Technical Paper

Pipeline & Logistics 2025 | ISSN 2447-2069 | biblioteca.ibp.org.br

Reducing people on board by using a novel dynamically MESH AI digital connectivity

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Abstract:

One of the options to decrease OPEX is to mitigate the high costs for people on board (POB) by enabling remote operations using enhanced digital connectivity. Enabling remote operations requires planning and deploying a very high-reliability network that supports high capacity and low latency in all conditions considering end-to-end communication. This requires a set of digital solutions from connectivity solutions, high reliability planning, fast and stable deployment and easy maintenance. The current digital connectivity solutions are based on fiber, satellite and microwave. Fiber has very high-capacity solutions but are high-cost and are sensitive to cuts. Satellite solutions suffer from higher latency, even LEO, and lower capacity than the fiber and MW solutions. In this paper we present an enhanced wireless MESH AI network design with better results than satellite and fiber solutions. The MESH AI solution also supports dynamic links, which means the physical links can be modified, to even further increase the reliability of the digital communication network. We analyze our dynamically wireless MESH solution using different physical connectivity, such as fiber, satellite and MW and compare them using different KPIs such as CAPEX, OPEX, latency, and reliability. In addition, we will use several real-life examples to demonstrate our suggested solution. We will show that the dynamically wireless MESH solution can achieve 100% end-to-end SLA solutions with lower costs.

Keywords: Reliability; MESH; AI planning.

Received: May, 2nd | **Accepted:** August, 6th| **Available online**: September, 9th
Article nº: 4800
DOI: https://doi.org/10.48072/2447-2069.rpl.2025.4800

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Reducing Offshore People on Board (POB) Costs Using Dynamic AI-Driven Wireless Mesh Digital Connectivity

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"Your digital transformation is only as good as your connectivity"
Gil Gabay, SVP Global Business Development, Ceragon

Abstract

One option for decreasing operating expenses (OPEX) related to offshore sites is mitigating the high costs for people on board (POB) by enabling remote operations using enhanced digital connectivity. Enabling remote operations requires planning and deploying a very high-reliability network that supports high capacity and low latency in all conditions for efficient end-to-end communications. This requires a set of digital connectivity solutions, high-reliability planning, fast and stable deployment, and easy maintenance. Current digital connectivity solutions are based on fiber, satellite and microwave (MW) technologies. Fiber provides very high-capacity solutions but are high-cost and sensitive to cable cuts. Satellite solutions (even LEO) suffer from higher latency and lower capacity than fiber and MW solutions.

In this paper we present an enhanced wireless mesh artificial intelligence-driven network design with better results than satellite and fiber solutions. The AI-driven wireless mesh solution also supports dynamic links, which means physical links can be modified to even further increase the reliability of the digital communication network. We analyze the dynamic wireless mesh solution using different physical connectivity options, such as fiber, satellite and MW, while using different key performance indicators (KPIs) such as capital expenditures (CAPEX), OPEX, latency, and reliability. In addition, we present a real-life offshore example to demonstrate our suggested solution. We ultimately show that the dynamic wireless mesh solution can achieve 100% end-to-end SLA solutions with lower costs.

1. Introduction

Reducing offshore personnel can lead to significant cost savings in areas such as personnel wages, accommodations, transportation, and safety provisions. By estimating the average daily or weekly costs per offshore worker and projecting the percentage reduction in POB, including operational efficiencies, reduced safety incidents, and lower insurance premiums contribute to overall cost reductions.

Offshore oil and gas (O&G) remote operations involves the integration and interconnection of onshore and offshore sites, facilities and resources to increase production efficiency, safety and security, while at the same time decreasing the total costs of, and need for, offshore personnel (Söderberg, Johansen, & Nieminen, 2015; OE, 2019). Personnel that would normally work offshore are now able to monitor ongoing operations while physically placed onshore, with reliable access to data from multiple locations while working in a safe onshore environment, reducing the number of POB (Söderberg, Johansen, & Nieminen, 2015; Offshore, 2023).

Remote operations include using extensive monitoring systems for gathering and transmitting critical information and data for offshore systems (such as pumping machines and drilling equipment) from offshore sites to personnel located in onsite control rooms. Monitoring operations closely and in real-time for any anomalies enables operators to prepare and react to emergencies immediately. The throughput requirements for remote operation systems are over 32 Mbps for drilling rigs and over 100 Mbps for larger production rigs (Söderberg, Johansen, & Nieminen, 2015).

