MASH: Multimedia Architecture that Scales across Heterogeneous Environments

R. H. Katz, S. McCanne, E. A. Brewer
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New Ideas

• Comprehensive collaboration architecture
  – Enhanced MBone applications
  – Media data types, coordination, resource allocation, annotation and archiving
  – Scalable reliable multicast for active object dissemination

• Proxies to mitigate heterogeneity
  – Image, video, audio transcoding in R/T

• Experimental architecture for room-sized collaboration environments
  – Multi-room, distributed testbed

Impact

• Fundamental technology for 21st Century collaborative environments: support for wide diversity of image/video/audio data and active object types & coordination protocols

• Demonstrate comprehensive architecture with scalable media performance, ease of adding new media types, integrated active object dissemination and extended session archiving

• Demonstrate extension of desktop collaboration technology to room-sized environments, with richly extended set of input & display devices

Schedule

Design and demo local coordination, dissemination & archiving architecture

Design global coordination architecture; Demo scaled proxies and archive

Final architecture & demonstration of ease of adding new media types & algorithms

Sep 96 Start

Sep 97

Sep 98

Sep 99 End

Design global coordination architecture; Demo scaled proxies and archive

Deployment of 3rd room & human factors evaluation

Deployment of 2nd room & distributed experimentation

Initial collaboration room design & deployment
MASH Mini-Retreat

• Thursday, January 9
  1300 - 1350  MASH Project Overview, Randy Katz
  1350 - 1420  MASH Project Infrastructure & Directions, Steve McCanne
  1420 - 1430  SRM Introduction & Status, Steve McCanne
  1430 - 1500  Break
  1500 - 1520  MediaBoard, Suchitra Raman & Teck-Lee Tung
  1520 - 1530  Layered Video Introduction & Status, Steve McCanne
  1530 - 1550  Scalable ConsensUs-based Bandwidth Allocation (SCUBA), Elan Amir
  1550 - 1610  Video Archiving, Angela Schuett
  1610 - 1800  Break
  1800 - 1930  Dinner
  1930 - 1930  Demos and Posters
MASH: A Multimedia Architecture that Scales Across Heterogeneous Environments

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The Challenge: Heterogeneous Collaboration Environments

- **Hardware**
- **Bandwidth**
- **Media Representations**
- **Routing Protocols**

**PC**
- 8 bit frame buffer
- 75 MHz Pentium (2.31 SpecInt95)
- No compression hardware

**Internet (MBone)**
128 kbps

**Private Network**
- PC’s
- Workstations
- Laptops

1.54 Mbps

**High-end Workstation**
- UltraSparc2 (6.41 SpecInt95)
- Hardware Compression
- 24 bit frame buffer

10 Mb/s

**Pen-based Computer**
- Grayscale LCD display
- Low power processor
- Limited I/O bandwidth
- No multicast support
New Enabling Technologies

• Multicast-based networking protocols
  – Multicast backbone (MBone) represents inexpensive, ubiquitous method for multipoint communications
  – Real Time Protocol (RTP): vic and vat MBone tools; Scalable Reliable Multicast (SRM): wb MBone tool
  – MBone tools in wide spread use

• Proxy architecture
  – Mediators for real-time, scalable adaptation of widely-used media representations (image, video, audio)
  – Appropriate transformations of RTP control protocols
  – Unicast-to-multicast routing translation
New Challenges

• Beyond desktop collaboration
  – New display and capture technologies
  – E.g., large-scale displays, gestures

• Beyond images/continuous media
  – Integrated control protocols like floor control
  – Distributed platform-independent computation
  – E.g., active objects and distributed simulation

• Beyond ephemeral interaction
  – Integrated archiving and retrospective playback
  – Session indexing over independent media types
A Comprehensive Architecture

• Distributed Coordination and Control
  – Local management: coordinates local interactions among tools to form session on the behalf of a single user
  – Global management: distributed floor control and global conference bandwidth management

• Integration of Heterogeneous Formats and Protocols
  – R/T transcoding of media representations subject to manage local and global b/w demands

