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Outline

I. Pervasive Medical Monitoring
   What, Why, Why Now?

II. SMART Project
   Goals
   Architecture
   Operations
   Challenges

III. Evaluation
   Status
   Plans
What is Pervasive Medical Monitoring?

- Monitoring patients’ vital signs in non-traditional contexts:
  - At home
  - At work
  - While exercising
  - While waiting for medical attention
- Access to patient information instrumental for making good decisions and taking action
  - Location
  - Vital Signs
  - Past medical history
Why Is Pervasive Medical Monitoring Important?

- Response time is critical
  - e.g., stroke, myocardial infarction
- Allows for increased outpatient care
  - Decrease length of hospital stay
- Increases patient independence
  - Increased mobility & control of environment
- Changing Demographics
  - More elderly, more people living alone
- Increases provider efficiency
  - Lower costs for all
Why Now?

– Advances in microelectronics make devices
  • easier to build
  • less expensive
  • lower power
  • lighter weight

– Advances in wireless technologies
  • 802.11 drove the wireless revolution
  • Bluetooth
  • Zigbee

– Patients and health care providers are familiar with information technology
  • Web
Ideal Elderly Care

• Patient: elderly woman
  – Debilitating multiple sclerosis
  – Lives at home with husband
  – Husband works during the day

• Situation:
  – Woman trips and falls, breaking her hip and losing consciousness

• Response:
  – At-home monitors notice she is lying on floor
  – Monitors notify her husband, EMTs and hospital
  – Hospital receives full vital sign history
  – Monitors continue to work throughout ambulance ride
  – Triage decisions are based on these data
  – Trauma team is ready for patient upon arrival
  – Husband arrives at hospital soon after patient
Pervasive Medical Monitoring Testbed: SMART

• Opportunity to deploy pervasive medical monitoring in Emergency Department of Brigham & Women’s Hospital (Boston, MA)

• Controlled environment: test technologies before deploying in non-traditional settings.
  – In SMART, only patients with chest pains or respiratory complaints will be monitored

• Goal: develop infrastructure for increased use of pervasive medical monitoring.
Challenges: Emergency Care

• Excessive time spent in waiting room
  – 3 hour wait for medical care
• Difficulty finding patients, personnel and equipment when needed
  – over 50 beds in three units at BWH ED
• Understaffing
• Units must expand and contract
• Triage Priority System cannot account for changes:
  – Medical conditions can worsen in waiting room
• Too many uncoordinated alarms and alerts: sensory overload for caregivers
Waiting Room Emergencies

• Emphysema patient arrives at ED
  – Chief complaint: shortness of breath
  – Patient is likely not in serious trouble, receives triage status 3
    • But oxygen saturation level could fall, placing patient at imminent risk (status 1)
  – Respiration problems difficult to monitor by triage nurse

• Sensors can identify this problem easily.
  – Computers can alert triage nurse immediately
SMART Operations

1. 

2. 

3. 

4. 

Exit
SMART Architecture
Challenges: Medical Sensors

• Trade off quality data vs. price/weight
  – SMART must deal with noisy data
  – Sensors can fall off of patients
• Oximeter (SpO$_2$)
• 2-Lead ECG
• Other sensors: Respiration, Blood Pressure
Challenges: Location Sensors

- **Cricket**
  - Location determined at PDA
  - No extra wires required (for light powered cricket)
  - Requires extra accessories on PDA
- **802.11**
  - Location determined by separate infrastructure
  - Extensive wiring required
  - No additional hardware needed at PDA
- **RFID**
  - For tracking equipment
  - Larger granularity
- **GPS**
  - Outdoors
  - In ambulance
Challenges: Managing Sensor Data

• Time stamping data from multiple sources
  – Synchronized clocks required
• Storing and retrieving continuous streams of data
• Dealing with noisy data from low-cost sensors
  – Motion artifacts: Patient movement can affect sensor readings
  – Gaps in waveform data: sensor falls off, patient walks out of range.
Challenges: Decision Support

- Integrate data from multiple sensors
- Recognize potentially dangerous medical conditions
- Allocate equipment and personnel to handle critical medical conditions
- Avoid broadcast alerts
- Re-prioritize patients according to present medical condition
- Integrate with current procedures
- Minimize false alarms
- Allocate decision support tasks between PDAs and SMART Central
Challenges: Privacy

- Must maintain patient privacy (HIPAA)
- Simple, flexible, consistent access control framework
  - Works across all SMART devices
  - Determines who sees what data
- Wireless encryption
  - Key distribution
  - Power consumption
    - Significant for the smallest sensors (motes)
Challenges: Scalability

• Dimensions of scalability
  – More patients
  – Bigger/Improvised ED
  – Use of technology in more settings

• SMART scales easily
  – SMART Central can be replicated
  – Addition of patient involves addition of PDA and associated processing power
  – Limited global interaction required for very large improvised care facility
Evaluation

SMART will be evaluated *by the medical community* based on tangible medical results:

- Improved response time for emergencies that develop in the waiting room?
- Improved triage priorities in waiting room?
- Improved Emergency Department (ED) operations during peak (overload) demand?
- End user acceptance?
Status

- Evaluating sensors
- Evaluating location systems
- Evaluating streaming databases
- Developing user interfaces
- Developing evaluation study
- Obtaining Institutional Review Board approval
Plans

- Deploy in laboratory environment by end of summer 2004
- Deploy in limited scale at BWH ED in a small number of patients by summer 2005
- Deploy in all eligible patients at BWH ED from Sept 2005- August 2006
- Extend to Ambulances, 2006
- Plan for Mass Casualty Events
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