Ubiquitous Computing for Improving Industrial Safety and Security Management

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Abstract

The existing safety management systems are mostly manually triggered and reactive. Since real time on-line data about the safety and security parameters are not available, there is minimal scope to take any prior preventive measure to avoid any kind of safety & security hazards. Since identification of any forthcoming crisis requires current information, and such information must be communicated in real-time, therefore the need arises for an integrated ubiquitous communication network for industrial safety, security and its management that provides efficient, reliable, secure exchange and processing of relevant information.

The objective of the paper is to analyze the impact of using our Real-Time Tracking, Sensing and Management System using Active RFID, Sensors and Wireless Mesh Network for improving industrial safety & security. We will discuss a unified ubiquitous framework for both object visibility and environment visibility of an enterprise through real-time tracking and monitoring of enterprise objects using the Internet. It also allows controlling the objects and the environment by triggering actuators, which are also part of the enterprise objects. The core objective is to develop a system that helps not only to view but also to control enterprise objects through the Internet.

1. Introduction

Safety is of paramount importance in industrial operations, not only for prevention of accidents and failures, but also for improving operational efficiency and security. However, absolute safety, where risk is completely eliminated, can never be achieved; risk can only be reduced to an acceptable level by improving safety practices through gathering real-time data about the safety parameters. In this paper, we have discussed a generic ubiquitous framework which can be used to develop real-time tracking, sensing and management system applications using Active RFID, Sensors and Wireless Mesh Network for improving industrial safety & security. The system provides anytime anywhere visibility (location, activity status, condition) of industrial assets, resources as well as industrial environment in real-time so that timely and appropriate actions, precautions can be taken and alert notifications can be generated in case of any emergency.

Industrial safety primarily encompasses three aspects: safety of workers, safety of assets and safety of working environment.

The paper is organized as follows.

Section 2 illustrates the architecture of the ubiquitous framework supporting enterprise visibility. Subsequently, the features of unified real-time tracking, sensing and management system based on the proposed framework are discussed.

Section 3 discusses the safety & security related problems of in two different industries: a) Railways and b) Mining sector (both underground and opencast mining) and how to handle them using the proposed framework. Indian Railways have two important problems a) controlling unmanned level crossing and b) remote detection of fish plate removal to avoid accidents. In mining sector, there are three major problems; a) managing disaster by tracking miners and mining environment in underground mines, b) securing the explosive magazine premises of opencast mines.

Section 4 concludes the paper with further scope of applicability of real-time tracking, sensing to detect industry's safety scenario and to control it.

2. Proposed ubiquitous framework for enterprise visibility

Ubiquitous framework for "Enterprise visibility" essentially creates a wireless communication environment by attaching intelligent wireless devices, sensors and actuators to the industrial objects and environment so that each and every object, human being and the environment of any enterprise can be made visible and controlled (actuated) in real-time from anywhere in the world at any point of time [1].

The building blocks of this framework are

a) *active RF tags and sensors* for tracking status and location of enterprise resources and environment
b) *Wireless routers and gateway* for creating a self-forming wireless mesh network with tags and sensors in their vicinity to transmit tag/ sensor data from field to a control station for remote real-time monitoring.

This wireless network, thus formed, is also known as LR-WPAN since it uses low power and low data rate short range wireless communications suitable for tracking and monitoring applications. Low data rate protocols have been designed specifically for these needs lately, which is a significant deviation from the trends of building high-bandwidth networks. The protocol ratified by IEEE is 804.15.4 in 2003 and updated in 2006. The 802.15.4 standard provides specifications for the Physical and Medium Access Layer. The upper layers (Network to Application) have been developed by a consortium of wireless device manufacturers and enthusiasts called ZigBee [2].

We have developed an *end to end architecture for such remote visibility of enterprise "objects"* and *remote actuation necessary for controlling these "objects"* using the basic building blocks described above. The architecture comprises of three basic components: (a) the wireless mesh network, consisting of RFID tags, sensors and/or actuators (b) the gateway and the central server and (c) the Internet [3].

