WIRELESS SENSOR NETWORK IN PIPELINE MONITORING SYSTEM

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Abstract : A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. WSNs measure environmental conditions like temperature, sound, pollution levels, humidity, wind speed and direction, pressure, etc. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance,today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.This paper describes about the application of wireless sensor networks in water pipeline monitoring.Water distribution systems present a significant challenge for structural monitoring. They comprise a complex network of pipelines buried underground that are relatively inaccessible.Maintaining the integrity of these networks is vital for providing clean drinking water to the general public. This paper presents the design development and testing of a smart wireless sensor network for leak detection in water pipelines, based on the measurement of relative indirect pressure changes in pipes. The sensors are capable of measuring pressure changes due to leaks. These pressure profiles can also be used to locate the leaks. These capabilities are vital for reducing the time taken to identify and repair failures and hence, mitigating impacts on water supply.The developed monitoring system has significant advantages such as low cost, great flexibility, low power at high duty cycles, scalability etc over currently used telemetry systems.

***IndexTerms* - Autonomous Devices, Structural Monitoring, Sensors, Scalability.**

I. INTRODUCTION

The Wireless Sensor Network is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.The use of many wireless distributed sensors enables the creation of a more accurate map of the water status, and allows the permanent deployment of monitoring stations in locations of difficult access, without the need of manual data retrieval.Drinking Water Distribution Systems (WDS) carry potable water from water sources (reservoirs, water tanks) to industrial, commercial and residential consumers through complex pipe networks.Urban population growth adds to the demands on the water supply infrastructure. Utilities are faced with increasing costs of installing new pipelines to serve the growing population as well as maintaining and replacing the aging system.Leaks and bursts are an unavoidable aspect of water distribution systems management, and can account for significant water loss within a distribution network if left undetected for long periods.Leaks often occur through a build up of corrosion that causes structural failures in aging pipes, particularly at joints. For water utility operators, the ability to detect and localize pipe bursts and leaks quickly is important: bursts can occur in pressurised water transmission mains and distribution pipelines, and can be costly in terms of repair and damage to surrounding property and facilities. In addition, such failures can have significant social and environmental impacts .In buried pipeline monitoring, sensor nodes are deployed in soil. The underground environment imposes major limitations on sensor nodes, such as poor RF transmission and lack of maintainability. Digging trenches in order to repair or replace nodes is extremely costly; therefore sensor nodes should have a long operational life without any maintenance. This means that sensor nodes are required to be robust and consume a small amount of energy in order to last their desired lifetime. Despite the limitations, Underground Wireless Sensor Networks (UWSN) have a wide range of applications. Pipeline monitoring is one of the main areas in which UWSN can be used. A suitable UWSN for pipeline monitoring should be easy to deploy on existing and new pipes. Measurements of the pipe's condition should also be non-invasive to the pipe in order to maintain the structural integrity of the pipeline. This creates a need to design and develop new methods of measuring pipeline characteristics in order to monitor their structural integrity.