Remote operations require bandwidth that is beyond what very small aperture terminal (VSAT) satellite systems can offer today. Users in the same area utilize the same bandwidth, thus capacity is divided between them. It was found that due to the large cell sizes in low Earth orbit (LEO) non-terrestrial networks (NTNs), the estimated area capacity density is moderate: 1–10 kbps/km^2 in the S band downlink, and 14–120 kbps/km^2 in the Ka band downlink depending on latitude (Sedin, Feltrin, & Lin, 2020). For example, Gilat SkyEdge IV can support up to 100Mbps using GEO satellite (Gilat, 2024).

Fiber links support high-capacity demand but require high-cost installation. Submarine fiber connectivity requires significant installation costs; for example, installing a 430km line connecting 12 production facilities in Brazil cost $146 million (Palmigiani, 2020).

Another problematic aspect of submarine fiber optic cables is their vulnerability to physical damage. Natural disasters such as mudslides, typhoons and earthquakes have caused serious damage to offshore cable networks. Based on published reports, there are approximately 150-200 cases of cable cuts per year. Service-level agreement (SLA) repairs take from one week and up and cost from $0.5M (Burdette, 2024) (Koshino, 2024). Reparations can be complicated, as cables have to be lifted from the seabed and repaired on-board specialized vessels (Söderberg, Johansen, & Nieminen, 2015). Thus, fiber often lacks the flexibility and resilience needed to support digital O&G operations.
In this paper we suggest a framework for a wireless mesh solution that covers the full network lifecycle. Wireless links can support very reliable long-distance connections with high capacity and dynamic configuration for onshore and offshore sites (Ceragon, 2025). We show that high-capacity wireless mesh networks can provide end-to-end reliability and handle disconnect events with lower CAPEX than fiber and satellite. We compare the three main relevant technologies and show that wireless mesh networks are preferred.

2. AI-Driven Wireless Mesh

In wireless mesh networks, network planning and deployment greatly impact network coverage, connectivity, lifetime, and costs (Bosio, Capone, & Cesana, 2007; Li, Ota, Dong, & Chen, 2017; El-Hajj, Al-Fuqaha, Guizani, & Chen, 2009). The simplest architecture for wireless links uses star and chain topologies where there is a central node with whom all the points communicate, as shown in Figure 1. When using a ring topology, all the points are circularly connected, which increases network reliability and makes it more desirable for offshore networks (Söderberg, Johansen, & Nieminen, 2015).

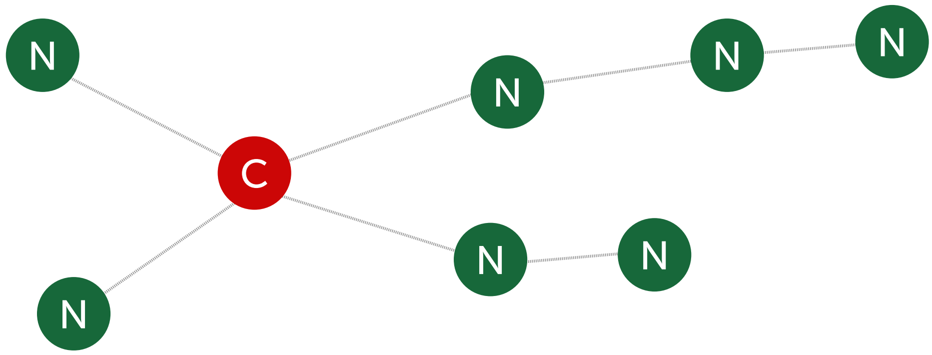

Figure 1: Example of core node (c) connecting other nodes (N) using star with chains

In a multi-hop wireless ad hoc network (WANET), all nodes work alongside each other so that they form a network without requiring any infrastructure (like bases station or access points). In a mobile ad hoc network (MANET), communication among nodes outside the transmission range is enabled if the mobile nodes can forward packets for each other. The network nodes can move independently and in any direction. These nodes can arbitrarily leave and join the network. As a result, a node will regularly go through changes in its link conditions with other devices (Chitkara & Ahmad, 2014) (Al-Dhief, Sabri, Fouad, Latiff, & Albader, 2019).
As an example of wireless mesh for offshore O&G, we start with basic concepts from a mesh architecture for local wireless networks supporting high-reliability connections. The HART Communication Foundation proposed the WirelessHART standard (Comission, 2010), which, like MANET (Chitkara & Ahmad, 2014), uses time-synchronized, self-organizing and self-healing mesh architecture to provide a complete solution for real-time process control applications.
These self-organizing and self-healing mesh technologies enable wireless field devices to self-route through the process environment and reroute when the environment changes; this guarantees long-term reliability and predictability, even under changing environmental conditions (Chen, Zhang, Lim, Kwok, & Sun, 2019). Those models suggested several ad-hoc network architectures and deterministic routing algorithms. In our solution, we enhance those concepts to support point-to-point (PtP) or point-to-multipoint (PtMP) links, which use directional antennas. Our full lifecycle solution starts with network planning and includes AI-based routing to handle extreme events and enable self-healing capabilities.

