



INFRASTRUCTURE-FREE NETWORKING IN UNDERGROUND MINES

- Instantly deployable networks
- Data communications in extreme environments
- Integrates with existing networks and applications
- Low-cost deployment and operation

ROBUST AND LOW-COST INDUSTRIAL NETWORKING

Opportunistic networking that relies on direct device-to-device contacts instead of fixed infrastructure can provide rapidly deployable and cost efficient networking in challenging industrial environments, such as underground mines.

There are thousands of actively operating mines worldwide. Within these mines there may be tens to hundreds of pieces of equipment – drills, loader, roof bolters and other special purpose machines – as well as personnel operating in two to three shifts per day.

Robust communication systems are crucial for managing and operating the fleet of equipment and personnel operating in challenging environments. Above ground the mining operations are often situated in remote areas, while underground the propagation of radio waves is severely limited by the topology of the tunnels (Fig. 1) and building wired communication infrastructure could be expensive or even impossible.

BENEFITS OF OPPORTUNISTIC NETWORKING

Building a data communication network based on opportunistic networking instead of fixed infrastructure installations has a number of key benefits:

- ***Rapid network deployment.***
- ***Coverage of challenging environments.***
- ***Cost effective deployment and operation.***

Opportunistic networks are composed of mobile devices carried by personnel, software integrated into existing equipment, and autonomous routing devices installed into equipment. This allows ***rapid deployment*** into environments without any existing communication infrastructure. Further, the reach is not limited by the ability to build infrastructure installations, and can

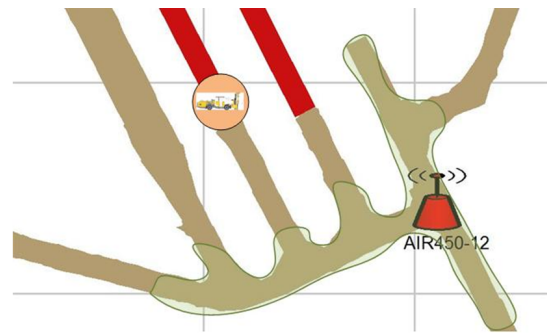


Fig. 1. Limits of radio propagation in underground tunnels.

therefore reach ***challenging environments*** impossible to cover with traditional networking technologies. All of this can be achieved highly ***cost effectively*** since expensive infrastructure does not need to be built and maintained.

Opportunistic networks integrate seamlessly with existing network infrastructure where available, extending their reach, and serving as a backup networks in case of disruptions. They can also be built as a rapid spearhead communication system while infrastructure networks are slowly built up.

EXAMPLE DEPLOYMENT CASE

Spacetime Networks Oy in cooperation with Cybercube Oy have installed an opportunistic networking solution in an underground chromium mine owned and operated by Outokumpu Oyj in Kemi, Finland. The underground mining operation has been ongoing since 1999 and has reached the depth of 500 meters below ground level. The deployment has been operating for a year based on the Spacetime Network's ***Scampi*** opportunistic networking platform.

The Kemi mine has an unusually well developed IT infrastructure, with Wi-Fi reaching many parts of the underground tunnels and full coverage in the offices and crew facilities. Despite the broad reach of the wireless network, data communications are still often not available in

remote tunnels and areas under active development. Mining machines often stay out of Wi-Fi coverage for hours to day while stationed at a work site, with no network access. Extending the fixed network to full coverage would be prohibitively expensive due to new tunnels being constantly developed, and any infrastructure

installations in frequently blasted areas being under high risk of damage.

As shown in Fig. 2, the opportunistic networking solution integrates with the existing equipment and software in the drill machines. In addition, embedded Linux devices have been installed into pickup trucks moving within the tunnels, operating as autonomous message carriers. Android devices carried by the personnel augment this further. All the devices can discover and exchange messages with each other when within wireless communication range, routing message over multiple hops from the drill machines to the mine control room and back.

THE TECHNOLOGY MAKING IT POSSIBLE

Opportunistic networking is based on a store-carry-forward style routing layer implemented on top of various communication technologies, including Bluetooth and Wi-Fi. The approach originates from deep space networks characterized by long delays and frequent disruptions, but has since been applied in various challenging scenarios including military, nomadic, and wildlife tracking networks.

The underlying protocols are developed in the Internet Research Task Force Delay-Tolerant Networking Research Group.

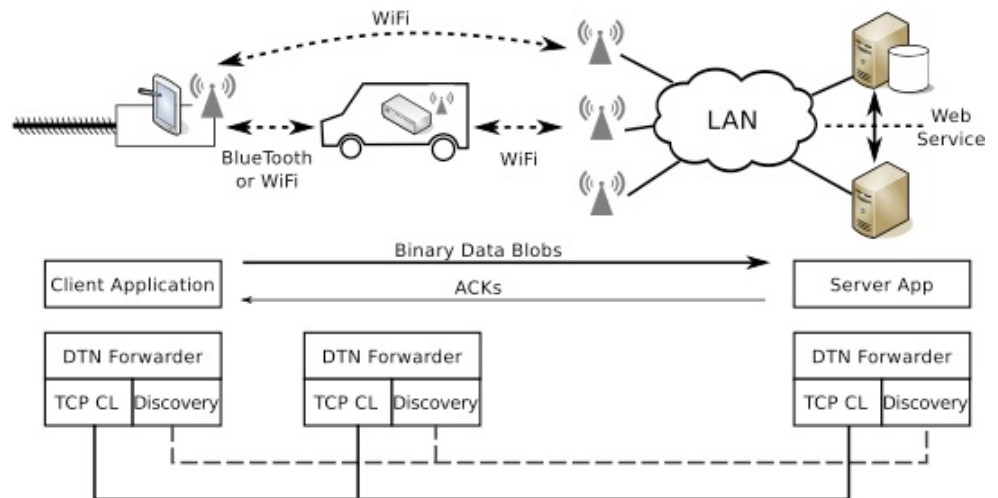


Fig. 2. Underground mine opportunistic network deployment.

SPACETIME NETWORKS SCAMPI PLATFORM

Spacetime Networks Oy has developed the Scampi opportunistic communication platform that serves as a basis for opportunistic networking solutions, including the Kemi mine deployment.

The platform is capable of communicating in fully disconnected ad-hoc environments without infrastructure support by using direct device-to-device communications, while also being able to exploit infrastructure and cloud-based communication opportunities where available.

Highlights of the platform include:

- JavaSE based implementation.
- Supported on Windows, Linux, Android and Mac OS X.
- Based on IRTF DTN RG standards.
- In continuous development since 2010.
- Open API for developing new applications and integrating existing ones.

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