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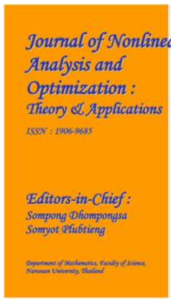

IMPROVING ENERGY EFFICIENCY IN PREDICTED ENERGY AND ACTUAL ENERGY CONSUMPTION USING WSN

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ABSTRACT

Recent advances in sensing modules and radio technology will enable small but smart sensors to be deployed for a wide range of environmental monitoring applications. They collect data from different environment or infrastructures in order to send them to the cloud using different communications platforms. These data can be used to provide smarter services. However, they are various issues and challenges related to the ubiquitous sensors that should be solved. In this paper we interest on analysis of wireless sensor network from an energy management perspective. The idea behind the energy-efficiency wireless sensor networks is that each node can only transmit to a limited number of other nodes directly. The limited resources of nodes imply that the transmission range is limited. In order to transfer the data to the final destination, the traffic must be relayed using intermediate nodes, creating a multi-hop route. The total energy consumption associated with an end-to-end transmission over such a route can be significantly reduced if the nodes are correctly configured. In this paper, underground mine monitoring system is presented with an overview of the related issues and challenges such as reliability, cost, and scalability.

INTRODUCTION

Wireless sensor networks (WSN) are one of today's most compelling emerging technologies. WSN is made up of a large number of inexpensive devices that are networked via low power wireless communications. It is the networking capability that fundamentally differentiates a sensor network from a mere collection of sensors, by enabling cooperation, coordination, and collaboration among sensor assets. Harvesting advances in the past decade in microelectronics, signal processing, wireless communications and networking, wireless sensor network technology is expected to have a significant impact on our lives in the twentyfirst century [1]. Unlike centralized networks, wireless sensor networks are working in ad hoc fashion. The self-configuring, selfhealing characteristics make WSN; and therefore allows them a significant advantage in a large number of situations. The development of this attractive network has many open doors for several numbers of "new and exciting" applications, in which flexibility, easy deployment, and configuration are essential properties. How can IoT help the mining industry? The general objectives can be summarized a as follows [2]-[3]: • Real time monitoring of gases and other parameters; • Monitoring equipment locations and operation statuses to improve productivity and reduce fatal collision accident; • Locating and tracking miners in case of disaster for emergency rescue operations; • Tracking and monitoring assets equipment; • Monitoring miner's unsafe practices and warning. • Automate maintenance and operations of machines – Leads to creation of newer collaboration models with OEMs for monitoring via cloud connectivity and networks. • Standardize processes – Helps build newer business models and highly agile processes at the operations level. • Improve traceability and visibility – Lets users automatically transfer and receive data over a network without requiring human intervention. Moreover, remote monitoring of operations ensures maximum efficiency, improved safety, decreased variability, and better identification of performance issues. • Ensure safety of people and equipment – Integrates mine automation system with automated physical elements to create a real-time, multi-dimensional model from a variety of data sources including the sensors on equipment as well as geological and other data. The system can then be used to optimize and coordinate the mine's layout, operation, and vehicle paths to ensure high efficiency and safety. The measurement of physical parameters makes the sensors the most suitable technology for monitoring and reporting critical quantifiable measures. Sensors though are not just limited to environmental sensing. Any application involving sensing of physical parameters like sound, pressure, temperature, etc., might use sensor networks [3]. The choice of WSN deployment in underground mine should make a compromise between conflicting requirements. The priority is to ensure a robust global network with battery-operated nodes. Therefore, these types of systems are usually developed with the following goals in mind. In short, there is an abundance of applications that could utilize wireless ad hoc networks. However, the other side of the coin is the numerous challenges associated with this kind of system. First, the nodes are, in most cases, tiny devices and often battery-powered. Some applications have stringent QoS requirements in terms of timely delivery of packets (bounded delay), high packet delivery ratio, and low jitter. Packet delay is directly related to the number of hops traversed by the packet and the congestion level of the network, while other networks might have a required system lifetime [4]-[5]. The distributed and the mobile nature of wireless sensor network combined with the QoS requirements makes traditional protocols unsuitable. Therefore, an alternative analysis should be adopted for the design of WSN [6]. Another technique, called modulation scaling, which exhibits benefits similar to those of voltage scaling has been presented in [7]. In [8], an adaptive modulation scheme for a point-to-point path loss Additive White Gaussian Noise (AWGN) channel has been investigated. In this work, the authors included circuit energy in the total energy budget. This creates a trade-off: Transmitting at a high rate requires more transmission power, but a shorter period is required to transmit the packet, thereby saving circuit energy, and vice versa. Routing problems are usually considered to be the core of wireless sensor network design. However, in most application scenarios, WSN nodes are powered by small batteries, which are often in practice non-rechargeable. Therefore, software solution, which combines cross-layer and energy-aware system design to increase energy efficiency, is a promising way worth exploring [5]. Bhardwaj and Chandrakasan [10] have provided upper bounds on the lifetime of sensor networks where sensor node locations are given. In [11], the authors propose a transmission range optimization scheme to maximize thenetwork lifetime given fixed node locations. However, many of these routing protocols separate the different layers (physical layer, medium access, and routing). This may lead to largely suboptimal network designs. Recently, many works are focused on "energy-efficiency routing." Joint power control and scheduling have been proposed in [12]. A hierarchical cross-layer design approach through mutual adaptation of nodes transmitting powers and route selection is proposed in [13] to increase network lifetime [14]-[18]. For instance, in the Radio Network model, the interference from non-neighboring nodes is neglected, and Signal to Interference- plus-Noise Ratio (SINR) is a simplified model. In addition, we consider an isolated network settings, by neglecting the interference from nodes that are not participating in the cooperation scheme. The paper focus on the link budget between two nodes to find minimized communication parameters by numerical analysis.

