

Survivable Systems Concept of Operations

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Research*

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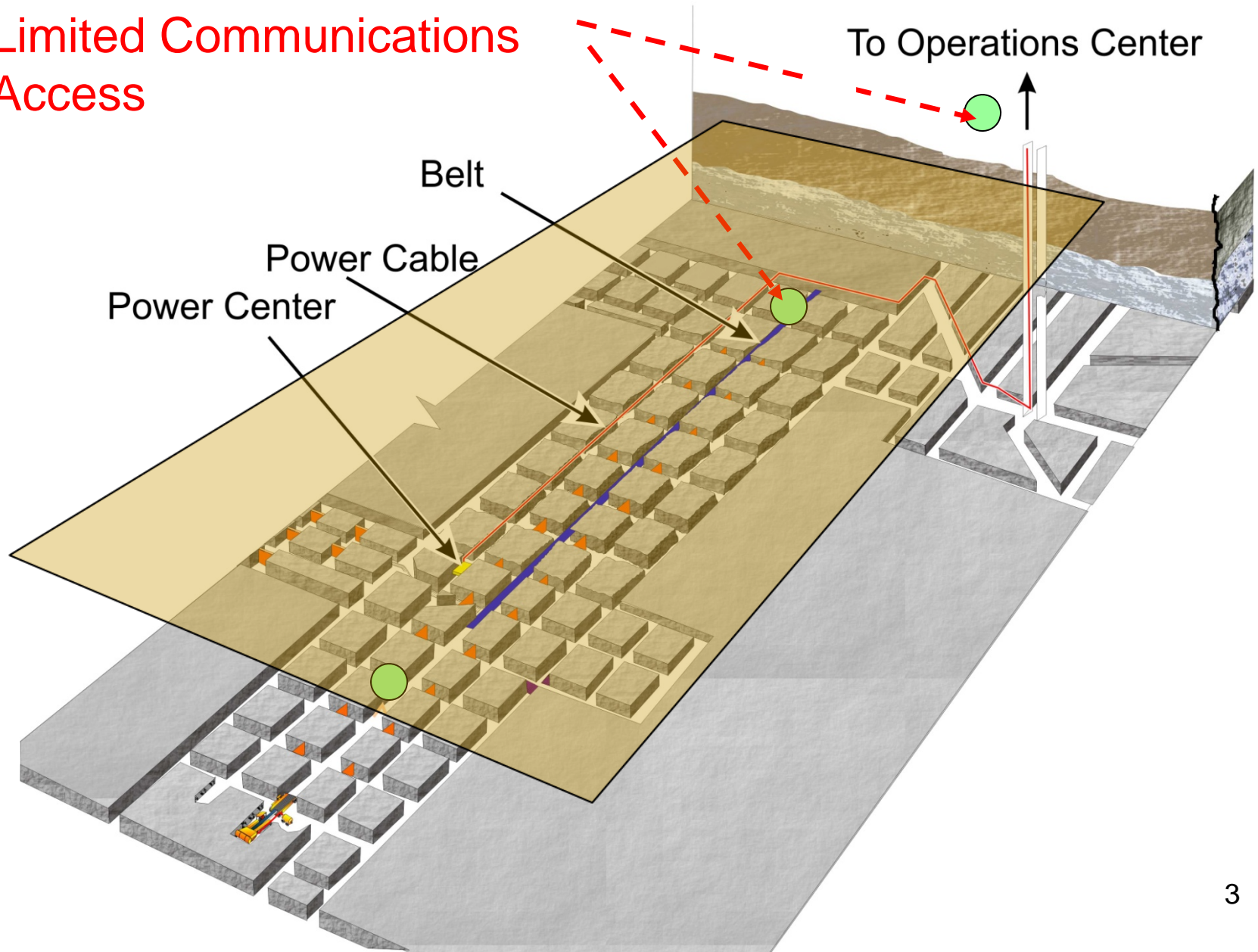
Overview

- Primary Communications Systems
- Secondary Communications Systems
- Interoperability Goals and Challenges
- Concept of Operations – ideas for discussion
 - Small Mine Example
 - Large Mine Example
- Single Channel Client Interoperability Example
- Infrastructure Interoperability Example
- Interoperability Observations
- Blocking Mitigation and Network Modeling

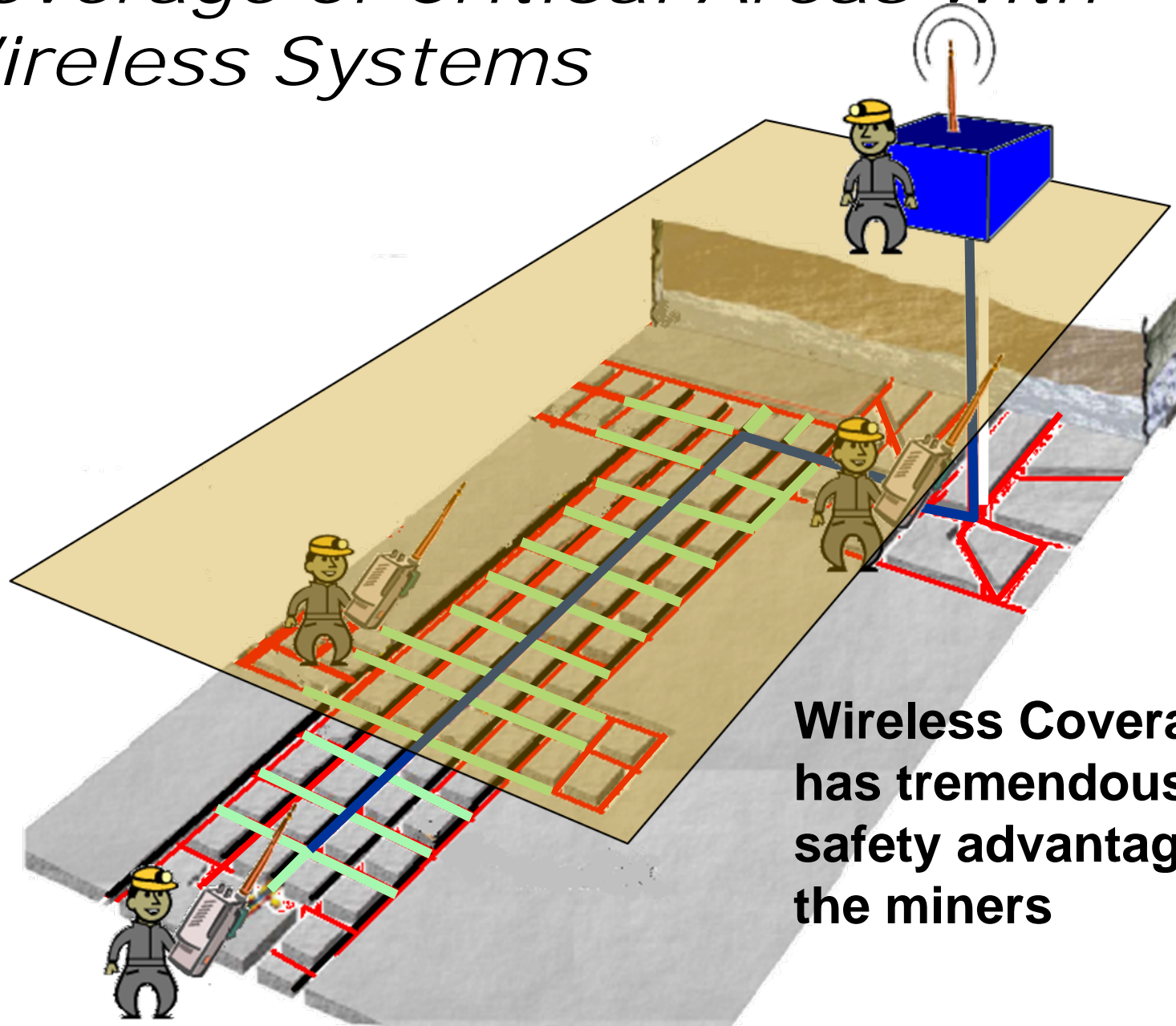


Hard-wired Systems – Pre- Miner Act

Limited Communications
Access



Coverage of Critical Areas with Wireless Systems



**Wireless Coverage
has tremendous
safety advantages for
the miners**

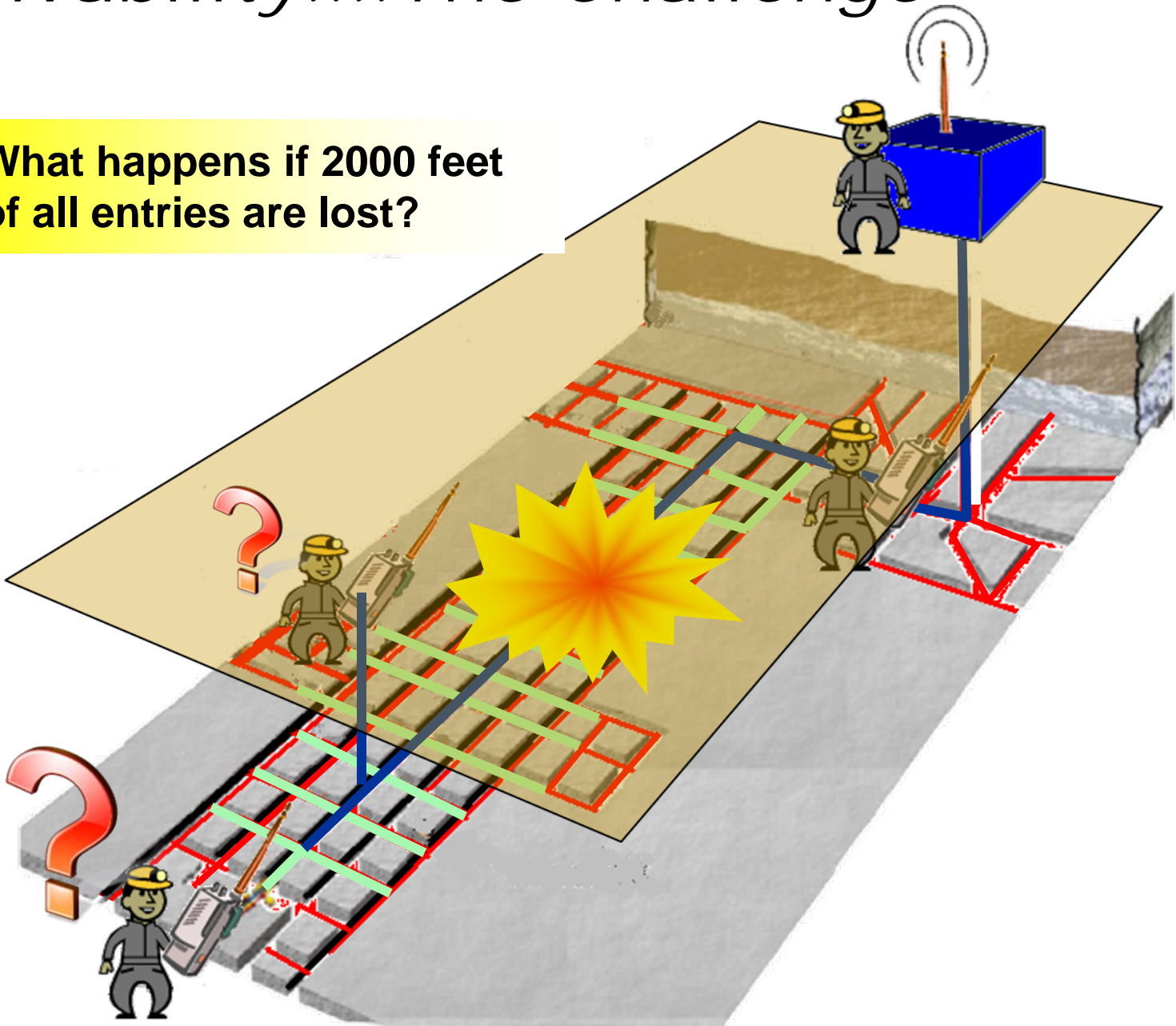
Primary Communications

- Primary communications systems are those that:
 - Operate in the conventional radio bands
 - Use small antennas that allow the miner to have wearable devices with long battery life
 - Have sufficient throughput for general operations
- Leaky feeder and node based systems are examples of primary systems
 - Either approach requires vulnerable infrastructure in the mine



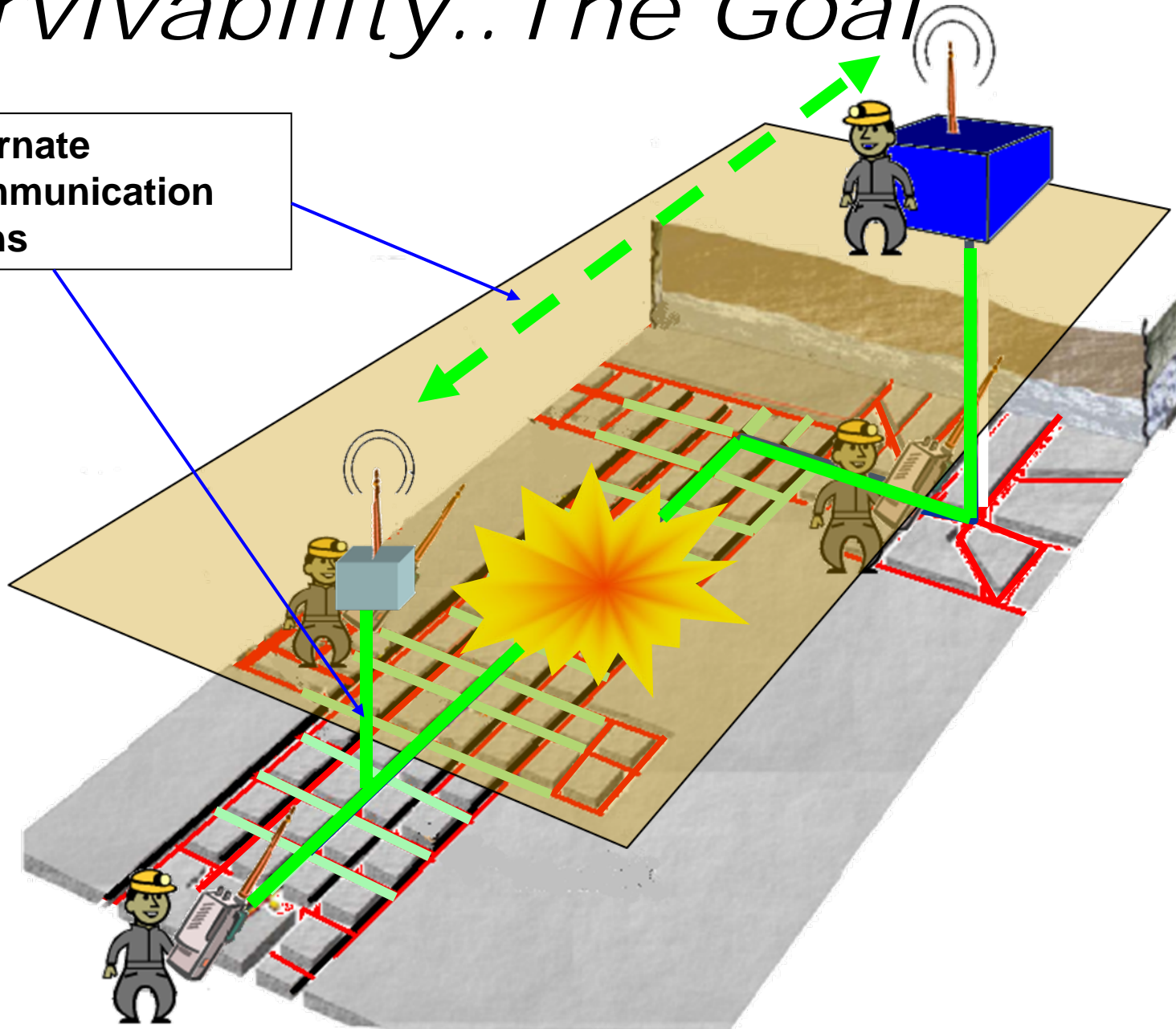
Survivability....The Challenge

What happens if 2000 feet of all entries are lost?



