Mining and mission-critical wireless connectivity

Laying the foundation for the digital transformation of mining

White paper

Mining is fast embracing automation and incorporating digital technologies across its operations. These transformative digital applications all require business-critical network connectivity and, given the nature of mining operations, wireless mobile communications are ideal. A number of wireless point solutions, such as Wi-Fi, have been deployed over the last decade but have limited capabilities. 4.9G/LTE mobile technology is now available for private wireless networks. It is highly modular, simple to install, maintain and scale, and meets the requirements for even the most ambitious digital mining applications.

In this paper, we look at the current trends in the automation of mining, the strengths and capabilities of 4.9G/LTE and outline a number of use cases that demonstrate its potential to provide the industrial communications platform for the digital mine of the future.

Contents

Introduction

The digital transformation of mining, although slow to develop, is accelerating quickly. Autonomous vehicle technology, internet of things (IoT) sensors and analytics, machine learning (ML) and artificial intelligence (AI) all hold tremendous promise for the mine of the future. They have the potential to dramatically improve efficiencies, productivity, safety, sustainability, asset predictability and, generally, optimize operational processes and costs. These technologies will accelerate almost every aspect of mining operations from exploration to exploitation, from pit to port.

Given the nature of most mining applications, one of the key supporting technologies for the digital transformation of mining is wireless connectivity. Current wireless technologies have not been engineered to provide sufficient coverage, reliability, security, service prioritization, and/or support for mobility and IoT.

Business-critical mining applications require robust wireless connectivity with very high reliability, intrinsic security and predictable performance. Operations cannot be prone to failure and stoppages. Automated haulage, for instance, requires wireless that supports mobility and ultra-fast reaction, often across extensive terrain with frequently changing footprint without breaks in coverage. Vehicle-mounted CCTV cameras and drones require true mobile broadband. Tele-remote operations require very low latency connectivity. Critical person-to-person communications will need support for real-time two-way voice and video, and emerging IoT and analytics applications will need to support massive numbers of devices and sensors.

As we will discuss below, these capabilities are only available with today's 4.9G/LTE and tomorrow's 5G cellular technologies. LTE/5G industrial wireless solutions can interwork between (or replace) what today may be isolated systems, allowing mines to connect all the digital aspects of their operations for environmental monitoring, situational awareness for safety and security, as well as predictive maintenance and workflow optimization across the mine. In this paper, we will look at the digital transformation of the mine and the use of these industrial wireless technologies across a number of specific mining use cases, to better understand the essential role they will play in the mine of the future.

Mining today

The mining sector is almost always under pressure in today's rapidly changing world. The global economy experiences rapid and global-sized shifts in supply and demand for commodities while government regulations and technology innovations can create spikes in demands for entirely new minerals or suddenly restrict demand for others. Often working in remote and challenging environments, mining companies have to work especially hard to meet stringent environmental strictures, as well as comply with worker safety regulations.

Throughout history, miners have looked to improve safety and gain a mechanical advantage using heavy machinery to automate tasks such as drilling, blasting, loading, hauling and crushing. Although mostly manually operated today, mining companies are pursuing a strategy of extreme autonomy, where all manually operated equipment including diggers, ore haulers, crushers and trains will eventually be replaced with their autonomous counterparts. Remote operations will further supplement automation, allowing personnel to monitor automated processes and operate machinery at a distance using virtual telepresence.

The benefits are obvious: world mining production in 2017 was just above 17 billion metric tons.[1] Average overall equipment effectiveness (OEE) performance without automation is 27 percent for underground mining, 39 percent for open-pit mining, and 69 percent for crushing and grinding.[2] Automation can add 10–20 percent productivity.[3]

The attraction of a particular automated application is not always directly related to cost savings. An autonomous ore hauler isn't significantly cheaper to run than one that has a driver. Of course, mines are always motivated to reduce cost per ton, but they are also very interested in predictability and continuous operations. Accidents, delays and handling errors are more likely with drivers, who suffer from fatigue, inattention and the need to take breaks.

