Design of Next Generation Internet Based on Application-Oriented Networking

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Agenda

• Background and motivations
• Application-oriented networking (AON)
• AON based multicast
• AON for next generation Internet management
• Conclusion
Towards Next Generation Internet

• Evolvement of the Internet
  – Common communication infrastructure supporting various multimedia applications
  – Emergence of new distributed computing models
  – Extension of connection to mobile users

• Efforts towards next generation Internet
  – Internet QoS and traffic engineering
  – Content-aware or application-aware processing
  – New management plane based on service-oriented architecture (SOA)
  – Wireline/wireless seamless interworking
Embedded Application Intelligence

• Fundamental network functionalities through application-layer protocols
  – Domain name service (DNS) and Dynamic host configuration protocol (DHCP)

• Emergency of application-specific nodes
  – Web caches, multimedia gateways, wireless access gates, and firewalls

• Active networks: a generic architecture to provision programmability within the network
  – Packets replaced with capsules, carrying program segments
  – Never been widely deployed
    • Large bandwidth overhead
    • Lack of common capsule program language
    • Security issue due to users’ active control capability

• Application-oriented networking
Service-Oriented Architecture

- Various resources are encapsulated with standard common interfaces
- Each service component publishes its location and service description
- Applications are created according to “find, bind and execute” paradigm
- SOA is mainly implemented with Web services interface and XML message communications
Cisco Application-Oriented Networking

• XML coding is verbose; pure software based XML parsing leads to unfavorable overhead
• Cisco propose to integrate the capability of intercepting and processing XML message into routers
  – Enable disparate applications to communicate
  – Enforce consistent security policies
  – Provide visibility of information flow
  – Enhance application optimization
• Current Cisco AON applications are limited to message processing at the edge
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Application-Oriented Networking

- A generic interpretation of AON: *the IP devices can intercept not only IP packet headers but also the payloads*
- AON is justified by the modern software and hardware technologies
- The AON routers, with embedded application intelligence, enable a chance to reexamine the design of Internet
It is currently obscure on how to exploit the AON capacity to facilitate or enhance Internet in a systematic manner
AON Router

- The traffic input to an AON router is classified as normal traffic and AON traffic
  - One bit in the packet header is set as normal/AON indicator bit
  - Fine-grained classification information is carried in the payload
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Multicast Issue

- **IP multicast, scalability issue**
  - Construct and maintain a tree structure for each group
  - Multicast forwarding entries grow linearly

- **Overlay multicast, efficiency issue**
  - Tree or other delivery structures are constructed and maintained in the overlay network over the unicast infrastructure
  - Different overlay links pass through common physical links in the underlying transport network

Multicast Routing Table

<table>
<thead>
<tr>
<th>Grp 1</th>
<th>1, 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grp 2</td>
<td>1</td>
</tr>
<tr>
<td>Grp 3</td>
<td>2</td>
</tr>
<tr>
<td>Grp 4</td>
<td>1, 2</td>
</tr>
</tbody>
</table>
AON-Based Multicast (AOM)

- Multicast requires network embedded intelligence
- Service model
  - Source based model
  - Multicast receiver addresses are encoded in the packet
  - AON router computes necessary copies for appropriate output interfaces according to those addresses
- Protocol components
  - Membership management
  - Forwarding protocol
Membership Management

- Receiver-side designated router (RDR)
  - Discover the active groups using IGMP
  - Maintain a group host list (GHL), storing the membership information
  - Send membership updating messages (MUMs) to the source node, in the format
    (IP address of RDR: group 1, ..., group n)
- Source node
  - Aggregate RDR-group messages received and maintain a multicast group list (MGL)
  - MGL establishes a record for each group provisioned by the source as
    (group ID: RDR 1, RDR 2, ..., RDR n)
For Forwarding Protocol:

- The normal/AON flag bit and the AON module classifier in the payload direct multicast packets to AON module.
- MGL record will be extracted.
- Necessary copies and corresponding output interfaces will be determined against unicast routing table and MGL record.
- The MGL record forwarded to downstream is updated: removing RDRs taken care of by other sub-trees.
Bloom Filter Implementation

• The MUM message and the MGL are compressed with bloom filter
  – MUM: (IP address of RDR: group 1, …, group n)
  – MGL: (group ID: RDR 1, RDR 2, …, RDR n)

• Bloom Filter Design
  – Reverse path routing for multicast
  – Longest prefix match issue
  – Small false positive probability
  – Asymmetric routing
Properties of AOM

