

Connected Mine: Unlocking Efficiency with Private 5G



Architecting Secure, Low-Latency Wireless Networks for Mission-Critical Excavation

Modern mining operations are rapidly evolving into highly automated, data-driven ecosystems that demand connectivity far beyond the capabilities of legacy mine networks. To enable autonomous haulage, real-time analytics and enhanced worker safety, the industry is embracing industrial-grade Private 5G solutions. Tejas Networks provides a comprehensive 5G private wireless portfolio designed to navigate the rugged topographies and interference-heavy environments of open-pit and underground mines. Our ultra-converged, O-RAN based architecture delivers high-throughput, low-latency connectivity essential for Mining 4.0. This technology has been successfully validated at Northern Coalfields Limited's Amlohri Opencast Coal Mine, where large-scale Private 5G deployment is currently driving operational excellence.



White Paper

Introduction

The mining industry is undergoing a shift toward digitalization and automation, a transition widely referred to as "Mining 4.0." This shift is driven by the need for greater efficiency, improved safety and sustainable practices. Mines are moving away from manual, reactive processes and embracing predictive, data-driven ecosystems.

In this new era, connectivity is no longer just a utility— it has become the lifeline of modern mining. Autonomous haulage systems, remote drilling, connected worker and AI-powered safety protocols all depend on the seamless flow of real-time data. Advanced connectivity solutions are essential to bridge the gap between physical machinery and digital intelligence across vast, remote, and often hazardous mining sites.



Unlike commercial mobile broadband networks that are predominantly downlink-centric, modern mining environments generate substantial uplink traffic from video surveillance systems, drones, connected machinery, environmental sensors, autonomous vehicles, and digital twin platforms. As a result, private 5G networks for mining are often designed with an uplink-throughput-centric approach, leveraging flexible TDD configurations that can be optimized from traditional commercial profiles (up to 80:20 DL:UL) to more balanced or uplink-focused allocations (such as 50:50 or 40:60) depending on operational requirements. This flexibility ensures reliable transport of mission-critical data to edge and cloud platforms for real-time analytics, automation, and safety applications.

Tejas Networks meets this challenge with a robust suite of end-to-end 5G wireless network solutions tailored specifically for the unique rigors of the mining sector. By leveraging O-RAN (Open Radio Access Network) and 3GPP standards, Tejas provides secure, low-latency, and scalable infrastructure that integrates seamlessly with existing operations.

Four Pillars of Next-Generation Mining Connectivity

To unlock the full potential of Mining 4.0, operators must build networks that go beyond basic connectivity. Legacy systems such as Wi-Fi and TETRA (Terrestrial Trunked Radio) are increasingly inadequate, creating bottlenecks that prevent mines from achieving the safety, efficiency and sustainability goals. Modern mining demands a strategic approach to networking, built on four critical pillars:

1. Safety and Security: Mining remains one of the most hazardous industries worldwide, with risks ranging from cave-ins and explosions to toxic air exposure, equipment collisions, and cybersecurity threats.



Requirement: Always-on, real-time monitoring systems that instantly detect hazardous conditions or intrusions and trigger automated alerts or shutdowns. A resilient network is essential to ensure a zero-harm, secure environment.

2. Communications and Operational Efficiency: Fragmented communication and outdated technologies slow down fleet coordination and decision-making, leading to costly delays.

Requirement: A unified, high-performance network that enables real-time communication, automation of drilling and haulage and seamless synchronization of assets—removing human error from routine tasks.

3. Data Management and Analytics: Modern mining equipment generates terabytes of telemetry data every second through extensive IoT sensors. Without intelligent handling, valuable insights are lost.

Requirement: High-bandwidth networks with edge computing to process data locally at the source. This ensures actionable insights in milliseconds, supports predictive maintenance and real-time analytics and scales seamlessly as sensor density and data volumes grow.

4. Environmental Impact and Sustainability: Mining operations carry a significant environmental footprint, often resulting in high carbon emissions and resource wastage.