The mesh networks house local information which is communicated through a gateway to the central server. The gateway handles the messages to and from the mesh network. The gateway is expected to be mains powered while the individual nodes (sensors/actuators) are battery driven. The information is then transported to a web endpoint by the Central Server. The central server essentially does the job of protocol conversion from the Internet to the sensor network and vice-versa. The information is displayed in the requisite format and provides an interface for object management. The web end point application can be a simple hosted page viewed on a personal computer or a message transmitted to a mobile device. We could think of supporting both push based and pull based systems. A push based system updates the status of the devices automatically, either periodically or when a status changes. In a pull based system, the latest information is provided when the user asks for it.

The conceptual framework is pictorially depicted in figure 1.

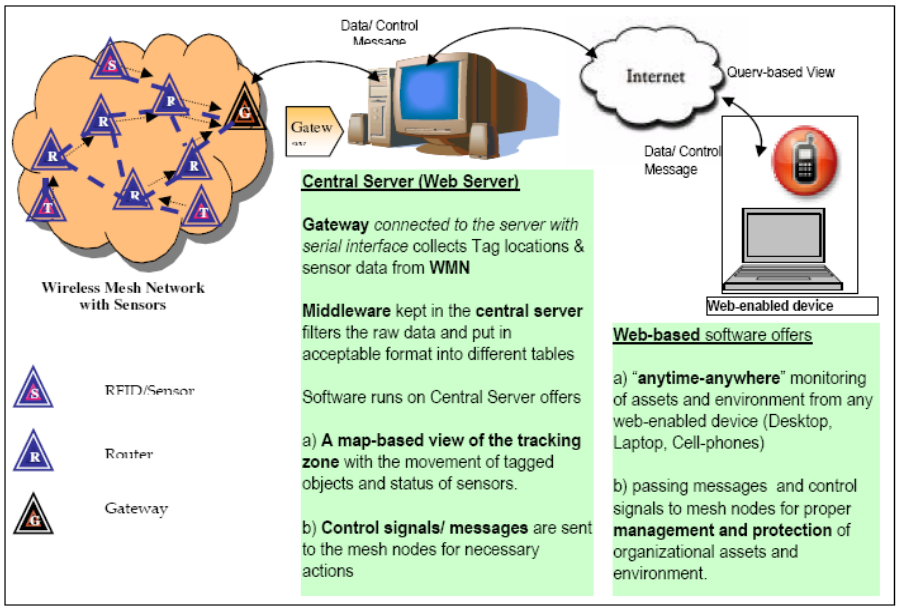

Figure 1. *A conceptual framework for Monitoring and Actuation of objects and environment through the Internet*

3.1. Safety and security related issues and challenges in Indian Railway

3.1.1. Managing unmanned level crossing

Managing unmanned level crossing is a major concern of Indian rail especially in the remote areas where there is no locality around a level crossing for miles. During the last decade, (1992-93 to 2001-02) on an average, 16 accidents took place at manned level crossings per year, whereas 56 accidents occurred per year at unmanned level crossings [4]. Moreover, Gatemen cannot be posted at gates, where the traffic is insignificant since it would result in wastage of manpower and financial resources [4]. It is, therefore, a burning problem for Indian Rail to effectively handle this issue.

Indian Rail, so far, has not taken much initiative for adoption of state of the art technologies to handle the problem of unmanned level crossing other than TAWD and Anti-collision device.

a) **Anti Collision Device** provides additional safety shield at manned and unmanned level crossings, through an audio-visual indication to road users.

b) An IR based **Train Actuated Warning Device (TAWD**) **for giving audio/ visual warning to road users about an approaching train has been under process** to reduce accidents at unmanned level crossings.