Safety incidents can delay or shut down operations, sometimes for days, while investigations are made — resulting in considerable loss of productivity and efficiency. The promise of autonomous vehicle technology is 24/7 operations in a predictable, safe way that maximizes equipment lifetime. For example, in the open-pit iron ore mines of the Pilbara region in Western Australia, autonomous trucks have provided upwards of a 15 percent gain in productivity and efficiency with autonomous haulage. The autonomous trucks operate for an average 1,000 more hours than conventional haul trucks, at 15 percent lower cost.[4]

Mine sites exist in the most remote parts of the planet where it is extremely difficult and expensive to maintain a large workforce for manual operations. Conditions at mine sites can be extremely hazardous and pose significant potential for injuries and fatalities. Excessive dust can lead to poor driver visibility or respiratory distress. Extreme temperatures lead to the risk of heat stroke and dehydration. Haul truck drivers may suffer from fatigue. Safety protocols and training help, but are sometimes ignored, resulting in serious accidents.

Data collected from a vast multitude of sensors below and above ground will allow miners to obtain situational awareness across mine, pit, rail and port by gaining near-real time visibility and identifying potential bottlenecks at every step of the process. By monitoring all assets, as well as the people using them, and leveraging advances in augmented human and machine intelligence, miners will dynamically track assets and deploy them on demand, while using predictive maintenance to schedule timely maintenance on equipment.

Along with automated and remote operations, which will remove workers from hazardous activities, the mine of the future will support wearable personal protective equipment (PPE) to enable tracking of personnel location, alertness and health parameters. Digital PPE may also be used in geo-fencing applications to enforce virtual exclusion zones, regulating unauthorized access to blast areas or areas where there is a danger of falling objects, moving machinery, chemical spills or fallen electrical cables.

One of the biggest challenges faced by mining is the effects its activities have on the surrounding environment. The recent Brumadinho disaster in Brazil highlights the importance of environmental management. IoT environmental sensors can dramatically reduce the impact of mining operations on the environment and increase safety for mine operations and surrounding communities. Environmental monitoring is now the number one driver of IoT adoption by mines.[5]

1 "World Mining Data 2019," Austrian Federal Ministry of Sustainability and Tourism, April 2019. Web: http://www.wmc.org.pl/?q=node/49
2 "How digital innovation can improve mining productivity," McKinsey & Company, November 2015. Web: https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-digital-innovation-can-improve-mining-productivity
3 "Tracking the trends 2018: The top 10 issues shaping mining in the year ahead," Deloitte, 2018. Web: https://www2.deloitte.com/tr/en/pages/energy-and-resources/articles/tracking-the-trends-2018.html
4 "Rio provides AutoHaul update," Mining magazine, 29 March 2017. Web: https://www.miningmagazine.com/innovation/news/1264244/rio-provides-autohaul-update
5 Inmarsat, 'The Future of IoT in Enterprise – 2017' involved 100 global mining companies. Almost half (47 percent) identified monitoring environmental changes as their number one priority for IoT deployments; a further 57 percent cited environmental monitoring as the most exciting IoT innovation.

Industrial-strength wireless connectivity

In this discussion of disruptive digital technologies for mines, there is a missing ingredient: industrial-strength, pervasive, wireless connectivity. Without it, most of these technologies will not achieve their full potential or, even, be deployable. Current IT wireless networking technologies, such as Wi-Fi and Wi-Max, are not designed for industrial-scale business-critical connectivity. Wi-Fi was designed for local area best-effort networks in the office or home, exchanging emails and browsing the web. These technologies have been adapted to industrial applications in the past with limited success, but they do not provide business- or mission-critical support for most industrial digital transformation projects.

Fortunately, most of us carry much better wireless technology in our pockets today. Used for a decade in public mobile networks worldwide, LTE cellular technology has all the features and characteristics required by the vast majority of mining applications. The next-generation of cellular, 5G, is also beginning to roll out, and it will support even the most extreme applications.

Until very recently, LTE technology was reserved for mobile operators because they had a monopoly on LTE radio spectrum. But governments around the world are releasing new spectrum specially designated for private networks. Mobile operators are also willing to lease their spectrum, especially in remote areas where mines commonly operate, as it goes mostly unused. LTE can operate in unlicensed/lightly licensed spectrum as well.

LTE has all the capabilities of Ethernet in a mobile wireless format. And, unlike most new disruptive technologies, it already has a mature system of LTE-connected industrial devices and has proven its capabilities for a decade in the most demanding networks in the world. Industrial wireless, based on LTE and evolving to 5G can support all mission- and business-critical applications on a single network. These applications include TETRA and P25 communications with both push-to-talk and push-to-video applications, high-definition video, low-latency edge computing for remote and automated operations, and support for low-power sensor networks and telemetry applications using NB-IoT or LTE-M device categories.

