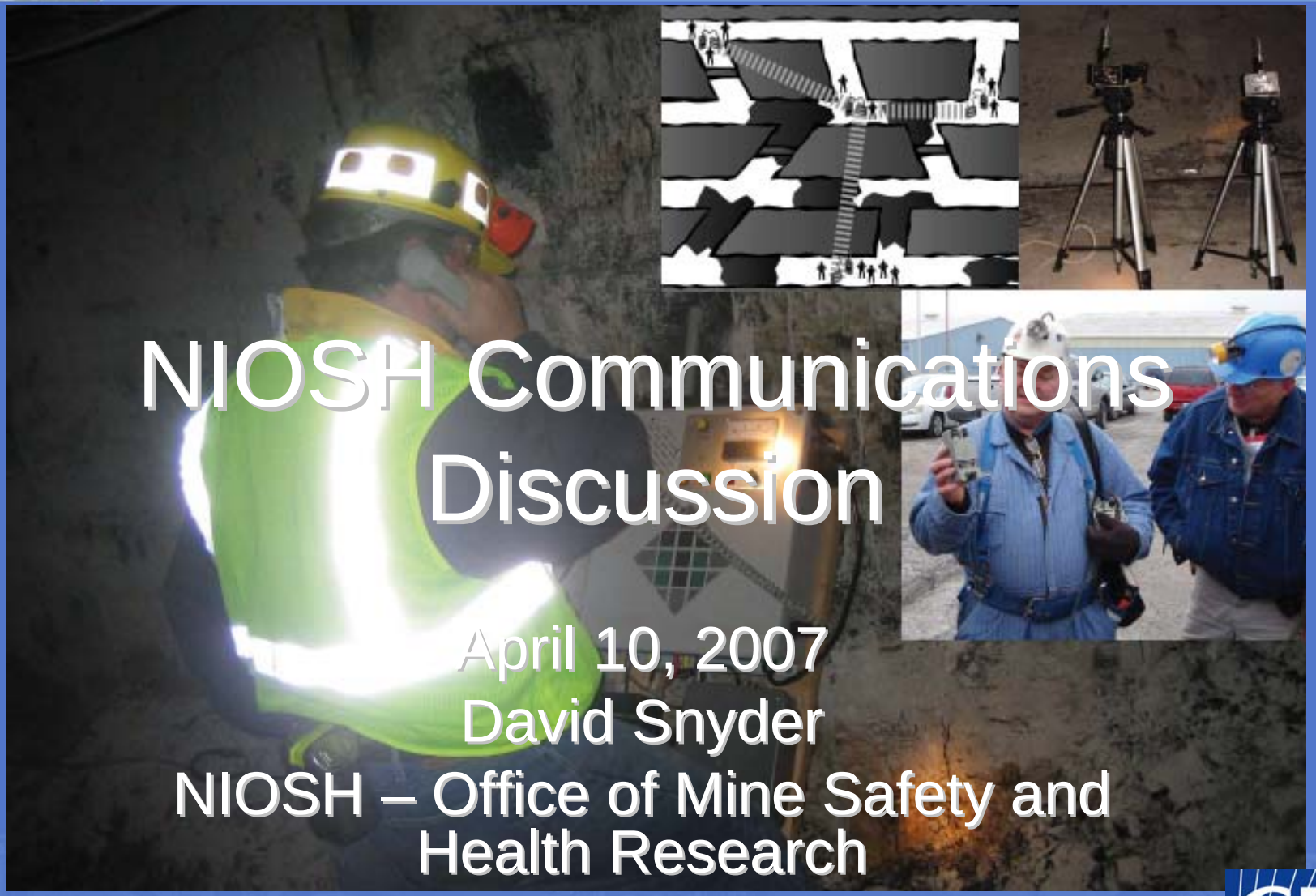
NIOSH
Spokane Research Laboratory



NIOSH Communications Discussion

April 10, 2007

David Snyder
NIOSH – Office of Mine Safety and Health Research

CDC
Centers for Disease Control and Prevention

Presentation Overview

- Background
- Goals of the Communication “Roadmap”
- Review of communications development conisiderations
- Proposed phased approach for mine communications partnership discussion

NOTE: The “Roadmap” is a work in progress, not a NIOSH position or recommendation

Background

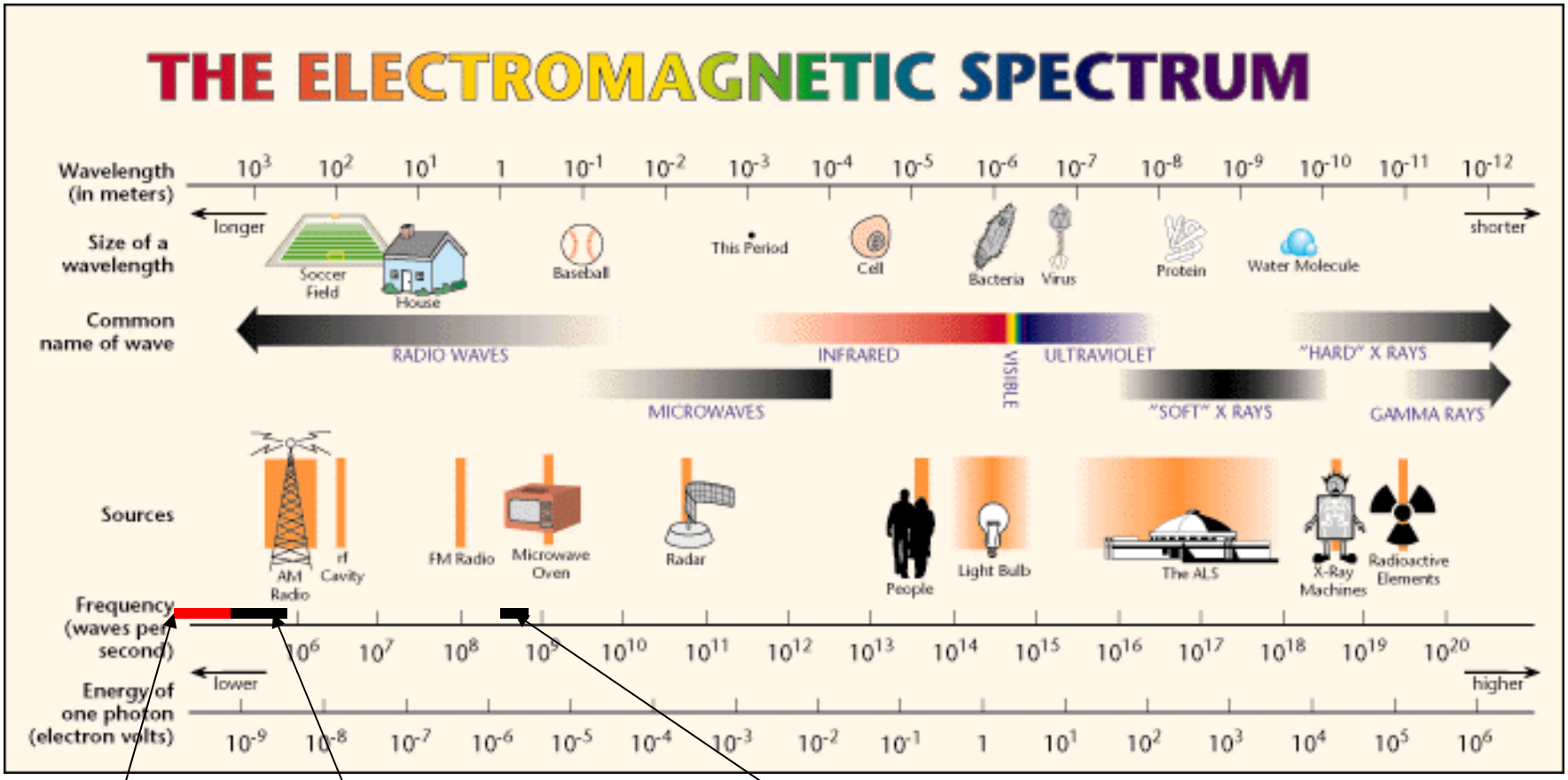
- Substantial expectation for mine operators to begin implementing wireless systems
- WV statutory mandate
- Challenge is to find a way for the operators to begin installing something to improve safety without:
  - Jeopardizing operators ability to implement upcoming technology developments
  - Requiring mine operators to replace or radically modify the installation to comply with future federal regulatory guidance

Communications “Road Map”

- Provide a systems architecture efforts that provides maximum survivability and a framework for success for the NIOSH development.
- Provide a “universal language” that can be used for future documentation and implementation guidelines.
- Provide a path to improve emergency communications capabilities in the short term, while enabling significant functionality advances

Radio Frequency & Underground Mines

- A relatively small portion of the electromagnetic spectrum works underground, even less works well
  - That spectrum should be used efficiently
- There are three different ways that radio waves travel underground
  - Through the Earth (TTE)
  - Parasitic Coupling to Metal Structures (MF)
  - Mine Entry acts as a “wave guide” (UHF)



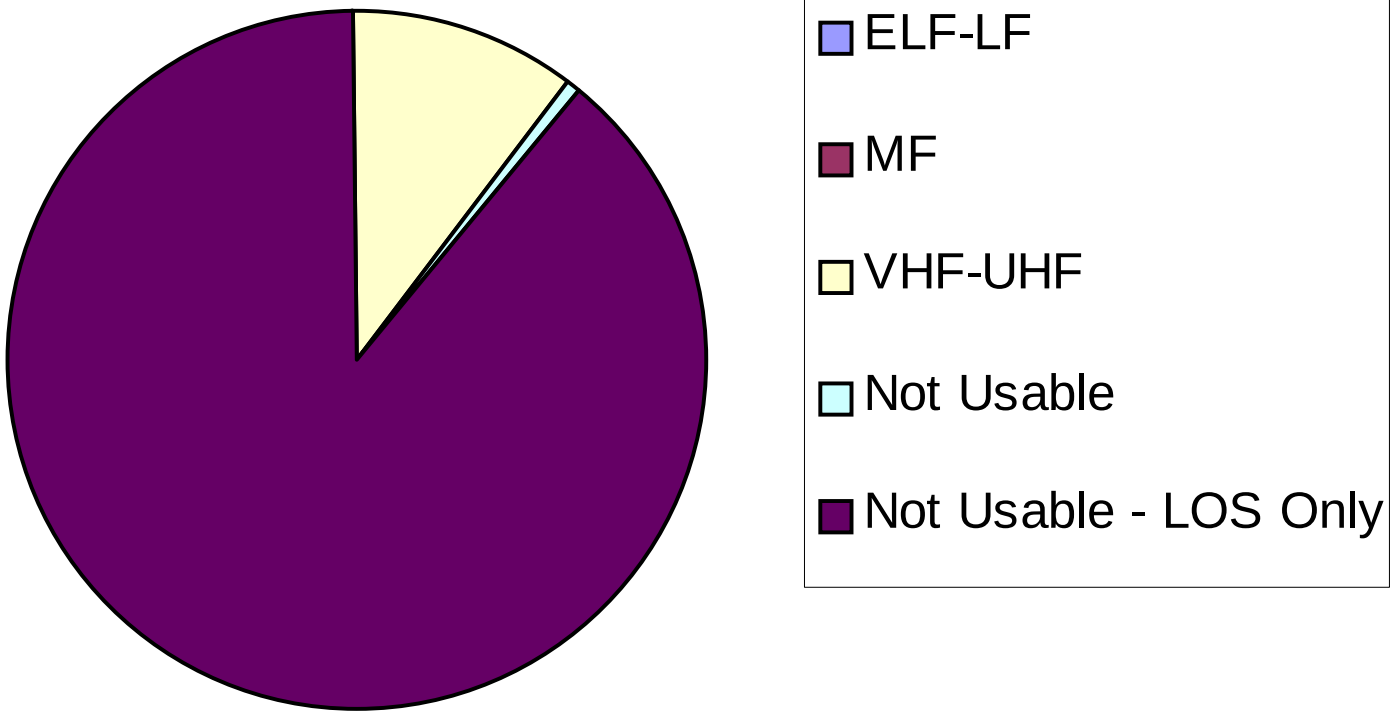
TTE (ELF – LF)

