LONG-RANGE ACTIVE RFID SYSTEM FOR UNDERGROUND MINES

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Abstract

With the forecast worldwide capital investment in municipal wireless broadband networks will reach $400 million in 2007 (by Yankee Group), we would need to consider additional benefits from building boom Wi-Fi and WiMAX networks. WiBorne has designed and developed Wi-Fi Citywide projects worldwide during past years, and are realising the benefits of Wi-Fi based location services and innovative Wi-Fi network planning and optimisation tools for Public Wireless LAN (P-WLAN). While deploying long range wireless projects, we feel that asset tracking for large scale wireless deployment is demanded and an improvement of existing active Radio Frequency Identification (RFID) technology is required.

The majority of our applications will be designed for large organizations because Wi-Fi and RFID have already been deployed in the enterprise. Applications will eventually be developed with these technologies to target the consumer space. However, due to such large coverage areas, wireless MAN will require some mechanism to further refine location to provide effective services.

We address the discussion of problems and solutions for such deployment, along with success case study for recently demonstration of WiFi and RFID tracking for a mine in Wyoming, USA.

Keywords: Active RFID; Wireless Sensors; Location-Aware Computing; Wi-Fi Citywide; WiMAX; Mine Safety

1. Introduction

The emerging local and wide area networking technologies, WiFi and WiMAX, have opened up exciting new modes of communication. Wifi was and still will be used in LAN environments for the foreseeable future. WiMAX was designed to provide (MAN) Metropolitan Area Access, to homes and businesses. The popularity of wireless 802.11 networks over the past few years has grown significantly and provides an excellent opportunity to include real-time location system (RTLS) based services in indoor and outdoor environments where GPS fails or cost issues. With the wireless networks in place, a user with a laptop or PDA and an 802.11 network card needs no further hardware.

Other similar positioning tool, such as a GPS device, through triangulation of multiple signals received and determination of propagation (how long it took the signal to go from the satellite to the GPS device), is able to accurately determine a users location to within few meters. The problem with GPS is that the device must have a clear line of sight between itself and the satellite. This means the technology is unusable in heavily forested areas, urban environments with tall buildings, underground such as mining, and indoor environments. Similarly, ultra-sonic based, infrared / optical-based, cellular-based, magnetic-tracking, has different level of strength and weakness for variety of applications.
The use of Radio Frequency Identification (RFID) technology is expanding rapidly in commercial. Active RFID uses an internal power source (battery) within the tag to continuously power the tag and its RF communication circuitry. Many resources within the RFID research and development community have been focused on hardware and firmware components, including active and passive RFID tags, tag readers, embedded software, error reduction, and stored in electronic databases, while applications of such RFID tags are limited with sensing of indoor or small coverage areas. Yet fewer resources have been focused on exploiting the applications of RFID are viable and cost effective for wireless MAN or large coverage areas.

There has been a great deal of research done on similar topic with limited range of wireless broadcasting. Therefore the aim of this paper is to improve existing techniques in location determination for services of long range wireless internet service provider (WISPer). The intent is also to demonstrate how one can access and utilize the data necessary for location determination as performed on existing 802.11 WiFi/WiMAX network that have vast implications in the area of context-aware and pervasive computing.

During deployment of long range WiFi, WiBorne encountered challenges of wide-scale of outdoor tracking techniques for application of horse tracking, children spotter, underground mine, and vehicle tracking. These are usually with range of 20 kilometres to hundreds of kilometres, with both indoor / outdoor environment, or uncovered by GPS systems. Newer technology is needed for active RFID to support such wireless MAN.

2. Related Work

Here we discuss existing RFID systems, along with applications of RFID onto mining industry for rescue, access control, equipments.

2.1 Active 802.11 RFID Systems

There have couple of research and commercial software that supports location tracking for 802.11 wireless tags. Most of are limited with few hundred meters of range. For example, MoteTrack[1], PlaceLab[2], RADAR[3], MagicMap, Ekahau, WhereNet, and Aeroscout. Followings show comparison of these systems:

Usually above location system is an active RFID system that includes Wi-Fi asset tags and all the software necessary to easily track assets over a wireless LAN which is a range of few hundreds meters at most, such as indoor or smaller outdoor community area.

The nearest neighbor search technique for RTLS is to take sample of radio signals and correlate them to known physical locations during when signal is unreachable. Once these samples were taken and stored, all recorded samples was performed with a linear search in real time and the closest signals match was determined to be the user's location.

The triangulation technique can offer additional gains in accuracy were made by averaging the three closest locations found during the search; what is referred to as triangulation. Means of determining location via formulating radio propagation models were discussed, but proved to be less accurate.

The probabilistic technique been applied for RTLS, is to find location that is based upon which location in the stored radio map which has the maximum probability given the received signal strength vector. Usually implementation of such wireless location determination must be done one step at a time even though the superiority of probabilistic approaches.

In the work of [4], the feasibility of building a wide-area 802.11 WiFi based positioning system is evaluated. It does not require line-of-sight (LoS). Their experiments show estimation a user's position with a median positioning error of 13–40 meters. As indicated by these authors, moving Wi-Fi location out of controlled indoor environments into this metropolitan-scale area is not as simple as just moving the algorithms outside. The calibration differences demand a careful examination of the performance of positioning techniques in this new environment.