LTE industrial wireless solutions are being used by large enterprises worldwide to support business- and mission-critical enterprise applications for everything from power utilities and smart cities, to manufacturing, airports and port operations.

Wireless access points, called base transceiver stations (BTS), come in outdoor and indoor versions, and can support up to 800 actively communicating users per small cell and many more for macro cells. The Nokia industrial wireless solution can scale from very small field operations to very large with coverage for up to 400,000 km^2 outdoor and 20 km^2 indoor. They can be connected by either CAT cables (existing or new), PON cabling or microwave links. Nokia Flexi Zone small cells have a compact all-in-one form factor, easing deployment with a single box solution, which is no more difficult to install than Wi-Fi access points.

Access to the network and priority/performance parameters are controlled by the mine. Defined applications, machines, sensors and workers are granted access and ensured the right level of performance. Both LTE and 5G support network slicing so that dedicated network resources can be reserved for specific applications. This application-centricity is enabled by combining LTE with IP/MPLS as the network-wide foundation for the converged mining automation network (MAN)[6]. Thus, for instance, autonomous ore haulers might be assigned a specific network slice, TETRA communications another, IoT sensors a third. This ensures that no other applications running on the network can compete for those bandwidth resources. This not only provides quality and performance control, it also secures different applications from each other. Slices, for all intents and purposes, operate as standalone, application-dedicated networks; yet all application slices actually share a single physical wireless network, which simplifies operations and reduces costs.

---

6   "The need for converged mining automation networks", Nokia white paper, 2018. Web: https://onestore.nokia.com/asset/202095

Figure 1. The business-critical features of private LTE vs. Wi-Fi.

Wi-Fi	LTE
Capacity: ~30-100 active connections per access point	**Capacity**: up to 800 connections on a single small cell; tens of thousands on a macro antenna
Coverage: access point radius of ~50-100 meters; truck mounted APs to cover the whole pit	**Coverage**: radius from 100 meter up to 30 km; 5-10 times less antennas needed
QoS: best effort; lack of prioritization	**QoS**: dependable quality of service management with prioritization
Performance: high peak rates; unstable performance/capacity	**Performance**: predictable data rates; 3-5 x 9's "carrier grade" reliability
Mobility: loss of connection up to 15 secs on handover between APs	**Mobility**: up to 350 km/h
Latency: fluctuating between 1 ms and 2 secs; reliability decreases with number of connections	**Latency**: between 8-20 ms; remains stable with increasing number of connections
Security: high risk for hacker attacks and intrusion	**Security**: security by design
Services: co-existence with private radio, no IoT support; no handover to public network	**Services**: one network for PTT/PTV, broadband, video streaming, IoT; same technology as public 4G
OpEx: frequent reconfigurations needed, up to 15 hrs/week	**OpEx**: 4 times less configuration, management and maintenance cost

Nokia LTE and 5G mobile networks have a distributed cloud architecture based on software-defined networking principles and virtualization.[7] They include robust IoT and device management solutions as well as analytics, machine-learning and AI capabilities. These capabilities are built into the network, but they can also be leveraged for specific mining applications. For instance, remote wireless automation solutions will require very low-latency communications. This in some cases will require edge compute resources to be placed very close to the remotely controlled or automated devices. Fortunately, edge compute resources are built into the LTE/5G architecture and can provide distributed cloud connectivity to support applications in the field, in railway tunnels or deep underground shafts.

---

7   "Reimagine mining networks for Industry 4.0", Nokia white paper, 2019. Web: https://pages.nokia.com/T003XE-reimagine-mining-networks.html

White paper
Mining and mission-critical wireless connectivity

Mining use cases

Exploration and prospecting

Modern mineral exploration is driven by geophysical and geochemical technologies that analyze soil, rock, water, vegetation and vapor. Technologies such as tomographic imaging, laser and X-ray fluorescence, near-surface seismic imaging and drone-based aero-magnetic surveys generate tremendous amounts of data. Field operations typically occur in remote areas under-served by communications networks. Prospectors and field engineers are often forced to carry laptops, hard disk drives and USB dongles to collect, transport and deliver the data manually.

