Looking to an LTE future

LTE private networks are booming in mining now both surface and underground, driven by the greater demands of multiple applications and the speed of automation implementation meaning WiFi cannot always deliver, reports Paul Moore

First ore loading in May 2019 at Tacora Resources' Scully iron ore mine near Wabush in Quebec, one of the first rollouts of LTE in an open pit worldwide

The deployment of private LTE networks in both underground and surface mines is really gathering pace now, and the benefits are being seen in terms of vastly reducing the number of fixed WiFi access points to only a handful of LTE radio points and at the same time improving security, overall network capacity, and system performance, particularly with most major miners running multiple applications and many also using, trialling or considering implementing equipment automation. As detailed later in this article, the demand for LTE has led to a number of collaborations and strategic partnerships between communications giants like Nokia, Ericsson, Huawei, Telstra and others directly with the miners themselves, with key mining equipment OEMs, and with system integrators. And while LTE development is still largely a 4G technology, going forward it will integrate with 5G elements as they become available, with the LTE networks being installed now effectively 5G ready. And 5G networks are already being installed at a number of sites as well.

IM spoke to Eric L'Heureux, President and CEO of **Ambra Solutions**, which has become a key turnkey engineering services systems integrator in the LTE market and therefore has a unique position in seeing trends. He comments: "There are two main drivers to the LTE trend – the need for better real time tracking of equipment, systems and people, and the increasingly remote nature of mining

Ambra cited more than 12 of its underground deployments of LTE networks alone, including the first which was widely published, namely Agnico Eagle's LaRonde gold operation, but more recently Vale's Garson nickel mine, the K+S Windsor salt mine and Glencore's Raglan operation amongst others including in Finland, Chile and Mexico. A number of deployments are also underway in open pit operations, though many of these cannot be detailed due to NDAs. One good example, however, is the Tacora Resources Scully iron ore mine in Labrador, Canada, where Ambra deployed a new 4G LTE network recently. This operation was using no less than 45 fixed WiFi points to support its fleet management system and a number of other applications. Now with only two LTE radio points, the network is being used by not only the mine but the nearby town of Wabush. This installation is also the first time the global leader in FMS Modular Mining has been running fully on an LTE network. The network also has the distinction of being one of the first open pit LTE deployments outside of Australia, which pioneered LTE in mining when a network was put into Rio Tinto's West Angelas iron ore mine in the Pilbara back in 2012 by Alcatel-Lucent (since acquired by Nokia).

For the Raglan nickel mine in Quebec, as part of an internal corporate initiative called ConnectedMine, Glencore selected Ambra as a partner of choice for the deployment of its private LTE network. In collaboration with a multidisciplinary team from Raglan Mine, the private 4G LTE network was deployed to the surface and at the 1190 level of the Qakimajurq mine. The Ambra team successfully completed the integration between February 18-25, 2019. The LTE infrastructure, including the core, was installed, powered and commissioned in just three days on the site. A Factory Acceptance Test (FAT) was performed in the Ambra Solutions labs to minimise installation time at the Raglan site. Redundancy tests were tested with the customer before the equipment was routed to the site. As a result, the network components were already pre-configured to integrate with the existing Raglan Mine network formed a turnkey system. The engineering team simply needed to connect the components to deploy the network. Raglan Mine's multidisciplinary teams were trained to install the cables and antennas at their own pace and in the targeted areas, according to their ConnectedMine project. In summer 2019 a standalone set of Ambras' cable and antenna kits was provided in key locations. The trained Raglan Mine teams will be able to freely install the "kits" in future locations.

Most recently regarding LaRonde's LTE evolution, where the system from Ericsson and Ambra was the first major deployment underground, Agnico Eagle in its Q2 2019 results states: "Following the successful deployment of the LTE network at LaRonde Zone 5, an LTE network was deployed at the LaRonde

Glencore Raglan has a private 4G LTE network both on the surface and at the 1190 level of the Qakimajurq mine, on which both Sandvik and Caterpillar machines are running

mine below level 269 in 2018. Extension of the network in the main sector from level 269 to surface and at LaRonde 3 will take place throughout 2019. The LTE network facilitates the integration of automation technologies currently being tested at LaRonde Zone 5, which are expected to allow the Company to maintain similar productivity levels at LaRonde 3 as it historically achieved in the shallower portions of the mine."

During the second quarter of 2019, the company continued to test autonomous mining using both Sandvik and Caterpillar equipment at LaRonde Zone 5 using the LTE network on weekend night shifts when underground activity is at reduced levels. Testing has yielded favourable results as autonomous mucking and hauling of ore from underground to surface was successfully achieved. Integration and pilot testing of automated mining equipment (two trucks and one scoop tram) began in the fourth quarter of 2018 at LaRonde Zone 5 and will continue throughout 2019.

Finally to Vale, and a report in local mining publication Sudbury Mining Solutions highlights that Vale installed LTE in a straight run down the ramp at its 114 Orebody last year and just recently wrapped up a proof of concept at Garson mine on the surface ramp down to the 600 level, a distance of 2 km.

The team is now planning an LTE deployment at its Voisey's Bay mine in Labrador and was planning to roll it out at its other mines in Sudbury in May or June 2019. Vale's Canadian operations are pioneering the use of LTE networks in their underground mines. Brad Atkins, digital node leader for the technology team planning the rollout is quoted as follows: "The big difference for us is that it works on a different frequency, so it propagates better underground. It's easier to maintain and less costly to.

At Voisey's Bay, LTE will replace leaky feeder, so miners will use phones instead of radios. At its existing mines in Sudbury, LTE will be deployed in parallel with existing WiFi and leaky feeder infrastructure. More bandwidth will enable improved equipment telemetry and more autonomous operation of mining equipment from surface, where equipment operators are a lot safer.

"Using LTE at Garson, we placed a video call on a tablet to someone in Thompson, Manitoba, from the 600 level in a moving jeep going down a corkscrew ramp using one antenna in a cutout on the 100 level. By comparison, we have 40 or 50 WiFi antennas on the ramp at Creighton to track and communicate, and ramp time is almost impossible to get if an access point goes down. We don't want to put our people on the ramp to maintain equipment because it's a busy place."

The publication said Vale is budgeting between $1.5 million and $2 million per mine for LTE deployment, most of which is the cost of the radiating cable.

Ericsson and Ambra deepen cooperation

In April 2019, **Ericsson** and Ambra announced a global cooperation agreement to lead automation for the mining industry. Ambra has selected Ericsson as a radio partner of choice to provide 5G-ready network solutions to automate ventilation systems, real-time personnel and vehicle tracking, and remote controlling of machinery like scoop diggers, hauler trucks, drillers, and other mining equipment.

