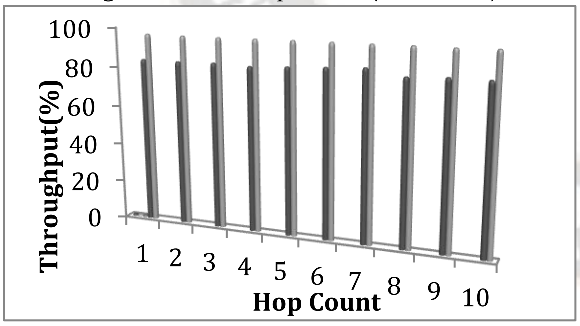

Fig.4. Throughput vs. Hop Count (Scenario 1)

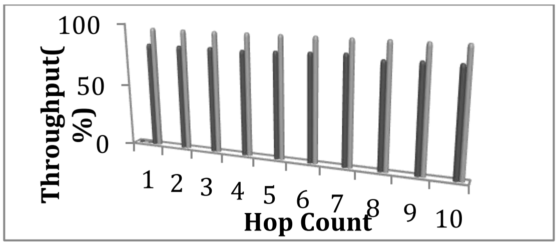

Fig.5. Throughput vs. Hop Count (Scenario 2)

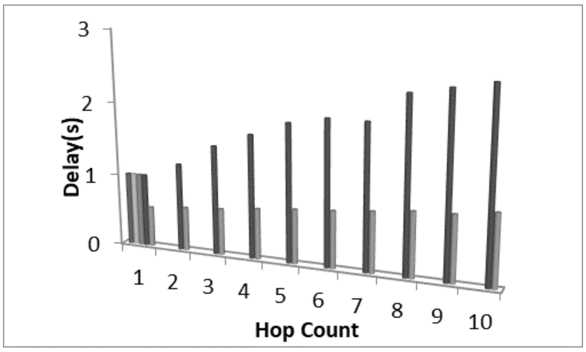

Fig.6. Delay vs. Hop Count (Scenario 1)

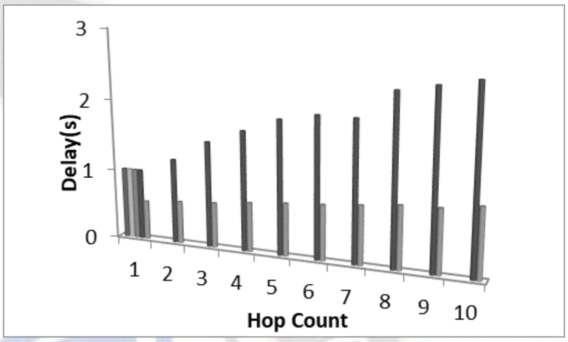

Fig.7. Delay vs. Hop Count (Scenario 2)

Data packets undergo a long buffering time because these measurements create severely crowded zones. Thus, compared to hop-count (about 46% for 1 radio along with 90% with 3 radios) along with WCETT (about 30% with 1 radio as well as 60% with 3 radios), L-MWBR achieved a reduced end-to-end latency. Furthermore, as compared to hopcount, L-MWBR improved the throughput and packet delivery percentage by about 30% with three radios and 50% with one radio. Yet, there is no discernible benefit when the amount of radio interfaces is increased beyond four. For the network with traffic pattern that were considered in our simulation, four orthogonal channels are sufficient to provide the required capacity and channel diversity. Conversely, the ideal quantity of radio interfaces will vary between network types due to inherent differences in size, density, and traffic volume.

Figure 4(a) shows the results of running L-MWBR in a single radio environment. Because there was a dramatic rise in the concentration of traffic, the network's gateway nodes were overwhelmed. This being said, L-MWBR outperformed hop-count and WCETT on a number of criteria. This could have been because it improved the network's traffic distribution. Increasing the amount of radios in a situation with numerous radios helped reduce the network load while operating in such environment. Another issue with hop-count with WCETT was the establishment of congested zones; L-MWBR prevented this from happening. This was achieved by selecting a path that relied on the transmission-inhibiting traffic load of nearby neighbors, had an elevated transmission rates, and had little interference. The result was decreased interference and collisions within the wireless network thanks to L-MWBR. As shown in Figure 4(b), while using 3-radio backbone routers under severe load (20 packets/second packet rates), L-MWBR lowered end-to-end latency by 15%, packet delivery percentage by 45%, and throughput by 45%. Compared to the hop-count, this was... The simulation results corroborated this, demonstrating that L-MWBR outperformed hop-count and WCETT in multi-radio backbone networks.

V. Conclusion

Within the scope of this article, we examined the issue of load imbalance in multi-radio infrastructural backbone networks. When it comes to multi-radio backbone networks, we suggest a routing method called Load-based Multihop-White Box Routing. Varieties in transmission rates, packet loss ratio, intra- and inter-W flow interference, as well as traffic load are all considered by this routing algorithm. When designing multi-radio networks, the L-MWBR metric may help you find the best paths for load balancing and reducing interference between and within flows. When compared to alternative routing metrics already in use, the simulation results showed that L-MWBR might significantly increase the overall throughput efficiency of multi-radio backbone networks.

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