Nokia's smallest LTE-based deployable solution incorporates carrier-grade Nokia Flexi Zone small cells and integrated core technology. A network serving hundreds of users can be set up in minutes, even in the most extreme conditions where there is no existing coverage or coverage has been lost. Paired with a satellite or microwave link at the field base camp, this solution can provide high bandwidth mobile connectivity in even the most remote locales for sensors, field workers and drones, both for collecting data, as well as providing field workers with access to remote data and remote processing capacity. The temporary network can easily be scaled as the field operation grows, literally taking the mine from its earliest beginnings to full-scale operations.

Automated drilling and blasting

Electric-powered, remote-controlled drilling is used in the Kiruna mine in Northern Sweden, for example, along with automated ore handling equipment.[8] Remote operators manage three drills at a time aided by mapping software for precision blasting. After blasting, automated load-haul-dump machines carry the run-of-mine to the nearest ore pass for loading on the automated trains.

Rio Tinto employs 20 automated hole-pattern drilling machines at Pilbara, Western Australia.[9] One operator, located 1,500 miles away in Perth, is assigned to four drills at a time, monitoring key points in the process. Holes are drilled in a pre-mapped order at the locations and depths loaded into the system. Using GPS, the drills move precisely to the designated drill spot. This enables far greater precision and almost continuous operation. Over a single year, they operated for an average 1,000 more hours per drill compared with conventional drills.[10]

In all cases, industrial wireless is needed to enable video monitoring, collecting of sensor data and the coordination by remote software of drills and blast trucks on the drill bench, as well as navigation to safe zones during blasting. This careful choreographing of equipment by software reduces drill cycle times and improves safety for equipment and personnel. Data from the as-drilled hole is also remotely analyzed to dynamically tailor the blast process for further safety and efficiency. Since their inauguration in 2008, the first four machines employed at Pilbara have drilled more than 5,000km.

Automated/remote operation for loading, haulage and train operations

In January 2019, Komatsu announced that its FrontRunner Autonomous Haulage System (AHS) has been enabled to run on private LTE in commercial operations, making way for ultra-high system availability, reliability and safety. The company completed a year-long qualification program, conducting extensive testing on Nokia's Future X infrastructure.[11]

8   "Kiruna Iron Ore Mine", Mining Technology. Web: https://www.mining-technology.com/projects/kiruna/

9   "Mining robots: Rio Tinto doubles down on autonomous drilling," Mining technology, 28 Aug 2018. Web: https://www.mining-technology.com/features/mining-robots-rio-tinto-doubles-autonomous-drilling/

10 "Rio provides AutoHaul update," Mining magazine, 29 March 2017. Web: https://www.miningmagazine.com/innovation/news/1264244/rio-provides-autohaul-update

11 "Komatsu first to operate Autonomous Haulage System over dedicated private LTE network", Komatsu press release, 21 Jan 2019. Web: https://www.komatsuamerica.com/our-company/press-releases/2019-01-21-ahs-lte

Sandvik, another tier-1 supplier of mining solutions, has also adopted LTE for delivering critical communications and industrial IoT to the mining industry. Working with Nokia is part of their strategy to develop innovative, open and interoperable solutions for smarter and safer mining operations.[12]

By the end of 2017, Caterpillar reported that it had 100 autonomous trucks operating on three continents.[13] In one mine, employing the largest fleet, 54 autonomous trucks had achieved 20 percent greater productivity than the other 150 manned trucks working in the same mining complex. They had no lost time due to injuries, in part because automation has reduced the number of people working in the area where they operate. They have proven reliable with 99.95 percent system availability. The trucks work more every day and they work faster, gaining 2.5 hours a day because there is no need for shift changes, breaks or lunch. Rio Tinto's success with autonomous haul trucks has led it to expand its fleet by more than 50 percent by the end of 2019, to 130, including the Brockman operation, which will be entirely autonomous haul trucks.[14]

Loading of trucks and train cars can be fully automated or utilize some automation with remote-control by an operator located centrally who manages multiple machines. Key moments in the loading procedure may, for instance, require operator supervision and, occasionally, intervention. The operator can work in a more comfortable and safer environment and is not exposed to health and safety risks. Remote control of machines can be passed instantly to other operators ensuring continuous usage of the machines even when operators go on break. Again, given the mobility of the loaders, remote operation will require industrial wireless for video monitoring and remote control.