Survivability..The Goal

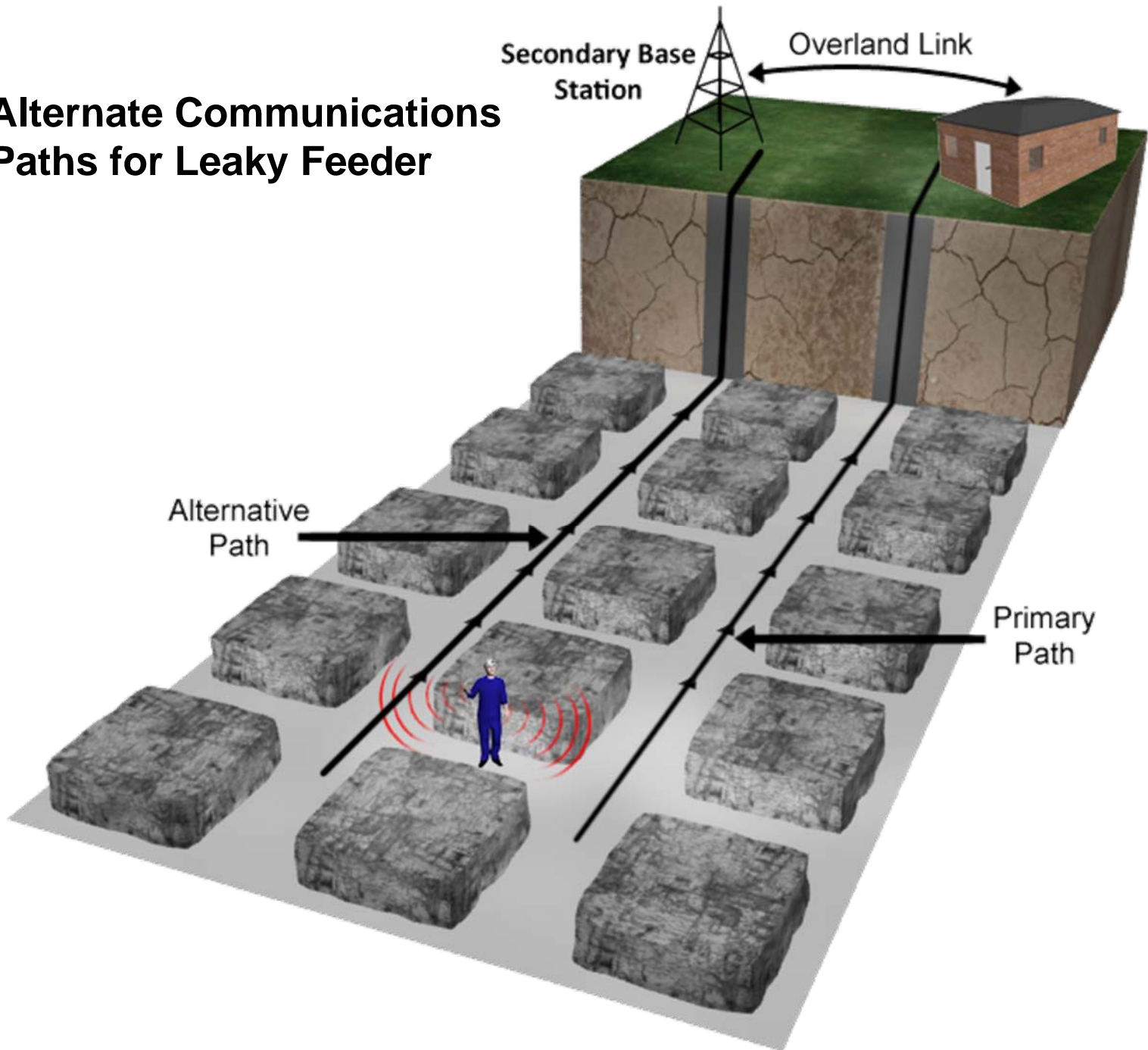
**Alternate
Communication
Paths**



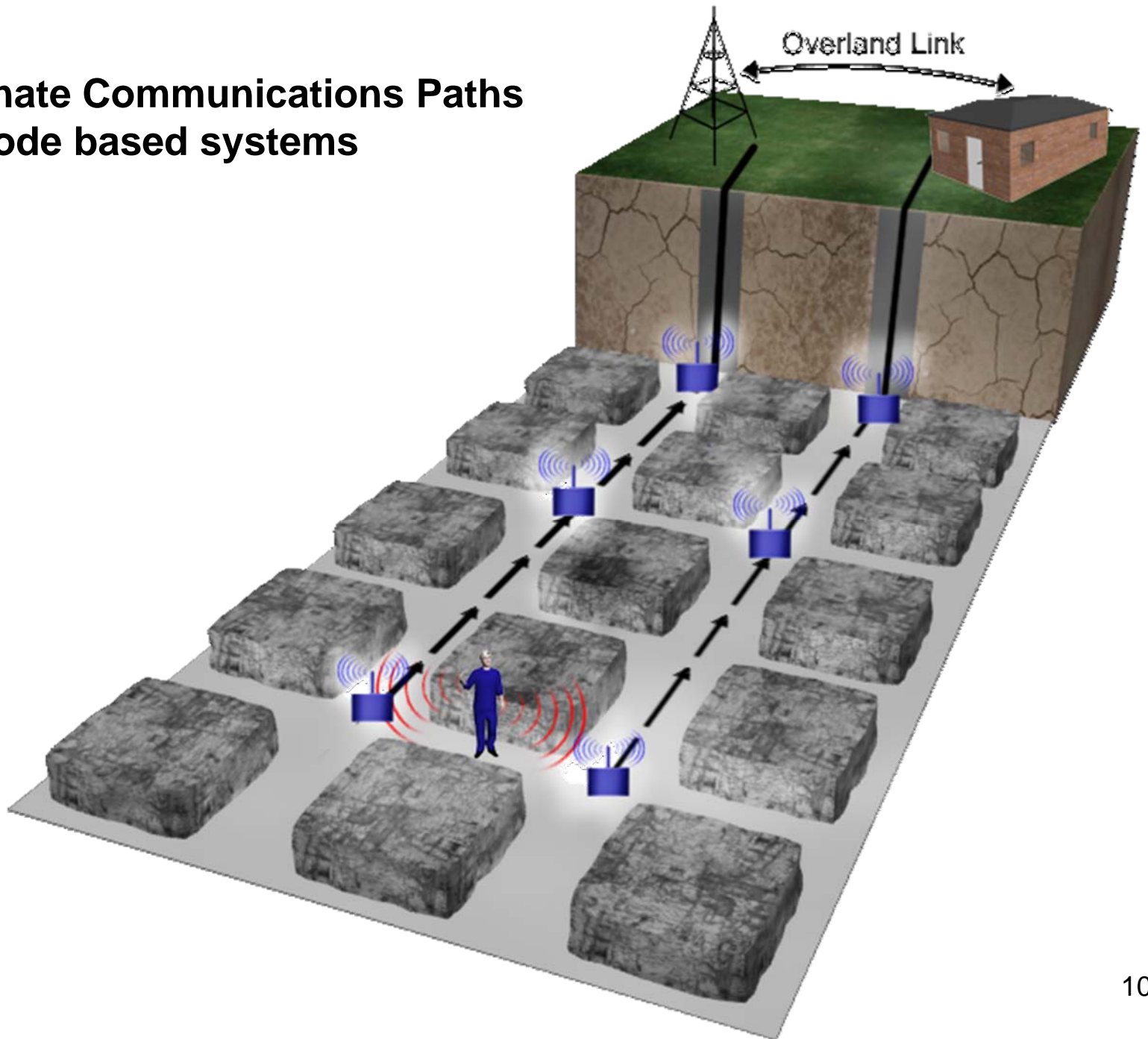
Alternate Communications Paths

- Ideally the alternate communications path is “truly diverse” and highly reliable
- Independent failure mechanisms
 - No shared components between the primary and alternate path that would fail from a common event
- Minimum number of active components (those that require electricity) yields the highest reliability
- Secondary Systems offer great potential for an alternate communications path, particularly near the face
 - A borehole directly to the miner would be the “ideal” alternate communications path

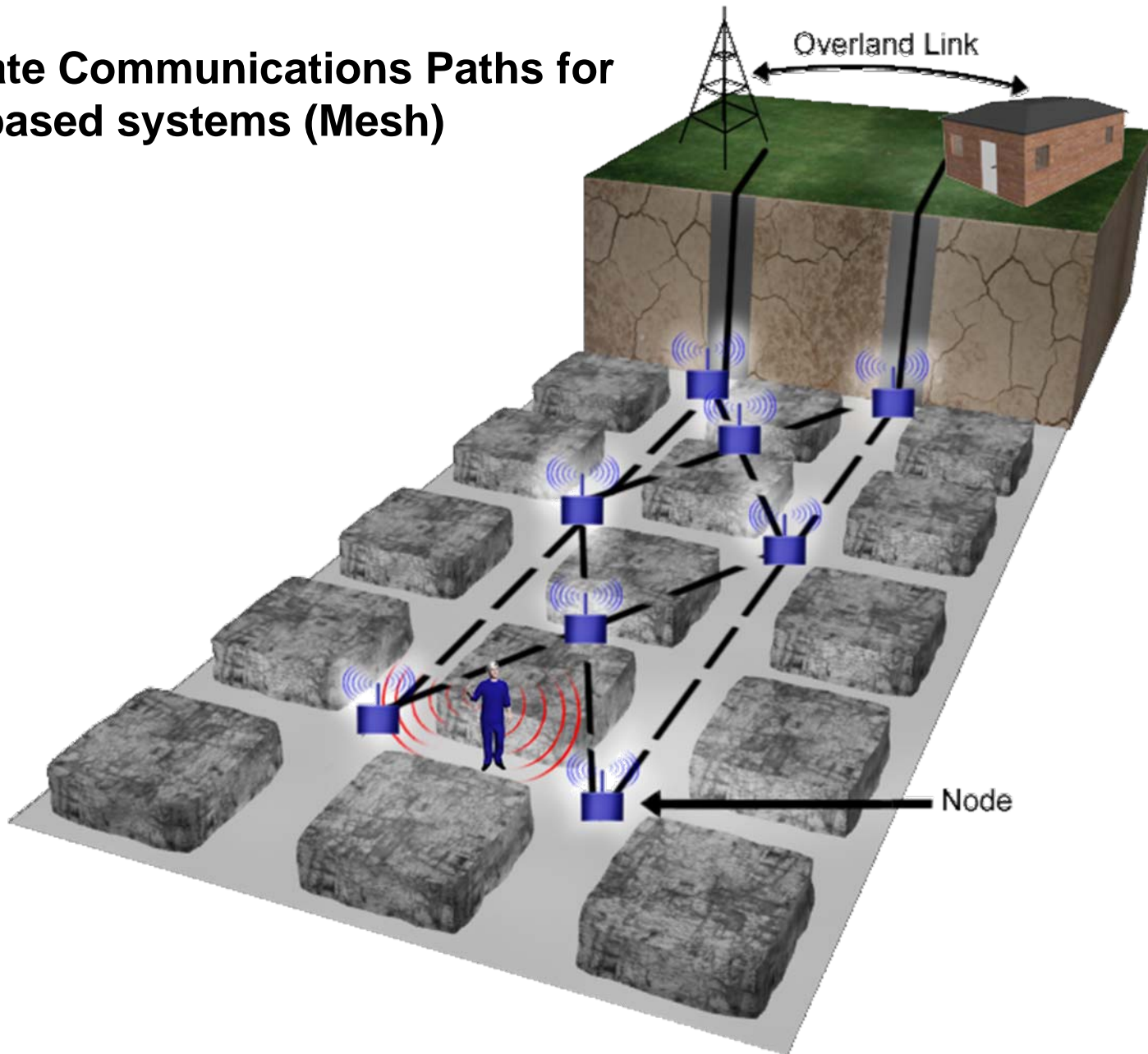
Alternate Communications Paths for Leaky Feeder



Alternate Communications Paths for Node based systems

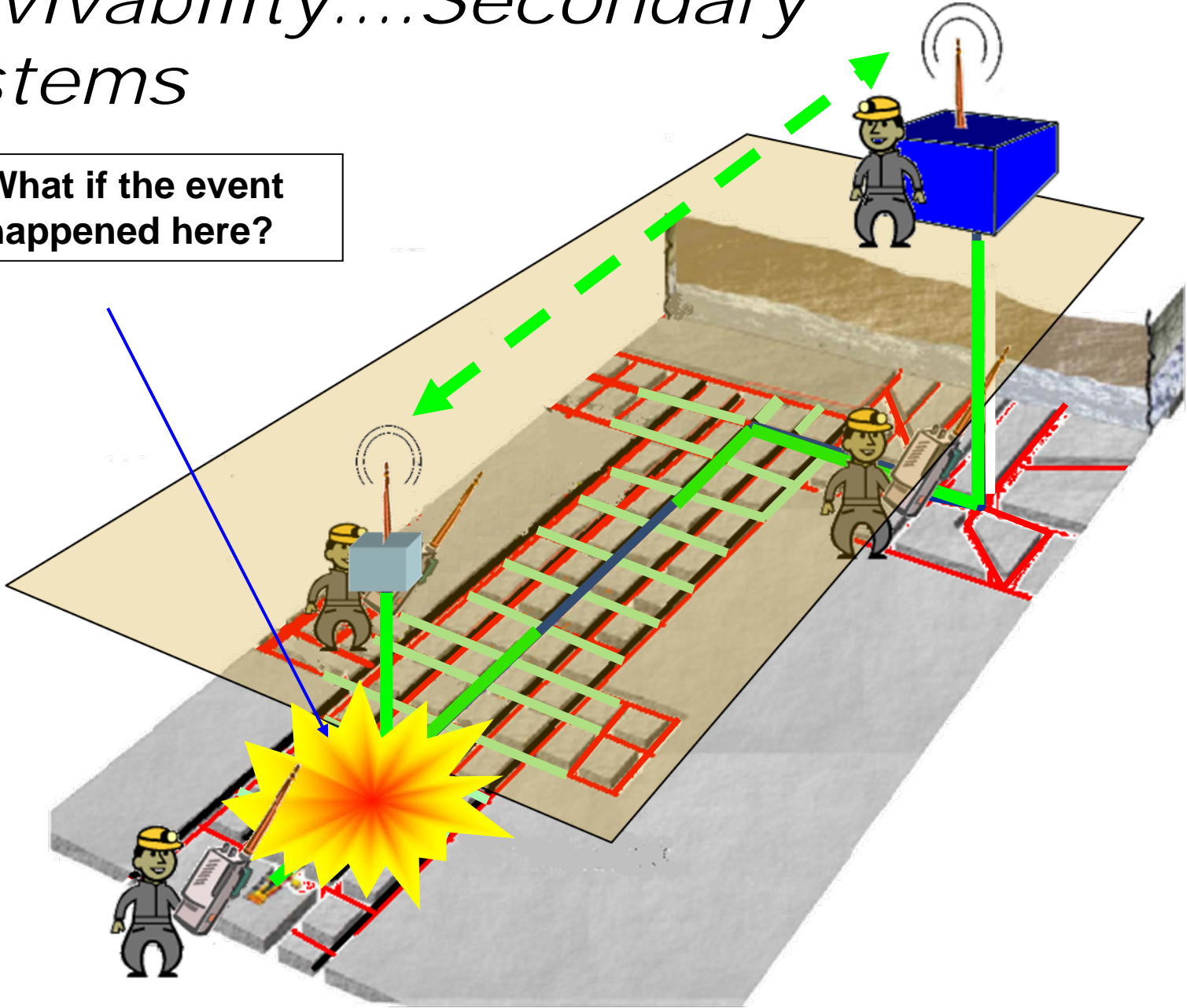


Alternate Communications Paths for Node based systems (Mesh)



Survivability....Secondary Systems

What if the event happened here?