LITERATURE SURVEY

L. K. Bandyopadhyay, S. K. Chaulya, P. K. Mishra. (2009), "Wireless Communication in Underground Mines: RFID-based Sensor Networking", Springer Editions.

Recent advances in sensing modules and radio technology will enable small but smart sensors to be deployed for a wide range of environmental monitoring applications. They collect data from different environment or infrastructures in order to send them to the cloud using different communications platforms. These data can be used to provide smarter services. However, they are various issues and challenges related to the ubiquitous sensors that should be solved. In this paper we interest on analysis of wireless sensor network from an energy management perspective. The idea behind the energy-efficiency wireless sensor networks is that each node can only transmit to a limited number of other nodes directly. The limited resources of nodes imply that the transmission range is limited. In order to transfer the data to the final destination, the traffic must be relayed using intermediate nodes, creating a multi-hop route. The total energy consumption associated with an end-to-end transmission over such a route can be significantly reduced if the nodes are correctly configured. In this paper, underground mine monitoring system is presented with an overview of the related issues and challenges such as reliability, cost, and scalability. Wireless sensor networks (WSN) are one of today's most compelling emerging technologies. WSN is made up of a large number of inexpensive devices that are networked via low power wireless communications. It is the networking capability that fundamentally differentiates a sensor network from a mere collection of sensors, by enabling cooperation, coordination, and collaboration among sensor assets. Harvesting advances in the past decade in microelectronics, signal processing, wireless communications and networking, wireless sensor network technology is expected to have a significant impact on our lives in the twentyfirst century [1]. Unlike centralized networks, wireless sensor networks are working in ad hoc fashion. The self-configuring, selfhealing characteristics make WSN; and therefore allows them a significant advantage in a large number of situations. The development of this attractive network has many open doors for several numbers of "new and exciting" applications, in which flexibility, easy deployment, and configuration are essential properties. How can IoT help the mining industry? 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Moreover, remote monitoring of operations ensures maximum efficiency, improved safety, decreased variability, and better identification of performance issues. • Ensure safety of people and equipment – Integrates mine automation system with automated physical elements to create a real-time, multi-dimensional model from a variety of data sources including the sensors on equipment as well as geological and other data. The system can then be used to optimize and coordinate the mine's layout, operation, and vehicle paths to ensure high efficiency and safety. The measurement of physical parameters makes the sensors the most suitable technology for monitoring and reporting critical quantifiable measures. Sensors though are not just limited to environmental sensing. Any application involving sensing of physical parameters like sound, pressure, temperature, etc., might use sensor networks [3]. 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The distributed and the mobile nature of wireless sensor network combined with the QoS requirements makes traditional protocols unsuitable. Therefore, an alternative analysis should be adopted for the design of WSN [6]. Another technique, called modulation scaling, which exhibits benefits similar to those of voltage scaling has been presented in [7]. In [8], an adaptive modulation scheme for a point-to-point path loss Additive White Gaussian Noise (AWGN) channel has been investigated. In this work, the authors included circuit energy in the total energy budget. This creates a trade-off: Transmitting at a high rate requires more transmission power, but a shorter period is required to transmit the packet, thereby saving circuit energy, and vice versa. Routing problems are usually considered to be the core of wireless sensor network design. However, in most application scenarios, WSN nodes are powered by small batteries, which are often in practice non-rechargeable. Therefore, software solution, which combines cross-layer and energy-aware system design to increase energy efficiency, is a promising way worth exploring [5]. Bhardwaj and Chandrakasan [10] have provided upper bounds on the lifetime of sensor networks where sensor node locations are given.