Trains can also be fully automated with remote supervision from pit to port. Rio Tinto uses automated trains to move ore from mining operations in Tom Price to the port of Cape Lambert, a distance of 280kms, remotely operated from the Rio Tinto operations center in Perth, which is 1,500 kms away.[15] The Kiruna mine in northern Sweden uses seven 500-ton capacity shuttle trains underground, all remotely controlled.[16] As with other parts of the ore moving system, the goal is 24/7 operation and the reduction of downtime due to safety issues or the needs for breaks. These systems can be operated with various narrowband wireless systems such as VHF, UHF, TETRA, or GSM-R. However, once on-board video is used for monitoring and controlling train operations, it is necessary to use mobile broadband wireless such as LTE or 5G.

Worker safety and mission-critical communications

Personal protection equipment (PPE) is the last line of defense for workers. It has traditionally meant equipment such as hardhats, ear muffs, face masks and steel-toed boots. Smart technologies are now being integrated into PPE creating Smart PPE. This new class of equipment includes integrated communications in ear muffs and helmets, heads-up displays, and embedded environmental sensors to monitor heat, sound, chemicals and gas, as well as impact. In some environments, these devices can use Bluetooth. In many mining environments they will need something more robust and with greater range such as LTE.

Smart PPE wearables can also be used in conjunction with LTE geo-fencing applications to alert miners to no-go zones. Drilling and blasting software that sets up safe zones for automated drills and blast trucks can also monitor workers in the area and warn them not to enter the blasting area. This requires personnel location tracking, which can be expanded, with wearable technology, to detect worker biometrics and man-down situations, and can be used to warn workers of any kind of hazards, from chemicals and explosives to falling rocks and autonomous truck routes.

12 "Sandvik and Nokia collaborate to deliver Industrial IoT to mining industry over LTE and 5G Networks", Sandvik press release, 4 Dec 2018. Web: https://www.rocktechnology.sandvik/en/news-and-media/news-archive/2019/01/sandvik-and-nokia-collaborate-to-deliver-industrial-iot-to-mining-industry-over-lte-and-5g-networks/

13 "Caterpillar offers stepping stones to full automation," Canadian Mining Journal, 13 Sep 2017. Web: http://www.canadianminingjournal.com/features/caterpillar-offers-stepping-stones-full-automation/

14 "Rio Tinto to expand autonomous truck fleet in Pilbara, Australia," Mining Technology, 19 Dec 2017. Web: https://www.mining-technology.com/news/rio-tinto-expand-autonomous-truck-fleet-pilbara-australia

15 "How did the world's biggest robot end up here?" Rio Tinto. Web: https://www.riotinto.com/ourcommitment/spotlight-18130_25692.aspx

16 "Kiruna Iron Ore Mine," Mining Technology. Web: https://www.mining-technology.com/projects/kiruna

TETRA and P25 networks, which are widely used in the mining community for critical person-to-person and group communications, can now be fully replaced by LTE/4G, offering mission-critical push-to-talk (PTT) and bringing, in addition, the capability of push-to-video (PTV) services.

Air and water management

Control of air and water pumps is extremely important in mines and being able to remotely manage them means big savings as well as a significant step towards more sustainable operations.

In underground mines, ventilation systems operate 24 hours per day, 365 days per year and account for 25 to 40 percent of the total energy costs and 40 to 50 percent of the electrical consumption. Many ventilation systems have efficiencies of 65 percent or lower.[17] On-demand ventilation can improve air quality by as much as 50 percent, and has already helped mining companies Goldcorp and Glencore to save as much as 2.5 million dollar a year and cut energy costs by more than 20 percent.[18]

Water management has also become a critical activity for the mining sector. Climate change raises concerns around water availability, but also increases the probability of extreme weather events.

BHP notes that "… competing with other commercial users and the broader community for resources in water scarce regions can be extremely challenging. In copper, as in mining more generally, effective, ethical water stewardship is expected increasingly to emerge as a competitive advantage for those operators that get it right. For those that do not, their ability to maintain their social license to operate may come into question."[19] The World Economic Forum estimates that smart sensors could reduce the mining sector's water consumption by approximately 400 billion liters.[20]

On the other hand, flooding, caused by heavy precipitation and uncontrolled surface runoffs, is one of the most dominant weather events to cause harmful impact to mines, especially with respect to tailing ponds. Ingress of ground water can damage the pit walls in underground mines, causing collapses and, in many cases, fatalities.

