第一章、现状与发展

2007年8月20日

中国科学院计算技术研究所
Institute of Computing Technology,Chinese Academy of Sciences

内容提要

1. WSN研究历史
2. WSN与Ad hoc网络
3. WSN体系结构
4. WSN的应用
5. WSN研究
6. WSN研究中的若干问题
7. 主要参考文献

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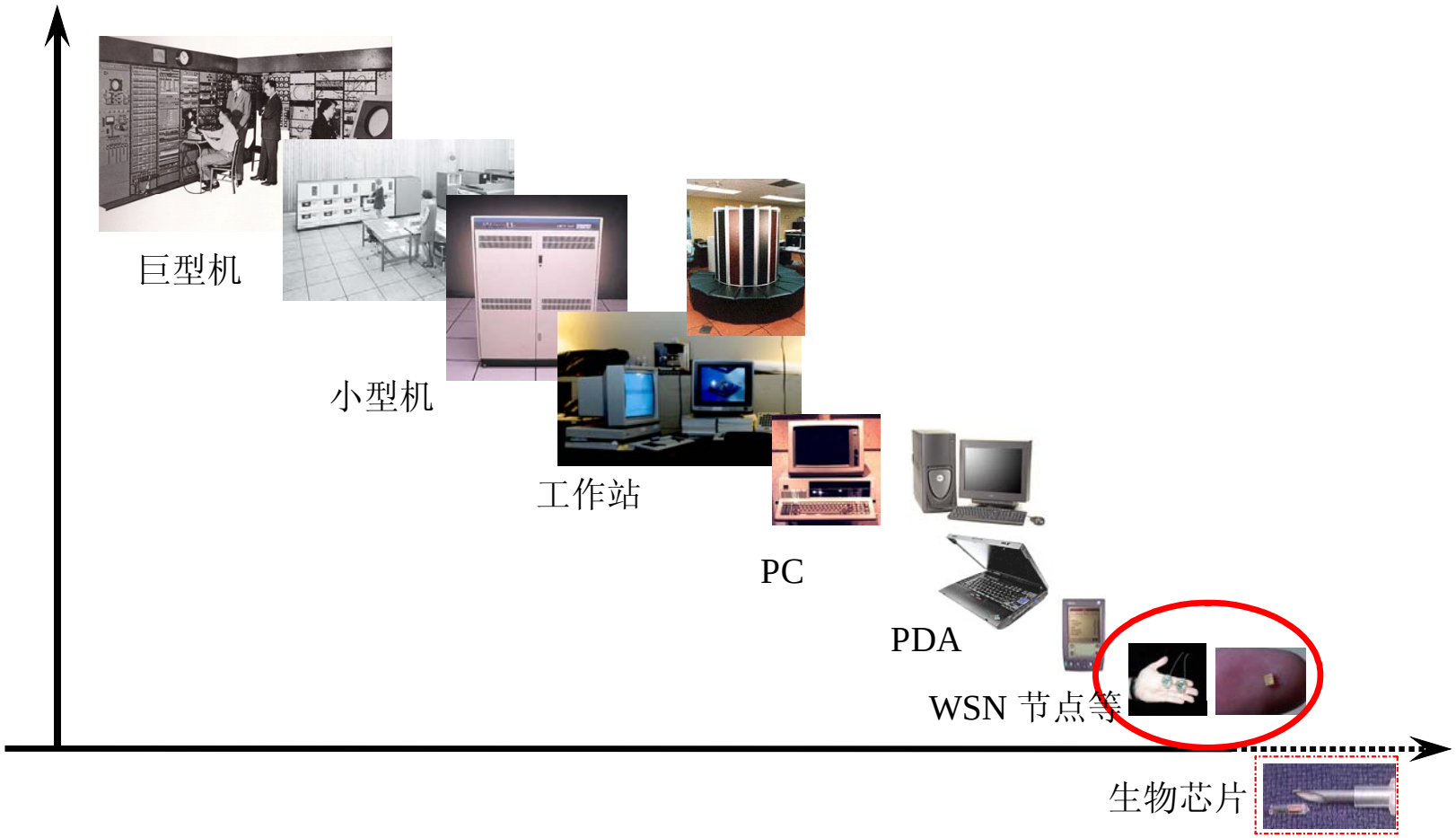
计算设备的演化历史



发展历程（一）

- **二十世纪70年代。**冷战时期的声音监测系统（Sound Surveillance System-SOSUS）、空中预警与控制系统（Air borne Warning and Control System-AWACS）
- **1980年。**DARPA的分布式传感器网络项目（Distributed Sensor Networks-DSN）
- **1994年 。**加州大学洛杉矶分校的William J. Kaiser 向DARPA提交建议书“Low Power Wireless Integrated Microsensors”， 里程碑。
- **二十世纪80年代至90年代之间。**美国海军研制的协同交战能力系统（Cooperative Engagement Capability-CEC），用于反潜的确定性分布系统（Fixed Distributed System-FDS）和高级配置系统（Advanced Deployment System-ADS），以及远程战场传感器网络系统（Remote Battlefield Sensor System-REMBASS）和战术远程传感器系统（Tactical Remote Sensor System）等无人看管地面传感器网络系统

发展历程（二）

- **1998 年。**Gregory. J. Pottie 阐释了WSN 的科学意义，DARPA巨资启动了SensIT项目，目标是实现“超视距”战场监测。
- **1999年9月。**商业周刊将其列位21世纪最重要的21项技术之一。橡树岭国家实验室(Oak Ridge National Laboratory ,ORNL) 提出了“网络就是传感器”（Network is Sensor）的论断。
- **2001年1月。**《MIT技术评论》将WSN列于十种改变未来世界新兴技术之首。
- **2003年8月。**《商业周刊》预测：WSN和其他三项信息技术将会在不远的将来掀起新的产业浪潮。
- **2004年《IEEE Spectrum》**杂志发表一期专集：传感器的国度，论述WSN的发展和可能的广泛应用。
- 我们国家未来20年预见技术的调查报告，信息领域157项技术课题中有7项与传感器网络直接相关。
- **2006年初**发布的**《国家中长期科学与技术发展规划纲要》**为信息技术确定了三个前沿方向，其中两个与WSN的研究直接相关，即智能感知技术和自组织网络技术。