A. Chehri, P. Fortier, P.-M. Tardif, (2006) "Deployment of Ad-Hoc Sensor Networks in Underground Mines", Sixth International Conference on Wireless Sensor Networks, WSN 2006, Banff, Alberta, Canada.

Wireless Sensor Networks (WSNs) offer numerous advantages over traditional networks, such as elimination of costly wires, enhanced monitoring precision and larger area coverage. This paper presents the design and implementation of a mine temperature monitoring based on sensor networks. For the proposed monitoring schema, we evaluated the performance and the interoperability of sensor network with various network such as IEEE 802.11g (WiFi), IEEE 802.11s (wireless mesh network) and Internet. So the ambient temperature of a mine gallery can be measured and displayed in real time no matter where we are. In addition we describe some initial results of link characteristics. We discuss on the sensor wireless link performance in terms of the received signal strength. A wireless sensor network (WSN) in its simplest form can be defined as a network of low-size, low-complex and locally powered sensor nodes that can sense the environment and communicate the information gathered from the monitored field through wireless links. The data is forwarded via multiple hops relaying to a central node (or sink) that can use it locally, or is connected to other networks through a gateway. The claim of wireless sensor network proponents is that this technological vision will facilitate many existing application areas and bring in to existence entirely new ones [1], [2]. Detection of world's physical parameters makes sensors most suitable technology for monitoring. Sensors though are not just limited to environment sensing. Any application involving sensing of physical parameters like sound, humidity, pressure, temperature, etc, might use sensor network. Considering the importance of this technology, a deployment of WSN in mining industry can be considered as original application. For example, an operator could remotely supervise different physical phenomena in the mine from his computer and thus provide safe air/oxygen for the miners underground by monitoring the level of methane and other noxious gases, dust and particulates from sources such as diesel vehicles. He could also monitor the temperature, detect any anomaly, or locate workers and objects in the galleries of the mine in real time. These applications can be seen as a first step toward the concept of "smart mine". Usually, we verify performance of any network by using simulations or experiments. In simulations, we cannot control precise packet timing, radio range transmission, an unlimited memory and processing resources, and real PHY/MAC layer events. In fact, not all simulation results are equal to the real experiments. In real experiments, we have complex environment settings and resource sharing problems. In this paper, we discuss the challenges and requirements of developing efficient WSN for temperature monitoring for mining industry. For this reason, we have set up a testbed at CANMET1 that provides a heterogeneous platform to support realistic environmental data measurement application. Real time monitoring of gases and other parameters; • Monitoring equipment locations and operation statuses to improve productivity and reduce fatal collision accident; • Locating and tracking miners in case of disaster for emergency rescue operations; • Tracking and monitoring assets equipment; • Monitoring miner's unsafe practices and warning. • Automate maintenance and operations of machines – Leads to creation of newer collaboration models with OEMs for monitoring via cloud connectivity and networks. • Standardize processes – Helps build newer business models and highly agile processes at the operations level. • Improve traceability and visibility – Lets users automatically transfer and receive data over a network without requiring human intervention.

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A. Chehri, P. Fortier, P.-.M. Tardif, (2007) "Security monitoring using wireless sensor networks", Proceedings of the IEEE Communication Networks and Services Research, CNSR'07, pp. 13-17.

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A. Chehri, P. Fortier, P.-M. Tardif, (2009) "Cross-layer link adaptation design for UWB-based sensor networks", Comput. Commun., 32(13), 1568-1575.

A routing protocol is essential for the success of wireless sensor networks (WSNs). Its task is to ensure a reliable communication between neighbouring nodes, and to transmit data (via an intermediate node) form any node to the central node. However, unlike traditional ad hoc networks, WSN are energy constrained since nodes operate with limited battery capacity. Thus, the routing protocols for WSN must be designed with a focus on the energy efficiency criterion. This paper presents a cross-layer link adaptation scheme for an energy efficient routing protocol for ultra-wideband (UWB)-based sensor networks. We use a joint consideration of physical and multiple access layer in order to minimize the energy consumption of the network, and hence increasing its lifetime. Multiple accesses are assumed to have a UWB time-hopping signalling structure. Our goal is to define the link adaptation as a numerical optimization in which the energy consumption of a multihop route is taken into account. Wireless sensor networks are special ad hoc networks with large number of nodes collaborating to accomplish common tasks such as data environment collection, security monitoring and positioning. Wireless sensor networks (WSNs) are energy constrained, while all nodes operate with limited battery capacity; their coverage is usually limited to a few meters.