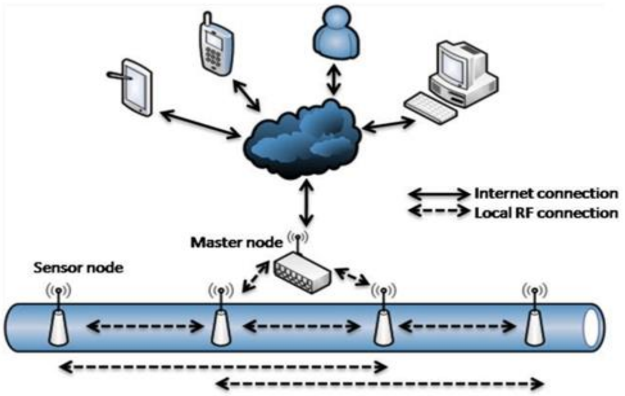

fig 1. wireless sensor networks

II. Origin And History Of Wireless Sensor Networks

To understand the tradeoffs in today's WSNs, it is helpful to briefly examine their history. Like many advanced technologies, the origin of WSNs can be seen in military and heavy industrial applications, far removed from the light industrial and consumer WSN applications that are prevalent today. The first wireless network that bore any real resemblance to a modern WSN is the Sound Surveillance System (SOSUS), developed by the United States Military in the 1950s to detect and track Soviet submarines. This network used submerged acoustic sensors – hydrophones – distributed in the Atlantic and Pacific oceans. This sensing technology is still in service today, albeit serving more peaceful functions of monitoring undersea wildlife and volcanic activity .While the market demand for WSNs was strong, moving beyond these limited applications proved to be a challenge. The military, science/technology and heavy industrial applications of previous decades were all based on bulky, expensive sensors and proprietary networking protocols. These WSNs placed a premium on functionality and performance, while other factors such as hardware and deployment costs, networking standards, power consumption and scalability fell to the wayside. The combination of high cost and low volume prevented the widespread adoption and deployment of WSNs into a broader range of applications.

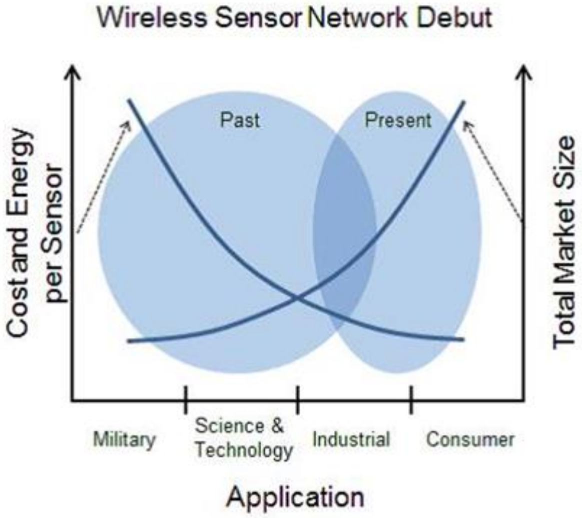

Fig 2.1 wireless sensor networks debut

III. WSN System

A wireless sensor network can have different topologies and structures. The restrictive environment of a buried pipeline enforces many limitations on the overall structure of the UWSN. The RF transmission range in soil is significantly lower than in air, therefore communication between nodes is much more limited. This imposes limitations on routing protocols and the overall structure of the UWSN. Moreover, the topology of the network is restricted by the topology of the pipeline .In the proposed UWSN each node communicates with both nodes in front and behind itself via RF signals. For every 4–5 nodes (up to maximum of 10 nodes) there is a master node which has the capability to communicate with the sensor nodes via RF transmission. Moreover, these master nodes should be able to connect to the internet and transmit the received data from the nodes to the cloud. Data in the cloud can then be accessed via different devices with internet connectivity

3.1Processing Unit

. Individual sensor nodes commonly have four main parts: a data gathering and processing unit, transmission unit, power management and sensors. Performance of each of these sections in terms of power consumption and reliability greatly affects the overall performance of the sensor nodes and network. Figure 2 illustrates a general schematic of different sections of the proposed sensor node for pipeline monitoring.

