Wireless sensor networks for health monitoring

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Abstract-In this report we will present an application of wireless sensor networks in the area of health monitoring for machine and structure. It specially targets working machine that may benefit from continuous, remote health monitoring. We present the advantages, objectives and status of the design. An experimental wireless temperature sensor network has been constructed at the department of Electrical Engineering of Penn State. Early results suggest a bright future for the applications in wireless sensor networks in the application of health monitoring of machine efficiency.

Keywords

Wireless sensor networks, health monitoring, Xbee/Xbee Pro Modules

1. Introduction

A wireless sensor network consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure or motion. Wireless sensor network enables low-cost sensing of environment. Many applications using wireless sensor networks have low duty cycle and low power consumption. However the ability of wireless sensor networks can be extended in reverse ways. Enhanced TinyOS, and new components opened possibility for more aggressive applications. Structure and machine monitoring is one example of such applications. To measure a machine, we measure behavior (e.g. temperature, current, voltage) of machine, and analyze health of the machine based on measured data. Figure 1 shows the whole system. In our case, sensor is temperature sensor which will be discussed, and wireless RF module, data acquisition software

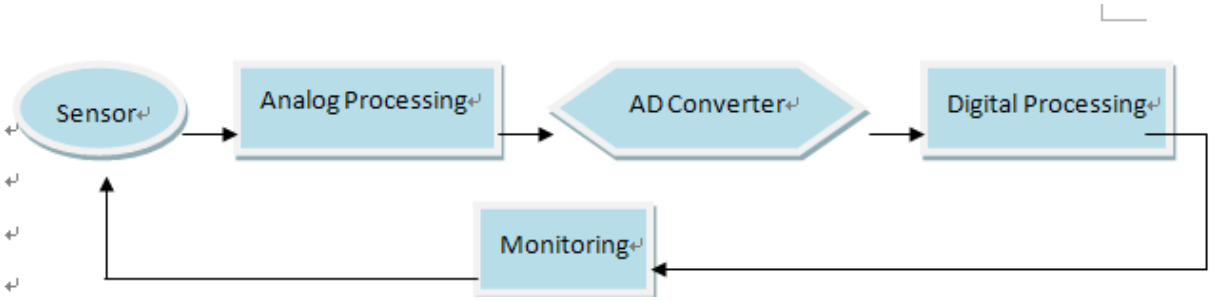

Fig.1. Whole system overview

2. Related work

Habitat monitoring is a leading application of wireless sensor network. And it is an example application with low duty cycle. ZebraNet use PDA-level device with 802.11b wireless network. Great Duck Island uses Berkeley mote, and watch ducks without disturbing them at low cost. Figure 2 shows the whole system.

On Maine's Great Duck Island, biologists put (1) sensor devices in nests and (2)outside birds burrows. These devices record data about the birds and relay them to (3) a gateway node, which transmits the info to (4) the research station then to (5) a satellite dish and, ultimately, to a lab in California. Scientists can study the birds' habit without interfering them.

Fig.2. Maine's Great Duck Island Project

3. Our main goal

We are developing a network architecture for smart machine health monitoring that will improve the efficiency and reduce the energy waste. High costs of installation and retrofit are avoided by using hoc, self-managing networks. Based on the fundamental elements of future health monitoring applications (integration with existing machine, real-time and long term monitoring temperature sensors), the wireless system will extend machine

maintain from traditional manual work to unmanned and real-time monitoring. The architecture is multi-tiered, with devices ranging from temperature sensors, to mobile components, and more powerful stationary devices. Figure 3 shows a XBee Pro RF module from DIGI with an temperature sensor mounted on it.

