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SMART SENSORS AND INTELLIGENT INSTRUMENTATION IN IWLAN

SMART SENZORY A INTELIGENTNÍ INSTRUMENTACE V IWLAN

Abstract

Paper deals with present state, trends and new challenges of Industrial Wireless Local Area Networks – IWLAN with new form of intelligent instrumentation. New type of smart sensors nodes with wireless connection bring some advantages and also disadvantages. There are problems with communication protocols, interaction between different nodes, and main problems there are the power supply of the IWLAN elements.

Some experience with wireless sensors and Zig Bee nodes will be presented and will be shown the interesting possibilities for another development. The problem is solved in the framework of the grant project Czech Science Foundation GAČR 101/04/1530.

Abstrakt

Příspěvek se zabývá současným stavem, trendy a novými výzvami v průmyslových bezdrátových sítích – IWLAN s novou formou inteligentní instrumentace. Nové typy senzorových nodů s sebou přináší mnohé výhody, ale také nevýhody. Vyskytují se zejména problémy při výběru vhodného komunikačního protokolu, interakcí mezi heterogenními nody, ale největší výzvy jsou v oblasti šetření elektrické energie jednotlivých bezdrátových nodů.

Bude prezentována zkušenost s bezdrátovými moduly a Zig Bee nody a budou představeny zajímavé možnosti dalšího možného vývoje. Problém je řešen v rámci grantového projektu Czech Science Foundation GAČR 101/04/1530.

1 INTRODUCTION

Instrumentation systems are open/closed loop control systems, they are formed using sensors and actuators and the objective is to control certain parameters, or state of the system. All the system elements are always in communication with each other, typically, requiring real-time performance.

Intelligent instrumentation with wireless sensor-based controls have drawn industry attention on account of reduced costs, better power management, ease in maintenance, and effortless deployment in remote and hard-to-reach areas. They have been successfully deployed in many industrial applications such as maintenance, monitoring, real-time control, security, etc. [HILL & CULLER, 2002].

A wireless ad hoc sensor network consists of a number of sensors spread across a geographical area. Each sensor has wireless communication capability and some level of intelligence for signal processing and networking of the data. The basic goals of a wireless sensor network generally depend

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upon the application, but the following tasks are common to many networks [CULLER & MULDER, 2005]:

- Determine the value of some parameter at a given location: In an environmental network there are a temperature, atmospheric pressure, amount of sunlight, and the relative humidity at a number of locations. This example shows that a given sensor node may be connected to different types of sensors, each with a different sampling rate and range of allowed values.
- Detect the occurrence of events of interest and estimate parameters of the detected events: In the traffic sensor network, one would like to detect a vehicle moving through an intersection and estimate the speed and direction of the vehicle.
- Classify a detected object, for instance a vehicle in a traffic sensor networks (cars, light trucks, buses, etc.
- Track an object: In a military sensor network, track an enemy tank as it moves through the geographic area covered by the network.

The aim of the paper is to outline possibilities of present state, trends and new challenges of IWLAN with new form of intelligent instrumentation. Some experience with Bluetooth and Zig Bee nodes will be presented and will be shown the interesting possibilities for another development.

2 SMART SENSOR NETWORK PROPERTIES

Sensor network requirements include the following:

1. Large number of (mostly stationary) sensors: Networks of 10 to 100 thousands nodes are envisioned, so scalability is a major issue.
2. Low energy use: Since in many applications the sensor nodes will be placed in a remote area, service of a node may not be possible. In this case, the lifetime of a node may be determined by the battery life, thereby requiring the minimization of energy expenditure.
3. Network self-organization: Given the large number of nodes and their potential placement in hostile locations, it is essential that the network be able to self-organize. Moreover, nodes may fail (either from lack of energy or from physical destruction), and new nodes may join the network. Therefore, the network must be able to periodically reconfigure itself so that it can continue to function.
4. Collaborative signal processing: To improve the detection performance, it is often quite useful to fuse data from multiple sensors. This data fusion requires the transmission of data and control messages so it may put constraints on the network architecture.
5. Querying ability: Users may want to query for information collected in the region. Depending on the amount of data fusion performed, it may not be feasible to transmit a large amount of the data across the network. Instead, various local sink nodes will collect the data from a given area and create summary messages. A query will be directed to the sink node nearest to the desired location [SMUTNÝ, 2003].