As shown in Figure 2 (below), a network lifecycle comprises four main stages: planning, deploying, routing, and monitoring. In the planning stage, the network node locations and the links between them are defined, and the nodes can be statically or dynamically located. The planning stage has a crucial impact on network reliability and its ability to handle extreme events. In this stage, customers define their throughput and reliability requirements. The planning stage defines the required links between the nodes and the potential routes to support customer requirements. Figure 3 (below) presents a simple example of increasing end-to-end reliability by adding one link between two nodes (in this case creating a simple ring). Adding a link creates an option to reach any node in the network even if one of the links or nodes fails. More reliable solutions can also be planned to support failure of two links and above.

The deployment stage requires manpower to install the links and configure the network. Network routing protocol design involves searching for the most appropriate routers subset among all routers deployed in the current network based on current network status and current demand. Network routing protocol design is usually performed online after the network has been initialized and stabilized, and rerouting will be triggered if any node is down (Chen, Zhang, Lim, Kwok, & Sun, 2019). We suggest distributed AI-based routing that learns and handles extreme events to decrease network SLA repair times in such cases. The network is constantly monitored to handle extreme events that impact the network. Based on the monitoring information, the network management system can predict events in advance and plan the required new network configuration. If using dynamic wireless links, such as PointLink (Ceragon, 2025) or Nextmove (Nextmove, 2025) solutions, network topology can be reconfigured dynamically to create new routes and bypass local problems.

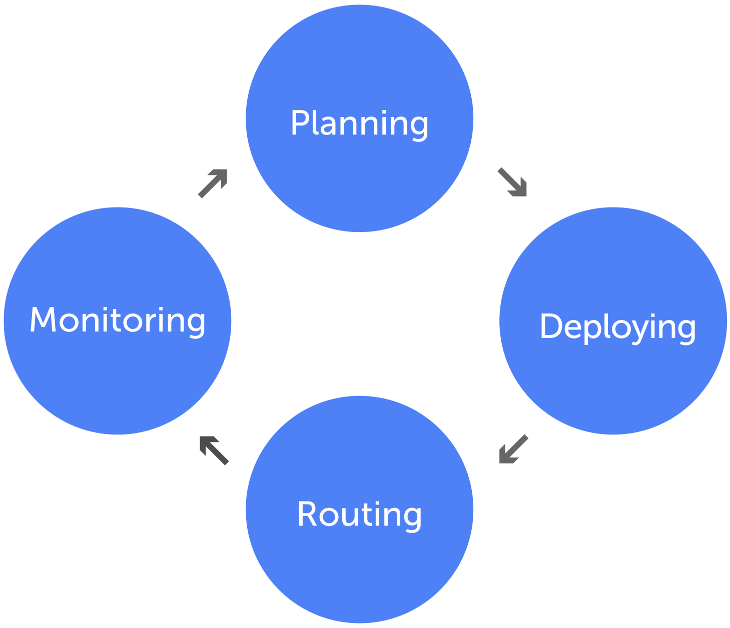

Figure 2: Network lifecycle

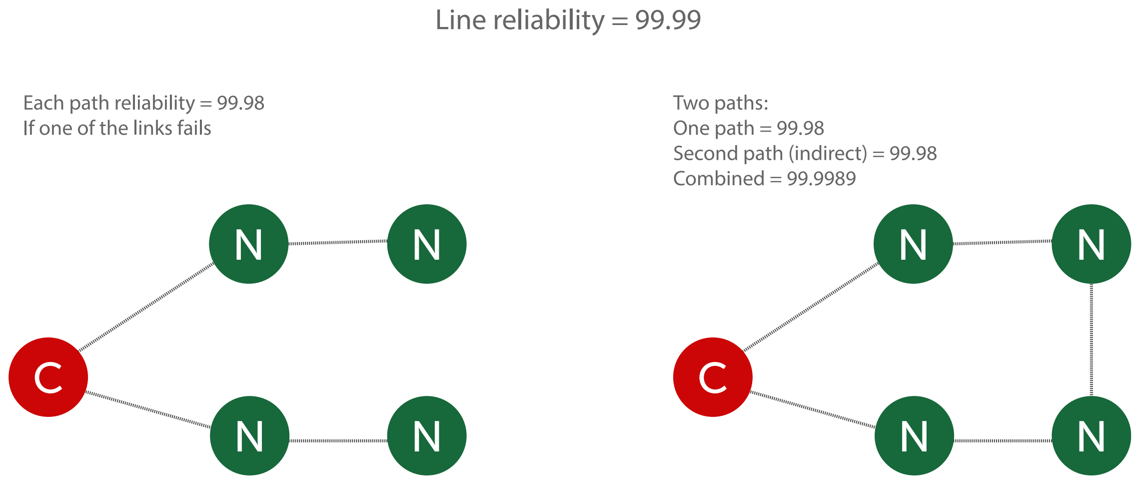

Figure 3: A simple example of increasing end-to-end reliability with wireless mesh