MF "Parasitic Propagation

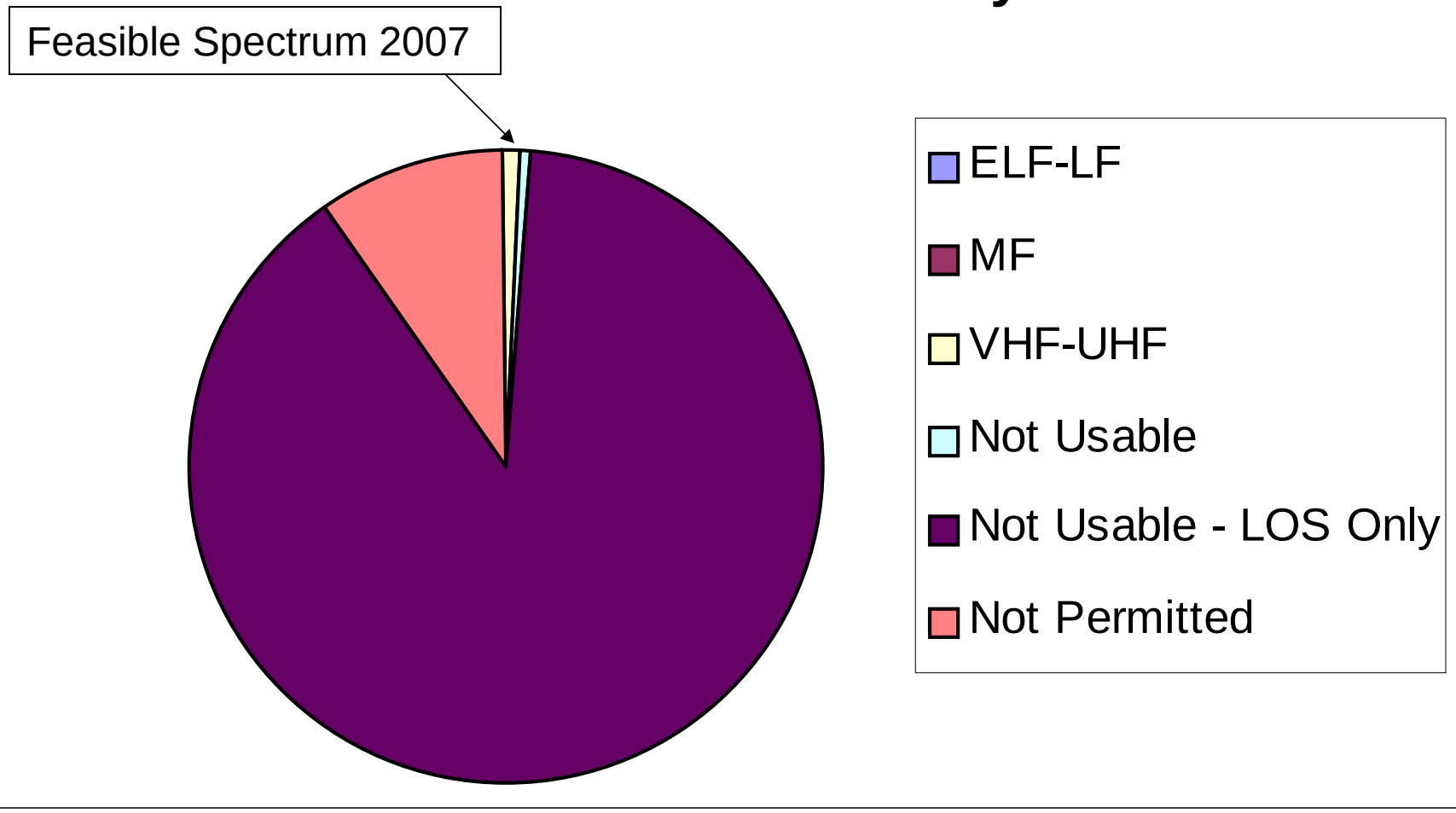
VHF/UHF Mine Entry Waveguide Prop.

Proposal for Partership
Discussions Only

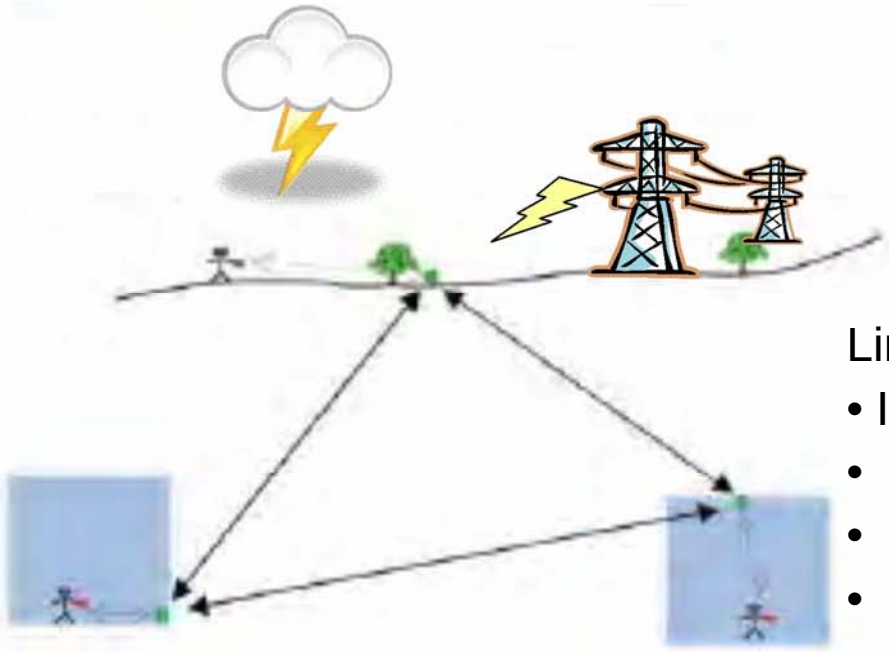
Radio Spectrum Suitable for Mine Communications



Radio Spectrum for Mine Communications
Short term Viability



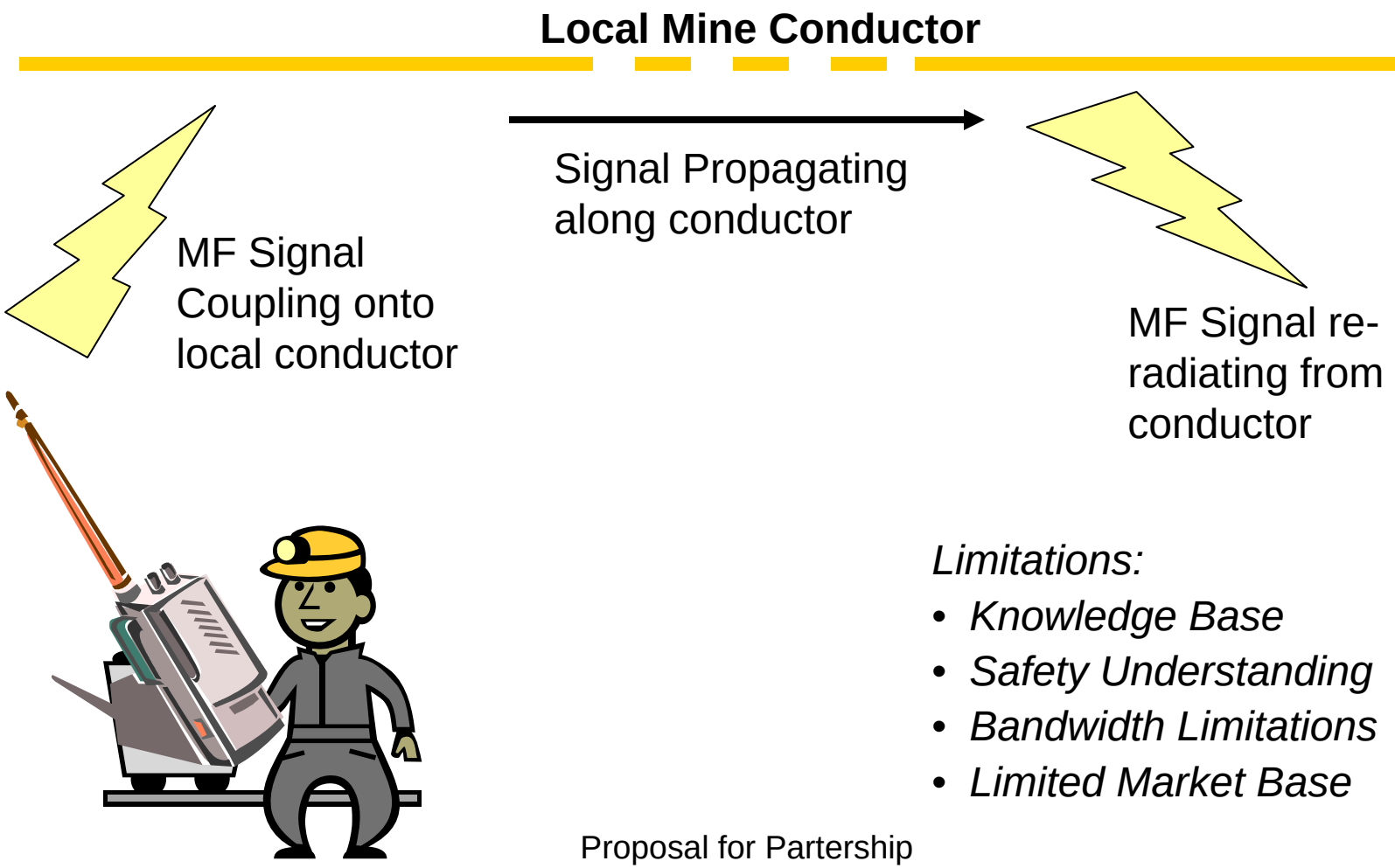
Through the Earth Communications



Limitations:

- Interference Sources
- Antenna Size
- Knowledge Base
- Safety Understanding
- Bandwidth Limitations
- No Market Base

MF Parasitic Coupling and Re-radiation



Limitations:

- *Knowledge Base*
- *Safety Understanding*
- *Bandwidth Limitations*
- *Limited Market Base*

Ultra High Frequency Systems (UHF)

- ***UHF advantages:***
  - **Large knowledge base and wide spread use of UHF radio for two way communications**
  - **Large commercial product base**
  - **Some MSHA approved hardware currently available.**
  - **Safety aspects relative to personnel and explosive devices are well understood.**
  - **High bandwidth for multiple voice channels and sensors, monitors, and other safety improvements**
  - **Large assortment of man wearable and long battery life devices can be adapted for underground use.**

UHF Systems (cont.)

- ***UHF Disadvantages:***
  - **Most widely available commercial product for mine applications are not in the best part of the frequency band for use underground.**
  - **Solutions require a lot of vulnerable infrastructure inside the mine**
- **Proposed methods of UHF signal distribution:**
  - **UHF Leaky Feeder**
  - **UHF Wireless Mesh**

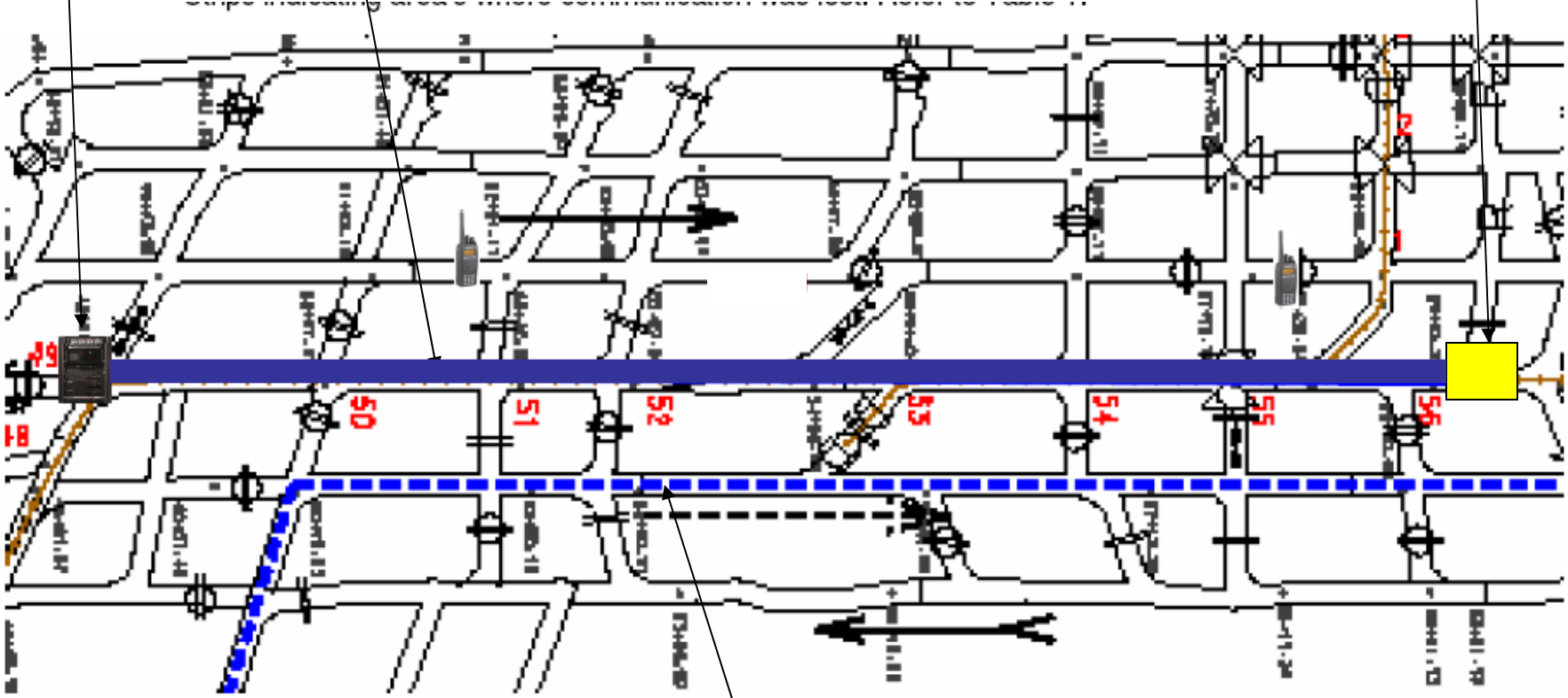
Radio Coverage considerations

- Miner Act requires “mine-wide coverage”
- Practical implementation of available systems will dictate areas with no coverage as a result of shadowing of the radio signals
- Upcoming developments will provide coverage enhancement mechanisms to allow operator to improve coverage in the longer term

