Ensuring continuous communication

Communications systems have changed a lot in the last decade but still have a vital role in safety and operations underground, finds Ailbhe Goodbody

Installing communications infrastructure in underground mines can be challenging; each mine is different and requires a system design specifically tailored to address its needs.

"Mines are dynamic environments and a communications system must support the ever-changing nature of the mine – with minimal network configuration and maintenance," says Phil Carrier, vice president of sales and marketing at Innovative Wireless Technologies (IWT). "We believe that understanding the realities of the mining process throughout the mine, and designing components tailored to those varying needs – in travelways vs working areas, for example – provides solutions that best optimise competing requirements of size, weight, power, feature support and cost."

One of the challenges often experienced in underground mines is establishing mine-wide communications coverage with continuous connection throughout; there are often distance limitations and breakdown of signal.

Many modern underground mines have fibre optic cabling to the level entry but they struggle to advance the network to the inner workings and headings. Fibre optic cabling provides high-bandwidth and low-latency communications but presents a number of challenges to the underground mining industry.

"Extending fragile, fibre optic cable to the high traffic headings where the data is needed is problematic due to the nature of the drill-and-blast cycle," explains Michael Gribbons, vice president, sales and marketing at Maestro Digital Mine. "In high traffic areas, fibre optic cables can get damaged and often require complex and time-consuming repairs. The dusty and humid environment makes splicing and repairing in the field extremely difficult and time-consuming. It is also expensive to repair and requires highly skilled professionals to repair, taking time and can often bring production to a grinding halt."

In systems that use nodes, their protection is also important. "[The] protection of communication nodes underground is imperative to sustaining a low-maintenance, cost-effective system," says Brian Jones, director of global business development at Matrix Design Group. "Our recommended solution is to place smaller nodes along the walls or tie them tightly to the roof. This layout is preferable to placing large nodes on the ground or hanging them down low in the centre of the entryway, which makes them targets for collision with passing machines."

Small, battery-powered infrastructure with a long communication range that stays out of the way of the mining process, yet is reliable, can be a good solution in working areas. Carrier comments: "These attributes enable quick deployment and re-deployment, and survivability of the mining process." ►

"Mines are dynamic environments and communications systems must support their ever-changing nature"

Matrix's METS provides text communication and is designed to optimise component battery life and minimise maintenance costs

Ensuring that a communications system is relatively simple to install, extend and maintain underground can be important too. Denis Kent, product manager, mining at MST Global, says: "This avoids the often large 'hidden costs' of installation that can be a significant part of the overall network deployment at a mine, and greatly reduces the on-going cost to maintain and expand the network as the mine grows."

For example, mines generally don't have IT specialists working underground. As a result, ensuring that system installation and local configuration can be done by trained electricians or instrument technicians is a big benefit, particularly in the on-going maintenance of the network.

FAILURE PREVENTION

In an emergency situation, parts of underground communication infrastructure may be damaged or cut off. In the potentially hazardous underground environment, it is important that communications systems are designed to withstand these circumstances to ensure safety of personnel.

Damage can also occur as part of day-to-day operations; for example, at times a cable can be cut or damaged by either a blast or by mobile equipment. With most current digital networks, the only practical method is generally to provide redundancy through alternate data routes. In the case of optic fibre-based networks, this is through providing redundant paths via a ring topology, so signalling defaults to another route if the main pathway is broken.

Redundant links can improve resilience should one connection or cable fail. Gribbons notes: "This results in a type of self-healing until the connection or cable is repaired by either a development miner or electrician."

The number of redundant paths used in a communications system is dependent on budget and, in an underground environment, access to alternative routes. Jones says: "In most instances Matrix will install redundant paths for communications in and out of the mine. These paths should have some sort of physical barrier in-between them; in a coal mine these would be in separate entryways; in a metal/non-metal operation this would involve an alternative path out of mine."

Kent states that MST's first-ever technology has been having somewhat of a resurgence in recent years because of its independence of conditions underground in its operation. He says: "The PED emergency warning and remote blast initiation system is designed to provide messaging to miners underground regardless of the miners' locations and the conditions underground. It achieves this by transmitting at ultra-low frequencies directly through-the-earth (TTE), enabling in many instances the antenna to be located on the surface of the mine only. As a result, this highly redundant, though one-way signalling system complements other higher-bandwidth two-way Wi-Fi and radio systems."

