Wireless Networks of Intelligent Sensors (WISE)

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Evolution of Computer Monitoring
Evolution of Computer Monitoring

- Process
- Signal conditioning
- Signal conditioning
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- Int. sensor
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Evolution of Computer Monitoring
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Wireless Sensor Networks

- Networks of wireless sensors
- Data collection, distributed monitoring

Applications
- military/surveillance,
- environmental,
- condition based maintenance
- ubiquitous computing
- disaster management
- medical applications
Existing Wireless Sensor Networks

- DARPA - SensIT
- Smart Dust - University of California at Berkley
  - Lasers/RF for wireless communication
  - Very small wireless devices that can be spread, and then dynamically organize to become a sensor net

Existing Wireless Sensor Networks

- Smart Dust Communication
  - Infra red (IrDA)/PDAs
  - RF 900 MHz communication
  - Laser communication
  - Corner Cube Reflector
  - Light Receiver Communication
Existing Wireless Sensor Networks

- **UCLA**
  - WINS (Wireless Integrated Network Sensors)
    - Embedded processors, multihop network, sensing
  - Fusing physical and cognitive spaces
    - Assess student learning
    - Position, orientation, acoustic data

- **Wireless Sensor Network (WSN)**
  - University of Tennessee, Knoxville
    - Small sensor scattered on or near a road, and detect enemy vehicle activity

**WINS, SCADDS**

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Oak Ridge National Lab

- “Critters on a chip” (bioreporters)
- “Nose on a chip”
- “Lab on a chip”
  - DNA biochip (2D)
  - Flowthrough genosensor (3D), etc.

**Medical Telesensors**
- (2x2 mm wireless temperature sensor)
**Medtronic**
- Division of Cardiology, Univ. of Western Ontario
- Implantable loop recorder
- Provides up to 14 months of cardiac monitoring
- 40 minutes of history can be stored after an episode
- Weight 17 g, volume 8 mL

**Existing Wireless Sensor Networks**
- Microstrain – Wireless Web Sensor Network
Issues

- Battery life
- Size
- Communication range
- Adaptivity/Robustness
- Seamless integration
  - Ad-hoc networks
  - Security
- Intelligence

Wireless LAN Protocols

- **802.11b**
  - 2.4GHz band, direct sequence spread spectrum

- **802.11a**
  - 5.8GHz band, orth. freq. division multiplexing

- **Bluetooth**
  - 900MHz & 2.4GHz bands, frequency hopping spread spectrum
Custom Communication Protocols
Super Frame Timing Diagram

Intelligent medical monitors

- Sudden collapse victims, result of
  - circulatory
  - hypoxemic
  - traumatic arrest
- estimated mortality 350,000 lives/year
- economic cost of trauma related injuries
  $400 billion / year (NIH PA-01-054)
Intelligent Personal Monitors

Solution?

Wireless Personal Area Network of Intelligent Sensors

+ Hierarchical Digital Signal Processing
Problems of existing systems?

- Development environment
  - custom VLSI, assembler?
- Resources for sophisticated real-time processing
  - memory
  - speed
- Price
Wireless Personal Area Network

- Wireless network of intelligent sensors
  - piconetwork
- Multiple WISE Devices and MOGULs

Initial WISE Architecture

- wireless transceiver
- microcontroller
- ECG amplifier
- ECG electrodes
Wireless Intelligent Sensor WISE

- **Battery**
- **Microcontroller**
  - TI MSP430F149
  - 8 channel 12-bit AD conv.
- **Accelerometer**
  - Movement detection
  - Analog Device ADXL202
- **Transceiver**
  - LINX 916 MHz

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Wireless Intelligent Sensor WISE

- **Low power microcontroller TI430F149**
  - 16-bit RISC architecture, 60KB flash, 2KB RAM
  - ultra-low power consumption (400 µA in active mode, as low as 0.8 µA in standby mode)
  - 8 channels (12+2 bit A/D)
- **Wireless transceiver**
  - LINX RF transceiver 916MHz
  - 33.6 Kbps data transfer rate
  - adjustable power/range
- **Biomedical amplifier**
  - Teledyne TETMD A110 (ECG/EEG amplifier)
  - custom amplifiers
Wireless Personal Area Network System with WISE

