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

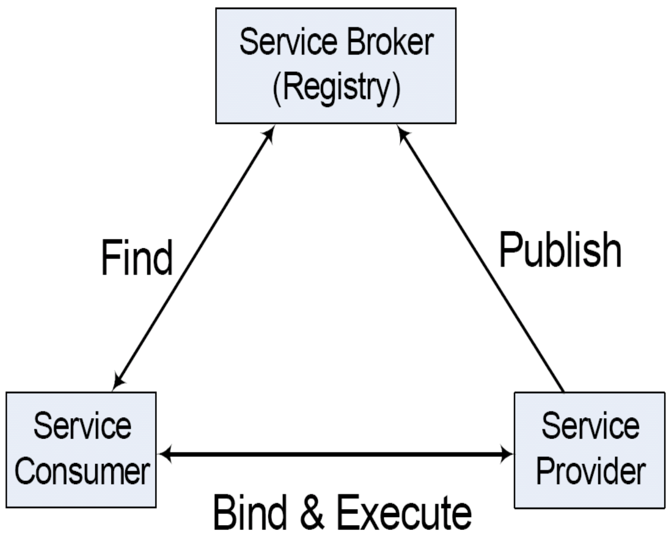
- Evolvement of the Internet
  - Common communication infrastructure supporting various multimedia applications
  - Emergence of new distributed computing models
  - Extension of connection to mobile users
- Efforts towards next generation Internet
  - Internet QoS and traffic engineering
  - Content-aware 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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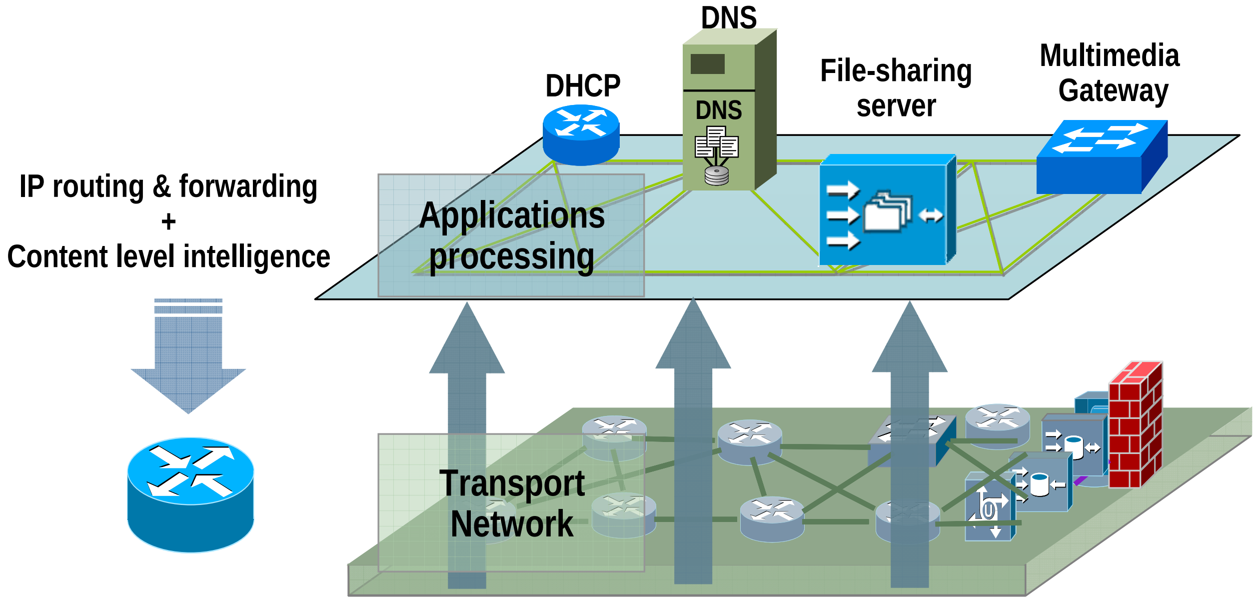
Application-Oriented Networking