Both the solutions offer audio-visual warning on detection of approaching train from a fixed distance from the level crossing. However, that serves only as a warning. If the warning gets unnoticed there will be chances of accidents

Proposed solution: Infra Red Sensor & ubiquitous framework based automated boom barrier system for managing unmanned level crossing

We propose an **Infra Red Sensor & RFID based automated boom barrier system**.

The conceptual framework of this system is as follows (Figure 2).

- IR Sensors will be fixed at 8 to 10 km away from the level crossing on both the ends of the level crossing to detect approaching and passing train.
- As the approaching train blocks the IR reception, the signal from IR receiver is sent through wireless routers to a remote wireless gateway/coordinator connected to a host machine at the nearest cabin office. The controlling software, on detection of approaching train at 10 km away, will automatically issue a control command to the wireless interface of the motorized boom barrier. Motor drives access control bar to close the gate.
- Next, when train crosses next IR pole, kept 10m away from level crossing, the motor opens the access control bar using the same process.

The solution uses *Active RFID based Wireless Mesh Networking Architecture* to receive and send IR and wireless control signal to control station

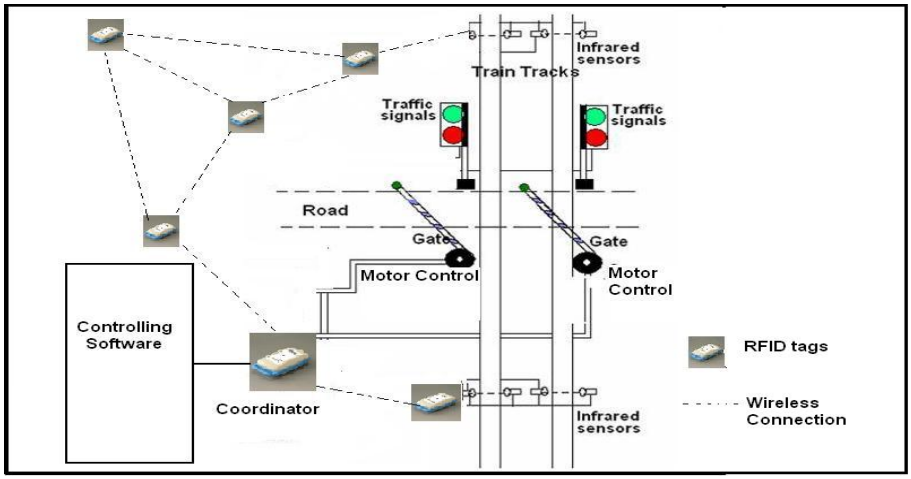

Figure 2. *Conceptual framework for IR & RFID based boom-barrier system*

3.1.2. **Fishplate security**

Indian Railways carries over 18 million passengers & 2 million tons of freight every day. A lot of industries depend on railways for the transportation of goods and raw materials. Hence in such a case, security of trains and rails on which they run becomes very important. In recent years, many passenger and goods train have derailed due to damages in rails of which missing fish plates accounts for the maximum number of such cases. Fish plates are made up of metals which have high market value. People illegally remove fish plates for monetary benefits. Various terrorist outfits have also been involved in such illegal activities. Maoists in Chhattisgarh and Andhra Pradesh have resolved to such techniques for disrupting public properties. Various measures have already been taken in the case of train security. However, no significant steps have been taken in the field of security of rail tracks to overcome fishplate removal problem.

Proposed solution for remote monitoring of fishplate security using RTLS & IR sensors

We propose to use of *ubiquitous Real Time Sensing System framework* to secure the fish plates and generate alert (with location of incident) on their illegal removal. The objective is to sense the removal of an object from its location. The system ensures immediate response in case of removal, so that proper steps can be taken with immediate effect and rail accidents can be prevented. The system comprises of a pair of sensors to be fitted on both sides of the fish plate, sensor output is connected to RFID tags which is kept beneath the rail lines for sending the sensor status to nearest monitoring station (cabin room). Routers are mounted on the electric poles. The information gathered by the sensors and tags will be communicated to the monitoring stations through multiple hops of routers. The whole system can be powered by the solar energy which . Medium sized solar panel can be placed on the signal posts or small sized panels can be placed with IR sensors near the fish plate to power the tags, sensors and routers. Various sensors can be used for the purpose; IR sensors, micro-switches, etc. However, we have chosen IR sensors for the purpose because of their low cost and greater efficiency.

