WIRELESS SENSOR NETWORKS FOR SMART MAINTENANCE SYSTEMS

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Abstract

Ubiquitous computing, miniaturization, low power radio, MEMS and low cost signal processing all together have led to development of Wireless Sensor Networks with wide variety of applications such as military, health, industrial and condition based maintenance.

Most manufacturers realize equipment or process downtime, planned and unplanned, carries a huge cost .One of the significant work in maintenance is real time monitoring of equipment through collection of data and its analysis. Wireless Sensor Networks will make it possible to facilitate real time monitoring of machine condition in various constrained environments

In this paper we have proposed a new intelligent data gathering technique to monitor machine condition through the use of Wireless Sensor Networks The technological requirements to physically realize the system are discussed at block level.

Keywords: **Sensor Network, Wireless Communication, Energy efficiency, Communication Protocol**

1. Introduction

Unplanned equipment downtime is a pervasive cost that drags down ROA. Huge amount of costs are incurred each year to replace perfectly good equipment because no reliable and cost-effective method is available to predict the equipment's remaining life. What if there was a way to drastically reduce equipment downtime through real-time analytics for critical equipment?

Present Situation Top-level manufacturers have instituted comprehensive condition-based maintenance (CBM) programs. But in most cases, this involves a technician running routes with a data collector on a monthly or quarterly basis [2]. Data are collected on machine vibration, temperature, oil levels, and running speed. With trending analysis software, you can assess and project machine health, and with the ability to predict failures and prevent downtime, you can achieve optimum production output. The next step in the evolution of CBM is online surveillance systems, which provide more frequent machine-condition information than data collectors. The online systems include hard-wired sensors connected to multiplexers, which are networked to a main database computer. Most manufacturing facilities can't fully implement a surveillance system because of the high capital costs, installation difficulties, and overall complexity of the system. Online systems are most often used on the most critical pieces of equipment

Wireless sensor network technology. Advances in wireless technology, battery chemistry, and miniaturization have made large-scale wireless CBM data gathering systems practical. Wireless sensing no longer needs to be relegated to locations where access is difficult or cabling is not practical. Wireless CBM data gathering can be cost effectively implemented in extensive applications that were historically handled by route running.

The condition based maintenance practice of surveillance monitoring would benefit significantly from intelligent, inexpensive, wireless sensors. The result would be a lower cost surveillance program, easier sensor node placement, simpler data gathering, increased safety, and seamless reconfiguration or expansion of sensor nodes. In short, surveillance programs would be easier to apply to a wider variety of applications.

Frequent condition monitoring can change the way maintenance and production decisions are made. After a fault is discovered, the next question is, can the machine continue to run or can it make it to the next outage? A system of thousands of sensors monitoring a facility's equipment (including some with developing faults) provides management with a clear, up-to-date picture of its infrastructure's condition. With analysis software that can predict the life expectancy of a failing component, plant maintenance and production can schedule downtime when it is the least disruptive, which maximizes process throughput and minimizes costs

With the new online technology, facilities will be able to run leaner because they'll have more confidence in their ability to eliminate unscheduled downtime. Up-to-date information can also ensure that equipment is not replaced too early. Most manufacturers have excess production capacity in their facilities to handle unexpected breakdowns.

The remainder of this paper is organized as follows: We present system requirements for wireless sensor networks in section 2. In section 3 we present energy efficient sensor node architecture. In section 4, we present overview of communication system of sensor networks for industrial applications. We present application scenario – Diagnostic monitoring in section 5. We summarize our paper in section 6 with some future directions.

2. System requirements

Challenges to be met to realize the wireless sensor network based maintenance system are [4]:

- Low installed costs
- Easy-to-use products that simplify maintenance and eliminate process problems
- Fault-tolerant technology
- Compatibility with other systems
- Capability to extend the system
- High reliability
- Long sensor life
- Adaptability

For wireless CBM systems, sensor nodes must be plug-and-play and have ad-hoc networking capability. This will allow additional sensor nodes to be added easily and let you quickly reallocate existing nodes. For a system incorporating thousands of sensors, anything less requires significant installation and upkeep effort.