The 5G-ready Ericsson Radio System portfolio enables Ambra, a turn-key engineering services systems integrator, to simplify network deployments and replace up to 60 WiFi access points with a single Ericsson solution.

L'Heureux said: "We are excited to expand our partnership with Ericsson to a global footprint. The Ericsson products are optimal to deliver the most demanding applications used by the mining 4.0 industry. The reliability of Ericsson products enables more predictable, secure and lower-cost connectivity, and mining companies want to use a reliable product that is available worldwide."

Mission-critical Private LTE deployed for Ambra's mining customers opens a new suite of capabilities and possibilities to cost-effectively enable digitalisation of mining-related tasks for open pit or underground mines. Prior to this modernisation, specialised tasks and applications were difficult or simply impossible to achieve across the entire mining coverage area when using legacy 'leaky cable' or Wi-Fi connectivity.

Shannon Lucas, Head of Customer Unit Emerging Business for Ericsson North America, said: "The global mining industry has been vulnerable to challenges of energy consumption, equipment loss, and human safety. We have designed an easy-to-use cellular connectivity solution to address these issues and deliver efficiency through digital transformation, while creating a path to 5G. Ambra will sell this solution as part of its portfolio and will partner with Ericsson customers (global service providers) to deliver it, which opens up exciting new opportunities and revenue streams for the service provider."

As stated, Ericsson and Ambra partnered last year to deliver the world's deepest underground LTE network for the Agnico Eagle mining complex, LaRonde, in Abitibi, Quebec, Canada. Located 3.5 km below the surface, the mission-critical private network provides data and voice services across the LaRonde mine site and enables several Internet of Things (IoT) use cases to improve safety and mining operations. Since then, several applications have been deployed using Ericsson solutions to deliver automation of ventilation systems, real-time personnel and vehicle tracking and remote controlling of machinery like scoop diggers, hauler trucks, drillers, and other mining equipment.

The solution is software upgradable to provide massive IoT capabilities for sensor-based applications, supports 5G-ready radio capability, and is delivered globally by Ambra and in partnership with Ericsson's mobile network operator customers.

Huawei plans to help Chinese miners get 5G benefits

At MWC Shanghai 2019, Huawei Deputy Chairman Ken Hu gave an update on **Huawei**'s progress in 5G deployment, sharing concrete examples of how service innovation and cross-industry collaboration are driving the next phase of growth in 5G. "The networks themselves are

At Citic Pacific Mining, Huawei's eLTE solution implements seamless Wide Area Network (WAN) coverage for truck dispatching, and eliminates the need to routinely relocate base-stations

the foundation of everything, but the future of 5G development will rely heavily on services. 5G-enabled service innovation will help us push network performance to the next level, and help operators get greater returns on their 5G investment."

He went on to discuss the potential role of 5G in mine safety citing a rare earth mine in Inner Mongolia. "Mines aren't generally located in the best of environments – the climate is rough, and the sites can be chaotic. It's dangerous, especially for drivers who have to haul pay dirt back and forth across the site. At this particular mine, they have 30 trucks, each of which has four drivers working in two different shifts. This presents some challenges for the mine operators and their workers. The first is frequency of accidents. Even the most experienced drivers have trouble avoiding dangerous situations in this type of environment. Second, efficiency is low. The best drivers can only travel about 10 km per hour – anything faster would be unsafe. Third, cost. Haul truck drivers in this mine make about 250,000 RMB per year – roughly 20,000 per month. This is a pretty high salary for drivers in China, and even then the mines have difficulty finding the right people. The environment is just too harsh, and many people aren't up for it. Today, 5G can help them solve these problems. With 5G networks and modules, we can enable driverless mining trucks. Cost-wise, this saves roughly one million RMB per year per driver. It also greatly increases efficiency, enabling the trucks to speed up from 10 km/h to about 35 km/h. Most importantly, because the trucks are driverless, the drivers aren't subjected to dangerous working conditions. In terms of costs, efficiency, and safety, 5G can provide a ton of value in the mining industry."

At the same event, Li Degang, Vice President of the owner of the mine in question, Baogang Group, and Chairman of Inner Mongolia Baotou Steel Union Co Ltd, elaborated on Baogang Group's 5G-supported intelligent mining project. "Baogang Group is bringing its intelligent mining plan into reality with 5G," said Li. "We are using 5G in many areas, including autonomous driving mining vehicles, UAV (unmanned aerial vehicle) mapping of geographic information, mine production scheduling and monitoring, and wireless data transmission."

Baogang Group owns the Bayan Obo mine, which is 150 km from Baotou, the biggest city in Inner Mongolia. This mine is not only an iron mine, but also the world's largest rare earth mine. Last year, Baogang Group built a new intelligent mining system at the Bayan Obo mine based on the latest information and automation technologies. This system consists of three integrated parts.

"The first part is driverless vehicles. Mining vehicles and equipment are major parts of an open-pit mine, and Baogang Group is piloting driverless vehicles and unmanned equipment operation," explained Li. "The second part is the application of UAVs. UAVs can send back geographical mapping data to facilitate mine management. The third part is the production scheduling system based on the first two parts."

Overall, Baogang Group's intelligent mining project is an integrated application of technologies including driverless vehicles, UAVs, mine scheduling, 5G, and BeiDou/GPS navigation systems. Baogang Group is also working on developing an intelligent mining security system, effectively establishing security standards for using driverless vehicles in mining.

Li Degang elaborated on the three major parts of intelligent mining. In terms of autonomous driving, the first part, many companies are developing 5G autonomous driving technology. Autonomous driving for mining is simpler than it is for civil use, because the use cases at mines are less complicated. They use the same vehicle control technologies, such as the millimetre wave radar and video data monitoring. The problem to be solved is replacing human drivers with a 5G control system for driving mining vehicles.

In addition to mining vehicles, Baogang Group also owns a large number of loader trucks that need to be remotely controlled. As the outdoor temperatures in winter in the region often fall below –30°C, this remote control technology is a welcome improvement that allows drivers to work comfortably indoors. This is similar to autonomous driving.

The second core system is UAV mapping. Baogang Group uses UAVs for mapping, which send back geographical data for analysis. This way, mining locations, mining quantities, and explosive quantities for each day are no longer issues. Baogang Group also builds digital models for optimizing the management of mining processes. Baogang Group checks mine slopes with HD videos shot by UAVs to prevent landslide accidents. "This system also requires 5G data transmission," said Li.