• Dissemination of Executable Objects
  – Reliable object dissemination, based on SRM
  – Active objects based on Java and Tcl/Tk
A Comprehensive Architecture

• Archive and Annotation
  – Capture, index, store, and retrieve collaboration sessions
  – Integration with tertiary storage for “infinite” capacity

• Development and Testing with a Real Testbed Environment
  – Virtual Rooms
    » 2-3 experimental room-sized collaboration environments
    » “Use what we build”: collaborative design sessions using DartNet II
    » New tools and interfaces beyond the desktop, e.g., gesture recognition, wireless/roaming access
Collaboration Functionality & Tools

MASH Architecture

Data

- Audio
- Video
- Media Board
- Active Objs

IP-Multicast

Control

- Proxy
- GUI
- Archive
- Floor Cntl

Coordination Bus

SRM

IP-Multicast

TCP

IP-Unicast

IPC

- Agents and Applications
- Middleware
- Communications
Outline

• Coordination and Control
  • Heterogeneous Formats and Protocols
  • Dissemination of Executable Objects
  • Archive and Annotation
  • Virtual Room Testbed
Coordination Architecture

• **Existing Media Tools**
  – Monolithic and unintegrated
  – No building blocks exist for composing new tools

• **Distributed Communications**
  – Data transport based on real-time protocol (RTP) mature and well understand
  – Reliable control signaling, via scalable reliable multicast, needs development

• **Framework for control, management, coordination of media components**
  – Little work within the context of IP multicast
Coordination Architecture

• Composable Tools
  – vic, vat, wb abstracted into media processors
  – shared user interface

• Coordination Bus
  – distributed, reliable communications medium based on IP multicast

• Construct new applications from communicating, composed building blocks
  – e.g., Internet phone, seminar broadcast, distributed simulation, proxy-end node communications
Coordination Architecture

- Broadcast Event Bus
  - Event consumers register with subsystem
  - Multiple buses and partitioned flows for performance
  - Extend over network using SRM
Coordination Architecture

- Local coordination bus API
- Global coordination framework
- Coordination bus optimization
- Suite of coordination bus-based widgets:
  - Floor control
  - Session bandwidth manager
  - “Secure sessions” prototypes
Outline

• Coordination and Control
• **Heterogeneous Formats and Protocols**
• Dissemination of Executable Objects
• Archive and Annotation
• Virtual Room Testbed
Proxy Architecture

• Requirements
  – Bandwidth variation:
    » Transcode data to appropriate bandwidth level
  – Format conversion
    » Handle client variation by transcoding to known formats (and protocols)
  – Quality of Service optimization:
    » Tune audio/video quality based on client hardware (e.g. resolution, color depth)
  – Wide-area control protocols:
    » Hierarchy of proxies must work together
    » Both clients and effective bandwidth affect proxy
  – Scalability: both to wide area, and to many clients per proxy (exploit NOW)
Proxy Architecture

• Proxy Control
  – Scalable Proxy Transcoder Manager and its protocols
  – User “focus” detection to drive allocation decisions
  – Distributed consensus-based bandwidth allocation
  – Common control abstraction for web proxy and real-time gateways via coordination bus mechanism

• Applications
  – Session Management: transcoders, filters, forwarding agents
  – Wide-area cache coherence with conflict resolution
Outline

• Coordination and Control
• Heterogeneous Formats and Protocols
• **Dissemination of Executable Objects**
• Archive and Annotation
• Virtual Room Testbed
Active Object Model

- **Current wb model**
  - postscript objects

- **Active objects:**
  - General objects that can be rendered
  - Rendering can be ordered in time and synchronized
  - Enables stateless representation for easy storage, replay, play backwards, etc
  - Disseminated via SRM
Active Object Architecture

- Sample Application: Network Animator
Active Object Architecture

• SRM base protocol + profiles
  – Active objects, coordination
• SRM toolkit
  – C++ class library
• Active Object architecture and toolkit
• Early prototype: MediaBoard
• Application: interactive network animation (Collaboration with VINT)
Outline

• Coordination and Control
• Heterogeneous Formats and Protocols
• Dissemination of Executable Objects
• Archive and Annotation
• Virtual Room Testbed
Archive System