With the coming availability of low cost, short range radios along with advances in wireless networking, it is expected that smart sensor networks will become commonly deployed. In these networks, each node will be equipped with a variety of sensors, such as acoustic, seismic, infrared, still/motion video camera, etc. [WIRELESS, 2005].

These nodes may be organized in clusters such that a locally occurring event can be detected by most of, if not all, the nodes in a cluster. Each node will have sufficient processing power to make a decision, and it will be able to broadcast this decision to the other nodes in the cluster. One node may act as the cluster master, and it may also contain a longer range radio using a protocol such as IEEE 802.11, Bluetooth, or use proprietary routing algorithms.

A new class of microelectronic devices frees us to mix computers much more freely with the objects and places of everyday experience. Now we can join simple computers to radio transceivers and sensors to form small autonomous nodes that we call "motes" running an operating system (for instance TinyOS), each mote links up with its neighbours from the moment it is turned on. Although these smart sensors have limited power and processing capabilities, an assembly of hundreds of them can spontaneously organize into a perceptive network that is spread throughout the physical world, able to perform tasks no ordinary computer system could.

On the Figure 1 we can see the example of wireless sensor kit, from MOTE (USA) for measurement of acceleration, magnetic field intensity, light intensity, temperature and sound. They work on frequency 2.4 GHz and support IEEE 802.15.4 and ZigBee WILAN with TinyOS software platform [MOTE, 2005].

Fig. 1 MOTE wireless sensors kit – Processor /radio module MPR2400

3 SMART SENSOR NODE DESIGN IN WIRELESS ILAN

The motive of the smart sensor project is to create:

1. A general purpose hardware interface for diverse sensors and actuators, which can be customized for any application through over-the-air firmware downloads.
2. It creates a data processing infrastructure at the backend to implement applications.
3. The sensors are directly connected to the central control unit through a RF link, which can be Bluetooth, Zig Bee or WiFi.
4. Each sensor or actuator is equipped with a reconfigurable generic wireless interface or smart sensor interface.
5. The interface extracts data from the sensors and commands the actuator and provides a data communication interface to the central control unit.

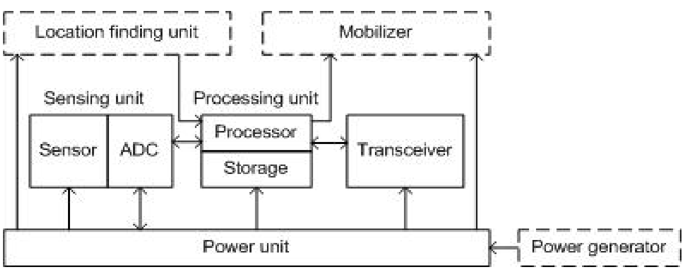

Fig. 2 Wireless sensor node design

A sensor/actuator coupled with smart sensor interface is termed as a smart sensor node.

The proposed solution consists of a network of sensors, and actuators communicating with the central control unit using standard RF-links. The basic block schema is shown in Figure 3.

