A Survay on Underground Distributed Wireless Sensor Networks:Design & Research Challenges

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Abstract: This paper introduces the concept of design and research challenges in wireless underground distributed sensor networks. Generally WSN's plays a vital role in the development of communication, sensor technologies and owned worldwide attention in recent years. The major application areas of WSN's are distributed data collection, environment monitoring, healthcare, agriculture and underground survivalence etc. Generally, the sensors used for underground communication is to perform the functionalities such as monitoring verity of conditions like soil salinity, water content and temperature for agricultural applications, environment monitoring etc. the major challenge for the designers is to establish effective communication between sensor nodes in underground like water environment soil environment etc, which is the challenging task compared to air medium. This work provides an overview of applications and design challenges for WUSNs, deployment of sensor nodes in the underground and existing, proposed commendations methods between underground sensor nodes and above ground sensor nodes and challenges for the underground communication channel including methods for predicting path losses in an underground link.

Index Terms—Underground communication, sensor nodes, distributed data collection.

I. INTRODUCTION

In present days, the importance of wireless sensor networks plays a vital role in many application areas such as industries, agricultural monitoring, and environmental monitoring (earthquakes, animals, volcanoes etc...), and healthcare and particularly in underground communication etc. A Wireless sensor network is a collection of sensing devices that can communicate wirelessly [1]. Each device senses the input from other device and processes it and communicates to its neighboring nodes. Historically, WSN's have been characterized as wireless networks consisting of numerous small, energy constrained, low cost, autonomous nodes that are distributed over an area for the purpose of monitoring and sensing [1][2]. The ultimate goal of WSN's is long lasting, flexible and reliable operation of nodes with respect to security and routing.

The sensor networks are already implemented in existing and potential applications from commercial agricultural and geology to security and navigation has limited capabilities for monitoring various underground conditions. Generally field conditions are the important deciding factor for agricultural production. Data acquisition method is one of the primary technical problems in field information research and realization in modern agricultural production, which can collect variable information of crop growth environment in many-sides, accurately, rapidly and effectively. It is also the key and decisive factor of the modern efficient agricultural production. Perception, processing, management decision-making and Information integration control of farmland information has become the focus in the field of contemporary international agricultural science and technology research. The wireless sensor network technology has been applied in agricultural information monitoring field, and it has achieved good scientific research achievements. In case of underground communication water as the medium (like in the sea etc.), the major challenging factors are strength of signal and distance of communication etc. The Electromagnetic waves can easily attenuated in the water, so that it's not possible to transmit information to long distance [3].

A. Applications of WUSN:

WUSN's have many application areas such as agriculture, infrastructure monitoring, earthquake monitoring, environmental monitoring, Border patrol and security monitoring, underwater communication in the seas etc...

I. Environmental monitoring: Wireless underground sensor networks can be used to monitor the soil in conditions such as

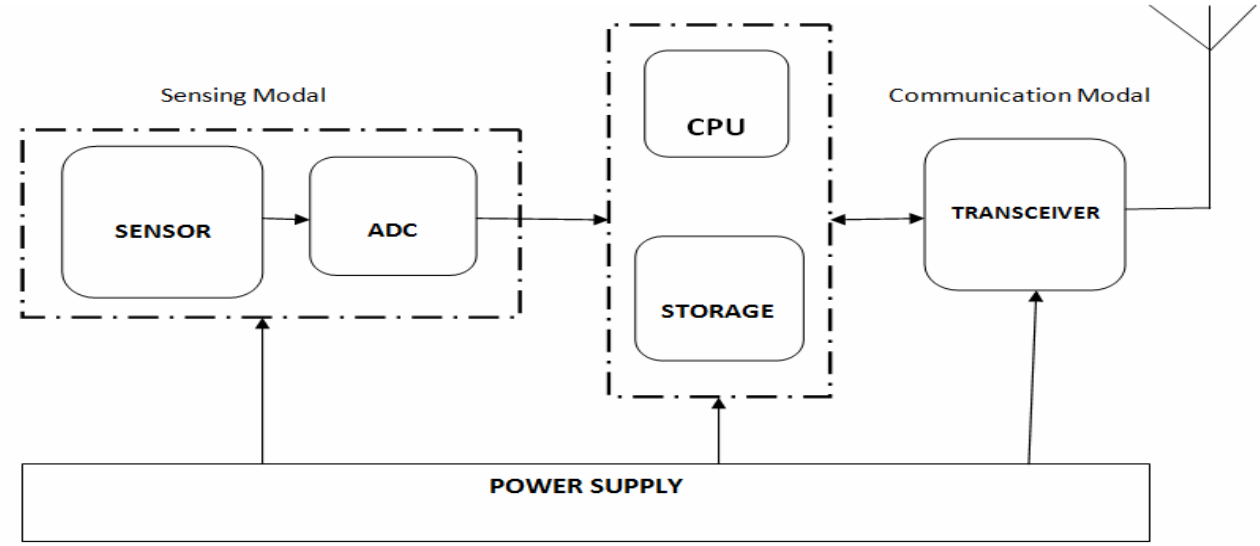
- Monitor soil water and mineral content for irrigation
- Monitor soil conditions for sports field monitoring
- Monitor soil movement for landslide prediction
- Coal mine monitoring
- Monitor glacier movement
- Earthquake monitoring

