Guideline Review – Underground Mine Communications Infrastructure: August 16 and 18 Workshops Outcomes

These outcomes are from virtual workshops where participants completed a review of the Underground Communications Infrastructure Guideline suite, including Parts I-III. Participants of the working sessions included those with knowledge and expertise who assessed the content of these guidelines to provide feedback for the upcoming revisions.

Some of the key themes that were noted throughout includes:

- Addition of advances in technology (e.g., 4G/LTE, 5G)
- Addition of more up to date case studies
- Rework of ideal network topology models for underground mines sections

Part I: Lifecycle Diagram

Review the content and share ideas about how it could be revised.

Location of Change	Review Comment
Exploration: Positioning and Radio Communications	• Addition of LTE & 5G cell networks • Private wireless networks being deployed already during exploration to allow for high bandwidth local wireless connectivity
Construction	• Addition of 4G/LTE and 5G • Perhaps listing all existing geolocation protocols for underground could be a good input in here (4G LTE, BLE, RFID, UWB, Wi-Fi, underground GPS) as 5 years back LTE didn't have much presence.
Commissioning: Full global integration	• Network capabilities for the remote monitoring
Mature Mine (Sustainability)	• Maybe 3-4 years is a lot of time for today.
Environmental Restoration - Decommission	• Need to add people and information for decommissioning • Will any communications infrastructure need to be maintained for long-term monitoring for environmental parameters after mining operations cease?

Part II: Scenarios and Applications

Review the list of scenarios and identify what's new or if other scenarios should be considered.

Scenario	Review Comments
Scenario 1: Operations between shifts	• This has been done for years. Very easy to do - semi autonomous control of scoops and trucks from surface. Pull from ore passes and dump - keep skipping between shifts. • Remote operation center
Scenario 2: Accelerate post-blast re-entry	• Does MOL allow re-entry with out handheld check? Need to check dead headings that would be tough to do remotely.
Scenario 3: Monitoring and dispatching systems	• Not many companies offering U/G Dispatch. Some companies may have something soon. Easy to do with coverage in haulage ramps and drifts. • Personnel monitoring (e.g., RTLS)
Scenario 4: Auto drilling support	• Need coverage at the face. This is possible with Mesh and Wi-Fi.
Support 5: Autonomous activities mining	• Load and haul • Inspection • Basic vehicle connectivity for predictive maintenance etc. • Being done now. Semi-autonomously is not hard with a network installed. • Need to consider the in-device computing since there is a significant rise in various sensing units related to operations & sharing all the data to base station/cloud will consume good amount of bandwidth and other resources. Also need to consider the e-mine scenario.
Scenario 6: Underground environment monitoring analysis	• Structural & geotechnical Monitoring. • Need to consider the in-device computing since there is a significant rise in various sensing units related to environment monitoring as well as geostructure monitoring & sharing all the data to base station/cloud will consume good amount of bandwidth and other resources. • Processing high volume of data at edge. • IoT / sensors. • PLC / SCADA. • Easy to do - equipment off the shelf - has been done on leaky feeder for years. • Geotechnical monitoring and structural monitoring. • Ventilation and water monitoring. • Control room feedback.
Scenario 7: Post-accident communications	• Lots of portable comm systems on the market.
Scenario 8: Underground mapping and sampling	• Drones have taken over this market successfully. • Need a significant revision considering autonomous e-vehicles. • LIDAR/point cloud.

Scenario	Review Comments
	• Decision support to autonomy.
New scenarios and applications that should be added?	• CxS (collision avoidance). • Separate high security or criticality networks (separate fire alarm, electrical management, safety critical). • location tracking. • Remote expert (AR glasses etc.). • Drones. • BEV and autonomy. • Mine Electrification, energy management, and monitoring. • Collaborative automation - multi-vendor automation working together. • BEV/Battery telematics data. • Consideration of autonomous vehicles including drones to explore the abended region. • Cloud Connectivity (Drill alignment, reporting, online forms). • Collision awareness and avoidance (could that fit under traffic management - more encompassing, or V2X category).

Additional considerations when looking at scenarios:

- Putting 1-8 all together without interference.
- Relationships between items. E.g., one feeds into the other; foundational elements, and then we build on top of them.
- A master point - technology selected needs to hit as many of these scenarios as possible. those roadmaps need to be considered. there are operational use cases and enabling technologies

Part III: Review of Table of Contents

Section and Subsections	Participant Comments
6. ADMINISTRATION: GENERAL GUIDANCE AND RECOMMENDATIONS	• Training and Development of maintenance crew
7. GENERAL BEST PRACTICES	• Pull out some overly specific stuff and refer to online resources • UWB infrastructure for comms (and usually location) • LoRAN • quality of service
7.4 Seven-Layer Model for Networking	• 5G as technology layer for precise positioning
7.5 High-Level Communications Infrastructure Decision Matrix	• Update with best practice of recent years
7.7 LTE ® as a Communications Infrastructure	• updating to LTE & 5G • move to section covering types of technology
8. GENERAL TOPOLOGY	• Topologies very dated and probably not important to infrastructure choices

