Critical Communications in Remote Areas using LEO Satellites

Scoping a research problem

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**Introduction**

Nowadays, mobile network technology is jumping into an epochal of fifth-generation, relevant Internet of Things (IoT) technology that is also getting to grow up fast. With increased market demand for IoT network communication, people now notice the importance of LEO satellites implementing in remote areas. Such as indispensable internet service providing people a more convenient life in information communication, however, it is not common in most remote areas, not even in a developed country. Broadband Internet is either not available or not fast enough in most rural and remote parts of Canada for cloud-based software, videoconferencing, online classes, and learning tools (Ahmmed et al., 2022). Actually, not only Canada, but also Australia and New Zealand's governments have special problems getting people in remote areas connected to the Internet over very long distances, since fibre and other solutions are not realistic yet.

However, a ground station, on the other hand, can only cover a small area, which makes it harder to plan for consistent network management and smooth routeing service (Xia et al., 2019). Due to its limited view of the entire LEO network, a single ground station cannot successfully watch over and direct LEO satellites. Keeping a consistent and complete view of the network is also challenged because LEO satellite networks are dynamic, meaning that the places of the satellites are always changing.

Therefore, this research aims to develop the solution regarding implementing stable LEO satellite network by methodology of viewing and comparing previous peer-reviewed research papers, discussing executable implementation solutions.

**Literature review**

The purpose of my research is to figure out how to provide remote areas with a stable LEO satellite connection. It will discuss covering different types of remote areas, such as the sea, rural areas, and mining environments, where establishing reliable LEO satellite architectures is more difficult compared to metropolitan areas. Through a comparative analysis of peer-reviewed research from scholars with varying countries as well as professional backgrounds—including systems, electrical, and computer engineering in Canada, as well as intelligent telecommunication software and multimedia in China— this review aims to develop potential solutions for stable satellite connectivity in remote locations while this review will not cover solutions for urban and metropolitan. The literature review approach adopted involves a comparative analysis of existing excellent research to measure the viability of various LEO satellite architectures in challenging environments.

For this literature review, we will procedure a thematic approach to present, analyse, evaluate, and synthesize the existing research on the use of LEO satellites for critical communications in remote areas. This approach will focus on key themes: challenges in remote areas, technical limitations, and proposed solutions. The review will integrate insights from various sources and compare their contributions to the development of stable LEO satellite networks in such environments.

The two amazing research written by Xia et al. (2019) and Ahmmed et al. (2022), propose solutions like the hierarchical terrestrial controllers architecture (HTCA) and increasing ground station density to enhance network management and reduce latency. These approaches are capable but also face practical hurdles, such as the high cost of deploying additional ground stations and the complexity of managing dynamic satellite handovers in vast and remote areas.

By comparing existing peer-reviewed studies and examining practical case studies, this research will provide a comprehensive analysis of potential network architectures and implementation strategies that can improve the existing limitations. Finally, it will firstly contribute to the ensuring reliable communication networks for people who lives in remote areas or isolated regions globally; Secondly, additionally, these findings could have a significant impact on industries such as agriculture, mining, and disaster recovery, improving the standard of living in many developing countries. However, despite the valuable contributions of these studies, there are notable gaps in the literature. Few works address the specific needs of extremely remote environments, such as deep-sea regions or isolated mining areas, where ground station deployment is highly impractical.

**Methodology**

This research is going to develop the solutions to address the gap in remote locations by implementing LEO satellites and helping locals increase life quality by analysing and comparing previous papers. This is important to regions like China; LEO satellites are seen as a solution to the problem of limited terrestrial network coverage in remote regions like forests, deserts, and coastal islands (Jin et al., 2019; Jin et al., 2022). Also, according to some published papers, the following three main challenges are limited ground infrastructure, power and resource limitations, and maintaining reliable communication connections. Therefore, they will be declared in this research one by one.