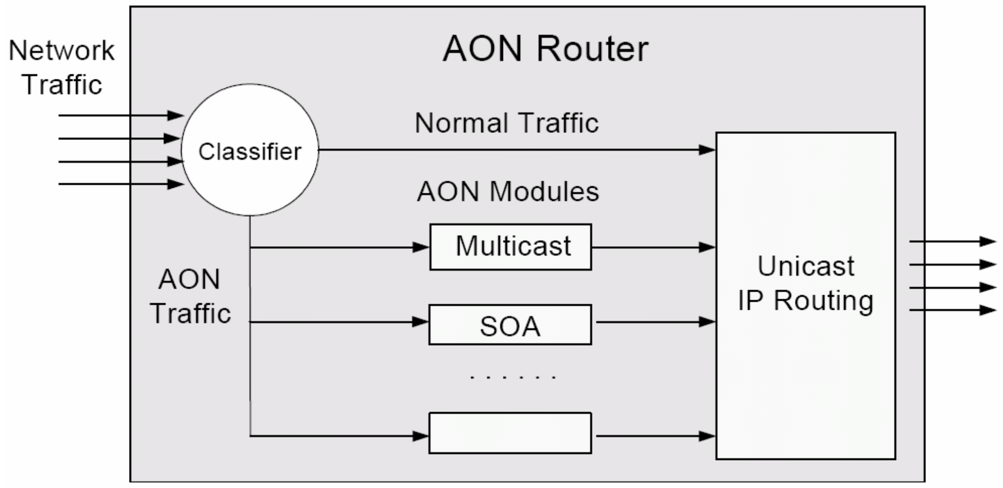
- A generic interpretation of AON: ***the IP devices can intercept not only IP packet headers but also the payloads***
- AON is justified by the modern software and hardware technologies
- The AON routers, with embedded application intelligence, enable a chance to reexamine the design of Internet



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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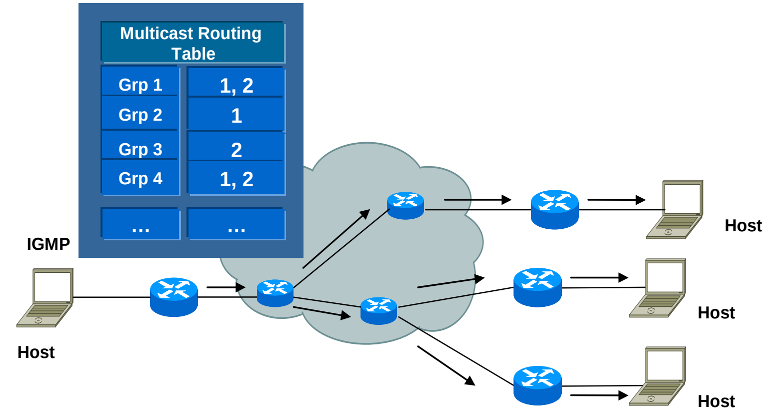
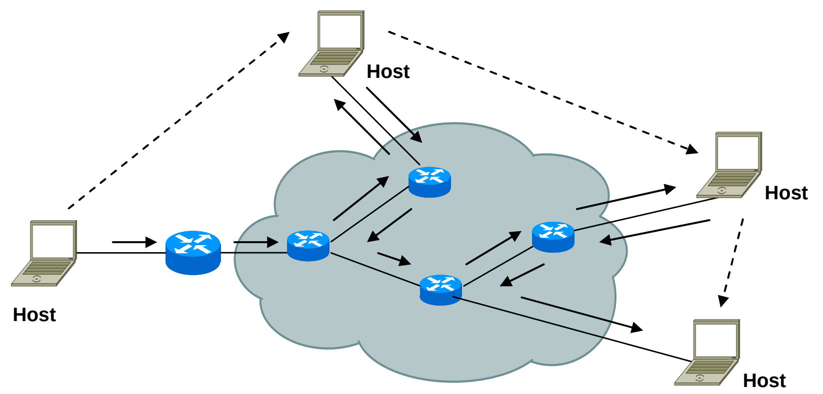
Multicast Issue

