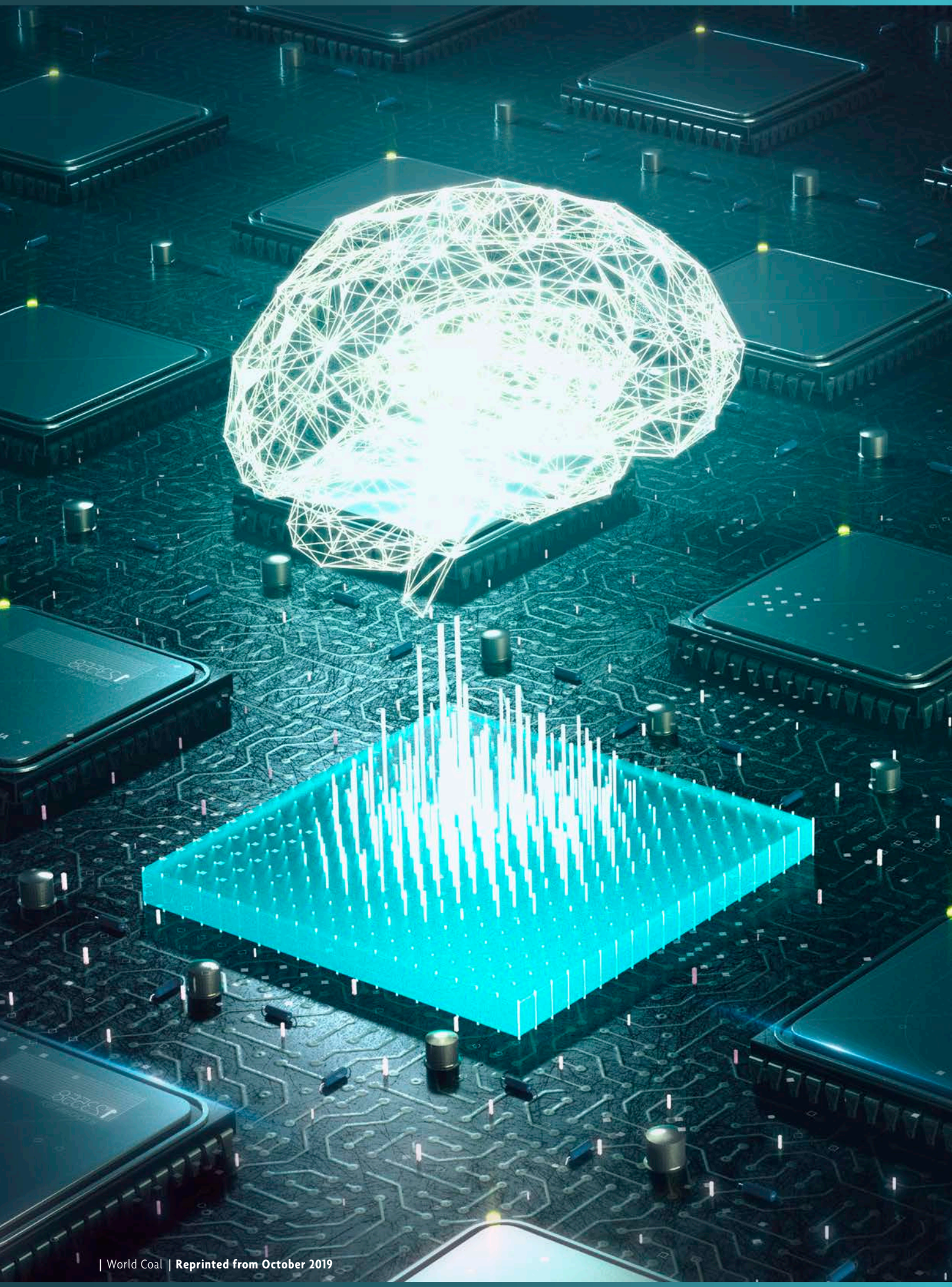

NEXT GENERATION COMMUNICATION NETWORKS

Jeremiah Colling, Innovative Wireless Technologies, Inc., USA, reviews the need for next generation communication systems, and explores some of the considerations and challenges associated with selecting and deploying these systems.

The mining communication systems of the future must have the capability to provide reliable connectivity and multiple layers of redundancy while supporting a myriad of critical services, both above and below ground. These services include operations, communication, tracking, environmental monitoring, and more. Next generation communication systems must also take safety into account, along with the need for advances in technology to address market and production requirements for mining operations, who have ever-moving and constantly changing environments.