Situational awareness

Situational awareness through video coverage and massive sensing is key to the safety, sustainability and security of future mine operations. To achieve 360-degree situational awareness, the wireless network must be able to meet the excessive bandwidth demands of video cameras across the entire coverage area spanning mine sites, rail and ports. Many of these cameras may be mounted on mobile vehicles or drones. It must also be able to manage and link thousands of IoT sensors providing machine health and diagnostics, position reporting, process monitoring and control, and environmental monitoring. Add to this growing list: digital PPE for mobile workers, smart tools, and communication devices.

The Nokia industrial wireless solution also includes video analytics capabilities. The Scene Analytics solution analyzes video data in order to learn what constitutes normal behavior patterns and, thus, identify anomalous behavior. Human operators are then alerted and can judge whether or not the anomaly warrants attention. In this way, they train the application to be more accurate.

Increasing situational awareness using video and IoT sensors is a key to mine safety and sustainability.

17 "Cost saving strategies in mine ventilation", E. De Souza, Queen's University Kingston, Canada, CIM Journal, Vol. 9, No. 2, 2018
18 "Technology helps keep miners afloat but prices under water", Reuters, 16 February 2016. Web: https://www.reuters.com/article/mining-tech/technology-helps-keep-miners-afloat-but-prices-under-water-idUSL3N15M0O0
19 "Ten reasons why we like copper", BHP, November 2017. Web: https://www.bhp.com/media-and-insights/prospects/2017/11/ten-reasons-why-we-like-copper
20 "Digital Transformation Initiative - Mining and Metals Industry", World Economic Forum, January 2017. Web: http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-dti-mining-and-metals-white-paper.pdf

Predictive maintenance using IoT and analytics

The maintenance and repair of mining equipment poses challenges in planning the use of repair equipment and teams. Breakdowns and unscheduled maintenance of aging assets can wreak havoc with even the best maintenance and repair planning. Predictive maintenance applications leverage pervasive LTE coverage to collect data from IoT sensors throughout the mine to feed asset management and advanced data systems analytics.

Predictive, condition-based maintenance solutions improve on today's preventive and calendar-based maintenance. Many assets fail during operations when using calendar-based maintenance schedules from the equipment vendor. Yet too-frequent maintenance leads to waste by refurbishing or replacing assets that are actually in serviceable condition.

The Nokia asset lifecycle optimization solution uses condition-based asset assessment to predict failure times and optimize maintenance options. It reduces costs, increases utilization, enhances safety, and minimizes delays and revenue loss. Having all of the mine's critical operations using the same private LTE network helps enormously to join isolated data lakes and derive the maximum benefit from the analytics engines.

Advanced analytics can correlate data from IoT sensors, environmental information and historical trends to provide operations intelligence, solve specific operational and maintenance pain points, and optimize asset lifecycles.

The end-to-end benefits of private LTE

Mining operations teams usually consider the merits of different technologies based on specific use cases. We have highlighted a number of use cases above that by themselves would justify the adoption of an LTE industrial wireless solution. However, we would be remiss not to point out some mine-wide benefits of adopting LTE as general support for digital transformation.

Virtually any application requiring wireless connectivity, and even some that could be served by a cabled connection, can be served by 4.9G/LTE and (in the future) 5G. This is because LTE and 5G have the capability to handle the bandwidth required, even for HDTV camera feeds, as well as supporting low-power sensor and IoT networks, and are adaptable to older, network protocols used in legacy applications. Both LTE and 5G are as reliable as a dedicated wired network, but far more flexible. Using network slicing, a single LTE or 5G network can provide multiple applications with dedicated resources and quality of service that are programmed to have specific parameters for each use case.

What this means in practice is a big reduction in operating costs and a huge increase in possible use cases. For future digital transformation projects, it also means that the question of which connectivity technology to use is a non-issue. Virtually all applications requiring connectivity will be able to piggy-back on the existing LTE or 5G system, which will act as a 'unified' communications infrastructure. Beyond operational cost savings and simplicity, there are a number of other benefits to consider.

One of the principal benefits of digital transformation is the ability to create data synergies between applications. The more data lakes that can be joined, the greater the possibility of finding correlations that can create system-wide efficiencies. Traditionally, specific applications on a mine site have not been connected because the costs outweighed the perceived benefits. But once many applications are using the same communications infrastructure, linking data between applications is relatively trivial.