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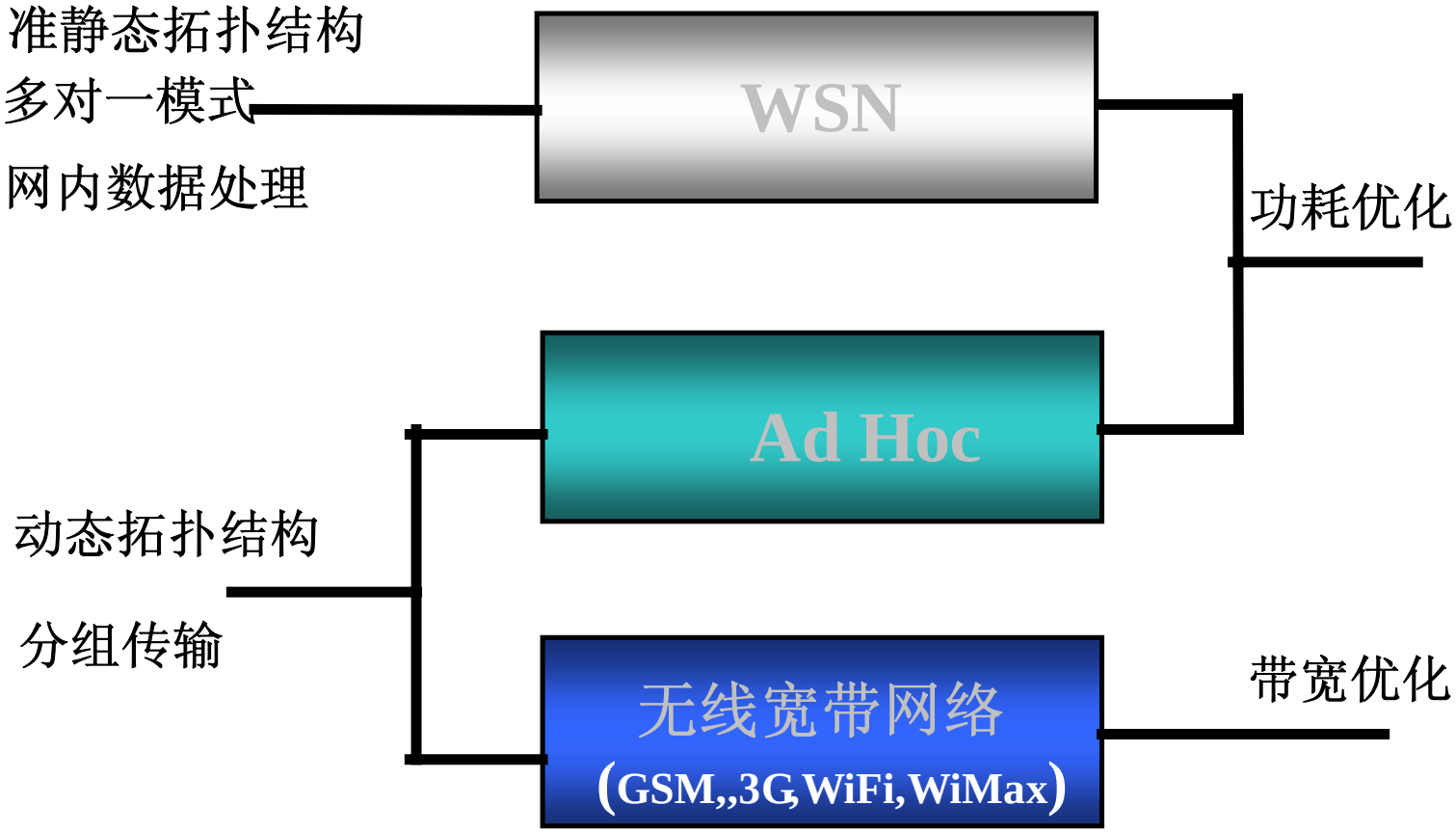
WSN与Ad hoc网络

- 相同点：
  基本不需要人的干预，大部分工作是以自组织的方式完成的，二者统称为自组织网络。二者的研究都是追求低功耗的自组织网络设计。
- 不同点：
  （1）网络拓扑结构和工作模式各不相同。
  Ad hoc网络：网络拓扑结构动态变化。
  WSN：网络拓扑结构是静态的。
  （2）工作模式不同。
  WSN：多对一(Many-to-One)通信，节点之间几乎不会发生消息交换。
  Ad Hoc网络：网络中任意两节点之间都有通信的可能。

三种网络之间的关系


准静态拓扑结构
多对一模式
网内数据处理
WSN
功耗优化
Ad Hoc
动态拓扑结构
分组传输
无线宽带网络
(GSM,,3G,WiFi,WiMax)
带宽优化

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WSN体系结构

- 典型的WSN体系结构有：
- 动态协议栈的体系结构
- 层次性的体系结构
- 自适应体系结构
- 可编程的体系结构
- 自管理的体系结构
- 自恢复的体系结构
- 多任务的体系结构
- 基于代理的体系结构

WSN体系结构

- 体系结构设计中需要考虑的要素：
- 节点资源的有效利用
- 支持网内数据处理
- 支持协议跨层设计
- 增强安全性
- 支持多协议
- 支持有效的资源发现机制
- 支持可靠的低延时通信
- 支持容忍延时的非面向连接通信
- 开放性

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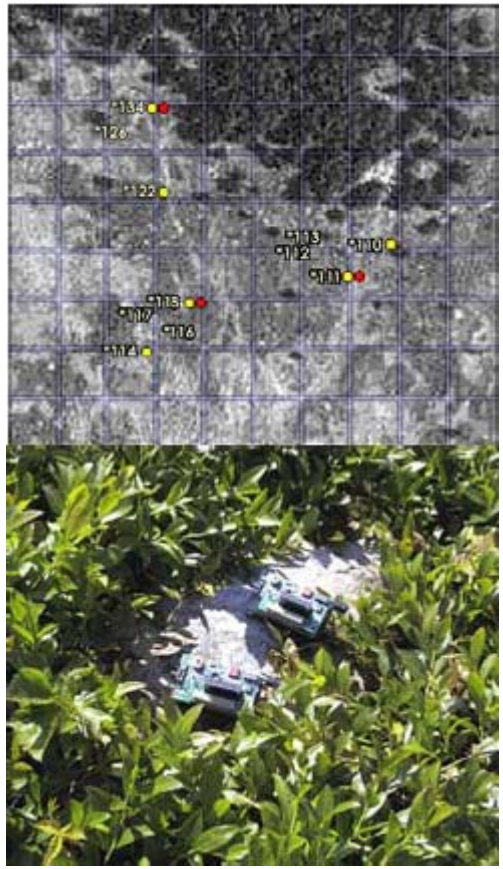
WSN的应用