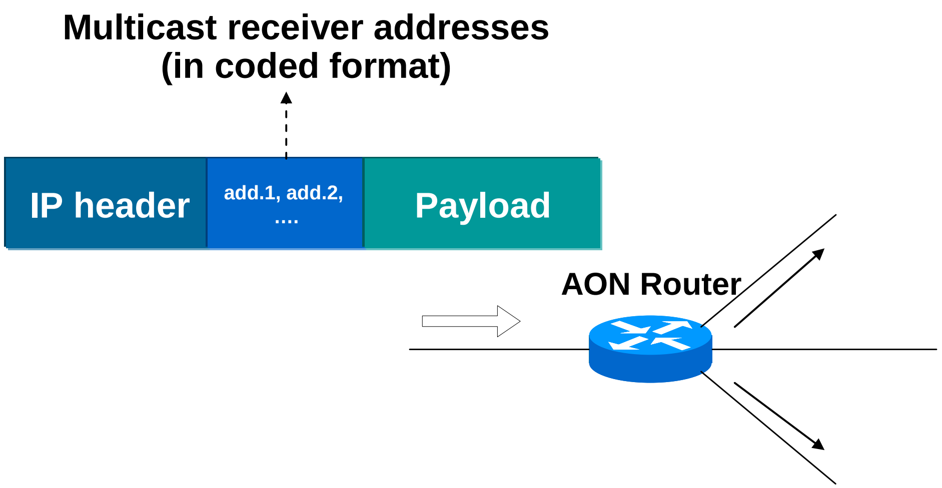
- IP multicast, scalability issue
  - Construct and maintain a tree structure for each group
  - Multicast forwarding entries grow linearly
- Overlay multicast, efficiency issue
  - Tree or other delivery structures are constructed and maintained in the overlay network over the unicast infrastructure
  - Different overlay links pass through common physical links in the underlying transport network