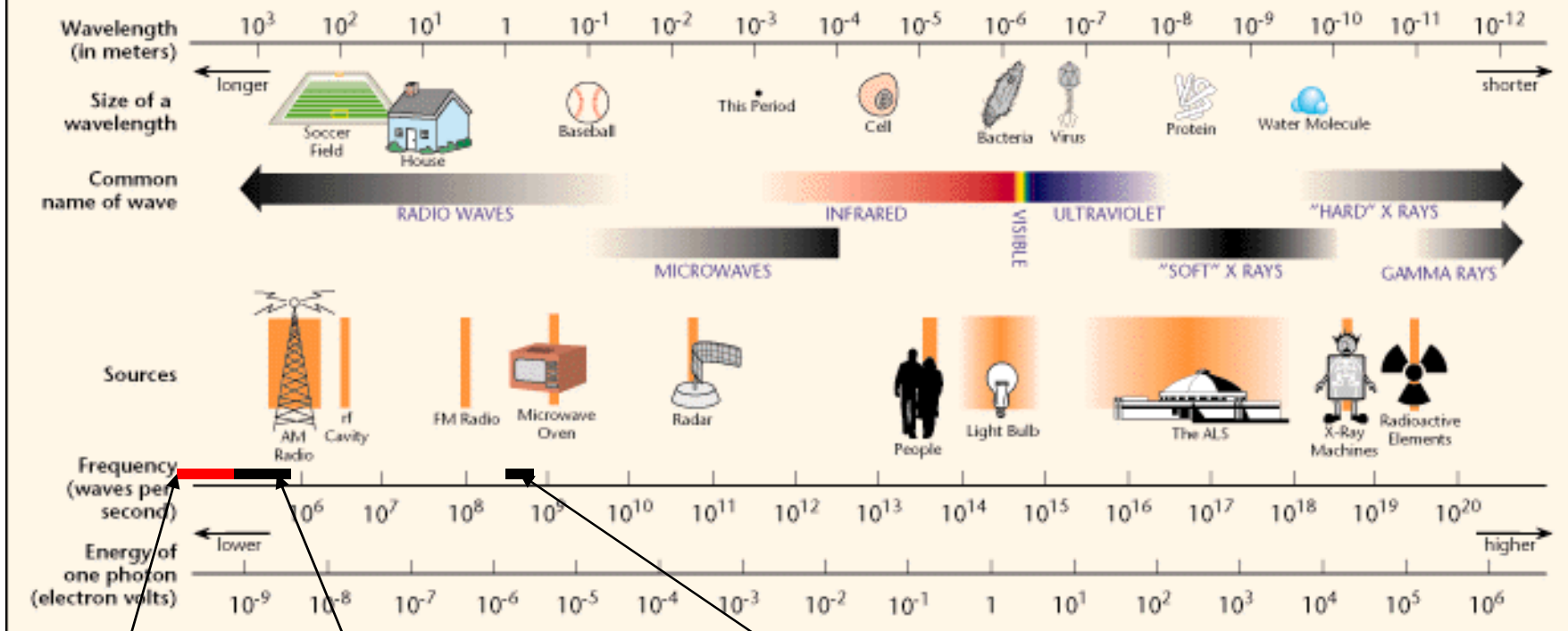


Secondary Systems

- Secondary Systems are those that have few active components and a high potential to survive a disaster
- Medium Frequency Systems and TTE Systems are secondary systems may provide survivable alternative paths
- A secondary system is one which:
 - Operates in non-conventional frequency bands
 - Uses a large antenna that is best suited for fixed locations or portable applications
 - Does not have sufficient throughput for general operations



THE ELECTROMAGNETIC SPECTRUM

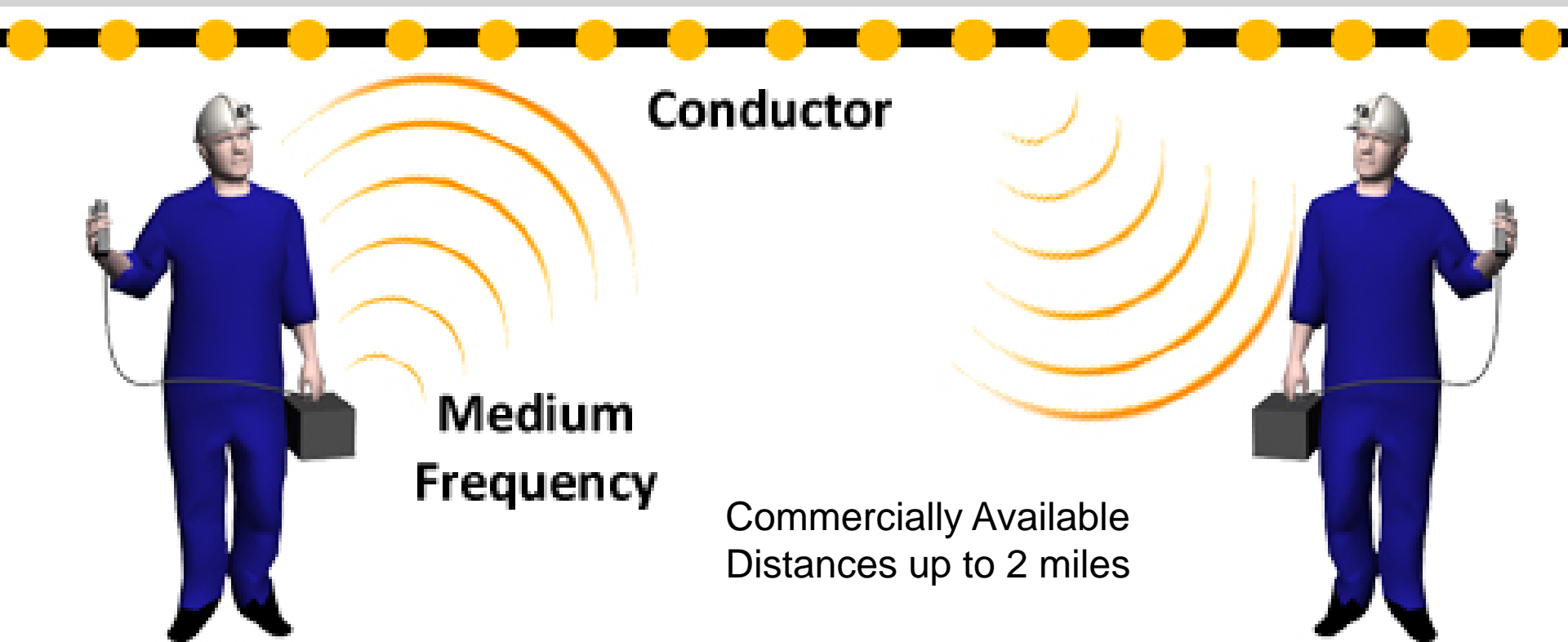


TTE (ELF – LF)

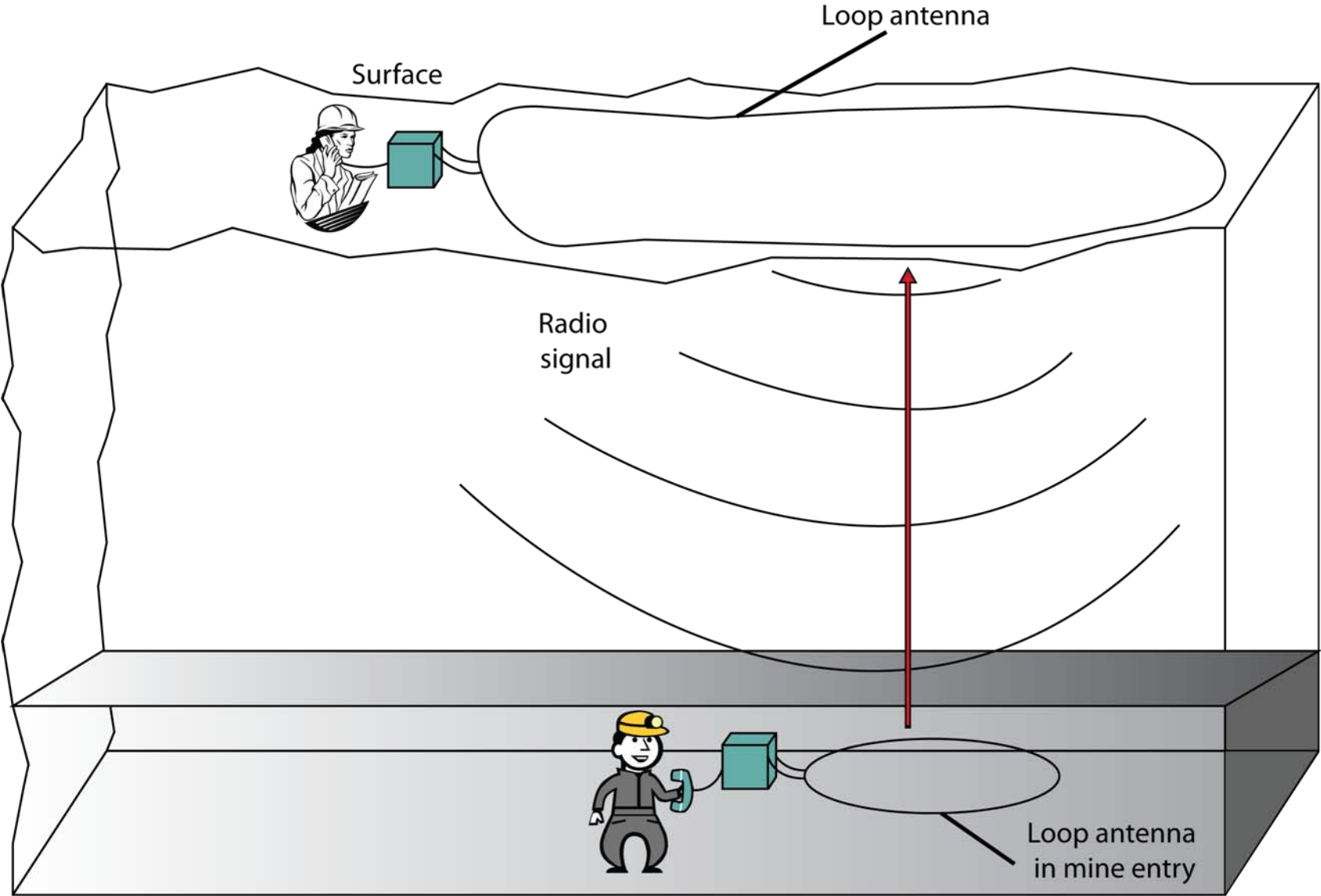
MF "Parasitic Propagation"

Primary Wireless "UHF" Systems UHF/VHF/SHF

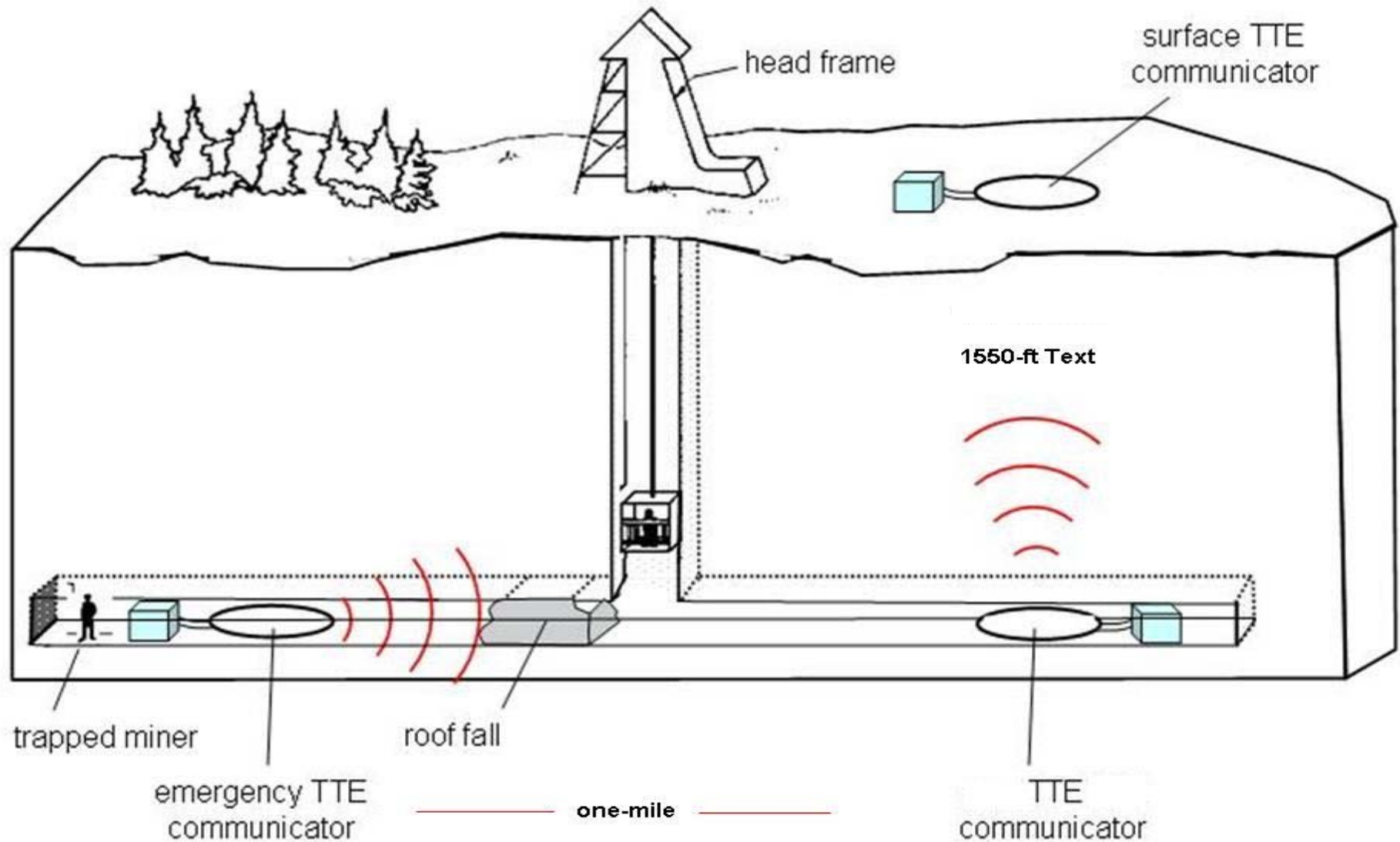
Medium Frequency Communications



Through the Earth (TTE) Communications



Permissible Systems Results



Interoperability

- “Interoperability” refers to our vision of the future of survivable mine communications in which a low bandwidth secondary communications channel would be used as a backup for the primary communications system.
- Key goal - Miner would be able to communicate using the same wearable device as used for day to day operations

