



Office of
Mine Safety and
Health Research

Node-Based Communications Overview

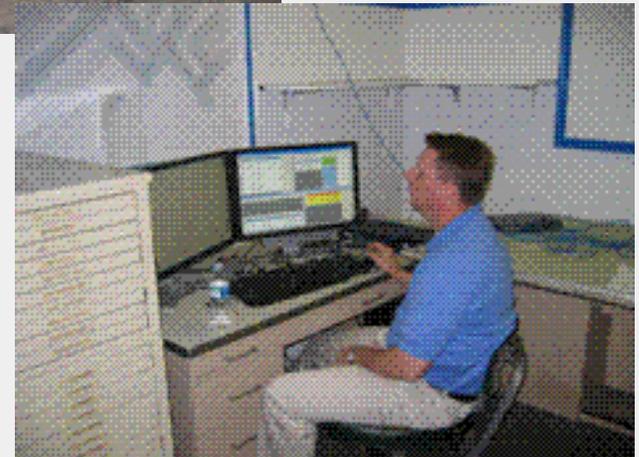
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Laboratory**

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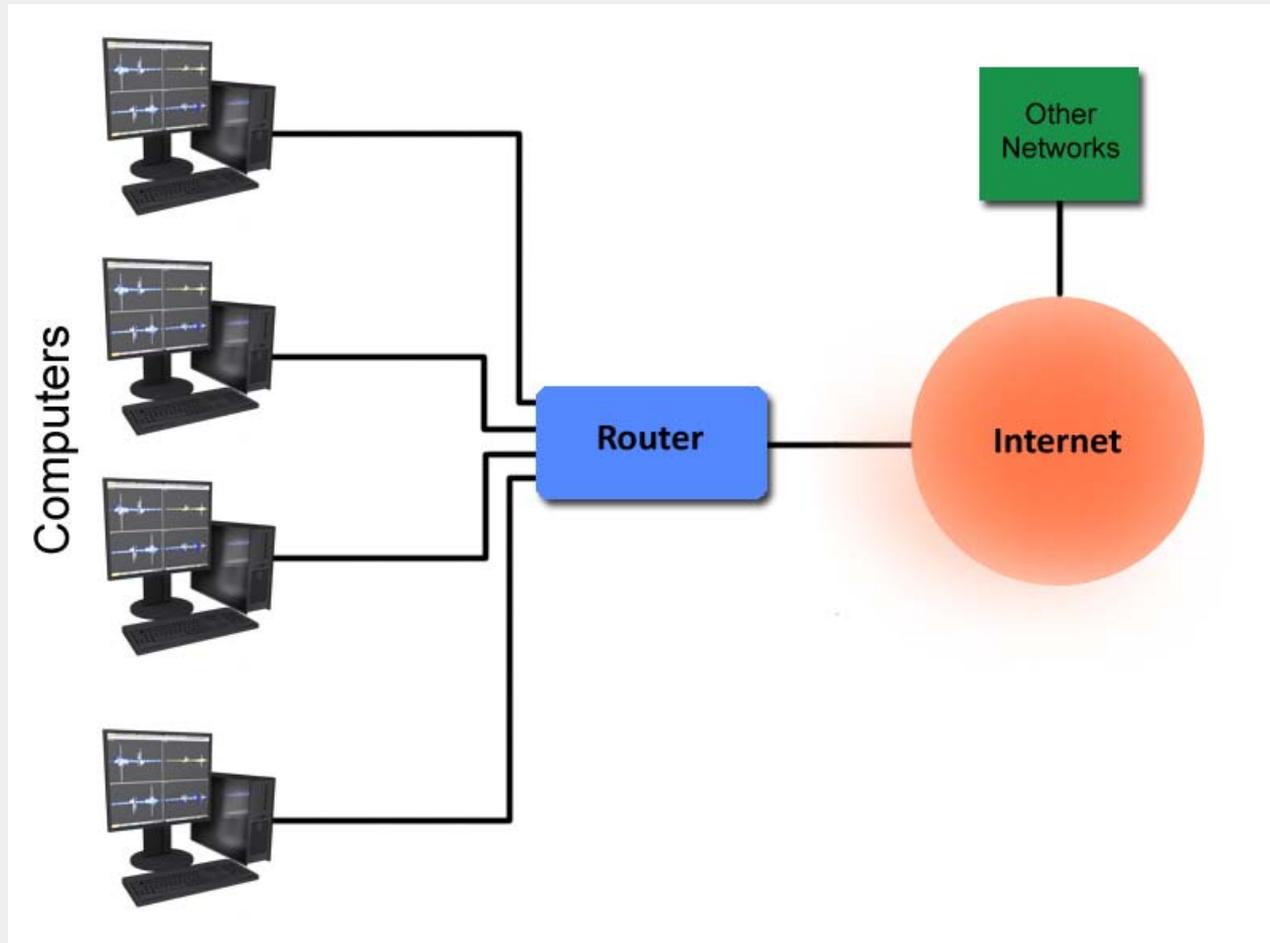