Requirement: Digital optimization of fleet routes and predictive maintenance to reduce fuel consumption, idle time and unnecessary equipment replacement—helping mines meet sustainability targets.

The Four Connectivity Pillars of Mining 4.0



The Connectivity Gap: Why Legacy Networks Are Falling Short

While the network requirements for Mining 4.0 is clear, the infrastructure needed to support it is difficult to implement with existing technologies. Mines are among the most hostile environments on earth for wireless signals. Open pits change topography daily with every blast, while underground tunnels act like faraday cages, susceptible to extreme interference with rock walls and heavy machinery. For years, operators have tried to bridge this gap by combining Wi-Fi for data, TETRA for voice, and public cellular for everything else. But these legacy technologies were never designed for mission-critical automation. To understand why a shift is necessary, it is important to see where current networks fail to support the four pillars.





Wi-Fi: Mobility Problem

Wi-Fi is designed for offices, not for the demanding conditions of a mine. As workers or autonomous haul trucks move across a pit, connections must hand over seamlessly between access points. But these handovers are often unreliable, and even brief connection interruptions can trigger safety protocols. Wi-Fi's limited range also forces mines to deploy hundreds of mesh nodes, creating a costly and difficult-to-maintain infrastructure in constantly changing terrain.



Public Wireless: Reliability Problem

Mining traffic competes with consumer traffic, leading to unpredictable latency. Remote drilling rigs and autonomous vehicles cannot operate safely if their data is delayed. Beyond performance, routing sensitive operational data through public internet backbones raises serious concerns about cybersecurity and data sovereignty.



Land Mobile Radio/TETRA: Bandwidth Problem

Land Mobile Radio systems such as TETRA remain the industry standard for voice, and they serve that purpose well. But they are fundamentally narrowband and cannot support the heavy data loads modern mining requires—such as real-time video analytics, digital twin telemetry, or massive sensor streams. As a result, they are increasingly obsolete in the context of Mining 4.0.

The Architectural Shift: Private 5G Networks

To truly enable the “Smart Mine,” operators are moving away from this multi-technology patchwork approach and adopting Private Cellular Networks. Unlike public or legacy options, a Private 5G network provides dedicated spectrum—a unified nervous system that covers every inch of the operation.

This is more than an upgrade; it is an architectural shift that solves the connectivity crisis by delivering:

- **Deterministic Latency:** Guaranteed sub-millisecond response times for surveillance and automation.
- **Seamless Mobility:** Cellular technology designed for high-speed movement, ensuring rock-solid connections for people, vehicles and sensors across the pit.
- **Massive Capacity:** Bandwidth to support hundreds of concurrent 4K video streams for AI analytics, while connecting thousands of IoT sensors without congestion.

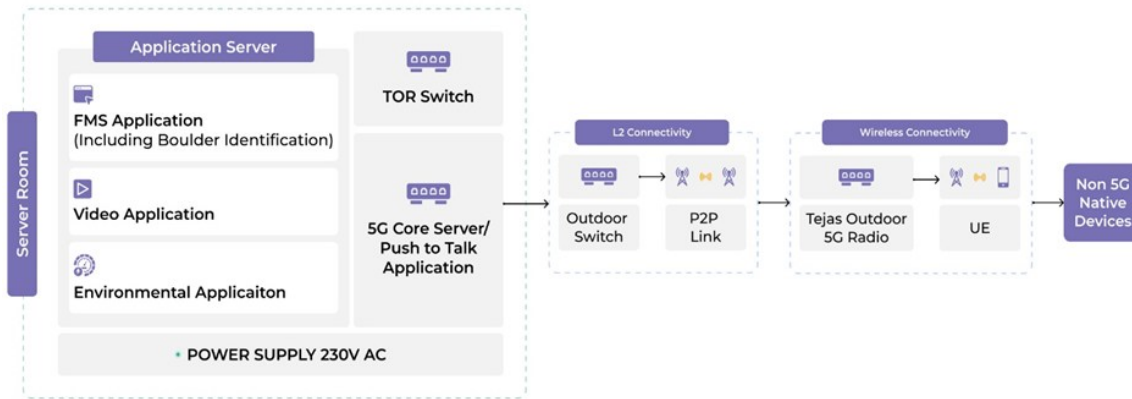
From Pit to Core: Tejas' End-to-End Connectivity Solution