- 目标跟踪
- 大鸭岛海燕监测
- 冰河监测
- 医疗健康
- 电子牧场
- 结构化监测
- 火山观测
- ……

大鸭岛海燕监测

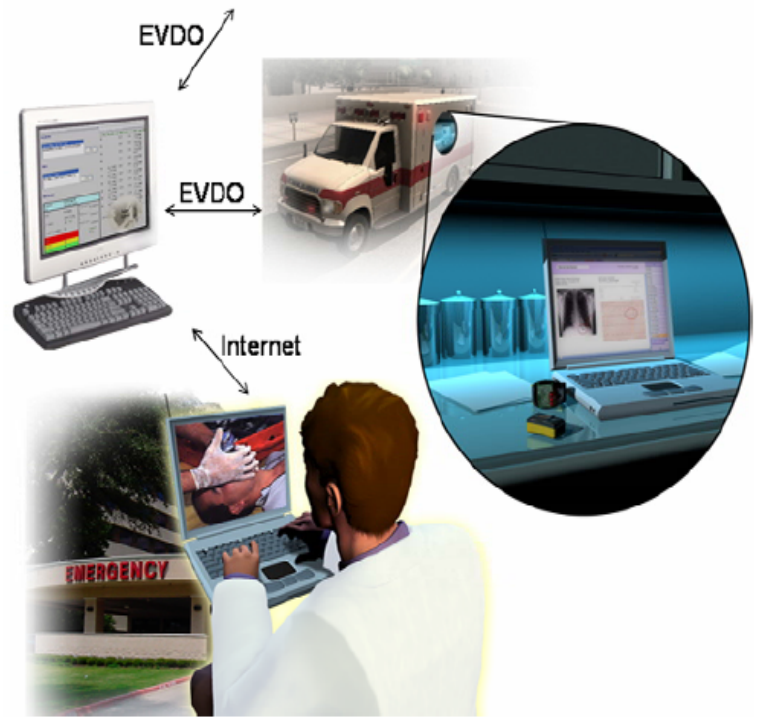
- 项目开始时间：2002年
- 参与者：英特尔研究实验室和加州大学伯克利分校
- http://www.greatduckisland.net/



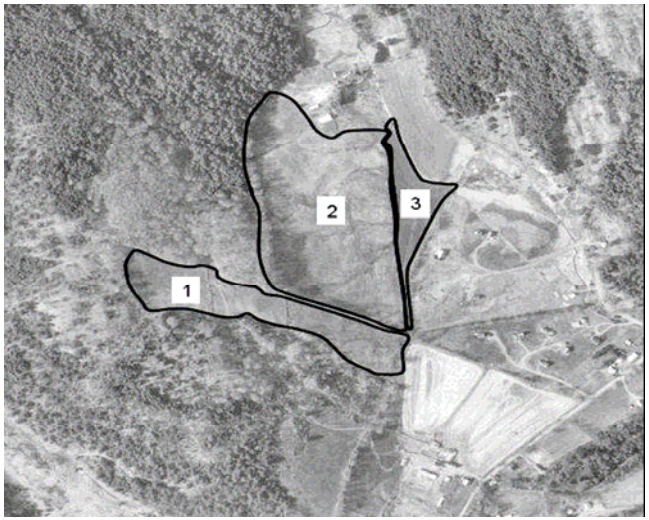
冰河监测

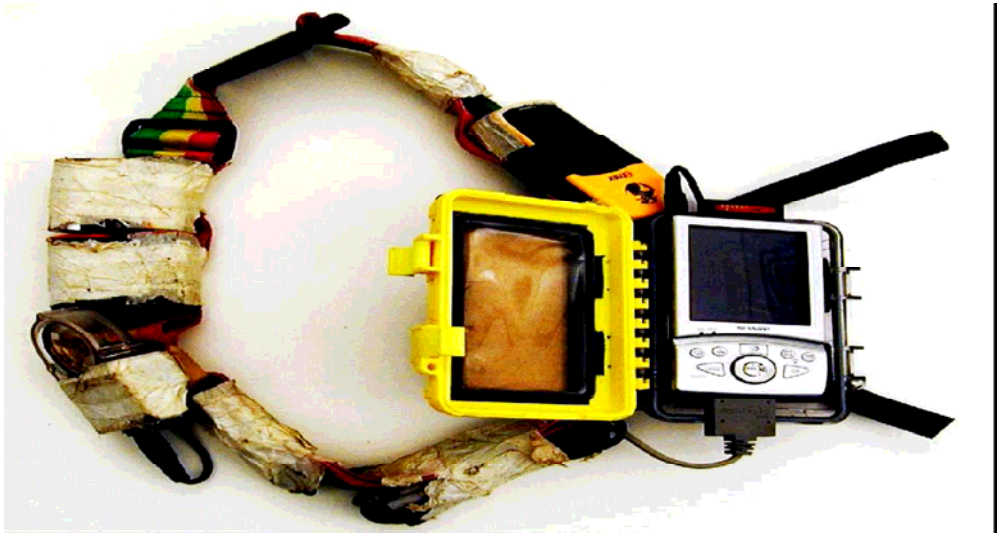
- 利用WSN监测冰河的变化情况，目的在于通过分析冰河环境的变化来推断地球气候的变化。