The interest in low energy consumption is growing steadily. In fact, the energy efficiency is the key issue for wireless sensor networks, which mainly rely on limited batter power. In these types of networks the focus is more on minimizing energy consumption than maximizing rate.

Ultra-wideband (UWB) is an emerging technology for short-range wireless communications. UWB technology has several advantages over more conventional technologies. It seems to be a viable candidate to offer ideal solutions for sensor networks applications [1]. In fact, UWB based systems have potentially low complexity and low cost, use noise-like signal, very high time-domain allowing for location application and are robust to multipath fading and jamming. For the energy consumption, UWB has the potential of efficient operation, since UWB has the lowest consumed energy per bit among other RF technologies according to the measurement and simulation results [2].

Energy efficiency in UWB sensor networks depends mainly on the time a node has to listen, receiving or idle listening requires a lot more energy than sending or active-off states [3]. Therefore, an efficient management of the limited power supply is the key element for achieving acceptable network lifetimes.

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Many routing algorithms have been proposed in prior researches. The shortest path is the typical and fundamental consideration for network flow routing problems [4]. Bhardwaj and Chandrakasan [5] have provided upper bounds on the lifetime of sensor networks where sensor node locations are given. In [6], the authors propose a transmission range distribution optimization scheme to maximize the network lifetime given fixed node locations. However, many of these routing protocols separate the different layers (physical layer, medium access and routing). This may lead to largely suboptimal network designs.

Weilian Su and Tat L. Lim. (2006) "Cross-layer design and optimization for wireless sensor networks", In SNPD-SAWN '06: Proceedings of the Seventh ACIS International Conference on Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing (SNPD'06), pages 278–284, Washington, DC, USA.

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A. Chehri, G. Jeon, and B. Choi, "Link-quality measurement and reporting in wireless sensor networks," Sensors, vol. 13, no. 3, pp. 3066-3076, March 2013.

Wireless Sensor networks (WSNs) are created by small hardware devices that possess the necessary functionalities to measure and exchange a variety of environmental data in their deployment setting. In this paper, we discuss the experiments in deploying a testbed as a first step towards creating a fully functional heterogeneous wireless network-based underground monitoring system. The system is mainly composed of mobile and static ZigBee nodes, which are deployed on the underground mine galleries for measuring ambient temperature. In addition, we describe the measured results of link characteristics such as received signal strength, latency and throughput for different scenarios. In recent years, wireless sensor networks have attracted significant attention due to their integration of wireless, computing, and sensor technology. Wireless sensor networks consist of a number of nodes that are equipped with processing, communicating and sensing capabilities. They use *ad hoc* radio protocols to forward data in a multi-hop mode of operation [**1**]. In the mining industry, sensor networks can provide prompt response to identification of workers entering or leaving a mine, control personnel traffic into hazardous areas to provide warning indication signals, identification of vehicles entering or leaving production areas or passing specific locations in the mine, tracking of supplies and materials, reducing the fatal accidents due to collision, monitoring of underground gases, and maintenance scheduling. The general objectives can be summarized as follows [**2**]:

- Real-time monitoring of gases and other parameters;
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- Locating and tracking miners in case of disaster for emergency rescue operations;
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- Monitoring miner's unsafe practices and warning;

Generally speaking, the measurement of physical parameters makes the sensors the most suitable technology for monitoring and reporting important quantifiable measurements. Besides, sensors are not just limited to environment sensing. Any application involving sensing of physical parameters like sound, humidity, pressure, temperature, *etc.*, might use sensor network [**3**–**9**].

When choosing the deployment of WSN in underground mine, it may be necessary to make a compromise between conflicting requirements. The priority is to ensure a robust global network with battery-operated nodes. Therefore, these types of networks are usually developed with the following goals in mind. Firstly, the nodes must be able to communicate with other nodes via a highly reliable radio module that is compatible with the communication protocol of the network, such as the IEEE 802.15.4 standard in our case. Secondly, the network should be robust to monitor the required measurements, such as temperature, for a long time.