Overview

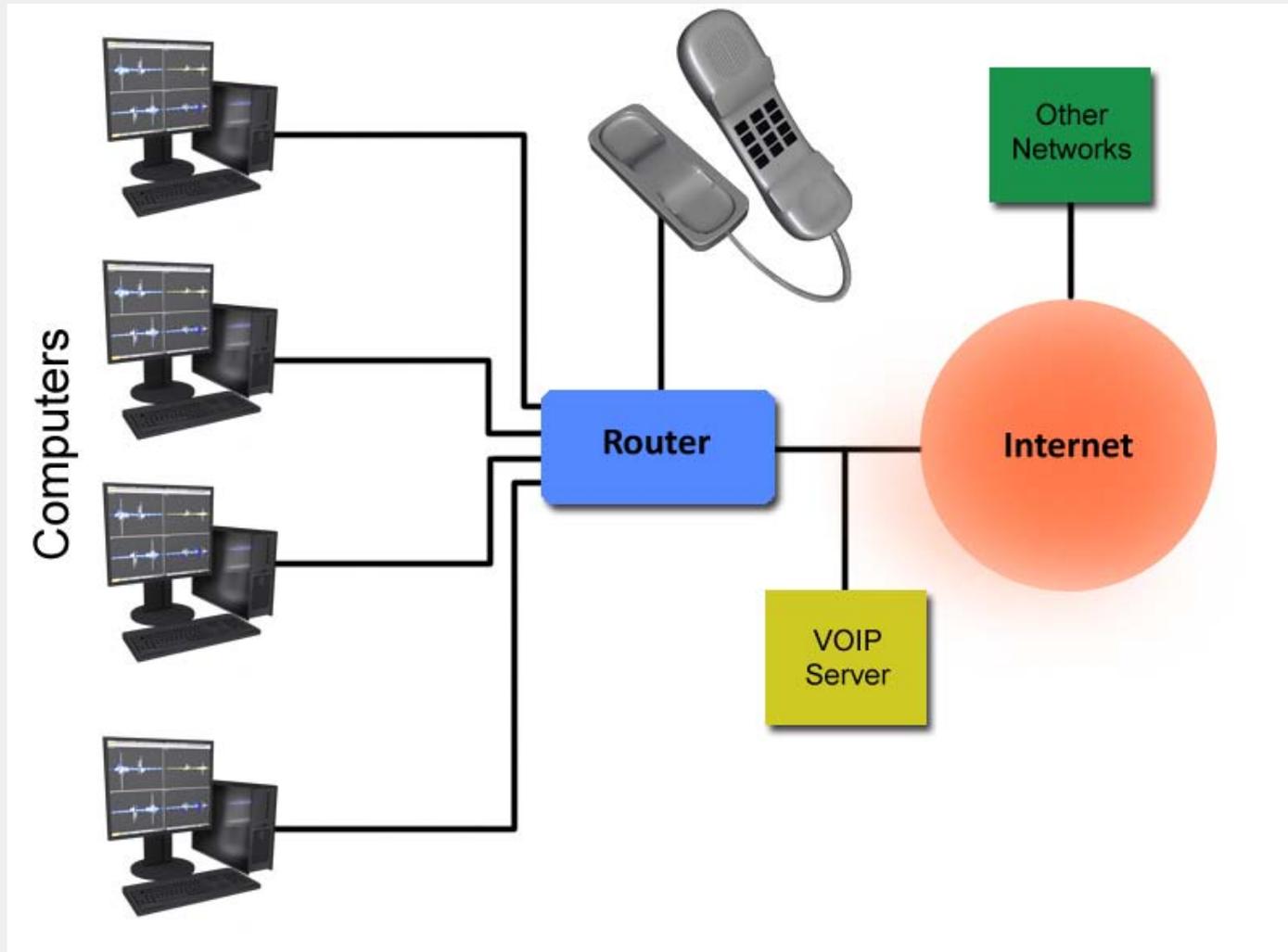
- **System architectures**
 - LAN/WLAN
 - WiFi/WiFi mesh
 - Ad Hoc mesh/Zigbee
- **UHF propagation in mine entries**
- **Redundant network topologies**
- **NIOSH wireless mesh contract**



