This white paper explains how DISH’s private 5G wireless network technology can enable a system-wide digital transformation to an autonomous, intelligent, and most of all, safe mining industry of the future.
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Executive Summary

Industry 4.0 is the fourth industrial revolution that involves the digitization and automation of enterprise end-to-end operations to drive efficiency, scale and innovation at an unprecedented pace. One industry at the core of this revolution is mining, where investments in new technologies like wireless, edge computing and teleoperations are required to increase productivity, reduce operational downtime, minimize environmental impacts and ensure the highest level of safety.

The vast array of minerals produced by the mining industry are essential to our modern way of life. Continuous advances in automation have more than doubled production at mines to meet the huge market demand, but the industry is still plagued by excessive operational costs and capital expenses (as high as $1M per worker and $6M per haulage truck). These factors demand the mining industry look for 100x higher efficiencies per ton delivered. [1]

While enhanced efficiency and optimization are primary goals, the hazardous nature of mining environments also mandates greater emphasis on worker safety, which has created an unprecedented demand for digitizing, automating and optimizing all operations. [1]

Improvements of this scale can only be delivered through significant change to the entire mining process from pit-to-port, enabled by the deployment of next-generation wireless technology. DISH stands ready to power the next evolution in mining by delivering the following three critical elements:

- **Flexible and Dynamic Connectivity**
- **Mission-Critical Performance**
- **Advanced Technology Enablement**

These three elements power the required innovations and enhancements, including functional automation and autonomy, connected workers, remote operations, integrated platforms, machine intelligence, advanced sensing, analytics and data-driven decision support.

DISH wireless 5G technology can deliver a single network that will drive mission-critical innovation and optimized efficiencies into the entire value chain. This revolutionary network will enable mining operations of the future to produce significant tonnage in a safer environment while delivering substantial value to stakeholders.
The Case for Next Generation Wireless

Each stage of the mining process has unique requirements and can benefit from the implementation of a customizable wireless network that can support all mission-critical operations, both today and well into the future.

The development of open pit or underground mine sites is a complex undertaking, fraught with risk to both personnel and the mining enterprise. Successful site exploration and selection requires a massive data analysis effort. The ore extraction process of blasting, drilling, hauling and processing requires secure, real-time communications that drive advancements in automation and autonomy. Transportation from pit-to-port requires multi-site communications, data-driven logistical decisions, IoT remote sensing and augmented intelligence to fully optimize the cost per ton of ore extracted.

Current connectivity solutions, such as Wi-Fi and private LTE, lack the advanced capabilities mining companies need to succeed in the industry. Instead, legacy technologies have become bottlenecks in the supply chain, resulting in loss of productivity and efficiency.

Wireless 5G network technology offers mining operators substantial improvements, delivering operational, financial and safety benefits not provided by standalone Wi-Fi or LTE. Deploying wireless 5G network technology across the entire value stream enables mine operators to significantly reduce costly network downtime while improving the ongoing operations from pit-to-port, yielding increased return on invested resources. Figure 1 outlines how DISH’s 5G network technology can enable the full suite of advancements the mining industry requires to achieve the next level of safety, efficiency and profitability.

The future mining network must support converged wireless and wireline access with high-bandwidth fiber connectivity, both within and between mine sites, as well as remote command centers that may be located thousands of miles away. Since many of the future mining connectivity needs are distributed over a wide area and require mobility, networks based on wireless 5G technology are ideally positioned to handle the full host of demanding performance requirements. DISH 5G wireless solutions can operate using licensed or unlicensed spectrum, support the service requirements for voice, sensor data and video, and are designed to meet future bandwidth and latency requirements for autonomy, advanced cognition and real-time teleoperations.
Figure 1 - Mining Advancements Enabled by DISH 5G Network Technology
Flexible and Dynamic Connectivity

Open-pit and underground mine sites, along with the pit-to-port logistics chain, consist of sprawling areas that continuously evolve throughout their lifetime. This large scale ecosystem demands a connectivity solution that can adapt dynamically.

Constant changes to machinery, personnel and site topography bring significant disruption to the production process and connectivity architecture. To provide the required, mission-critical communications for both personnel and machines while improving safety, productivity and efficiency, the network must offer immense flexibility in its deployment, be rapidly reconfigurable and dynamically scalable to meet current and future needs. See Figure 2. These requirements can be fulfilled with the implementation of DISH 5G wireless technology.