• Forwarding complexity is totally independent of the number of groups to be supported
• No new multicast routing protocol needs to be introduced. Existing intra-domain and inter-domain IP routing protocols are leveraged
• The membership management component, the multicast forwarding component, and group ID are completely decoupled
• The cost incurred in the AON-based multicast is the bandwidth overhead, due to the AON classifier and the MGL/GHL record carried with each packet.
Performance Evaluation

• Simulation topology
Performance evaluation

- Bandwidth Cost Percentage (BCP)

\[ BCP = \frac{T}{C \cdot D} \times 100\% \]

- AOM is very close to IP multicast in terms of bandwidth efficiency
Performance evaluation

- Forwarding FALSE Positive Rate
- Binary tree topology with different tree heights

<table>
<thead>
<tr>
<th>$H$</th>
<th>AOM</th>
<th>FRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>$2.6934 \times 10^{-53}$</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>$1.4433 \times 10^{-15}$</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>$2.3242 \times 10^{-10}$</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>$6.6281 \times 10^{-6}$</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>0.0111</td>
</tr>
<tr>
<td>7</td>
<td>128</td>
<td>0.4358</td>
</tr>
</tbody>
</table>

Performance evaluation

- Packet Overhead

![Graph showing Packet overhead vs. False positive rate](image-url)
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Next Generation Network Management

• Internet developing into an extremely complex system
• Efforts to reduce the development complexity, lower the management cost, and shorten the time-to-market of new Internet applications
  – Service-oriented architecture (SOA)
  – Application-oriented networking (AON)
  – Autonomic computing
• Technologies are not developed in a coordinated manner
• Autonomic service management framework (ASMF)
  – Every thing is a service: any capability that may be shared and exploited in a networked environment, including physical and virtualized services
  – Incorporate SOA, AON, and autonomic computing for optimal scalability, resource utilization, and QoS performance
SOA to be Enhanced

• Implementing the service broker
  – The universal description, discovery, and integration UDDI approach
  – Broker overlay network
    • How to organize the overlay
    • How to search a set of correlated services
    • How to negotiate SLAs in a distributed approach

• Dependable and automatic service composition
  – The business process execution language (BPEL)
  – Service composition and invocation to be handled by the broker overlay

• Web services and XML messages based SOA implementation
  – Verbose XML coding
  – Triggering AON
AON for Service Management

• Integrating XML message backbone to network devices
  – XML parsing expedited by hardware processing
  – Message routing at network layer facilitated by easy access to resource availability and QoS information
  – More thorough investigation of how to exploit AON capability to facilitate SOA based service creation and management in the architecture level
Autonomic computing

- Automated management with properties of self-configuration, self-optimization, self-healing, and self-protection
- A collection of autonomic elements
- “Monitor, analyze, plan, execute” control loop
- Integration consideration
  - component-based reference models
  - Autonomic element encapsulated with Web services interface
  - “find, bind and execute” SOA principle to orchestrate the autonomic service component
  - Issues of distributed service composition and integration with AON
Autonomic Service Management Framework

- Web services network (resource virtualization layer)
  - Manageable Web services with an autonomic manager for internal management
  - Manageability interfaces (distributed service location/composition and SLA based resource allocation considered as important manageability capabilities)
    - Semantic description
    - SLA negotiation
    - Autonomic management (sensor and effector)
- Autonomic application enabling fabric
  - Overlay of autonomic service brokers
  - Distributed service location and composition
- AON transport network
ASB Overlay

- Distributed data base storing published service descriptions
- Automatic service location and composition
  - Semantic request analyzer
  - SLA translator
  - Composition message generator
- Delegated service management
Distributed Service Composition

- Semantic graph based service component location
  - P2P ASB overlay
  - Tree ASB overlay
- SLA negotiation incorporated with service composition
Exploiting AON

• Locality-aware P2P overlay
  – AON router know both application and network layer information
  – Select best path for a logic link

• Network layer solution to ensure an application-layer link
  – Service differentiation
  – Traffic engineering

• Overlay topology optimization
  – P2P implying end hosts at edge
  – A tree structure for ASB overlay (each ASB attached to an AON router)
Summary

• AON provide an opportunity to streamline Internet design
• How to exploit AON capacity in a systematic way is not clear
• This talk presents some initiating work and thinking towards next generation network design
• For future work
  – IPTV over the application-oriented multicasting
  – Develop implementations for ASMF
  – Apply ASMF to manage a prototype DiffServ/MPLS network
References
