Article ID　1004-924X(2003)03-0227-07

Wireless networked microsensor and its embedding system

ZHONG Xian-xin , LI Xiao-yi , WU Zheng-zhong , YU Wen-ge

(*Microsystems R &D Center , The Key Lab for Optoelectronic Technology & Systems of the Ministry of Education , Chongqing University , Chongqing* 400044 , *China*)

Abstract : The classification and architectures of wireless networked microsensors , and the architectures of two wireless microsensors with Bluetooth , RF-MEMS antenna and embedding system in partucular , are discussed in detail. The technical requirements for wireless networked microsensors and associated key techniques , including adaptive brequency-hopped spread spectrum and self-configuration Bluetooth networking , are discussed with emphasis on stability and reliability of wireless communication and wireless networking schemes including real-time connectivity to internet. A wireless networked microsensor can be designed with an embedding system to achieve environmental monitoring and transfer of measurements through wireless network communication. Low-level drivers , schedulers and Bluetooth high-level protocols can be designed by selecting appropriate 32 bits embedded processor and clinus operating system. The whole design and operating process of a wireless netwokred microsensor and its embedding system are illustrated with a wireless remote image surveillance system used as typical example.

Key words : wireless microsensor ; networking ; embedded system ; bluetooth

CLC number : TP212.9　**Document code** : A

1　Introduction

Pervasive microsensing and actuation may revolutionize the way we understand and manage complex physical systems : from airplane wings to complex ecosystems. The availability of low-power microsensors , actuators , embedded processors , and radios is enabling the application of wireless network sensing to a wide range of applications , including environmental monitoring , smart spaces , medical applications , and preci - sion agriculture , etc.[1] In future smart environments , wireless microsensor networks will play a key role in sensing , collecting , and disseminating information about environmental phenomena. Consequently , wireless networked microsensors (WNMSs) will undoubtedly provide new monitoring and control capabilities for civil and military applications.

Fusion of physical and information processes presents the single and most important opportunity and challenge for us. From avionics systems to

Received date :2002-12-17 ; **Revised date** :2003-03-17.

Foundation item : It is supported by the Major State Basic Research Development Program" Integrated Micro-Optical-Electronic-Mechanical System "(Project No. G1999033105)

smart precision instruments, embedded information processing is the primary source for superiority in sensor and actuator systems. The new wave of inexpensive MEMS-based sensors and actuators and the continued progress in computing and communication technology will further accelerate this trend. Sensor and actuator systems will become increasingly "information rich", where embedded monitoring, control and diagnostic functions penetrate deeper and with smaller granularity in physical component structures. Given this trend, the relative separation of physical and information processing architectures is not sustainable. Strong mutual interdependence requires coherent fusion at fine levels of granularity, *i. e.* the distribution of information processing among physical components. The coordinated operation of distributed embedded systems makes coordination, distribution and embedding the fundamental technical challenge for software.

This paper discusses recent advances in wireless networked microsensor and wireless network sensing embedded system (WNSES) techniques.

2 Architectures of wireless networked microsensors

Due to the wireless networking, one of its essential characteristics, a WNMS generally operates within a certain wireless sensor network (WSN). So in this section, we first give a classification for WSN, then describe architectures of WNMSs.

2.1 WSN types

WSN technologies emerged about in the second half of 1990's; from then on, interacting with associated technologies, they have advanced rapidly. Nevertheless, there isn't any explicit assortment for WSN so far. Below we only present some angles of classifying WSN types.

From the angle of its scale, the WSN is of either large scale or small scale. WINS (wireless integrated network sensors) networks described in [2] represent the former, and local area WSNs using Bluetooth[3] in [4,5] the latter. Bluetooth is an adhoc short range wireless networking technology operating in the 2.45 GHz ISM band. WINS networks mainly feature Multi-hop radio communications among their sensor nodes, while Bluetooth-enabled WSNs are based on straight-through/Single-hop radio communications between sensors (nodes) and observers within piconets, complemented by Relay-like communications among sensors of a certain scatternet.

With regard to issues that influence the second level *i. e.* the network protocol level of a WSN, which is responsible for creating paths and accomplishing communication between the sensors and the observer(s), there can be three aspects of classifying WSN types: communication models, data delivery models and network dynamics models[6]. The further classification for this is shown in Table 1.