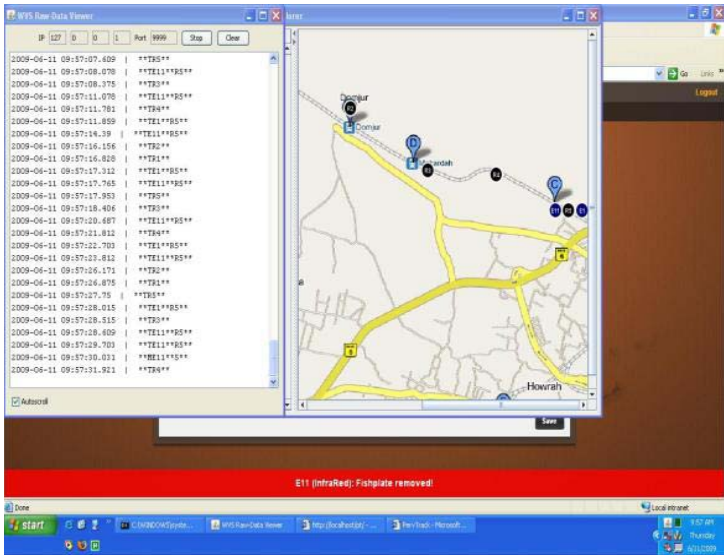

Figure 3*. Screen shot of tracking software showing warning message (in red bar area) on removal of fish plate. Coursey: Pervcom Consulting Pvt. Ltd.*

Whenever, the fish plate was removed from the rails, IR sensor status changes and that status was sent to control station with the location of the event. The event location is highlighted on the map based visualization window at the cabin indicating the spot of emergency. Figure 3 displays the visualization and warning system software at the monitoring station.

3.2. Safety and security related issues and challenges in Mining Sector

3.2.1. Managing disaster by tracking miners and mining environment in underground mines

The physical and geographical complexity of tunnels in underground mines impairs the visibility of environment and operating assets, including human beings. Irrespective of the acuteness of locating mineral though proper mining design and planning, the hazards of the sub-terrestrial world remains unpredictable. This increases the vulnerability of the miners. Most of the available technologies are restricted in being reactive rather than proactive, which means that it can not predict an imminent disaster situation. And, once the disaster strikes sub-terrestrially, it leaves very little window of opportunity to control the disaster from getting worse.

Very limited work is done to remotely monitor the location and activity status of miners and mining environment in real-time from the surface. Real-time data about mining environment i.e., emission of poisonous gases in underground mines is also not available currently at the mine office on the surface. Wireless communication inside the underground mine is one of the most promising and effective technique that is being used in number of solutions. The limited infrastructure required as compared to the legacy wired communication technology, which is very much susceptible to the disaster itself, has paved the way for ingenious solution development to tackle the mining disaster issue.

Proposed Solution using Active RFID and wireless sensor based tracking and monitoring system

Active RFID technology integrated with sensors for real time location monitoring and sensing emerges to be the obvious solution which has the capability to address the mining disaster handling issue competently.

The RFID tags attached to the miners or assets are capable forming a network between them even under constant mobility. This smart active RFID tags are capable of communicating in both directions, so the miners can also communicate with the control station on the surface and vice versa. The routers are placed in strategic locations in the various mining tunnels and they are capable of forming autonomous, fault tolerant and robust wireless network to carry miners' tag data to control station on the surface [5].