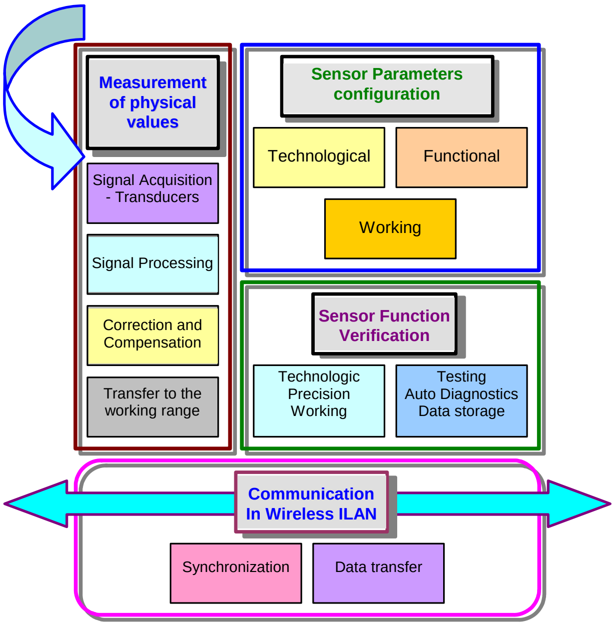

Fig. 3 Structure of smart sensor and its basic functions

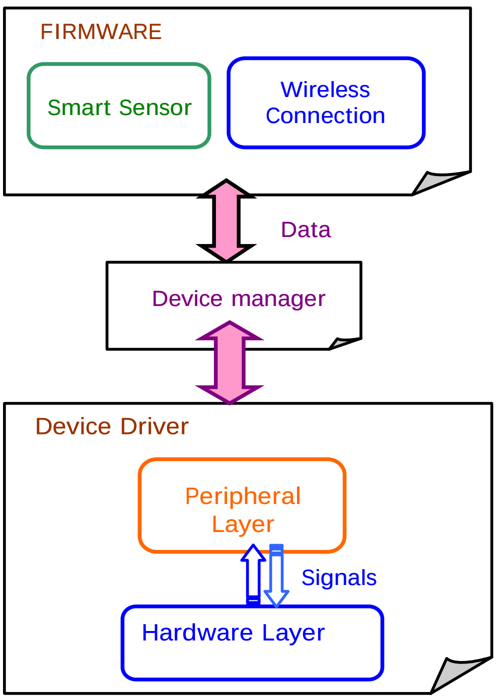

Fig. 4 Smart Sensor Node Software Design

The software design of the smart sensor interface is shown in Figure 4. The software module stack on the smart sensor interface consists of three layers. The bottom layer is the Device driver which directly interfaces with the hardware interface and extracts digital data.

The Device manager interfaces with the device drivers and exposes a multiple data channel interface to the Firmware layer. In the software framework, each sensor/actuator is composed of a combination of digital, analog or serial channels. Establishment of context to the extracted channel data is done at the firmware layer. The firmware layer "composes" the sensor by combining data from multiple data channels. It also implements the application specific functionalities like real-time performance, data communication protocol with central control unit, smart sensor node management, etc.

PROTOTYPES OF PERCEPTIVE NETWORKS

PURPOSE	SENSORS	NODES	ORGANIZATION
Observes weather and nesting behaviors of seabirds on Great Duck Island, Me.	Temperature, humidity, infrared	150	Berkeley, Intel
Analyzes activity of residents in elder care facilities in Portland, Ore., and Las Vegas	Motion, pressure, infrared	130	Intel
Antitank mines communicate and reposition themselves to close gaps in a mine field	Location, orientation, acceleration	96	DARPA
Collects readings on microclimates surrounding redwood trees	Temperature, humidity, light, atmospheric pressure	80	Berkeley, Intel
Monitors the performance of pump and scrubber motors in a microchip factory	Vibration and RPM	70	Berkeley, Intel
Maps growth conditions and susceptibility to fungal infections in a vineyard	Temperature	65	Intel
Listens for gunshots and then triangulates shooter position	Sound, shock wave, location	45	DARPA, Vanderbilt
Records microclimates within James San Jacinto Mountains Reserve, Calif.	Temperature, humidity, rainfall, light, wind	30	U.C.L.A.
Monitors movement of Golden Gate Bridge	Vibration and acceleration	Under design	Berkeley

Fig. 5 Short review of Smart Sensor Nodes

This separation of data acquisition tasks across three layers in the smart sensor interfaces helps support functionalities like over-the-air update of parameters, plug-n-play of sensors, multiple sensor support, multiple wireless technology support, universal data interface etc.

Software TinyOS makes a perceptive network system function much like a database. A user can "query" all the smart nodes at once with a request for, say, any vibrations between 40 and 120 Hz stronger than a certain level. The request enters the network at its "root" node, which forwards copies to its neighbors and so on until all sensors have received the command. TinyOS has built in algorithms that can authenticate the identity of motes. But for the system to work well, keys must be distributed to a large number of small nodes in reliable and uncomplicated ways. Over the next decade, WS nodes and perceptive networks will probably evolve into a much less distinct and less visible form. Devices will gradually migrate out of their little boxes and will instead be incorporated directly into various materials and objects (Fig. 5) [CULLER & MULDER, 2005].

4 CONCLUSIONS

A wireless smart sensor platform targeted for instrumentation systems and predictive maintenance was presented. The experimental results show that a sustained near-real-time system can be set up with the smart sensor nodes and they will draw energy directly from the environment in which they operate. To the extent that these kinds of sensors and instrumentations infiltrate workplaces, homes, transportation terminals and shopping sites and are able to sense the presence, motion and even physiological states of individuals, they will raise substantial privacy concerns. Indeed, a discussion about such technology has already begun over the use of passive RFID tags.

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