Tab. 1 Classification for WSNs in terms of the network protocol level

Communication models	Data delivery models	Network dynamics models
Cooperative application communication	Continuous	Static sensor network
Noncooperative application communication	Event-driven	Mobile sensor network
	Observer-initiated	
	Hybrid	

WSNs can also be viewed in the perspective of wireless media such as radios, infrared devices and laser communication devices. Radio communications are more practical in most WSN applications because of their key advantages of Beyond Line of Sight, easily networking etc. However, infrared and laser may be utilized as supplemental links in some cases.

2.2 WNMS architectures

WINS nodes are typical WNMSs composing

large scale WSNs. A single WINS node combines microsensor technology, low power signal processing, low power computation, low power, and low-cost wireless (radio) networking capability in a compact system, whose architecture is depicted in Fig. 1[2].

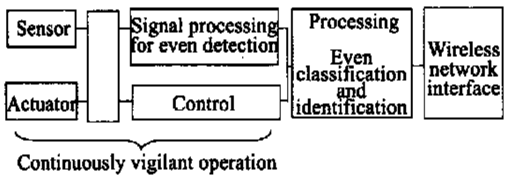
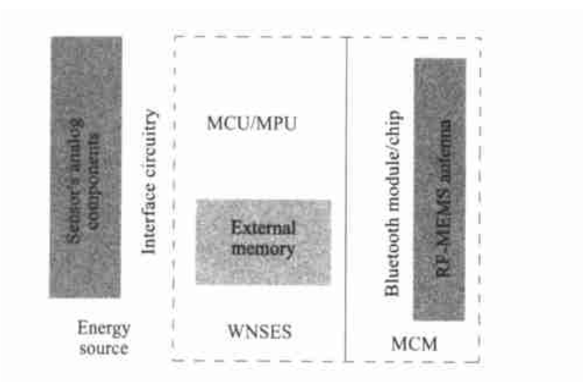


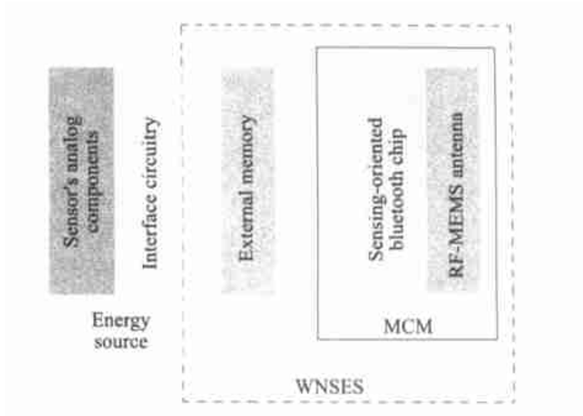
Fig. 1　WINS node architecture

The WISARD (wireless sensing and relay device)[7] architecture, similar to the WINS node architecture, is also a type of WNMS architecture adopted in the large scale WSN. A WISARD consists of three subsystems: a suite of sensors, a microcontroller, and an RF transceiver. The single-chip RF transceiver operates in the 902-928 MHz ISM band.

Ever since Bluetooth technology formally took the stage at the end of the 20th century, it has received considerable research attention in the IT (information technology) realm including the WSN field. We began our research on WSNs with the



(a) The architecture exploiting the existing Bluetooth module or chip



(b) The architecture adopting the intending sensing-oriented Bluetooth chip

Fig. 2　Architectures of Bluetooth-enabled wireless networked sensors

study of WNMS architectures; especially, two sorts of architectures of Bluetooth-enabled wireless networked sensors have been presented, as shown in Fig. 2, where MCU, MPU and MCM are acronyms of micro control unit, microprocessor unit and multi-chip module respectively.

Both architectures have two features: one is design and implementation of the WNSES, the other the MCM for Bluetooth module or chip and RF-MEMS antenna. Issues of the WNSES are detailed in the fourth section. As most of current portable radio devices, including Bluetooth systems, are still using off-chip antenna, the MCM for Bluetooth module or chip and RF-MEMS antenna may engender ground-breaking advances contributing to the constitution of a single-chip transceiver. Design and fabrication techniques for the MCM are involved in[8].

3　Technical requirements and key techniques for WNMS

We now discuss technical requirements for WNMSs common to most types of WSNs, followed by key techniques.