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



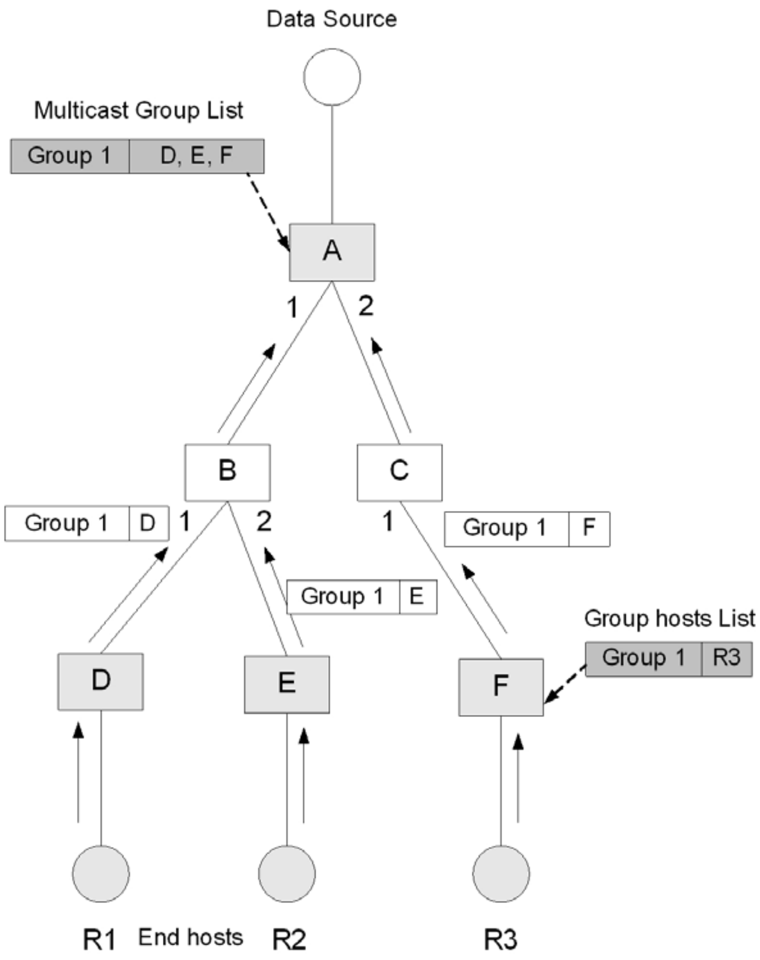
Membership Management

- 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

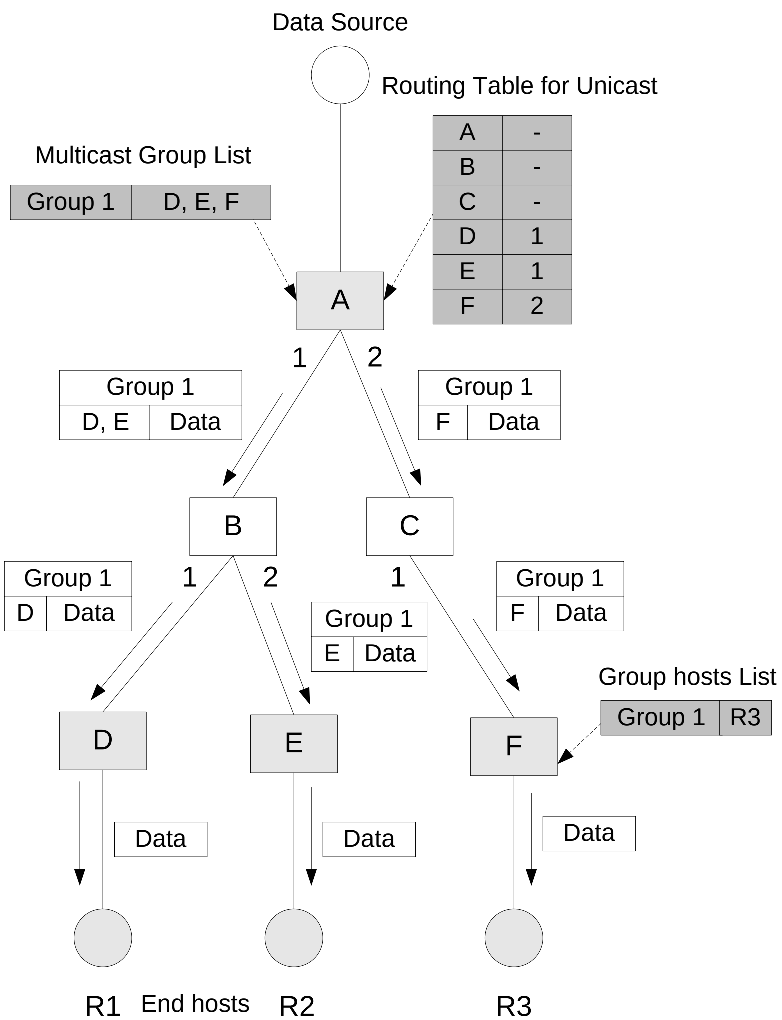
(group ID: RDR 1, RDR 2, …, RDR n)



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

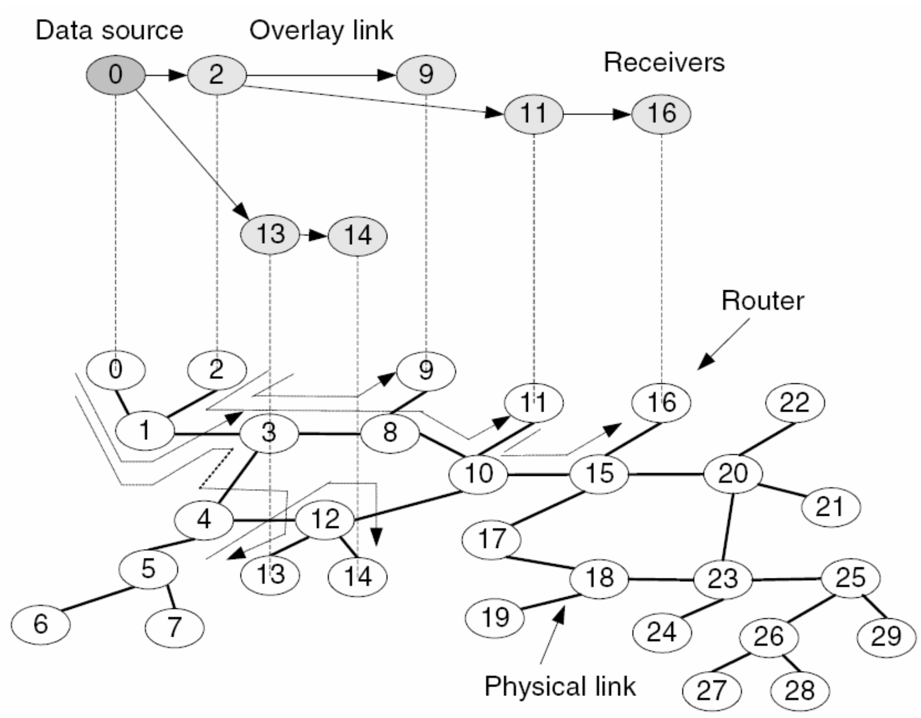
- The MUM message and the MGL are compressed with bloom filter
  - MUM: (IP address of RDR: group 1, …, group n)
  - MGL: (group ID: RDR 1, RDR 2, …, RDR n)
- Bloom Filter Design
  - Reverse path routing for multicast
  - Longest prefix match issue
  - Small false positive probability
  - Asymmetric routing