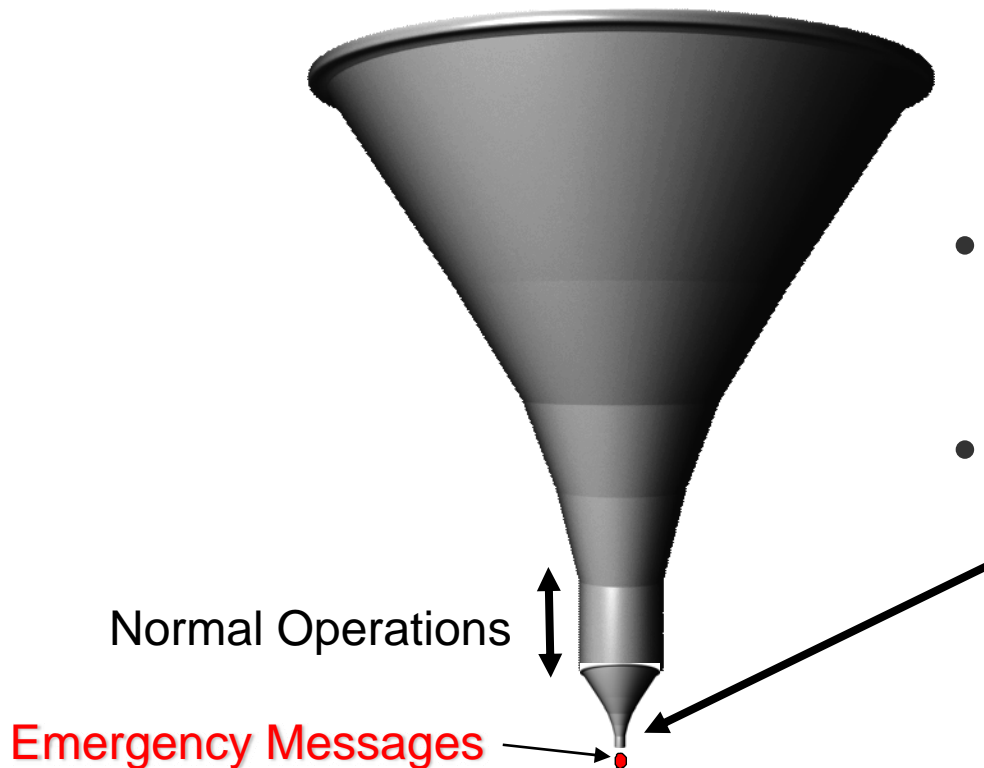


Interoperability Goal

- To keep things as simple as possible for the miner, while ensuring system robustness
 - Need to avoid unintended consequences of integrating systems
- Assumption is that the miner's best alternative for accessing the secondary system is the day to day communication device
 - Only valid if there is simplicity of access from the miner device



Interoperability Challenge

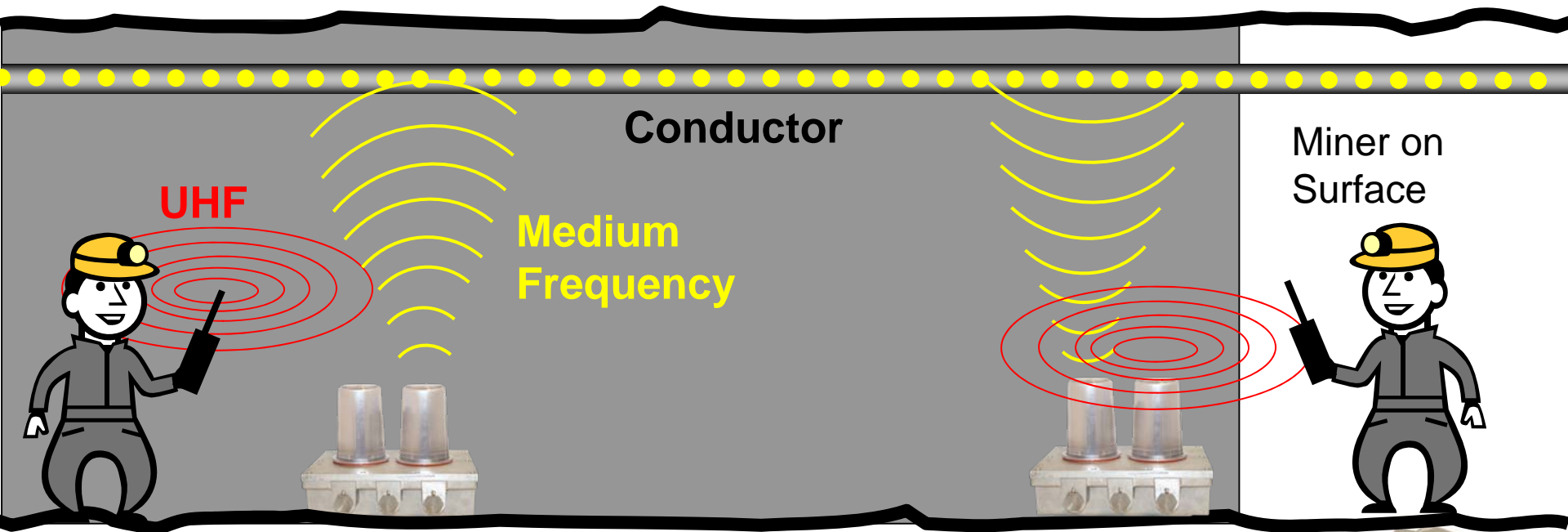


- Interoperability with digital and multi-channel communications is more complicated
- How do we ensure that only emergency traffic is directed to this secondary system?

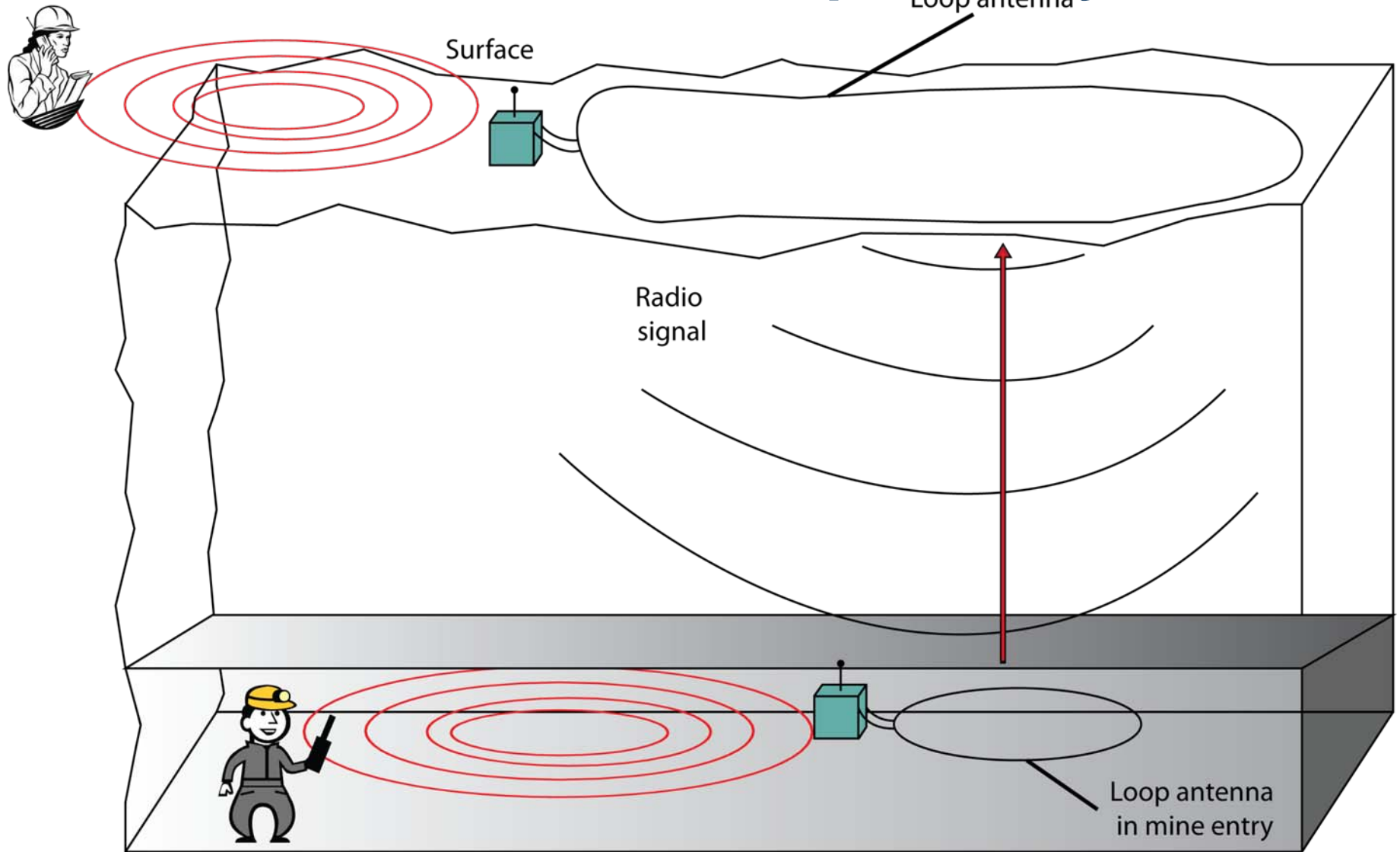
Hybrid Systems will need to be developed to address the “bandwidth mediation” challenge.



