2014 3rd International Conference on Geological and Environmental Sciences
IPCBEE vol. 73 (2014) © (2014) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2014. V73. 2

Communication Networks in the Service of the Environmental Monitoring

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Abstract. In the paper selected issues relating to communication networks in the services of the environmental monitoring (EM) have been described. It is divided into three main parts: introduction, wire and wireless networks. At the beginning of the basic definitions were explained. The wire part focuses on a plain old telephone service (POTS), an integrated services digital network (ISDN), a digital subscriber line (DSL) and a fiber-optic technology (FOT). On the other hand, the wireless part focuses on short-range wireless networks, cellular networks and satellite networks. Finally, the last section concludes the paper. The advantages and disadvantages of both solutions (wire and wireless) for EM application have been presented.

Keywords: Environmental monitoring, environmental protection, communication system.

1. Introduction

Environmental monitoring (EM) can be defined as the observation of the presence of harmful factors such as toxins, bacteria, chemicals and other pollutants in a specific location. On the other hand environmental monitoring is a system of detection, measurements, evaluations and forecasts of environmental states, and the collecting, processing and spreading of information on the environment [1]. The EM is an important part of measuring the positive or negative effects of a given project or event. Technological advances have been an important driving force behind the growth of the EM. Technology today is faster, more advanced, and more reliable than in the past, which has allowed for environmental information to be shared almost instantly, even when there are great distances between providers and their sources. We have seen a tremendous increase in environmental monitoring applications, and there are thousands of news articles and peer-reviewed publications available regarding EM around the world. Environmental monitoring requires electronic data communications networks to facilitate the exchange of environmental information between two or more parties. In connection with this a data communications network is simply defined as two or more hosts, such as computers, connected together by some interconnecting media that facilitates information sharing among them. The type of network needed will depend on the specific needs for your EM application, but some points to consider are bandwidth, security, and mobility requirements [2]. In this paper basic type of communication networks in the service of the environmental monitoring have been described. There are two major type of communication networks: wired networks, in which the transmission of information is via fiber or copper cabling and wireless networks, in which the transmission of information is via radio waves. Moreover there are two major modes for conducting environmental monitoring: store and forward (asynchronous) and real time (synchronous).

Store-and-forward solution refers to asynchronous transmission of environmental information that can be accessed at a later date or time. This includes images, videos, documents, or any form of digital information that can be transmitted from one computer to another. A major benefit of store-and-forward solution is that information can be sent and accessed at one's earliest convenience from any location with access to the network. This means that environmental information can be available 24 hours a day, 7 days a week.

Real-time monitoring is the synchronous transfer of environmental information between two or more parties. A primary benefit of real-time solution is the instantaneous availability of environmental information. The networking infrastructure must be reliable, free of errors and congestion, and preferably managed by quality of service (QoS).

Both wired and wireless network technologies can provide excellent performance, and both can have problems. Wireless communications are generally less reliable than wired over time, but in some cases wired communications are not feasible.

The environmental monitoring issue became a subject of research at the Department of Radio Communication Systems and Networks in cooperation with the Department of Analytical Chemistry. This research team developed the original applications of the mobile monitoring system for gas air pollution measurements [3]-[6] and the data monitoring system with self-organizing sensors network destined for treats monitoring [7]-[9]. The air pollution monitoring system has been tested by the foundation ARMAAG (Agency of Regional Air Quality Monitoring in Gdansk metropolitan area) in real conditions.

This paper is organized as follows. Section 2 describes an overview of wire technologies used for environmental monitoring. Section 3 presents an overview of wireless networks for EM application. Finally, Section 4 concludes the paper.

