WHITE PAPER

5G Network Empowering Intelligent Upgrade in Mines

DINGLI 5G Private Network Testing & Optimization Solutions

DingLicom

Introduction

The mining industry is facing numerous challenges, including harsh underground working environments, high dust concentrations, and complex equipment wiring. These conditions result in poor coordination among various control and monitoring systems, leading to frequent “information silos.” Additionally, choppy high-definition video transmissions and data security risks significantly hinder production efficiency and safety management.

To address issues such as high labor costs, inconsistent workforce quality, and frequent accidents, mining enterprises urgently need to adopt intelligent and standardized approaches that enable real-time monitoring and precise control throughout the entire process. Centering on smart mining equipment and leveraging high-speed, high-capacity bidirectional digital communication networks has become an inevitable trend in industry transformation.

With its low latency, high bandwidth, high reliability, and massive connectivity, 5G technology offers a novel solution to overcome the communication challenges in mining operations. By implementing a 5G private network tailored for mines, enterprises can establish efficient communication links among devices, eliminate information silos, and ensure the stable transmission of high-definition video and equipment status data. This robust network foundation paves the way for AI-driven intelligent analytics and remote control.

This white paper explores typical mining application scenarios and network requirements while demonstrating how Dingli's private network testing and monitoring solutions can facilitate the efficient deployment and reliable operation of 5G private networks, accelerating the journey towards a digital and intelligent future.

Mining Application Scenarios

Open-Pit Mining

Encompasses remote control of open-pit mining equipment as well as unmanned truck operations on the surface.

Underground Mining

Covers unmanned underground extraction operations, information collection from underground equipment, and AI-driven high-definition inspection applications.

Typical Application Scenarios and Network Technical Requirements

1. Remote Control of Open-Pit Mining Equipment

Remote control is achieved by installing remote control systems and monitoring equipment on devices such as drills, electric shovels, etc., enabling the remote operation of open-pit mining machinery.

System Requirement

The remote control system must operate under various environmental conditions. Cameras should deliver real-world 3D data at 4K resolution or higher, with capabilities for video data processing. Additionally, the system must support the collection of multiple signal types and precise positioning functionalities.

Table 1: Network Technical Requirements for Remote Control of Open-Pit Mining Equipment

Business Scenario	Typical Application	Uplink/Downlink Speed	End-to-End Latency
Remote control of open-pit mining equipment (e.g., drills, electric shovels, hydraulic shovels, excavators, dump trucks, road graders, bulldozers, etc.)	Remote operation monitoring of open-pit mining equipment (2-4 cameras, recommended 4K resolution)	Uplink: ≥12 Mbps per channel Downlink: ≥100 Kbps per channel	≤100 ms
Equipment-based remote control	Upload: 1-2 Mbps per device Downlink: ≥100 Kbps per channel	≤20 ms	
Vehicle-based remote control	Uplink: ≥10-14 Mbps per vehicle Downlink: ≥100 Kbps per vehicle	≤20 ms	

2. Surface Unmanned Truck Operations

The aim is to establish an autonomous driving system to enable the automated transportation of mined materials, thereby reducing human involvement and enhancing safety. In mining operations, unmanned truck services require ultra-low latency and the high bandwidth and low latency capabilities of 5G to support simultaneous communication among multiple vehicles.

Table 2: Technical Requirements for Surface Unmanned Truck Operations

Scenario Category	End-to-End Latency	Uplink Speed	Downlink Speed
Autonomous Trucking	≤20 ms	≥2-4 Mbps per vehicle	≥100 Kbps per vehicle

3. Underground Unmanned Mining

By equipping unmanned mining equipment with remote control systems and video surveillance devices, remote commands can be transmitted to facilitate underground mining operations. This approach reduces the number of personnel required in the underground working area, thereby enhancing the intelligence and safety of underground extraction. In such scenarios, both uRLLC and eMBB 5G use cases are employed, requiring high uplink and downlink speeds.

Table 3: Network Technical Requirements for Underground Unmanned Mining

Scenario Category	End-to-End Latency	Uplink Speed	Downlink Speed
Underground Unmanned Mining	≤50 ms; recommended latency ≤20 ms	≥4 Mbps per channel	≥100 Kbps per channel

4. Underground AI High-Definition Video Monitoring

This application utilizes high-definition video to monitor equipment operating conditions and personnel activities, enabling intelligent regulation between personnel and mobile equipment as well as oversight of operational processes. Underground AI HD video monitoring demands the high uplink and downlink speeds offered by 5G and can be further enhanced with edge computing capabilities as needed.