Traditional VHF leaky Feeder coverage in entry only

Base Station

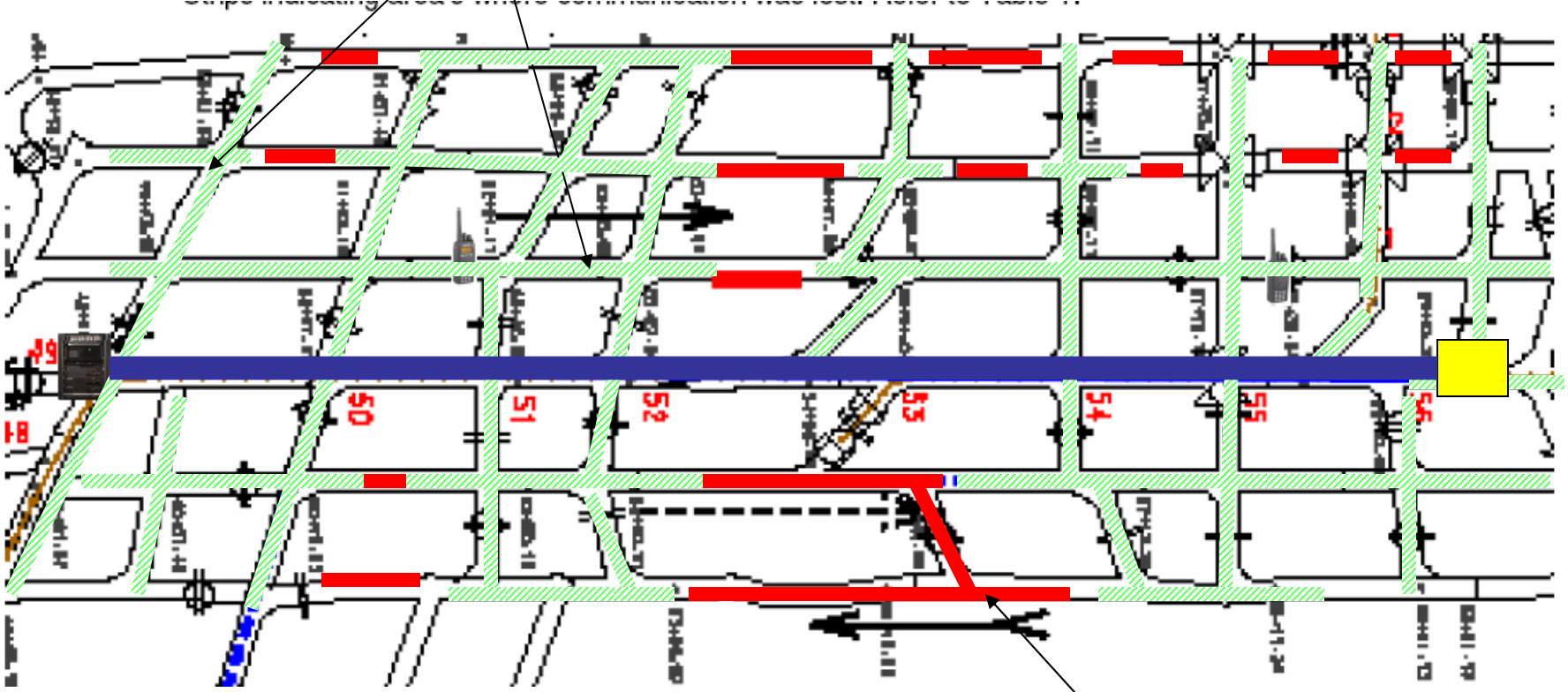
Amplifier 1



Belt Entry

Proposal for Partership
Discussions Only

UHF Leaky Feeder Cable systems increases coverage to adjacent entries



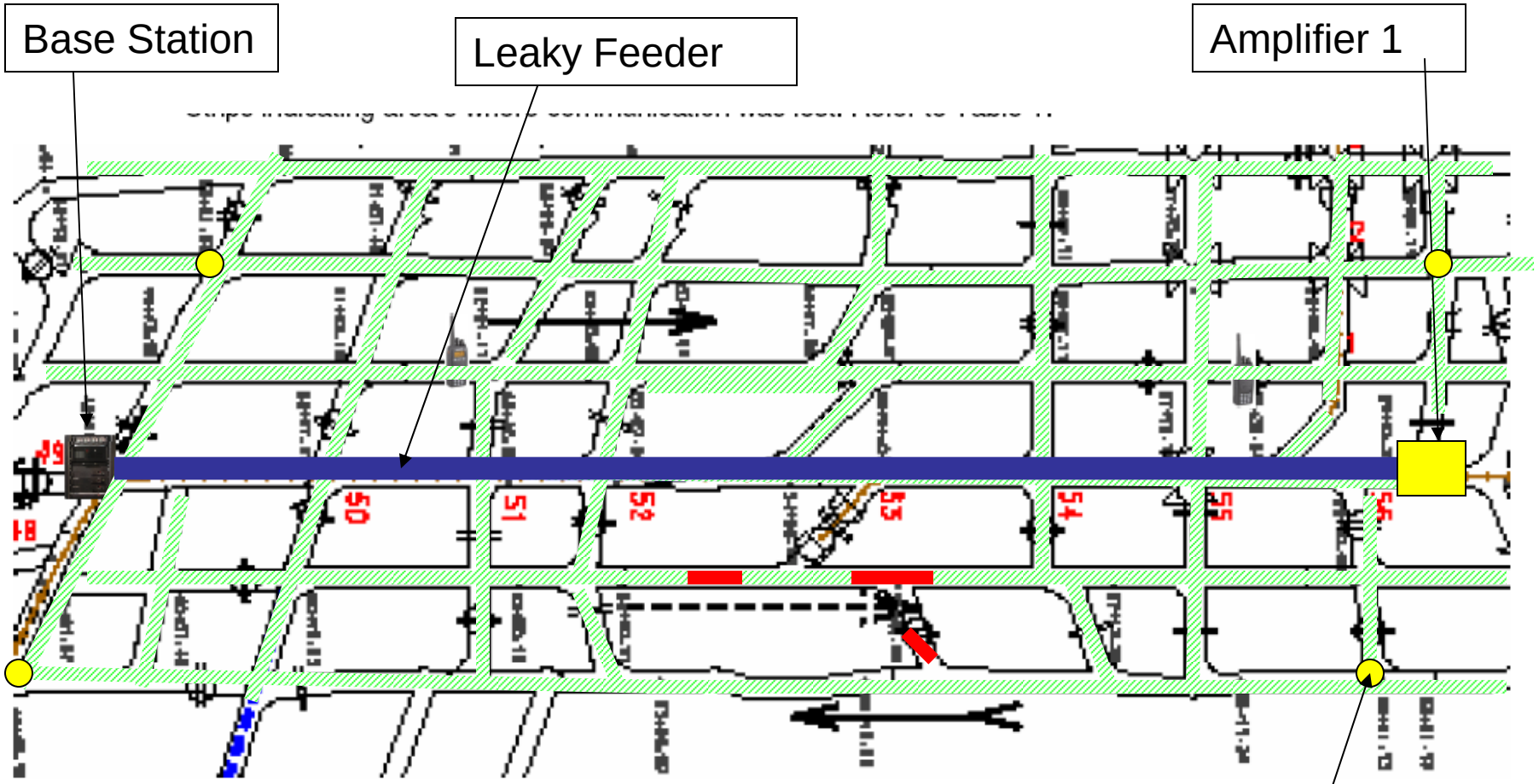
No Coverage

Legend

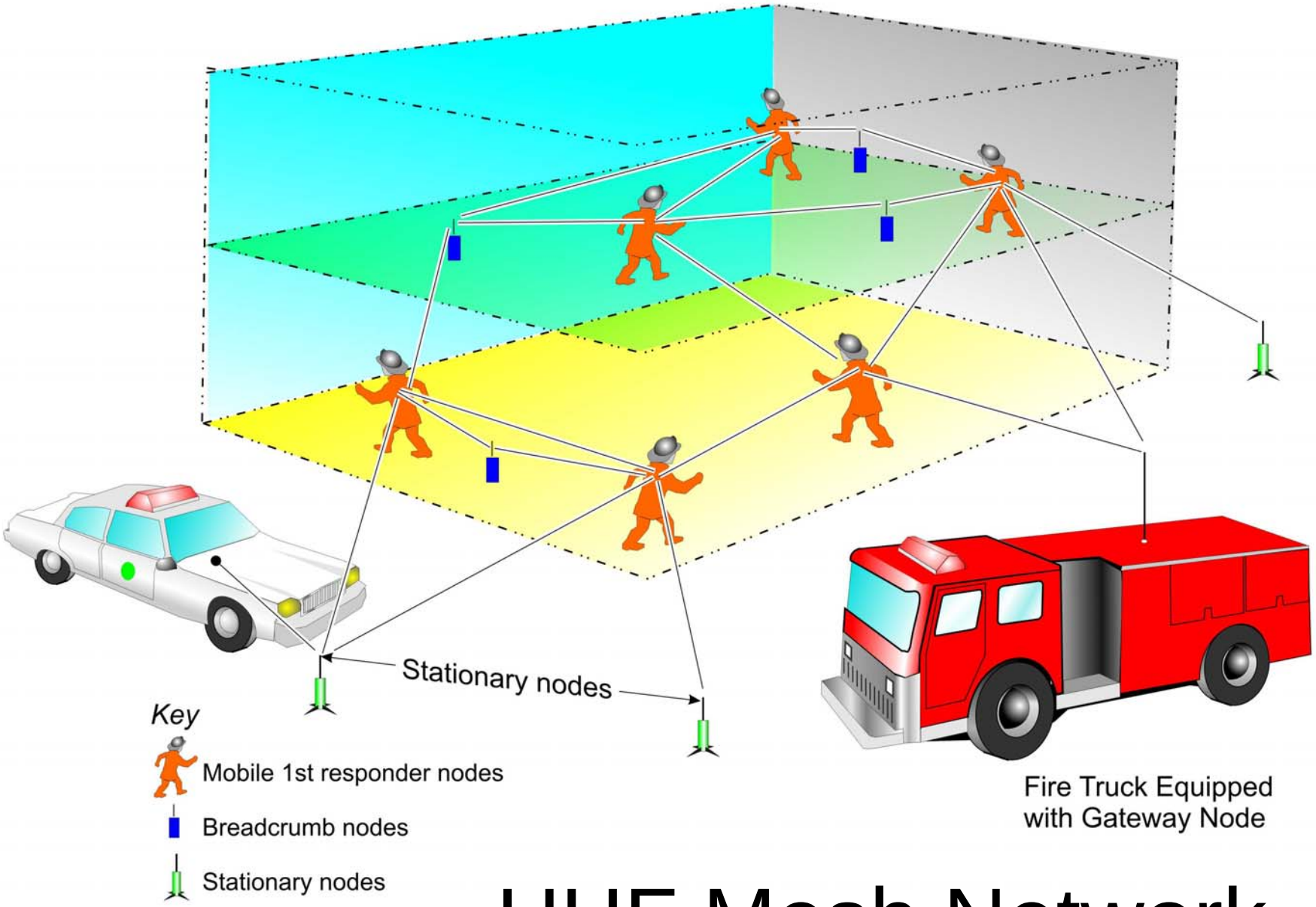
Entry with Radio Coverage

Radio Coverage Hole

UHF Leaky Feeder w/ Coverage Extension

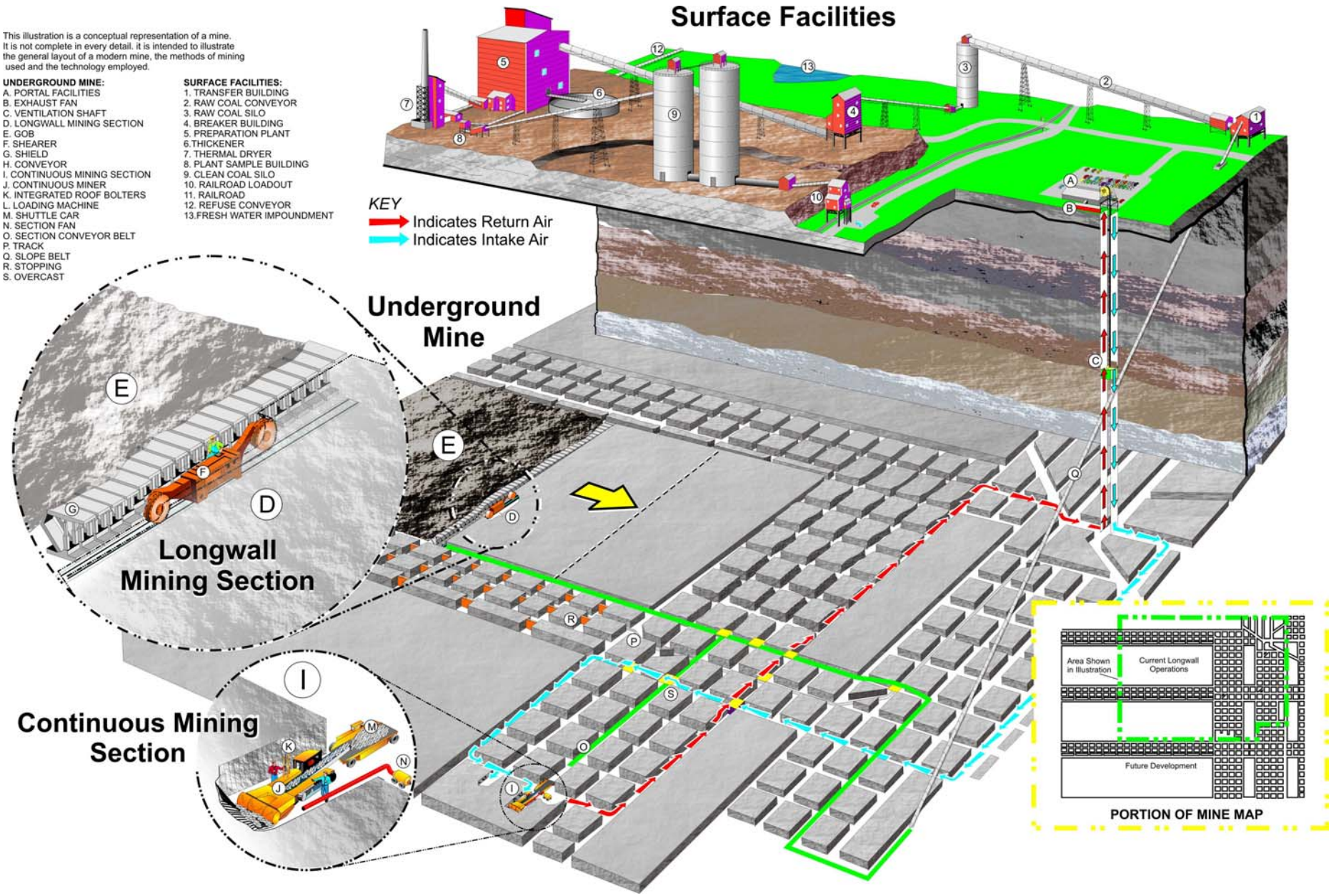


Note: Coverage includes implementation of coverage extension approaches

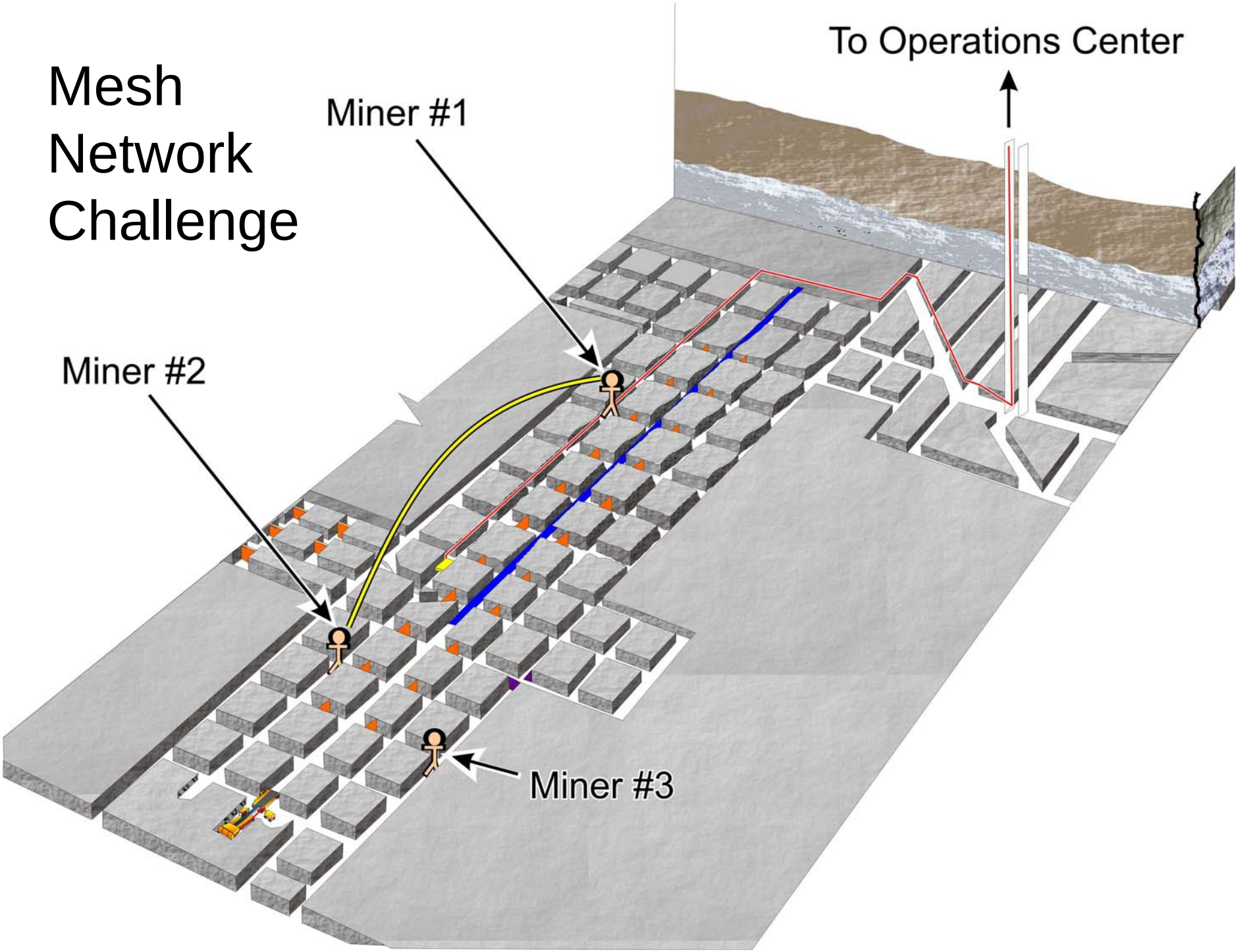


UHF Mesh Network

Communications Limits – Geometry and Physics



Mesh Network Challenge