To truly enable the “Smart Mine,” Tejas Networks, together with global partners, delivers a converged, software-defined network stack built for industrial resilience. The solution goes beyond basic connectivity, creating a unified fabric designed for the toughest mining environments.



Leveraging O-RAN and 3GPP standards, Tejas provides secure, low-latency and scalable infrastructure that integrates seamlessly with existing operations—realizing the architectural shift essential for Mining 4.0.

Flexible Radio Units (RU)



Tejas radios support full 3GPP standards with O-RAN options, ensuring flexibility and future-proofing. O-RAN compliance enables a disaggregated RAN architecture with functional splits between the Radio Unit (RU) and Baseband Unit (BBU) offering deployment flexibility and multi-vendor interoperability. Tejas also has Massive MIMO RU options with support up to 64T64R, enabling advanced beamforming and spatial multiplexing. This dramatically increases spectral efficiency, user throughput, and coverage reliability—critical for dense IoT deployments and high bandwidth applications in mining.



Multi-Band Support:

- **Sub-GHz (n28 / 700 MHz):** Deep pit penetration and long-range coverage (up to 15 km).
- **Sub-3 GHz (n41 / 2.5 GHz):** Good balance of coverage and capacity; better penetration into deep pits than mid-band.
- **Mid-Band (n78 / 3.5 GHz):** High capacity for 4K video, drone feeds, and dense sensor zones.

Key Benefits:

- Multi-band, multi-mode RU options (4G, 4G with 5G upgrade, 5G SA; FDD/TDD).
- Avoids vendor lock-in through O-RAN interoperability.



- Optimized coverage and capacity, dimensioned for growth—supporting 10x IoT expansion, peak concurrent HD video sessions, and URLLC control loops for advanced automation.

5G Core for Intelligent Network Slicing & QoS Management

The Tejas in-house Cloud-Native TJ9500 5G Core, enables precise control over network resources through Network Slicing. Operators can partition the network into multiple virtual segments, each optimized for specific applications. Resources such as bandwidth, latency, and processing power are dynamically allocated based on application criticality.

Benefits:

- **Guaranteed Performance for Mission-Critical Applications:** Ensures that crucial applications like emergency stop signals or autonomous vehicle controls always receive the highest priority and lowest latency, regardless of network load from less critical traffic.
- **Enhanced Security:** Each slice can have its own isolated security policies, preventing potential breaches in one slice from affecting others.
- **Resource Efficiency:** Prevents over-provisioning by allocating resources only as needed, leading to more efficient use of network infrastructure.

Edge Computing Enablement for Real-Time Intelligence & Data Sovereignty

To achieve true real-time decision-making in mining, data must be processed as close to the source as possible. Our converged network architecture is designed to support and integrate edge computing deployments seamlessly.

Capabilities Enabled by Tejas Architecture:

- **Local Data Processing:** Compute resources can be co-located with Tejas BBUs or aggregation sites, allowing sensor, camera and machine data to be processed directly on-site.
- **Ultra-Low Latency Analytics:** By minimizing backhaul to centralized clouds, latency is reduced—critical for AI-driven applications such as anomaly detection, predictive maintenance and collision avoidance.
- **Data Sovereignty & Security:** Sensitive operational data can remain within mine premises, supporting regulatory compliance and enhancing cybersecurity posture.
- **Reduced Backhaul Costs:** Less data transport off-site translates into significant savings in bandwidth and operational overhead.
- **MEC Applications:** The architecture supports integration with edge applications such as real-time video analytics, telemetry processing, autonomy control loops, AR/VR streaming for maintenance, and local anchoring for Push-to-Talk (PTT) and video services.