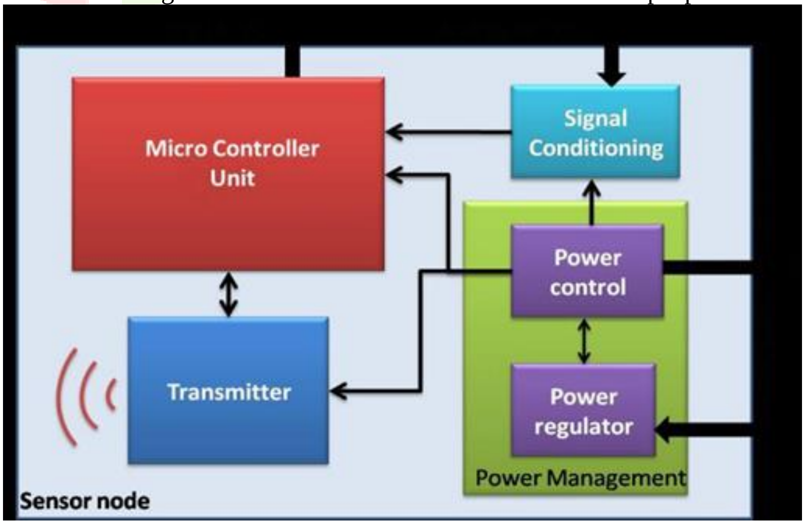

fig 3.1.1 schematic of the sensor nodes and its components

The Micro Controller Unit (MCU) is responsible for gathering measurements from the sensors, processing data, managing the power regime of the nodes and sending data to the transmitter. The performance of the MCU highly affects the overall performance of the node. A careful balance between the processing capability and power consumption is required to achieve optimum overall performance. The power management unit is responsible for converting the input voltage from the battery to a usable voltage for the MCU and other components. The Transmitter is one of the main parts of any sensor node. This unit is responsible for transmission of the data which is collected by MCU to other nodes via RF signals. Signal conditioning is composed of a voltage divider circuitry and passive filters to regulate and condition the signals from the sensors before they are transferred to the analogue to digital converter in the MCU. Another aspect which affects the performance of the sensor node is its firmware. This can greatly affect both the power consumption and reliability.

3.2 Transceiver Power Management

A transceiver consumes generally the largest amount of a node’s energy. In TX and RX modes, it usually consumes about 20 mA . Most of the time, though, the transceiver is in idle state, listening to the channel if there is an incoming message, because the message can be received only if the radio is ON. Unfortunately, the idle state consumes almost as much as the RX/TX states. Since the node receives messages relatively rarely, lots of effort have been done to reduce the useless idle listening of the transceiver, usually by periodically switching the radio on and off. Another recent effort has been invested to wake the node (and the entire network) on a message reception. When two nodes are to communicate, the receiver node must be awake when the sender initiates the communication, which is referred to as a rendezvous..

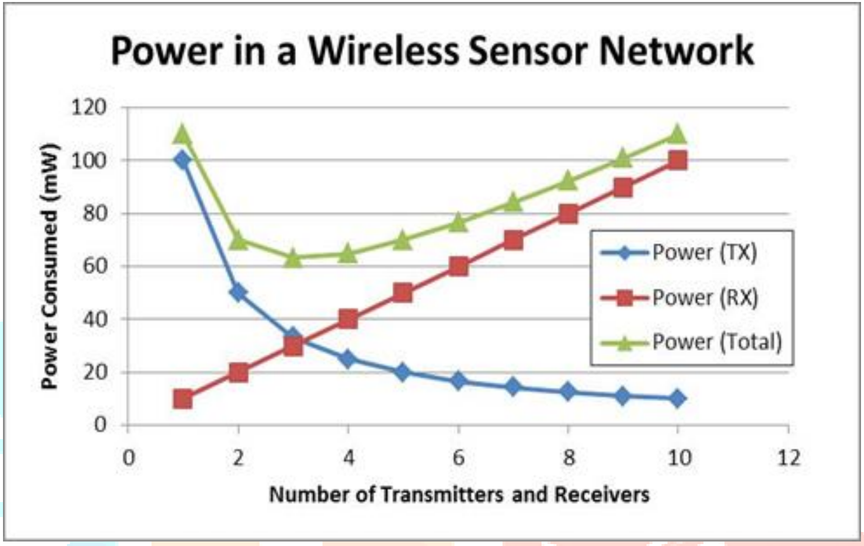

fig 3.2.1 power in a wireless sensor networks

3.3 Sensors

The ideal sensor for pipeline monitoring should be non-invasive to the pipe, low in power consumption and easy to install. Furthermore, they should be able to gather useful information without extensive data processing or high sampling rates.

One of the key parameters in pipeline monitoring is the internal pressure of the pipe. Leaks or blockages can potentially alter the normal pressure in the pipe and hence monitoring the pressure can potentially help to identify these. Temperature measurements of a pipe and its surroundings can also provide useful data in pipeline monitoring. A slow leak might not have a major effect on the internal pressure of the pipe, but it can potentially change its surrounding temperature profile.

Common pressure sensors used to measure the pressure inside water pipes require pressure tappings or special valves that allow access to the sensor to the inside of the pipe. This can have a negative effect on the structure of the pipe and is not suitable for certain types of pipe (e.g., old PVC pipes, older more brittle cast iron, glass reinforced or asbestos cement pipes). A novel, relative pressure sensing method based on force sensitive resistors (FSR) is used for pressure measurements in the proposed UWSN for pipeline monitoring [25]. This system operates based on the principle of a changing diameter of the pipe caused by an internal pressure change. Figure 6 shows a schematic of the sensor node assembly.