Section and Subsections	Participant Comments
	• 5G systems are already being built underground in China, Europe, and Africa, and there are quite a few problems, so CMAC can undertake some work. • More realism on leaky feeder installed. Most mines still using it as primary comms. If a greenfield mine is starting a ramp - Leaky Feeder is very efficient for the beginning voice, blasting and fan controls. (re-use of leaky feeder infrastructure for 4G/5G networking)
8.3 Ideal Network Topology Models for Underground Mines	• Is "Ideal" the best heading? Maybe "Proposed" or something else?
8.3.1 Bus Topology	• it is relevant, maybe just one section - Network Topology, rather than all these separate sections • IoT topology considerations
8.3.2 Ring Topology	
8.3.3 Mesh Topology	
8.3.4 Star Topology	
9.BEST PRACTICES AND RECOMMENDATIONS FOR UNDERGROUND MINES	• Do we talk about wattage limits on outputs (Vales 1 watt rule) • EIRP • Not enough applications that are practical and pay for a system - fan controls, gas monitoring, blasting from surface, tracking ore/waste pass loads, ground control alarms on surface ect. Speeding up stench gas testing - tagging. • Risk: interference with blasting systems • Bandwidth, latency, mobility • add a point on cyber security. should be a best practice point. or maybe add "best practice" to title of section 10 • Sensor networks (situation awareness) related to detection systems and tracking technologies QoS
9.1.2 Video Communication Systems	• Video analytics
9.4 Case Study: Implementation of LTE at LaRonde Mine	• Updated/Case study (5G case study) • 9.4 still useful now to get a 4G LTE use case? (Was very good 5 years back though) • More case studies - would be nice to have them relate to the scenarios of before
10.NETWORK SECURITY FOR UNDERGROUND MINING OPERATIONS26	• Converged networks vs segregation • Trustsec, different security models etc. (service mesh, identity services-based access) • Consideration of cloud-based support and analytics • Risk discussion for patching risk to operations versus cyber exposure of vulnerable platforms • Segregation of systems. cannot have a voice system in a shaft open to voice systems on the level when doing critical movements etc.

Section and Subsections	Participant Comments
	• Segregation of critical or safety-related services
10.1.2 Physical Access Protection	• Access Control (Physical and Cyber) as a single topic to align with ISA 62443
11. CONTROL ROOMS AND REMOTE MANAGEMENT	• Considerations for comms to the site • Redundancy, back up comms routes, etc. tied to cloud dependency

Missing content for part III:

- Surface or wider guideline, covering common challenges
- IoT might need updating with tech development might be in topology, in best practices, etc. multiple locations in guideline where IoT needs to be addressed.
- Personnel resourcing to support the technologies that are deployed. OT vs IT resourcing
- maintenance and life cycle management; software defined networks
- future proofing best practice
- Consideration of high-power interference
- Discussion on when not to use a network or lower spec'd network. Smart autonomy.

Part III: Key Themes from Review

Topic	Sections Applicable	Context	Participant comments
Scope of the guideline	Section 5	The scope currently section of the guideline currently states: "This document provides an initial overview of the factors to consider when installing a network at an underground mine…. While not comprehensive, this document should provide a starting point for underground network selection and design. No two mines are identical; therefore, each situation will require a unique solution to provide the best communications infrastructure and technologies for that mine" A reviewer noted that the scope should more explicitly mentioned that the guideline focuses on digital IP networks. Should there be changes in the scope?	• There are common aspects applicable to all mines • All networks
Ideal network topology models for underground mines	Section 6 Section 8.3 Section 8.3.4	Four of the main network topologies mentioned in this guideline include: bus, ring, mesh, and star. Reviewers reviewed the section and identified some areas of inaccuracies or missing information. • E.g., a reviewer mentioned that the descriptions of bus, ring, and mesh topology are not useful. • Star topology mentions wired star communication technology. Is wireless star topology something to consider for the section as well? Are there new considerations and recommended updates around network topologies?	• Topology doesn't seem relevant. Bandwidth and redundancy. • I agree as not being useful - most system based on mine layout, haulage ways, and combining existing systems i.e., Fiber and Wi-Fi, and fiber + 4G/5G, F5G • Section does need to be rewritten - general cleanup • Buy-in/change management
Accommodating advances in technology	Throughout the guideline	What kinds of advances in technology should be included? The following are examples of new or evolving technologies that reviewers mentioned:	• SD-WAN • Not to be self serving but add real mesh. in over 260 mines. • V2X (802.11p)

		• Zigabee or other technologies using 802.15.4 physical and mac layer • 4g/5g cellular technologies • LoRaWAN • UWB • Starlink • BLE • Drones/robots for 3D mapping • Technologies for optimizing processes	• c-V2X • Digital twins - network digital twin • Consider end-of-life type of recommendation for older tech • Considerations for spectrum management • Avoid spectrum squatting • Data communication protocols with sensors
Seven-layer model for networking	Section 7.4	The open systems interconnection (OSI) (ISO 35.100) seven-layer model for networking is covered in the guideline.	• Not useful • Move to appendix with a reference in guideline
Wireless Networks	Section 10.1.5	This section of the guideline, on wireless networks, notes that although wireless networks have advantages, there are still a long list of security problems without also noting that wired networks have security concerns as well. Does there need to be a section on wired networks as well to indicate that these security challenges are also applicable to them?	• Access Control (Physical and Cyber) as a single topic to align with ISA 62443 • The reliability of wireless networks for control needs further study • Wireless section is valid but needs to be updated for considerations of various solutions - different categories of wireless networks. can then also have wired networks section. maybe a categorization approach.
Useful case studies	Section 9.4	Version 1 includes a case study of the Implementation of LTE at LaRonde Mine. What kinds of case studies would be of value to supplement a new version?	• Standard WIFI based mode • 5G case study - Application of 5g communication system in underground coal mine of China • what could go wrong • Outside vs underground GPS: perhaps to mention as 'advance in technology' • More 4G/5G • Examples of redundant network connections to the mine • UWB

			• Full system designs
Further Comments	• ROI • Rollout and continued expansion plan • Changes to network protocols with respect to underground mine electrification • We should consider the security of radio energy in underground mine • We've studied EMC of communication system in underground mine, we should consider the influence of high-power complements. • Are there parallels we could draw from the civil tunnelling industry? • Standards awareness piece		