2.2 Wireless Mine-Rescue Systems

In wake of recent mining tragedies, some technology companies have suggested extension of wireless real-time location technology using WiFi networks to pinpoint miners trapped underground -- a solution that could save lives in the near future.

Mining is a perfect example of an industry with a strong need for real- time location. Mine equipments such as vehicles, containers, drills and other pieces of valuable mobile ore production equipment are constantly moving through large underground areas. Because the equipment does not necessarily follow a pre- defined track and is spread throughout the mine, it is difficult to locate particular assets that are needed in real-time. By attaching RFID tags to equipment, miners can use the mine's existing wireless access points to determine their location instantly and with high accuracy. The joint solution offers instant tracking of personnel, equipment and other assets for improved safety and efficiency.

Condition in mines to consider deployment of RFID system, such as telecommunication cables, water, sewage, oil, gas, surface irrespective of soil conditions in terms of the presence of metal, water, concrete, also battery-life hours that powers the miners' lamps and RFID tags. Other consideration such as poor signal penetration, high implementation costs and, in the case of systems that used battery-powered tags, the inability to control the tag's RF signal.

Figure 1. Minor's Tracking Tag

Mining companies will also be able to use the same infrastructure in the future for other location-based applications such as supplies and energy management. The use of existing access points as readers enabled the system to be installed quickly and at a low total cost of ownership. Mine's information from drills and trucks, such as their positions and the weight of their loads, is relayed via wireless base stations to a computer in a control room above ground. With Wi-Fi networks, fewer miners have to face the risks of working underground, and those who do have a more durable link to the outside.

A summary can be found from [5] that constitute a brief review of mine communications concepts and technologies, based on information that has been previously published by NIOSH, the former U. S. Bureau of Mines and other sources, including information from manufacturers.

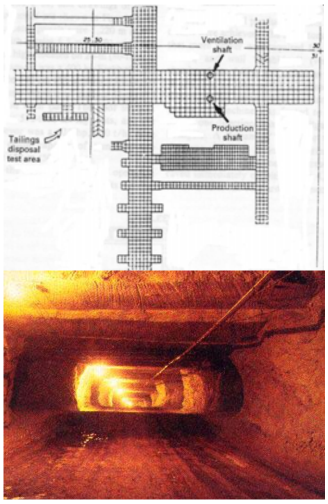

Figure 2. Mine Tunnels

Through joint development of Exavera Technologies (www.exavera.com) [6], Dmarc Netcom Inc. (www.dmarc.us), and WiBorne, Inc. (www.wiborne.com), we have piloted demonstration for long range RFID tracking with a trona mine of FMC Corp. at Green River, Wyoming. We has integrated dual band of real-time location systems, 802.11 2.4GHz and UHF 915MHz, into a 5 miles of tunnel for broadcast of wireless and tracking of moving vehicles. Objective of our truly long range (1 mile) active RFID tag, with is installed into minors' cap lamps or battery packs, providing Wi-Fi based location tracking. With this in place, the location of workers, as well as valuable mobile equipment, can be continually tracked and viewed in real-time from any web browser, to ensure safety and to improve operations.

Figure 3. FMC's Trona Mine in Green River, Wyoming

3. Methodology

Research and experience has shown that communication systems may not work equally well in every mine. Each mine requires a customized solution that caters to the individual requirements of the mine environment and avoids interference with other mine monitoring and control systems. Since communication systems may not cover the entire underground working area of the mine, the area of coverage is an important planning aspect. Also, all underground mine communication systems require MSHA (www.msha.gov) approval (30 CFR 23) [7].

We have concluded design of that such mine communication systems must be: look at a big picture, combine different technologies, incorporate mine layout, and perform risk assessment.

To deploy wireless for mines, we consider it's an indoor GPS system that as many uses underground, keeping track of explosives, trucks, compressors, drills and above all, the well-being and safety of miners.

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Communication systems components such as Leaky Feeders or wire connections may break from a roof fall or during an explosion. They also may get destroyed in a fire or may stop functioning due to power failure. Designing systems for redundancy can maintain operability after such events.

Certain mines such as coal mines, are a particularly unique environment for radio signals. Radio systems require a clear path or open air for signal propagation. Stopping or roof falls halt or impede conventional signal propagation. It is also believed that ionized air as a result of a mine fire can be a problem.

With the increase of WiFi networks in mines for data and voice lines, the proliferation in WiFi networks has created a standard wireless infrastructure in which products like our wireless tracker device can operate.

Ideally, a miner's battery powered WiFi tag has a call button which a miner pushes letting the tag alarm by sending the precise location to a remote server outside of the mine.

Then using wireless computers, outside staff are able to access location information on internal Web pages by pointing their Web browsers to an intranet page. Movement and location of each tagged miner, vehicle, or equipment is tracked in a database and shown on a visual map. The last known locations of a miner will be mapped, in the event the wireless network has collapsed. As long as the WiFi network extended with the coverage of depth or length of the area underground, then the tracking device would be able to stay connected with the RTLS server.

