Overlay Multicast for Efficient Group Communications
Cross-Network Overlay Multicast (XOM)

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Agenda

- Background
- Overlay Multicast Concept
- XOM Concept of Operations
- Simulation Message Flow Characterization
- Prototype and Experimentation
- Proposed Architecture for XOM
- Conclusions and planned work
Background

- Simulation community desire to enable use of web services in distributed real-time simulation
- Early workshop developed basic network performance requirements:
  - End-to-end QoS in a statistical sense
  - Multicast: Many-to-many group communication
  - Reliable in the sense of high confidence of delivery
  - End-to-end network status and performance monitoring
  - Multi-sensor systems: Must manage streaming data with low latency
- DMSO funding development of Architecture and early prototype

XOM Cross-Network Overlay Multicast

Overlay Multicast:
- Many-to-Many
  - Many senders to same group
  - Source-Based Trees
- Open Network
  (Independent of Management Domain)
- Responsive to Application
  - End-to-End QoS Considerations
  - Group Management Efficiency

Traditional IP Multicast:
- Usually One-to-Many
- Single Sender
- Core/root-Based Tree
- Closed Network
  (Single Management Domain)
- Insensitive to application

Any subnet host can be Head-end Route Point for all local multicast traffic

Single Head-end Route Point for all multicast traffic

Private Network

Single Head-end Route Point for all multicast traffic
XOM Concept of Operations

- Application B sending implies routing to group \( G_3 = (G_1 \cup G_2) \)
- XOMR on each subnet
- IGMP for group management
- Central Registry for COI
- XOMRs self-organize for optimal performance

Simulation Message Flow Characterization

- Observed three simulation environments
  - Single Federate/single entity: NPS naval vessel
  - Single Federate/multiple (30) entities: Army maneuver to contact convoy operation
  - 211 federates/multiple (110,000) entities: JFCOM J9 Urban Warfare
JFCOM Urban Warfare Experiment

- ~110,000 entities (objects)
- 211 Federates (players)
- TCP used across "pseudo form of multicast via intermediate hosts in hierarchal structure"

JFCOM Experiment Tier Message Flow

- Each application layer message spawned message flow in groups of 5-8 messages averaging 1448 bytes
- Average network message size of 1200 bytes (includes ACK messages from TCP)
- ON/OFF pattern observed: 1/1 seconds
ON/OFF Traffic Model

- **Threshold/capacity = C**
- **ON Period**
- **OFF Period**

Queue Model for XOMR

Probability of message loss (M/D/1)

\[ P(x) = \frac{\lambda * D}{C - A_M} \left( \frac{1}{1 - T_{ON} * (R_{ON} - C)} \right)^{x-1} \]

- **D** = Erlang call waiting formula
- **C** = Capacity of local XOMR
- **T_{ON}** = Period of message flow ON
- **R_{ON}** = Aggregate rate of message flow during ON period
- **T_{OFF}** = Period of message flow OFF
- **R_{OFF}** = Aggregate rate of message flow during OFF period
- **A_M** = Average aggregate message flow
- **\lambda** = Average message rate of a flow

Measurable parameters
XOMR Prototype

Monitoring via Web browser
Registry Web service
Internet
WAN
LAN
data
Statistics
Incoming
outgoing
MulticastRouter* (Java or C++)
Routing
Other XOM Sites
IPmc Host
IPmc Host
*All modules except Router are Java

NPS Naval Vessel Simulation with three Federates over Internet

INTERNET
VMASC
HLA Federate
XOM
DMSO Booth
WSIM Client
Viewer
VMASC
HLA Federate
XOM
NPS
GMU C3I Lab
XOM
WSIM Server/Federate
IEEE 1516 RTI provided by Pitch
WSIM Multicast group
RTI Multicast group
XMSF Booth
GMU C3I Lab
XOM
WSIM Client
Viewer
WSIM Multicast group
Lab Test Configuration

- 4 Subnets
- 3 Receivers (node degree of 3)
- Linux Router
- XOMR Hosts – Linux
- Message size of 150 bytes

Loss Ratio (%) Performance Test

![Graph showing loss ratio performance test with 4 subnets and 2 subnets]
Buffer Capacity Overflow Model
M/D/1 Queue*

*Analysis based on message size of 150 bytes and Java Socket Queue size of 64,000 bytes and service rate of 5,900 m/sec and throughput threshold of 0.8.

XOM Top-level Architecture

- Group Management
- Partner Discovery via Registry
- Performance Measurement for Path Management
- Periodic Routing Update to each partner
DISA Content Staging/Information Dissemination Management (CS/IDM) Project
- Crawl through all the data available
- Provide a forward-staging capability
- Create a smart-pull for preferred sources of information and receive automatic updates on a regular basis.

**XOM Concept for Many Sensors – Many Receivers**
- XOMR on each subnet (Local control)
- IGMP for group management (No special protocol for announcement on the subnet)
- Central Registry for COI (User registers for interested groups of sensors or “flows” of information)
- XOMRs self-organize for optimal performance (Based on available network resources)

$G_2 = \{B, C, D\}$

Application B sending implies routing to group $G_3 = \{G_1 \cup G_2\}$
Conclusions and Future Work

- Initial results indicate overlay networking is a promising strategy for providing many-to-many multicast in an open network environment
- Add commercial quality encryption, suitable for FOUO, and explore alternatives for adding additional security features
- Complete integration of NPS prototype for a Web-service-based registry and routing information system
- Use next version of prototype in live simulation exercise
- Demonstrate use of WSIM and XOM to accomplish multicast streaming of user-selected information

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Additional Information and XOM prototype download available at http://netlab.gmu.edu/XOM