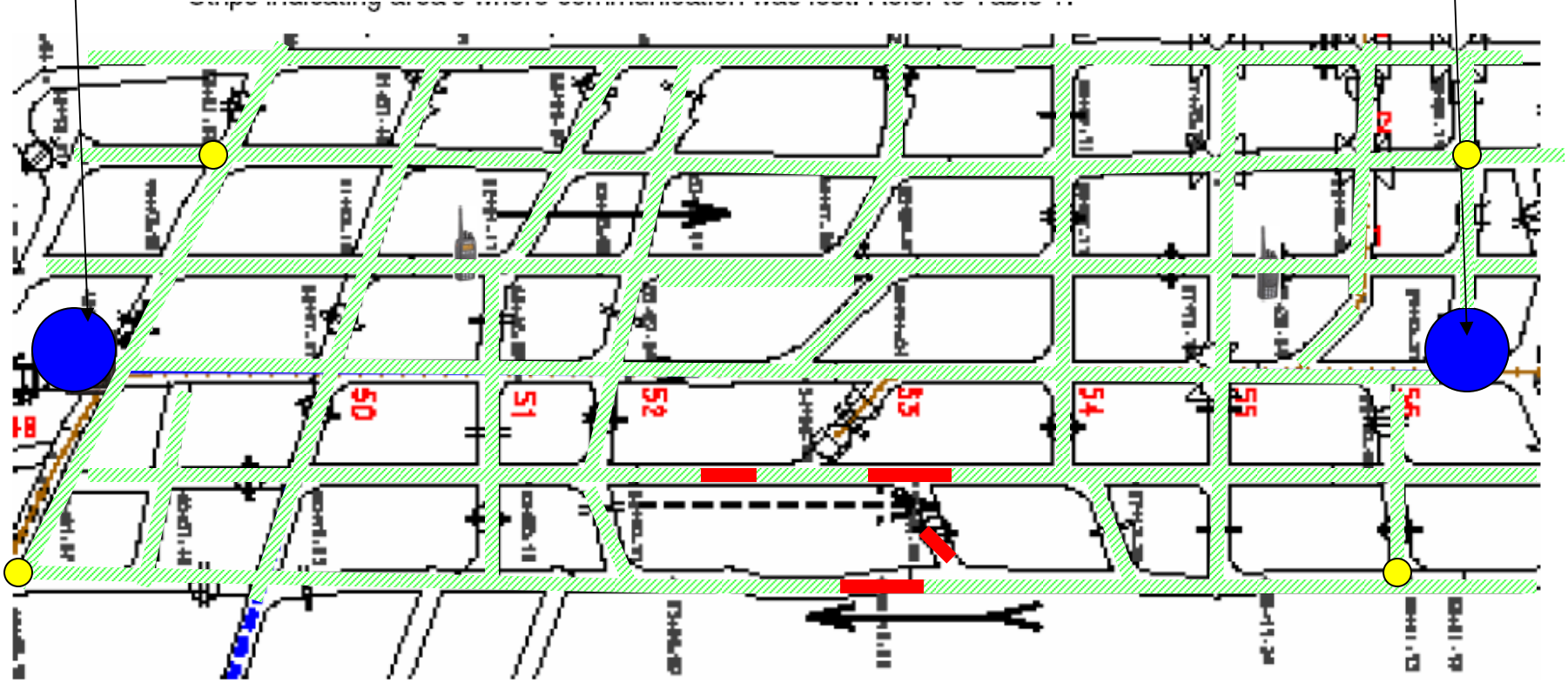
“Commercially Available” WiFi Mesh nodes at 2.4 GHz (upper UHF)

Proposal for Partership
Discussions Only

UHF “Mesh” system ‘adapted’ to underground mining geometry

Node 1

Node 2

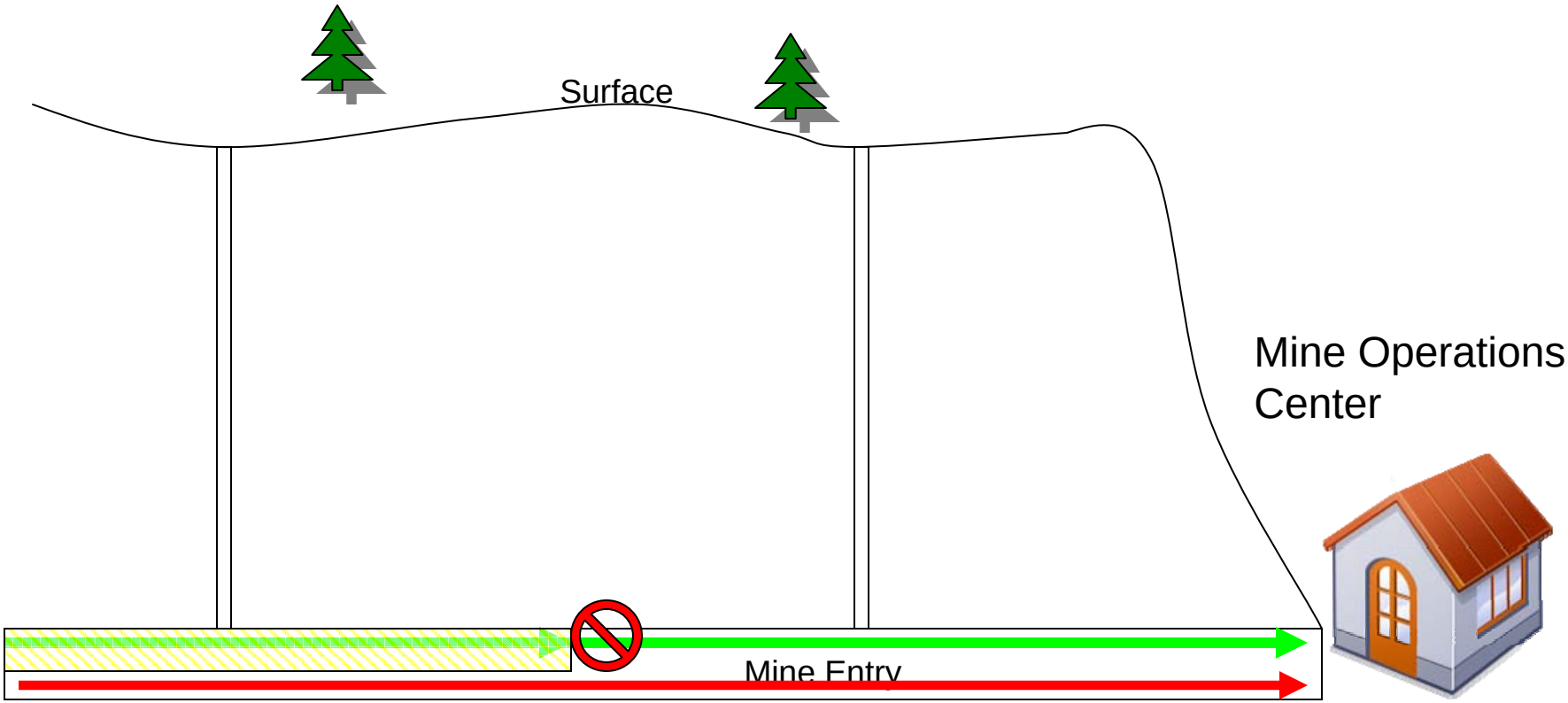


Note: Coverage includes implementation of coverage extension approaches

Survivability Considerations

- Miner Act Requires system to be available post disaster
- Telecommunications systems achieve survivability through design
  - Hardening of system Components
  - Redundancy – power, connectivity, and radio coverage
- Lesson learned – self healing network with true physical route diversity provides maximum survivability