医疗健康

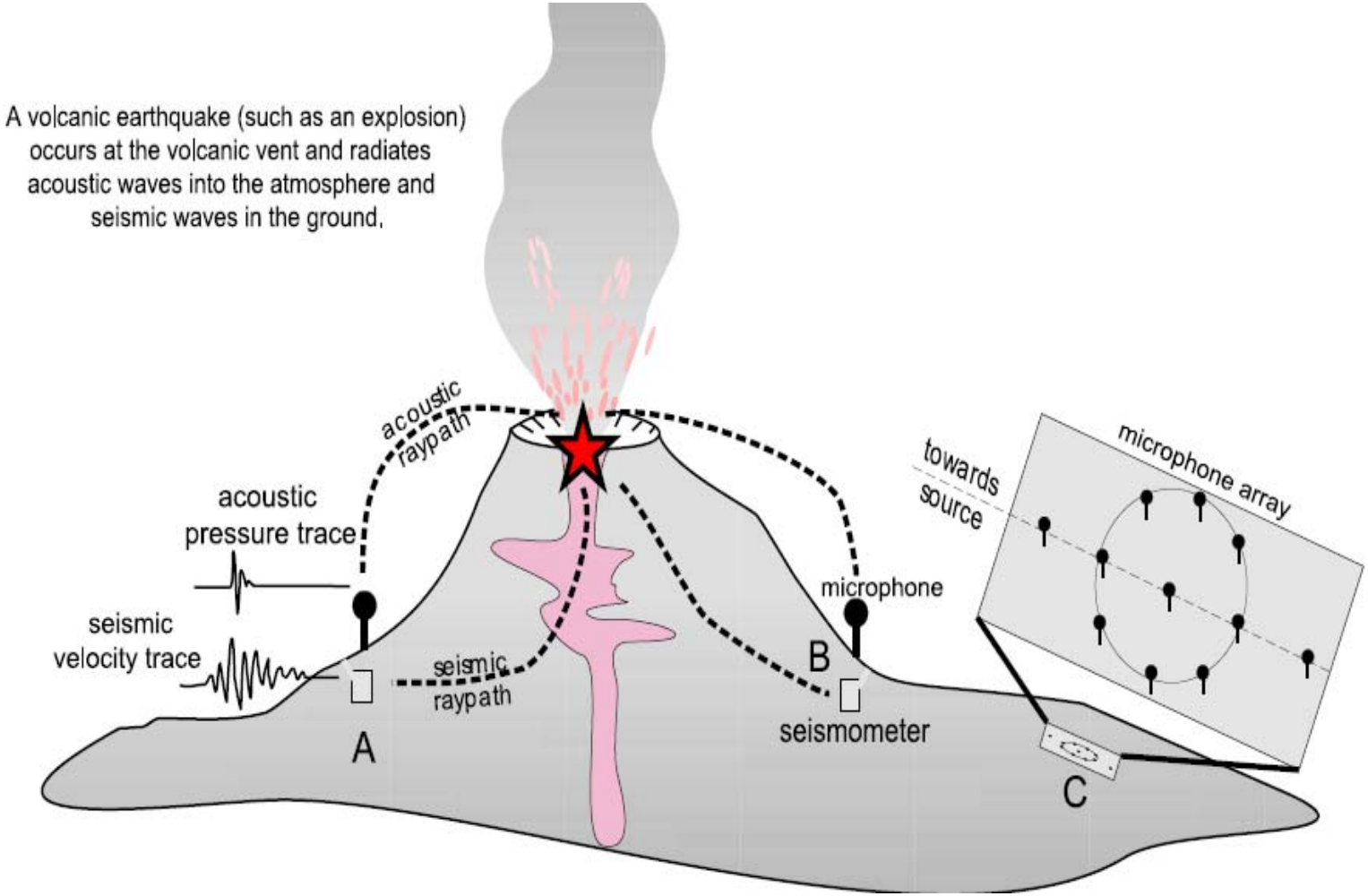


电子牧场





火山观测


A volcanic earthquake (such as an explosion) occurs at the volcanic vent and radiates acoustic waves into the atmosphere and seismic waves in the ground.
acoustic raypath
acoustic pressure trace
seismic velocity trace
seismic raypath
A
B
microphone
seismometer
towards source
microphone array
C

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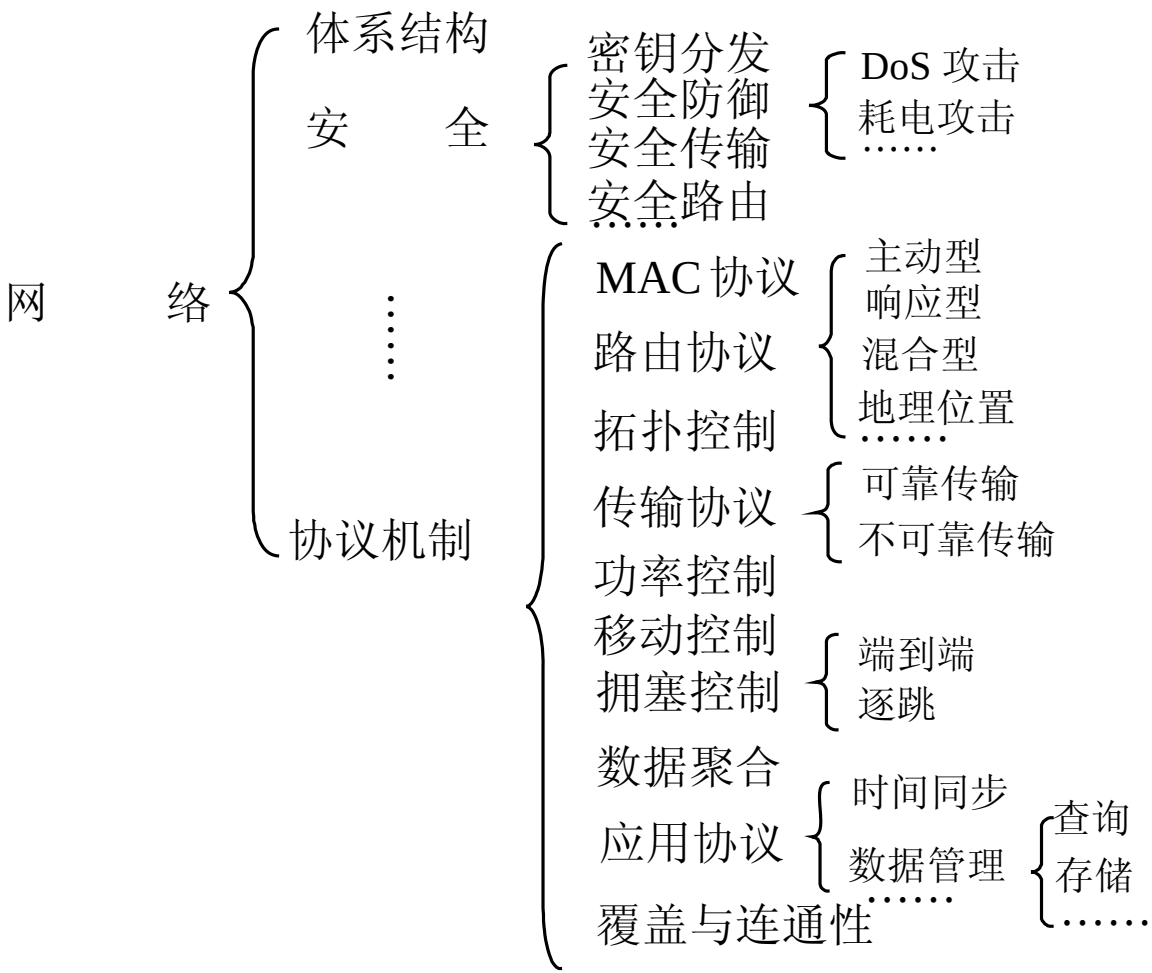
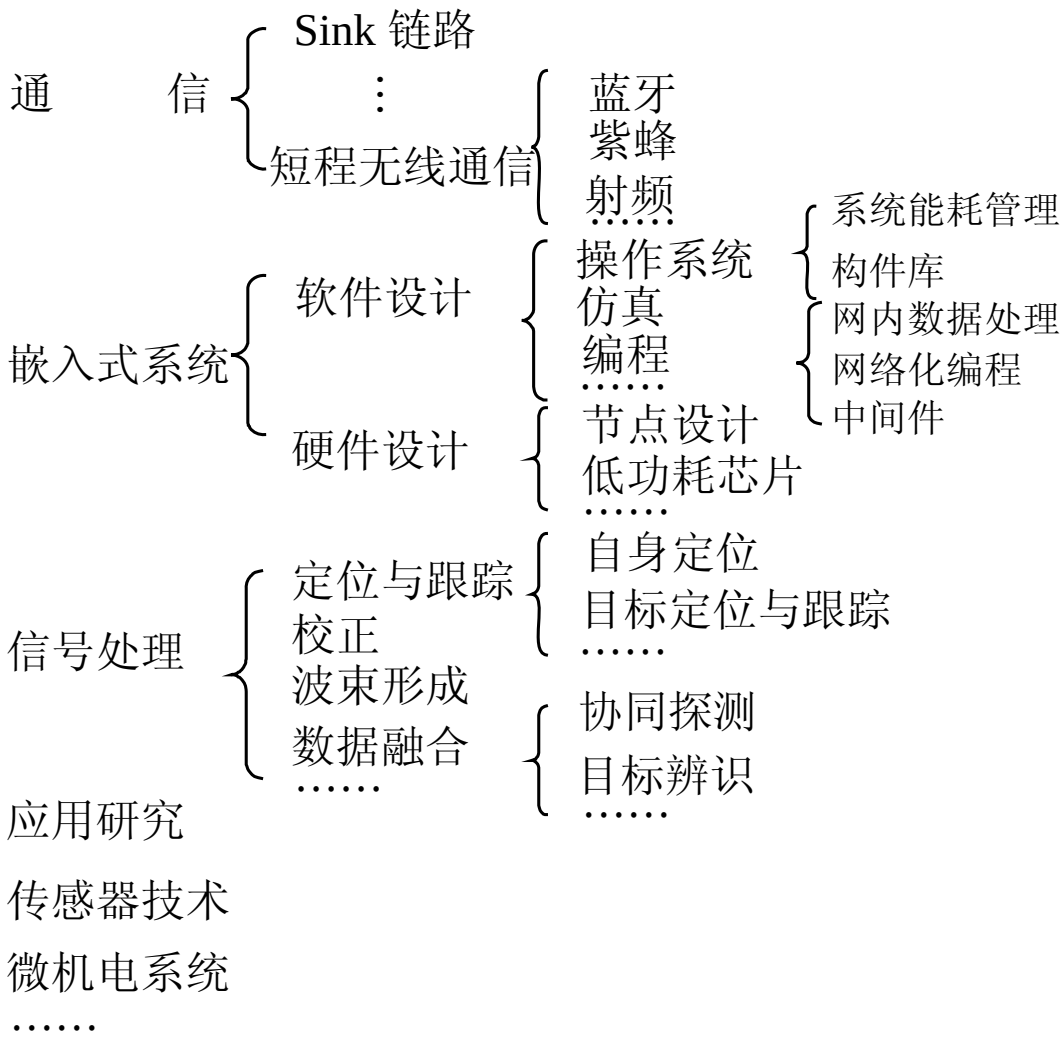
研究方向及分类（一）