The third core system is the scheduling system. Baogang Group optimises the entire scheduling system based on the data transmitted from the above two systems. "This is the very core of intelligent mining," said Li. With these data, Baogang Group can find the best control methods and monitor the entire production process.

"5G is an absolute necessity for transmitting data between our core systems, because 5G features fast speed and high throughput," said Li. To support autonomous driving, regular cars require one or two on-board cameras, whereas mining vehicles need multiple cameras to cover 360 degrees and transmit data about vehicle conditions, road conditions, and so on. "The intelligent mining project has so much data to transmit, so 5G is a necessity for the intelligent mine project," said Li. "It would be very hard to build an intelligent mine without 5G."

Baogang Group kicked off the intelligent mining project last year, and by the end of April 2019, it had completed the 5G communications system for the mine. Prior to China's Labor Day holiday in May, a 5G video call was made between leaders of the Inner Mongolia Autonomous Region and the mine staff to verify the system usability.

"With 5G, it is possible for technologies such as autonomous driving to be applied in the intelligent mine," said Li. "We expect to be the

first company in the industry sector to put the 5G system into commercial use this year."

In Australia, iron ore miner Citic Pacific Mining (CPM) several years ago planned to gradually upgrade its data centers and network devices to simplify network management, improve Information Technology (IT) operational efficiency, enhance network security, and improve network experiences for offices and living entertainment.

Huawei offered a family of powerful digital platforms for CPM's production and campus networks, such as the eLTE industry wireless private network, cloud data centre, and smart campus. Huawei implemented direct connections to core mining services, and IT and Operational Technology (OT) integration, making the communication among offices, living quarters, and production sites more efficient.

Finally, CPM chose Huawei, and the two signed a Memorandum of Understanding (MOU) for strategic cooperation in November 2016, to address major projects such as truck dispatching LTE, port communication LTE, and urban data centre and mining-area data centre upgrades.

"Huawei's eLTE solution implements seamless Wide Area Network (WAN) coverage for truck dispatching, and eliminates the need to routinely relocate base-stations. The unified delivery of stable and reliable dispatching information improves loading efficiency of dump trucks and excavators. For production scheduling, video, data, and voice services are also carried in a unified manner that includes rich and visualized onsite information — a combination that improves unit-collaboration efficiency. One network carries multiple services, such as video surveillance, truck dispatching, and production scheduling, which together are expected to save 30% in operating costs. With further major changes expected in the mining environment, Huawei can help improve the eLTE signal strength and the coverage range to ensure operational continuity."

Komatsu's AHS running on LTE

In January 2019, Komatsu America Corp's FrontRunner autonomous haulage system (AHS) achieved a mining industry first, after the system qualified to operate on private long-term evolution (LTE) mobile broadband technology. This made it the sector's first AHS enabled to run on private LTE in commercial operations, paving the way for ultra-high system availability and reliability, while adhering to Komatsu's renowned safety standards, the company said.

Komatsu's FrontRunner AHS allows unmanned operation of ultra-class mining trucks. It delivers significant benefits, including reduced worker exposure to harm, protocols designed to constantly improve mine-site safety, reduced operating costs, and increased productivity and efficiency. The company completed a year-long qualification programme at the company's proving grounds in Tucson, Arizona, conducting extensive testing of the FrontRunner AHS on **Nokia**'s Future X infrastructure, a leading provider of private LTE communication solutions for the mining industry.

Extensive testing of Komatsu's AHS capabilities on machines like the IAHV are carried on Nokia's Future X network infrastructure at Komatsu's proving grounds near Tucson, Arizona

Komatsu said: "Mining operators demand wireless networks with high-availability, seamless mobility, world-class quality of service, and the ability to support multiple applications and services simultaneously. Accordingly, the industry is moving away from less predictable wireless technologies such as Wi-Fi, and towards private LTE networks, that improve security, capacity, and overall performance within a multi-application environment."

Luiz Steinberg, Komatsu Global Officer and President/CEO of Modular Mining Systems, said: "This industry milestone represents a key step in Komatsu's exploration of private LTE and highlights Nokia's role as the leading global supplier of mission-critical solutions and services for the mining industry.

"As the leader in autonomous haulage technology, we are firmly on our way to helping the industry move the next billion tons of material with autonomous technology. We have come together with Nokia to further this vision of delivering increased value to the mining industry."

Kathrin Buvac, President of Nokia Enterprise, said: "We are excited to be engaging the mining automation market with Komatsu, a powerhouse in the industry, to further highlight the benefits of Future X for mining companies as a strategic advantage in their operations.

"Private LTE is a key element in the Nokia Bell Labs Future X architecture to help industries, such as mining, create an intelligent, dynamic, high-performance network that increases the safety, productivity and efficiency of their business."

Komatsu pioneered the first AHS for the mining industry with a commercial deployment in 2008 at Codelco's Gabriela Mistral (Gaby) copper mine in Chile. In November, the company's FrontRunner AHS system marked the movement of 2 billion tons of surface material moved.

Epiroc teams up with Ericsson

Epiroc recently signed a cooperation agreement with Ericsson to jointly help mining companies achieve optimal wireless connectivity in their operations through Long Term Evolution (LTE) and 5G technologies. Key advantages of LTE and 5G solutions compared with other wireless solutions include better coverage, higher reliability and stronger security, especially when machines are in the same area and share information, according to Epiroc.

The technology has already been tested on Epiroc's machines at the company's test mine in Kvarntorp, Sweden, with further testing scheduled before providing solutions to customers.

Epiroc said: "Mining companies are increasingly seeking to digitalise and automate their operations to increase productivity, enhance operator safety and lower cost. This includes, for example, remotely operating machines from a control room, and collecting machine performance data to optimise use of the equipment." All of this creates a need for reliable, high-performance wireless connectivity at the mines, it said.

Helena Hedblom, Epiroc's Senior Executive Vice President Mining and Infrastructure, said the mining OEM is happy to team up with Ericsson so that its mining customers can get the most reliable and high-performing wireless connectivity possible.

"This is a crucial step in our ongoing work to ensure mining customers reap all the benefits, including higher productivity and better safety,

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made possible by digitalisation and automation," she said.

Åsa Tamsons, Ericsson's Senior Vice President and Head of Business Area Technologies & New Businesses, said cellular technology and the introduction of 5G is critical to realising the full value of digitalisation and automation "for smart industries".

"By combining our expertise in connectivity and Epiroc's cutting-edge technology in mining equipment, we will be able to ensure stable and secure mining operations, leading to increased utilisation, improved productivity and reduced costs."