Most envisioned WNMSs encounter the following technical challenges:

* Measures against multipath and shadow effects to ensure stability of radio communications.

* Anti-interference measures against multiuser interference, coexistence interference in the shared electromagnetic environment and even deliberate interference to enhance reliability of wireless communications.

* Relatively long lifespan and multi-choice of energy sources to adapt to practical untethered operation either outdoors or indoors. While battery is the primary energy source of WNMSs today, photocells or piezoelectric materials are optional promising means.

* Efficient energy management to prolong lifetimes of energy sources as much as possible.

* Automatic configuration and reconfiguration (self-configuration) to accommodate unattended operation[1].

* Localized sensing and networking signal processing in response to distributed signal processing, which essentially results from a design constraint of finite energy.

* Microminiaturization aiming at fundamental sensing advances at micro- and nanoscale.

* Real time connectivity to Internet to swim with the tide of increasingly information oriented world.

All of requirements above can be abstracted as guidelines for wireless, networked, intelligent and micromation sensors. To address these technical challenges, following key techniques are being focused on a great deal of research.

* Frequency diversity techniques by employing some combination of frequency-hopped spread spectrum (FHSS), interleaving, and channel coding[2]. We are also interested in researching adaptive FHSS technique, which promises to enhance present Bluetooth anti-interference performance.

* Multihop communication or network scheme appropriate to densely distributed WNMSs[2,7]. Based on topologies of starlike piconet and conceptual scatternet[3], We are studying a self-configuration network scheme specially to enable Bluetooth networking.

* To facilitate Real time connection of WNMSs to Internet, we are integrating Mobile Internet techniques, e.g., GSM (Global System for Mobile communications), GPRS (General Packet Radio Service), and 3 G (Third Generation), with our local area wireless techniques including Bluetooth.

* Other key techniques include MAC (medium access control) and routing protocols, self-configuration and reconfiguration, coherent processing algorithms, distributed power-aware management etc. For in-depth knowledge about these techniques, see[1,2,6,9].

4 Embedded system techniques

To fulfill physical sensing of environmental phenomena and reporting of measurements through wireless network communication, a wireless networked microsensor is to be designed with an embedded system, which is referred to as WNSES. In fact, most of software-related techniques mentioned in the third section, say, adaptive FHSS, self-configuration networking, and distributed power-aware management, need to be implemented in the WNSES. Typically, a wireless networked sensor consists of five components-sensing hardware, embedded processor, memory, transceiver, and energy source (also see Fig. 2). The embedded processor is the hardware core of the WNSES as well as the WNMS. Since embedded systems will make progress in their microminiaturizations with advances of hardware and software techniques, the microminiaturizations of wireless networked sensors can also benefit from the research on the WNSES.

To build a WNSES, we have exploited some hardware and software techniques. First, an appropriate type of 32 bits embedded processor has been selected. The reasons of choice of a top grade embedded processor (Motorola MCF5272 etc.) mainly lie in the potentialities of various sensing applications, e. g., image and video applications. Then, Having limited us to a Bluetooth-enabled WNSES, the system hardware design has been conducted with support of other mating components such as Flash Memory and bus interfaces. Afterwards, a RTOS (Real Time Operation System) called as uClinux has been decided on. The uClinux is one of embedded versions of Linux Operating System, which has been developed for micro-control domain. We have also done the corresponding system software design. The system software provides low-level drivers, a scheduler and BHLP (Bluetooth high-level protocols). The drivers are been prepared for sensor and digital I/O signals. The scheduler provides event-driven scheduling of system and application tasks. The BHLP requires multithreading capabilities and access to peripherals, which can be solved by the scheduler and the driver.