Flexibility

Due to the large acreage of typical mining operations, wireless connectivity using 150+ Wi-Fi access points for complete coverage is not uncommon. However, modern wireless technology allows for the same network coverage to be achieved with only a few 5G cells that offer better signal coverage, cost savings and installation flexibility. The spectral diversity and power output advantages of DISH 5G mean specific frequencies can be leveraged for the best performance under specific operating conditions.

Dynamic Scalability

Connectivity is a key resource across the entire mining ecosystem, and it must be ready to scale up or down with no operational impacts as needs evolve. Therefore, the network used by mines of the future must be seamlessly dynamic and have the ability to meet all levels of potential access requirements. Opening new areas while closing out others, adding new machinery and sensors and implementing new capabilities like drones and teleoperations requires an agile network that can adapt to satisfy ever-changing demands.
The virtual nature of DISH’s 5G wireless technology is ideally suited to this challenge, allowing for seamless, efficient changes to be made via its cloud-native network architecture.

**Simplicity**

Currently, mining operators use a diverse set of technologies to meet their connectivity needs. Personnel communicate via Land Mobile Radio (LMR) and Project 25 (P25) for Push-to-Talk (PTT). Wi-Fi is used for local enterprise connectivity and to support mission-critical operations. Commercial services from wireless operators connect handheld devices, like smartphones and tablets, and some mining companies are deploying private LTE networks and considering low-power, wide-area network technology for sensor connectivity. These legacy systems quickly become prohibitive, with high procurement costs and complex management requirements. In addition, they often do not truly offer the required performance to support advanced applications. Alternatively, a single point (indoor/outdoor) solution based on DISH’s 5G wireless technology offers an elegantly simple path to meet all connectivity requirements, both now and in the future, across the complete range of pit-to-port operations.

**Seamless Integration**

Many view wireless 5G and existing wired/wireless solutions as competitors, but in reality it’s quite the opposite. For example, DISH’s wireless 5G can be deployed to not only work with existing solutions, but also enhance the network to create a more robust and reliable connectivity architecture. A 5G wireless network can seamlessly integrate with existing wired, Wi-Fi and other unlicensed, low-power protocols for IoT devices. The result is a simplified, integrated network solution that can be controlled from a single management platform, leverages the best of all solutions, maximizes prior investments and enables new use cases. DISH is working with industry-leading partners to develop and deploy comprehensive 5G wireless connectivity solutions that are flexible, dynamic and simple to integrate. These solutions are designed to scale easily and quickly to meet the ever-changing needs of the mining industry. DISH 5G wireless connectivity is the next-generation network architecture that can deliver the desired mission-critical improvements, production efficiencies and cost reductions across the full spectrum of current and future mining operations.
Figure 2 - Distributed Mining Ecosystem and Mission-Critical Network Architecture

- IoT Sensor Networks
- Autonomous Operations / Equipment
- Small Cell Network
- Drone Surveillance / Surveys
- Process Optimization
- Mission-Critical Comms (PTT)
- Digital PPE / Health Monitoring
- Edge Compute / Cognition Systems (AI / ML)

- IoT Sensor Communications
- Current / Future Trains and Trucks
- Logistics / Process Optimization
- Cognition Systems (AI / ML)

- IoT Sensor Communications
- Trains and Truck Offload Ops
- Crane / Slipping Load Ops
- Human / Dock Ops
- Logistics / Process Optimization
- Cognition Systems (AI / ML)
Mission-Critical Performance

The mine of the future will require reliability, bandwidth, low-latency and high fidelity representations of physical mine assets in the digital domain. It will need to support a wide range of capabilities.

Mines prioritize safe operations for both personnel and equipment with the goal of eliminating all accidents, injuries and fatalities. The mine of the future must be absolutely secure, eliminate system downtime and deliver tonnage on demand with 100x greater efficiency than current operations. A network based on 5G wireless technology can satisfy these key, mission-critical requirements, and that network must be capable of simultaneously delivering multiple, customized Quality of Service (QoS) levels that match each unique application as summarized in Figure 3.