There are no interview, simulation, or survey events that will be applied under this research; instead, comparative work between relevant papers in order of the three problems that were mentioned earlier with their possible and executive solutions. The problem of limited ground infrastructure because building such infrastructure is not affordable financially to local organisations (Jin et al., 2019; Jin et al., 2022) will be discussed ahead. Secondly, based on Jin et al.'s (2019) and Su et al.'s (2019) points of view, another serious concern lacking power and resources in remote areas, it is very important to manage energy sources properly. Finally, how to maintain reliable communication connections will be the last topic in this research. Reddy et al. (2023) mentioned that LEO satellite networks require sophisticated handover techniques and phased array antennas to ensure continuous connectivity.

There is no need to submit permission documents or sign-up agreements because this study does not include any participants. Since the study only uses secondary data from previously published studies, participant engagement raises no ethical issues. However, in order to maintain academic integrity and respect for copyright and intellectual property rules, all materials utilised in this study will be appropriately cited following QUT APA format.

On the other hand, the limitation of this research is that its results are not evaluated by simulation or other testing functions. As a result, some statements present in this content may not totally suit the current’s environment since technology is growing and changing very fast. Future studies could address this limitation by incorporating simulations or practical testing to further authorise the findings and ensure they remain relevant in the face of evolving technologies.

**Progress to date**

Considering comparative work is mainly applied in this research, the progress so far is that over 14 value research papers have been chosen as the references, while some new papers are still being researched. Nevertheless, because the resources are from various topics regarding LEO satellites, i.e., the Internet of Things (IoT), communication engineering, data collection, etc., it has been organising the resources up to date.

In terms of ground station, Ukommi et al., (2021) presented that implementing a satellite communication network can be divided into two main parts, which are the space element and the ground foundation; also, in some cases, the ground base is not necessary or only to set up in the "ground," but also can be set up on the sea. This finding is extremely important to some remote areas, like small countries where they were surrounded by oceans and had not enough wild land to build such construction due to space-ground connection, which is particularly significant in satellite network communication, and as such, it may be planned for as a separate space-ground connectivity component in component-based design (Tian & Gao, 2024).

Furthermore, as is well known, providing electrical power to an area that is remote from the city's central business district can bring difficulties for the local administration, ground station of the LEO satellite construction is not an exception. Even though LEO satellites are supposed to save energy, a ground station's power requirements might range from 50 watts to 2 kW or higher, depending on the size of its infrastructure. Collaborative LEO satellite systems provide a solution to these power constraints by lowering the requirement for ground stations to run at greater power levels. In case of IoT usage, the transmit power needed by Internet of Remote Things (IoRT) devices may be greatly decreased by using numerous satellites to receive signals and coherently combine them, which will save energy for ground stations (Yue et al., 2023).

In summary, the research so far has focused on organising resources from diverse topics related to LEO satellites, particularly in IoT and communication engineering. However, a noticeable information realised while doing this research is that the solutions and applications may not be applied in every remote area since it highly depends on geographical limitations.

**Expected outputs and future work**

The main aim of this research is to give effective solutions for the three specific problems that LEO satellites are now facing in a tight corner. It includes limited ground infrastructure, which affects the ability of LEO satellites to maintain continuous communication with terrestrial stations; power and resource limitations, given the constraints on size, weight, and solar harvesting capabilities in space; and the need to maintain reliable communication connections. It is expected that addressing these issues will enhance the performance and overall reliability of LEO satellites, so that help this society have a better experience in global IoT network.

The future work will focus on improving power efficiency or reliable communication so that LEO satellite would be able to answer the request of current IoT network complexity.

This includes optimizing energy generation through advanced solar panels and energy storage technologies, such as electro-mechanical batteries (EMBs), while integrating more efficient communication protocols to handle the dense interconnectivity of IoT devices (Abdi et al., 2013; Ali et al., 2021). For example, in a place that is around mountains, increasing the architecture of the power grid can be the first step due to the geographical features, sheer mountain sides and steep slopes (Qiu et al., 2023). This can be achieved by implementing the distribution of substations, particularly if it has not been applied enough.

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