网络
体系结构
安全
密钥分发
安全防御
安全传输
安全路由
……
DoS 攻击
耗电攻击
……
协议机制
MAC 协议
路由协议
拓扑控制
传输协议
功率控制
移动控制
拥塞控制
数据聚合
应用协议
覆盖与连通性
主动型
响应型
混合型
地理位置
……
可靠传输
不可靠传输
端到端
逐跳
时间同步
数据管理
……
查询
存储
……

研究方向及分类（二）


通　　信
Sink 链路
⋮
短程无线通信
蓝牙
紫蜂
射频
……
嵌入式系统
软件设计
操作系统
仿真
编程
……
系统能耗管理
构件库
网内数据处理
网络化编程
中间件
硬件设计
节点设计
低功耗芯片
……
信号处理
定位与跟踪
校正
波束形成
数据融合
……
自身定位
目标定位与跟踪
……
协同探测
目标辨识
……
应用研究
传感器技术
微机电系统
……

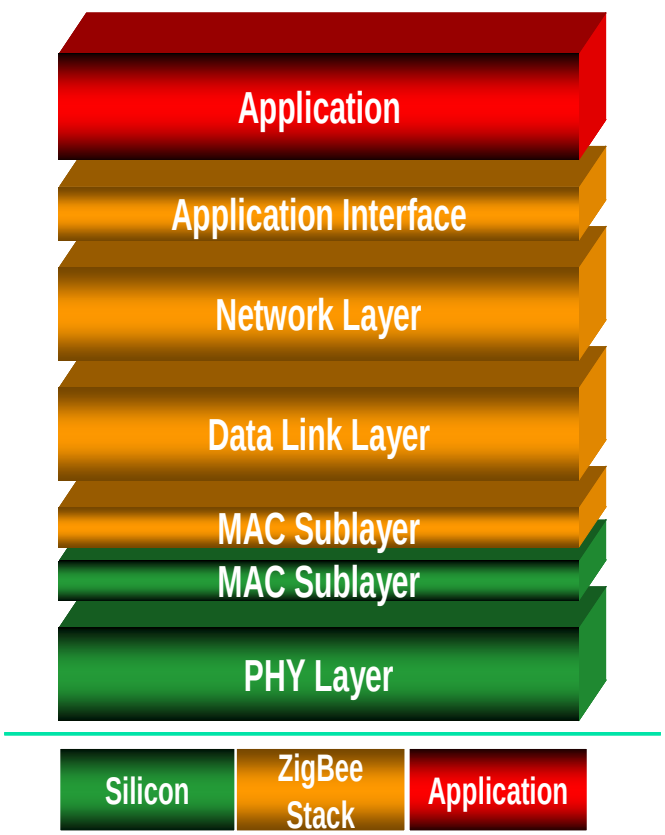
操作系统—TinyOS

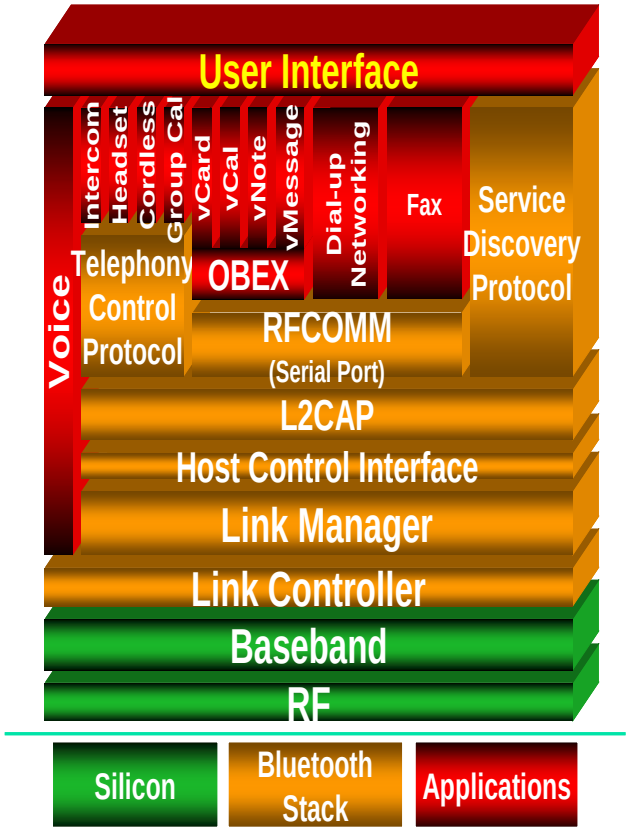
- TinyOS是UC Berkeley的David Culler领导的研究小组为WSN量身定制的嵌入式操作系统。
- WSN对操作系统的特殊要求主要表现在：
- （1）节点的计算资源有限，需要尽可能的减小系统开销；
- （2）节点由电池供电，且要求较长的工作周期，因此需要系统的能耗管理策略与方案，包括操作系统的支持；
- （3）节点的各模块之间需要一定的调度协调机制，同时支持并发控制；
- （4）观测任务需要操作系统支持实时性。