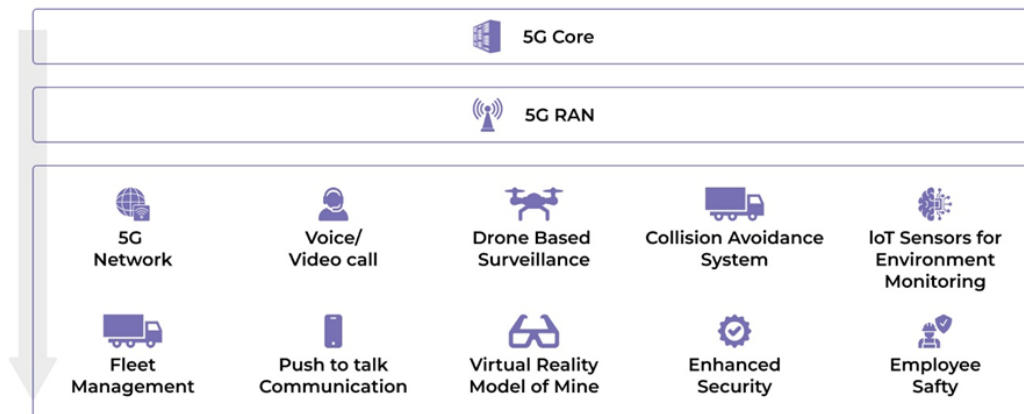


Comprehensive Management, Security & Support

Tejas along with its partners, delivers an end-to-end solution that extends beyond physical infrastructure, encompassing robust management, security, and lifecycle services to ensure continuous, reliable operation.

- **Resilience & Timing:** Redundant xHaul, SyncE/GNSS with PTP fallback, hardened sites for dust, heat, and vibration.
- **Lifecycle Services:** Feasibility studies, RF surveys, phased rollouts, FAT/SAT testing, NOC support, SLA management, firmware lifecycle and 24x7 assistance.
- **OSS/BSS & Integrations:** AI-driven RAN optimization, predictive energy management, capacity forecasting, and northbound APIs for integration with FMS/SCADA and digital twin platforms.
- **Device & Ecosystem Partnership:** To provide certified rugged 5G/4G handsets, MC-PTT devices, vehicle gateways, OEM integration kits (CAN/OBD/Modbus), Video Management System (VMS), Computerized Maintenance Management System(CMMS) and digital twin services.

Overall Benefits & Business Outcomes



Deploying the Tejas Private 5G solution delivers a range of quantifiable benefits, directly addressing the core challenges of Mining 4.0:

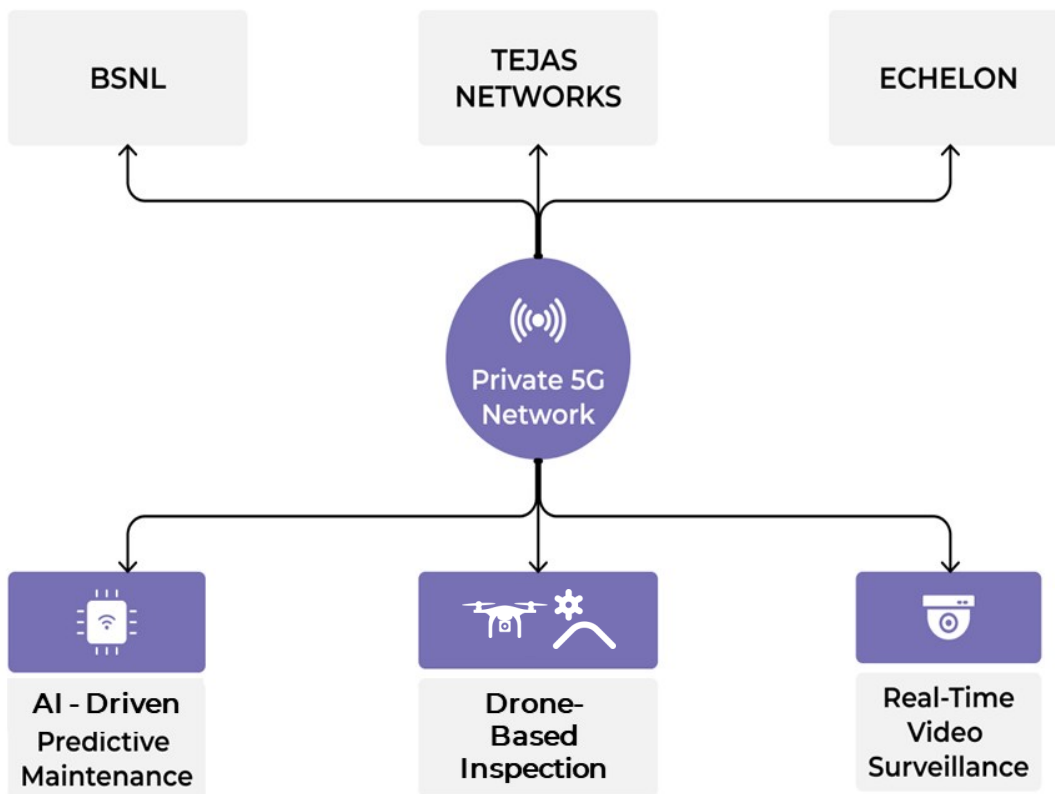
- **Deterministic Performance:** Achieves 5 ms ~ 50 ms latency for tele-remote control and autonomous operations, far exceeding the capabilities of legacy networks.
- **High Availability:** Designed to deliver 99.999% mission-critical uptime, ensuring continuous operations even in the harshest conditions.
- **Massive Scalability:** Supports thousands of sensors and hundreds of concurrent HD/4K video streams without congestion, enabling exponential IoT growth.
- **Reduced Total Cost of Ownership (TCO):** Converged hardware and single-vendor integration reduce both CAPEX and OPEX, offering 30–40% savings compared to fragmented, multi-vendor solutions.



- **Faster Time to Value:** Phased pilots and rapid integration with third-party cores accelerate deployment, bringing operational benefits online sooner.

Tejas Private 5G in Action: Amlohri Opencast Coal Mine

The Amlohri Opencast Coal Mine stands as a landmark in India's digital mining journey and a testament to the transformative power of Tejas Networks' indigenous Private 5G solutions. In 2024, Northern Coalfields Limited (NCL), a subsidiary of Coal India Ltd., partnered with BSNL, Tejas Networks and Echelon Edge to deploy India's first large-scale Private 5G Standalone (SA) network in a mining environment. This pioneering deployment validated the ability of 5G to operate flawlessly in one of the harshest industrial settings and deliver measurable business outcomes.



Project Overview

Client: Northern Coalfields Limited (NCL), Coal India Ltd.

Location: Singrauli, Madhya Pradesh, India

Site Dimensions: ~780 hectares of rugged, actively mined terrain

Partners: BSNL, Tejas Networks and Echelon Edge

Objective: Transform a traditional coal mine into a digitally enabled, automated ecosystem under BSNL's CNPN framework



Unique Challenges at Amlohri

The Amlohri site presented a “worst-case” scenario for wireless networks, pushing the boundaries of conventional connectivity:

- **Dynamic Topography:** Constant excavation and blasting reshaped the terrain daily, creating shifting signal shadows and dead zones across deep pits and haul roads.
- **Extreme Environmental Stress:** Temperatures exceeding 50°C, pervasive coal dust, high humidity, and continuous vibration from heavy machinery and blasting shockwaves tested network resilience.
- **Mission-Critical Operations:** Applications such as autonomous haulage, collision avoidance, and remote drilling demanded zero tolerance for latency or downtime—any disruption could pose safety hazards, environmental risks, or costly production halts.