Customizable Performance

5G radio technology offers greater spectral efficiency than LTE or Wi-Fi, meaning it can deliver greater data throughput, faster speeds, lower latency and more reliable communications. At the mine site and across the pit-to-port ecosystem, unique applications demand different QoS guarantees. Communications from sensors for machine health, diagnostics, position reporting and process control all require low bit rate with moderate-to-high latency being acceptable. On the other hand, on-demand video, teleoperation, drone reconnaissance and augmented reality all require high bit rate and low latency. Digital PPE for personnel health and safety monitoring requires low bit rate and latency. DISH’s 5G wireless technology can satisfy these diverse application requirements in several ways, including the ability to dynamically provision and partition a set of network services, functions and resources tailored to the specific application. This is the essence of network slicing. Instead of overlaying disparate dedicated networks for PTT, slicing allows the networking, storage and computational needs for all these services to be dynamically
managed with a single network. For example, one slice can provide a minimum required data throughput for high-bandwidth use cases such as drones or video surveillance, while another slice provides a high level of network availability and reliability for remote operation of drilling equipment.

Available, Reliable and Resilient

Ideally, connectivity across the ecosystem would be 100% available. This means the system must rarely break down. If a breakdown occurs, the 5G network will diagnose and heal itself quickly and efficiently with little or no human intervention. 24/7 operations, the holy grail of the mining industry, can only be achieved by deploying a 5G wireless network that supports mission-critical initiatives. Wi-Fi-based networks require trailer-mounted access points (150+ for a typical mine site). The same area could be covered by fewer than ten 5G wireless macro cells. Less equipment needs less maintenance, and that results in less total system downtime. Also, Wi-Fi equipment cannot be deployed inside blast zones and must be relocated whenever blasting needs occur. If Wi-Fi systems must be relocated repeatedly, and new site planning is required each time, the resulting operational downtime, additional cost and hazard exposure can be significant. Again, the superior performance and flexibility of 5G wireless technology does not result in similar downtime or cost because macro cells can be deployed outside blast zones. Handoffs with 5G wireless are also much more reliable, because the system is built for mobility. If a loss of connectivity occurs, which often happens with Wi-Fi, autonomous vehicles stop operating to ensure safety. This gradually escalates into system-wide stoppages of vehicles and production, requiring manual intervention before operations can be restarted. With DISH 5G, such stoppages are avoided, leading to increased productivity and significant per-ton cost reductions.

5G-Grade Security

DISH 5G wireless technology improves on the security shortcomings of previous generations by encrypting more information, and because key functions are software-based, customers can maintain a higher level of monitoring for threats to prevent hazardous and costly system intrusions. Today, mine operators collect, process and store large quantities of data, from geological surveys to sediment analyses, and this data storage will continue to increase as time goes on. Mining data is invaluable, and many operators want to ensure it’s absolutely secure to maintain complete control. Network slicing and customer-controlled security policies can be easily deployed with 5G, allowing operators to customize their networks the way they want, without relying on a provider. In addition, DISH 5G allows the mining operator to decide whether the most
sensitive data traffic will remain physically on-premise or travel offsite in a separate and secure channel. A private 5G wireless network removes the reliance on public infrastructure and the cloud, allowing the enterprise to access data faster. DISH 5G wireless technology guarantees mine operators a robust layer of security for their most valuable assets by delivering comprehensive, customizable and self-controlled connectivity.

5G wireless technology can deliver the network needed to support mission-critical initiatives required by the mine of the future. Next-level, system-wide performance is key, along with the ability to customize and simultaneously deliver multiple, unique QoS levels that support massive-scale sensing, machine intelligence and autonomy, human augmentation and low-latency remote operations control. All of these exceptional network capabilities must also be combined with the highest level of system reliability and security to ensure the desired operational outcomes are achieved.
Figure 3 - Requirements for Reliability, Bandwidth, Latency in Future Mining Applications
Advanced Technology Enablement

A major digital disruption in mining is about to take place. New technological applications that embrace augmented human and machine intelligence will transform the mine of today into a fully integrated, highly automated system-of-systems, delivering continuous improvements in safety, productivity and efficiency.

The next generation of mining capabilities will be made possible by 5G wireless network technology, and DISH is poised to deliver this next level of 5G connectivity, described in Figure 4. Massive functional automation with extreme autonomy, cognitive operations characterized by connected workers, remote operations and augmented human/machine intelligence derived from IoT based sensing, represent just a short list of new applications necessary to drive the mining industry forward.

Extreme Autonomy

To achieve the desired safety, productivity and efficiency, mining companies must replace all manual operations like exploration, drilling, blasting, digging, loading, hauling, crushing and transportation with fully autonomous systems. This transformation will enable a high degree of autonomous operations. Autonomous equipment and systems can function 24/7 in a predictable manner, ensuring safety, mitigating human error and maximizing equipment lifetime.