Hierarchical Signal Processing

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Speed</th>
<th>Power</th>
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<td>I</td>
<td>WISE</td>
<td>10 MIPS</td>
<td>10's mW</td>
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<tr>
<td>II</td>
<td>Personal Area Network</td>
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<td>Personal network server</td>
<td>500 MIPS</td>
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<td>IV</td>
<td>Internet</td>
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Wireless PAN configuration

Hierarchical DSP System Design

- Constraint programming
  - set of constraints
- Process scheduling
- Performance evaluation
- Energy profiling
- Iterative process
Hierarchical process scheduling
Exploring the design space

Wearable physiological monitors

- ECG (heart activity)
  - myocardial ischemia
  - arrhythmia
  - circadian rhythm analysis of heart rate variability
- EEG (brain activity)
  - epileptic seizure detection
  - drowsiness detection
- Heterogenous sensors (polygraphy)
  - sleep apnea monitoring
  - physical therapy feedback for stroke victims
  - new generation human-computer interfaces
Wireless PAN - Applications

- Wearable physiological monitors
  - intelligent monitoring/early warnings
  - decrease hospitalizations & nursing visits
- Intelligent control of medication
  - sensing, dosing and compliance monitoring
- Aids for disabled
- Computer assisted rehabilitation
  - stroke victims
  - supervised heart attack rehabilitation
- Battlefield soldier monitoring
- Advanced human-computer interfaces

Currently active WISE projects

- Wireless Heart Rate Monitor WHRM
- Breathing monitor
- Pulse oxymeter
- USB interface
- Power aware kernel
- OS support for mobile code
- Wireless data acquisition and processing
- Portable physical rehabilitation
  - Accelerometer based monitoring position/forces
- WISE Internet server
Wireless Heart Rate Monitor WHRM

- Developed with Naval Aerospace Medical Research Lab, Pensacola, FL and RPTechnologies
- Army’s project “The War Fighter’s Stress Response”
- Wireless monitoring (belt), wireless uplink
- 24 hour heart data acquisition
- iPAQ PDA used as mobile gateway for data upload
- Estimation of stress resistance based on Heart Rate Variability

Intelligent data acquisition

250 Hz * 2 channels * 2B * 86400 seconds = 84 MB / day

Secondary memory
PDA based wireless PAN

- TETMD bioamplifier
- Wireless module
  - LINX 916 MHz transceiver
- Compaq iPAQ PDA
  - Personal server
  - Internet connectivity

Long term breathing monitor

- Sensor design
  - Chest belt
  - Thermistor based differential breathing sensor
- Intelligent data acquisition
- Wireless link
- Smart card/flash memory
  - When_available archiving
- Hierarchical processing
Intelligent CCD Imaging Sensor
IVIS 1.0 Board

Dynamic Power Measurement

- Dynamic power supply current measurement
  - Resolution 80-200 KHz, 12 bit precision
- Power aware RT kernel implementation
- Micro C/OS II implemented
  - Energy per task
  - Realistic battery life monitoring/prediction
Power Monitoring Device

- Real time dynamic power supply current monitoring
  - Power efficient computing
- Resolution 80-200 KHz, 12 bit precision
- Power aware RT kernel implementation
  - Micro C/OS II implemented
- Energy per task
- Realistic battery life monitoring/prediction

Emotion (Arousal) Sensing Device

- GSR electrodes
- Speech processing
Situational awareness

Problems
- mission critical systems
- lack of spatial and temporal cues
- information overloading

Solution
- Position sensing
- Sound beacons
- prioritized warnings
- integrated with command and control system
- Mobile networked 3D sound system
- Electronic compass

Future WISE projects

Multimodal guidance system
- Electronic compass
- Sound beacon

GPS based control/guidance system
- New wireless communication interface
Conclusion

- Enabling technology for a new generation of control & monitoring systems
- Sensor technology
  - Implantable sensors as natural extension
  - Single chip intelligent sensor ("intelligent patch")
- Optimum drug administration
- Prolonged monitoring
- Portable "guardian angel"
- Research issues
  - resource allocation
  - constraint solving
  - power optimal system organization