



UNDERGROUND COMMUNICATIONS INFRASTRUCTURE GENERAL GUIDELINE

These General Guidelines are the core content of the Underground Mine Communications Infrastructure Guidelines and are intended to provide an overview of the planning and design recommendations for underground communications development, some of the best practices used within mining environments, and where to find more information regarding digital communications standards and frameworks. It includes some guidance on technical best practices, security management and remote operations.

ADMINISTRATION: GENERAL GUIDANCE AND RECOMMENDATIONS

The important factors to consider during underground network selection and design, including local legislation, current network infrastructure, stakeholder engagement during planning, prioritizing needs, researching the options and system selection. An overview of potential administrative tasks is provided, followed by examples of the communication regulatory bodies and legislative acts that are in effect in key mining jurisdictions around the world. Finally, common choices that must be made during communications infrastructure development are identified in a risk matrix along with pros, cons and mitigative measures.

GENERAL TOPOLOGY

Discussions of mine structures, idealized communications topology, the pros and cons of different topologies and failure modes.

Mine topology has a direct effect on where and how a communications system can be designed, installed and used so the two topics are discussed together. Mine topology itself is influenced by the type of mining in questions, including:

- Mineralization in ore body and surround
- Temperature
- Humidity
- Gasses present

These factors will influence the mine structure, the communications network and the hardware accessories (e.g.: enclosures, cables)

CONTROL ROOMS AND REMOTE MANAGEMENT

The terms used to describe remote operations are defined, benchmarking requirements for different types of remote operations are discussed, and control room and remote operations station designs and ergonomics are explored.

BEST PRACTICES AND RECOMMENDATIONS FOR UNDERGROUND MINES

Topics on communications networks specific to the underground environment are covered, including recommended communications coverage underground; asset and personnel tracking underground, including real-use cases; and installation of equipment underground. A case study of LTE implementation at Agnico Eagle's LaRonde Mine is included.

GENERAL BEST PRACTICES

An overview of communications networks, including definitions of common terms, guidance for selecting industrial network technology, an overview of a commonly used model of communications technology layers, and several tables outlining the characteristics, applications, pros and cons of different communications network technologies. The section closes with an overview of long-term evolution (LTE).

Communication Layer	Type	Technology	Complexity	Signal attenuation	Typical Coverage	Interference / noise resistant	Maintenance / Manoeuvre + If something breaks	Capacity (bandwidth)	Latency (based on same distance)	Security (Data)	Setup (intrinsically safe)	Availability	Reliability	Resiliency	Compatible of redundancy	Security	Battery Powered compatible	Mobility	Cost	
Physical Layer (OSI: Layer 1)	Copper (Twisted Pair)	UTP Cat5/6/7	Low	High	low	Medium	low	high	low	Medium	Medium	High	high	medium	yes	high	yes	no	low	
		RG6, RG11, Axa50, LMR, Other "Non-Leak" Cable	Low	Medium	medium	high	low	high	low	Medium	Medium	High	high	medium	yes	high	yes	no	low	
	Copper (Coaxial)	Leaky feeder (VHF/UHF)	Low	High	low	low	low	medium	low	Low	Low	medium	medium	medium	yes	high	yes	no	low	
		HF/VHF/UHF/Microwave	Medium	Low to High (Depends on the frequency)	very high (if not obstacle or curvature)	low	medium	high	medium	Low	Low	medium	medium	high	yes	high	yes	yes	medium-high	
Optical	Fiber Optic		Low	Low	high	high	high	high	low	High	High	high	high	medium	yes	high	yes	no	medium-high	
			Medium	n/a	medium	high	low	high	low	medium	n/a	medium	low	n/a	n/a	high	yes	n/a	low	
Modulation techniques used in Physical layer	Modulation is Media type independent #1	Spread Spectrum (Frequency Hopping) radios	medium	n/a	medium	high	low	high	low	medium	n/a	medium	low	n/a	n/a	high	yes	n/a	low	
		Modulation (OFDM, QAM, PSK, AM, FM, etc...)	medium	n/a	high	low (AM) to medium (PSK, FM)	medium	high	low	low	n/a	medium	medium	n/a	n/a	high	yes	n/a	medium	
Transport Layer (Brings the technology) (OSI: Layer 2)		Ethernet	Low	n/a	low	high	low	high	low	low	n/a	high	high	n/a	n/a	high	yes	n/a	low	
		WiFi (802.11)	low	n/a	medium	medium	medium	high	low	medium	n/a	medium	medium	n/a	yes	high	yes	yes	medium	
		WiMAX (802.16)	medium	n/a	high	medium	high	high	low	medium	n/a	medium	medium	n/a	yes	high	yes	yes	high	
		Infiniband	low	n/a	very low	low	low	very high	very low	high	n/a	high	high	n/a	n/a	high	yes	n/a	medium	
		Token Ring / FDDI	low	n/a	low	low	low	low	low	low	n/a	high	high	n/a	n/a	high	yes	n/a	obsolete	
		Fiber Channel	low	n/a	low	low	low	very high	very low	medium	n/a	high	high	n/a	n/a	high	yes	n/a	low	
		Bluetooth Transmitters / Receivers	low	n/a	low	low	low	low	low	low	medium	n/a	low	low	n/a	no	high	yes	yes	low
DocSIS	medium	n/a	high	high	medium	high	low-medium	low	low	n/a	medium	medium	n/a	n/a	high	yes	n/a	low		
Network Layer (End Points) (OSI: Layer 7)		Digital RF (i.e. DMR, TETRA, P25)	medium	n/a	very high	medium	medium	low	high	medium	n/a	high	high	n/a	yes	high	yes	yes	medium	
		LTE (4G and up)	high	n/a	high	medium	high	high	medium	medium	n/a	medium	high	n/a	yes	medium	yes	yes	high	
		RFID Transmitters / Receivers	low	n/a	low to medium	medium	low	low	low	low	medium	n/a	high	high	n/a	no	medium to high	yes	yes	low
		Spread Spectrum	low	n/a	medium	medium	low	medium	low	medium	n/a	medium	medium	n/a	no	high	yes	yes	low	
		HSPA (3G)	medium	n/a	high	medium	medium	medium	medium	medium	n/a	medium	high	n/a	yes	high	yes	yes	medium	
Telephone / Mobile Phone	medium to high	n/a	n/a	medium	high	n/a	n/a	medium	medium	high	medium	low	no	high	yes	yes	yes	low to medium		
Application Layer (End points) (OSI: Layer 7)		Pagers	low	n/a	n/a	medium	low	n/a	n/a	low	medium	high	high	medium	no	high	yes	yes	low to medium	
		2 Way Radio	medium	n/a	n/a	low to medium	low	n/a	n/a	medium to high (if using specific model)	high	high	high	high	no	high	yes	yes	low to medium	
		Bluetooth Devices	low	n/a	n/a	low	low	n/a	n/a	low	high	high	low	low	no	medium to high	yes	yes	low	
		RFID Tag	low	n/a	n/a	low	low	n/a	n/a	low	high	high	high	very high	no	medium to high	yes	yes	very low	