Available Communications Redundancy

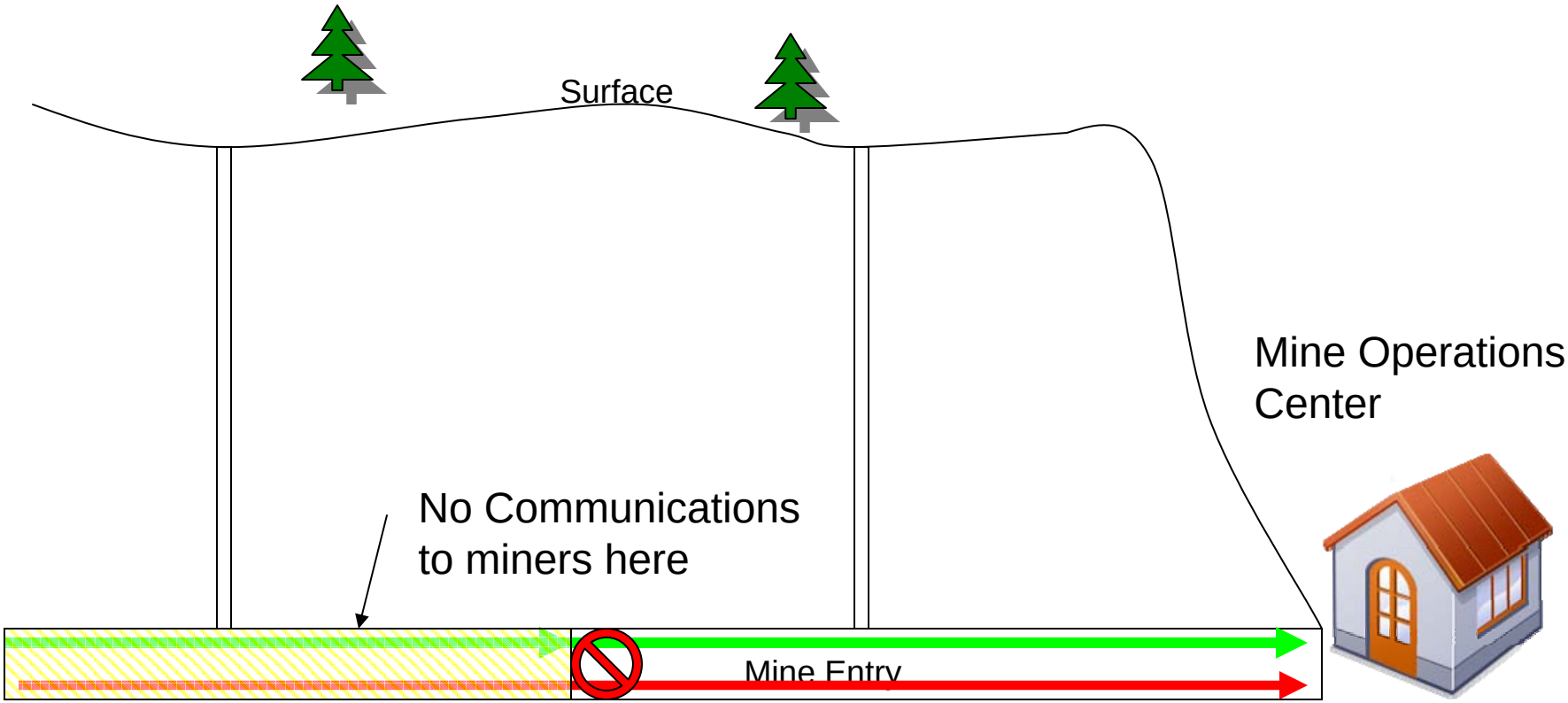


Normal Traffic Flow

Emergency Traffic Flow

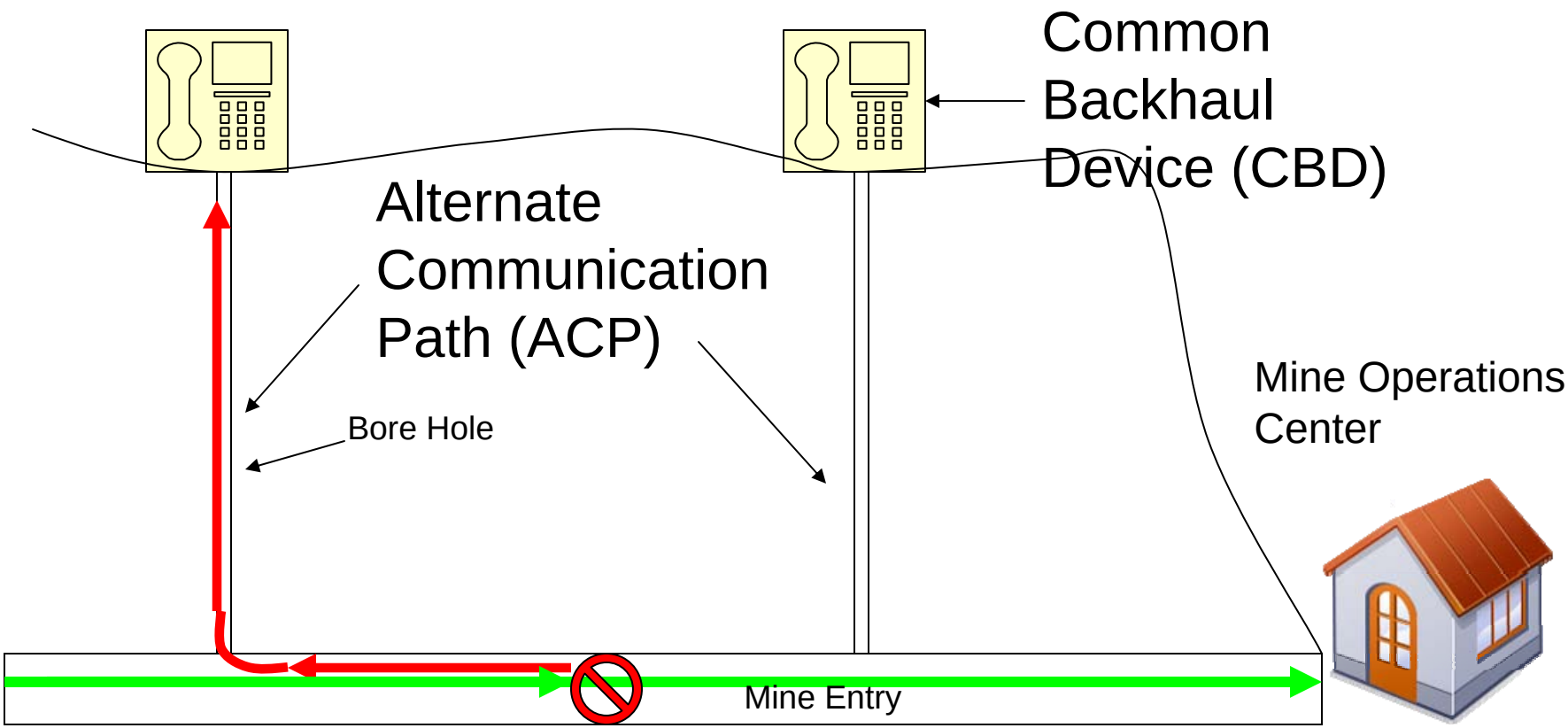
Proposal for Partership Discussions Only

Available Communications Redundancy



Proposal for Partership Discussions Only

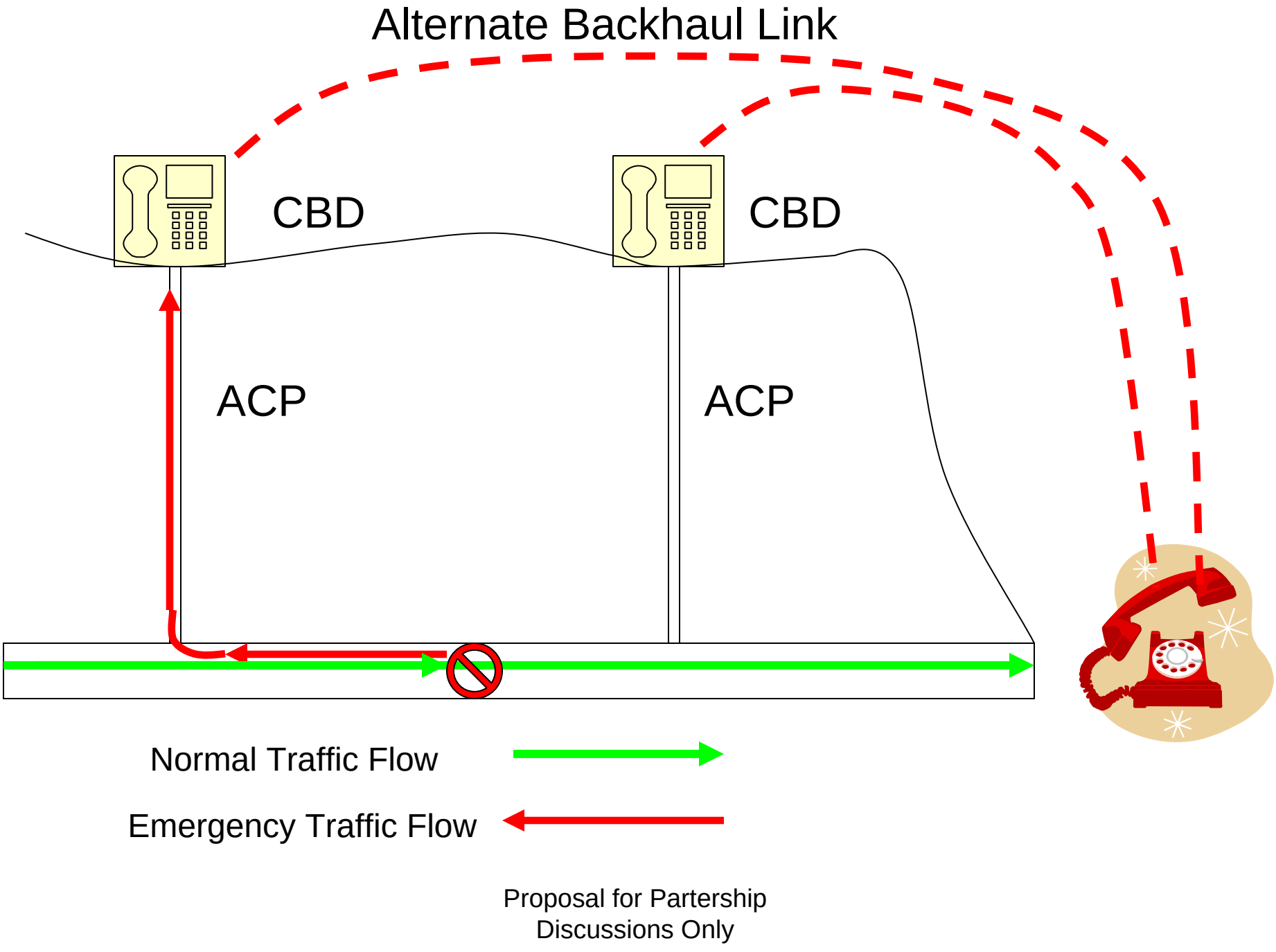
Bi-Directional Communications Redundancy



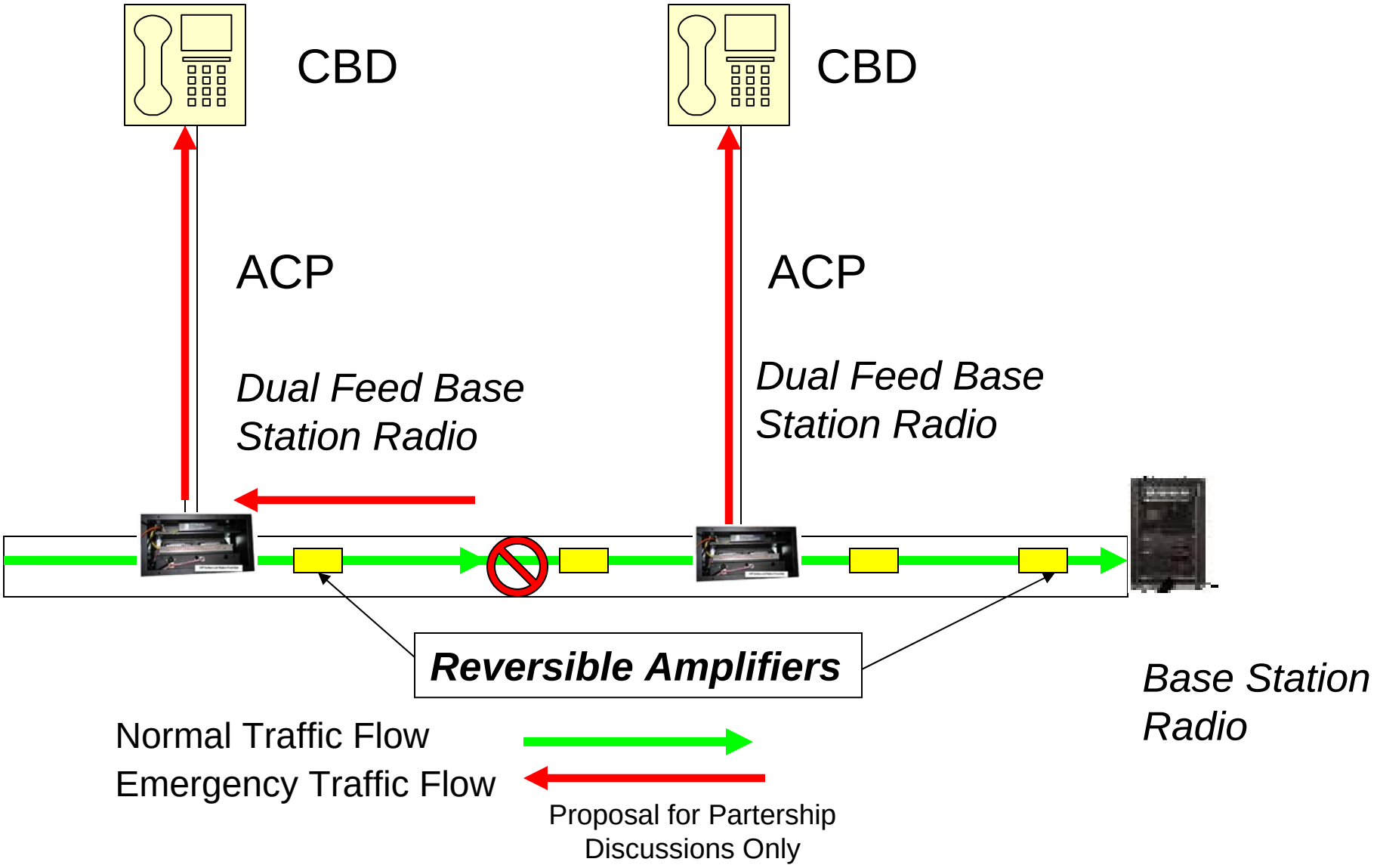
Normal Traffic Flow

Emergency Traffic Flow

Proposal for Partership
Discussions Only


Alternate Backhaul Link
CBD
CBD
ACP
ACP
Normal Traffic Flow
Emergency Traffic Flow
Proposal for Partership
Discussions Only