Higher levels of autonomy have the additional benefit of reducing expenses associated with equipment maintenance and workers operating in potentially hazardous mining environments. For example, since open-pit iron ore mines in Western Australia began using autonomous trucks, they have achieved over 15% gain in productivity and efficiency for just 20% of the operations, all while ensuring 24/7 safe operations. [2][3]

Autonomous guided vehicles (AGVs) have increased mining companies’ operational speed, decreased maintenance, reduced planning costs and improved safety by removing the need for drivers. While AGVs primarily utilize onboard intelligence like GPS, LiDAR and management planning systems to operate, the entire system is still managed through a human interface. This interface includes the use of video cameras installed throughout the mine to enable teleoperators to monitor, intervene, redirect or even cease vehicle operation if there is a problem.
Current cameras need significant uplink throughput to send live video, and while adding ultra-high definition (UHD) cameras provides a path toward greater autonomy and safer operations, existing networks are not up to the task. Beyond hauling, future mining operational efficiency will demand autonomy from drills, monitors, sensors and PPE, which will further increase the need for even higher levels of dedicated uplink data throughput — far beyond the capabilities of legacy network technology. DISH’s 5G wireless technology can deliver the customized QoS uplink throughput required to enable these industry advancements.

The Smart Network

In the future, mining will not only leverage mechanical automation, but will also gain cognitive advantages in all stages of operations, including exploration, production and transportation. In each of these stages, massive amounts of data are collected and analyzed, creating actionable insights for the enterprise. This wealth of data acquired can be used in augmented intelligence systems that employ a wide range of machine learning (ML) and predictive analytics techniques to assess, control and optimize operations. Problems or anomalies in operations can be proactively detected and automatically corrected, improving safety and optimizing operations across the site by gaining near real-time visibility and identifying potential bottlenecks at every step of the process — all made possible by DISH’s intelligent, cloud-native 5G network. Low-latency applications (5 ms or less), such as real-time motion control, telepresence operations with haptic feedback and virtual reality, must be supported with Multi-Access Edge Computing (MEC). MEC is a key differentiator of DISH’s 5G wireless network technology, which allocates computing power and storage closer to the devices and applications that require them most. With MEC, edge systems can also provide critical local data storage and processing needed for a mine to function by itself in the event of command center connectivity loss. Other key differentiators of DISH’s 5G network include software-defined networking in conjunction with network function virtualization (NFV). All of these powerful capabilities combine to create a supremely intelligent, customizable network of the future that can quickly address the dynamically changing end-to-end needs of the entire mining industry.

Complete Situational Awareness

Achieving complete situational awareness is critically important to the future of mining, as it enables human or autonomous intervention to minimize or eliminate disruptions and drive new efficiencies across the entire value chain.
Future mine connectivity will demand high throughput to support on-demand uplink and downlink video, low-latency command and control, and multifaceted sensing (e.g., for drills, drone inspections and teleoperated vehicles).

DISH’s 5G wireless network provides built-in capabilities, including multi-antenna support, carrier aggregation and multi-connectivity, that allow a plethora of network resources (including Wi-Fi) to be leveraged to meet these increased levels of performance.

- A single teleoperated drill may require three or more full-resolution video feeds during operations (requiring data rates of up to 18 Mbps or more). These requirements are only expected to grow as video resolution increases.

- Historically, it takes a four-man crew 96 hours to survey a site of three open-pit mines, and up to a week to process and analyze the data collected. Drones can reduce these processing times to 24 hours while eliminating safety concerns. Scaling up to multiple drones allows for more detailed imagery and even further acceleration of data processing from hours to minutes.

- Operators need to be able to command and control equipment remotely via telepresence. In the future, as the 5G network evolves to support UHD video, full scale sensing, VR/AR and low-latency control, it will be possible for an operator to remotely control machinery from the safe confines of a command center anywhere in the world.

- Mines need to wirelessly report data from a large number of sensors deployed across the full pit-to-port enterprise. DISH’s 5G wireless technology integrates with NB-IoT, which is specifically designed to support short packet access, long battery life and extended sensor coverage.