2. Wire Networks

Today's wire communication networks can be considered to consist of three sub-networks: access (spanning about 1 to 10 km), metropolitan (covering about 10 to 100 km), and long haul (extending to 100s or 1000s of km). Typically, the network topology for access can be a star, a bus, or a ring; for metro a ring; and for long haul a mesh [10]. Each of these sub-networks has a different set of functions to perform. For example, for the long-haul network, carriers are more concerned with capacity, protection, and restoration, while for the metro or access network, carriers are more concerned with service provisioning, flexibility, etc. A star topology is a common type of network topology in which remote systems and nodes are connected point-to-point to a central system, and not to one another. If the central system on a star network fails, the entire network is unable to intercommunicate. One advantage is centralized administration and security. Star topologies are used in many phone and data networks. A bus topology is a network topology in which individual nodes are connected to a single communications line which is terminated at either end. If one node or system goes down, it affects the entire network. A ring topology is a network topology in which each station in the network is connected in a closed loop so that no termination is required. It is very close by the previous one. A mesh topology is a type of topology in which data can travel back along the backbone if a node becomes unavailable due to a disruption, such as line breakage or failure [11].

An example of access network is a plain old telephone service (POTS), a standard analog dial-up telephone service that provides voice and limited amounts of data between two points. POTS is the most basic form of communications used to conduct environmental monitoring. The maximum bandwidth that can be achieved over a dial-up network connection using POTS is around 56 kbps. However, factors such as telephone line quality and dropped calls can greatly reduce actual data transmission throughput speeds. An integrated services digital network (ISDN) is a digital telephone technology that utilizes existing telephone system copper wiring. ISDN offers a substantial improvement over a single POTS connection because it utilizes two or more simultaneous data channels, and because it is a digital network it greatly improves performance and reliability compared to analog dial-up networking. This allows ISDN to send and receive at least twice the bandwidth of standard phone lines at rates of 128 kbps. Digital subscriber lines (DSL) are very similar to ISDN networks in that they transmit information through pre-existing telephone lines. There are several differences that make DSL a better choice over ISDN. One of them is that DSL lines are less expensive than ISDN services and provide a similar range of performance.

Generally, metropolitan and long haul sub-networks are based on a fiber-optic technology (FOT). This technology is characterized by potentially limitless capabilities: huge bandwidth (nearly 50 Tbps), low signal attenuation, low signal distortion, low power requirement, low material usage, small space requirement, and low cost.

3. Wireless Networks

The existing wired-based environmental monitoring systems are generally uncomfortable for users. Wired systems restrict users' mobility and comfort level. Future implementation of EM solution will based on small, low-power sensor nodes with wireless capability. The majority of the existing environmental monitoring systems use the short-range wireless system such as ZigBee (IEEE 802.15.4 standard) and Bluetooth (IEEE 802.15.1 standard). These technologies are used to collect data from low-power sensor nodes.

In the last decade the construction of EM systems used cellular networks. Currently, mobile broadband download speeds can range anywhere from 200 kbps to 14 Mbps, depending on the service used, and future 4G technology could achieve up to 100 Mbps [12]. Upload speeds will be significantly less than the download speeds. Mobile broadband is a very flexible option because you can make a connection anywhere you have cell phone service. Unfortunately, during an emergency or disaster, cellular communication lines are usually one of the first systems to go down. However, cellular technologies are becoming a new way to instantly share stored information.

Satellite connectivity is a unique form of wireless broadband access. Connectivity is based through satellites thousands of miles above the Earth [13]. It is particularly useful for users in remote locations and for times of emergency when terrestrial forms of communication are down or destroyed. Transmissions via satellite communications must travel over thousands kilometres before reaching their destination. These great distances that time becomes apparent in the form of latency in our communications. This latency is most apparent in real-time communications. Satellite connections, however, can provide very usable asynchronous communications services and are capable of several megabit download speeds. Upload speeds are typically much slower – hundreds of kilobits per second.

4. Conclusions

Network connectivity is one of the most important considerations when developing an environmental monitoring system. Considerations must be based on the type of information that will be sent across networks, type of EM system (real time or store and forward) that will be implemented, availability of technical infrastructure, and cost. One significant element to be considered is the exploitation space of EM system. In a fixed location, the more traditional land-based options will be the best choice: POTS, ISDN or DSL. For the move solutions a combination of two or more services may be necessary. In the future for the most applications, a high-speed broadband connection will be needed, especially for real time applications. Table 1 provides a summary of the advantages and disadvantages to each communication networks in the service of the environmental monitoring.

Table 1: Advantages and disadvantages to each communication networks in the service of the environmental monitoring.

