Internet Protocol
Telemedicine and Pediatric Cardiology Education
(N01-LM-9-3541)

Center for Health Sciences Communication
East Carolina University
Brody School of Medicine
Overview

- Introduction
- Major Technology Evaluations
- Findings and Recommendations
- The Future of IP Telemedicine
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ECU Telemedicine Overview

• All circuit-switched N/W prior to NLM contract
  – T-1
  – ISDN
  – POTS
• Active since 1991
• 14,000 mi² service area
• Also distance learning and grand rounds
Impetus Behind this Project

• The Promise:
  – IP networks pervasive (ubiquitous?)
  – Can serve multiple applications, versus dedicated circuits for “traditional” TM

• The Reality:
  – IP networks not designed or optimized for videoconferencing
Contract Overview

Five Primary Objectives

1. IP telemedicine (10 specialties)
2. Store-and-forward cineangiograms
3. Electromyography
4. Pediatric cardiology education
5. Microweb servers
Major Technology Evaluations
Technology Foci

• Interactive Teleconsultation
  – IP videoconferencing: Objectives 1 & 3
• Store & Forward Teleconsultation
  – Cineangiograms: Objective 2
• Distributed Multimedia Education
  – Pediatric heart sounds: Objective 4
• Microwebbservers
  – Vital signs, audiometry: Objective 5
Major Technology Evaluations: *Interactive Teleconsultation*
H.323 basics

• H.323 is the International Telecommunications Union (ITU) standard for network/IP videoconferencing

• A family of standards:
  – H.261, H.263: video codec
  – G.711, G.722, G.728: audio codec
  – T.120: multimedia conferencing
MPEG basics

- **MPEG-1:**
  - 352 x 240 pixels
  - 30 frames/second
  - CD-quality audio

- **MPEG-2:**
  - 720 x 480 pixels
  - 30 frames/second
  - Surround Sound audio
CODEC & Network Performance

- First test in lab, then in clinical setting
- Lab testing:
  - SMPTE time code – dropped video frames
  - Video test equipment – objective video quality
  - Clinical opinion of diagnostic quality using “gold standard” sources
- Clinical testing:
  - EMG’s: Tarboro & Edenton via T-1, Windsor via microwave Ethernet
  - Pediatric Echo’s: Wake Forest via Internet 2
  - Specialty Consults: Windsor & Ahoskie via microwave Ethernet
Advertised vs. Actual FPS

CLI @ 768 (H.320) = 29 fps

VCON @ 768 (H.323) = 14 fps
Advertised vs. Actual FPS (cont’d)

Proshare @ 400 (H.323) = 15 fps  
Polycom @ 768 (H.323) = 26 fps

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<th>OnTape</th>
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<tr>
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<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18</td>
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1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Video Testing

SMPTE Color Bars – Waveform (Saturation)

SMPTE Color Bars – Vectorscope (Hue)

Luminance 5 Step (Linearity)

Multiburst 100 (Detail)
Audio Testing

**White Noise**

Polycom

Vbrick

Minerva

**Stethoscope**

Polycom

Vbrick

Minerva
Physician Assessment of Dx Quality

- Gold standard DV tapes developed in 10 specialties: Adult Cardiology, Allergy, Dermatology, Endocrinology, Obstetrics, Pediatric cardiology, Psychiatry, Pulmonology, Rehabilitation Medicine, Trauma
- Tapes played through codecs with different network (bandwidth) settings
- Three physicians/specialty assessed point at which video/audio was unusable for Dx
- Results used to select codecs for regional network
Internet 2 Pediatric Cardiology

- Internet 2 connection (NCREN) between ECU and Wake Forest
- VBrick 3200 (MPEG 1) codecs
- 20 patients (10 in each direction)
- Tested agreement between in-person and tele-diagnosis
- Sessions comprised patient interview, stethoscopy, and echocardiography
- No clinically significant disagreement measured
Tele-EMG (Objective 3)

- Need to transmit waveform, audio, video of patient (needle placement)
- Progression of solutions tried
  - Scan conversion of VGA
  - 2-camera approach
  - Direct IP telemetry (device modification)
  - Remote control software
  - Tandberg DuoVideo
  - Polycom Visual Concert
Polycom Visual Concert