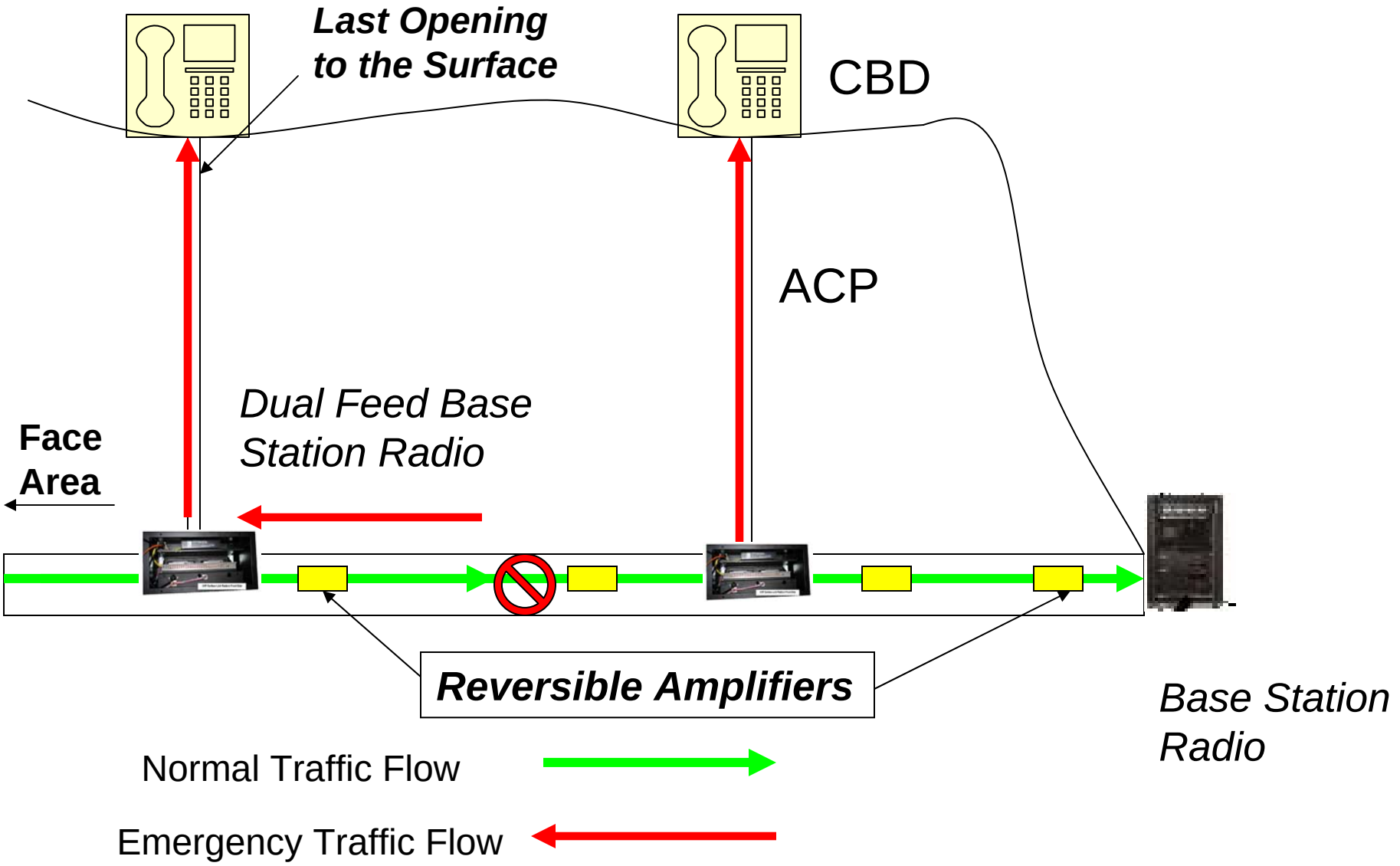
Leaky Feeder Bi-Directional Redundancy



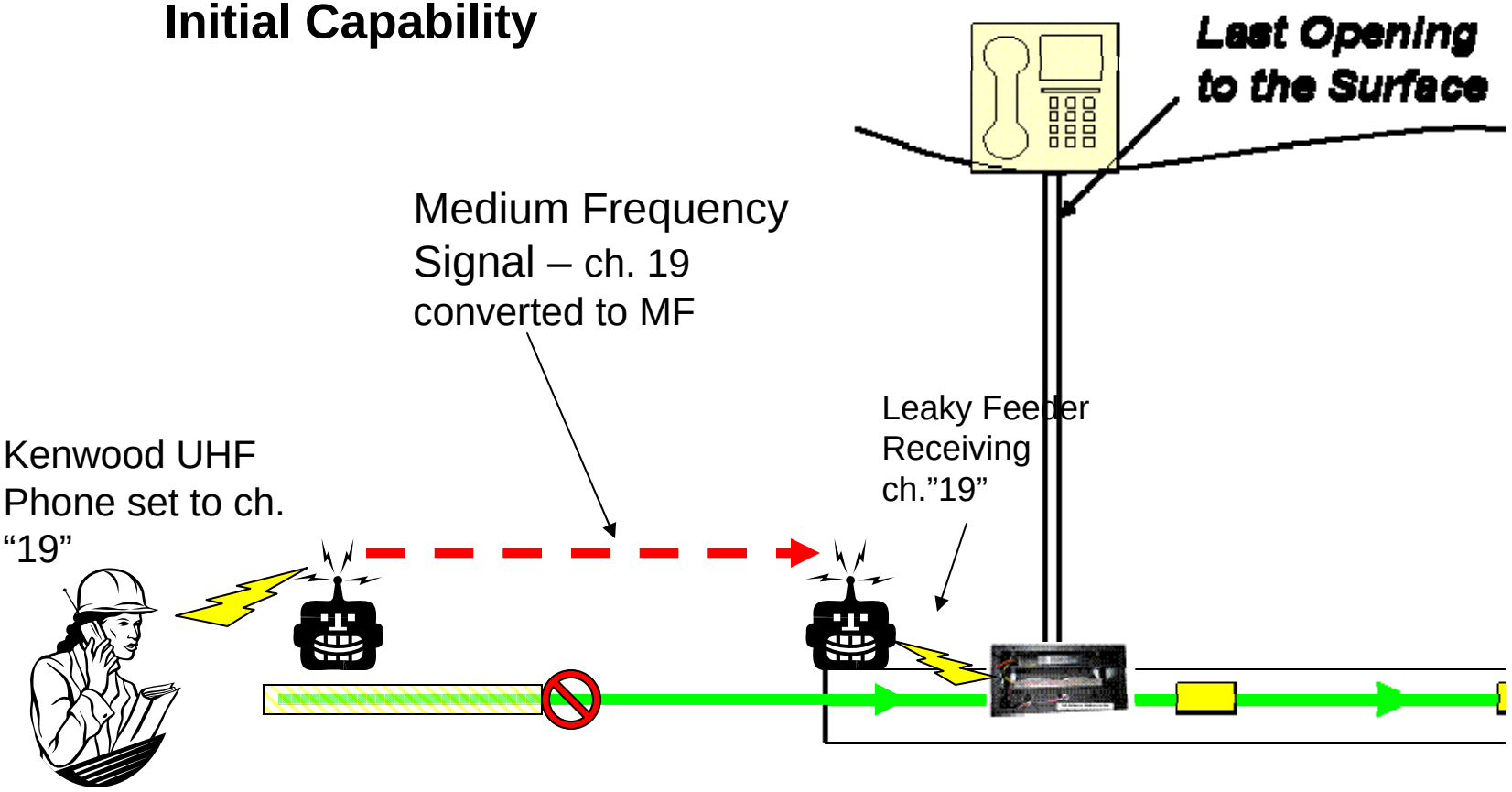
Redundancy Challenges

- Face areas and areas beyond the last opening to the surface do not have the option of an ACP through a borehole
- Even with Bi-directional redundancy the area in the immediate vicinity of damaged nodes and amplifiers will not have radio coverage
- Medium Frequency systems can potentially provide a solution to both challenges

Bi-Directional Communications Challenge



Face Area Redundancy – Initial Capability



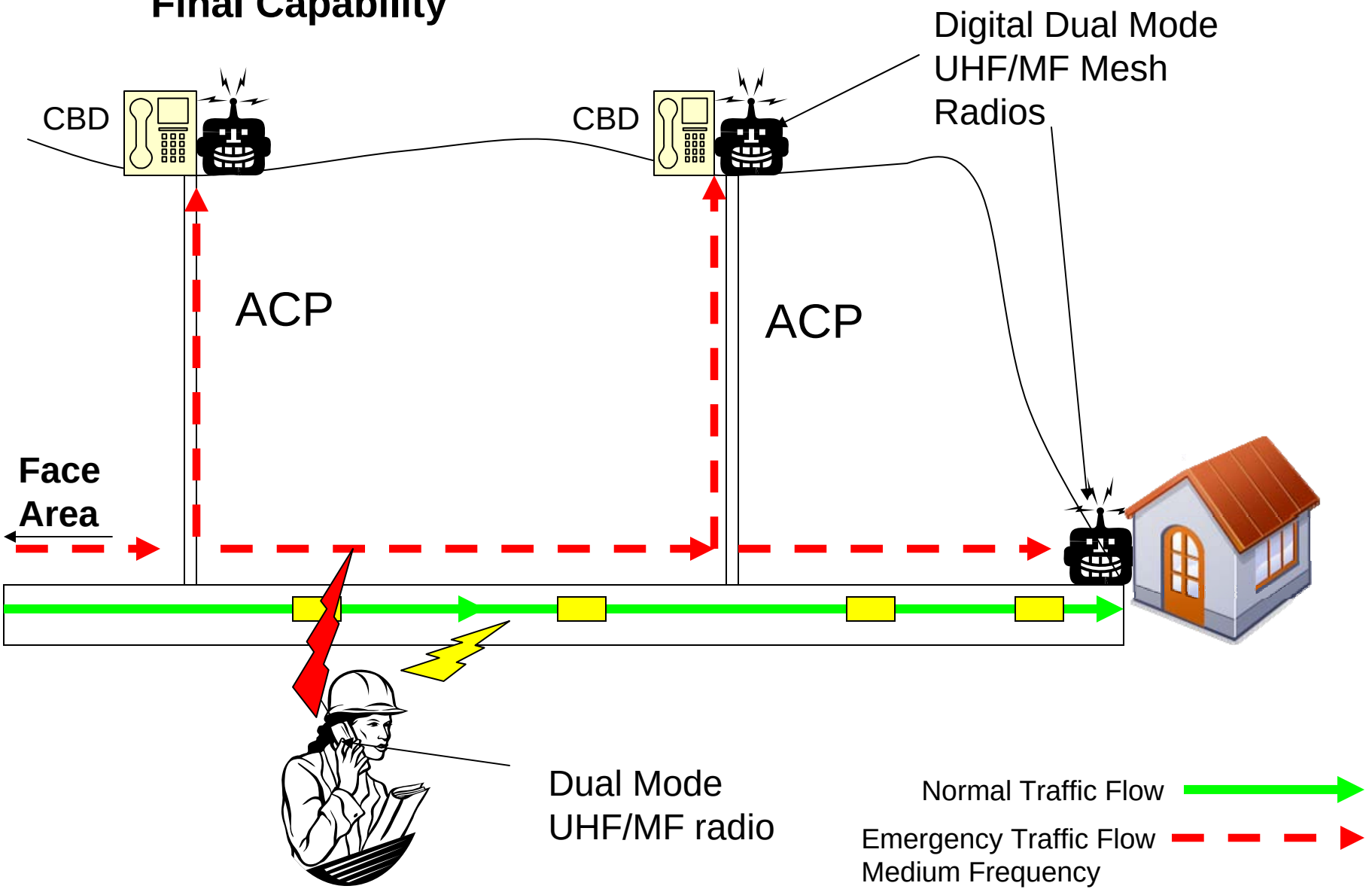
Legend

UHF to MF repeater set to Channel "19"

Normal Traffic Flow (ch. 2-17)

Emergency Traffic Flow (ch.19 Converted to Medium Frequency)

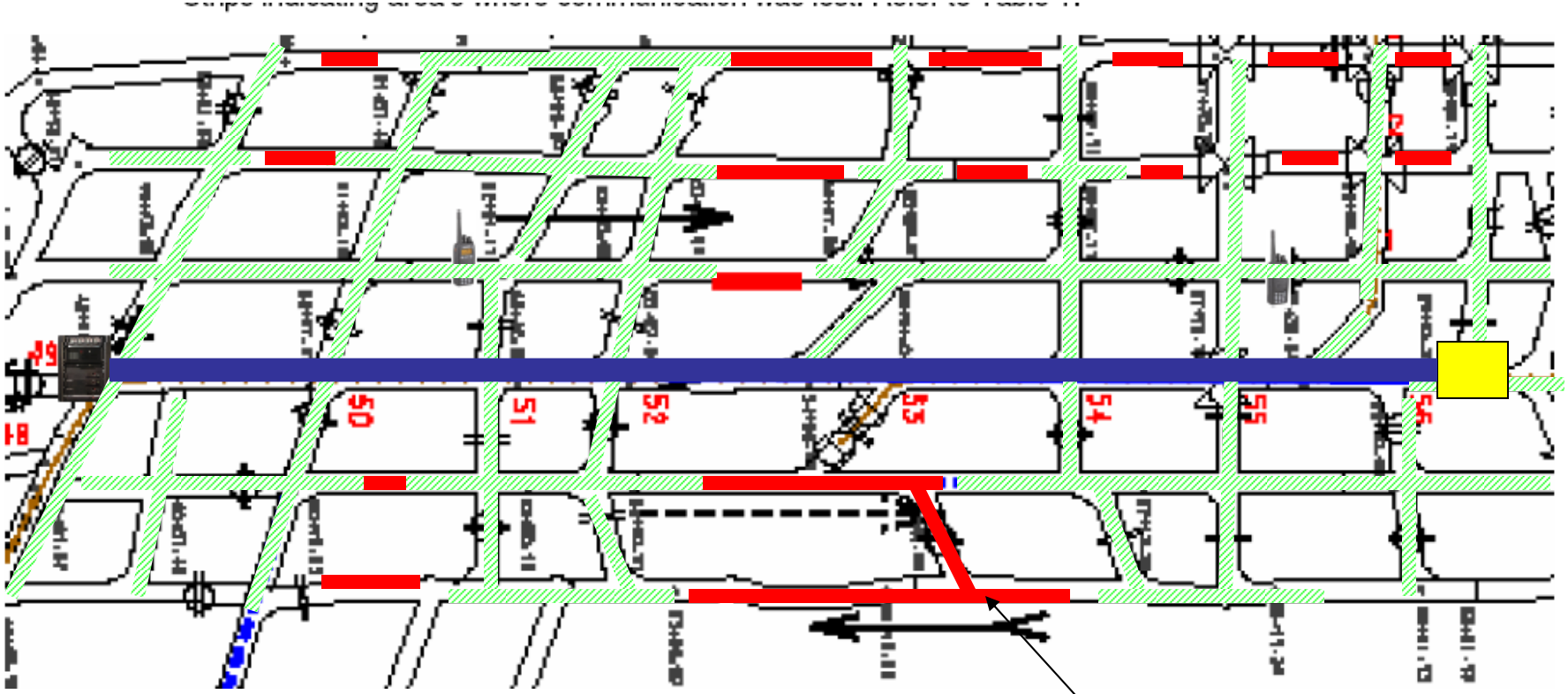
Mine Wide Redundancy – Final Capability



Proposed Phased Approach for Discussion

- Phase 1 – Non-redundant Wireless Coverage
- Phase 2 – Bi-directional communication path redundancy
- Phase 3 – Redundant radio coverage (one of which is hardened) and coverage enhancements