IV. PRESSURE CHARACTERISTICS OF BURST

Many events of interest in a water distribution system, such as bursts, leaks or valve operations can be detected as pressure transients. Slow leaks, valve and other maintenance operations typically result in transients that can be detected over a time scale of minutes or hours. Conversely, pipe burst events result in pressure transients that must be detected over time-scales from milliseconds to seconds (Tullis 1989). Pipe breaks and bursts occur in pressurized water pipes over time due to the cumulative effects of corrosion, structural fatigue (due to fluctuations in fluid pressure) or external environmental factors associated with ground movements or third-party impacts (surface loading etc.). As pipes age, they become increasingly susceptible to bursts and leaks (Pearson et al. 2005). Pipe burst events result in a sudden change in the flow through the pipe producing a pressure transient which propagates along the pipeline. This pressure pulse travels in both directions away from the burst origin at the speed of sound in water (wave speed of the pipe) (Misiunas 2005). Pipe junctions and endpoints in the physical network reflect the pulse, and its speed is altered by the pipe material and diameter as it travels through the network (Young, Boulos and Wood 2007). The transient is also attenuated by friction in the pipes, causing dispersion that reduces the slope or steepness of the transient wavefront (Bergant et al. 2008a, Bergant et al. 2008b). The burst (and subsequent leak) also creates distinct acoustic emissions, changing the background acoustic signature of the pipe. There is a significant literature and established practice for determining accurately the location of existing leaks using the cross-correlation of ground level (microphone) or insertion-based (hydrophone) acoustic measurements (Brennan et al. 2006, Hunaidi et al. 2004). However, in order to detect and localize instantaneous burst events (and hence, give a starting point to accurately locate the leak), it is advantageous to use pressure measurements. This is because acoustic signal attenuation increases with frequency and the frequency of acoustic emissions can extend into the kilohertz range depending on factors such as pipe material/size and soil type. In addition, the lower frequencies are significantly affected by environmental noise, such as that from vehicles and pumps. Thus, acoustic detection techniques are effective only within few tens of meters of the leak (Loth et al. 2004). On the other hand, pressure transients are less readily attenuated and the pressure signature is relatively unaffected by background noise increasing the distance over which they can be reliably detected (Srirangarajan et al. 2012). WaterWiSe's IDEAS layer is capable of using a variety of different techniques to detect transient events that are indicative of bursts. The two most-used detection techniques are described in this section: the first is based around the wavelet decomposition of the pressure signal, and the second is based around time domain series analysis.

V. SENSORS

The heart of any WSN lies in the sensors. The past decade has seen rapid advancement in multiple sensing technologies:

- Micro electromechanical systems (MEMS) – gyroscopes, accelerometers, magnetometers, pressure sensors, pyroelectric effect sensors, acoustic sensors

- CMOS-based sensors – temperature, humidity, capacitive proximity, chemical composition

- LED sensors – ambient light sensing, proximity sensing, chemical composition

When combined into a network, these cost-effective sensors enable new applications such as optimizing HVAC control and lighting inside of homes and buildings. According to the
US Department of Energy "Annual Energy Outlook 2012" report, HVAC and lighting accounted for 48.1 percent of all commercial energy used in the US in 2010, a significant amount of which was wasted due to the absence of smart systems. Most HVAC and lighting systems are programmed on timers at best and do not take into account the physical presence of humans. Using MEMS, CMOS, and LED sensors to track environmental conditions (humidity, temperature, ambient light) and the presence of people (pyroelectric, proximity, and acoustic), smart systems can be designed to drastically reduce the overall power used by shutting off power to environmental control when no human presence is detected and dimming light fixtures if the ambient lighting is adequate.

Furthermore, once a sensor network is in place, additional functions can be implemented. For example, acoustic sensors can be reused to monitor human physical presence during the day and to detect broken glass from a potential break-in during the evening hours. Another example is using human presence information to eliminate "vampire power" drawn from powered devices (e.g., computer monitors, televisions, etc.) when humans are not present by removing power from wall outlets. Exper estimate vampire power alone is responsible for 7-15 percent of commercial power usage.