Wireless node-based communications systems are battery powered, so do not require the same redundancy planning. "These are

independent from all other systems and power sources and remain connected and functional regardless of the mine status and situation," explains Mike Berube, CEO of Strata Worldwide.

"If a wireless node is damaged, the node-based mesh network will automatically reconfigure to heal itself. It will re-route the signal to a different node. If this fails, a simple replacement of the damaged nodes will automatically re-establish the network connection – even in a situation where rescue teams carry in replacement nodes as they advance into the mine."

In such a system, the locations of the damaged nodes are highlighted on the user interface at the surface, and surface operators can direct personnel underground to the locations.

There is also the opportunity to use wireless redundancy in some areas where the communications system is fibre-based. However, Kent cautions that wireless redundancy still requires those alternate paths to be available and open during any disruptions underground.

While no system that requires infrastructure underground is completely unaffected by explosions or fires or roof falls, various steps can be taken to minimise the impacts from these events.

"For example, systems that minimise cabling between infrastructure devices are less likely to be impacted by roof falls," says Carrier. "Networks that are redundant can automatically re-route around impacted areas. Systems that provide long-range communication can be placed further away from working areas while still supporting the communication and data requirements for safety and operations. Tucking equipment out of main travelways reduces the risk of damage."

THE FUTURE

Communications systems in underground mines are set to be more high-tech in the future as various technologies become more prominent and reliable. "The definition of mine communications has evolved in the past 10 years," explains Jones. "It has expanded to include the network – including voice, data tracking, text and sensor readings. More recently, of course, there has been a big push for IoT [Internet of Things], which has incentivised mines to pull out all available data and use the networks to integrate the communications elements."

One of the technologies influencing innovations in underground communication is Big Data via high-speed networks such as Wi-Fi and Ethernet. "[They are] now making it possible to pull all kinds of key data – digital and visual – out of mines in near real time and extract information to expose inefficiencies and improve productivity," says Jones. "Mines can accurately know where their people and assets are through Wi-Fi (or radio-frequency identification (RFID)) tracking; IP radio handsets and VoIP [voice over internet protocol] phones can be used for two-way voice communications; internet/intranets can be accessed, and video can be used to monitor critical points.

"Ventilation, gas levels, environmental conditions and ground strata can also be monitored. As we move into the future of mining, the network provides bandwidth for adding teleops and autonomous vehicles."

In addition, open-source networks can attach any number of data collection sensors or devices. This gives mines more flexibility in purchasing so that they can use preferred products and often save costs.

Furthermore, Jones states: "Technology used in innovative modular design now allows relatively novice users with no networking background to install and maintain a high-performing underground network. With plug-and-play systems, there is simple and low-cost installation and upkeep."

All mining, including underground, is also going towards automation; some autonomous vehicles are already in use in surface operations today.

"Underground mining operations are heading that way as well, although the challenges are greater with respect to vehicle location and broadband networking technologies," says Carrier. "Supporting all of the requirements – communications, tracking, high-speed data, a growing number of devices with IoT – in one network that is robust, reliable, and easy to maintain and support is a challenge." ►

"The definition of mine communications has evolved in the past 10 years"

AXON is MST Global's latest underground technology platform

"All mining, including underground, is going towards automation"

Kent comments: "The future, and hence our product roadmap, is being driven by the much-talked-about increase in remote and autonomous mining and the increasing use of data."

Various technologies, such as mesh networking, Wi-Fi, 5G and long-term evolution (LTE), are in use or in development to meet these needs. 5G or LTE networks can be established in the same way as digital Wi-Fi access.

"LTE/5G is high on the agenda for many people, and rightly so as it has the potential to offer some significant benefits," says Kent. "MST has invested a lot into being 'LTE ready'. With the current state of the technology, one thing we have found is that amongst all the hype, there is some difficult challenges in deployment and on-going extension of LTE in the underground environment. This seems to be reflected in that there have been numerous trials, tests and the like of LTE underground, but we aren't aware of any mine-wide deployments with LTE being used as the primary communication system for daily operations.