We deployed a wireless sensor network in experimental underground mines, CANMET (Canadian Center for Minerals and Energy Technology (CANMET) experimental mine). The network contains all elements of the architecture. To harden the test nodes and other hardware against temperature conditions, dust, and humidity present in underground mines, we designed environmental protective packaging to protect the hardware. The selected nodes by their design are fairly robust mechanically, with the battery case firmly integrated with the main processing and sensor boards [10]. Wireless communication is achieved with a transceiver compliant with the IEEE 802.15.4/ZigBee™ standard. ZigBee™ is a global standard for wireless network technology that addresses remote monitoring, environmental data measurements and control applications. ZigBee™ is an open specification that enables low power consumption, low cost and low data rate for short-range wireless connections between various electronic devices. In wireless networks, several applications and protocols utilize link quality estimations to enhance the performance of the system. However, a precise characterization of wireless links in realistic wireless networks is a challenging problem since the links experience frequent channel variations and complex interference patterns [10]. Usually, we verify the performance of any network by using simulations or experiments. In simulations, we cannot control precise packet timing, radio transmission range, memory, processing resources, and real PHY/MAC layer events [11,12]. In fact, not all simulation results are equal to the real experiments. In real experiments, we have complex environment settings and resource sharing problems.

In this paper we conducted measurements and analysis of the link quality between sensor nodes. However, the link impairments (hence quality) are intimately linked to MAC operation and therefore cannot be estimated purely on the basis of PHY measurements such as signal-to-noise ratio (SNR), even if the study integrates the MAC and PHY layers in the same problem. The MAC layer is not investigated deeply in this paper. In addition, high level measurements such as throughput and delay statistics could be better indicators of the link quality.

C. Schurgers, O. Aberborne, M. Srivastava, (2001) “Modulation scaling for energy-aware communication systems”, in ISLPED, 96-99.

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Generally speaking, the measurement of physical parameters makes the sensors the most suitable technology for monitoring and reporting important quantifiable measurements. Besides, sensors are not just limited to environment sensing. Any application involving sensing of physical parameters like sound, humidity, pressure, temperature, *etc.*, might use sensor network [3–9].

When choosing the deployment of WSN in underground mine, it may be necessary to make a compromise between conflicting requirements. The priority is to ensure a robust global network with battery-operated nodes. Therefore, these types of networks are usually developed with the following goals in mind. Firstly, the nodes must be able to communicate with other nodes via a highly reliable radio module that is compatible with the communication protocol of the network, such as the IEEE 802.15.4 standard in our case. Secondly, the network should be robust to monitor the required measurements, such as temperature, for a long time.

We deployed a wireless sensor network in experimental underground mines, CANMET (Canadian Center for Minerals and Energy Technology (CANMET) experimental mine). The network contains all elements of the architecture. To harden the test nodes and other hardware against temperature conditions, dust, and humidity present in underground mines, we designed environmental protective packaging to protect the hardware. The selected nodes by their design are fairly robust mechanically, with the battery case firmly integrated with the main processing and sensor boards [**10**]. Wireless communication is achieved with a transceiver compliant with the IEEE 802.15.4/ZigBee™ standard. ZigBee™ is a global standard for wireless network technology that addresses remote monitoring, environmental data measurements and control applications. ZigBee™ is an open specification that enables low power consumption, low cost and low data rate for short-range wireless connections between various electronic devices. In wireless networks, several applications and protocols utilize link quality estimations to enhance the performance of the system. However, a precise characterization of wireless links in realistic wireless networks is a challenging problem since the links experience frequent channel variations and complex interference patterns [**10**]. Usually, we verify the performance of any network by using simulations or experiments. In simulations, we cannot control precise packet timing, radio transmission range, memory, processing resources, and real PHY/MAC layer events [**11**,**12**]. In fact, not all simulation results are equal to the real experiments. In real experiments, we have complex environment settings and resource sharing problems.

In this paper we conducted measurements and analysis of the link quality between sensor nodes. However, the link impairments (hence quality) are intimately linked to MAC operation and therefore cannot be estimated purely on the basis of PHY measurements such as signal-to-noise ratio (SNR), even if the study integrates the MAC and PHY layers in the same problem. The MAC layer is not investigated deeply in this paper. In addition, high level measurements such as throughput and delay statistics could be better indicators of the link quality.

CONCLUSION

In this work, we investigate a route optimization problem for wireless sensor networks for localization and monitoring in underground mines. Our goal is to adapt all routes in the networks to transmit the data from any node to the central node with the best energy performance. This is calculated according to a certain quality of service (QoS) in under to provide an energy-efficiency routing strategy. The algorithm should be taking into account the mobility of the node as well as the propagation characteristics of the underground mines channel. The optimization formulation assumes that at least an existing route has been found between node and sink. It allows QoS requirements in terms of end-to-end bit error rate. The analysis given here takes into account the mutual interactions between the physical and routing layer. In fact, the cross-layer study is still a complex problem. Hence, some assumptions must be considered to give a useful analysis.

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