Network type	Advantages	Disadvantages
POTS	Inexpensive. Utilizes existing telephone lines. Good for small data files.	Limited bandwidth (56kbps maximum). Long transmission times. Not suited for large files.
ISDN	Faster than dial-up via POTS. Utilizes existing telephone lines. Available in most areas. Bandwidth can be increased by pairing lines.	Data rates limited by high cost.
DSL	Utilizes existing telephone lines. Supports real-time services.	Requires special hardware and filters. Availability limited outside of urban areas.
Fiber-optic	High-speed connection. Supports real-time services.	Rather expensive solution outside the cities.
Sort-range	Inexpensive. Mean-speed connection. Supports real-time services.	Sort-range and low resistance to interference.
Cellular	High-speed connection via cellular towers supporting 2G, 3G, or 4G. Allows user to be mobile. Supports real-time services.	Usually requires a year contract
Satellite	High-speed connection via satellite. Allows connectivity virtually anywhere at anytime. Potential to support some real-time communications. Portable satellites allows for mobility.	Requires a satellite dish to receive/send data. Expensive compared to other options. High latency. Signal degradation during bad weather. Rather high cost.

5. References

[1] R. J. Katulski, J. Namiesnik, J. Sadowski, J. Stefanski and W. Wardencki. Monitoring of Gaseous Air Pollution. In book: M. K. Khallaf (eds.). *The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources*. Published by InTech. Rijeka, Croatia. 2011, pp. 143-158.

[2] R. Latifi. *Telemedicine for Trauma, Emergencies, and Disaster Management*. Artech House, 2011.

[3] R. J. Katulski, J. Namieśnik, J. Sadowski, J. Stefanski, K. Szymańska, W. Wardencki. Mobile System for On-Road Measurements of Air Pollutants. *Review of Scientific Instruments*, vol. 81, iss. 4, 2010, pp. 045104-1 - 045104-5.

[4] R. J. Katulski, J. Stefanski, J. Sadowski, S. J. Ambroziak, J. Namiesnik, W. Wardencki. Mobile Monitoring System for Control of Atmospheric Air Quality. *Polish Journal of Environmental Studies*, vol. 20, no. 3, 2011, pp. 677-681.

[5] R. J. Katulski, J. Namiesnik, J. Stefanski, J. Sadowski, W. Wardencki, K. Szymanska. Mobile Monitoring System for Gaseous Air Pollution. *Metrology and Measurement Systems*, vol. 16, iss. 4, 2009, pp. 677-682.

[6] W. Wardencki, R. J. Katulski, J. Stefanski, J. Namiesnik. The State of the Art in the Field of Non-Stationary Instruments for the Determination and Monitoring of Atmospheric Pollutants. *Critical Reviews in Analytical Chemistry*, vol. 38, iss. 4, 2008, pp. 259-268.

[7] R. J. Katulski, S. J. Ambroziak, J. Sadowski, J. Stefanski. Self-Organizing Wireless Monitoring System of Cargo Containers. *Polish Maritime Research*, vol. 16, 2009, pp. 45-50.

[8] R. J. Katulski, J. Namiesnik, J. Stefanski J., J. Sadowski, W. Wardencki, S. J. Ambroziak. Wireless Systems of Threats Monitoring. *2010 IEEE International Conference Technologies for Homeland Security*, November 8-10 2010, Boston, 2010, pp. 314-320.

[9] R. J. Katulski, J. Sadowski, J. Stefanski, S. Ambroziak, B. Miszewska. Self-Organizing Wireless Monitoring System for Cargo Containers. *Polish Maritime Research*, vol. 16, no. 3, 2009, pp. 45-50.

[10] M. Ilyas, H. T. Mouftah. *The Handbook of Optical Communication Networks*. CRC Press, 2003.

[11] J. K. Petersen. *The Telecommunications Illustrated Dictionary*. CRC Press, 2002.

[12] K. Fazel, S. Kaiser. *Multi-Carrier and Spread Spectrum Systems; from OFDM and MC-CDMA to LTE and WiMAX*. Wiley & Sons, 2008.

[13] D. Roddy. *Satellite Communications*. McGraw-Hill, 2001.