Portable Telemedical Monitoring
Using Wireless Sensors
on the Edge of the Internet

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Intelligent 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

Can we make it without wires?

- Wireless infrastructure
  - 700 million subscriber units by 2002
- Mobile computing
  - system on chip
- Intelligent wireless sensors
- Intelligent health monitors / warning devices
- Personal Area Network (PAN)
  - body network / intelligent clothes
  - wireless personal area network
  - hierarchical processing
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
- Wireless Intelligent Sensor (WISE)
- Piconetwork
- Sensors
  - EEG
  - ECG
  - breathing
  - movement

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
WISE Architecture

WISE Ver. 1.2
Hierarchical Signal Processing

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Wireless PAN configuration
Hierarchical DSP System Design

- Constraint programming
  - set of constraints
- Process scheduling
- Performance evaluation
- Energy profiling
- Iterative process

Process scheduling issues

- System parameters
  - execution time
  - energy per process
  - communication
- Constraint based scheduling
System Implementation

Hierarchical process scheduling

I Workstation

II DSP

III μC
Environment for dynamic energy profiling


DSP Application Profiling Example

![Diagram showing a graph with labels for CF Active, CF Read, and CPU Active]
Exploring the design space

Examples

• ECG analysis (ischemic event monitor)
• Activity monitor
• Breathing monitor
• Civil Disaster Data Acquisition Device
ECG Analysis

• Sophisticated analysis in
  • High performance/low power DSP
• Warnings (sometimes life saving)
• Typical ECG processing algorithms
  • Initialization (thresholds, polarity, gain control)
  • Filtering (band pass filters, notch filters)
  • QRS complex detection
  • Heart rate variability processing
  • Baseline correction
• Robust algorithms
Hierarchical processing issues

- Data mining on higher levels
- Adaptive thresholds
- Multi-sensor synergy
  - running/sitting?
- Environmental effects
User activity monitoring

Accelerometer based Wireless Intelligent Sensor
- Analog Devices ADXL 202/210 MEMS
- Digital front-end of WISE
Alternative processing methods

Breathing sensor
Breathing sensor

- Custom analog front end
- Thermistor based differential breathing sensor

Circadian breathing rhythm analysis

- Wireless link
- When_available archiving
- Hierarchical processing
ECG system setup and monitoring

- System setup & debugging
- Visual Basic application on portable computer
- WISE Gateway with serial link interface

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

Conclusion

• Enabling technology for a new generation of telemedical systems and intelligent sensors
• Sensor technology
  ● Implantable sensors as natural extension
    ● glucose blood monitors, drug pumps
• Optimum drug administration
• Prolonged monitoring
• Portable “guardian angel”
• Research issues
  ● resource allocation
  ● constraint solving
  ● power optimal system organization
## Acknowledgments

### DSP Challenge
- Dejan Raskovic
- John Price
- John Chapman
- Anthony Moore
- Abhishek Krishnamurthy

### Student projects
- Lou Woods
- Daniel Pritchett
- Sergey Dergunov
- Dejan Milutinovic

### Collaborators
- Dr. Krishna Kavi
- Dr. Tom Martin