IEEE 802.15.4

- 主要技术特点包括：
- （1）功耗低
- （2）成本低
- （3）延时短
- （4）规模大
- （5）更安全

ZigBee与BT协议栈比较





典型无线通信技术的特点

标准	802.1.5.1 (BlueTooth)	802.11b (Wi-Fi)	802.15.4 (ZigBee)
应用领域	替代外设线缆	无线接入	监测与控制
带宽(Kbps)	1000~3000	11000+	20~250
传输距离(米)	20(2 类) 100+ (1 类)	100+	20~70 100+(放大器)
节点个数	7	32	25400
电池寿命(天)	1~7	0.5~5	100~1000+
发送功率	45mA (2 类) <150mA (1 类)	300 mA	30mA
低占空比支持	弱	弱	强
扩频技术	FHSS	DSSS	DSSS
内存开销 (KB)	50+	70+	40+
技术优势	成本，便捷	带宽，灵活性	功耗，成本

节点试验平台

- 第一代（1996~1999）：代表性的平台有UCLA的WINS[61]，UC Berkeley的SmartDust[62]、WeC和Rene[63]。
- 第二代（2000~2001）：典型平台的有UCB的Mica与Dot[64]，MIT的uAMPS-I和uAMPS-II[65]，以及Rockwell公司的HYDRA。
- 第三代（2002~2003）：两款代表性的试验平台：Mica2和MicaDot2，以及NASA JPL实验室的Sensor Web[66]。
- 第四代（2004~）：典型的平台有MicaZ、Telos、EmberNode、Imote、Imote2、BTNode3和DSYS25。

第四代节点平台比较

平台	Mica2	Micaz	Telos	Inote	Inote 2
CPU @[MHz]	8bit Atmel @8	8bit Atmel @8	16bit TI @8	32 ARM @12	32bXS@13(104)
SRAM [kB]	4	4	10	64	256/32,000
FLASH [kB]	128 + 512	128 + 512	48/1024 KB	512	32,000
无线通信	300-900MHz	ZigBee	ZigBee	BT	Zigbee/BT/WiFi
带宽 [kb/s]	15	250	250	720	250 (720/11,000)
功耗 C/R/T [mA]	8 / 10 / 27	8 / 20 / 18	1 / 20 / 18	15 / 24 / 24	40/20/18
休眠功耗 [uA]	19	27	6	1-250	1-100
安全	N	AES-128	AES-128	4LFSR-128	Y

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关于WSN的定义

- 目前大多数研究者普遍接受的既成事实的WSN定义：

  大规模、无线、自组织、多跳、无分区、无基础设施支持的网络、其中的节点是同构的、成本较低、体积较小、大部分节点不移动、被随意撒布在工作区域，要求网络系统有尽可能长的工作时间。

WSN研究方法

- WSN的研究具有较强的试验科学的特征，强调试验而非单纯依赖仿真。
- WSN的研究需要广泛的合作
- WSN的研究划分为两大类：

  （1）基础研究—强调理论突破

  （2）应用研究—偏重挖掘WSN的应用潜能

主要参考文献（一）

1. C.-Y. Chong, “Sensor Networks: Evolution, Opportunities, and Challenges”, IEEE，0018-9219/03
2. William J. Kaiser, “Low Power Wireless Integrated Microsensors,” http: // www.janet.ucla. edu /WINS/lwim-innovative.htm
3. G.J. Pottie. “Wireless Sensor Networks.,” In IEEE Information Theory Workshop, 1998, 139-140
4. D. Estrin, R. Govindan, J. Heidemann, and S. Kumar, “Next Century Challenges: Scalable Coordination in Sensor Networks,” In Proc. of Mobicom’99, 1999,Seattle,USA, 263-270
5. BusinessWeek Online,“Tech wave 2: The sensor revolution,” http://www. businessweek.com /magazine/content/03_34/b3846622.htm
6. Terry van der Werff, “10 Emerging Technologies That Will Change the World,” http://www. globalfuture .com/mit-trends2001.htm
7. 国务院, “国家中长期科学与技术发展规划纲要,” http://news.sina.com.cn/
8. David Culler, “Wireless Sensor Networks - the Next IT Revolution,” http://www.cs.berkeley. edu/~culler/talks/KES2004.ppt
9. Chalermek Intanagonwiwat, Ramesh Govindan, Deborah Estrin, John Heidemann, and Fabio Silva, “Directed diffusion for wireless sensor networking,” IEEE/ACM Transactions on Networking, vol.11(1),2-16,2003
10. Charles E. Perkins, Elizabeth M. Belding-Royer, and Samir Das. "Ad Hoc On Demand Distance Vector (AODV) Routing." IETF RFC 3561
11. Perkins C, Nhagwat P. Highly dynamic Destination-Sequenced Distance-Vector routing(DSDV) for mobile computers. In:Proc.of the ACM SIGCOMM Conf. on Communication Architectures,Protocols,and Applications, 1994.pp:234~244
12. ChenTien Ee, Ruzena Bajcsy, “Congestion control and fairness for many-to-one routing in sensor networks,” In Proc. of the 2nd international conference on Embedded networked sensor systems(Sensys2004) , Baltimore, MD, USA,2004, pp:148~161