Sandvik tie-up with Nokia

This connectivity tie-up follows a recently-signed agreement between **Sandvik Mining** and Nokia to further develop solutions for private LTE and 5G technology. Sandvik has signed an agreement with Nokia to further develop solutions for private LTE (Long Term Evolution) and 5G technology, continuing its focus on IoT solutions for the mining industry.

The Nokia Digital Automation Cloud (NDAC) platform offers pervasive connectivity enabling advanced applications and will initially be implemented and tested in the Sandvik test mine in Tampere, Finland, Sandvik said.

"Sandvik's decades-long work in automation has grown to include robust data analytics and process optimisation offerings, where connectivity and local computing power are crucial. Applications requiring high capacity and low latency are becoming increasingly important," the company said.

"Private LTE networks bring reliable and secure high capacity, low latency and wide coverage mobile broadband to serve mission and business critical industrial connectivity needs and offer a variety of terminals, sensors and other devices," Sandvik added.

The Nokia digital automation platform will operate both underground and in open-pit mines and offers a flexible connectivity platform for testing and developing Sandvik technology, according to Sandvik. "This network enables operation of autonomous vehicles, real-time monitoring of underground and outdoor premises to keep people and equipment safe, remote diagnostics and predictive maintenance, as well as asset management, control and authentication," the company said.

Riku Pulli, Vice President, Automation, Sandvik Mining and Rock Technology, said: "Our cooperation with Nokia is another important part of our strategy to develop open, interoperable solutions for future mining needs. Enhanced connectivity is critical for smarter and safer underground operations, and we're proud to work with Nokia to develop these enhanced connectivity options for our test mine and mining industry going forward."

Stephan Litjens, General Manager, Nokia Digital Automation, said: "Pairing Sandvik solutions with 5G-ready NDAC architecture has proven to be an excellent match. We are truly motivated to continue collaborating to develop technology that meets the requirements of the often-harsh conditions they operate in – be it moist, hot, cold, and/or dusty."

Sandvik's Pulli concluded: "Sandvik is a leader in mine automation and digitalisation, and Nokia offers leading technology in wireless connectivity. Together, we create innovative solutions for mining customers."

First 5G network underground at Boliden Kankberg

SIMS project partners Boliden and Ericsson, together with **Telia**, say they have deployed the world's first 5G network using New Radio in an operational underground mine, the Boliden Kankberg mine in Sweden. The deployment came in July 2019 less than a month since Telia and Luleå University of Technology, in Sweden, inaugurated a 5G-testbed as part of its Wireless Innovation Arena project.

The Kankberg mine is located around 10 km west of the Boliden Area Operations process plant in Boliden, and produces gold and tellurium. The mine has been in production since 2012 and has since then increased the annual production capacity to around 450,000 t. In 2018, the mine produced 456,979 t grading 4.4 g/t Au, 10.7 g/t Ag and 188.3 g/t Te.

SIMS, or Sustainable Intelligent Mining Systems, is part of the Horizon 2020 program, the biggest EU-backed research and innovation program ever with nearly ¤80 billion ($90.1 billion) of funding available over seven years (2014 to 2020).

"Productivity and safety requirements are very high in the mining industry. This customer configured network can function standalone, allowing mining operations to continue even if communication is disrupted to the mine," SIMS said.

The 5G technology is superior to other communication solutions for connectivity in demanding environments like mining and manufacturing where continuous operations and close monitoring of processes are required, according to SIMS. With characteristics like very low response times and the option for local data handling, 5G is the best suited technology to

SIMS project partners Boliden and Ericsson, together with Telia, say they have deployed the world's first 5G network using New Radio in an operational underground mine, the Boliden Kankberg mine in Sweden

meet the safety and efficiency requirements of the mine, it added.

Magnus Frodigh, Head of Ericsson Research, said: "5G is designed to support industry automation and industrial IoT and will be a platform for innovation in industries. The Boliden underground mine is a great example of a sector with tough requirements that will benefit immediately. [This technology]...will ensure connectivity for applications with high performance requirements."

Magnus Leonhardt, Head of Strategy and Innovation at Telia, said: "Industry 4.0 is becoming a reality. This is another good example of how 5G can be used to build networks adapted to the customer's operations. To guarantee safety in the mine, for example, the network must function even if communications to the outside world is disrupted. Reliable communications can now be secured with the network we have built."

Peter Burman, Program Manager at Boliden, said: "We work actively with robotisation to improve productivity and safety in the mine which requires future proof communication solutions. 5G is an important component enabling advanced automation and by that, a safer and more sustainable mine."

Telstra implements LTE at Lihir

Telstra Mining Services says it has implemented Papua New Guinea's first private 4G LTE (Long-Term Evolution) mobile network at Newcrest's Lihir gold mine. "The next generation wireless communications platform will allow for greater levels of safety, remote operation and automation, according to Telstra, which worked with Newcrest to provide design, staging, site deployment and testing of the network."

Every kind of production vehicle asset, including trucks, drills, excavators, dozers, shovels and barges have now been connected and operationally proven over LTE. This process has revealed significant performance improvements in terms of reliability, speed and latency, according to Telstra. "The network has been able to resolve challenges with existing Wi-Fi connectivity and is making Newcrest's safety and productivity systems more effective," Telstra said, adding that fleet efficiency and real-time visibility have benefited from an 80% improvement in communications reliability on LTE-enabled assets.

Dr Jeannette McGill, Head of Telstra Mining Services, said Newcrest's decision to invest in Private LTE technology further validates it as a dependable and scalable networking platform for the mining industry and one that enables mining houses to digitally transform.

"We've provided Newcrest with a tailored platform that will underpin its safety and digital mining ambitions and will help improve productivity and deliver new value and efficiencies to the business," she said. "They'll be using it to further modernise the mine site to enable the use of current and future mining applications, including tele-remote and autonomous systems, more extensively."

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The platform is completely independent from public mobile networks, according to Telstra, with Newcrest having been provided with its own dual-frequency base stations, LTE core and SIM cards, with the network's configuration and coverage designed and implemented to meet the Lihir mine's safety strategy and long-term mine plan.

Telstra Mining Services' solution also includes 'HetNet' functionality that allows the Newcrest vehicle fleet to seamlessly switch between LTE and existing Wi-Fi networks without impacting critical mining applications.

Newcrest complemented the LTE technology solution by implementing new towers, data centres and redundant power systems across the site, according to Telstra.

McGill added: "Newcrest and Telstra Mining Services took what has become a best-in-class preliminary deployment approach with the network. Designing it for full production but initially deploying at two sites allowed Newcrest to validate the design principles, implementation techniques and practical capabilities of LTE before scaling their investment."