List of commonly available networking technologies. A communication system can be composed of the elements presented here but is not limited to them.

NETWORK SECURITY FOR UNDERGROUND MINING OPERATIONS

A general discussion of security risks due to unauthorized physical and data level access, how and where these breaches can occur, and the unique challenges surrounding modern technologies such as wireless and Internet of Things (IoT). A discussion of networks segmentation to facilitate security is included.

PARTICIPATING COMPANIES

ABB, AGNICO EAGLE, AKROM, ALPHA TECHNOLOGIES, AMBRA SOLUTIONS, ANIXTER, AUSTROROBOTS, AVEVA, BARRICK GOLD, BBA, BESTECH, BHP, BOGE BOGE, CHECKMARK CONSULTING, CISCO, DELOITTE, DETNET SOUTH AFRICA, DEXCENT, DRAEGER, ECM NETWORKS, EPIROC, FLOW PARTNERS, GLENCORE, GLOBAL IO, GRANITE TECHNOLOGY GROUP, GROUNDPROBE, HATCH, HEXAGON MINING, HINTEC, INNOVATIVE WIRELESS TECHNOLOGIES, IREDES, INVOLVE, JVA, KOMATSU, LAC DES ILES MINE LTD, LAIRD, LUNDIN MINING, MAESTRO DIGITAL MINE, METSTECH, MICROMINE, MINE VISION SYSTEMS, MINERA YANACOCCHA, MINERP, MINETEC, MOBILARIS, MOTOROLA, MST GLOBAL, NEWMONT, NEWTRAX, NHP ELECTRICAL ENGINEERING, NORTHERN LIGHT TECHNOLOGIES, NORTHERN STAR RESOURCES, ORBCOMM, PA SPATIAL, PBE GROUP, PRAIRIE MACHINE & PARTS, PSA INTEGRATION, RAMJACK, RAPIDBIZAPPS, RCT, RIO TINTO, ROCKWELL AUTOMATION, RPM GLOBAL, SANDVIK, SDMT, SIBANYE-STILLWATER, SIEMENS, STANTEC, STOCKDALES ELECTRIC MOTOR, STRATEGY FOCUSED INNOVATION, SYMBIOTIC INNOVATIONS, TECHNICAL UNIVERSITY OF MADRID, TELSTRA, TERRATIVE DIGITAL SOLUTIONS, TETHERCO, THYSSEN KRUPP, TOREX, TUNNEL RADIO, UNIVERSITY OF THE WITWATERSRAND, UNSW, VALE, WEST ARM CONSULTING GROUP, YAMANA GOLD, YOURPACE