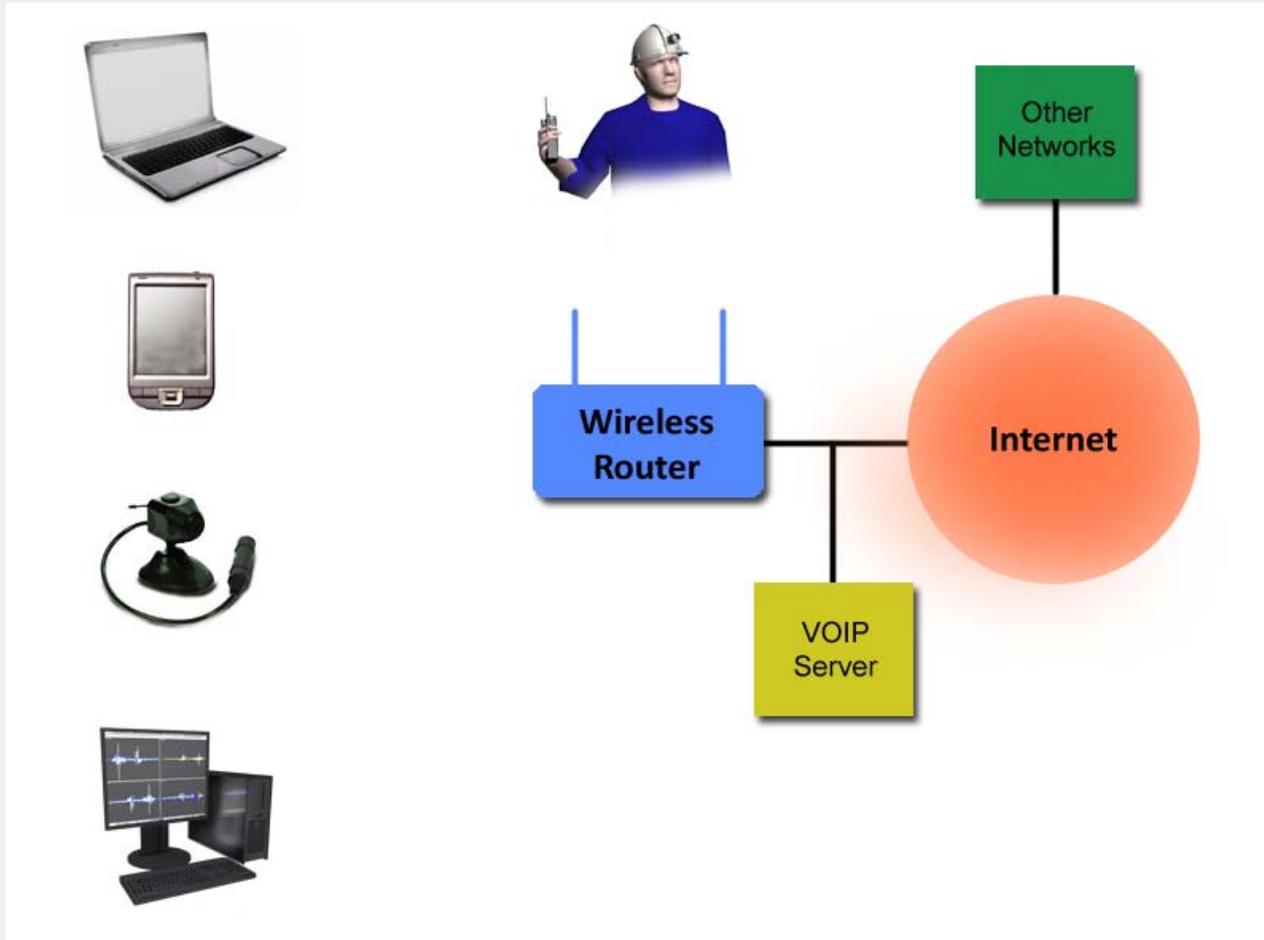
Local Area Network (LAN) Example



LAN with Voice-Over-Internet Protocol (VoIP) Phone



Wireless LAN



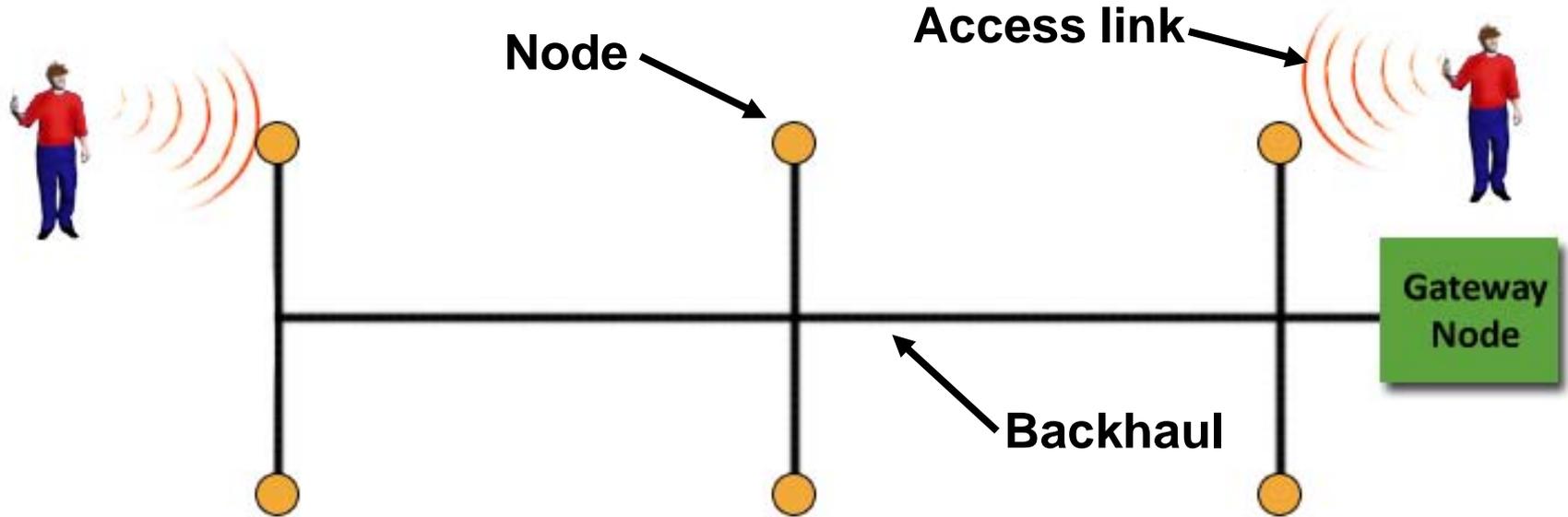
Wireless user devices and routers are now very common

Nodes

- **We refer to these wireless routers as “nodes”**
 - Radio transceivers
 - Router (small computer)
 - Antennas
 - Battery backup
 - For in-mine use
- **Coverage range is limited for a single node**