Two primary routing protocols are defined: segment routing (IETF, Segment Routing Architecutre - RFC 8402, 2023) and Ethernet/IP routing (IETF, Requirements for IP Version 4 Routers, 1995). In segment routing, the complete routing path from source to destination is explicitly written in the ongoing packet. Thus, the routing is predefined by a centralized global router and each node routes the packet based on its associated header. Therefore, the resulting centralized routing solution does not support dynamic and disconnected networks.

Ethernet/IP routing specifies only a destination ID in the packet. The graph information corresponding to this destination is preconfigured by the network manager prior to its use and route or learnt using protocol messages. Thus, when an arbitrary node receives this packet, it will check the corresponding routing table to determine the current packet forward destination (Chen, Zhang, Lim, Kwok, & Sun, 2019). This routing method is basically static since each node routing table is predefined. There are routing enhancements that update the node routing table based on link disconnection but not based on traffic prediction or network status prediction.

A more advanced routing solution is AI-based dynamic routing. In this routing protocol, the routing is decided in the node based on network status and traffic demand (Paul, Cohen, & Kedar, 2023) (Gahtan, Cohen, Bronstein, & Kedar, 2023) (Danilchenko, Kedar, & Segal, 2023). Each node has an internal machine learning (ML) agent that updates its internal weights from a centralized router and can also learn by itself. When a packet arrives, the node agent decides on the next hop node and the next timeslot transmission power, as shown in Figure 4 (below). Those AI-based routing algorithms consider wide input information and have an enhanced ability to control the links, including deciding which link to use and configuring the transmission power. Those solutions handle various network effects such as weather, link problems, and user traffic demand to define the current relevant routing. Thus, they can support self-healing and reconfiguring networks.

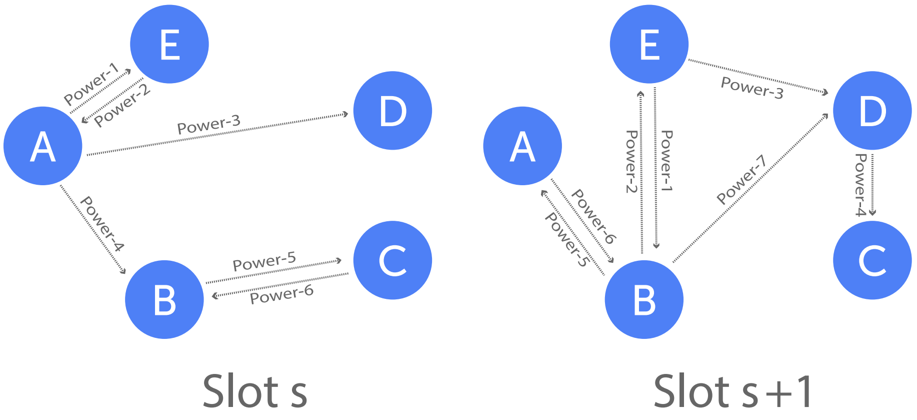

Figure 4: Example of AI-based routing decision between steps (Gahtan, Cohen, Bronstein, & Kedar, 2023)

3. Offshore Example Based on Real -Life Scenario

In the following example shown in Figure 5 (below), the main site and a secondary site are connected to shore via a PtP wireless link and a fiber connection for redundancy. The offshore sites are partially mesh connected between themselves using PtP and PtMP wireless links creating a wireless mesh network. This architecture results in a very high end-to-end reliable network by creating two different onshore connections and internal offshore small rings. The offshore links can be reconfigured since they are based on the PointLink solution that can rotate and direct the link to another site (currently also requires reconfiguration in the link units to configure the RF link).