3. Energy Efficient Wireless Sensor Node Architecture

The proposed node has the ability to scale the energy consumption of the entire system in response to changes in the environment, state of the network, *and* protocol and application parameters in order to maximize system lifetime and reduce global energy consumption. Thus, all layers of the system, including the algorithms, operating system, and network protocols, can adapt to minimize energy usage. Figure 1 gives an overview of the architecture of the sensor node.

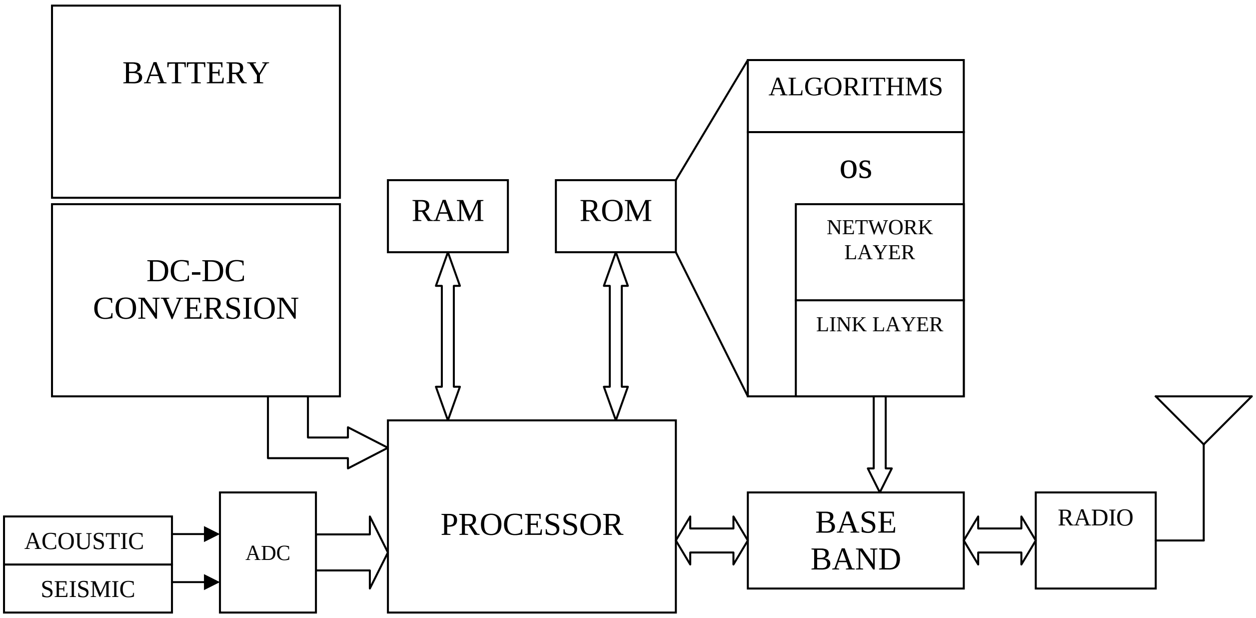

Figure 1: Architectural overview of microsensor node.

The overall node can be broken down into different variables that define the energy consumption at each architectural block, from leakage currents in the integrated circuits to the output quality and latency requirements of the user. As a result, the energy consumption of every component in the system can be exploited at the software level to extend system lifetime and meet user constraints. Information about the environment is gathered using some sensing subsystem consisting of a sensor connected to an analog-to-digital (A/D) converter. A wider variety of sensors can be supported.

Once enough data is collected, the processing subsystem of the node can digitally process the data or it can relay the data to a nearby node (or faraway base station). The primary component of the data and control processing subsystem is the StrongARM SA- 1110 microprocessor. Selected for its low power consumption, performance, and static CMOS design, the SA-1110 runs at a clock speed of 59 MHz to 206 MHz. The processing subsystem also includes RAM and flash ROM for data and program storage. A multithreaded “OS” running on the SA-1110 can be customized to allow software to scale the energy consumption of the processor. Code for the algorithms and protocols can be stored in ROM.