Current technology

Some of the current generation of 2006 Miner Act compliant communications and tracking systems have adopted the architecture shown in Figure 1, where each internode connection path can be wired or wireless. In this architecture, Path 2 provides only dual redundancy for a handset and nothing more. If any node or cable along Path 1 fails, the entire path is down and dependent upon Path 2.

Others systems, such as the IWT SENTINEL™ system, provide additional redundancy by also supporting crosslinks

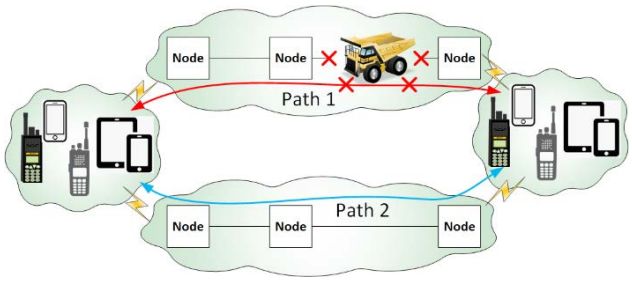

Figure 1. Minimally compliant redundancy.

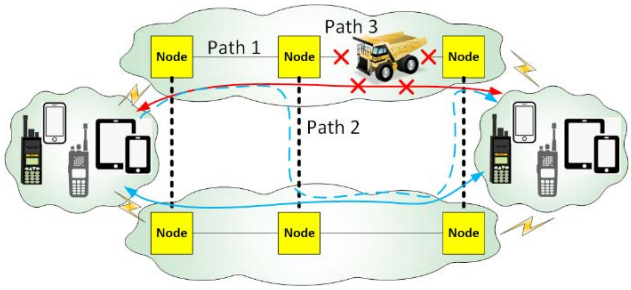

Figure 2. Crosslinks for additional redundancy.

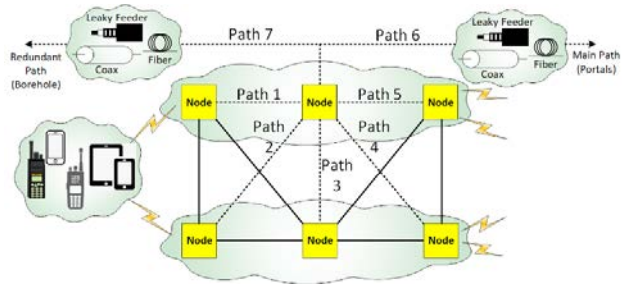

Figure 3. System using all possible connections.

between nodes using mesh networking, as shown in Figure 2. To provide full redundancy between nodes, using a fully cabled system would require one cable for each surrounding node, which is up to five cables for each node in a dual entry system. With a wireless mesh network, short cables and antennas replace the long internode connection cables, which provides viable architecture with multiple communication paths on multiple entries for a truly redundant system.

Existing solutions for underground communications include copper, fibre, leaky feeder, mesh, WiFi and RFID. Even with the additional benefits of mesh, most existing underground communications systems are still only designed to meet the minimum requirements of the law, and are not entirely capable of fully capitalising on the amount of redundant paths into and out of tunnels of mines, preventing them from being a complete technological solution with growth potential. As such, they have struggled to keep up with the fast pace of technology evolution, lack interoperability, and fall short in reliability and redundancy of communications into and out of the underground space.

Redundancy

The next generation of communication systems must be interoperable and capable of supporting existing and future forms of communication seamlessly. This includes both wireless and wired paths of communication. Using all possible entry and exit points with multiple technologies maximises redundancy and increases safety, as shown in Figure 3.

Several benefits of a wired/wireless configurable communications solution include the following:

- True autonomous operation without the presence of coordinating nodes.
- Automatic discovery and maintenance of network topology.
- Time synchronised operation among network nodes.
- Interoperability with existing equipment including fiber and leaky feeder.
- Configurable infrastructure nodes for best individual mine integration.
- Simultaneous operation of many nodes in a shared internet protocol (IP) and RF medium.
- Reliable packet data transfer across a multi-hop network.

IWT's SENTINEL system is optimised to support above-ground and underground communication with multiple layers of redundancy by accommodating both wired and wireless paths of communication (Figure 4). Providing mines with the ability to connect through standard portals or via boreholes miles away from existing infrastructure enables scalability and improves redundancy and overall system survivability.