Phase 1 – Leaky Feeder Implementation

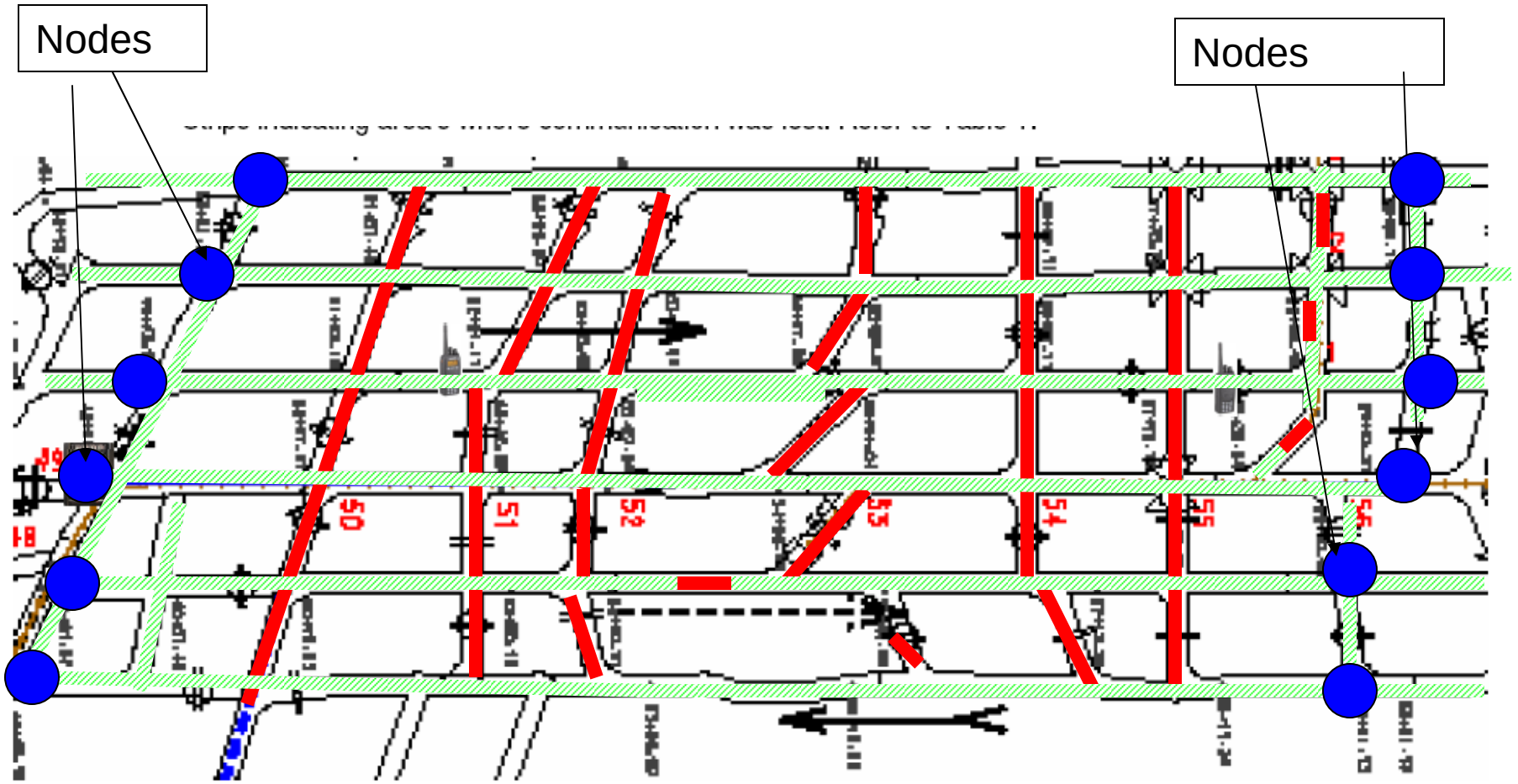


Legend

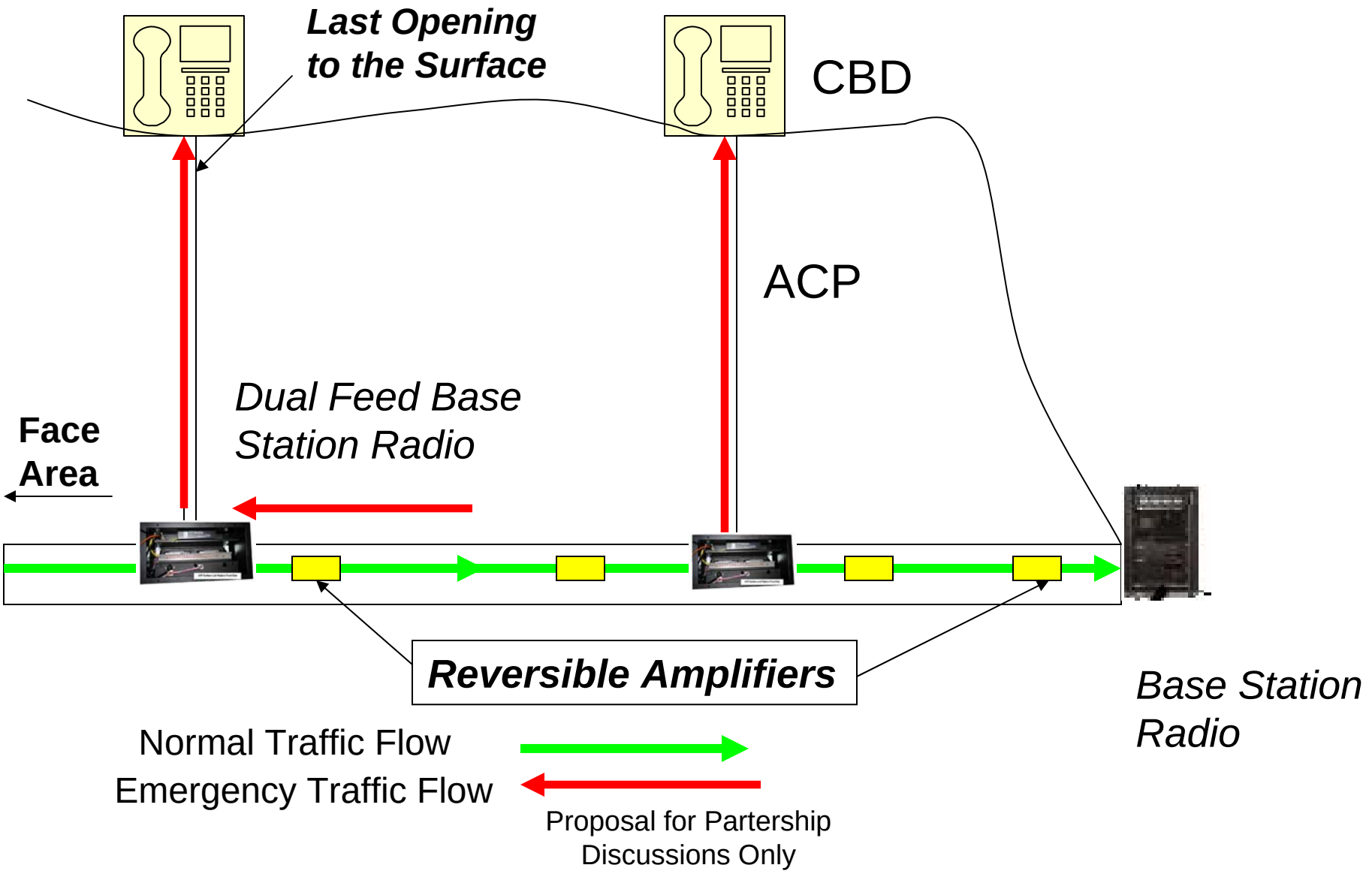
Entry with Radio Coverage

Radio Coverage Hole

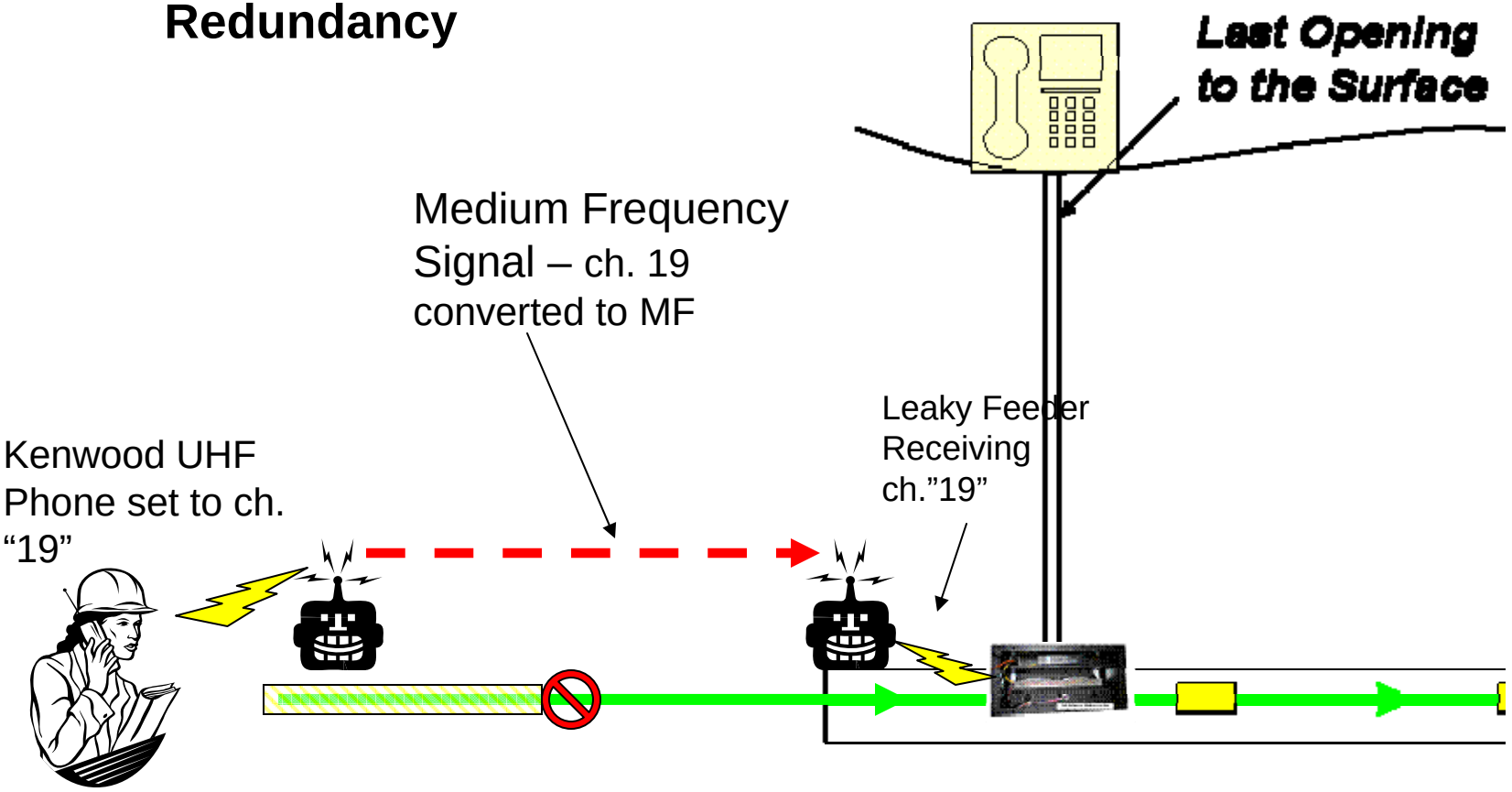
Phase 1 – Mesh Implementation



Phase 2 - Bi-Directional Redundancy



Phase 2 - Face Area Redundancy



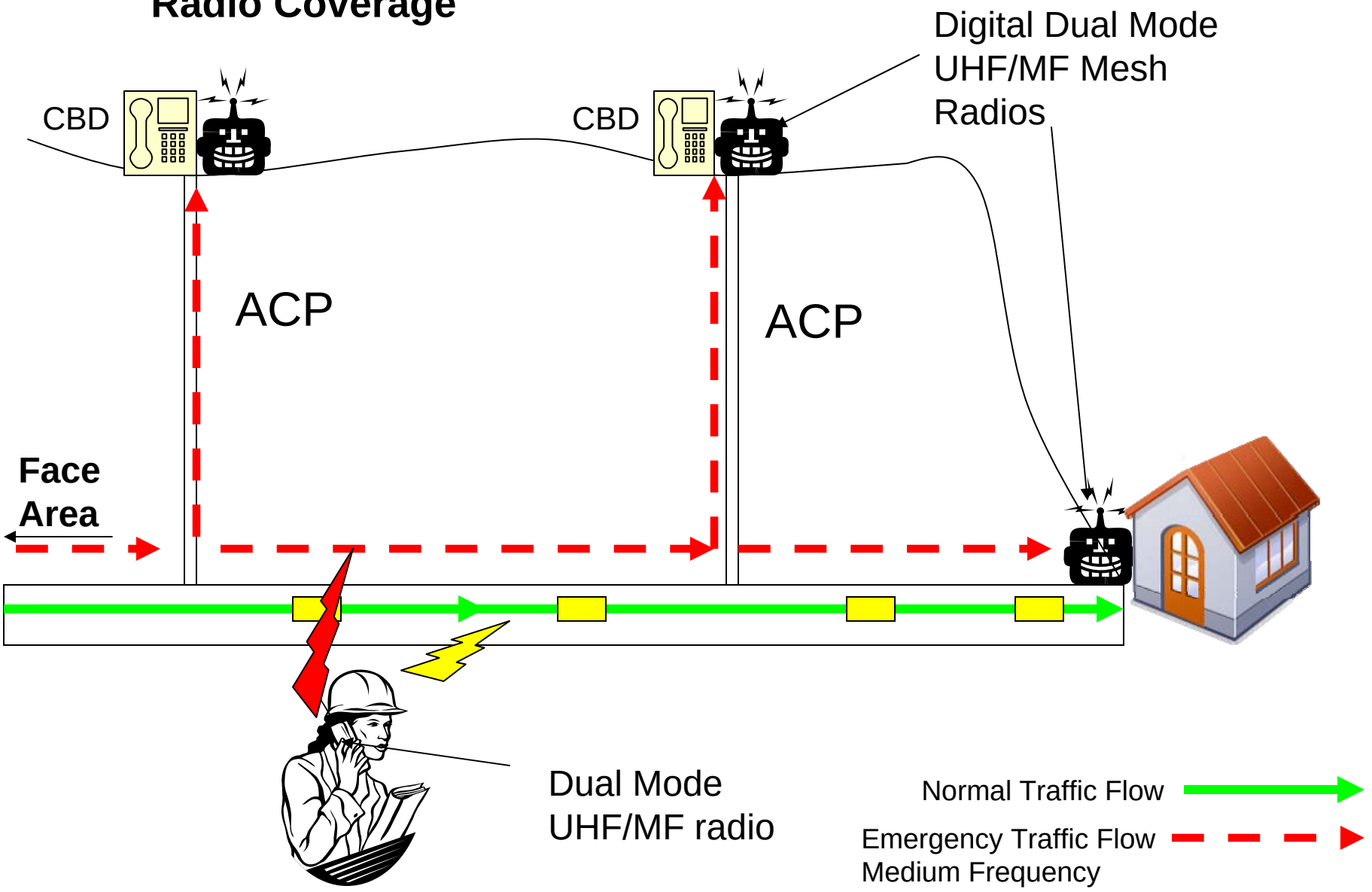
Legend

UHF to MF repeater set to Channel "19"

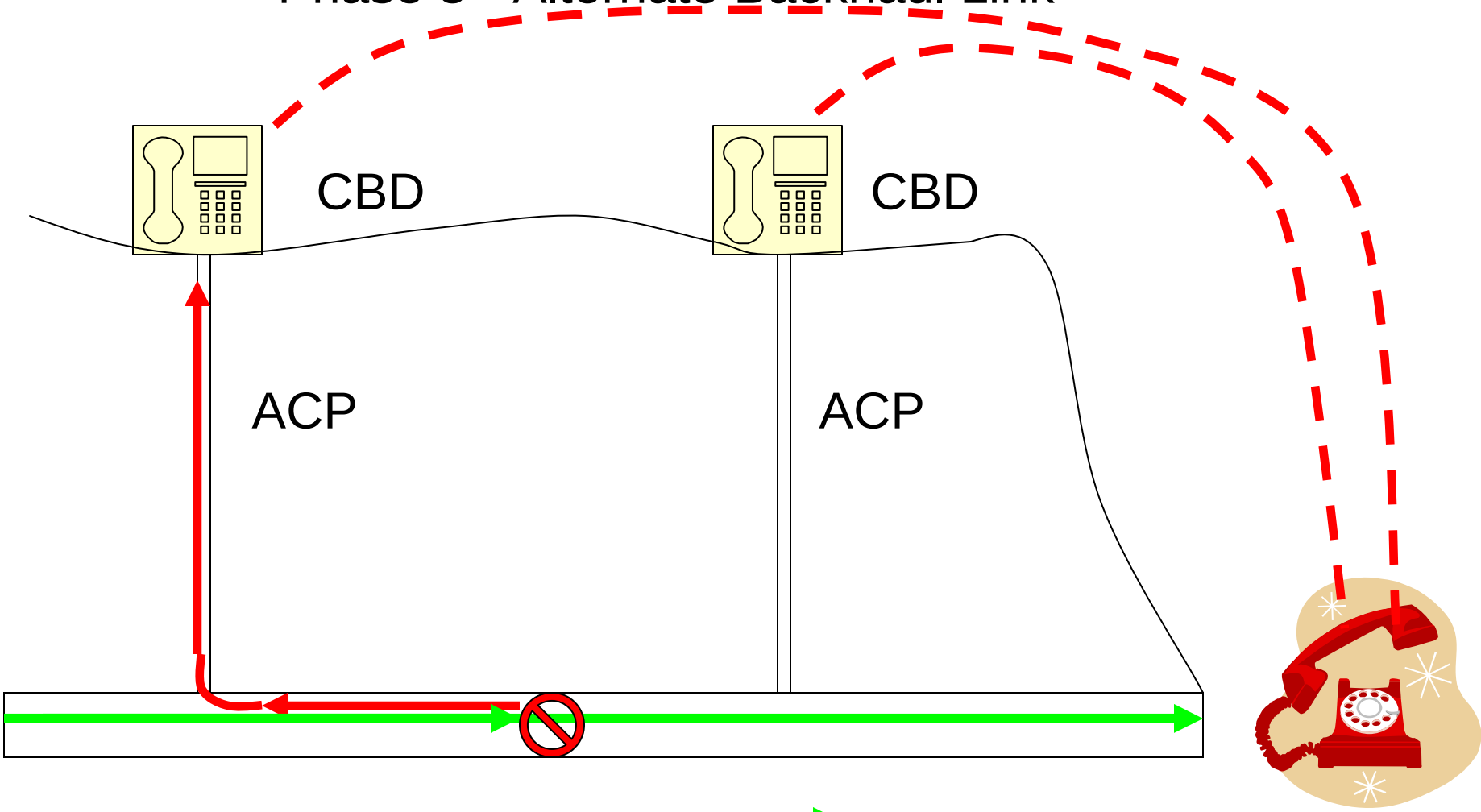
Normal Traffic Flow (ch. 2-17)

Emergency Traffic Flow (ch.19 Converted to Medium Frequency)

Phase 3 – Redundant Radio Coverage



Phase 3 - Alternate Backhaul Link



Normal Traffic Flow

Emergency Traffic Flow

Proposal for Partership
Discussions Only

Summary

- The proposed communications “road map”
  - Provides a path to improve emergency communications capabilities in the short term, while enabling significant functionality advances over the long term
  - Regulators will need to be reasonable with their interpratation of the laws for the approach to be acceptable
- Further discussions and industry input are required to encouraged to arrive at specific recommendations

NOTE: The “Roadmap” is a work in progress, not a NIOSH position or recommendation

Next Steps

- Solicit input from stakeholders on proposed phased implementation plan
- Arrive at government agreement on specific recommendations if possible
- Translate phasing plans into technical guidelines and regulatory recommendations as information becomes available

Wireless Communications "Road Map" Proposal for Discussion

Glossary of Terms for Presentation

Wireless system – includes any system that provides for radio service to a radio device that is carried by an end user (i.e. miner) for the purposes of communications to the mine operations center and other miners.

"Mine Wide Coverage" as used for the purpose of wireless coverage is Radio Coverage that includes coverage of Critical Areas.

Critical Areas – proposed definition is to include any place in a coal mine where miners are regularly required to work or travel. The specific coverage proposed varies by implementation phase and location within the Critical Areas. See Implementation Guideline Proposal below and related coverage definitions.

Radio Coverage – High reliability wireless system service as defined by engineering parameters specific to the technology.

Radio Link – is the radio path from the miner's radio to the first fixed antenna system.

Communication path – is the transmission path from the antenna system to the first point outside of the mine.

Primary Communications Path – Communication path that is used for day to day mine communications and typically terminates at the mine operations center.

Alternate Communications Path (ACP) – A communication path that follows a physically separate route that terminates at a different point outside of the mine relative to the primary communications path. The ACP can be either coaxial cable, wire, fiber, or a radio path.

Common Backhaul Device (CBD) – The common backhaul device serves as the termination point for the Alternate Communication Path (ACP) on the surface. The device will contain a handset for direct voice connections with the mine wireless system. The device will include a method to continually verify the integrity of the ACP and the CBD. The CBD will also serve as the interface for the Alternative Backhaul Link. This interface is proposed to be an IP compatible interface.

Alternative Backhaul Link – This is the link from the Common Backhaul Device to the mine operations center. This is proposed to be an IP compatible link such that it can use a cable modem, telephone modem, DSL, cellular data, satellite IP link, fiber, or any other link that supports Internet access so that the mine operator has maximum flexibility in obtaining this connectivity.

Bi-Directional Communication Path Redundancy - A method that ensures system survivability if a section of the mine infrastructure is lost. This is accomplished by the system ability to automatically redirect traffic from the primary communication path to the ACP in a disaster situation or if the primary communication path is interrupted.

Redundant Radio Coverage – two radio systems are required both of which provide radio coverage to the areas. It is proposed that the definition includes a requirement that one of the radio systems is hardened.

Coverage Enhancement Device – is any device that extends the coverage from the main antenna system. This can include passive reflectors, active repeaters, and low

power mesh nodes. These devices are generally intended to fill in gaps of coverage relative to the main antenna system.

Hardened System – A system is considered hardened if there are no vulnerable components in the mine other than the handset that the miner is carrying.

Vulnerable components – a component that may be may be damaged by fire or explosion. Components are considered not vulnerable if, based on its location in the mine and the history of mine explosions and fires in the mine; it is likely to withstand the event intact.