Table 4: Network Technical Requirements for Underground AI High-Definition Video Monitoring

Scenario Type	End-to-End Latency	Uplink Speed	Downlink Speed	Notes
Underground AI HD Video Monitoring	≤20 ms	≥8 Mbps per channel	≥100 Kbps per channel	• Supports ring network configuration and network redundancy, enabling direct connections and wireless networking among multiple base stations. • The backbone network should have a bandwidth of no less than 10,000 Mbps. • It is recommended to allocate a separate VLAN or establish a dedicated monitoring network.

Mining 5G Private Network Requirements

In mining scenarios, harsh environments, complex terrains, and diverse application needs impose exceptionally high demands on the network. The specific requirements include:

1. High Performance and Low Latency

Real-Time Control and Monitoring

Remote control of equipment (such as drills, electric shovels, excavators, etc.) and autonomous mining trucks requires millisecond-level response times to ensure timely transmission of operational commands.

High-Definition Video Transmission

For underground AI HD monitoring and remote video guidance, the network must support real-time transmission of video streams at 4K resolution or higher to guarantee image quality and stability.

2. High Capacity and Multi-Service Integration

Simultaneous Multi-Terminal Access

Mining sites are equipped with numerous sensors, cameras, and control devices. The network must be capable of handling large-scale data transmissions concurrently without congestion.

Mixed Traffic Transmission

It should support the simultaneous operation of various services—including remote control, autonomous driving, equipment data collection, and HD video monitoring—by dynamically allocating and optimizing network resources.

3. High Capacity and Multi-Service Integration

Complex Terrain Coverage

Environments such as underground tunnels, mine galleries, and open-pit areas present significant challenges for signal penetration and coverage. The private network must offer robust penetration capabilities and broad coverage.

Interference Resistance and Stability

In environments with high dust levels, fluctuating temperature and humidity, and severe multipath interference, the network must ensure stable signal transmission and reliable system performance.

4. Coverage and Environmental Adaptability

Data Security Assurance

End-to-end encryption, firewalls, VPNs, and other security measures must be implemented to protect critical mining data and operational commands from being intercepted or tampered with.

Protocol Compatibility and System Integration

The network should support common industrial communication protocols such as CAN, RS485, and RS232, ensuring seamless connectivity among automated devices, monitoring systems, and management platforms.

5. Intelligent Management and Remote Monitoring

Real-Time Monitoring and Early Warning

Leveraging edge computing and cloud platforms, the network should enable real-time monitoring of equipment status, network performance, and potential faults, providing timely risk alerts to safeguard mining operations.

System Disaster Recovery and Automatic Switching

In the event of network interruptions or anomalies, the system must be capable of rapid switching, data backup, and local storage to ensure uninterrupted business continuity.

Mining 5G Private Network Testing Challenges

Given the unique demands of mining 5G private networks, the testing phase encounters several major challenges:

1. Coverage Testing in Complex Environments

Underground and Tunnel Testing

In mine galleries and other underground complex terrains, severe multipath interference, signal attenuation, and physical obstructions necessitate comprehensive coverage verification in real-world conditions.

Dynamic Scenario Testing

During open-pit mining and underground extraction, equipment locations constantly change. Testing teams must ensure that signal stability and continuous coverage are maintained even under mobile conditions.

2. Verification of Low Latency and High Bandwidth Performance

Real-Time Control Testing

For remote-controlled equipment and autonomous driving systems, tests must accurately measure end-to-end latency at the millisecond level to ensure prompt and reliable command transmission and feedback.

HD Video Transmission Testing

Evaluating the stability of 4K video streams under high data loads and concurrent usage is essential, with particular attention to packet loss rates, latency fluctuations, and data integrity.

3. Large-Scale Concurrent and Multi-Service Scenario Testing

Multi-Device Access Testing

Simulating scenarios where a multitude of devices concurrently access the network helps verify its stability and throughput under high traffic and distributed access conditions.

Mixed Traffic Collaboration Testing

When remote control, video monitoring, data collection, and other services operate simultaneously, it is crucial to assess the network's resource scheduling and load balancing capabilities to ensure that different services do not interfere with one another.

4. Environmental Adaptability and Long-Term Stability Testing

Harsh Climatic and Industrial Environment Testing

In mining environments characterized by high dust levels, high humidity, and drastic temperature fluctuations, both the testing equipment and the network must demonstrate long-term stability and robust interference resistance.

Continuous Operation Verification

Extended continuous testing is necessary to evaluate the network's durability under extreme conditions, ensuring high availability and reliable performance in critical application scenarios.

5G Private Network Testing Solutions

Due to the high complexity of 5G network architectures, rigorous testing at every deployment stage is critical. This not only accelerates network preparation, deployment, and operation but also ensures outstanding performance and stability across all business scenarios.