Newcrest's pragmatic approach, combined with flexibilities in the solution from Telstra Mining Services, enabled the desired outcomes and learning to be achieved within a relatively short timeframe, despite the remoteness of the Lihir operation, according to Telstra. Future phases of the project will further enhance coverage in-line with Lihir's 20-year mine plan, and provide for expansion of coverage and capacity across the mine, processing plant, port and camp.

Chris Jordaan, General Manager, Newcrest Lihir, said: "The Lihir mine extends 300 m into a volcanic crater and our workers can often be exposed to elevated temperatures. Tele-remote and autonomous mining technologies are fundamental to working the hot work areas that will become more dominant features of our operation in the future.

"The private LTE network will be a great enabler for these technologies and, coupled with the existing in-pit Wi-Fi network, we have been able to create a heterogeneous network that covers the whole mining lease."

Gavin Wood, Chief Information & Digital Officer at Newcrest, said: "Safety is Newcrest's number-one priority and the network Telstra Mining Services has built with us at Lihir will enable safer and more efficient mining using new technologies. The success of this project was 100% driven by leadership and personal commitment of the Lihir's OT/IT team working together with Telstra Mining Services."

Boliden LTE goes live at Aitik

Moving to Boliden and surface mining, it recently went live with 4G (LTE) network services at its Aitik open-pit copper mine in Sweden, Fredrik Kauma, Project Manager, told attendees at the recent Mines and Technologyconference in London.

The company, one of the mining sector's leaders when it comes to employing innovative technology, installed its first underground Wi-Fi network in 2013 and has since come a long way on this connectivity journey as evidenced by the 5G network at Kankberg.

A direct outcome of the work on the underground network has been the addition of 4G network services at Aitik, one of Europe's largest and most efficient open-pit copper mines. This will allow the company to, primarily, carry out accurate remote control of its fleet of Epiroc Pit Viper blasthole drill rigs. "But, long-term we

believe it will replace our existing production WiFi network," Kauma said.

While WiFi does offer Boliden much in terms of connectivity, it cannot match 4G/5G when it comes to robustness and coverage. This is part of the reason the company is pursuing developments with 5G technology. Equipment tracking is one area that could potentially be improved with 5G, Kauma said.

Today Boliden currently uses "passive" Wi-Fi tags for this task, with active antennas mounted on mining vehicles. The signal reflection is only picked up if the tags face the direction of the active antenna and the vehicle with antenna passes close by. While this system adds a lot of value, it does not currently offer the reliability Boliden would like to see, he said.

With 5G, Boliden expects to have "active", as opposed to passive, tags, which transmit information on a pre-determined basis. What Kauma termed "advanced remote control" operation is another area set to benefit from 5G connectivity.

The company already has remote control operations today, but it is either line-of-sight or a pre-determined, repetitive type of remote operation; not advanced. In advanced remote operations, the performance of the wireless communications network has a direct impact on how well the operator can handle the machine, with control responsiveness and picture quality the main factors here.

According to Kauma, low latency will greatly improve the real-time aspects required for secure and efficient handling of vehicles, machinery and other equipment such as drills, hammers, shovels, etc.

In addition, the Quality of Service concept, where priority of connection is given to certain customers, will guarantee bandwidth needs for a detailed enough video stream to the remote operator – even on a heavily loaded network, he said.

"Higher data rates and increased network capacity will enable remote control on a larger scale than what's possible on today's 4G technology," Kauma said.

The improved connectivity expected to come with employing 5G will also be beneficial for wearable technologies, which Boliden has been trialling to help improve the safety and well-being of employees.

The company recently tested out use of a prototype "smart vest" at one of its underground mines for, primarily, proximity detection, but also to "gain a better understanding of other possibilities that comes with this technology", Kauma said.

Boliden would like to, in the near-future, use wearable technology for the monitoring of employees in physically-demanding environments; for analysis of the immediate environment surrounding employees (extreme temperatures, dangerous air quality, strong vibrations or sounds); and for positioning and situational awareness (ie warnings for approaching vehicles).

Key ingredients to make this a reality include a reduction in power consumption – low power means smaller and longer lasting batteries – a fall in cost, enabling the company to equip its entire workforce, and better network coverage and reliability – hence the use of 5G.

"If 5G delivers on its promise, it will be a critical component enabling wearable technology in an industrial environment like ours," Kauma concluded.

Volvo CE set up for 5G at Eskilstuna

Telia, Ericsson and **Volvo Construction Equipment** (Volvo CE) have launched Sweden's first 5G network for industrial use today at Volvo CE's facility in Eskilstuna. Volvo CE will then become one of the first OEMs in the world to use 5G technology to test remote-controlled machines and autonomous solutions.

The 5G network will be used at Volvo CE's research and development facility at Eskilstuna to further develop solutions for remote control of construction machinery and fully automated solutions. It will also be used to increase understanding of how connected machines can create added value for the customer.
"Automation has several levels and having 5G is an important technical support to enable us to drive development in this area. These trials in Eskilstuna will include the remote control of a conventional wheel loader but also further tests of the HX2 concept load carrier," says Melker Jernberg, President Volvo CE. Currently the company is focusing the 5G R&D on its L180H wheel loader remote-controlled prototype, but will soon test 5G on the HX2 concept autonomous hauler as well.

"We can see that the industry's interest in 5G is considerable. Automation of the entire flow will mean new ways of working and greater gains from efficiency. But to connect business-critical machines and vehicles requires a solution that is able to handle the massive amounts of data with guaranteed connection. That is what 5G can give us. And we are proud to lead the 5G-development in Sweden together with our partners," says Anders Olsson, CEO of Telia Sweden.

Even with fully-automated systems, human intervention is still needed now and again for control. Todays' remote-control technology has a time lag that makes it difficult to control at high speed or with high precision. 5G will make remote control simpler and safer.

Redline and Hard-Line integrate for remote LTE ops

Redline Communications Group and **HLS Hard-Line Solutions** have successfully integrated the operation of Hard-Line's Teleop Teleremote Control System with Redline's industrial private LTE solution, enabling tele-operation of heavy mining machinery from a remote-control station.

This integration will allow machinery such as rock breakers, drills, excavators, wheel loaders and dozers to be operated by operators totally out of the proximity of danger, in addition to "more easily expand a mine's progression", Redline said.

"The system saves time, heightens operator safety, improves comfort, and allows a greater percentage of the workforce to operate equipment," the company said. "Together, the companies demonstrated they could deliver safe, reliable and cost-effective remote operations, on a fit-for-purpose, secure private LTE infrastructure designed for the mining environment."