主要参考文献（二）

13. Bret Hull, Kyle Jamieson, Hari Balakrishnan, “Mitigating Congestion in Wireless Sensor Networks,” In Proc. of the 2nd international conference on Embedded networked sensor systems(Sensys2004), Baltimore, MD, USA,2004,134~147
14. Jason Hill and Robert Szewczyk and Alec Woo and Seth Hollar and David E. Culler and Kristofer S. J. Pister, “System Architecture Directions for Networked Sensors,” Architecture Support for Programming Languages and Operating Systems (ASPLOS'00)., November 2000,pp:93~104
15. David Culler, Prabal Dutta, Cheng Tien Eee, Rodrigo Fonseca,Jonathan Hui, Philip Levis, Joseph Polastre, Scott Shenker,Ion Stoica, Gilman Tolle, and Jerry Zhao, “Towards a Sensor Network Architecture: Lowering the Waistline,” In Proceedings of HotOS X: Tenth Workshop on Hot Topics in Operating Systems, June,2005.
16. Linnyer Beatrys Ruiz, Jose Marcos Nogueira and Antonio A. F. Loureiro, “MANNA: A Management Architecture for Wireless Sensor Networks,” IEEE communication magazine, Feb. 2003, pp:116~125
17. David Culler, Prabal Dutta, Cheng Tien Eee, Rodrigo Fonseca, Jonathan Hui, Philip Levis, Joseph Polastre, Scott Shenker, Ion Stoica, Gilman Tolle, and Jerry Zhao, "Towards a Sensor Network Architecture: Lowering the Waistline", In Proceedings of the Tenth Workshop on Hot Topics in Operating Systems (HotOS X), 2005.
18. Mukundan Venkataraman, Kartik Muralidharan and Puneet Gupta, “Designing new Architectures and Protocols for Wireless Sensor Networks-A Perspective”, IEEE SECON, September 2005.
19. Venkata A. Kottapalli, Anne S. Kiremidjian, Jerome P. Lynch, Ed Carryer, Thomas W. Kenny, Kincho H. Law, and Ying Lei. “Two-tiered wireless sensor network architecture for structural health monitoring”, SPIE.10th International Symposium on Smart Structures and Materials, San Diego, March 2-6, 2003
20. R. Govindan, EKD Estrin, F. Bian, K. Chintalapudi, O. Gnawali, S. Rangwala, R. Gummadi, and T. Stathopoulos, “Tenet: An Architecture for Tiered Embedded Networks”, Tech. Rep., November 10 2005
21. Santashil PalChaudhuri, Raymond Wagner, David Johnson, Richard Baraniuk, “An Adaptive Sensor Network Architecture for Multi-scale Communication”, 2005 Corporate Affiliates Meeting
22. M. Welsh and G. Mainland. Programming Sensor Networks Using Abstract Regions. In Proc. NSDI'04, March 2004. 9
23. Linnyer Beatrys Ruiz, Jose Marcos Nogueira and Antonio A. F. Loureiro, “MANNA: A Management Architecture for Wireless Sensor Networks,” IEEE communication magazine, Feb. 2003, pp:116~125
24. Nogueira, and Antonio A. F. Loureiro, "On the Design of a Self-Managed. Wireless Sensor Network", IEEE Communications Magazine, 2005, 43. (8), pp. 95-102

主要参考文献（三）

25. Tatiana Bokareva, Nirupama Bulusu, Sanjay Jha: "SASHA: Toward a Self-Healing Hybrid Sensor Network Architecture" Embedded Networked Sensors, 2005. EmNetS-II. The Second IEEE Workshop on Publication Date: 30-31 May 2005
26. J. Steffan, L. Fiege, M. Cilia, and A. Buchmann. Towards Multi-Purpose wireless sensor networks. In Proc. of Conf. on Sensor Networks (SENET'05), August 2005
27. Sajid Hussain, Elhadi Shakshuki, and Abdul W. Matin, Agent based system architecture for wireless sensor networks, Second IEEE International Workshop on Heterogeneous Wireless Sensor Networks (HWISE'06)
28. Mikael Brannstrom, Erland Jungert, “A Scalable Agent Architecture for a Dynamic Sensor Network”, Electr. Notes Theor. Comput. Sci. 68(3): (2003)
29. Tian He et al., “VigilNet: An Integrated Sensor Network System for Energy-Efficient Surveillance,” to be published, ACM Trans. Sensor Networks, 2006
30. Murat Demirbas, Ken Yian Chow, Chieh Shyan Wan, “INSIGHT: Internet-Sensor Integration for Habitat Monitoring,” Proceedings of the 2006 International Symposium on World of Wireless, Mobile and Multimedia Networks, 553 – 558
31. GENI,Global Environment for Network Innovations,http://www.geni.net
32. J. Saltzer, D. Reed, and D. Clark, End-to-end Arguments in System Design. ACM Trans. on Computer Systems (TOCS), Vol. 2, No. 4, 1984, pp. 195-206.
33. S. Shakkotai, T. Rappaport, P. Karlsson, "Cross-layer design for wireless networks", IEEE Communications Magazine, vol.41, no.10, October 2003, pp. 74-80
34. G. Pau, D. Maniezzo, S. Das, Y. Lim, J. Pyon, H. Yu, M. Gerla, “A cross-layer framework for wireless LAN QoS support”, Proceedings of IEEE ITRE, August, 2003
35. F. Akyildiz, D. Pompili, T. Melodia, Underwater Acoustic Sensor Networks: Research Challenges, Elsevier's Journal of Ad Hoc Networks, Vol. 3, Issue 3, pp. 257-279
36. I F. Akyildiz, Erich P. Stuntebeck, Wireless underground sensor networks: Research challenges, Elsevier's Journal of Ad Hoc Networks, Vol. 4, Issue 3, pp. 669-686

主要参考文献（四）

37. Kristofer S.J. Pister ,“Tracking vehicles with a UAV-delivered sensor network,” http:// robotics .eecs.berkeley.edu/~pister/29Palms0103/
38. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, and J. Anderson, “Wireless Sensor Networks for Habitat Monitoring,” In Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications, 2002, pp:88~97
39. Gilman Tolle, Joseph Polastre, Robert Szewczyk, Neil Turner, Kevin Tu, Stephen Burgess , David Gay, Phil Buonadonna, Wei Hong, Todd Dawson, David Culler, “A Macroscope in the Redwoods,” In Proc. of the 3th international conference on Embedded networked sensor systems (Sensys 2005), San Diego, USA,Nov., 2005:51~63
40. Cerpa, J. Elson, D. Estrin, L. Girod, M. Hamilton, and J. Zhao., “Habitat Monitoring: Application Driver for Wireless Communications Technology.,” ACM SIGCOMM Workshop on Data Communications in Latin America and the Caribbean, April 2001
41. K. martninez, R. ong, J.K.Hart and J. Stefanov, “GLACSWEB: A Sensor Web for Glaciers,” In Proc. European Workshop on Sensor Networks (EWSN'04), Berlin, Germany, Jan. 2004
42. Tia Gao, Dan Greenspan, Matt Welsh, Radford R. Juang, and Alex Alm, “Vital Signs Monitoring and Patient Tracking Over a Wireless Network,” In Proceedings of the 27th IEEE EMBS Annual International Conference, September 2005
43. Anu Bhargava and Mike Zoltowski, “Sensors and Wireless Communication for Medical Care,” International Workshop on Database and Expert Systems Applications (DEXA'03), 2003, pp:956~960
44. Kristof Van Laerhoven et al, “Medical Healthcare Monitoring with Wearable and Implantable Sensors,” In Proceeding of the UbiComp 2004.
45. Z. Butler, P. Corke, R. Peterson and D. Rus, “Netowrked Cows: Virtual Fences for Controlling COws,” In Proc. WAMES 2004, Boston, USA
46. Shamim N. Pakzad, Sukun Kim, Gregory L Fenves, Steven D. Glaser, David E. Culler, and James W. Demmel, “Multi-Purpose Wireless Accelerometers for Civil Infrastructure Monitoring,” In Proceedings of the 5th International Workshop on Structural Health Monitoring (IWSHM 2005), Stanford, CA, September 2005
47. Ning Xu, Sumit Rangwala, Krishna Kant Chintalapudi, Deepak Ganesan, Alan Broad, Ramesh Govindan, Deborah Estrin,“A wireless sensor network For structural monitoring,” In Proceedings of the 2nd international conference on Embedded networked sensor systems(Sensys2004), Baltimore, MD, USA, 2004,pp:13~24
48. Werner-Allen, J. Johnson, M. Ruiz, J. Lees, and M. Welsh, “Monitoring Volcanic Eruptions with a Wireless Sensor Network,” In Proc. European Workshop on Sensor Networks (EWSN'05), January 2005