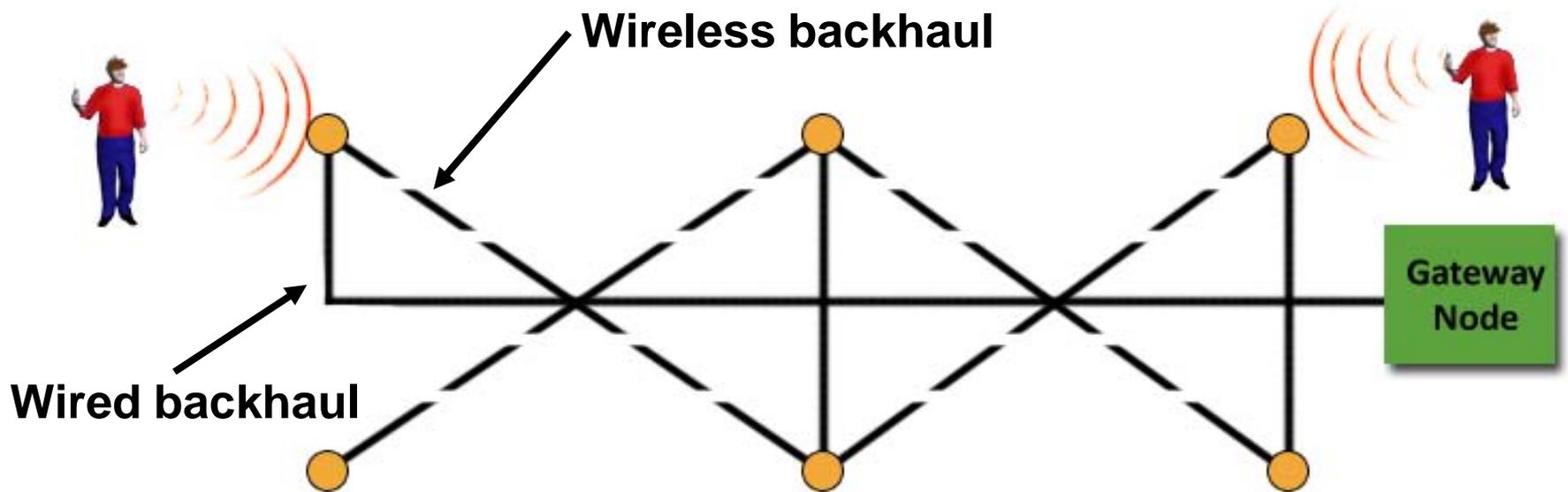


To cover a wide area you need to have multiple nodes



Nodes relay messages over backhaul links

Backhaul Links can be Wired or Wireless



Backhaul links can be laid out in many different ways, or *topologies*

WiFi is a type of Wireless LAN

- **WiFi refers to wireless LAN products certified to IEEE 802.11 standards by the WiFi Alliance**
- **Wide variety of WiFi devices available (e.g. WVoIP phones)**
 - Original WiFi standards IEEE 802.11 a/b/g
- **Original standards have drawbacks relative to some wide area applications**
 - High speed mobility
 - Wiring to connect nodes over long distances
 - Communications support in isolated segments
- **WiFi radio range limited (2.4 or 5.8 GHz)**
- **Variety of proprietary modifications have been created to overcome some of the drawbacks**