In order to deliver data or control messages to neighboring nodes, the data from the StrongARM is passed to the radio subsystem of the node via a 16-bit memory interface. The primary component of the radio is a Bluetooth-compatible commercial single-chip 2.4 GHz transceiver with an integrated frequency synthesizer. The on-board phase-locked loop (PLL), transmitter chain, and receiver chain can be shut-off via software or hardware control for energy savings. To transmit data, an external voltage-controlled oscillator (VCO) is directly modulated, providing simplicity at the circuit level and reduced power consumption at the expense of limits on the amount of data that can be transmitted continuously. The radio module, with two different power amplifiers, is capable of transmitting at 1 Mbps at a range of up to 100 m.

Finally, power for the node is provided by the battery subsystem via a single 3.6 V DC source with an energy capacity of approximately 1500 mAH.

4. Wireless Communication

Areas of concern with digital radios are cost, size, battery drain, reliability, distance of transmissions, carrier frequency, wireless protocol for multiple sensor nodes, and compliance with regulations.

The radio begins with the physical layer [1], which is the actual radio circuitry, and it is the transmitter and receiver of information. The communication protocol is built on top of the physical layer, and it defines how information is packetized, routed, and encrypted, and how error checking and correction are handled. The final layer is the application, which defines what information must be transmitted through the communication protocol and what to do with received information once it is stripped out of the protocol (see Figure 2).

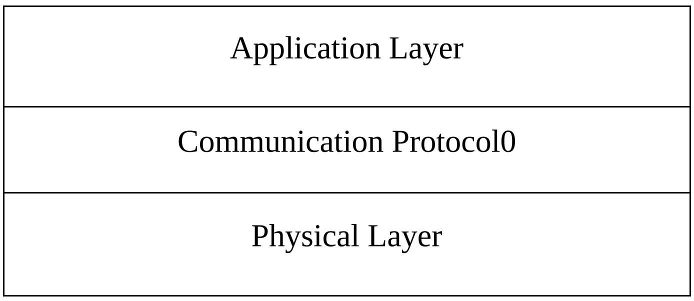

Figure 2 Simplified view of digital radio layering in wireless sensor nodes.

Many possible combinations of the physical layer, communication protocol, and application exist for wireless communications. But a design must carefully balance performance, cost, size, and power consumption.

A wireless data-gathering network must be reliable in industrial environments, where RF interference from motors, lighting, and other wireless systems is typical. Most industrial interference is caused by intermittent bursts of narrow-band signals, random EMI (background noise), and deterministic EMI (radio stations).

At any given time, the wireless link does not have to be reliable, but there must be a 100% probability the message will get through within a reasonable time. It’s also necessary to guarantee that any errors in the message will be detected and corrected. Lost or corrupt data will show up as distortions and could produce false equipment-condition reporting. Collisions between packets and interference from other radio sources must also be addressed.

The wireless CBM communications method must allow thousands of sensors to coexist in a single network. Various techniques are available to ensure dependable coexistence. Some of the more common are time division multiple access (TDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA). The circuit cost and complexity of TDMA is the lowest, followed by FDMA and then CDMA. For CBM monitoring, you don’t need to have multiple, simultaneous communications.

Wireless standards offer additional interplay between sensor manufacturers. Any wireless sensor standard will have to specify the physical layer, the communication protocol, and significant aspects of the application. In effect, the standard must define a universal wireless sensor node. The IEEE 1451.X working group and the Bluetooth SIG are doing some work in these areas.

Many possible solutions exist for wireless communications; however, a design must carefully balance performance, cost, size, and power consumption. This balance is particularly important in wireless sensors.

5. Application example - Diagnostic Monitoring

One area of application in Maintenance systems is application for wireless, multi-hop, mesh network in the diagnostic monitoring of devices [3]. This monitoring can occur outside the normal control loop and wireless communication can be sent to notify the system user of any abnormal operation.