Hard-Line is certified for installation of Redline Private LTE networks and is partnering with Redline to deliver communications infrastructure solutions to the mining industry. Its latest Teleop Auto system delivers 2D and 3D views, with 'real-time' operator control achievable when the system is coupled to robust communication networks.

Louis Lambert, Senior Vice President, Business Development for Redline Communications, said: "As the mining industry progresses through digital transformation to enable 'smart mining', private LTE is surfacing as the wireless technology of choice to deliver robust, reliable and secure mobile communications."

Hard-Line's, Scott Whelan, Vice President of Sales, said: "As a result of our collaboration with Redline, Hard-Line is now certified in both Wi-Fi and LTE solutions to satisfy our customers' needs. This enables our customers to have the flexibility to operate our products on the solution and infrastructure of their choice."

In addition to the collaboration with Hard-Line, Redline continues to invest to further develop communication solutions that are fit-for-purpose for mining companies to deliver on smart mining initiatives globally, it said.

Going for the satellite option

With more and more automated machinery being deployed across mining sites, one of the major challenges that businesses face is managing the data that these machines generate. Joe Carr, Director of Mining Innovation at **Inmarsat** states: We have spoken to mining companies that are gathering two gigabytes of data every hour from sensors on their trucks. When you multiply that across a fleet of 50 trucks, that's a lot of data that isn't necessarily being put to good use.

Inmarsat argues that satellite communication networks, which offer highly reliable, global connectivity, can play a critical role in supporting the deployment of automated solutions

What mining businesses really need, rather than vast quantities of data, is to manage their data better, so that they have the right data, in the right place, at the right time."

"Some miners might at the most basic level use data analysis tools to look at, for example, engine temperatures and conclude that a rise in operational temperatures will lead to a fault, so they can then use this trend to spot problems before they happen. Drawing a conclusion from a single metric may be a useful indicator for providing predictive maintenance, but it won't tell businesses much about the several factors that can contribute to a particular event. On the other hand, some mining companies are capturing and keeping every data point that they produce, which often leads to capacity problems, not only at a network level in simply moving the data but also with storage and analysis. With this approach they may have the data they need to make better decisions, but too often they are swamped and not analysing the right data points or getting the right insights."

Key to the efficient use of data is a data management strategy where the edge and the cloud are considered. Data produced from machines, sensors and vehicles can be connected by edge connectivity then aggregated and processed at the edge before the critical data is sent to the cloud.

"With this approach, mining businesses are able to benefit from the oversight of a broad set of data, with only the critical data sets, highlighting changes, being transferred into the cloud to be used to improve operations. This significantly reduces the cost for mining businesses to transfer data for analysis, from remote sites to control centres, because they are only sending data that needs to be sent, rather than everything that is collected. This also minimises congestion on communication networks, ensuring that the necessary data can always reach the right place. One of the major issues facing miners today on sites is networks at full capacity, with no ability to add more machines."

Critical to this approach is having robust, reliable communication networks that can transfer the aggregated data from the edge back to control centres for analysis, in real-time. If staff in control centres do not have constant visibility over their automated machinery then they may have to shut them down to avoid a safety issue, having a serious impact on production and profitability. Likewise, if machines cannot get the right information back from central servers to confirm safe operation, they may also shut down.

"While many mining businesses have traditionally used terrestrial communication networks to collect and transfer data, this approach to staying connected has its limitations – these networks are costly to deploy and maintain. Satellite communication networks, which offer highly reliable, global connectivity, can play a critical role in supporting the deployment of automated solutions, especially when delivered as a managed service, where the service provider guarantees uptime levels. With minimal equipment required and very low up-front investment costs, mining businesses can rapidly deploy satellite communication networks, connect their automated machinery and start gathering the right kind of data to help them make better decisions on their operations."

3D-P and Rajant make the difference for copper giant

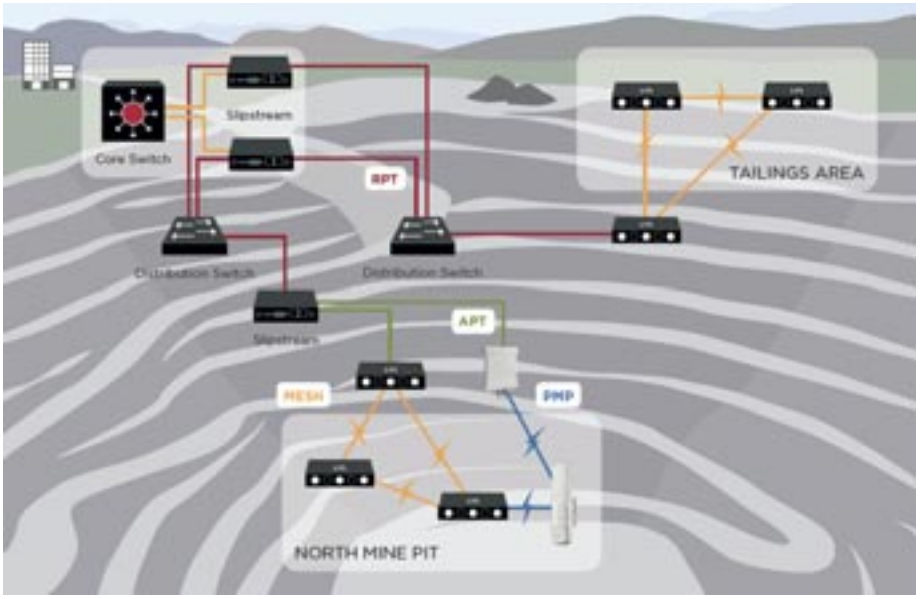
A multinational mining company with multiple sites across the globe including copper mining operations in the Americas was looking for ways to reduce wireless network management and improve network performance while gathering additional machine health data and improving their operational capacity. The company had been running an 802.11g wireless network for a number of years. The head office was however concerned by the amount of maintenance required to preserve the performance of the wireless network at each of the sites, as trailer moves were becoming a frequent activity.

In parallel, the sites had been running several applications on-board their mobile equipment, each using their own hardware, including Honeywell MEM for asset health, Modular Dispatch and High Precision GPS. Many of these systems were due for upgrade, which in some cases would include increased network requirements. Led by the global IT department, the miner was investigating a wireless network upgrade, complete with infrastructure and on-board radio upgrades. At the same time, the maintenance department was investigating an upgrade to their on-board asset health dataloggers, adding functionality and supportability.