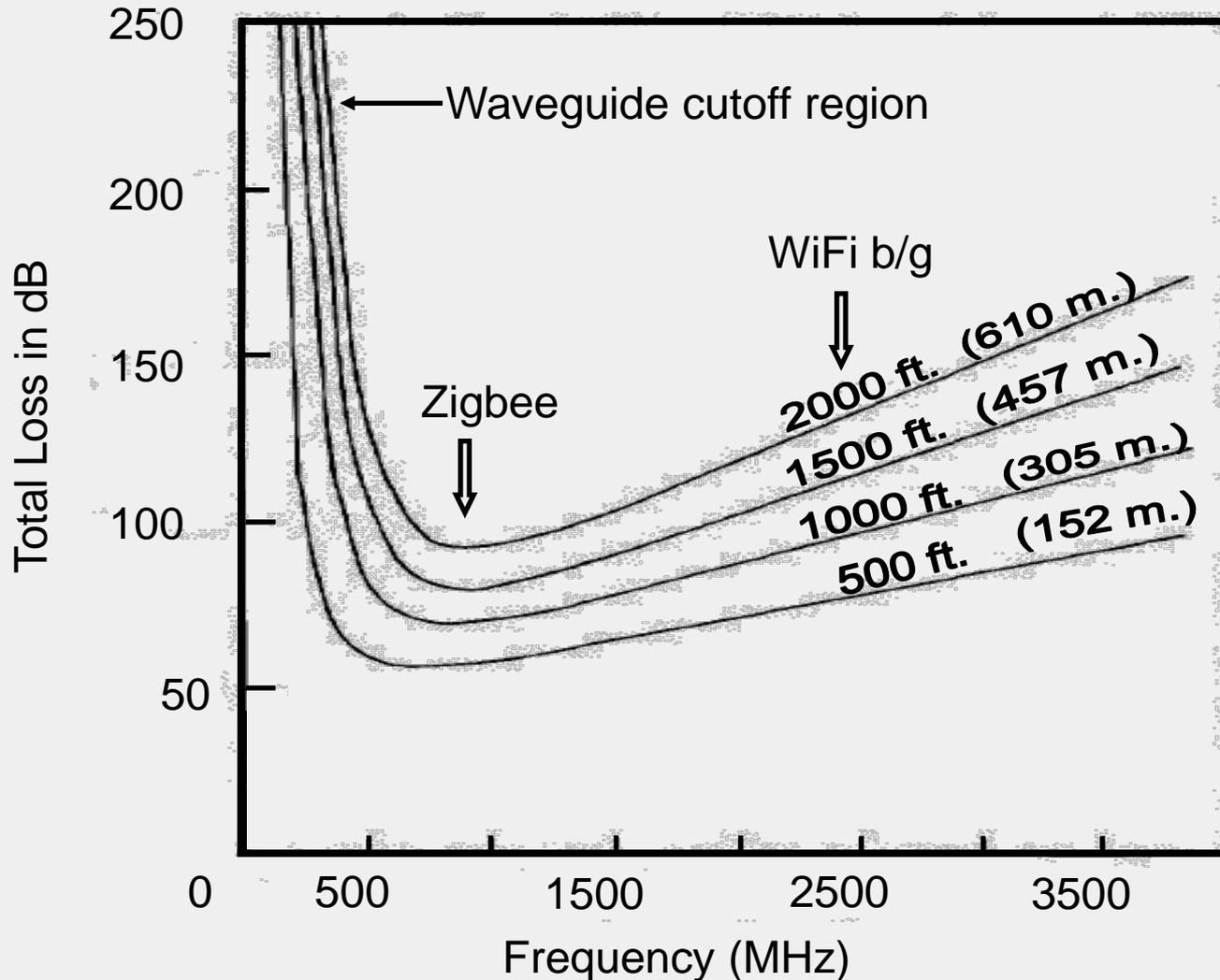
WiFi Mesh Networks

- **Refers to proprietary variants that allow direct node-to-node communications as an option to wired connections**
 - Still allows use of WiFi a/b/g devices
 - Proprietary protocols used for networking between nodes
- **Operates at 2.4 or 5.8 GHz**
- **Mesh standard in development (802.11 s)**

Ad Hoc Mesh Network

- **Node can autonomously communicate with any other node in radio range**
- **User devices may act as nodes or relays**
- **Isolated node clusters can reform a network**
- **Zigbee (IEEE 802.15.4-2003) is a true ad hoc mesh standard**
 - 900 MHz band option for good signal propagation in open entries
 - Originally designed for low bit rate and power personal area networks

Theoretical propagation loss vs. frequency for various distances down a mine entry 7 ft high by 14 ft wide



UHF Propagation Limited By

- **Entry**
 - Dimensions (waveguide effect)
 - Bends
 - Elevation changes
 - 900 MHz provides some non-LOS coverage around bends and elevation changes
- **Stoppings**
 - Concrete (moderate @ 900 MHz)
 - Metallic (severe)
- **Belt structure**
- **Vehicles (allow adequate backhaul fade margin)**

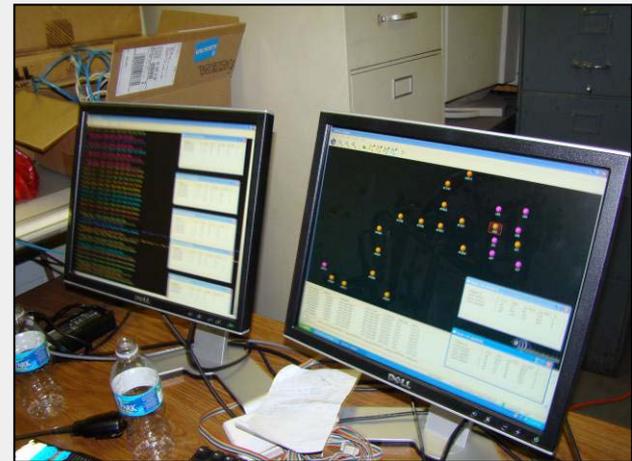


Network Management

- **Graphical user interface**
 - Mine maps need updated frequently
- **Monitoring and diagnostics**
 - Node, power, battery status
- **Disconnect node and node power to check**
 - Redundant communication paths
 - Battery switchover & capacity
- **Security**
 - Firewalls
 - Antivirus software
 - Encryption
- **Internet connectivity**