Play & Stop buttons

VGA input
Chowan Hospital Setup (Edenton)
Bertie Hospital Setup (Windsor)
Sample EMG
Regional Wireless Network Overview

- Bertie Memorial Hospital
- Williamston Repeater
- Windsor Repeater
- Ahoskie Repeater
- Roanoke/Chowan Hospital

All radio links 45 Mbps full duplex

(Diagram not to scale)
Network Design

- Selected a microwave Ethernet solution (Proxim Tsunami Wireless Ethernet Bridges)
- Commercial repeater towers
- VLAN in hospitals to connect microwave N/W to codecs
- L2 switches at repeater towers
- L3 switches at hospitals
- IP-enabled A/V switching
- Backup power
Setup Gallery
Setup Gallery
N/W Performance Measurement

- Ping tests
- Radio performance
  - From SNMP MIB’s
- Video tests
  - Packet loss from codec mgt. interfaces
  - Linux shell and Python scripts
- Port monitoring on N/W devices
- Fluke Optiview Network Analyzer
Web Interface

[Image of a web interface for Polycom, showing options for Setup System, Diagnostics, Admin Home, Place a Call, View a Presentation, and Select a Presentation. The interface includes an Address Book and a Manual Dial section. The system name is Microwave H323.]
Major Technology Evaluations: Store & Forward Teleconsultation
Original SOP (Pre-NLM)

- Cardiac cath. lab at Nash performs cine study
- Study transferred to another machine to burn CD
- CD delivered to PCMH cardiology via courier or FedEx (6 hrs. – 2+ days)
- Study reviewed by cardiologist
- Patient scheduled for procedure if necessary (1-2 days)
New SOP via IP network

- Cardiac cath. lab at Nash performs cine study
- 1-button pressed to send to PCMH (cardiology or CT surgery)
- Study transferred w/in 30 min.
- Typical study 200-250 MB
- Study reviewed w/in 3 hr.
- Patient @ PCMH for procedure same or next day
Technical Solution

- Linux PC’s set up as DICOM workstations
- VPN over T-1 connection between facilities (SSH)
- 32-bit checksum & 1024-bit encryption
- Generated page to PCMH cardiology when study arrived
Cineangiograms
Number of Transmissions per Month
(Nash Hospital to Pitt Memorial Hospital)

Total Number

Months: March 2001 through February 2002
Outcomes

• Reduced time-to-procedure
• Reduced hospital LOS, but not statistically significant (p=0.09)
• Increased # consults (and procedures)
• Started to use as 2nd opinion tool
• Hospital purchased COTS DICOM solution as a result – will expand to other cath labs in region
Major Technology Evaluations: Distributed Multimedia Education
Multimedia Pediatric Auscultation

- System developed for improving auscultation skills
- High-fidelity audio and video elements delivered over NGI
- Tested with 32 UNC-CH nursing students (via NCREN (I2))
  - Least experienced had most improvement
  - Correlation between time used and accuracy
  - Users rated system good to excellent
- 2 servers used (one for echo video)
Choose a heart sound you wish to listen to:

- Normal
- Atrial Septal Defect
- Ventricular Septal Defect
- Functional Murmur
- Aortic Stenosis
- Pulmonic Stenosis
- Mitral Valve Regurgitation
- Patent Ductus Arteriosus
- Tetralogy of Fallot
- Waveform Comparison

- Introduction
- Quiz Yourself Randomly
- Overview of Auscultation

- About This Program
- Sound Advice
Waveform Comparison

Move your mouse over the waveform you wish to listen to

Normal
Aortic Stenosis

Atrial Septal Defect
Pulmonic Stenosis

Small Ventricular Septal Defect
Tetralogy of Fallot

Large Ventricular Septal Defect
Patent Ductus Arteriosus

Functional Murmur
Mitral Valve Regurgitation

You are listening at the Upper left sternal border
Atrial Septal Defect

Move the mouse to the area of the heart you wish to listen to

You are listening at the Upper left sternal border

The systolic murmur and the widely split second heart sound are best heard here

About atrial septal defect sounds  View echo
ASD Echocardiogram

Normal speed
Parasternal long axis view

Connecting...
www.telemed.med.ecu.edu/HeartSounds/EchoHart3_TB86.tbk

Need to load Neuron 8.6 plug-in:

home.click2learn.com/en/toolbook/neuron.asp
Major Technology Evaluations: Micro-webservers
Micro-webservers