The new wireless network should have the ability to reside on Layer 3 to bring the network routing as close to the edge as possible as a best practice for more efficient networks, as well as to satisfy the miner's corporate security mandate. The new network should also require minimal maintenance and have the ability to scale as the need to expand wireless coverage at each of the sites would appear.

Part of the global IT department's vision was to consolidate the radio and the different applications running on-board the fleet into a single platform. In addition, there was a requirement to include an accelerometer and a gyroscope allowing geo-referenced and time-stamped monitoring of the quality of the haul roads, as well as induced stress on the truck itself. Aligning with the miner's corporate network switch standard, the solution should include a Cisco switch.

Working with **3D-P** as a technology partner, and with a long-term vision and understanding of the uniqueness of both the IT department's requirements and the requirements of operations and maintenance, the partnership was able to create a truly unique solution that would consolidate these departmental needs into a single on-board platform, reducing initial costs



Functional representation of the 3D-P mining customer network

and downtime significantly while providing the significant performance improvement each department required. Additionally, the miner was looking for a technology partner that would support them through the lifespan of the technology from design and deployment, to training, consulting and ongoing support. The partner should also have in-depth mining experience.

The expected result was an easy-to-maintain end-to-end solution that would support the miner's requirements overtime while reducing their technology "clutter", improving operations and reducing maintenance time and associated costs.

Rajant was selected as the technology of choice for the miner's requirements for its self-forming, self-healing capabilities that would allow significant reduction in ongoing maintenance of the network infrastructure in the mines' pits. Its meshing capabilities would also allow cost effective increased coverage through dynamic meshing, while Rajant's RPT protocol and significant security capability allowed both the required layer 3 connectivity and the IT departments security requirements.

For high speed wireless backhaul, Cambium Networks PMP radios were used for their known reliability, GPS synchronization, channel re-use capacity as well as non-collision based channel access. The miner's networks consists of multiple segregated VLAN's serving machine applications and network management. These networks span multiple layer 2 segments across each site, being brought from the wired network to strategic locations throughout the sites with Cambium PMP radios. Rajant BreadCrumbs are placed at these locations, and others, creating high speed multi-channel InstaMesh links to other RF visible Breadcrumbs, either embedded in the 3D-P Intelligent Endpoint® (IEP) or standalone. Data generated on the mobile clients is transferred from machine to the IEP, or standalone Breadcrumb, to the Rajant wireless InstaMesh network and routed by Rajant's InstaMesh

This data is routed to its final destination by Rajant's APT protocol (layer 2 InstaMesh routing, within single segment) and RPT protocol (layer 3 InstaMesh routing, between layer 2 segments) while using the most cost efficient route whilst being blind to the type of network medium used.

At the client access level, the solution consists of the 3D-P Intelligent Endpoint. Designed as an open computing platform and mobile radio with onboard network management and data collection capabilities, selection of the IEP platform allowed development of a solution that met all the miner's needs in a single device. The IEP model developed for the miner includes a Rajant ME4 radio and a Cisco ESS2020 switch, while hosting the Honeywell MEM asset heath system. It also includes GPS information and accelerometer data, all in one platform.

The native suite of tools residing on-board the IEP allowed development of a few customised solutions including network health monitoring, a publish/subscribe solution for delivery of HPGPS corrections where required, and the firewall capability to provide connectivity via BINAT (bi-directional network address translation) to the P&H Centurion systems running on their shovels where local static IP addresses are utilised, which are not compatible with the miner's IP networking scheme.

"The solution provided the miner with tremendous benefits including significant reduction in capex for the on-board solution, as well as reduction in opex through significant savings in installation and troubleshooting time, all while delivering a new and simplified, performant and manageable network."

Available as part of the native IEP suite of tools, the miner leverages 3D-P's Network Performance Analysis Toolkit (NPAT), to regularly monitor the health of their wireless network from the mobile client's perspective. The NPAT data collector runs a number of active and passive performance tests directly on the IEP, including ICMP pings of varying size, upstream and/ or downstream UDP/TCP throughput, connectivity, neighbour tables, noise levels and location, etc. The collected data is geo-stamped and timereferenced, and is visualised on a map for a more user friendly analysis.

3D-P and the sites are also developing a solution to automate the data collection and provide it to the miner's own analytical tool. Looking at a deployment of the solution across the multiple sites, the miner decided to perform the upgrade one site at a time over the course of a year. A formal 'train the trainer' model was followed at each of the sites. An assigned 3D-P technical lead would come to site for a two-day period and train the site champions on RF fundamentals, antenna theory, Rajant InstaMesh fundamentals, Rajant BC Commander handson, IEP configuration, 3D-P deployment methodology and best practises, Rajant and IEP troubleshooting.

The upgrade at each site followed a two-phase process. It would start with an upgrade of the backhaul and distribution layers with deployment of Cambium Point-to-Multipoints (PMP) at pre-selected infrastructure locations. With the miner previously running a Wi-Fi network, the Rajant infrastructure radios were co-located with the Wi-Fi radio system for the switchover phase.

The upgrade of the mobile equipment then followed and was staged. The previous radio equipment and asset datalogger was exchanged for the 3D-P Intelligent Endpoint. With the upgrade completed, Dispatch and the other on-board applications were tested prior to the equipment being released into the mine.

The upgrade at the first five sites was delivered on time and on budget, with the remaining sites scheduled to be completed by the end of 2019. Close partnership between 3D-P and the miner played a critical role in this success, through design and development of a complete end-to-end solution that met both the IT and asset health groups.

Fluidmesh technology

Fluidmesh is an MIT spin-off that has established itself as a very solid alternative to LTE and WiFi Mesh solutions in open-pit and underground mining in the last few years. The Brooklyn-based company developed an MPLS-based wireless transmission protocol with built-in Artificial Intelligence to deliver 5G-like performance in

unlicensed spectrum. The company currently has deployment in production in mines in Australia, USA, Canada, Chile, Peru, Mexico, Ukraine, Colombia, South Africa, and Namibia.

Fluidmesh technology can be used as a standalone solution as well as a complementary solution to LTE or WiFi, depending on the requirements of the mine site. The company has been focusing on delivering a true multiservice network for mining supporting applications such as dispatch, tele-remote dozers, Geo-mechanical radars, Autonomous Drilling and Autonomous Haulage. By using an MPLS-implementation, the Fluidmesh network is able to guarantee a 0-ms handoff time while roaming and a sub-10ms end-to-end latency to trucks which is extremely valuable in autonomous and tele-remote applications. In addition, the Fluidmesh network supports a special 2x2 MIMO dual-polarity antenna/radio configuration with active beam-forming which is able to deliver up to 500 Mbps of usable TCP throughput per trailer with a range which is 30-50% greater than 802.11-based alternatives used in mining today.