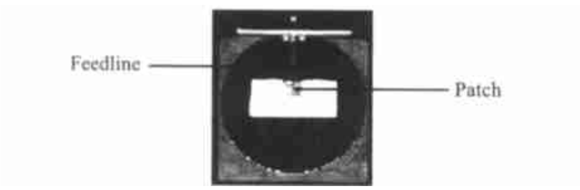


Fig. 3　RF-MEMS double C microstrip patch antenna (for demonstration)

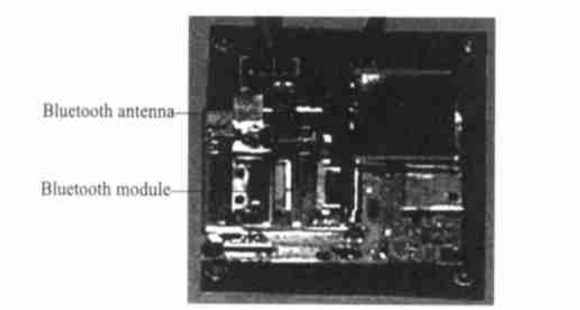


Fig. 4　Bluetooth computer communication demo device

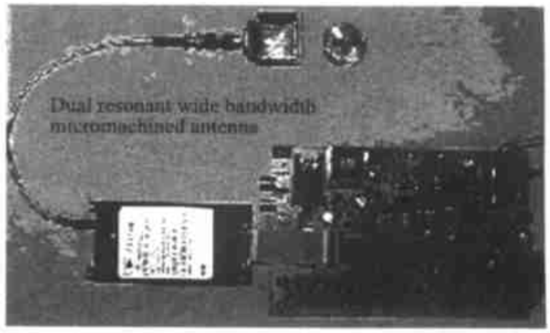


Fig. 5　GSM/GPRS data unit board for wireless remote image surveillance system

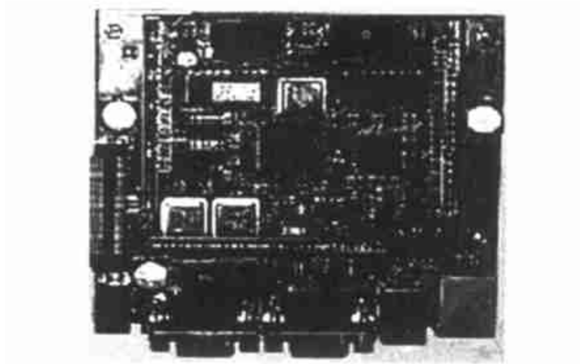


Fig. 6　Embedded system development board with uCLinux RTOS

We have developed some components, devices and solutions so far, as shown in Fig. 3 to Fig. 6, which are expected to be applied to wireless networked microsensors and their embedded systems.

5　Application paradigm

In this section, we give an application paradigm of WNMSs and their WNSESs-Wireless Remote Image Surveillance System (WRISS), which is under our development. Fig. 7 illustrates WRISS's block diagram.

Hybrid networking features largely in the WRISS, i. e. it combines both radio, infrared wireless media and wire or fiber optic medium, and integrates local area WSN with global Internet. Additionally, adaptive FHSS and self-configuration Bluetooth networking techniques are to be achieved in the WNSESs of Bluetooth cameras.