By connecting data from different applications, mines can use big data techniques to do things such as end-to-end workflow optimization, predictive maintenance and performing forensic analytics on incidents. It is also possible to extract data from sensors all over the mine, whether environmental monitors, integrated sensors in PPE and embedded sensors on equipment. This can give new meaning to "situational awareness", providing a much more thorough and detailed understanding of the safety of workers and the mine environment.

In a 2018 EY survey, 55 percent of mining and metals companies reported they had a significant cybersecurity incident in the last year.[21] Cyber-security is another end-to-end benefit. Running multiple application-dedicated networks requires IT to adopt different security measures for each. LTE/5G standards are engineered for very exposed, public mobile networks and have many in-built security features that have proven their worth in the most stringent public safety or defense deployments. For instance, unlike Wi-Fi, they use hardware SIMs to grant access to wireless devices. This makes it impossible for those with malicious intent to join the network, unless they have access to company-controlled equipment.

In addition, LTE standards define end-to-end security as a base requirement. LTE is able to work in interference prone environments, meaning even if attackers use interference-based attack techniques from outside the mine (unlikely to affect the whole site), the network will continue to operate. Harnessing the power of IP/MPLS, network slicing is another technique for virtually isolating applications from one another. Thus, a temporary contractor using the central office network slice for emailing and web access cannot access the slice of the network supporting drilling and blasting or autonomous ore haulers.

Future security requirements are being built into the 4.9G/LTE and 5G standards. The LTE security architecture as defined by 3GPP (TS 33.401) and standardized by the National Institute of Standards and Technology (NIST) will recommend additional security measures including the use of universal integrated circuit card tokens, device and network authentication, air interface protection and backhaul protection.

Conclusion

The digital transformation of mining is moving ahead quickly. There is a strong movement among mine operators to embrace automation. Early applications of autonomous technologies have shown significant gains in productivity, predictability and worker safety.

These new digital mining applications require industrial-strength and, almost invariably, wireless connectivity. Current wireless technologies, such as Wi-Fi, are being stretched to the limit to accommodate these use cases and will not be able to continue meeting the future requirements of mines.

Fortunately, there is a simple answer: 4.9G/LTE and 5G mobile cellular technologies. Although not previously available, due to a lack of spectrum and, as a result, a dearth of custom-designed industrial wireless solutions, LTE and 5G are now robust, industrial-strength technologies that are available for mines. Even if the mining sector consistently underspends in innovation relative to other sectors (~1 percent R&D/sales),[22] private wireless broadband (LTE, Wi-Fi) represents a mere 1.5 percent of total mining CAPEX.[23]

LTE and 5G can accommodate the connectivity needs of any and all digital mining applications, such as autonomous vehicle technology, IoT sensing and remote operations and make an ideal industrial wireless connectivity platform for supporting the digital transformation to the mine of the future.

21 "Mining and metals sector struggling to close cyber maturity gap", EY, 2018. Web:
    https://www.ey.com/en_gl/news/2018/03/mining-and-metals-sector-struggling-to-close-cyber-maturity-gap

22 "Tracking the trends 2018: The top 10 issues shaping mining in the year ahead," Deloitte, 2018. Web: https://www2.deloitte.com/tr/en/pages/energy-and-resources/articles/tracking-the-trends-2018.html

23 "US$2.9 Billion Market Opportunities for LTE Vendors in Mining Sector," ABI Research, 2017. Web: https://www.abiresearch.com/press/us-29-billion-market-opportunities-lte-vendors-min/

NOKIA **RFS**

At Nokia we help our customers to address the digital mining opportunity. Talk to our experts who have a broad experience in digital technologies, mining operations, digital transformation and mission-critical networks and start realizing your goals for taking mining to the next level. For more information, visit our web page https://www.nokia.com/networks/industries/mining/.

> The Nokia Bell Labs Future X architecture for mining provides an intelligent, dynamic communications and cloud-based platform as its foundation. This smart network interconnects all of the individual systems, processes and activities within the mine and provides integrated analytics, machine-learning and digital support for innovative new applications and services.
>
> To find out more about the Future X architecture for mining see Nokia Bell Labs "From vision to reality — an autonomous, intelligent, and safe mining industry utilizing mission-critical Future X architecture." Available at https://pages.nokia.com/T002FO.futureX.mining.html

CONTACT RFS