Dispatch Display

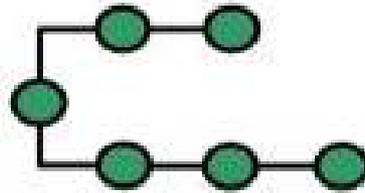


Network Display

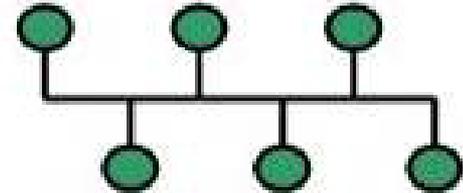
Network Topologies



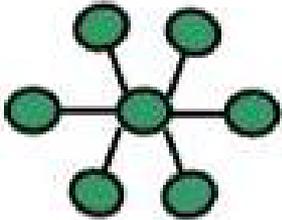
line



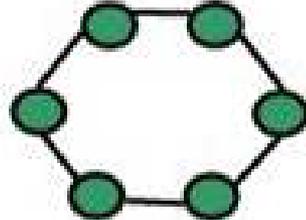
tree



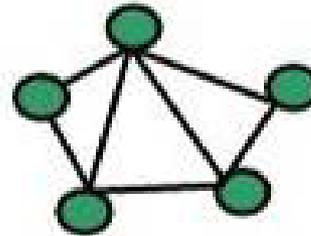
bus



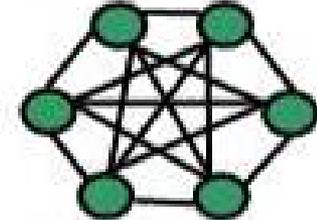
star



ring



partial
mesh

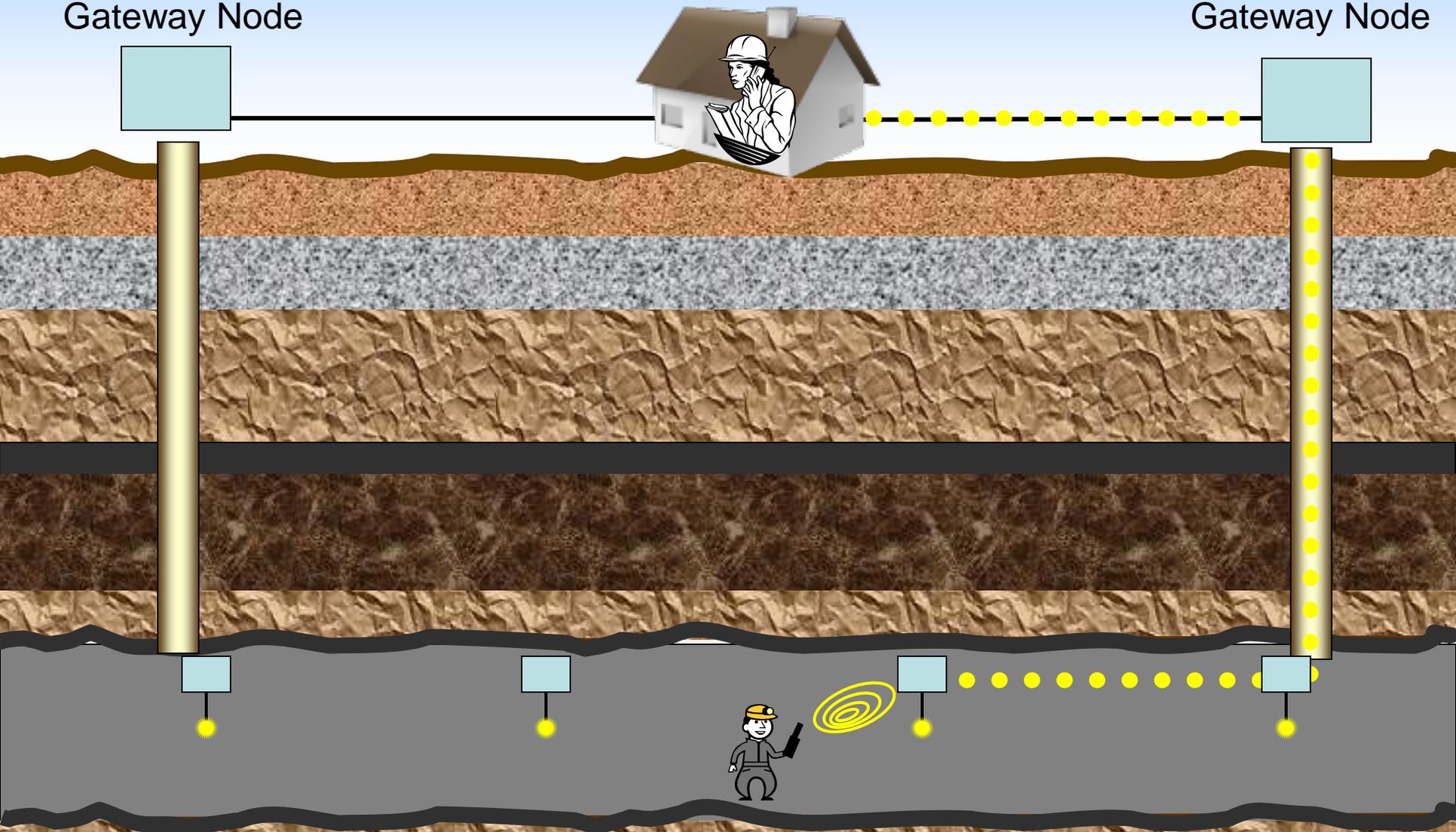


full
mesh

Linear Topology Between Two Portals To The Surface

Gateway Node

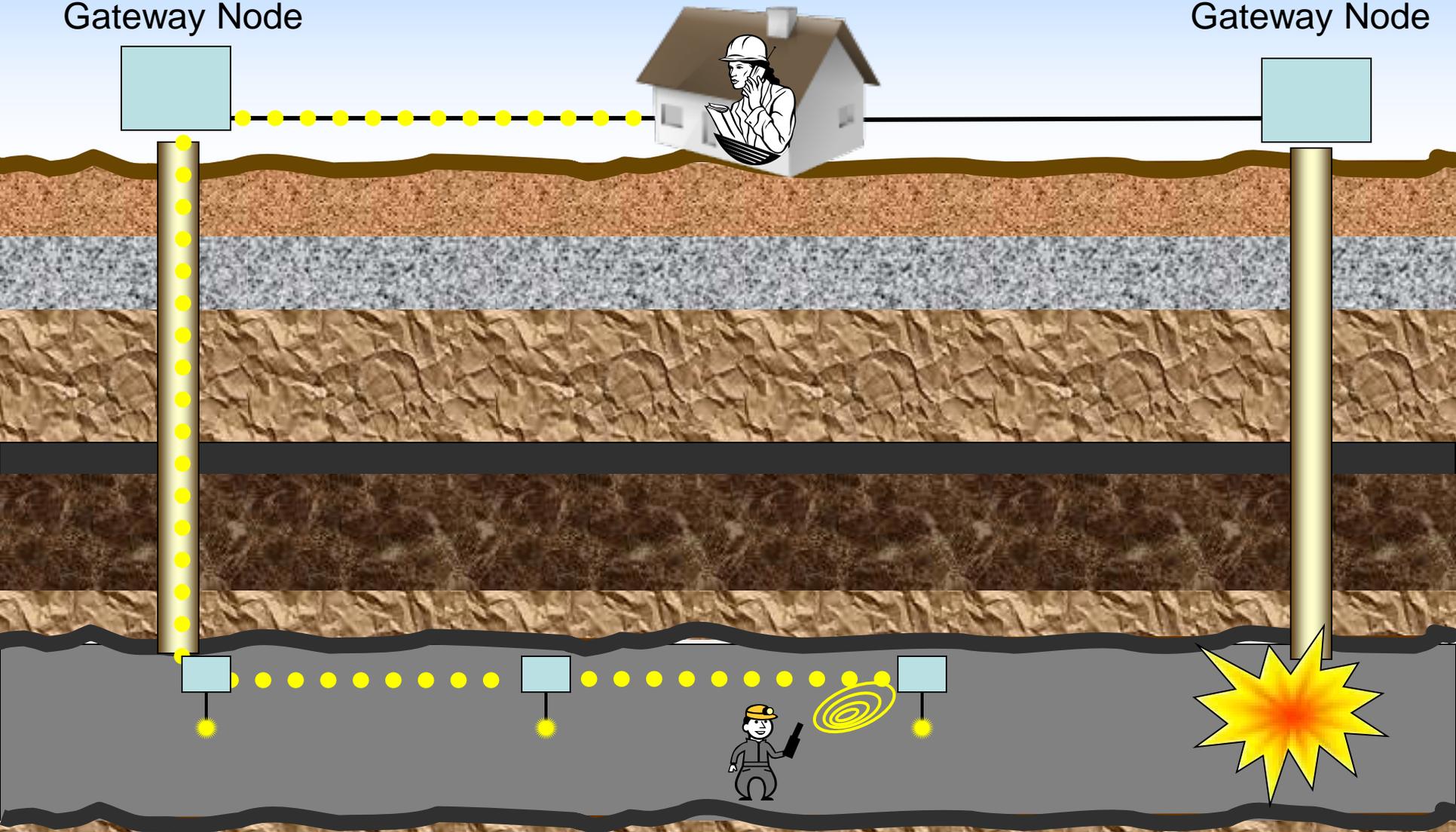
Gateway Node