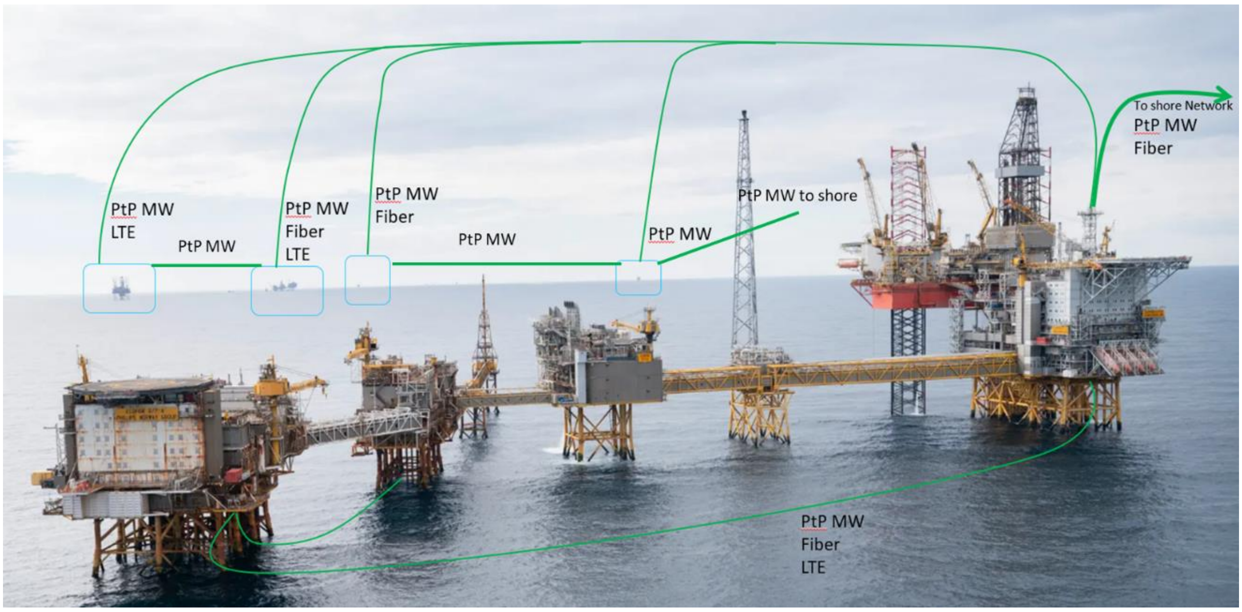

Figure 5: An example of possible wireless mesh network offshore

4. Discussion

In this section we compare fiber, satellite, and wireless mesh technologies based on various parameters. The installation cost of a fiber link is the highest among the three, while a satellite link is the cheapest installation cost since it requires only installing a VSAT antenna. Wireless links are more expensive than satellite links, but they are much less expensive than fiber connections. Both wireless and satellite networks can support moving nodes such as ships, while fiber networks are for static locations.

All technologies can be affected by natural events, such as weather. The main difference is the network's ability to recover and the cost to fix it. As was described above, the cost for fiber fixes is very high compared to satellite and wireless links. Wireless link capacity can be decreased or disconnected due to weather events. However, wireless networks can self-heal themselves using dynamic links and AI-based routing, as described above.

Both fiber and wireless can support parallel paths between two nodes to increase reliability. However, building a reliable network with several paths using fiber is very expensive compared to a wireless mesh network.

A unique perspective of a wireless network is that it can support network self-healing of the physical links layer by dynamically reconfiguring the links between the nodes. In addition, AI-based dynamic routing can be reconfigured by defining the packets' route based on the current network situation and traffic demand.

Table 1: High-level comparison between the three technologies

	Fiber	Satellite	Wireless Mesh
Installation Cost (CAPEX)	High	Low	Medium
Operational Cost (OPEX)	High	High	Low
Latency	Low	Medium / High	Low
Reliability	High	Medium / Low	High
Repair Cost (CAPEX & OPEX)	High	Low	Medium
SLA Repair Time	High	Medium	Low
Dynamic Network Support	No	Yes	Yes
Moving Endpoint Support	No	Yes	Yes
Throughput	Very High	Medium / Low	High

Supporting scalability, flexibility and high end-to-end reliability as O&G operations grow, wireless mesh networks can expand effortlessly to cover new areas, equipment, and IoT devices. Adding capacity or coverage is seamless and does not require lengthy planning and costly infrastructure upgrades that fiber demands.

5. Conclusion

AI-driven wireless mesh networks can serve as a perfect solution for offshore O&G remote operations. Supporting low-cost OPEX, wireless mesh technology enables very high-reliability networks that can be reconfigured and self-heal to handle extreme events.

This work is supported by UNITY-6G project, funded from European Union's Horizon Europe Smart Networks and Services Joint Undertaking (SNS JU) Research and Innovation Programme under Grant Agreement No 101192650.

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