We have developed a hybrid frequencies system by utilized both 915MHz and 2.4 GHz. UHF such as 915MHz works in a metal-heavy environments, or partial Non-LoS. Standard 2.4 GHz is for longer range of wireless deployment with LAN network based on WiFi technology. Miners can utilize such 2.4 GHz for data / voice communication too.

Figure 4. Real Time Location Tracking for Moving Vehicle

The safety system in the mining industry should evolve with the technology that is being made available. WiFi technology is evolving and products like WiBorne's hybrid systems are becoming cost effective.

4. Results, analysis and discussions

Our system demonstrates significantly contribute to safety on mines through measures like tagging of lamps, gas meters and rescue packs. Not only does this ensure that each miner has the correct equipment with him, but also that the equipment is functional and within calibration limits. This provides a portable database that travels with the product and can interface to any existing mining management system providing the ideal tool for quality control and selective mining.

The upside to the system is that even if disrupted it still provides the last known location of personnel and equipment but conversely, the system is subject to damage from fire and explosion, which could compromise the ability to track, or send messages on a data line.

The only downside could be employees not wanting to be tracked. Therefore an efficient system would need to be place when employees aren't tracked during downtime like lunch.

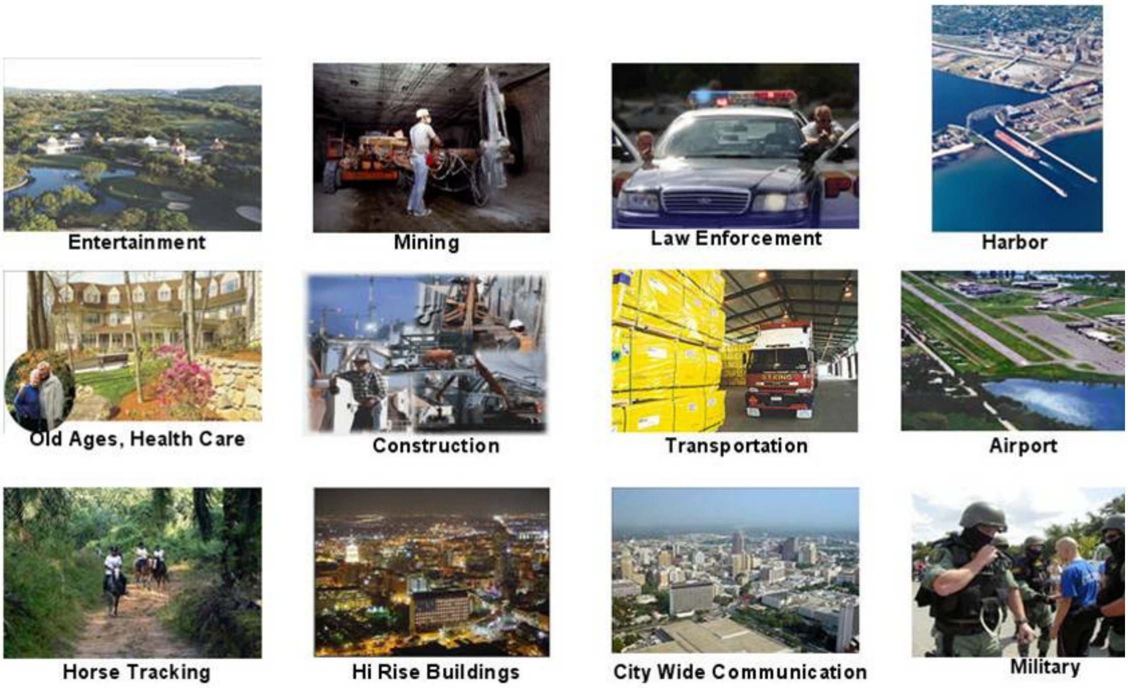
A recent discussion from West Virginia's mine emergency response center, can be found from [8]. The objective of such discussion was to collect expert opinion on the challenges and opportunities to better inform the discussion regarding implementation. A roundtable meeting was hold at the same time to convene a roundtable of 40 mining experts2 with a collective experience of 946 years

5. Conclusions

The major advantages that we offer to such project, is to have true long-range of RFID readers which also act as wireless access points for communication. This dramatically reduces cost of installation and maintain. Our how power RFID tag and RTLS system ensure ubiquitous computing with accuracy yet battery-life saving.

There has limitation that most of systems would encounter. We had concerns about keeping the network operating after an explosion or collapse.

WiBorne's asset location tracking system, LOC-1000, is web based and can be applied for standard 802.11 wireless broadcast with frequencies of long range 802.11. For example, facilities such on below figure such as Asset Tracking, Automated Parking, Access Controls, Hospitals, Airport, Harbor, Communities, Commercial Facilities, Animals, Horse Riding, Mining, and Transit Stations. It applies to any 802.11 applications such as Data Logging, Surveillance, Emergency, Proprietary Tracking, Field Force Automation, Law Enforcement, Tracking Fleets, Couriers, and Construction.



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