"This will change as 5G becomes fully developed, but like we see in our daily lives, 4G and mobile/cellular networks are very useful but it doesn't stop Wi-Fi and IP networks still being a fundamental part of any business's data requirements. Mining is no different, so Wi-Fi is still going to handle a lot of the high-bandwidth requirements for modern mining, with LTE/5G entering for particular aspects, such as voice communications and automation systems."

SYSTEM PROVIDERS

There are several companies that supply communications systems for underground mines – *Mining Magazine* speaks to some of the main players to find out what is available.

Innovative Wireless Technologies

Innovative Wireless Technologies (IWT) offers system solutions consisting of AC- or battery-powered infrastructure nodes that incorporate wireless mesh networking technologies.

"Our mesh nodes communicate wirelessly with each other – no fibre or cable between them – and act as repeaters to 'hop' data from one node to the next," notes Carrier. "Mesh networks inherently require no addressing (self-forming) and are redundant (self-healing) and thus form robust networks to enable communication, tracking of people and vehicles, and the transport of data."

IWT's mesh networking technologies were developed specifically for the challenging requirements of underground mining operations and have been deployed since 2008 in over 80 mines of various minerals, such as coal, trona, salt and limestone. Carrier says: "Our wireless networks support voice and text communications, continuous tracking, atmospheric monitoring, belt monitoring, and operational data from machines, video cameras etc."

An IWT communications system was recently deployed at an underground limestone mine. The system uses both AC-powered infrastructure in the main travelways and battery-powered infrastructure in the working areas. Carrier explains: "The system provides voice and text communications, the tracking of people and

vehicles, and Wi-Fi access and the wireless transmission of machine data from the working area to the mains where fibre is available."

Maestro Digital Mine

Maestro Digital Mine works with mining companies globally to address the challenges associated with traditional communication backbone solutions.

Its Plexus PowerNet, which is one of the first powered coaxial gigabit networks, delivers a high-speed, low-latency digital communication network that provides PoE+ [power-over-Ethernet] power to WAPs [wireless access points], cameras and any other IP-based device.

Gribbons says: "The system eliminates the need for costly outside fibre optic contractors and can be installed and maintained by any internal tradesperson or development miner."

It provides a robust, simple-to-deploy, one-cable solution for network connectivity. Gribbons states: "Plexus makes installation simple, using a single coaxial cable that carries both power and network connectivity. This eliminates the need to run both fibre and power to new network devices."

It is designed to simplify the installation, extension and maintenance of the network, while enabling high-bandwidth, low-latency, low-jitter data and endpoint power using coaxial copper cable. Gribbons says: "The termination process now becomes easy and cost-effective, utilising basic tools. A termination can be completed by any tradesperson in less than two minutes."

In addition, the nodes provide an easy way to terminate, troubleshoot and deploy standard based IP devices from the Plexus PowerNet embedded network switch.

The Plexus PowerNet is currently installed and being expanded at 20 mines in Canada, the US, Spain 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," explains Gribbons. "The Plexus PowerNet can be used in mines with or without a fibre optic network. The Plexus has been designed for the quickest, simplest and least expensive 'last mile' of communication."

Maestro continues to develop Wi-Fi, Bluetooth and LTE devices and networks. Gribbons says: "LTE is being attempted at a few mines in Canada but so far, the current technology is not available for accurate tracking. Likely in the next five years, this will be addressed but for today, 802.11 Wi-Fi is the only network that can handle all of today's use cases."

StrataConnect Wireless is a completely wireless, battery-powered option for two-way, text-based communication

Matrix Design Group

Matrix Design Group's Miner and Equipment Tracking System (METS) 2.1 provides a proprietary wireless communications, electronic tracking and atmospheric monitoring system. Jones states: "The most widely used tracking system in US underground coal mines, METS provides text communication and is designed to optimise component battery life and minimise maintenance costs. With its scaleable design, it works effectively in small or large operations and features simple, flexible deployment options."

N-Connex, a recent addition to the Matrix product suite that is manufactured by Northern Light Technologies (NLT), is a ruggedised high-speed network installed in mining markets across the globe.

"N-Connex provides Wi-Fi network connectivity to every corner of the metal/non-metal mining operation, allowing for data collection, asset tracking, radio communications and system controls throughout the mine and provides a foundation for adding teleops and autonomous vehicles," says Jones. "N-Connex's innovative modular design makes it possible for non-specialised staff to install and operate, and mines can grow the network as their needs require, thus lowering up-front costs. As a standard 802.11 Wi-Fi network, N-Connex can support a wide variety of sensor traffic, including Matrix's full suite of atmospheric monitoring solutions."