Deployment & Solution Highlights



Tejas Networks, in collaboration with its partners, deployed a robust and resilient Private 5G SA network specifically engineered for Amlohri's unique demands.

- **Private 5G Rollout:** Dedicated 5G SA network designed for rugged terrain and interference-heavy conditions.
- **Seamless Integration:** Supported autonomous haulage, remote drilling, and connected worker systems alongside existing operations.
- **Performance Validation:** Benchmarks confirmed sub-50 ms latency, high throughput, and reliable coverage across pits and haul roads.
- **Optimized Radio Placement:** n41 (2.5 GHz) for deep pit penetration and haul road coverage; n78 (3.5 GHz) for high-capacity zones.
- **Edge Computing Integration:** Localized servers processed critical data on-site, minimizing latency and ensuring data sovereignty.

Transformative Applications

The Tejas Private 5G network transformed Amlohri into a fully connected ecosystem, enabling a range of applications that significantly enhanced safety, efficiency and sustainability:



AI-Driven Predictive Maintenance



Smart Helmets & Connected Worker Safety



Real-Time Video Analytics & Surveillance



Drone-Based Inspections & Digital Twins



Autonomous Haulage Systems (AHS) Readiness

Strategic Significance and Impact

- **Proof of Concept:** Indigenous Private 5G SA networks can deliver deterministic performance and resilience in one of the harshest industrial environments.
- **Mining 4.0 Enablement:** Provided the digital backbone for automation, predictive maintenance, connected worker safety, and real-time analytics.
- **National Impact:** Aligned with Atmanirbhar Bharat, showcasing how homegrown technology can power strategic industries.
- **Replicability:** Established a scalable model for digitizing other mines across India and globally.



30%reduction in unplanned equipment
downtime**25%**

improvement in fleet utilization

20%

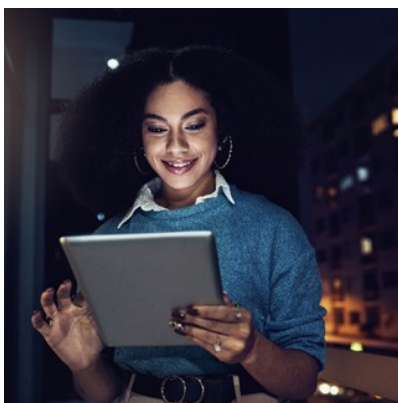
lower fuel consumption and emissions

>99.999%reduction in unplanned equipment
downtime**Zero**major safety incidents post-
deployment**Source:** As per internal estimates

Conclusion: Charting the Path Forward for Digital Mining

The transition to automated, data-driven mining is not just an aspiration—it's an imperative for survival and growth in a rapidly evolving global economy. As we have explored, the limiting factor for realizing the full potential of Mining 4.0 is no longer the machinery itself, but the robust, intelligent network that connects it.

Tejas Networks offers a proven, industrial-grade Private 5G solution that effectively bridges the gap between physical excavation and digital intelligence. Validated by the groundbreaking success at the Amlohri Opencast Coal Mine, our indigenous, ultra-converged architecture delivers the ultra-low latency, unwavering reliability, and robust security essential for mission-critical operations. By choosing Tejas, mining enterprises gain not only a future-proof, cost-efficient network built with O-RAN flexibility, but also a strategic partner dedicated to empowering smarter, safer, and more sustainable mining practices through unparalleled innovation and battle-tested resilience.



Tejas Networks

Tejas Networks is a global broadband, optical and wireless networking company, with a focus on technology, innovation and R&D. Tejas' carrier-class products are used by telecom service providers, utilities, government, and defense networks in 75+ countries. To know how we can help you fulfill your business objectives, contact us today!

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