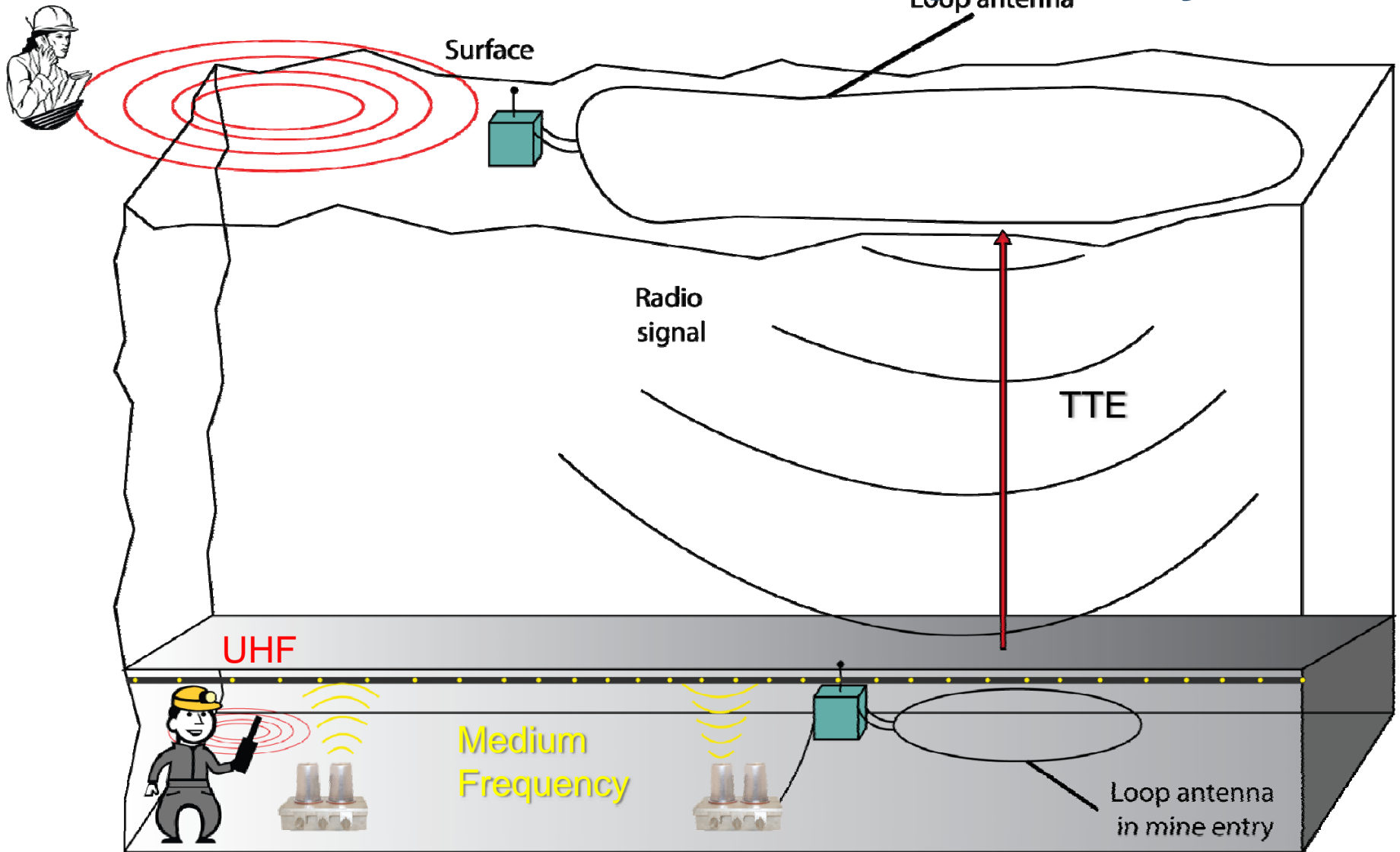
UHF to MF Interoperability



UHF to TTE Interoperability



UHF to MF to TTE Interoperability

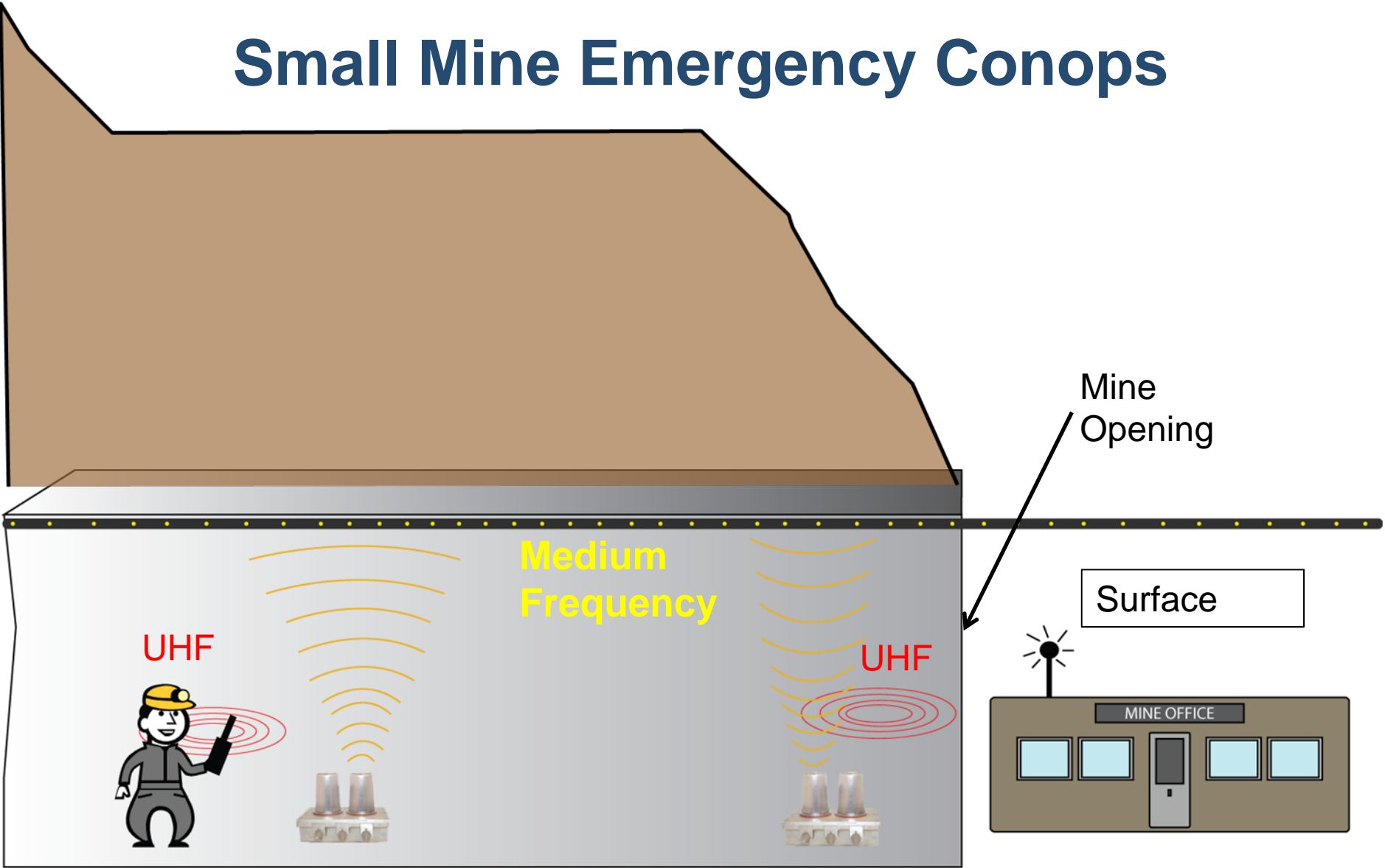


Implementation Conops

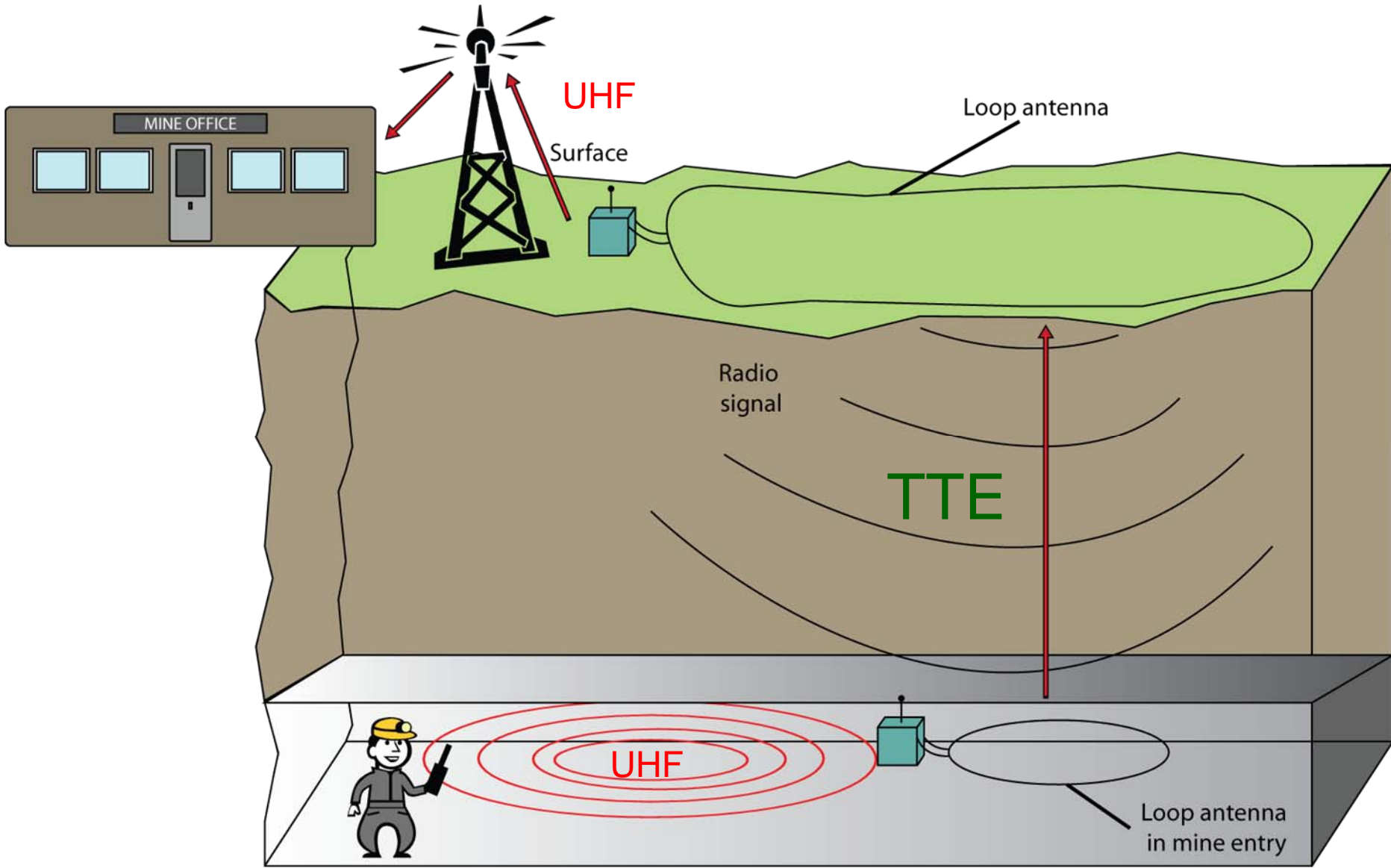
- The ability to define an appropriate systems solution is highly dependent on an understanding of how these systems are likely to be used.
 - We call the scenarios describing the use of the system as the Concept of operations or Conops



Small Mine Emergency Conops



Small Mine Emergency Conops



Small Mine Considerations



- The small mine scenario brings up several likely interoperability desired features and combinations
 - End to End Testing
 - From the client device to the Mine Operations Center (MOC)
 - Fail Safe mechanism so secondary system can be used directly
 - MF to UHF and TTE to UHF
 - UHF to IP or Multichannel Voice on the surface



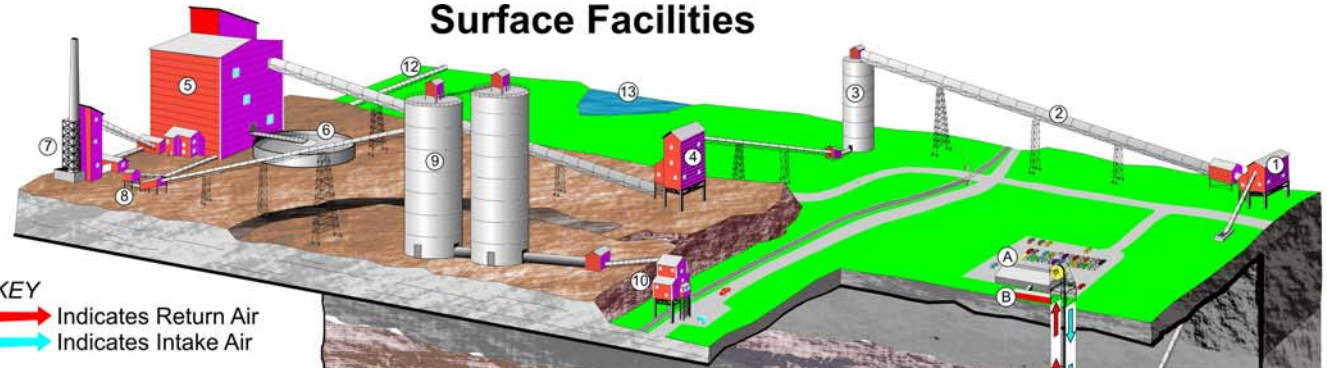
This illustration is a conceptual representation of a mine. It is not complete in every detail. It is intended to illustrate the general layout of a modern mine, the methods of mining used and the technology employed.

- UNDERGROUND MINE:**
 A. PORTAL FACILITIES
 B. EXHAUST FAN
 C. VENTILATION SHAFT
 D. LONGWALL MINING SECTION
 E. GOB
 F. SHEARER
 G. SHIELD
 H. CONVEYOR
 I. CONTINUOUS MINING SECTION
 J. CONTINUOUS MINER
 K. INTEGRATED ROOF BOLTERS
 L. LOADING MACHINE
 M. SHUTTLE CAR
 N. SECTION FAN
 O. SECTION CONVEYOR BELT
 P. TRACK
 Q. SLOPE BELT
 R. STOPPING
 S. OVERCAST

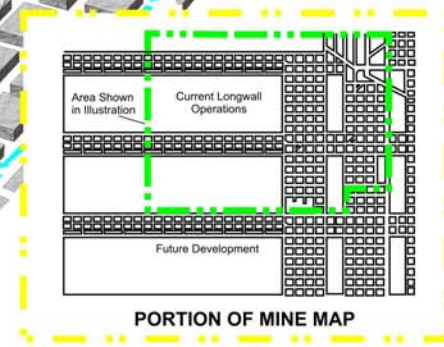
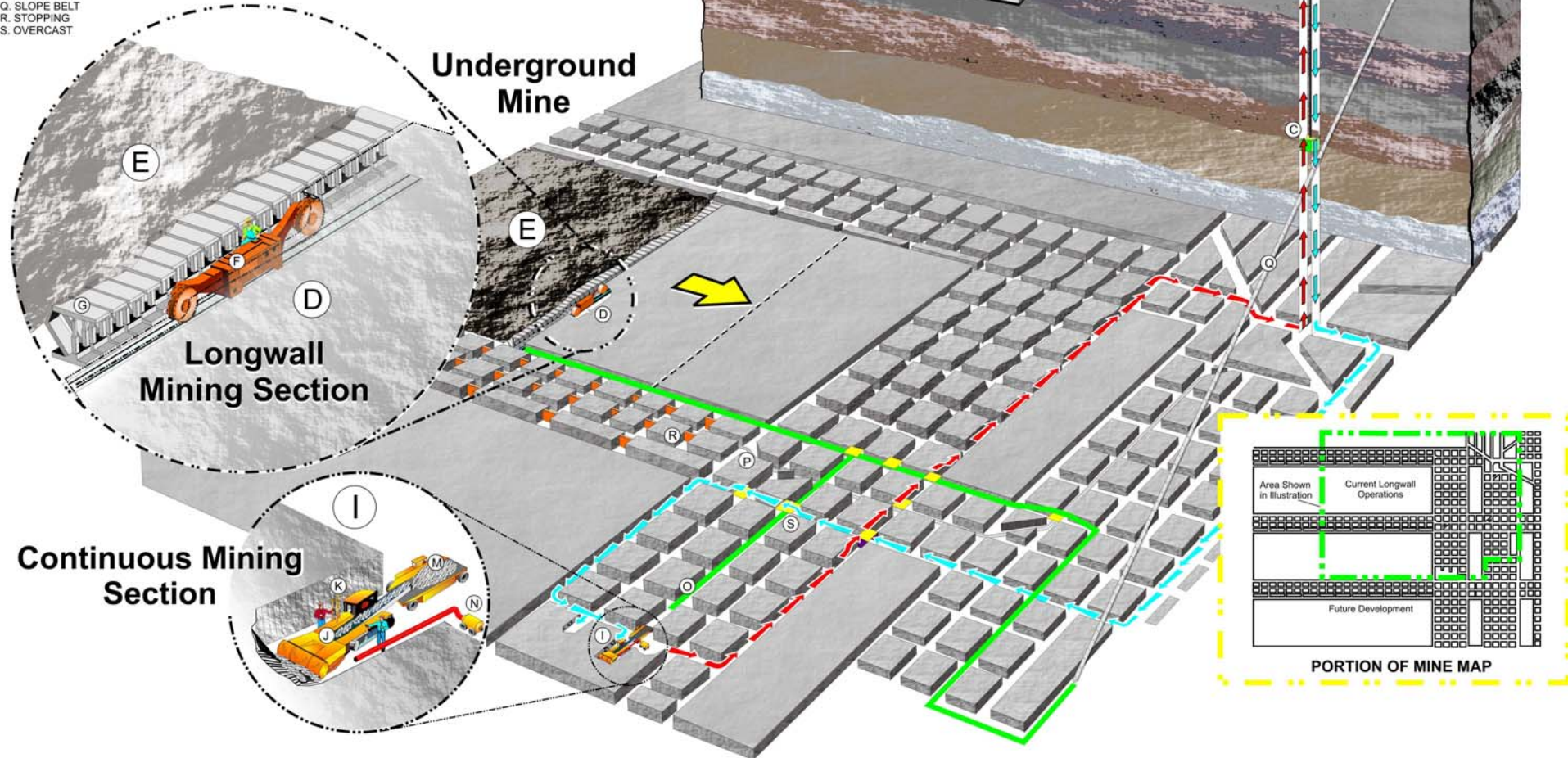
- SURFACE FACILITIES:**
 1. TRANSFER BUILDING
 2. RAW COAL CONVEYOR
 3. RAW COAL SILO
 4. BREAKER BUILDING
 5. PREPARATION PLANT
 6. THICKENER
 7. THERMAL DRYER
 8. PLANT SAMPLE BUILDING
 9. CLEAN COAL SILO
 10. RAILROAD LOADOUT
 11. RAILROAD
 12. REFUSE CONVEYOR
 13. FRESH WATER IMPOUNDMENT