主要参考文献（五）

49. TinyOS, http://www.tinyos.net/
50. Jason Hill and Robert Szewczyk and Alec Woo and Seth Hollar and David E. Culler and Kristofer S. J. Pister, “System Architecture Directions for Networked Sensors,” Architecture Support for Programming Languages and Operating Systems (ASPLOS'00)., November 2000,pp:93~104
51. Wei Ye, John Heidemann and Deborah Estrin, “An Energy-Efficient MAC Protocol for Wireless Sensor Networks,” In Proc. of the 21st International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2002), New York, NY, USA, June, 2002
52. Injong Rhee, Ajit Warrier, Mahesh Aia and Jeongki Min, “Z-MAC: Hybrid MAC for Wireless Sensor Networks,” In Proc. of the 3th international conference on Embedded networked sensor systems (Sensys 2005), San Diego, USA, Nov., 2005:90~101
53. Intel Company, “Intel Mote: Sensor nets/RFID,” http://www.intel.com/research /exploratory/motes.htm
54. Martin Leopold Mads Bondo Dydensborg Philippe Bonnet, “Bluetooth and Sensor Networks: A Reality Check,” In Proc. of the 1st international conference on Embedded networked sensor systems (Sensys 2003), Los Angeles, California, USA, 2003, 103~113.
55. Jan Beutel, “BTnodes: A Distributed Environment for Prototyping Ad Hoc Networks,” http://www.btnode.ethz.ch
56. Joseph Polastre, Robert Szewczyk, David Culler, “Telos: Enabling Ultra-Low Power Wireless Research,” In the Fourth International Conference on Information Processing in Sensor Networks: Special track on Platform Tools and Design Methods for Network Embedded Sensors (IPSN/SPOTS), April, 2005
57. Crossbow Company, “MicaZ ZigBee series,” http://www.xbow.com/Products
58. Henry Tirri, “Challenges of large-scale heterogeneous wireless sensor networks,” Keynote talk at DMSN’05, http://www.cs.helsinki.fi/u/tirri/
59. ZigBee Alliance ,“ZigBee and 802.15.4 for Personal Area and Sensor Networks,” http://www.ZigBee.org
60. Benny Lo, Surapa Thiemjarus, Rachel King and Guang Zhong Yang, “Body Sensor Network – A Wireless Sensor Platform for Pervasive Healthcare Monitoring”, Adjunct Proceedings of the 3rd International Conference on Pervasive Computing (PERVASIVE 2005), May 2005,pp.77-80,

主要参考文献（六）

61. G. Asada, M. Dong, T.S. Lin, F. Newberg, G. Pottie, W.J. Kaiser, and H.O. Marcy, “ Wireless Integrated Network Sensors: Low Power Systems on a Chip,” In Proc. of the 1998 European Solid State Circuits Conference.
62. J. M. Kahn, R. H. Katz and K. S. J. Pister, "Mobile Networking for Smart Dust", ACM/IEEE Intl. Conf. on Mobile Computing and Networking (MobiCom 99), Seattle, WA, August 17-19, 1999
63. Joseph Polastre, Robert Szewczyk, Cory Sharp, and David Culler, “The mote revolution: Low power wireless sensor networks,” In proc. of the 16th symposium on high performance chips(HotChips), Aug. 2004
64. K. Bult, A. Burstein, D. Chang, M. Dong, W.J. Kaiser，“ Wireless Integrated Microsensors,“ Proceedings of Conference on Sensor s and Systems (Sensors Expo). Anaheim, CA, USA, April 16-18 1996, pp. 33-38.
65. Wang, A. P. Chandrakasan, "Energy-efficient DSPs for wireless sensor networks," IEEE Signal Processing Magazine, Vol. 19, No. 4 , pp. 68-78, July 2002
66. PASTA, http://pasta.east.isi.edu/
67. Kevin A. Delin, “The Sensor Web: A Macro-Instrument for Coordinated Sensing,” Sensors, Vol. 2, 2002, pp. 270-285
68. Wisenet, http://cegt201.bradley.edu/projects/proj2003/wisenet/downloads.html
69. Kris Lin, Jennifer Yu, Jason Hsu, Sadaf Zahedi, David Lee,.Jonathan Friedman, Aman Kansal, Vijay Raghunathan, and Mani Srivastava, “Heliomote: enabling long-lived sensor networks through solar energy harvesting,” In Proc. of the 3rd international conference on Embedded networked sensor systems, San Diego, California, USA, 2005:pp 309~309
70. Sung Park, Ivo Locher, Mani Srivastava, "Design of a Wearable Sensor Badge for Smart Kindergarten", In the 6th International Symposium on Wearable Computers (ISWC2002), Seattle, WA, October 7-10, 2002

主要参考文献（七）

71. EYES: Energy efficient sensor networks, http://www.eyes.eu.org/sensnet.htm
72. S. Saruwatari, T. Kashima, M. Minami, "PAVENET: Hardware and Software Framework for Wireless Sensor Networks," Transaction of the Society of Instrument and Control Engineers, vol. E-3, 2005，http://www.mlab.t.u-tokyo.ac.jp/publications/
73. Ember Company, http://www.ember.com
74. Brendan O'Flynn, Andre Barroso, Stephen Bellis, Jonathan Benson, Utz Roedig, Kieran Delaney, John Barton, Cormac Sreenan, and Sean O'Mathuna, “The Development of a Novel Miniaturized Modular Platform for Wireless Sensor Networks,” In Proceedings of the IPSN Track on Sensor Platform, Tools and Design Methods for Networked Embedded Systems (IPSN2005/SPOTS2005), Los Angeles, USA, April 2005
75. S. Park, A. Savvides, and M.B. Srivastava., “SensorSim: A Simulation Framework for Sensor Networks,” MSWiM'00, August 2000
76. P. Levis, N. Lee, M. Welsh, and D. Culler., “TOSSIM: Accurate and Scalable Simulation of Entire TinyOS Applications,” The First ACM Conference on Embedded Networked Sensor Systems (Sensys03), November 2003
77. Polley, J.; Blazakis, D.; McGee, J.; Dan Rusk; Baras, J.S.; Karir, M., “ATEMU: A Fine-Grained Sensor Network Simulator,” IEEE SECON 2004, October 2004
78. QualNet, http://www.scalable-networks.com/products/developer.php


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