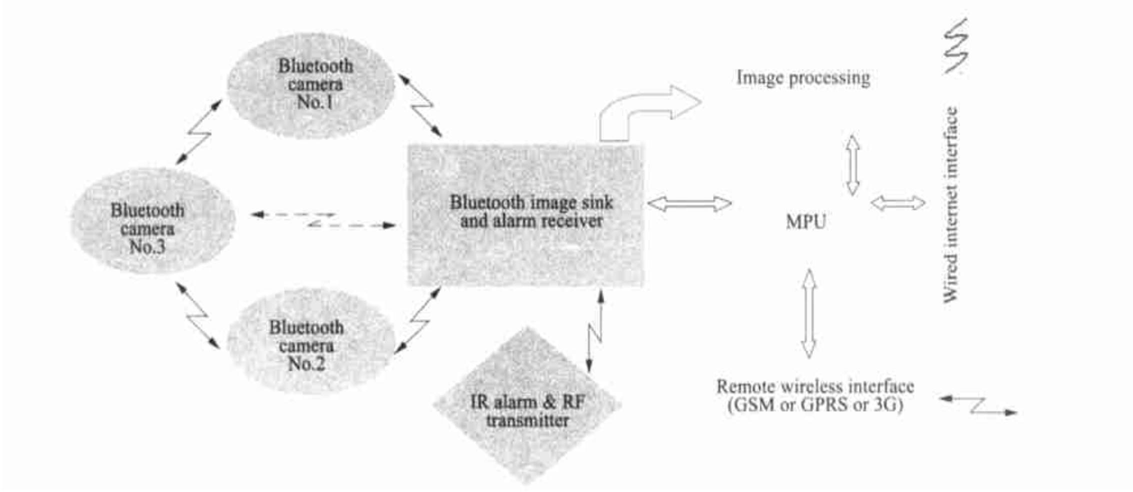


Fig. 7 Block diagram of the wireless remote image surveillance system

6 Conclusion

Wireless networked microsensors promise extensive application prospects, their architectures must satisfy specialities of wireless networks, and most of associated key software-related techniques are intended to function in embedded system environments. We have begun studies of WNMS architectures featured with Bluetooth, RF-MEMS antenna and wireless network sensing embedded system, presented new ideas of adaptive FHSS and self-configuration Bluetooth networking, as well as basic hardware and software developments for WNSES and a new video application paradigm. Further research is being directed towards associated hardware fabrication and protocols or algorithm implementations.

Reference:

[1] ESTRIN D, GIROD L, POTTIE G, *et al*. Instrumenting the world with wireless sensor networks [A]. *Proc. ICASSP* '2001 [C]. Salt Lake City, UT, 2001. 2675-2678.

[2] POTTIE GJ, KAISER WJ. Wireless integrated network sensors[J]. *Commun ACM*, 2000,43(5) :51-58.

[3] Bluetooth Special Interest Group. Bluetooth specification version 1.1 Volume 1[Z]. 2001.

[4] LI X Y, ZHONG X X. Interface techniques for bluetooth wireless sensing system[J]. *Piezoelectrics & Acoustooptics*, 2001,23:425-427.

[5] RAVINDRAN V, VARADAN V K. Implementation of local area wireless sensor networks using bluetooth[A]. *SPIE Proceedings* [C]. San Diego, CA, USA, 2002. 258-265.

[6] TILAK S, ABU-GHAZALEH N B, HEINZELMAN W. A taxonomy of wireless micro-sensor network models[A]. *ACM Mobile Computing and Communications Review Volume* 6, *Issue* 2 [C]. New York, NY, USA: ACM Press, 2002. 28-36.

[7] FLIKKEMA P G, WWST B W. Wireless sensor network: from the laboratory to the field[A]. *National Conference for Digital Government Research* (dg.o2002) [C]. 2002.

[8] LI X Y, ZHONG X X. Bluetooth-enabled wireless sensor and corresponding integration design & fabrication techniques [A]. *Xiamen*: *Pacific Rim Workshop on Transducers and Micro/Nano technologies* [C]. 2002. 801-804.

[9] SOHRABI K, GAO J, AILAWADHI V, *et al*. Protocols for self-organization of a wireless sensor network[J]. *IEEE Personal Communications Magazine*, 2000,7(5) :16-27.

无线网络化微传感器及其嵌入式系统

钟先信 ,李晓毅 ,巫正中 ,余文革

(重庆大学 光电技术及系统教育部重点实验室 ,重庆 400044))

摘要:首先对无线传感网络作了分类 ,描述了无线网络化微传感器的体系结构 ,提出了两种蓝牙无线网络化传感器的体系结构 ,其主要特征是蓝牙、RF - MEMS 天线及嵌入式系统。然后 ,讨论了无线网络化微传感器的技术要求与关键技术 ,包括自适应跳频与自配置蓝牙组网等新思想;研究重点在于无线通信的稳定性与可靠性、无线组网方案及实时互联网连接。为实现环境监测并通过无线网络通信传递测量值 ,可设计无线网络化微传感器嵌入式系统;选用了适当型号的嵌入式处理器和 uClinux 操作系统 ,设计了系统软件、低层驱动程序、调度程序及蓝牙高层协议程序。最后 ,以无线远程图像监视系统作为实例加以说明。

关 键 词:无线微传感器;网络化;嵌入式系统;蓝牙

中图分类:TP212.9　　**文献标识码**:A

作者简介:钟先信(1935 -) ,男 ,重庆万州人 ,重庆大学光电工程学院教授 ,博士生导师 ,主要从事微机电系统(MEMS) 、智能化仪器与机械、纳米技术研究;

李晓毅(1973 -) ,男 ,重庆荣昌人 ,重庆大学光电工程学院博士研究生 ,主要研究方向为 RF-MEMS、无线局域网及嵌入式系统技术。