Common Digital Interface – The common interface required to let digital systems transfer data from one to another on an emergency basis. It is proposed that this development consider the requirements of transferring voice and data between UHF systems, MF systems, and TTE systems. This will include the ability to mediate data rates and prioritize traffic in an emergency situation.

Implementation Guideline related definitions:

Maximum outage area w/ single failure – this is the maximum gap in Radio Coverage that can result from a single active component or antenna failure. This distance is proposed to be 1000 feet in any direction from the failed component.

Active Components – Includes radios, amplifiers, and other powered devices within the Radio Link or Communication Path.

Maximum Spacing of ACPs – This is the maximum spacing that is recommended between alternate communication paths in the mine. This is proposed to be a distance of 2 miles along the travel routes in the mine.

Partial coverage – Coverage along an entry that is available at minimum of 300 ft intervals at cross cuts or other readily identifiable location. Any location designate for storage of SCSRs will necessarily have radio coverage.

Implementation Guideline Proposal

The following are implementation guidelines by Phase which are proposed for discussion purposes. Terms within the guidelines that have proposed definitions in the glossary of terms above are Capitalized in **bold** in the discussion below:

Phase 1

UHF Non-Redundant **Radio Coverage** is proposed which provides for complete coverage of the primary escape ways and main travel routes. The adjacent entries and the secondary escape ways are proposed to have **Partial Coverage**. **Radio Coverage** will be maintained within 1000 feet of the active face at a minimum. Point to point radios will be installed on the continuous miners and shuttle cars operating at the active face as well as any SCSR storage locations.

Proposed Methods of Deployment - UHF Leaky feeder or Wireless Mesh.

Technology Recommended as part of installation - Reversible amplifiers and head end radios for leaky feeder systems and true self healing adhoc capability for wireless mesh systems. These technologies will be needed to support bi-directional redundancy in Phase 2.

Phase 2

Bi-Directional Communications (BDC) Paths Redundancy will be implemented as well as complete coverage of the face area and redundancy of the communications path to

the face area. BDC path redundancy will be maintained within 1000 feet of the face. **Common Backhaul Devices** will be used to support communications with the mine wireless system across the **Alternate Communication Path**.
Proposed Methods of Deployment – UHF Leaky feeder with reversible amplifiers connected to the ACP and the installation of the common backhaul devices on the surface. Alternately, truly adhoc mesh networks can be used which support a bi-directional redundancy arrangement. Fiber based self healing rings are also a possibility. For the face area coverage a dual frequency MF/UHF repeater arrangement would be used that provides a wireless bridge from the active face to the first ACP in the mine.

Phase 3
Redundant Radio Coverage systems will be provided in **Critical Areas** of the mine. One of the radio systems will be designed to be **Hardened**. Non-redundant wireless coverage will be provided in less frequently traveled areas (i.e. longwall bleeders) when personnel are present.
Additionally the **Common Backhaul Devices**, installed for Phase 2 requirements, will be connected back to the mine operations center via the **Alternative Backhaul Links.**
Proposed Methods of Deployment – the same system as installed in phase 2 will be used with the addition of a medium frequency or other hardened overlay system and the introduction of the alternative backhaul links. Compliance can be achieved by automatic cutover of the primary to the secondary system or the miner carrying a dual mode radio.

Related definitions:

Per MSHA PROGRAM POLICY LETTER NO. P06-V-10:

When hardwired systems are used to meet the MINER Act requirement for redundant communication between surface and underground personnel, wires should be routed through separate entries or boreholes continuous to the surface.

MSHA interprets the term "wireless," as used in the MINER Act, to mean that no wired component of the system exists underground where it may be damaged by fire or explosion. Post-accident communication technology would be considered acceptable if, based on its location in the mine and the history of mine explosions and fires in the mine; it is likely to withstand the event intact.

Per West Virginia Law:

“Wireless” means allowing individual communications by a miner through a mine communication and tracking/location system without a physical connection.

The wireless emergency communication device shall, at a minimum, be capable of receiving emergency communications from the surface at any location throughout the mine.

The operator shall install in or around the mine all equipment necessary to provide real-time emergency monitoring of the physical location of each person underground.