Abstract:

Mine Site Technologies (MST) has finalized the development of a network communications platform to extend a site’s WLAN Ethernet topology into the underground workings. The proposed paper intends to explain the development of this purpose built wireless communications device. Practical examples will be quoted from use in Australian and Canadian mining operations where the Underground WLAN Network provides wireless communication to a range of management, control, monitoring and safety devices.

A key aspect is the large bandwidth enabling an order of magnitude increase of data handling rate over more conventional leaky feeder type and hybrid Ethernet radio systems. This provides a mine a high throughput and robust communications infrastructure to support the deployment of general IP applications, with a focus on mobile data solutions.

The paper will address the specific requirements and deployment considerations associated with the challenging environments existing in underground mines.

The presentation will make reference to case studies.

Introduction:

The provision of an effective reliable communications system within any underground mining environment, has always been a significant challenge for mine operators. Most underground mines experience harsh and difficult conditions in which to install, maintain and operate an effective communication system, which is further compounded by the extensive and distributed layout of many mines.

Their have been many communications technologies deployed over the previous 30 years, all with various limitations and varying degrees of success. These include:

- Hard Wired standard Telephone Systems
- 2 Way Leaky Feeder VHF/UHF Radio Systems
- 2 Way Inductive Radio Systems
- ULF “Through the Earth” PED Communications Systems
- Generic Ethernet/ Fiber Data/Wireless Networks
- Hybrid Ethernet/Leaky Feeder Systems
To date there has been no single technology or system that can provide the full spectrum of communications requirements required to operate, manage and support every type and size of mine. Mines range from short life, very small operations with a dozen miners, right up to large scale fully mechanised mines with thousands of miners underground every day. They may also include both Open Cut and Underground operations.

I.T and Communications Technologies are now critical to the smooth running of a mines, day to day operations and impact on a mines ability to ensure:

- Maximum operational efficiencies
- Effective management of the workforce and equipment
- Minimise downtime and equipment failures
- Safe working environment
- Profitable operation

As a result Mines are required to deploy a collection of communications systems, networks and technologies to provide:

- Voice communications,
- Systems and equipment monitoring and control
- Ventilation systems
- Video
- Remote Blasting
- Vehicle management
- Personnel, equipment and vehicle Tracking
- Emergency Evacuation Systems

Over the past 2 years there have been significant developments in the design and implementation of 802.11b/g WLAN communications systems with network infrastructure, equipment and applications specifically designed to meet all the requirements in an underground mining environment.

For the first time one communications system, its technology, design and network infrastructure is leading the way in achieving the “holy grail” of underground communications providing:

- All communications system and applications requirements
- Easy installation, maintenance and expansion
- Robust and reliable with redundancy capabilities
- Non Proprietary Industry Standards utilised
- Seamless integration with the mine’s surface data and communications network
- Cost effective with significant bandwidth available
- No requirement for remote power supplies
The system is known as ImPact WLAN consisting of network infrastructure, products, S/W and applications. The ImPact WLAN is 802.11b/g standards based and Wi-Fi compliant. The underground network provides high throughput and robust communications infrastructure to support the deployment of general IP applications with a focus on mobile data solutions.

Some of the advanced applications supported by the IMPACT WLAN in an underground mining environment include:

- Mobile Vehicle Data Solutions
  - Production Monitoring
  - Ore Flow Modeling
  - Utilization Monitoring and Optimization
  - Condition Monitoring
  - Equipment Tracking
  - Equipment Scheduling and Traffic Control
- Voice over Internet Protocol (VoIP over wireless IP phones)
- Mobile Data (PDA and Pocket PC) Applications
  - Equipment Operators Logs
  - Shifters Log
  - Surveying Input
  - Geology Input
  - Materials Management (i.e.: bar scanner apps.)
- Mobile and fixed Video over Internet Protocol
- Provide wired LAN connectivity in remote areas

Mine operators who have installed the initial systems are already viewing this system as “The Future for all Underground Mining Communications” which will eventually make most existing communications systems and technologies redundant.

Technical System Overview

The system introduces a purpose designed network communications platform that extends a site’s Ethernet topology into the underground workings.

The design architecture philosophy, provides extended general IP functionality with the added benefit of utilizing productivity enhancing tools available through proprietary and off-the-shelf wireless networking technologies.
The important design features that the ImPact WLAN architecture provides over standard Data / Ethernet networks include:

- All cable and connectors are Pre terminated negating the requirement for fiber terminations underground
- No additional Fiber switches or routers are required
- The network cable provides DC power removing the requirement for local power sources at each WAP.
- The network installation and maintenance is truly “Plug & Play” installation.

The ImPact WLAN and Wireless LAN technologies utilize carrier quality wired and wireless components and include design criteria that ensure high reliability and maintainability through architectures such as redundant loop implementations and SNMP fault detection and network management tools.
The primary components of the underground WLAN network infrastructure are:
2. Composite Cable – Fiber and Copper cable
3. 240/110VAC to 30VDC Power Supplies

**ImPact 802.11x Wireless Access Point**

Among the principal design criteria incorporated into the **ImPact 802.11** Wireless Access Point are the following:

- Standards based and compliant with: IEEE 802.3, 802.11; IREDES Wireless Data Standard; XML Wireless standard; Wi-Fi compliant;
- Integrates fast switch to facilitate hub/branch configuration or to switch between access cards based on data priority (e.g. VOIP packets assigned priority for QoS performance)
- The switch is capable of switching two wireless segments and four fibers segments at full wire line speed.