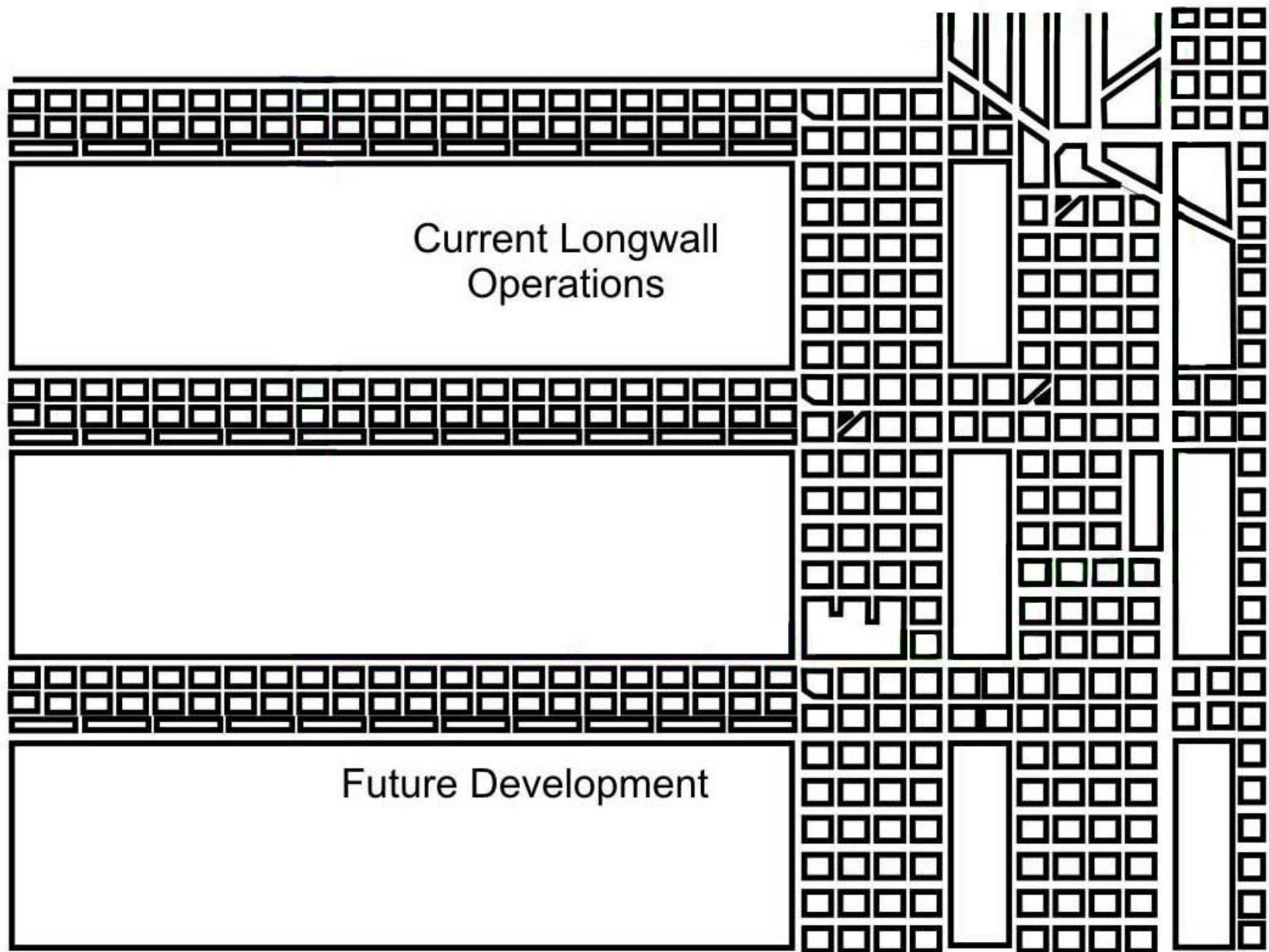
KEY
 Indicates Return Air
 Indicates Intake Air