Highly effective and small sensors can be integrated with these tags. The flexibility to attach gas sensors, capable of sensing toxic gasses such as carbon monoxide, carbon dioxide, methane etc. and to subsequently transmit that information in real time to a monitoring station on the surface creates the absolute critical visibility of the sub-terrestrial mining world [6]. Specific sensors, such as vibration sensors, soil moisture sensor, smoke sensors for fire detection can be placed in critical locations and they can detect the environmental parameters continuously to predict

immanent disasters. The integrated nature of the system enables the location tracking of every individual tagged object as well as miner in time of imminent disaster and subsequently sends alarms to warn the miners to take necessary actions, such as evacuation. Even in case of disaster recovery, this real time location information is critical for prompt and effective rescue operation. Thus, we can see the completeness and effectiveness of such integrated real time location tracking and sensing system in improving the mine safety tremendously [7].

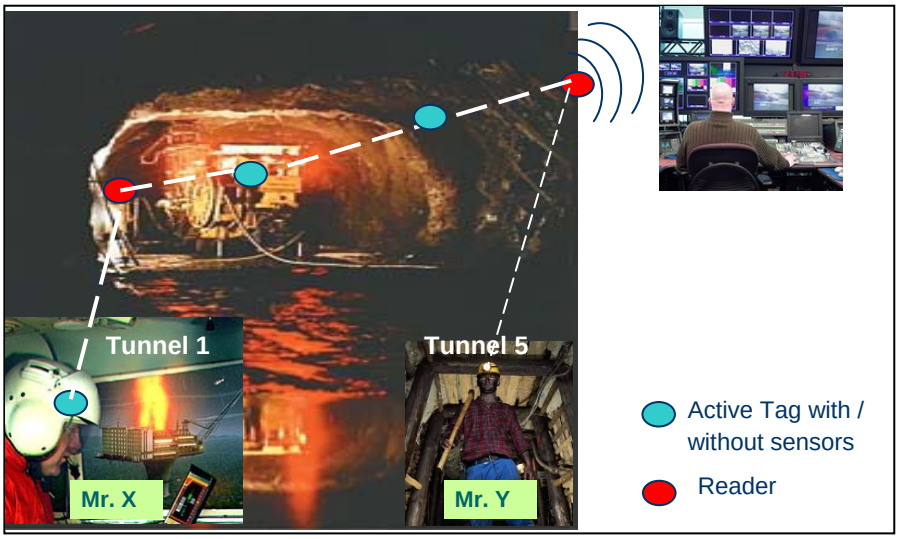

Figure. 4. *Conceptual framework for Underground Miners' Tracking & Poisonous Gas Detection System: Coursey: Pervcom Consulting Pvt. Ltd.*

3.2.2. Securing the explosive magazine premise against unwanted intrusion and theft in opencast mines

Securing the explosive magazine premises in an opencast mine against un-wanted intrusion is critical. Breach of physical security can result in not only theft of expensive equipments but also put severe threat to the safety of the plant and the people working inside. Traditional ways of securing the perimeters of factories, plants and mines only consists of barbed wire fencing with limited number of security personnel patrolling the entry gates. These methods are nowhere close to being full-proof against intrusion, simply because of the huge size of the perimeters, which is physically impossible to monitor through limited number of human eyes. Most of the plant uses barbed wire fencing and electronic power fencing. Barbed wire fencing can be easily broken down, whereas, power fencing security can be broken by making hidden underground passes. Common fencing solutions do not provide location of breach. So, reaction time for counteraction is quite significant. Killing of security guards in recent maoist attack at one of the blue-chip aluminum company has once again raised the need of exploring new technology option to improve perimeter security that can autonomously track the actual location of breach in real time and take preventive measures immediately.