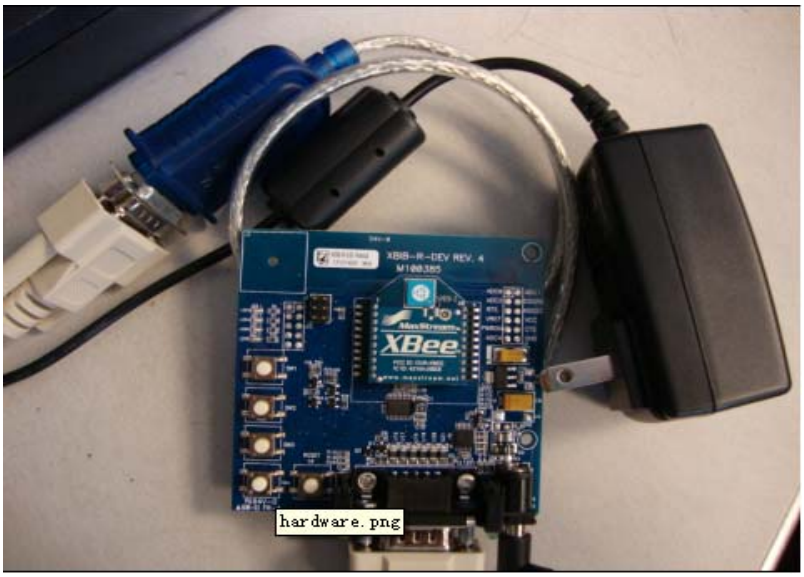

Fig.3.XBee PRO RF Module

Here are some benefits compared to conventional wired sensors:

a.. Low price. Devices can be deployed in potentially large quantities with dramatically less complexity and cost compared to wired networks. Existing machine, can be easily augmented with a WSN network whereas wired installations would be expensive.

b. Ease of deployment and scalability. No wires run all over the machine, so WSN will not disturb the normal operation of the structure.

c. Real-time and always-on. Environmental data can be monitored continuously, allowing real-time response by workers. The data collected form a machine journal and are valuable for improving the efficiency of machine. Even thought the network as a whole is always-on, individual sensors still must conserve energy through smart power management and on-demand activation.

d. Maintenance is less expensive

Since there is no fixed installation, adding and remove sensors instantly reconfigure the network. Sensors self-organize to form routing paths, collaborate on data processing.

4. High lever system architecture

System overview

The machine sensor network system integrates heterogeneous devices, some temperature sensors, some current sensors and voltage sensors. Together they inform the worker about the health status of the machine. Data is collected, pre-processed, stored, and acted upon using a variety of sensors and devices in the architecture. The components of the architecture are shown in Figure 4. Typically, a wireless sensor node (or simply sensor node) consists of sensing, computing, communication, actuation, and power components. These components are integrated on a single or multiple boards, and packaged in a few cubic inches.

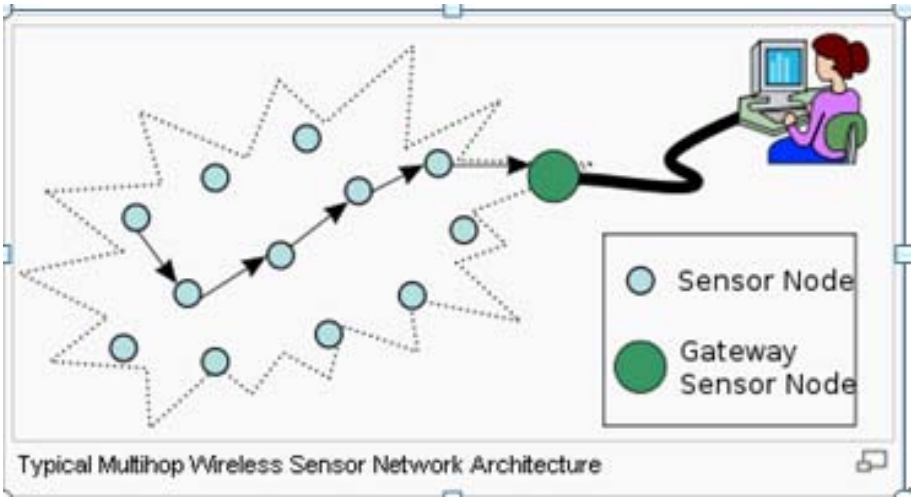

Fig.4. Wireless sensor network architecture

5. Data acquisition

The XBee and XBee-PRO RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other. We use the X-CTU， which is showed in Figure5, to require the data from the XBee RF Modules. The output voltage range is 0 to 3.3 voltages. And the parameter range of X-CTU is 0 to 3FFF in hex decimal. And we set the reference voltage as 3.3 volts. And for the temperature sensor, the output is 0.25 volts at 0 Celsius degrees. And the output of the temperature sensor is 3.05 volts at 100 Celsius degrees. And according to the calculation of the above data, we can make a table of the temperature and output voltage. Figure 6 shows the table.