Surface Facilities



Underground Mine





Current Longwall
Operations

Future Development

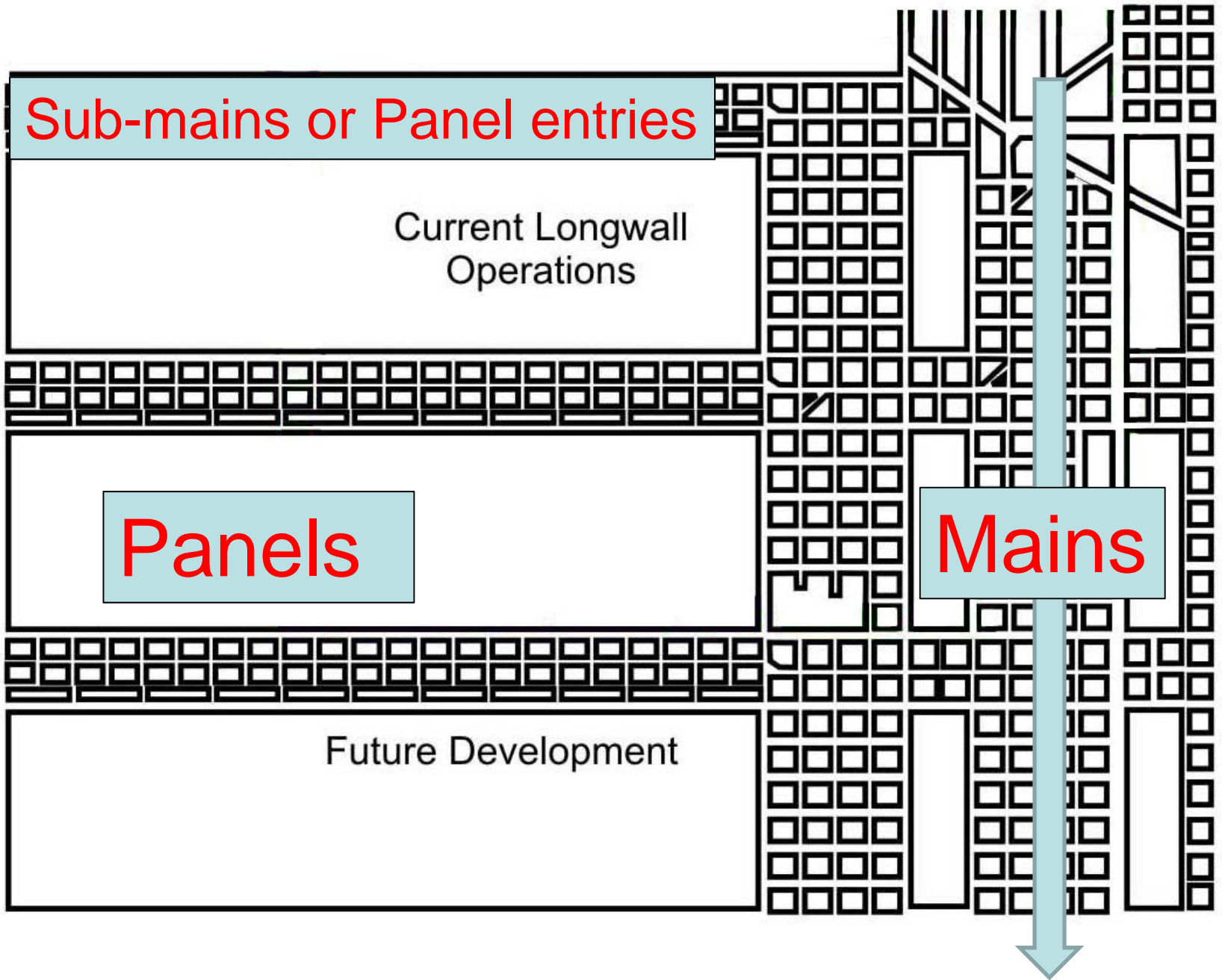
Sub-mains or Panel entries

Current Longwall
Operations

Panels

Future Development

Mains



Sub-mains or Panel entries

Current Longwall

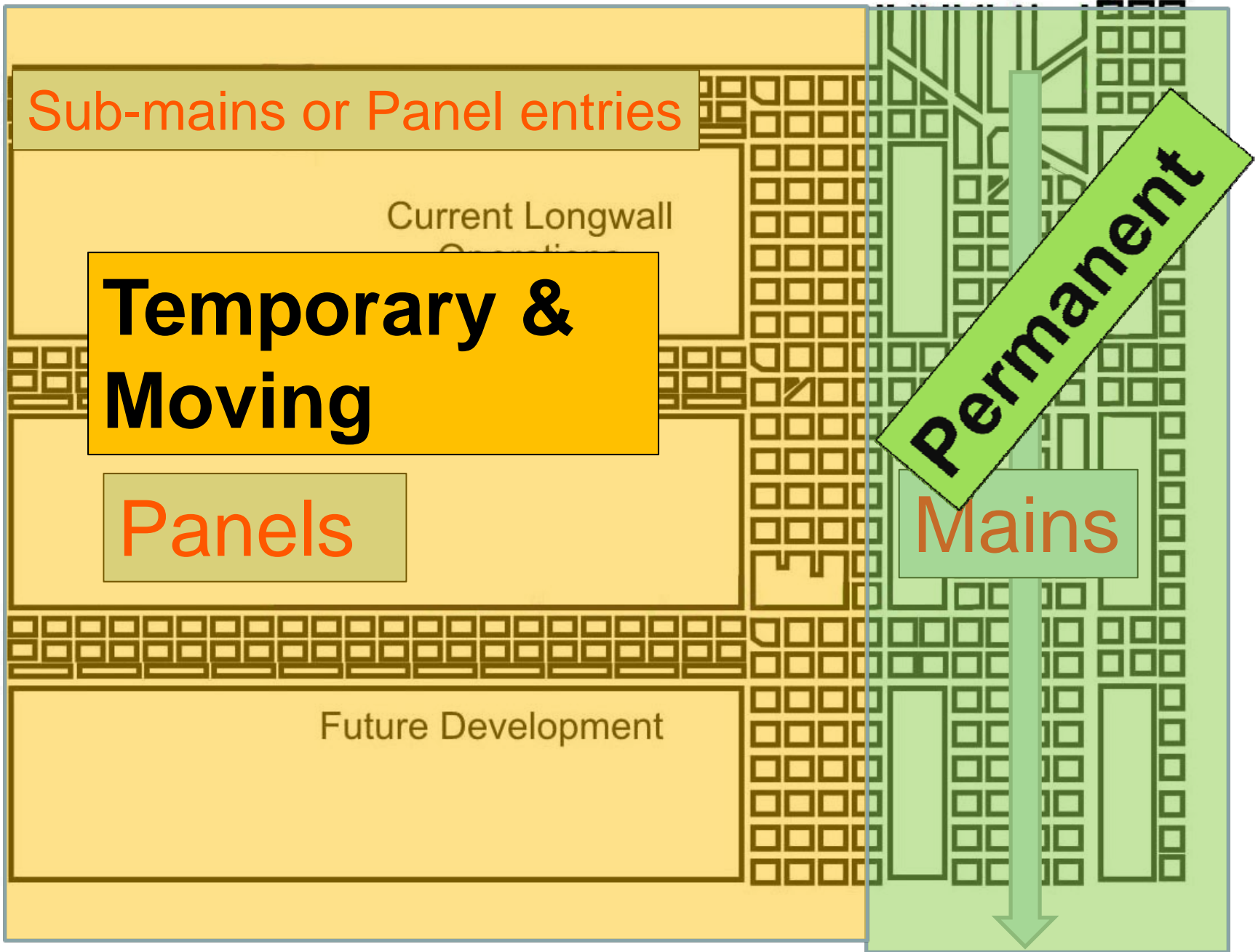
Temporary & Moving

Panels

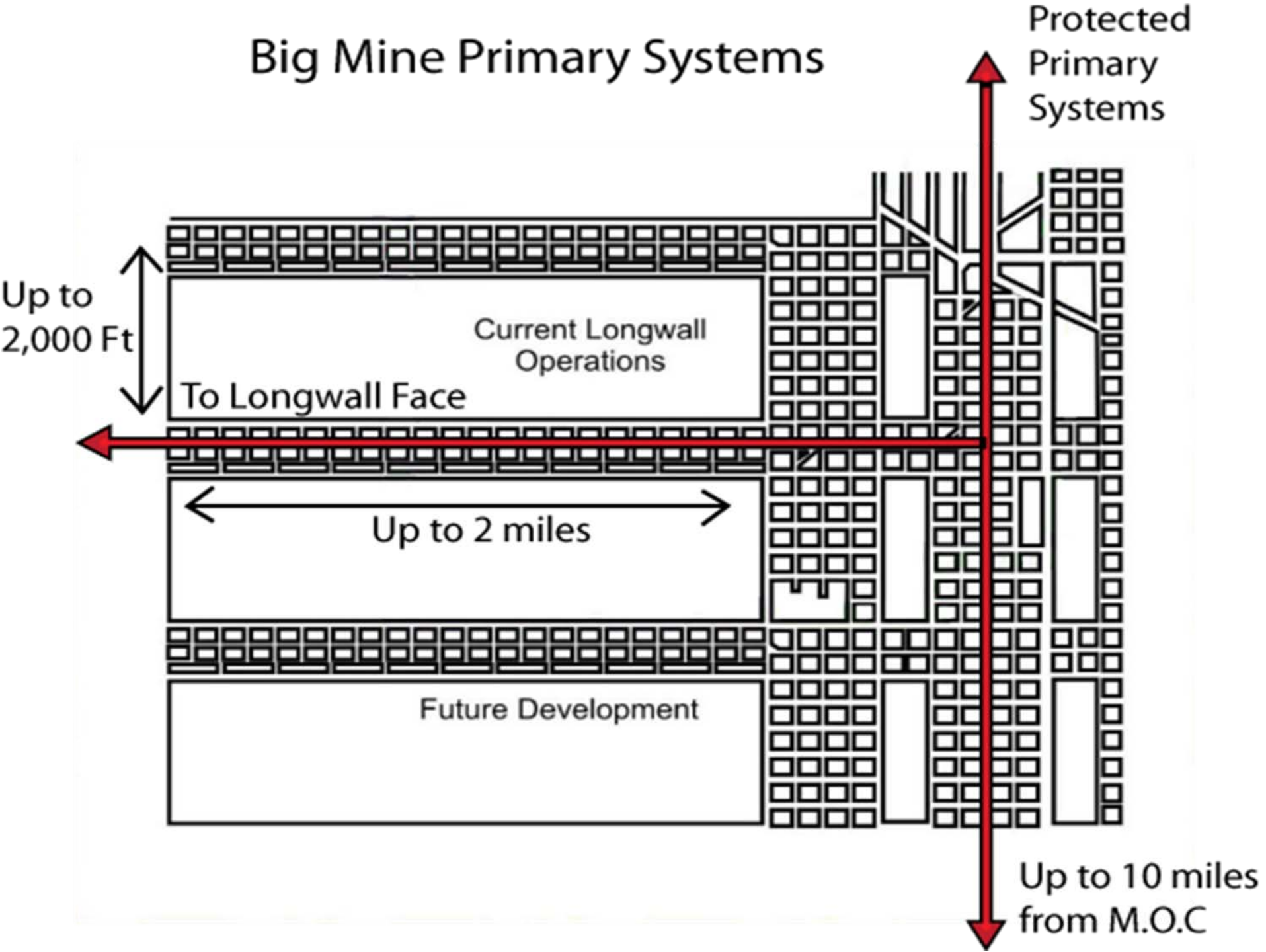
Future Development

Permanent

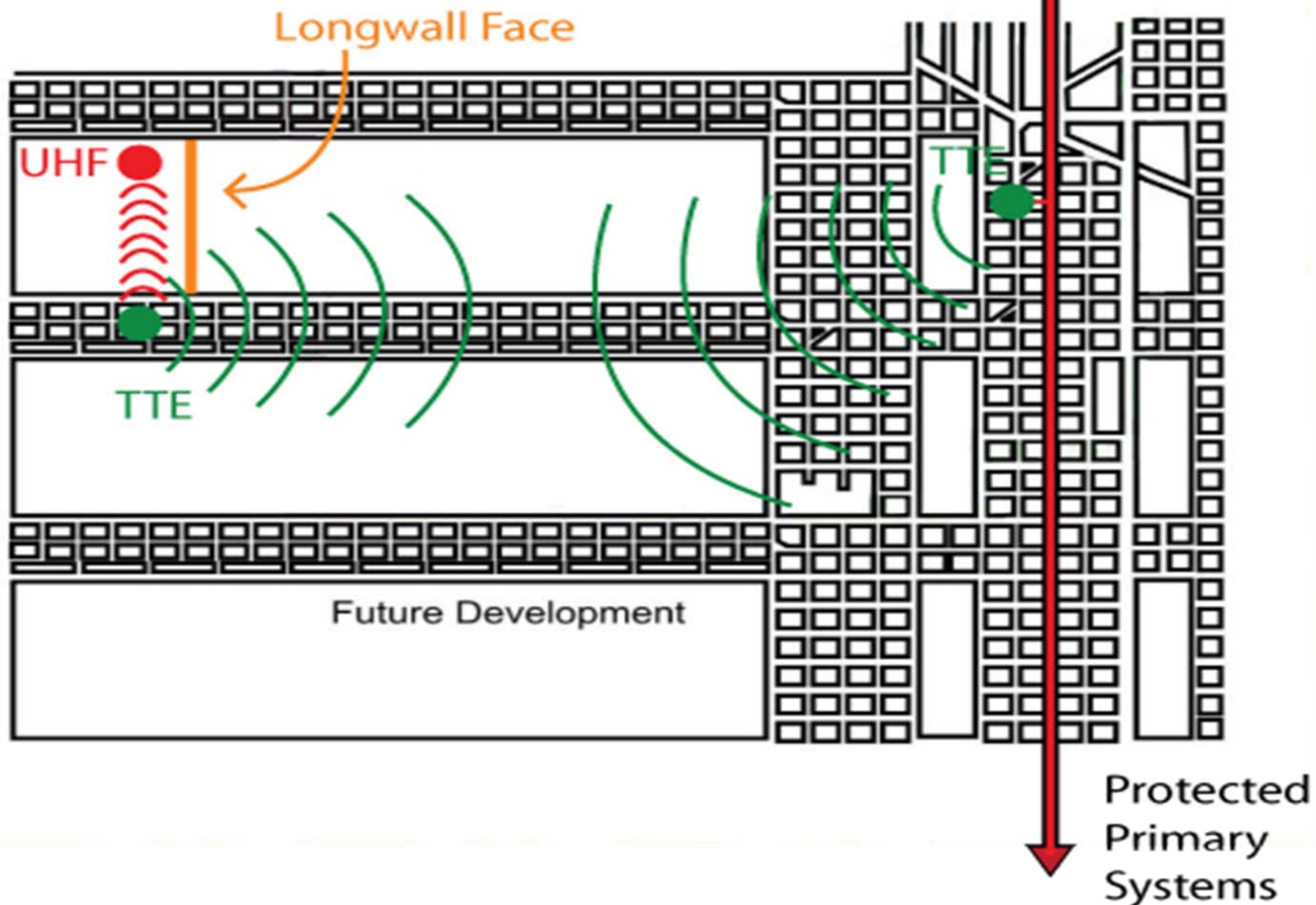
Mains



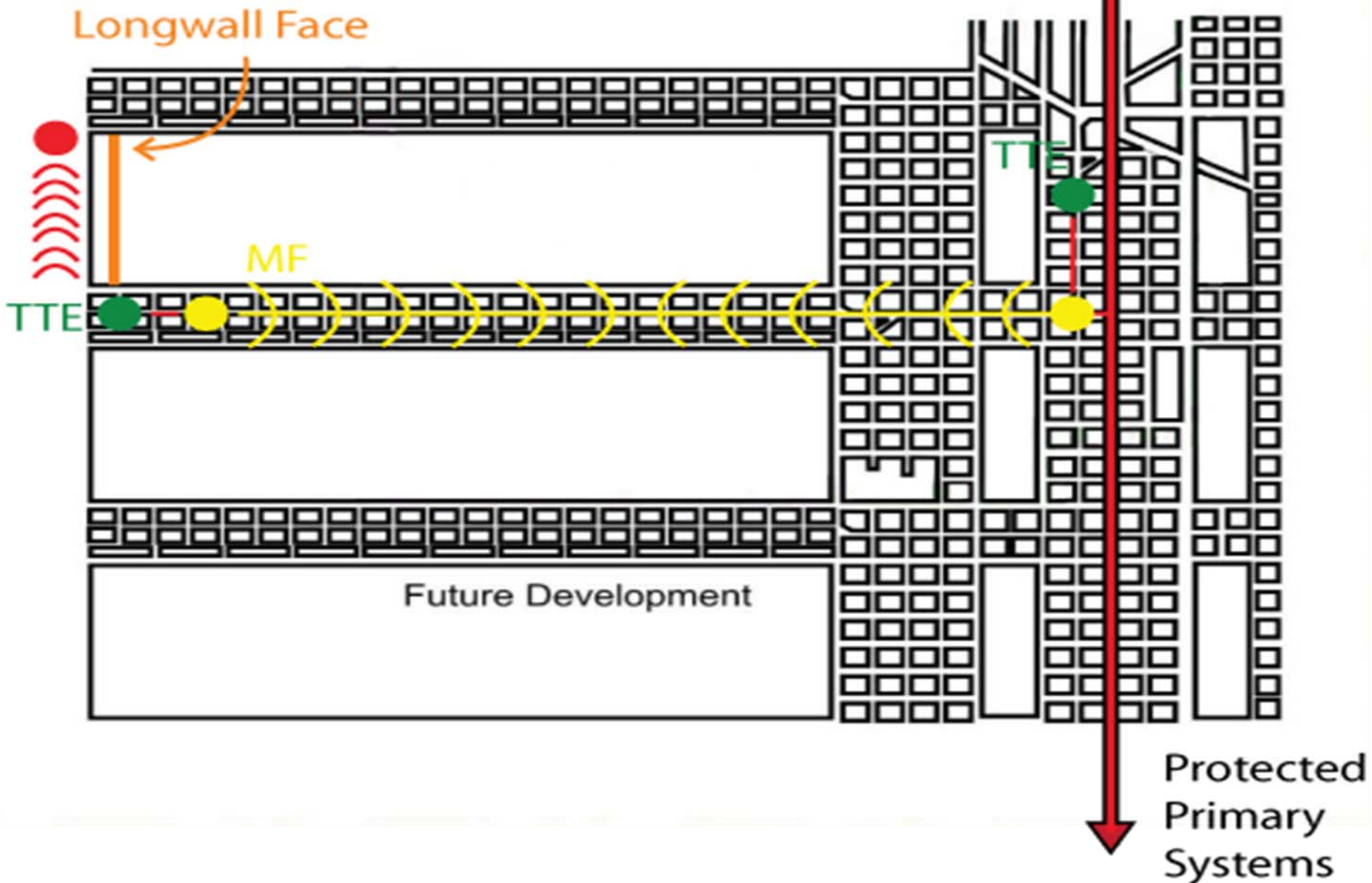
Big Mine Primary Systems



Big Mine Scenario 1



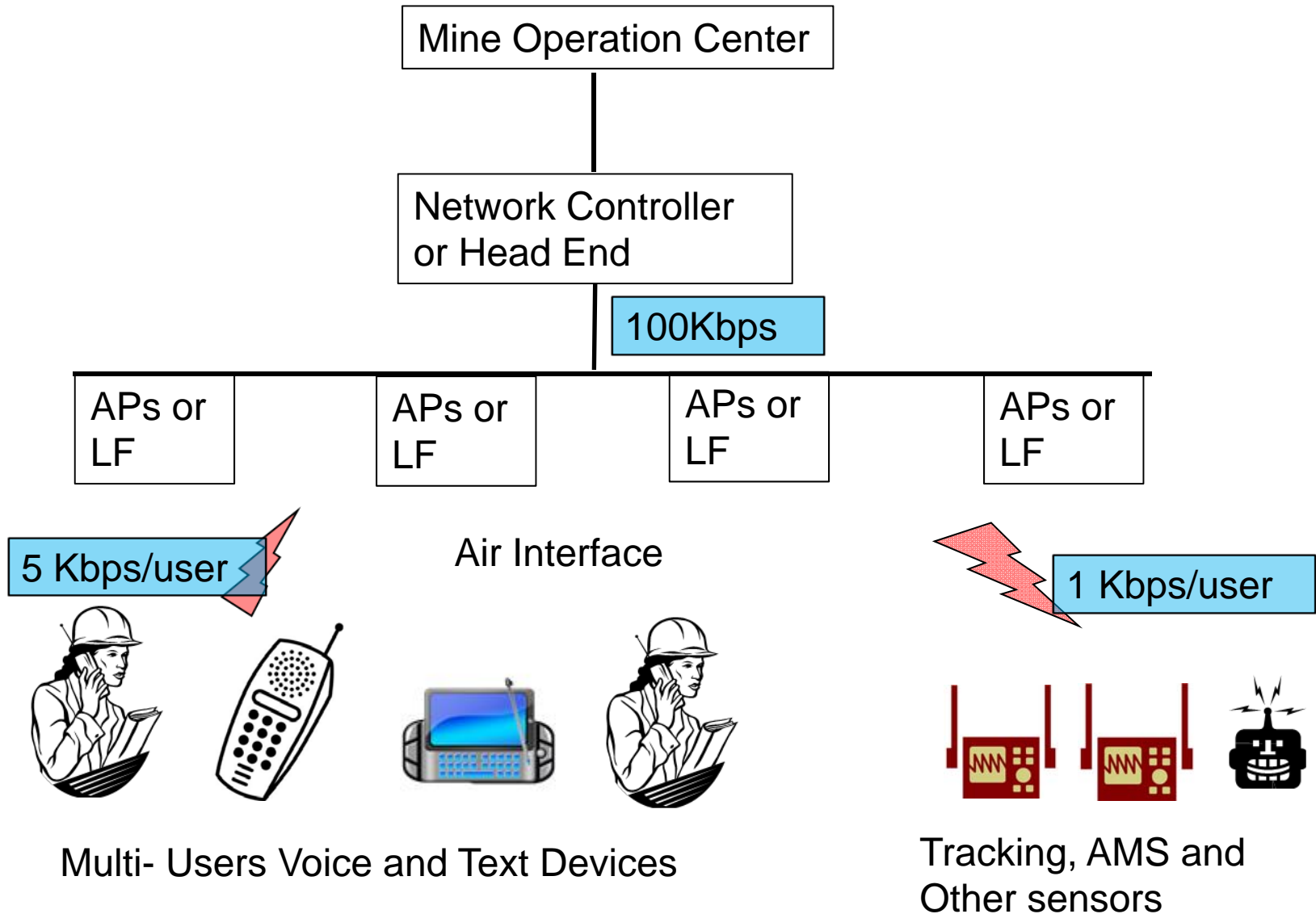
Big Mine Scenario 2



Big Mine Considerations

- Big Mine protected primary system differentiator = multichannel high bandwidth backbone
 - End to End test is more complex
- Big Mine Conops brings up additional interface considerations
 - UHF to TTE to TTE to High bandwidth survivable system
 - UHF to TTE to TTE to MF to High bandwidth
- Fail safe mechanism so that secondary system can be used directly