II. Infrastructure monitoring: WUSN's used to monitor the Underground infrastructure like pipes, wiring etc. also these WUSN's are used for Monitoring underground components of bridges, dams etc.

III. Security – WUSN's can have the ability to monitor the aboveground presence and movement of the people and objects with the use sensors like pressure, vibration, or sound. This may be useful for business and home

security as well as for military applications. On extend these WUSN's can be used for border patrol by deploying wireless pressure sensors along length of the border could be used for the detection of intruder or an object and information will be transmitted to responsible authority[4].

The figure2 shows the communication between mote and gateways. All the motes are comminicate wirelessly and gateway uses wired communication with mote. For long distance communication gateway is interfaced with internet so that infromation will be open, hence it can be accessd by using any communication device.



Fgure1: Architecture of wireless underground sensor node

II. Architecture of WUSN

The figure1 shows the general architecture of wireless underground sensor node. The system structure is composed of four modules such as sensing module, processing module, communication module and power supply module.

The sensing module uses the sensor and ADC device. The system uses different types of sensors for different verity of applications but the selection of sensor should have minimum characteristics of miniaturization, low power consumption, high performance, strong anti-interference ability and it should easily interface with processor/ controller used in the design of sensor node [5].

The communication module composes of a transceiver and antenna, which are used for transmission and reception wirelessly between the sensor nodes in underground.

Along with WUSN node, the designers will develop the sink node which is generally placed on the top the ground which acts as central hub having the effective communication with all the WUSN nodes in underground, the structure of sink node as similar to WUSN node.

III. Sensors deployment for designing of motes and gateways

Motes and gateways are two different types of sensor nodes which are used for construction of wireless sensor network. Motes are the devices which are connected wirelessly over an area and give the information to the sink [6]. This mote will connected to gateway through wired communication. This gateway provides out of network connectivity.(e.g.: internet)

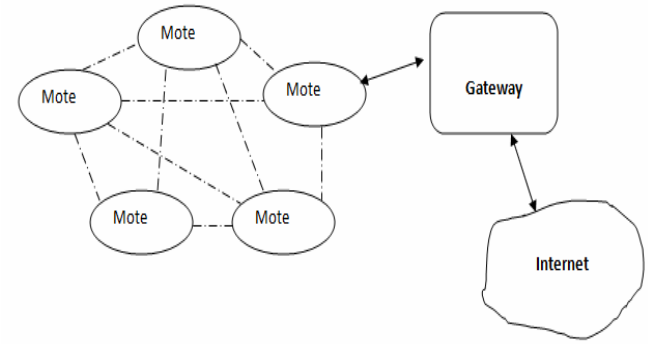


FIGURE2: COMMUNICATION BETWEEN MOTE AND GATEWAY

A. Existing Method for deployment:

In the existing methodology, underground sensing systems require data loggers or motes or gateways deployed at the surface of the ground providing wired communication to underground sensors in order to avoid the challenge of wireless communication in the underground. All of these existing solutions require sensor devices to be deployed at the surface and wired to a buried sensor. There are certain limitations that can impede new and more varied uses. These equipment exposed on the ground not only influence farming, wireless transmitting functions of wireless node also be affected because of geography, meteorology and natural factors. The limitations of existing methodology can be shown in below table[6][7]

Table1: Limitations and comparisons with WSN's and WUSN's

Concealment	• In existing systems the dataloggers are deployed on surface of soil • Communication is easier as no underground communication is involved • Above ground equipment is vulnerable to agricultural and landscaping equipment or unacceptable for aesthetic reasons • In WUSN the equipment is underground secure from any theft and protected from damage
Ease of deployment	• Current technology uses wired systems • Tough to add new sensors or data loggers • No scalability issues with WUSN as its fully wireless
Timeliness of data	• Due to wireless nature the data from sensors is forwarded in real time to sink. • In data loggers the data may be stored for later retrieval
Reliability	• Current systems are fully dependent on data loggers • Data logger failure means whole network failure • Each sensor can forward sensor readings independently • WUSN's are self healing
Coverage density	• Current systems require the sensor to be deployed close to the data logger, it results in less coverage • Sensors can be deployed anywhere, hence increasing the coverage area

Based on these disadvantages, the wireless underground sensor networks (WUSN) provide a new method for underground monitoring. WUSN has also become a new research direction in the agricultural industry. Sensor equipments with wireless receiving and send module have been completely deployed in certain depth of soil, induction module sending data in the way of wireless when it perceives data. Many sensor nodes were formed into sensor networks, which complete automatically the whole process of perception and collection of data.