Proposed solution on IR based perimeter fencing

Automating the whole security process through sophisticated sensors and wireless networking technology could be the answer to the age old security problems mentioned before. Infrared

sensors can easily detect the breach of a security perimeter. These infra-red sensors can be electronically interfaced with tiny wireless devices. And, with the help of wireless networking technology the information from the infrared sensors can be spread across the enterprise and be aggregated at a central security station to generate a real time status of the fencing. To ensure reliability in data transmission, not only the wireless mesh networking infrastructure can be used, the public GSM service based SMS messages can also be sent to notify concerned person in real time. In case of a breach of security, detected by the infrared sensors, real time alert notifications can also be generated through this kind of Wireless Infrared Intrusion Detection (WIID) system (figure 5).

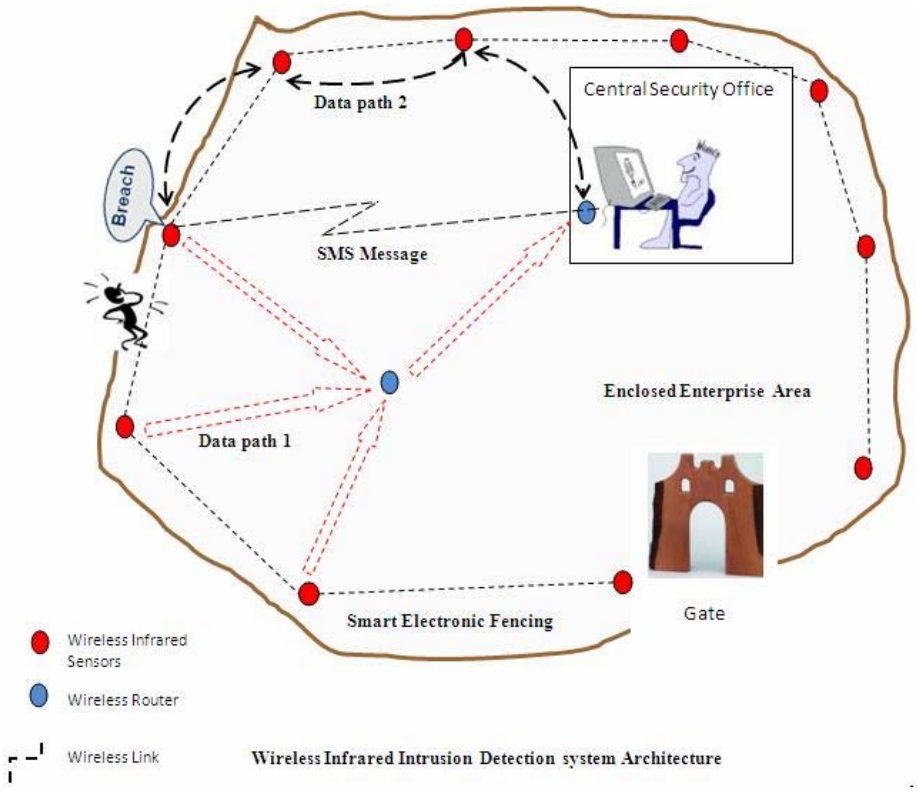

Figure 5. *Conceptual framework for Wireless Infrared Intrusion Detection (WIID) system*
Courtesey: PervCom Consulting Pvt. Ltd.

4. Conclusion

In this paper, we have discussed a ubiquitous framework for *Real-Time Tracking, Sensing and Management System* using Active RFID, Sensors combined with Wireless Mesh Networking technology that can be used to detect emergency events and safety threats and provides warning signals or other control signals to handle the emergency.

In the context of industrial safety and security, the system offers real-time data about workers' location and activity status, level of pollutants in the industry premises, breach of security at industry perimeters. The real-time data helps to get early warning about a possible danger, even enables the authority to spot and alert their workers in case of emergency. The same framework

is used along with IR sensors and other suitable sensors to automatically control boom barriers and detect the event of fishplate removal at once. The system allows view and control of enterprise objects, events "*anytime anywhere*" through the Internet. The proposed framework is generic and has a tremendous application potential to handle safety and security issues in different industrial scenarios with necessary customization.

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