VI. LEAKAGE DETECTION

When a leak happens along the pipeline, the liquid density of the leak point declines immediately due to the fluid medium losses and the pressure drops. Then the pressure wave source spreads out from the leak point to the leak upstream and downstream ends. Taking the pressure before the leak as the reference criterion, the wave generated by such a leak is called the negative pressure wave. When the negative pressure wave reaches the pipeline terminal end, it will cause the drop of first the station inlet pressure and then the station outlet pressure. The pressure reduction signal is collected by pressure sensors installed on both ends of the pipeline. As the locations of the leak are different, different time difference of the negative pressure wave are captured. Based on the different time difference that pressure sensors on both sides detect, pipeline length and negative pressure wave velocity, the leak point can be determined . The negative pressure wave method is not dependent on system hardware and it also does not need to set up the mathematical model, which means less calculation costs. However, it requires that the leak be quick and abrupt, since especially in the case of a slow leak, there is no obvious negative pressure wave.

VII. PERFORMANCE EVALUATION

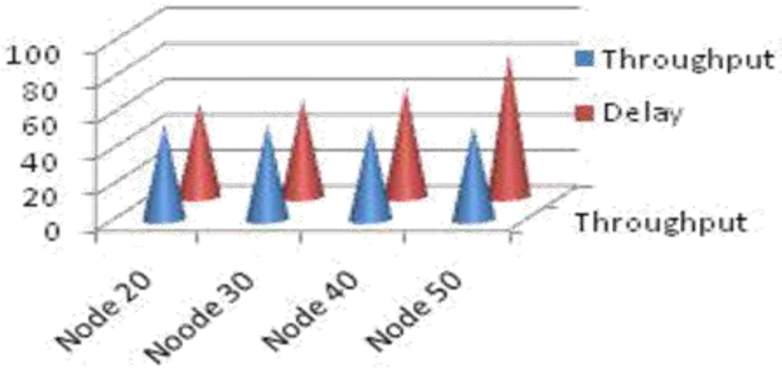

fig 7.1. variation of throughput and delay with respect to number of nodes.

VIII. Conclusion

Wireless smart sensor networks are a viable solution for monitoring the condition, in particular the pressure and hence leaks, of buried water pipelines. Their advantage over other commonly used leak detection methods is that they have a degree of redundancy as individual faulty nodes do not render the whole system obsolete and allow for continuous monitoring without operator intervention. Ultra-low power smart wireless sensor networks allow them to stay operational for extended periods of time without maintenance. This makes them now viable for both existing and novel power supplies. The ultra-low power consumption of 2 µW was achieved by a careful hardware selection and also adaptation of the firmware. Through advances in sensor, networking, semiconductor and energy storage technologies, future WSNs will combine to form the nervous system of the IoT. When combined with cloud computing and big data processing, the number of applications for and market size of the Internet of Things are almost limitless and will allow humans and machines to interact in unprecedented and unanticipated ways. End users will be able to control their entire home through a single easy-to-use interface. Energy content and distribution systems will increase their efficiency. Farms will produce more crops. Lives will be saved with continuous in-home medical monitoring systems. In short, the coming years are an exciting time in the world of wireless sensor networks.

References

[1] Simon R. Saunders, “Antennas and Propagation for Wireless Communication Systems”, WILEY, 1999.

[2] BBC news, “South East England still in drought”,http://www.bbc.co.uk/weather/features/understanding/drought2006.shtm, 2006.

[3] Sarah Mukherjee, BBC environment correspondent,“Testing the wateron desalination”, http://news.bbc.co.uk/1/hi/uk/5009540.stm, BBC NEWS, 23 May 2006.

[4] Economist, “London Water Sunk Costs”, 13th July 2006.

[5] OFWAT, “Security of supply, leakage and the efficient use of water”,2003-2004 Report.

[6] Ian F. Akyildiz, Erich P. Stuntebeck, “Wireless underground sensor networks: Research challenges”,

Elsevier B.V. 2006.

[7] Arun Jain1 , Ramesh Bharti,” Simulation and Performance Analysis of Throughput and Delay on Varying Time and Number of Nodes in MANET”: International Journal of Recent Research and Review, Vol. VII, Issue 2, June 2014**.**