IV. WUSN DESIGN CHALLENGES

The design of sensor node itself a challenging task for the designers, it has to meet all the design considerations for its proper functioning. In particular Wireless underground sensor nodes have several challenges such as power conservation, topology design, antenna design and environmental conditions**.**

A) Power consumption:

power conservation is a primary concern in the design of WUSN's. It is the major challenging task for the designers to design the sensor node capable to transmit the information to more distance with less power consumption. Generally, it is not that much challenging if the sensor node placed is above ground, it could be difficult task if the sensor node is deployed in underground. The sensor nodes which are placed in underground work battery power because it's not possible to provide continuous power to the nodes[8]. So if power consumption is more the battery will easily destroyed and needs to recharge the battery, it's a typical task every time. So the remedy is to decrease the power consumption by the node so that life time will increases.

B) Topology design:

The design of an appropriate topology for WUSNs is of critical importance to network reliability and power conservation. WUSN's have two topologies such as underground topology and hybrid topology. The selection of topology is based on some considerations like intended application, power usage minimization and cost.

- **Underground topology:** In this topology al the sensors are deployed in underneath of a surface except the sink node. The sink node normally placed above the ground or below the ground, and all the protocols and routing algorithms are developed such that, it receives information from all the sensor nodes. Here all the sensors are at same depth or at different depths depends on the application[9]. The depth of the sensor also depends on the application, for example if it is a pressure sensor, needs to keep near to the surface or if it is a soil water sensor, needs to be placed longer depth near to roots of the plants.

- **Hybrid topology:** This topology is a mixture of underground and above ground topologies. The use of underground topology is require more power and also needs to design more sensors between source and destination because in the soil or water the Electromagnetic waves can be easily attenuated, hence this reason the designers will choose the hybrid model [9]. In this topology nodes are placed at the underground and above ground, the sensor node placed above ground is movable such that it can collects all the information from underground sensors.

C) Environmental extremes:

The underground environment is far from an ideal location for electronic devices. Water, temperature extremes, animals, insects, and excavation equipment all represent threats to a WUSN device, and it must be provided with adequate protection. Processors, radios, power supplies, and other components must be resilient to these factors [10]. Additionally, the physical size of the WUSN device should be kept small, as the expense and time required for excavation increase for larger devices. Battery technology must be chosen carefully to be appropriate for the temperatures of the deployment environment while balancing environmental considerations with physical size and capacity concerns. Devices will also be subjected to pressure from people or objects moving overhead or, for deeply deployed devices, the inherent pressure of the soil above.

V. COMPARISON BETWEEN WUSN AND WSN

The protocols which are used for providing security and routing in adhoc wireless networks are not efficient in wireless underground sensor networks because there are

several environmental differences in WUSN's and WSN's [11]. The differences are shown in table 2.

Table 2: Comparision between WUSN and WSN

Parameter	WUSN	WSN
Establishment	2004	1990
Frequency	Acoustic Waves	Radio Waves
Environment	Soil, rock and narrow Coal mines	Open and Terrestrial
Application	Agriculture, Coal mines	Environment Monitoring
Power Consumption	More	Less
Cost	More	Less
Protocol	GEAR, GEAR-R	AODV, DSR, DSDV etc
Node to Node Delay	More	Less
Duplication of Packets	More	Less

The difference mainly occurs because WUSN's, most sensors will be deployed by drilling a hole for each one, and thus, detailed location information can be recorded at the time of deployment.

VI. Conclusion

In this paper we introduced the concept of Wireless Underground Sensor Networks in which the sensor devices such as motes and gateways are deployed completely below ground. There are many applications of WUSN's such as soil monitoring for agriculture, underground security etc [11]. There are some existing methodologies for implementing sensor networks and we proposed some methodologies and benefits of WUSN's over current sensing solutions including concealment of network, ease of deployment of sensor node in underground etc. We demonstrated the design challenges of WUSN's, which enables the designers while designing the sensor nodes for the extended applications like military, sports where sensors should be hidden to avoid detection and deactivation. Underground is a particularly difficult environment for wireless communication which poses several research challenges for WUSNs.

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