- Full wireless access functionality is implemented via Wireless Access Card (WAC) – consists of a wireless network processor and integrated Cardbus (PCMCIA) 802.11 adaptor.
- Operates on touch voltage (30 VDC max) – no certifications or approvals required – do not need to use armored or Teck cable
- F/O interface to maximize WAP spacing (targeting 600m separation [802.11b] based on minimum signal propagation of 300 m in typical 4m x 5m openings)

**Operational Parameters**

ImPact WAC operational parameters such as the network description, radio channel etc. are all set through a web browser based interface.

- ImPact WAP software can be upgraded in the future to support other 802.11 standards or to implement proprietary OEM protocols in future applications
- Each ImPact Access Point can support 2 WACs to provide increased local throughput on network segments to support VLANs and accommodate usage peaks in high volume areas (hot-spots)
  - Consolidate high volume data transport (wired and wireless)
  - Facilitate wired LAN expansions in remote areas without impacting wireless Quality of Service (QoS)
- WAC configuration is standards variable (802.11a / .11b / .11e/ .11g / .11x...) and field upgradeable at minimal cost
- Configurable to dual band concurrent operation (.11b/g – 2.4GHz and .11a – 5 GHz)
- Dual antennas support spatial diversity for improved QoS in mobile applications and roaming
- Flexibility in network topology; star, cascade-star, etc. - Scalable
- Network deployment integrates high speed hub with gigabit backplane and upstream link to support future Gigabit Ethernet deployment.
Composite Network Cable.

The WLAN network WAPs are connected via a specially designed Composite Cable and Pre Terminated Hybrid Connectors. The cable consists of single or multiple pairs of Optical Fiber cables (Multimode/Single Mode) and 1 x pair of copper cables for the provision of DC power.

The ability to easily terminate and maintain optical fibre and required connections in an underground mining environment, have always posed problems for maintenance and installation personnel.

The ImPact WLAN system utilizes pre terminated cables and connectors provided in various lengths from 50-350M lengths. In addition customized Barrel Connectors are provided for connecting 2 lengths of Composite cables and plugs.

**Composite Cable Drawing**

![Composite Cable Drawing](image)

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Multimode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Diameter</td>
<td>62.5 µm</td>
</tr>
<tr>
<td>Cladding Diameter</td>
<td>125 µm</td>
</tr>
<tr>
<td>Primary Coating Diameter</td>
<td>245 µm</td>
</tr>
<tr>
<td>Secondary Buffered Diameter</td>
<td>900 µm</td>
</tr>
<tr>
<td>Numerical Aperture</td>
<td>0.275</td>
</tr>
<tr>
<td>Proof Test Level</td>
<td>100 kpsi</td>
</tr>
<tr>
<td>Wavelength</td>
<td>850 nm - 1300 nm</td>
</tr>
<tr>
<td>Attenuation</td>
<td>3.0 dB/km - 1.0 dB/km</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>200 MHz-km - 500 MHz-km</td>
</tr>
<tr>
<td>Cable Weight</td>
<td>220 kg</td>
</tr>
<tr>
<td>Cable Diameter</td>
<td>14.5 mm</td>
</tr>
</tbody>
</table>

**INSTALLATION**

| MAX. TENSILE LOAD | 2300 N |
| MIN. BEND RADIUS  | 21.75 cm |

**OPERATING**

| MAX. TENSILE LOAD | 500 N |
| MIN. BEND RADIUS  | 14.5 cm |

**IMPACT RESISTANCE**

| 1000 Impacts |

**CRUSH RESISTANCE**

| 1800 N/cm |

**OPERATING TEMPERATURE**

| -40°C to +85°C |

**STORAGE TEMPERATURE**

| -55°C to +85°C |
110/240 VAC – 30VDC Power Supplies:

One of the primary features of the ImPact WLAN network is that the system provides its own DC power to operate the WAPs. This negates the requirement for AC/DC power sources throughout the mine.

The system is powered by 110/240VAC- 30VDC Power Supplies which can power up to 10 x WAPs or 4kms of Composite cable. This significantly minimizes the power system requirements underground.

Applications:

Vehicle Intelligence Platforms (VIP)
The ability to download real time data from mobile vehicles has been one of the major drivers in implementing the ImPact WLAN system. Each vehicle is provided with a Wireless Interface to the On-board System Diagnostics and Payload Systems. When the vehicle passes a WAP generally located at a “Loading or Dump” point, the latest Vehicle stats are automatically downloaded and stored on an SQL Applications Database. This information is then displayed on a screen for easy viewing by mine personnel to identify potential vehicle system failures eg: Engine Overheating, Tyre pressure, Oil etc. prior to them reaching a critical situation.