1. Rollout Preparation

Requirements Research and Planning

Conduct in-depth research into private network needs based on actual mining and other complex scenarios, clearly defining key metrics and performance requirements.

R&D and Validation

Utilize laboratory testing platforms (such as Pilot Pioneer) to develop, validate, and certify the private network infrastructure, ensuring that network parameters and performance metrics meet expected standards.

2. Acceptance

On-Site Deployment Acceptance

During the network deployment phase, employ devices like Pilot Scout and Pilot Walktour to monitor real-time signal coverage, data transmission performance, and interference resistance across various areas.

Protocol and Interface Testing

Thoroughly test industrial protocols (e.g., CAN, RS485, RS232) and security mechanisms to ensure seamless interconnectivity among all devices and systems, thereby meeting the acceptance criteria.

3. Performance and Service Level Verification

Real-Time Performance Testing

Use Pilot Matrix to comprehensively test critical business scenarios—such as remote control, high-definition video monitoring, and equipment data collection—to verify that end-to-end latency, uplink/downlink speeds, and throughput meet business requirements.

Service Level Verification

Under conditions of multi-terminal concurrent access and mixed service operations, perform rigorous testing to validate the network's high reliability and stability, ensuring continuous, robust operation in real production environments.

4. Troubleshooting

Fault Identification and Resolution

Leverage comprehensive test data to promptly identify and locate network faults. Simulate various abnormal scenarios and evaluate functions such as automatic switching, data backup, and recovery to ensure rapid system recovery in case of faults.

Continuous Optimization

Based on troubleshooting insights and on-site monitoring data, continuously optimize network parameters and deployment strategies to enhance overall network stability and service quality.

1.BUILD

Research, develop, validate, and certify private network infrastructure

2.DEPLOY

Deploy, optimize, and facilitate acceptance of your private network

3.RUN

Monitor, secure, optimize and assure your private network

5G Private Network Testing Solutions

In mining environments, the challenges of complex underground terrains, difficult signal penetration, harsh conditions (high dust levels, elevated humidity, and wide temperature variations), and the need to support multiple services (such as remote control, HD video monitoring, and equipment data collection) impose higher requirements on 5G private networks.

To address these challenges, Dingli offers a comprehensive product portfolio that ensures stringent testing and performance optimization at every stage—from network construction and deployment to operation.

1. Pilot Pioneer – Comprehensive Network Testing and Optimization Solution

Product Features

- End-to-End Testing Coverage: A single software platform that handles station validation, performance testing, and fault troubleshooting.
- Integrated Laboratory and Field Testing: Capable of simulating real mining scenarios to validate network performance under conditions of low latency, high bandwidth, high capacity, and multi-service integration.

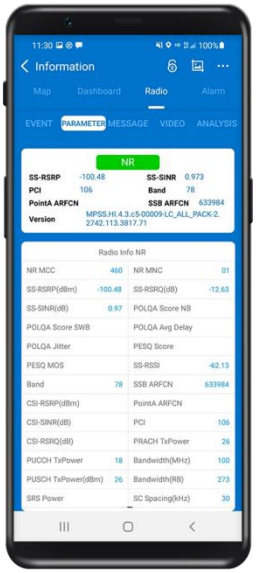
Test Cases

- Prior to deployment, Pilot Pioneer is used for R&D, testing, and certification of the private network infrastructure to ensure that base station coverage, signal penetration, and device interoperability meet design requirements in both complex underground and open-pit environments.
- For critical applications such as remote control and HD video transmission, it provides real-time measurements of end-to-end latency, uplink/downlink speeds, and packet loss, offering precise data to support subsequent field deployment.

2. Pilot Walktour – Portable Handheld Network Testing Solution

Product Features

- Portability and Efficiency: A handheld device that enables maintenance personnel to conduct routine on-site tests and rapid fault diagnosis.
- Environmental Adaptability: Built to withstand the harsh conditions of mining sites, including high dust levels, humidity, and vibrations.



Test Cases

- Field engineers can use Pilot Walktour to monitor signal coverage, data transmission quality, and overall network stability in both underground and open-pit areas in real time.
- During equipment inspections, base station adjustments, or preliminary fault diagnosis, it provides swift response and on-site optimization, ensuring that the mining private network remains in optimal operational condition.

3. Pilot Scout – 24/7 Continuous Network Monitoring Solution

Product Features

- Round-the-Clock Monitoring: Supports continuous 24-hour monitoring and real-time data collection on network status.
- Remote Control Capability: Allows remote adjustment of testing instrument settings, enabling centralized management and tuning.