- Needed means for IP comms c/ biomedical devices
- Assessed 8 COTS micro-webservers
- Selected Picoserver
- Developed code for:
  - Welch Allyn VSM
  - Critikon Pro 400 VSM
  - Roche Accu-Chek glucometer
Micro-webservers

• Displayed in browser (IE)
• Cold Fusion as back end with VFP d/b
• Testing determined:
  – Max. 12 simultaneous requests
  – Command reliability: 92.5% load over T-1, 30% load over 10 Mb Ethernet
  – 60% fatal failures
### Accuracy (unloaded N/W)

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TopHat

- 4 RS-232 i/f’s
- AC, battery, or solar power
- Bluetooth (via serial adapter)
- Drivers ported for multiple devices
  - Biomedical
  - Environmental
  - GPS
  - PDA

![Image of Top Hat and various devices]
Tele-Hearing System

- Audiometer retrofitted with microcontroller & microwebserver
- Audiologist remotely operates audiometer (Hz, dB) over IP N/W
- Responses logged in client S/W (PC or PDA)
Findings & Recommendations
Findings

- IP videoconferencing works, if you control the network
- IP video is sensitive (routers, NAT, firewalls, etc.)
  - Polycom recommends <1-2% packet loss
  - Seemingly minor factors can have major effects on performance, e.g. media converters
- Duplexing matters
  - Should hard code port settings
  - Half duplex worked best for μ-wave
- VLAN’s work (when set correctly)
Findings (continued)

• Difficult to determine the best quantitative metric for IP video quality
• Temporal aspects of audio/video errors are the most significant.
  – Distribution of audio/video errors was a better indicator of videoconference quality than mean error rates
  – Short-lived, high-error periods more acceptable than chronic low-error conditions.
• Video quality threshold @ continuous loss of 6-7 video packets/min.
Findings (continued)

- New skill set required for tech. support
  - Traditionally telemedicine tech’s have A/V production or telecommunications background
  - IP systems require knowledge of network eng. & operations, but a/v production elements still crucial
  - Future telemedicine technical support and operations teams will need both skill sets
  - Cross-training in both domains will be required.
Findings (continued)

- H.323 manages lost audio by repeating – this can sound like cardiac anomaly
- Similarly, crackles (lung sound) can be lost
- MPEG-2 best for *resolution*; video and audio (heart & lung sounds)
- Challenging to do N/W research when using production N/W elements. Several orgs. were involved:
  - University IT
  - Hospital IT (3 hospitals)
  - Our department (NLM research team & V/C ops)
Recommendations

• Set up PC’s for monitoring and control
  – Use codecs’ web interfaces
  – IP-enabled audiovisual routing
• Use switches instead of routers whenever possible
• Reset codecs frequently
  – Procedures should include rebooting codecs between consults, or at least between sessions of contiguous use.
• Build application-specific performance specifications into acceptance criteria
How to Address IP Challenges

• Overprovision your network
• Implement QOS mechanism
  – Works within your network/campus
  – In lab, we loaded N/W 100%, and could still get error-free video
• Avoid/eliminate bottlenecks
  – Hubs
  – Routers (use non-blocking wire-speed switches instead)
  – Firewalls
  – 802.11
The Future of IP Telemedicine
New A/V Standards

- H.264 video compression
  - Just ratified by ITU
  - Part of H.323
- MPEG-4
  - Recently adopted
  - Optimized for Internet/WWW multimedia
  - Scalable to support multiple bandwidths
  - Separate objects in stream (video, VRML, etc.)
Native IP Biomedical Telemetry

- Implemented intermediate solutions
  - $\mu$-webserver
  - VGA out from EMG
- Ideally would have direct IP interface for biomedical devices
- Issues
  - Addressing (IPv6?)
  - Directory services/device descriptions
  - Security
Just-in-time telemedicine

- A combination of:
  - Real-time (synchronous) – what we do now
    - Videoconferencing
    - Data streaming/telemetry
  - Store and forward (asynchronous)
    - E-mail with file attachments
    - Consultation server

- Use minimum interactivity to facilitate interaction and higher-resolution photo’s, video clips, data files as store-and-forward