Internet (MBone)

Remote Collaborators

Session streams captured and archived

Hierarchical Storage Archive

Interactive Streams

Coordination Architecture manages intersession b/w

Fast Forward Retrospective Playback

Proxy Arch manages FF representations
Basic Archive System

Real Time Protocol
Scalable Reliable Multicast

Archive Agent
Compression Proxy Agent
Recording Agent

Coordination Architecture
Identifies Sessions

WB Stream
Audio Stream
Video Stream

Internet (MBone)
NOWs + Disk Storage
Tertiary Storage

Real Time Protocol
Scalable Reliable Multicast

Archive Agent
Compression Proxy Agent
Recording Agent

Coordination Architecture
Identifies Sessions

WB Stream
Audio Stream
Video Stream

Internet (MBone)
NOWs + Disk Storage
Tertiary Storage
Scalable Archive System

Recording agents negotiate among themselves to record session components of “near-by” participants.
Annotation System

WWW-based User Interface

Manual Indexing

Indexing System

GiST or other indexing technology

Automated Feature Extraction

Scene Extraction Agent

Control Extraction Agent

Digital Library Technology

Audio/Speech Extraction Agent

Media Tracks
Archive & Annotation Archive

- **Standard Formats, Archiving, Playback Tools**
  - Standardize RTP Archive Format
  - Develop SRM Archiving Tool
  - Automatic Session Recorder: integration with session directory protocol for “operator-free” automated archive
  - Playback Tools: MBone tools, extended for random access, fast forward, integration with database system through forms, etc.

- **Indexing and Annotation Tools**
  - Semantically-based index structures, browsers, annotators, etc.
  - Hooks for feature extractors

- **Deployment of Public Archive Service**
  - Implementation of archive and annotation system on top of available distributed hierarchical storage systems being developed at Berkeley
Outline

• Coordination and Control
• Heterogeneous Formats and Protocols
• Dissemination of Executable Objects
• Archive and Annotation
• Virtual Room Testbed
Virtual Room Testbed
Virtual Room Testbed
## Project Plan

<table>
<thead>
<tr>
<th>Coordination</th>
<th>Proxy</th>
<th>Active Objects</th>
<th>Archive</th>
<th>Testbed</th>
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<tbody>
<tr>
<td>Develop local tool coord arch, API, and GUI</td>
<td>Develop global coord arch publ floor cntrl spec</td>
<td>Develop proxy mgr, wide-area “coherent” objects</td>
<td>Develop scalable R/T proxy Exploit user focus</td>
<td>Experimentation and Refinement of Coordination and Proxy architectures, IETF standardization;</td>
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<td>Active object extensions to MBone tools</td>
<td>Prototype network animator based on SRM toolkit</td>
<td>Extensive interoperability testing;</td>
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<td>Scalable reliable multicast “middleware”: C++ library</td>
<td>tk/java rendering widget, deployment and feedback</td>
<td>Demonstration of ease of extension thru object architecture</td>
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<td></td>
<td>RTP A/V storage repr, Server control protocol, Recording tools and formats</td>
<td>SRM archive tool, session recorder, playback tool; Integrate with Digital Libr</td>
<td>Deploy scaled archive &amp; annotation architecture; Integrate feature extractors</td>
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<td>Design and implement 1st collaboration room</td>
<td>Deploy second room and perform experiments</td>
<td>Deploy 3rd room and complete evaluation</td>
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Progress to Date

• **Coordination Architecture**
  – Restructured of vic, vat; reimplementation of wb as MediaBoard
  – Demonstration of composable mbone audio/video objects
    (Netscape vic/vat plug-in)

• **Proxy Architecture**
  – Design & evaluation of scalable consensus-based bandwidth
    allocation protocol for proxy control

• **Active Object Architecture**
  – MediaBoard prototype implementation

• **Archive and Annotation Architecture**
  – Initial design investigations
  – Raw capability to record RTP sessions and RTP archive format

• **Virtual Room**
  – Initial design complete, liveboard and A/V rack in place
  – Vint meetings to be held in room during Spring 1997
  – Cairn/DartNet II connectivity established