In addition, Matrix atmospheric monitoring sensors provide advanced wireless or wired air monitoring station (AMS) technology for mine ventilation management, including CO, methane and airflow. They are designed to operate on a number of networks, including Wi-Fi.

Matrix recently installed the N-Connex system at a surface/underground operation in West Virginia, US. Jones notes: "This mine was interested in initially installing a radio communications network but wanted the ability to expand its functionality as needed in the future without a large capital outlay. N-Connex provides simple scaleability and sensor addition capability, delivering a straightforward solution for the operation."

Matrix has also worked with North American Palladium (NAP), which has set the target of making its Lac des Îles mine in Ontario, Canada, the most technologically innovative mine ►

in the world. To do so, the company invested in several technologies that required a rugged network backbone to drive its IoT strategy.

The N-Connex Edge module and the N-Connex Bolt, installed through NLT in Canada, were used to collect and monitor the telemetry data of each of NAP's haul trucks. "The nodes provide Wi-Fi underground that allows for communication of telemetry data to the mine operators to gain insights on haul truck operations," says Jones. "These insights were used to drive greater efficiencies in haul truck operation."

"NAP is also using the N-Connex backbone to enable tele-remote operation of scoops underground including seamlessly connecting the Sandvik provided access point through the N-Connex backbone."

"It often suits a mine to deal with one vendor for voice communications, tracking systems, data links and software applications"

MST Global

MST Global has a broad suite of underground technologies, having focused on R&D and commercialisation of underground communication systems for the last 30 years. These systems range from ultra-low frequency TTE paging systems, to leaky feeder radio systems through IP and Wi-Fi networks, and emerging LTE capability.

"This large range of technologies has allowed MST to configure one, two or three of our technologies to provide a total communication solution to meet a mine's exact requirements," explains Kent. "This often suits a mine, as they are dealing with one vendor for voice communications, tracking systems, data links and software applications. Though one important aspect of our solutions is that the network is open to any third-party provider, the mine may choose from the client devices and sensors underground, through to streaming data into third-party software applications and ERP [enterprise resource planning] systems."

As demand increases for LTE applications, MST has been developing a new network platform that will allow both Wi-Fi and LTE to be deployed underground in a practical and reliable manner. Kent says: "Known as our AXON technology suite, a key aspect of the AXON platform is its modularity to allow different data networks to be deployed underground via snap in modules, be it Wi-Fi APs or eventually LTE/5G picocells."

Kent comments: "In summary, we provide the system to support our particular devices and applications, but also open it up to other devices and applications the mines want to use. This allows mines to converge all their communication and data requirements onto a single network."

One of MST's recent interesting installations was at a gold mine in Alaska, US. Its IMPACT network was originally installed to provide IP and Wi-Fi connectivity underground to enable tracking of people and equipment, but the plan was always to expand the applications this network could support.

Maestro Digital Mine's Plexus PowerNet

During the installation of N-Connex in a West Virginia mine, two mine employees check the system through the Distribution module

The company has also implemented expansions to system functionality, such as automation and ventilation on demand. "The MST network has been validated with several vendors' automation systems, such as Sandvik AutoMine and Cat Minestar," says Kent. "In the case of this mine, as part of their productivity improvement drive they chose to implement Sandvik's AutoMine system. With a proven network already in place, this implementation of AutoMine was greatly simplified as the networking required to support it was already there. Put simply, they were able to leverage the MST network already installed rather than needing to install another network and all that entails in regard to maintenance and support."

Another example of the engineers leveraging the network and its applications is using the location information from MST's tracking system at a mine. Kent notes: "Reliably knowing the location of people and mobile equipment has allowed logic to be applied to this location data to adjust the fans' control systems to set fans according to the presence of people and/or equipment in various ventilation districts to optimise ventilation energy use."

A lead-zinc mine in the US has installed MST's FARA workflow management solution. "FARA is an application-driven suite that uses iPads to use for completing forms digitally, rather than via paper," says Kent. "It also can monitor and manage workflow, such as cycle time monitoring of production vehicles, with reports available to all people equipped with an iPad.