A robust wireless 5G network that provides high data throughput, lower latency, significant edge network compute and data storage capabilities is the ideal solution to achieve the complete situational awareness necessary to fully realize the future of mining. The mining industry’s digital transformation is directly linked to the near-term deployment of new applications enabled by DISH’s state-of-the-art, cloud-native 5G network. Autonomy, augmented human and machine intelligence, real-time teleoperations, massive data collection and data analysis are just a few of the technological innovations that will deliver continuous improvements in mining safety, productivity and efficiency.
Figure 4 - Advanced Mining Applications Road Map

- PIT / Site Autonomy
  - Autonomous Haulers, Drills, and Processing Machinery
  - Teleoperated Drills
  - Limited Video Machine Guidance

- Human / Process Automation
  - Workflow Automation
  - Ubiquitous Operational Data Access for Workers
  - Limited Electronic Safety / Health Monitoring Systems

- Pit-to-Port IoT Systems
  - Sensing and Process Automation
  - Machine Health and Diagnostics
  - Fleet Management
  - Surveillance
  - Connected Devices (locks, tags)

- Digital PPE / Comms
  - Personnel Safety Devices
  - Health and Hazard Monitoring
  - Geofencing
  - Mission-Critical Comms (PTT)

- Rail / Port Autonomy
  - Personnel Connected / Autonomous Trains, Tugs
  - Pit-to-Port Analytics, Logistics, Decision Support (AI/ML)

- 360° Situational Awareness
  - Massive UHD Video on Demand
  - Drone Surveillance and Operations Inspection
  - AI / ML Predictive Maintenance

- Full Remote Operations
  - Real-Time Remote Operations
  - Precision Robotics
  - Cooperative Autonomy
  - AR / VR
  - Low-Latency Operations, Safety Systems

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**Additional Spectrum**

**CURRENT**

**NEAR TERM**

**FUTURE**

**HIGH BANDWIDTH**

**ULTRA RELIABLE LOW-LATENCY**

dish wireless
Conclusion

DISH’s next generation wireless capabilities offer the mining industry vastly improved, future-forward connectivity and agility. The need for continuous safety, productivity and efficiency improvements has created an unprecedented demand for digitizing, automating and optimizing all operations, placing the mining industry at the cutting-edge of the fourth industrial revolution.

Current connectivity solutions alone, like Wi-Fi and private LTE, simply cannot provide the capabilities nor the bandwidth necessary for success. Instead, these legacy technologies are sources of bottlenecks in the enterprise supply chain, resulting in loss of productivity and efficiency.

Improvements of this scale can only be delivered through significant changes to the entire pit-to-port mining process, and these next-generation advancements can be enabled through the deployment of DISH’s innovative 5G wireless network technology.

DISH stands ready to provide the next evolution in mining by delivering:

- **Flexible and Dynamic Connectivity**
- **Mission-Critical Performance**
- **Advanced Technology Enablement**

These three elements allow the future of mining to come to fruition, including imperative innovations like functional automation and autonomy, connected workers, remote operations, integrated platforms, machine intelligence, advanced sensing, analytics and data-driven decision support.

In the future, the mining industry will be driven by safe, secure and profitable operational processes that seamlessly connect from pit-to-port. This digitized environment will mitigate worker injuries or fatalities, employ perfectly timed productivity to deliver tonnage on demand and autonomously execute all operations 24/7 with 100x improved efficiency. At the heart of this industrial revolution is a next-generation, flexible, dynamic and easily scalable connectivity solution designed to meet any and all new demands. DISH Wireless offers the network technology that will fully realize the mining vision of the future.
References


Acronyms

4G / 5G ................................................................. Fourth / Fifth Generation

AGV ................................................................. Autonomous Guided Vehicle

AR ................................................................. Augmented Reality

CBRS ............................................................. Citizens Broadband Radio Service

GPS ............................................................. Global Positioning System

IoT ................................................................. Internet of Things

LiDAR .............................................................. Light Detection and Ranging

LTE ............................................................... Long Term Evolution

LMR ............................................................... Land Mobile Radio

MEC .............................................................. Multi-Access Edge Computing

ML ............................................................... Machine Learning

NBIoT .......................................................... Narrow Band Internet of Things

NFV ............................................................. Network Function Virtualization

P25 ............................................................... Project 25

PPE .............................................................. Personal Protective Equipment
Acronyms

PTT ................................................................. Push-To-Talk
QoS ................................................................. Quality of Service
ROC ............................................................... Remote Operations Center
UHD ................................................................. Ultra-High Definition
VR ................................................................. Virtual Reality
Wi-Fi .............................................................. Wireless Fidelity