Primary System Normal Traffic Flow – Non-Blocking



Single Channel Client Interoperability Example

Mine Operation Center

Network Controller
or Head End

APs or
LF

APs or
LF

APs or
LF

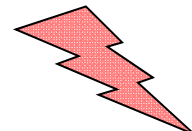
APs or
LF

Bandwidth
Restriction 5 Kbps

5 Kbps

Air Interface

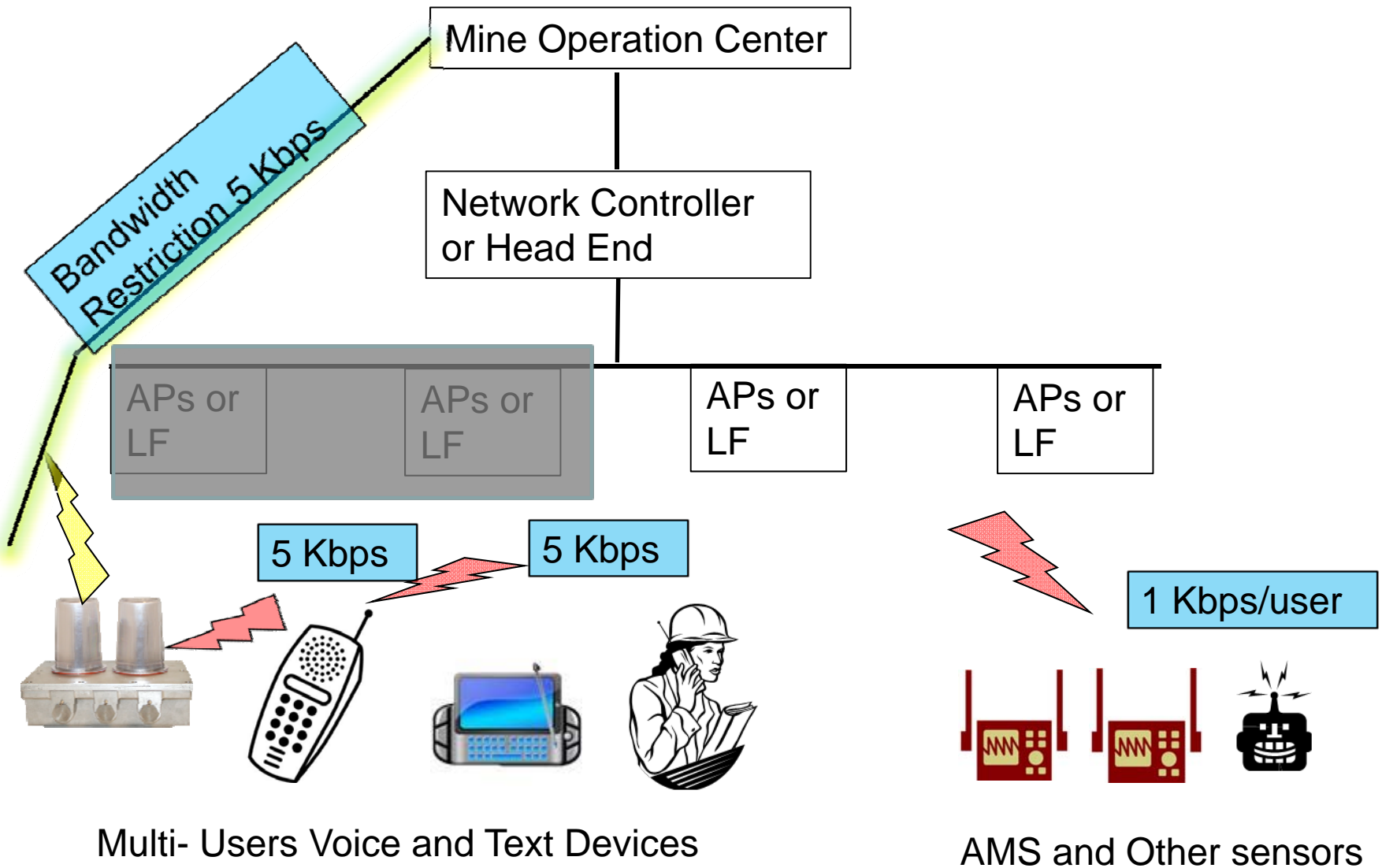
1 Kbps/user



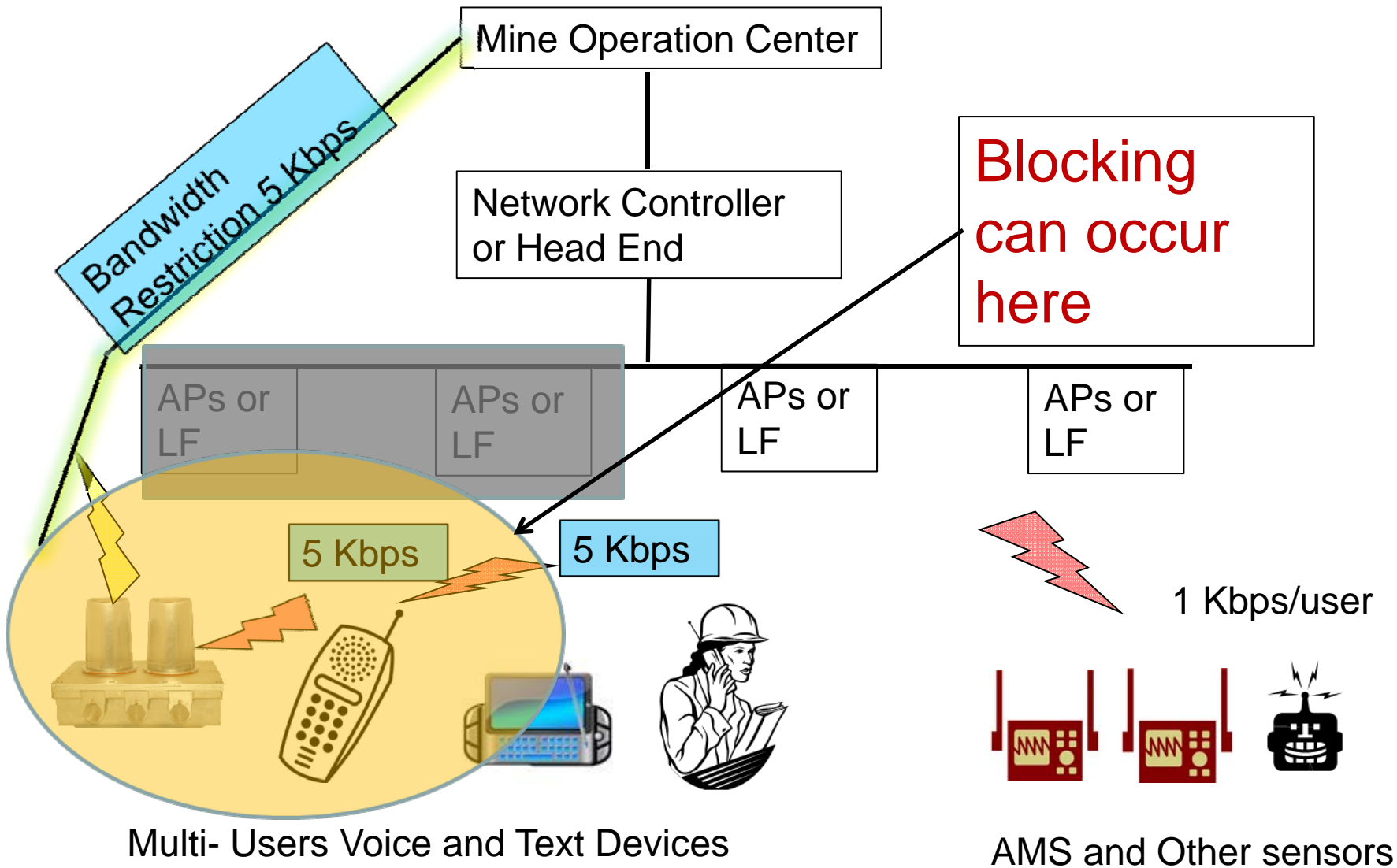
Multi- Users Voice and Text Devices

AMS and Other sensors

Single Channel Client Interoperability Example



Single Channel Client Device Interoperability Only

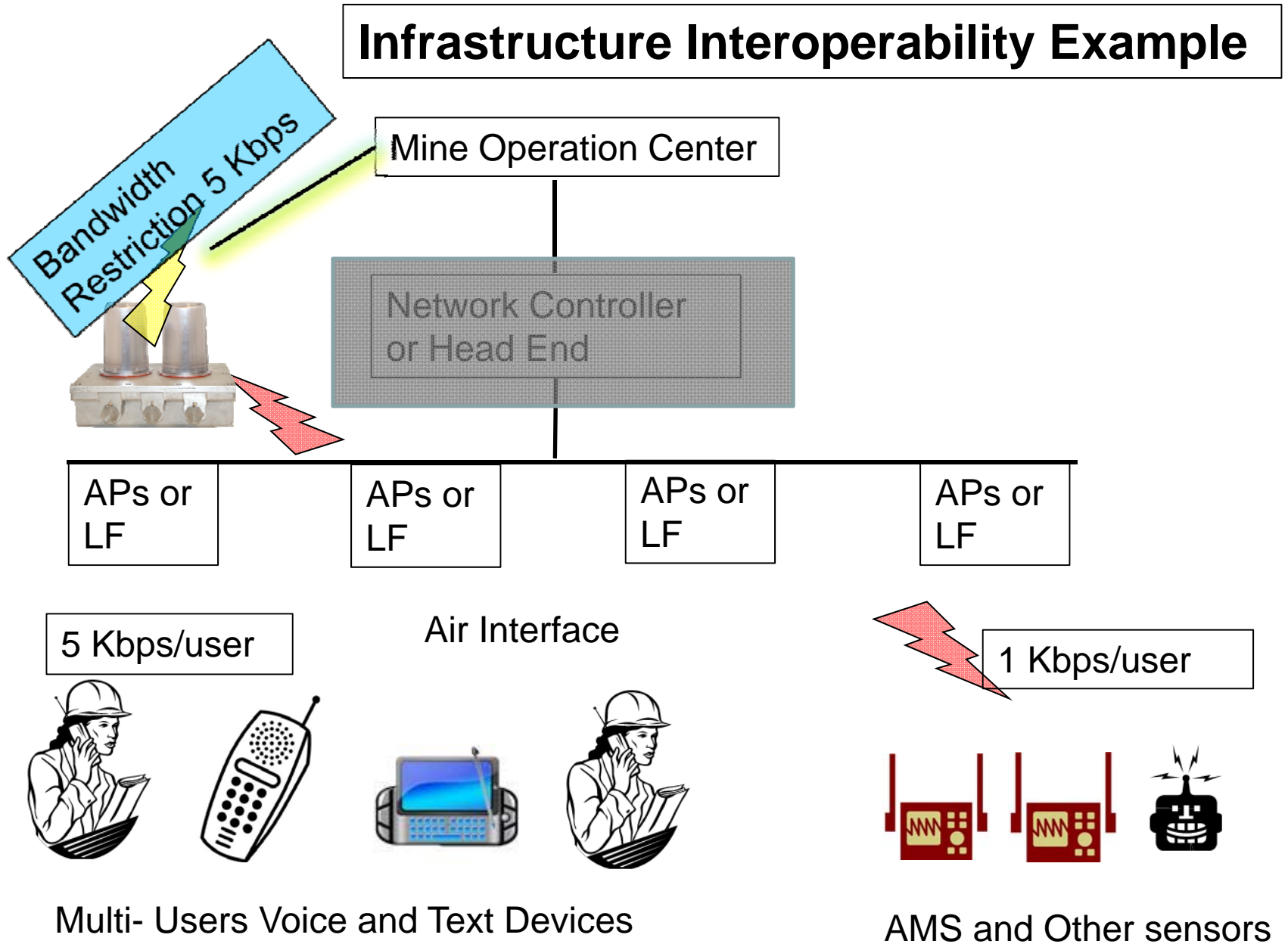


Single Channel Client Interoperability Issues

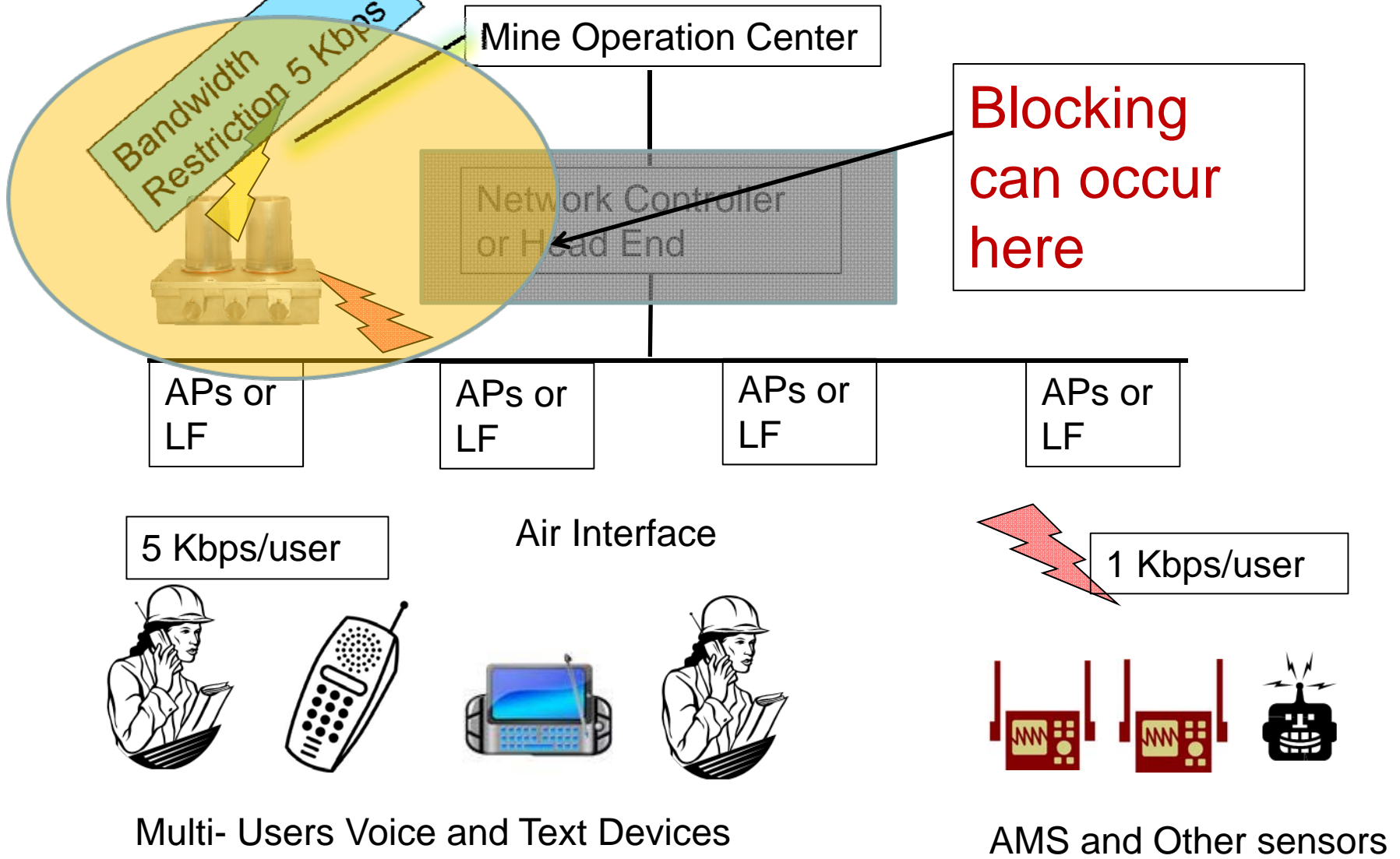
- Unless only one device is active, bandwidth limitations will result in unresolved blockage
- Connected device has to be within radio range of the secondary system
- Users on the Secondary System have no communications with people in the other part of the mine
- The advantage is that communications is not dependant on any aspect of the primary systems infrastructure



Infrastructure Interoperability Example



Infrastructure Interoperability Example



Infrastructure Interoperability

Example Issues / Advantages

- Potential for blocking is considerably greater than with the client only example
 - Emergency channel is available to a larger group of users
- Users within the mine could potentially still be able to communicate with surface (**Assuming no blocking**) and with each other if primary communications to the surface are lost
- By implementing the interoperability between the secondary system and the infrastructure, the user no longer needs direct UHF communications to the radio relay.



Interoperability Observation

- Ideally, the secondary system should be able to communicate either directly with a client device or with the network infrastructure.
- In either case, bandwidth restrictions in the communications path to the MOC could lead to blocking which causes:
 - Lost Messages
 - Inability to communicate to the surface
 - Lost data from sensors
- Clearly, the blocking implications are not desirable, so we need to:
 - Mitigate the effect of blocking to the extent possible
 - Decide what to do with the traffic that can not make it to the surface due to blocking



Blocking Mitigation Techniques

- There are several techniques that could be potentially employed to mitigate the blocking challenge to maximize the utility of the secondary communications channel
 - Multiple Access Protocols
 - Queuing
 - Traffic Reduction & Traffic Concentration
 - Traffic Control
 - Message Prioritization
 - Message acknowledgement and control of re-sends
 - Recording of traffic for later transmission
- Practicality and optimal placement of these “Network Management” features are a function of the protocols and system topology



Network Management Gateway Concept

- Conceptually, a potential solution is to have a “Network Management Gateway” between the secondary system and the primary system that:
 - Has an interface to the primary infrastructure
 - An air interface for client devices
 - An interface to the secondary system
 - Contains all of the blocking mitigation techniques hardware, software, and intelligence



Network Management Gateway



Air Interface

Gateway

Queuing
Prioritization
Compression
Ack/Nack
Recording
Etc.

Secondary System

To MOC

Direct Connection



Secondary Comms. Interface

Prim. Interface

APs or LF

APs or LF

APs or LF



Network Management Gateway

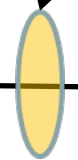
Standard
Physical
Interface???



Air
Interface

Gateway

Queuing
Prioritization
Compression
Ack/Nack
Recording
Etc.



Secondary
System

To
MOC

Direct
Connection

Prim. Inf.
Interface

APs or
LF

Secondary
Comms. Interface



Design Consideration

- The design of an effective interoperable system for maximum survivability in a real mine is a function of many things.
 - Location of secondary communications path in the network
 - Capabilities of the Network Elements and Client devices
 - Availability of AP or other traffic concentration points
 - Bandwidth of Primary and Secondary communications systems
 - Network topology as defined by the layout in the mine
 - Failure Scenarios as defined by the assumed mine emergency
- Fortunately, there are network models that can at least attempt to model the effectiveness of networks



Network Modeling

- NIOSH is very interested in network modeling to try to assess the effectiveness of systems before and after mine disasters
 - There are two types of modeling NIOSH is interested in
 - Propagation modeling (Physical channel)
 - Network simulation (OPNET/NIST)
- Propagation models can be developed somewhat generically (i.e. independent of any particular system)
- Network simulation is highly dependent of specific attributes of the system
 - Required information rests with the Equipment Manufacturers



NIOSH/NIST IAA

- NIOSH has entered into an Inter-Agency Agreement (IAA) with NIST to assist in the Network Modeling efforts
 - The first task was to model the performance of a Medium Frequency Network (OPNET)
- Future work will be shaped by your input!
 - Is there value to you as an electronic manufacturer in network modeling?
 - Is there a need to agree to a standard interface somewhere in the network?
 - Is this just a waste of time?



Things to think about today

- How would you, as an equipment manufacturer, envision an interoperable system working, given the challenges of making high-bandwidth systems interoperate with low bandwidth systems?
- What would be required or desirable in an interoperable system as described, and what are the technical hurdles?
- From an equipment manufacturer's perspective, what is the appropriate level of involvement of government agencies in realizing such a system, particularly R&D agencies (i.e., NIOSH) or in the area of standards development (i.e., NIST)?



Summary

- The NIOSH role with C/T to this point has been to fund enabling technologies and conduct research
- The challenges associated with interoperable primary and secondary systems are significant.
 - Many potential approaches exist
 - It is not clear that there is a “R&D Gap” in terms of enabling technologies
 - There does appear to be a gap in the ability to model system performance (blocking, survivability, etc.)
- We welcome your input as to where NIOSH should be spending our limited resources in this important area!



Disclaimer

The findings and conclusions in this presentation are those of the authors and do not necessarily represent the views of NIOSH. Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention



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NIOSH is a division of the Centers for Disease Control and Prevention within the Department of Health and Human Services www.hhs.gov