In this control loop, an additional signal is extracted and analyzed during the course of normal operation of the sensor. As the sensor operates, the signal is monitored for abnormalities without affecting the sensor’s operation. If an abnormal signal or trend is observed, an alert is triggered.

The beauty of using a wireless link for on-board monitoring and alert is that the monitoring link remains independent of the control loop. By using a wireless, multi-hop mesh network, data can be routed dynamically to similar wireless devices. Surrounding devices can respond to the alert from the failing device, even as the alert is being sent to maintenance personnel. Another benefit of wireless is that maintenance personnel can directly connect to the diagnostic output of the sensor,

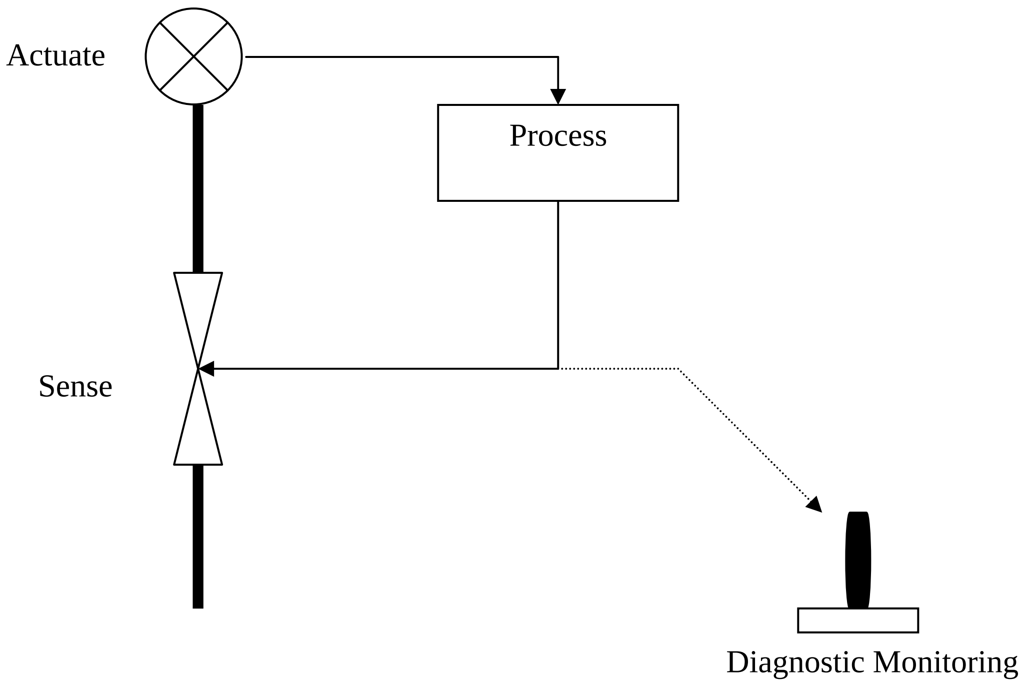

FIGURE 3: SCHEMATIC OF TYPICAL SENSOR CONTRO L LOOP

without running wires. This can eliminate a huge task in the case of a tank level sensor in a large storage tank, or a temperature probe at the top of a tower stack at a chemical refinery. In a wireless, multi-hop mesh network, a user can get that data via any wireless node on the network. By using a diagnostic device with additional processing power (such as a laptop computer, handheld computer, handheld diagnostic device), maintenance personnel can check on configuration and other information about any node on the network.

This information is a valuable tool for checking and verifying sensor operation when questionable data is received from a sensor through its primary control loop.

6. Summary and future directions

Advances in wireless technology, battery chemistry, and miniaturization have made extensive, wireless CBM data gathering systems practical. With up-to-date machine condition, maintenance, and production, decisions can be made to optimize production, and manufacturing facilities can operate more efficiently. Multi-hop mesh technology, however, is inherently reliable, redundant, and can be extended to include thousands of devices. The communication protocol architecture needs to be further explored to realize the sensor networks for industrial applications.

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