This capability provides Mine operators with the ability to view real time information from mobile vehicles including:

- Vehicle System and Diagnostic Information
- Payload Weights per cycle on a shift, week or monthly basis per vehicle.
- Vehicle Tracking and Management

In addition the ImPact WLAN VIP system information and data can be interfaced into existing Mine Management or ERP systems.

Typical Underground Vehicles Manufacturers interfaces include:

- CAT Trucks – EAM systems
- CAT Elphinstone LHDs - EAM and TPMS systems
- Atlas Copco Scoops, LHDs and Drill Rigs
- Sandvik - Tamrock and Torro Vehicles

Mine Monitoring & Control

The ImPact WLAN can also provide the network backbone required to provide a Mine’s complete equipment monitoring and control systems including:

- PLC Control of Pumps, Fans and Ventilation systems.
- Environmental, Gas Monitoring and Detection
- Conveyor Belt systems operation and status.

All equipment can be connected via an industry standard Ethernet /RS232 Wireless Bridge and PLC connected to the equipment. This provides the ability to manage, program and monitor all equipment PLC’s remotely from the surface without the requirement to program each device independently underground. Typical management and control Software systems for this include vendors such as Wonderware, Citect etc.

In addition any and all underground systems can be connected via a hard wired connection into any WAP via a standard J45 Ethernet plug connection.

Tracking
The Impact WLAN infrastructure also provides the ability to monitor and track personnel, vehicles and equipment underground, on a real time basis. This capability provides invaluable information in assisting mine operators to effectively manage their equipment and personnel.

The ability to identify the location of equipment and vehicles now makes Asset Management and the S/W applications available, an invaluable tool for mine operators.

Every Wireless device connected to the WLAN network, by default has a unique I.P address. This then provides the ability to monitor every device last known location, as its I.P address is automatically downloaded as it passes a Wireless Access point. Combined with a dedicated Tracking S/W application, the location of mobile equipment and vehicles can be identified at any time.

In addition mine personnel can be provided with RFID “Active Tags” that are worn on the miner’s belt or integrated into their Cap lamp Batteries. This then provides the capability of managing the mine’s personnel from an operational perspective and in the event of a mine evacuation, monitor and confirm the location and safe exit of all mine personnel.

Typical applications provided by the Tracking application include:

- Electronic Tag Board – Who’s IN or Out of the Mine
- Asset Management of all Vehicles & Equipment
- Identifying the location of key maintenance & support personnel
- Personnel Management in Emergency Evacuation

A RFID Tracking Tag can be integrated with a Cap lamp Battery Receiver, worn by miners.
An Active RFID Tag for use with Vehicles, Equipment or worn by personnel.

Size: 62x42x14mm Weight: 35gm I.P Rating: IP67

Conclusion:

The opportunity now exists for Underground Mine Operators to take advantage of the latest communications technology available. The ease of installation, maintenance and expansion negates many of the negatives associated with previous communications systems available to miners.

The ImPact·WLAN network infrastructure combined with existing and future Applications will provide mine operators with the ability to better manage their operations, achieve operational efficiencies and assists in delivering lower operating costs.

(End.)

Specifications:

ImPact WLAN Network & Radio Specifications

General
Radio Data Rate 11, 5.5, 2 and 1 Mbps, Auto Fall-Back
Range (open environment) 11 Mbps -300m/450m (200 mW / 23 dBm output)
5.5 Mbps -400m/600m (200 mW / 23 dBm output)
2 Mbps - 500m/750m (200 mW / 23 dBm output)
1 Mbps -800m/1200m (200 mW / 23 dBm output)
Operating Voltage 3.3V/5V
Regulation Certifications FCC Part 15/UL, ETSI 300/328/CE
Compatibility Fully interoperable with IEEE802.11b compliant products
LED Indicator RF Link activity
Network Information
Network Architecture Support ad-hoc, peer-to-peer networks and infrastructure communications to wired Ethernet networks via Access Point
Drivers Windows 95/98/ME/2000/NT 4.0/CE/XP
Access Protocol CSMA/CA
Roaming IEEE802.11b compliant
Security 64/128-bit WEP data encryption

Radio
Frequency Band 2.4 – 2.484 GHz
Radio Type Direct Sequence Spread Spectrum (DSSS)
Modulation CCK (11, 5.5Mbps)
DQPSK (2Mbps)
DBPSK (1Mbps)
Operation Channels 11 for North America, 14 for Japan, 13 for Europe, 2 for Spain, 4 for France
RF Output Power 23dBm(200mW)–FCC
20dBm(100mW)–CE
Antenna Two antenna connectors (MMCX female)
Omni Directional 2.4 GHz (default)
Directional Yagi 2.4 GHz (as defined by installation)
Sensitivity @FER=0.08
11 Mbps <-87dbm
5.5 Mbps <-90dbm
2 Mbps <-93dbm
1 Mbps <-95dbm

Environmental
Temperature Range 0 to 50 C (operating)
-20 to 80 C (storage)
Humidity (non-condensing) 5% to 95% typical

References:
* ImPact Technology Overview 2003: Mine Site Technologies Pty Ltd
* Composite Cable Drawing: Optical Cable Corporation 2004