Coverage

Many mines have multiple, parallel entries. Systems that provide coverage in entries adjacent to the escapeway entries and tunnels in which the system is installed further enhances the safety of those miners who work there, since they spend less time without communications capability. Figure 5 shows a basic system with two nodes and the amount of redundancy possible using multiple entries throughout the mine, in addition to multiple entry and exit points.

The SENTINEL system also provides ad hoc deployment in remote locations with or without 'mains' power. The peer-to-peer network allows connectivity to all nearby nodes via multiple routes for true redundancy. The mesh networking and operational management are based on local clusters with connection to gateway nodes that provide access to a wide area link back to the dispatch centre via fibre or high data rate mesh backhaul. The mesh supports multiple routes to eliminate single points of failure by automatically routing around failed nodes, along with using any entry/exit point of the mine, even a small diameter borehole, to the surface. The resulting network provides a topology that allows flexibility in network modification and expansion with a tiered structure defined by increasing functionality.

Case study

IWT's Battery Mesh Node (BMN) provides integrated voice-text-tracking services in areas where power is restricted. BMNs are being used in the walkable bleeder entry and communicating out through the bleeder shaft to the surface. This increased the safety for personnel walking this area of the mine, providing continuous communications where there was none previously. The BMNs are also used to cover a 15 000 ft tailgate without

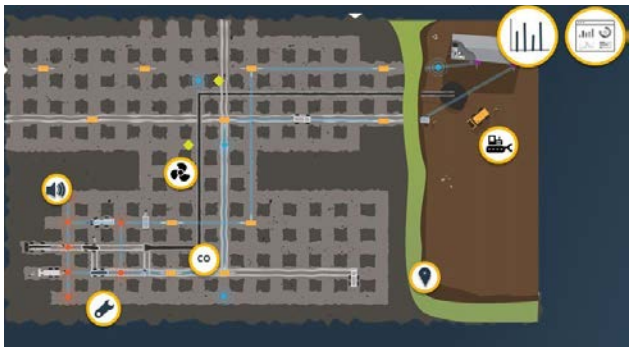

Figure 6. A data-centric mine of the future.

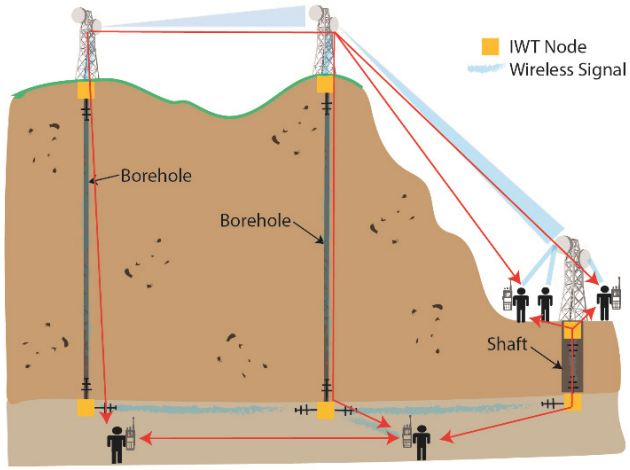

Figure 4. Multipurpose network using wired and wireless paths for maximum redundancy.

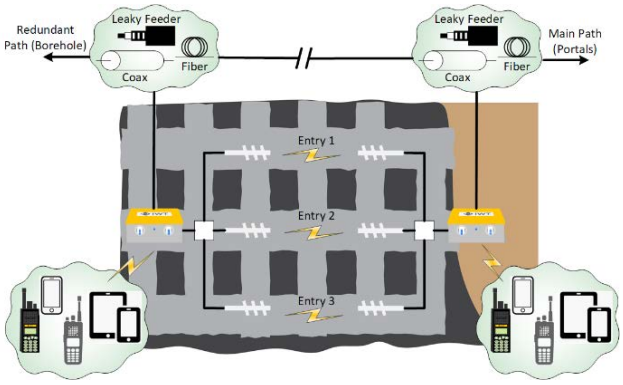

Figure 5. Wireless network using multiple entries.

permanent power, enabling the return entry to stretch further than the track entry and resulting in less downtime and increased productivity.