"What differentiates FARA is that it's personnel focused, in that the smart device is associated with a person rather than installed on the equipment. This reduces costs, as personnel just log into whatever task they are doing and the tablet runs the applications they need to manage and monitor that task. For example they log in as a truck driver on truck 'x', or as a geologist analysing the freshly exposed orebody."

Strata Worldwide

Strata Worldwide specialises in underground communication systems and offers a number of highly flexible options. For example, StrataConnect Wireless is a completely wireless, battery-powered and intrinsically safe option for two-way, text-based communication. It operates on a node-based mesh network that establishes total coverage through-out the installed area.

"The network can be extended right to the working face," states Berube. "The battery-powered nodes are suspended in the mine, with no line-of-sight required, and automatically connect to one another. StrataConnect Wireless is completely independent of other systems and external power sources, which ensures that it is resilient to voltage spikes and remains fully operational during a power shutdown."

The current device carried by miners for communication as part of StrataConnect Wireless is the Miner Communicator. It includes an LCD screen for messages and toggle arrows to compose and sort through messages, and fits into a small pouch on the belt.

Berube says: "Strata will soon be releasing the MC2 hand-held mobile device, which will be a significant upgrade to the current MinerComm. The unit will include a large display screen, a full, hard-button keyboard and visible LED lights for notification alerts."

StrataConnect DigitalBRIDGE is a point-to-multipoint PoE digital network that delivers both power and high-speed data over a single coaxial cable. It provides data capabilities and speeds comparable to fibre, with the added benefit and ease of working with coax.

"DigitalBRIDGE can be used to expand, replace or repair existing fibre or can be used as a new, standalone system," notes Berube. "Power can be injected into the network at any point and by utilising off-the-shelf tools and standard procedures, on-site personnel can tap into the cable anywhere to install Ethernet devices. Capabilities include Wi-Fi access, cellular LTE and 4G, VoIP, video, telemetry, RFID tracking, tele-remoting and more."

Strata's latest addition to its communications portfolio is DigitalBRIDGE Plus+, which is designed to offer the simplicity and performance of DigitalBRIDGE with the additional functionality of analogue or digital radio. Berube says: "With the use of a leaky feeder coaxial cable, along with the high-quality DigitalBRIDGE bi-directional line amplifiers (BDA), DigitalBRIDGE Plus+ delivers power, high-speed digital data and a full spectrum of VHF [very high frequency] radio frequencies all over a single leaky feeder cable network."

Mines can boost the performance of existing leaky feeder systems with the inclusion of DigitalBRIDGE VHF BDA line amplifiers. These units cover all the frequency bands of existing equipment, making them fully interoperable with any third-party line amplifier already in use.

"They can then upgrade the functionality of their leaky feeder systems to include digital by utilising DigitalBRIDGE line amplifiers with Ethernet," explains Berube. "These provide interfacing with fibre optics networks, and inject digital data into the leaky feeder network. Mines then have the ability to tap off of the leaky feeder with digital Ethernet devices as like standard coaxial DigitalBRIDGE."

All DigitalBRIDGE bi-directional line amplifiers pass digital data and the inclusion of digital does not affect VHF voice communications.

Strata has installed multiple StrataConnect Wireless systems and StrataConnect DigitalBRIDGE systems in mines in the US states of West Virginia, Kentucky, Wyoming and Utah over the last year. Berube says: "Mines installing StrataConnect Wireless are using it for the standard communications and personnel tracking features, but are also expanding the use to include gas monitoring with our wireless and battery-powered Trolex Sentro units, as well as belt monitoring."

For belt monitoring, the StrataConnect technology interfaces with the PLCs of the belt controller boxes and enables real-time monitoring and remote programming capabilities of the belt drives and lines.

Mines are installing DigitalBRIDGE to expand their digital network coverage beyond the end of their fibre. Berube comments: "Some mines elected to go with DigitalBRIDGE for the lower cost and ease of install as compared to extending the fibre."

Other mines have elected to use DigitalBRIDGE as opposed to fibre because of the lower cost and ease of use. Berube says: "Some mines do not have the manpower or employed skill-set to install and maintain a fibre network."

"Wireless node-based communications systems are independent from all other systems and power sources"

A geologist logging structure in real time via MST Global's FARA GeoApp