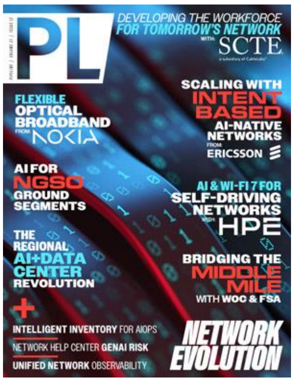

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Boosting Satcom Ground Segment Feasibility with AI

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The ground segment is a complicated beast that is undergoing a lot of change. Cloudification, virtualisation, and today's established and emerging networks in NGSO are increasing that complexity. It's also a numbers game, where ground stations must drive profitability. A November 2024 report on the ground segment by Novaspace, Ground Segment Market Prospects, revealed that, between 2023 and 2032, the cumulative market value of the global ground segment will rise to US$8 billion by 2033, and that there will be a 2.3 times growth in the number of commercial user terminals between 2022 and 2033 to 3.2 billion. As far as the ground station market is concerned, Global Market Insights predicts huge growth from US$53.8 billion in 2024 to US$176.6 billion in 2034. That's a CAGR of 12.8%.

What's Driving the Growth?

This demand for the ground segment is being stoked by the increase in NGSO constellations, driven by the likes of Starlink and increasing amounts of other NGSO constellations. Still, it's also down to a range of other notable industry trends. The data boom has pushed operators up into the higher frequency bands with HTS and VHTS that deliver more than twenty times the data capacity of traditional satellites at a fraction of the cost per bit. As with LEO constellations, activity in these higher bands, such as Ka- and Q/V- results in the need for a much larger number of gateways in the magnitude of tens or hundreds.

There has also been a rapid expansion of the ground segment in emerging markets as they strive to develop their own satellite programmes and respond to the growing requirement for satellite services. Add to this a burgeoning demand for multi-frequency ground stations to support a range of different applications from earth observation and remote sensing to communications on land, sea, and air. LEO traffic is exploding, and this is creating huge demand for hundreds of thousands of ground stations to manage higher traffic volumes and to offer global coverage. This is all set against a backdrop of geopolitical uncertainty, which is spurring governments to initiate national satellite programmes that will help ensure communications sovereignty.

The ground station market is an expensive one that involves a great amount of infrastructure and the upkeep of this is challenging and expensive. As satellite operators strive to deliver more at less cost, this can pose significant challenges. Regulatory requirements from an environmental and cybersecurity perspective influence the design of ground infrastructure and also push costs up.

Moreover, it is critical that each ground station operates smoothly, and that downtime is avoided so that RoI can be maximised. This is especially important for the ground stations and terminals that utiise the higher frequency bands. They are particularly sensitive to the impact of weather, especially precipitation which can negate a satellite link and potentially bring it down completely.

Where Does AI Fit In?

Competition is increasing, and this is driving innovation; at the same time, there is also rapid advancement in AI. While there's a great deal of talk about AI in satcom, adoption is probably slower than in some other sectors. Although some satcom tools are already utilising AI, primarily in the ground segment, it is really still in the very early stages of deployment.

For satellite operators, efficiency is critical. Each gateway is costly and must be optimised to avoid downtime, as this carries a financial impact. Coordinating and operating the ground segment also carries high costs. To do so efficiently, data must be gathered and processed in real-time to glean a true picture of performance. Fortunately, this is one area where AI is already making a big impact, supporting operators with site qualification, network design, coordinating gateways, and predicting downtime.

AI Use in Site Qualification and Network Design

Networks must be designed with efficiency in mind, right from the very beginning, in terms of how many gateways and diversity gateways are required, where each of these gateways is located for best availability, taking into account the impact of weather, and establishing the optimum link budget/fade margin and optimum gain for each gateway antenna.

Weather patterns are of particular relevance for networks employing higher frequency bands such as Ka-band and Q/V-band because these bands are highly susceptible to attenuation caused by precipitation. To determine the influence of weather on candidate ground station locations, it's necessary to take into account historical weather data. Traditionally, determining the optimal number and location of gateways, as well as planning for link availability and weather resilience, involved significant manual analysis and conservative assumptions. It's also worth noting here that when assessing the impact of weather, conventional approaches to ground network design do not always capture the impact of recent climate change. To address this, it's essential that recent years' weather data is included to ensure that the climate change impact is taken into account. Utilising AI tools with advanced algorithms, operators can now analyse historical rainfall as well as more recent weather data to determine link availability for potential gateway locations quickly. The same AI-based approach can also be used to identify correlations between different sites to help determine how likely they are to be affected by the same weather system. Operators can use these types of AI algorithms to run simulations and model various groupings of gateway sites to find the combinations that offer the highest availability at the lowest cost.

However, choosing the right number of gateways and where to put them is only part of the challenge. There's a constant trade-off between service availability and the cost of infrastructure. Operators must decide how many diversity gateways are required, determine optimal antenna gain, and calculate the right link budgets and fade margins. AI helps here, too, enabling operators to reduce capex. By selecting the right number of gateways, with locations that complement each other and reduce the chance of simultaneous weather outages, operators can build in resilience and ensure the desired throughput is reached, all without adding unnecessary diversity gateways that increase complexity and cost. The difference between needing, let's say, 22 antennas or 26 antennas, could well be in excess of several million dollars, so if AI tools can help operators to make these savings, that is going to make a huge difference to the industry.

Network Management Use Case: Maritime

Of course, designing a cost-effective, multi-gateway network is only half the job. Managing that network, with all its moving parts, brings about its own set of challenges, some of which AI can certainly help operators to overcome.

Let's take, for instance, the maritime market, specifically the autonomous service vessel segment. These vessels are often operated for offshore surveys, geophysical and geotechnical exploration, or to carry out inspections.

They are equipped with a wealth of sensors and technology for data acquisition, from acoustic sensors to sampling systems to video streaming. They can also contain remote operations centres that allow management and analysis of data. These autonomous types of vessels are also utilised for construction support, for the building of wind farms, for example.

Connectivity plays a critical role on board these vessels, as the amount of technological equipment on board and the sheer volume of data gleaned means that constant, uninterrupted connectivity is essential. Connectivity facilitates rapid decision-making and ensures that data can be sent directly to shore. Where there is no fixed communications infrastructure, such as subsea fibre, satellite is often the only connectivity option available; therefore, it is essential that it is kept up and always running.

The weather at sea is both harsh and unpredictable, and given the high amount of data traffic that is transported by survey vessels to and from a remote marine site, high-frequency, high-performance satellite links must be used. As previously explained, these sit in the high and very high frequency bands; therefore, the use of an AI tool can predict adverse weather changes using real-time weather data, enabling mitigating action to be taken in advance of the outage. This kind of intelligent network management allows for a proactive approach to service continuity. By anticipating weather disruptions and automatically or manually rerouting traffic through unaffected terminals, operators can maintain quality of service and minimise interruptions. The result is a more resilient and efficient network, capable of supporting the demands of modern satellite operations across every orbit.

Defining AI's Role

The role of AI in satellite ground networks will undoubtedly become better defined as it is increasingly used across the ground segment. It is already emerging as an important tool for monitoring and automation for ground segment operations. Ultimately, building and managing reliable ground networks at the scale required for every orbit requires far more than just infrastructure. It demands intelligent and proactive orchestration, and AI is fast becoming an indispensable tool in making that possible.