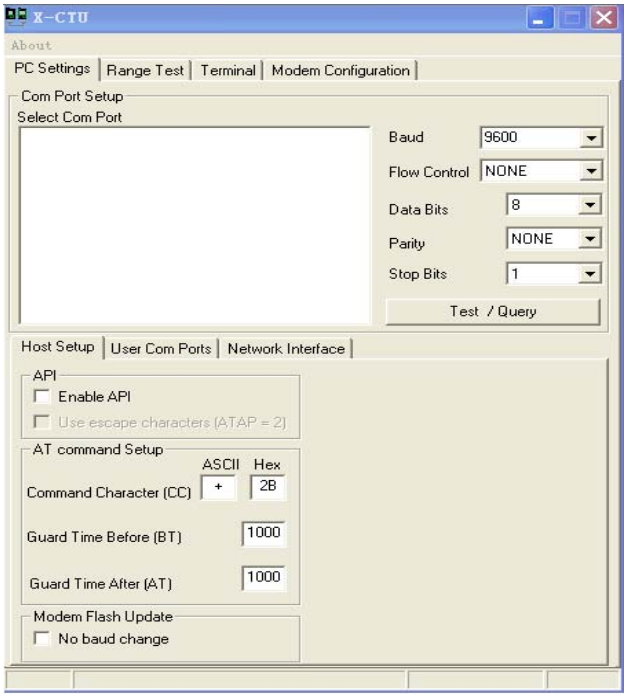

Fig.5. X-CTU software

Output(Hex)	T(Celsius degree)	T(Fahrenheit)	Output(Hex)	T(Celsius degree)	T(Fahrenheit)
F9	22.62672811	72.7281106	112	25.79493	78.43088
FA	22.75345622	72.9562212	113	25.92166	78.65899
FB	22.88018433	73.1843318	114	26.04839	78.8871
FC	23.00691244	73.4124424	115	26.17512	79.11521
FD	23.13364055	73.640553	116	26.30184	79.34332
FE	23.26036866	73.86866359	117	26.42857	79.57143
FF	23.38709677	74.09677419	118	26.5553	79.79954
100	23.51382488	74.32488479	119	26.68203	80.02765
101	23.640553	74.55299539	11A	26.80876	80.25576
102	23.76728111	74.78110599	11B	26.93548	80.48387
103	23.89400922	75.00921659	11C	27.06221	80.71198
104	24.02073733	75.23732719	11D	27.18894	80.94009
105	24.14746544	75.46543779	11E	27.31567	81.1682
106	24.27419355	75.69354839	11F	27.4424	81.39631
107	24.40092166	75.92165899	120	27.56912	81.62442
108	24.52764977	76.14976959	121	27.69585	81.85253
109	24.65437788	76.37788018	122	27.82258	82.08065
10A	24.78110599	76.60599078	123	27.94931	82.30876
10B	24.9078341	76.83410138	124	28.07604	82.53687
10C	25.03456221	77.06221198	125	28.20276	82.76498
10D	25.16129032	77.29032258	126	28.32949	82.99309
10E	25.28801843	77.51843318	127	28.45622	83.2212
10F	25.41474654	77.74654378	128	28.58295	83.44931

Fig.6. Temperature and output table

6. Conclusion

The baseline of the system is implemented. A one week experiment showed a robust system with some straightforward communications from front to backend of the system. The modularity of this system should enable progressive development of the research areas described in Part VI. We believe this system design will greatly enhance efficiency of machine.

7. Ongoing research topics

1. Multi-modal data association and multiple residents. Data association is a way to know "who is doing what?" in a system without biometric identification and with multiple actors present, such as an assisted-living community. It permits us to recognize the right person among others when he is responsible for a triggered event. This is indispensable for avoiding medical errors in the future and properly attributing diagnostics. Consequently, dedicated sensors and data association algorithms must be developed to increase quality of data.
2. Data integrity. When the data association mechanisms are not sufficient, or integrity is considered critically important, some functionalities of the system can be disabled.

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