Linear Topology Between Two Portals To The Surface

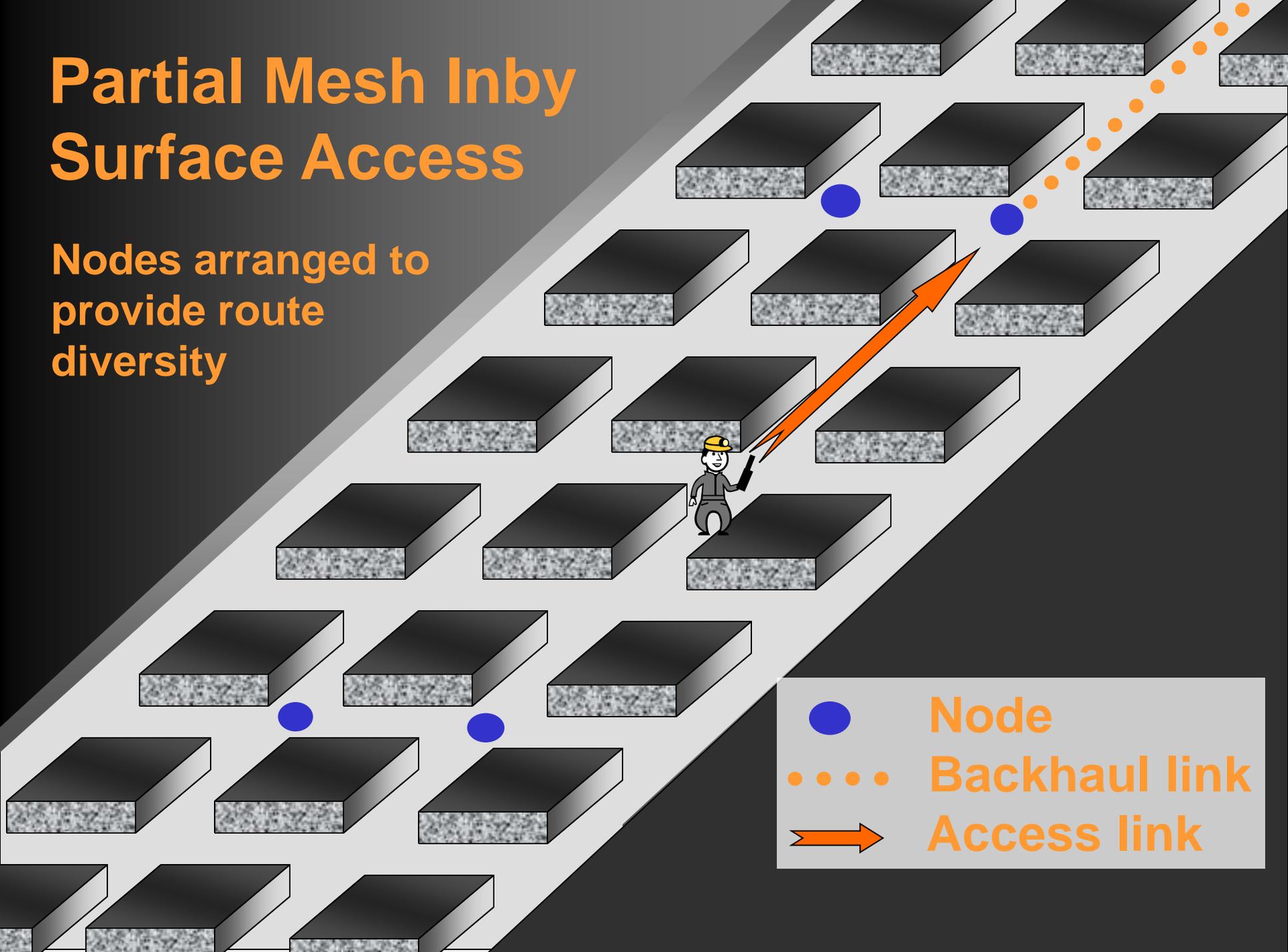
Gateway Node

Gateway Node



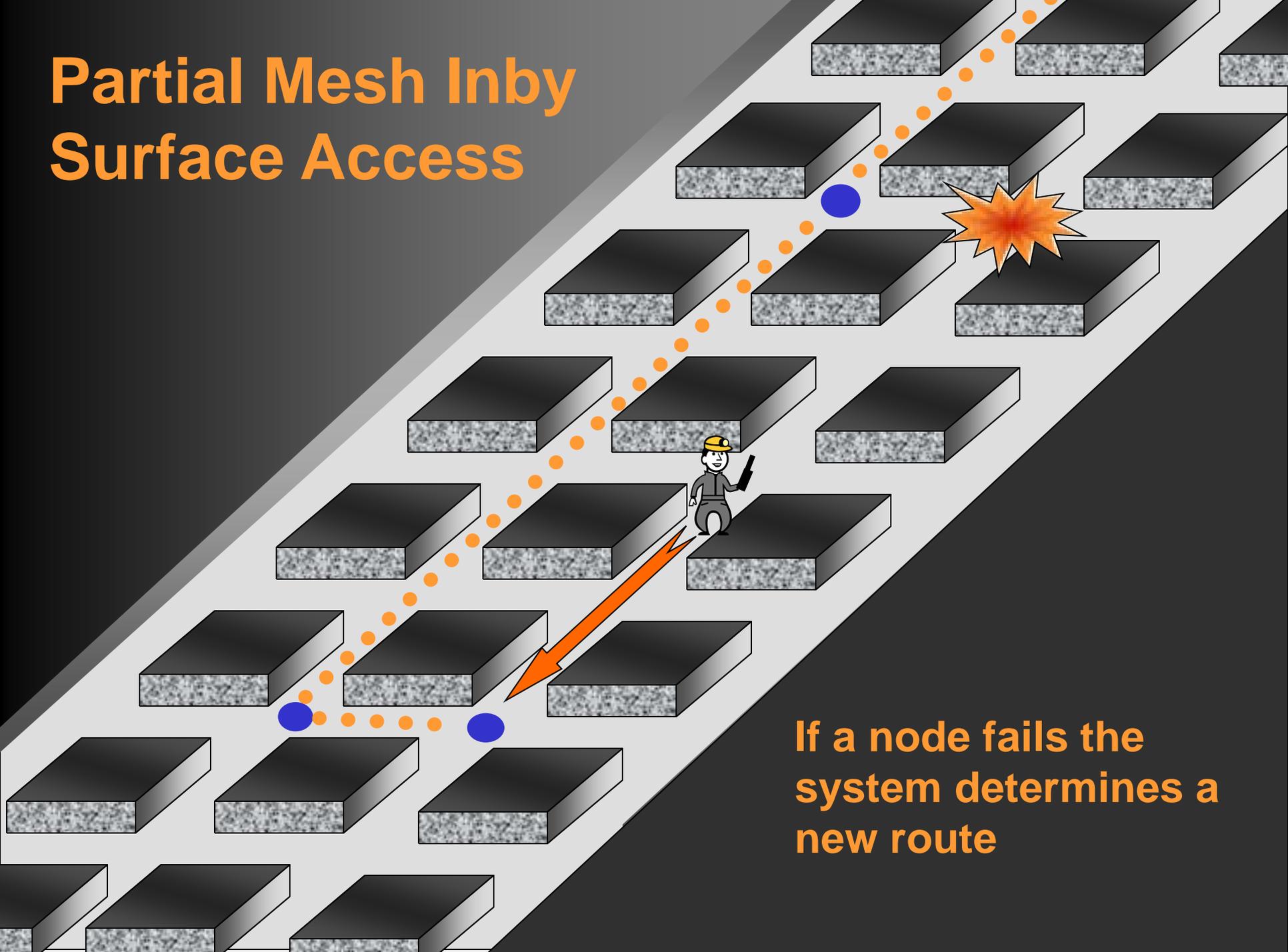
Partial Mesh Inby Surface Access

Nodes arranged to provide route diversity



- Node
- Backhaul link
- ➔ Access link

Partial Mesh Inby Surface Access



If a node fails the
system determines a
new route

NIOSH Contract: Wireless Mesh Mine Communication and Tracking System

- L3 Communications Global Security & Engineering Solutions
- ICG-Wolf Run Mining Co. Sentinel mine
- May 2007 – February 2009



L3 GS&ES Wireless Mesh Communication and Tracking

- **Full ad hoc mesh capabilities, which maximizes the flexibility of extending and/or repairing networks**
- **Good propagation in open entries**
 - 900 MHz operational frequency
- **Handset features**
 - Voice and Text
 - Tracking
 - “Talk around” handset to handset operation
 - Foster parenting
- **Compressed voice**
 - Can increase communication range,
 - May support future interoperability with through-the-earth and medium frequency systems