Fluidmesh told ***IM*** it is also the first company to bring Artificial Intelligence to deliver better wireless connectivity in open pit mining globally. The system implements a machine learning algorithm that optimises channel access and modulation schemes used by each truck to a given trailer. According to the company this innovation allows to address traditional CSMA congestion issues often present in WiFi Mesh networks in open-pit mining leading to an increase in overall in-pit network capacity up to 50%.

"Another great advantage of Fluidmesh technology is the capacity of supporting both a Layer 2 as well as a Layer 3 architecture with no impact on latency or roaming times. This provides much greater flexibility and scalability in comparison to WiFi based solutions and allowing the mine for a much easier network management. In fact, running a single broadcast domain for the whole mine-wide network can be very dangerous: a single broadcast storm can impair the overall network with a substantial impact on productivity. Being able to split the network in multiple subnets without impacting latency and roaming is huge advantage, particularly for large mines."

'We are excited in the success we have been having in mining in the last four years" – confirms Cosimo Malesci, Fluidmesh Co-Founder and EVP of Sales. "We believe that wireless networking in mining today can be a huge impediment to adopting automation and increasing overall productivity. Unfortunately, wireless for mining is a very small market thus limiting the amount of fit-for-purpose solutions that have been developed over the years. We are excited to have been able to bring an alternative solution to this market which offers disruptive performance in comparison with the standard options and we are looking forward to continuing to innovate and grow in the space".

Maestro Digital Mine Plexus PowerNet with Cisco WAP at Borden gold mine

Recently Fluidmesh has successfully deployed its technology in partnership with RCT and MST Global supporting six tele-remote dozers in a site in North America. The network is composed by a number of trailers covering an area of 10 square miles. Three more sites supporting dispatch and autonomy have been completed and will be announced shortly.

Maestro Plexus at Borden

Identifying the mining industry's rising demand for real-time data, **Maestro Digital Mine** works with mining companies around the world, such as Newmont Goldcorp, to address the challenges associated with traditional communication backbone solutions (broadband and fibre).Newmont Goldcorp's Borden Mine became one of the first mines to integrate Maestro Digital Mine's Plexus PowerNet™, which it says addresses the challenges associated with extending fibre optic-based communication backbone solutions for "last mile" data applications. Newmont Goldcorp's Borden Mine is located in Northern Canada, 11 km northeast of Chapleau, Ontario.

Newmont Goldcorp is the world's largest gold producer, and approximately 15% of its direct gold production comes from Northern Ontario, Canada. The battery powered all-electric underground mine is the first of its kind in Canada. "Newmont Goldcorp is a proven leader in implementing innovative solutions into their operating mines, partnering with like-minded technology suppliers such as Maestro Digital Mine to improve health and safety performance and reducing greenhouse gas (GHG) emissions."

Borden Mine first started using Maestro's digital ventilation technology, the Vigilante AQS™ air quality stations, to measure environmental conditions for worker health and safety and to reduce installation infrastructure costs. With this initial success, Borden soon became one of the first mines to integrate the Plexus PowerNet™ which addresses the challenges associated with extending fibre optic-based communication backbone solutions for "last mile" data applications. "The Plexus PowerNet™ system quickly extends communication and end-point power using copper coaxial cable to the face. The Borden mine all-electric vehicle fleet sets the conditions for a safer workplace for employees, while resulting in a smaller environmental footprint. Newmont Goldcorp expects to begin commercial production at the mine in the second half of 2019." Borden depends on real-time digital technology and intelligent controls, including tele-remote technology to maximise equipment use for continuous mining. Part of getting an underground mine online for production means embedding and advancing critical communication infrastructure throughout the mine and towards the face. Borden uses fibre optic cabling as far as the level entry or electrical sub-station as do most modern mines. While fibre optic cable provides high data rates and reliability, it also presents challenges to the underground mining industry. "Extending delicate, fibre optic cable to the high traffic headings like the mining face where the data is essential is challenging. Fibre optic cable can get damaged easily causing production delays. Terminating fibre underground is difficult, time consuming and requires expensive specialised training and a clean environment, which is frequently the biggest contributing factor limiting the advance of connectivity."

At Borden Mine, 144 strand fibre cable is run from the surface control centre to each level entry via the ramp and terminated in a fibre patch panel where a Cisco network switch is added. Borden was constrained with communications from the network switch out to the face. It required a durable solution that could bring both data and power to the face of each mine level that is easy to install, advance and repair with robust components that could be transparently integrated to a regular IP based network.

The decision to implement the Plexus PowerNet™ solution was made in December 2017 and the technology was integrated into the design and construction phase of the mine. Newmont Goldcorp now uses the Plexus PowerNet™ in conjunction with Cisco access points to extend their network from the fibre patch panel to the internal workings. Their primary and most demanding application was to run Sandvik's AutoMine® LHD tele-remote application. Tele-remote applications increase safety by removing the miners from their most dangerous jobs and at the same time allows the LHD to return to the face immediately after a blast thereby increasing vehicle up-time as well as productivity. Borden understood that without a reliable and high bandwidth connection, any automation project will fail. "The Plexus PowerNet™ provided all of this and more. The Plexus PowerNet™ nodes allowed Borden Mine to connect multiple devices such as high definition PoE+(Power-over-Ethernet) cameras, Maestro's Vigilante AQS™ Air Quality Station, Tele-Op Laser Safety Barriers and Underground Fleet Telemetry at each level. Newmont Goldcorp's Borden Mine continues to expand the Plexus PowerNet™ on each new level to provide a solid communication network in time for full production."

Patrick Gilbert reflects: "We are at a critical time in our production schedule and the simplicity of the Plexus PowerNet™ is working well with the team and will play an important role for monitoring the activity and keeping our workers safe at the face. Plexus PowerNet™ delivers a high speed, low latency digital communication network that provides PoE+ power to Wireless Access Points (WAPs), cameras and any other IP based device. The system eliminates the need for costly outside fibre optic contractors and can be installed and maintained by any internal tradesperson.

The Plexus PowerNet™ is currently installed and being expanded at 22 mines in Canada, the USA, Spain, South Africa, Mexico and Finland. Our current clients have compared other gigabit network solutions and concluded that Capex can be decreased in the area of 40-60% without any compromise of network speed or capability. The Plexus PowerNet™ can be used in mines with or without a fibre optic network.