Test Cases

- Deployed in complex underground tunnels and open-pit areas, Pilot Scout enables real-time network monitoring across the entire network, promptly identifying weak signal zones, interference issues, and performance fluctuations.
- The remote monitoring platform automatically reports faults and anomalies, allowing the operations center to quickly intervene, thereby reducing production risks and lowering maintenance costs.

4. Pilot Fleet Edge – Server-Based or Cloud Platform Post-Processing Solution

Product Features

- Centralized Data Processing: Supports large-scale data aggregation and analysis from multiple test points, providing real-time monitoring across the entire network.
- Intelligent Alerting and Remote Control: Enables remote control of testing instruments through the platform, promptly reporting network fault alerts and performance anomalies.

Test Cases

- In the long-term operation of mining private networks, Pilot Fleet Edge aggregates data collected by on-site testing instruments to facilitate centralized monitoring and comprehensive data analysis of network performance.
- Leveraging big data analytics and intelligent early warning functions, it provides decision-making support for network maintenance, optimization, and expansion, ensuring that critical services—such as remote control and HD video monitoring—continue to operate reliably and stably.

This comprehensive suite of 5G private network testing solutions ensures that mining enterprises can confidently deploy, monitor, and maintain robust networks, thereby driving the digital and intelligent transformation of the mining industry.

Solution Highlights

- Full Process Coverage

  From early-stage network R&D and pre-deployment testing to on-site acceptance, long-term monitoring, and fault troubleshooting, every stage is backed by professional testing methods.

- Efficient Collaboration

  Multiple products work in synergy, seamlessly integrating laboratory testing data with on-site monitoring insights to ensure that the network maintains high performance even in extreme environments.

- Intelligent Management

  Utilizing cloud platforms and edge computing technologies, the solution enables real-time data collection and analysis, automated alerts, and remote control capabilities—reducing maintenance costs and enhancing network operational safety and reliability.

Summary

With this comprehensive "Build-Deploy-Run" end-to-end testing approach, the Dingli 5G mining private network testing product suite delivers comprehensive, precise, and intelligent network testing and monitoring support for smart mine construction, ensuring efficient, safe, and reliable network operations in complex mining environments.

In such challenging conditions, the Dingli 5G private network testing solution effectively overcomes industry pain points—such as information silos, signal attenuation, and insufficient real-time responsiveness—thus providing a solid foundation for the intelligent upgrade of mining operations. Moving forward, we will continue to lead technological innovation, driving mining production towards a future of enhanced safety, efficiency, and intelligence.

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Empower a connected future

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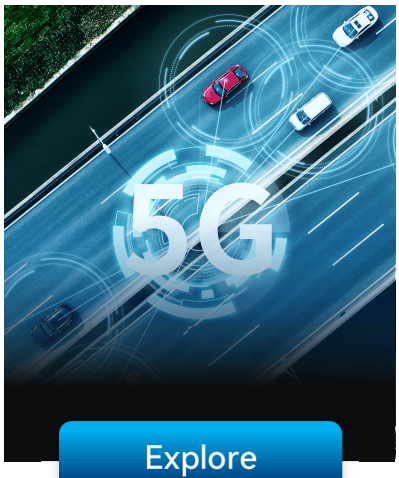
Discover more use cases

Access more cases and learn how Dingli's solutions can address your network testing project challenges in real-life.

Explore

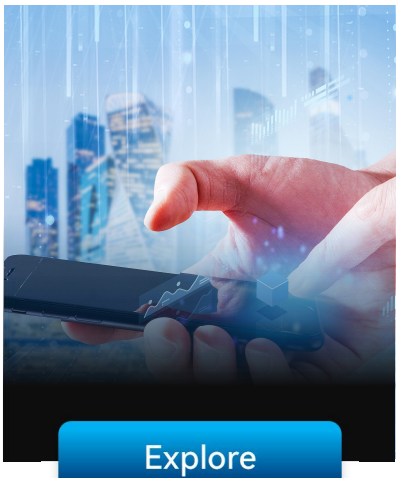
Find out our product offerings to elevate your network management

Drive Testing



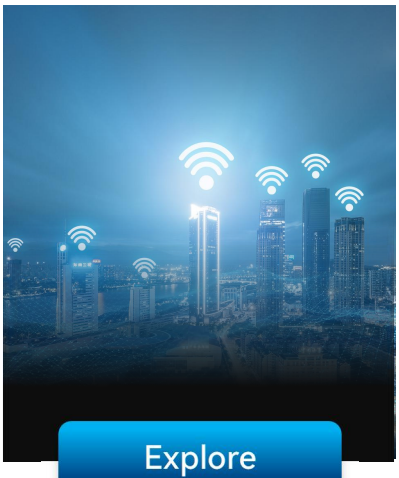
Explore

Portable Testing



Explore

Benchmarking



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