Next generation technology

Combining mesh networking with other existing and emerging telecommunication systems creates a more powerful and reliable solution for the industry. The evolution of long-term evolution (LTE) picocells, 5G, WiFi MANET and WiMax can greatly improve the network capabilities, while increasing redundancy and eliminating reliance on single point of failure high bandwidth fibre or cable. The proposed 5G standards support high bandwidth, low latency communication channels which can be used for voice, tracking and machine automation, as well as other data-centric applications. In addition, the Narrowband-Internet of Things (NB-IoT) and LTE-M extensions to the 5G standards provide support for low power IoT sensors, which enable a new generation of safety systems and devices such as ubiquitous gas sensing and fire detction, roof and rib monitoring, seismic sensors, and more. WiFi usage above-ground is ubiquitous, and new developments around mobile ad hoc networking provide innovative ways to bridge under/above-ground systems. New systems must also be able to support the amount of data required by all underground systems using existing technology that supports higher bandwidths, such as high data rate mesh and WiFi/fibre, along with new LTE/5G small cell technology.

Multi-service solution

A communication system that is capable of using wireless infrastructure will greatly improve overall system redundancy, while accommodating existing technology and provide a growth path for future technology. Infrastructure should also have the ability to interface with cabled systems, such as Ethernet or fibre, to provide an additional means of data passage and redundancy.

The ability to support multiple service types for communication and mobile devices could provide the ability for various forms of communication based on existing radios and mine data requirements (e.g. low/high data, small vs large mines). Regardless of the desired data rates, most technologies (WiFi, land mobile radio systems, mesh, LTE, 4G/5G etc.) allow for multiple streams of data over multiple paths, with emergency data able to use any of them.

A modular system capable of multiple services enables configurations that are best suited for the spatial coverage. In the underground space, mesh radio configurations provide the best redundant coverage while interfacing with every system in the mine. Low and high data rate mesh radio options allow for everything from basic text and tracking all the way up to autonomous mining. In the above-ground space, very high frequency/ultra-high frequency and land mobile radio systems provide excellent voice coverage, and with the advent of LTE/5G technology, the above-ground infrastructure could incorporate private LTE to support voice along with a mine's data requirements. The 5G radio design is currently being developed by multiple providers to support 5G voice communication and data interface, while part of LTE/5G is the LTE-M and NB-IoT specifically designed to support lower data rate long battery life applications.

Benefits of a single system

Having one system capable of meeting current communications and tracking requirements, as well as being scalable to incorporate next generation technology, is a big safety and maintenance advantage when considering how challenging it can be to learn and stay up-to-date on the unique aspects of multiple systems. Additionally, the comparative costs – both labour and material – of maintaining separate systems and networks for often overworked maintenance crews can degrade

system performance and negatively impact overall safety. There is also a corresponding impact on productivity that can be cumulatively substantial.

Another benefit of a single system is compatibility with existing equipment. The underlying ad hoc mesh network technology in the SENTINEL system was developed by IWT, and has been deployed in over 100 mines, tunnels and quarries over the last 12 years. IWT's next generation communication system supports existing and future technologies that operate in a variety of bands from low-band (sub 1 GHz), mid-band (1 - 6 GHz) to high-band (above 6 GHz).

Barriers

Any newly developed products require various certifications for commercial use, such as MSHA (intrinsic safety), FCC, and more. Radio communications in above-ground (free space) and underground (waveguide and free space) also provide various technical challenges due to vastly different environments. Other potential barriers include increased product costs, which becomes a huge barrier to entry for mine operators with already purchased, functional systems.

Case study

IWT's new Uniti node combines BMN voice-text-tracking with WiFi and the company's high data rate mesh. Since it is fully compatible with existing IWT SENTINEL systems, two longwall mines were able to install it and immediately expand capability of their existing communication system.

The Uniti nodes were used to extend voice-text-tracking services and provide high speed data services for IP devices (cameras, laptops etc.) and add fibre redundancy. This has prevented critical data at the longwall from being lost whenever fibre is cut, and has increased uptime due to being less vulnerable to outby conditions, obstructions and failures.

Conclusion

Communications and tracking systems have clearly impacted underground coal mining operations with improved safety and enhanced production. Some technologies are inherently more robust and better suited to the harsh realities of underground coal mines than others. All-digital systems, in particular, can be leveraged well beyond providing communications and tracking and support additional capabilities, such as gas sensors and system controls.

The next generation communication systems will support existing systems and future technologies, and lead to new innovations in analytics, machine learning, artificial intelligence and autonomous mining. As algorithms improve, machines will be capable of accomplishing high risk tasks autonomously to further improve miner safety. The key to this evolution is data throughput and accessibility, which will lead to further improvements in productivity and operational efficiencies. WC