Wireless Sensor Networks for Process Monitoring

The rise of remote control

Wireless sensor networks (WSNs), which are capable of monitoring or controlling the systems to which they are coupled, have seen increased usage in industrial applications over recent years. A WSN consists of multiple 'nodes': small, autonomous devices which are inherently resource constrained and must operate for extended periods of time from limited local energy reserves. Nodes typically contain sensors, a microcontroller, radio transceiver, and power supply. The node's sensors monitor the system to which they are coupled; for example, a node mounted on an electric motor could measure its vibration signature.

These data are locally processed on the embedded microcontroller, and subsequently communicated wirelessly in accordance with a communication protocol. Multiple nodes (forming a WSN) can communicate packets with each other in order to route data through a large or hostile environment. Information obtained from the network can be used for many purposes, including the identification of machinery wear and imminent failure (notifying maintenance personnel) and allowing remote monitoring via the internet.

Monitoring the health of machinery is often performed through periodic manual inspections. Condition monitoring (CM) systems can render manual inspections largely redundant. The use of WSNs in CM systems for industrial environments has proven a particularly attractive market, due to both the economic and application-enabling incentives that they offer.

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The economic benefits are largely driven by the cost of cabling between sensors, where it has been estimated that installing wiring for a single sensor can cost many hundreds of pounds and constitute the major cost in an installation. In a typical industrial scenario, it has been suggested that the total system cost (for both materials and installation labour) can be reduced by over 80% by using commercially available WSNs.

Due to the apparent cost-benefit, and as nodes are easily retrofitted, installed CM systems using WSNs have typically monitored many more of a company's machines than in wired systems. This has meant that, instead of monitoring only the most critical components, other machines whose potential failure would cause considerable disruption are also monitored. WSNs also enable applications that were previously difficult or impossible with wired sensors, such as the monitoring of environments under extreme conditions or the instrumentation of rotating machinery.

Energy is a scarce resource in a WSN, as nodes are locally powered and usually expected to operate autonomously for many years. A node's operation is typically duty-cycled, spending most of its time 'asleep' in an ultra-low-power state, only waking periodically to sense, process and communicate. As a result, its average power consumption is typically in the order of hundreds of microwatts to a few milliwatts. Nodes have traditionally been powered from batteries, typically offering an operational life of a few months or years.

Energy harvesting, the process whereby environmental energy is used to power an embedded device, offers nodes virtually indefinite operation. Energy can be harvested from incident light (using photovoltaic cells), temperature gradients, or from the mechanical vibrations that are inherent on many machines. Where sufficient vibration is present, harvesters present an attractive alternative to batteries, and can typically provide up to a few milliwatts of power.

There has been a considerable push towards the standardisation of wireless communication protocols for WSNs, which

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predominantly operate in the unlicensed 2.4GHz ISM band. These have commonly adopted existing standards such as Bluetooth and WiFi (IEEE 802.11), and also seen the creation of new protocols including IEEE 802.15.4, ZigBee, Wireless HART and ISA100.

The trade-off between communication bandwidth (at one extreme, communicating all data sampled by the node) and on-node processing (at the other extreme, processing all data locally and only communicating data when faults are detected) is a complex relationship. This trade-off is inherently intertwined with energy consumption and data throughput. A balance can be hard to strike and, as with most aspects of WSNs, is commonly application-dependent.

WSNs have transitioned from being solely a topic of academic research, and are now being used in numerous industrial environments to track products and assets, monitor the condition of machinery, and control processes. With the diversity in WSN applications and requirements comes an equally varied range of algorithms, architectures and platforms; hence by their very nature, a particular WSN will nearly always be application-specific. While this has perhaps slowed their adoption, the inclusion of pervasive technologies in industrial environments can only be expected to increase.