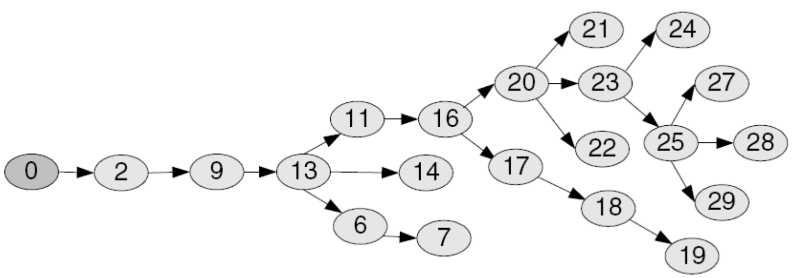
Properties of AOM

- 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.

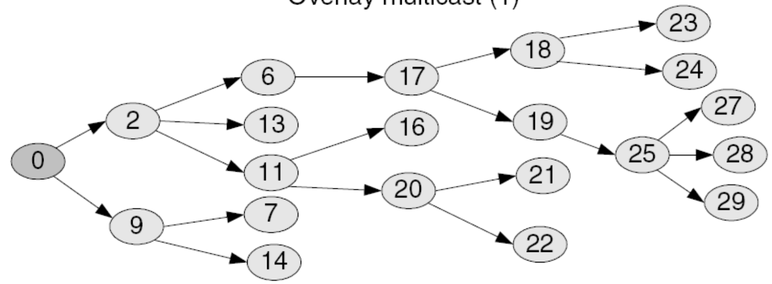
Performance Evaluation

- Simulation topology





Overlay multicast (1)



Overlay multicast (2)

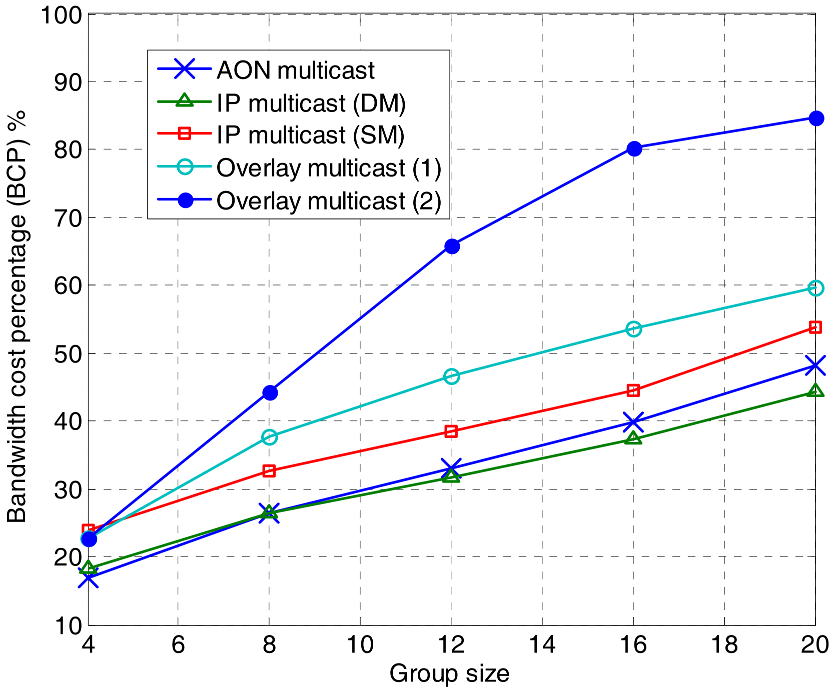
Performance evaluation

- Bandwidth Cost Percentage (BCP)

$$BCP = \frac{T}{C \bullet D} \times 100\%$$

T - the total number of bits traversing the physical network
C - the total network capacity (i.e., the summation of all link capacities), and
D - the simulation duration.

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



Performance evaluation

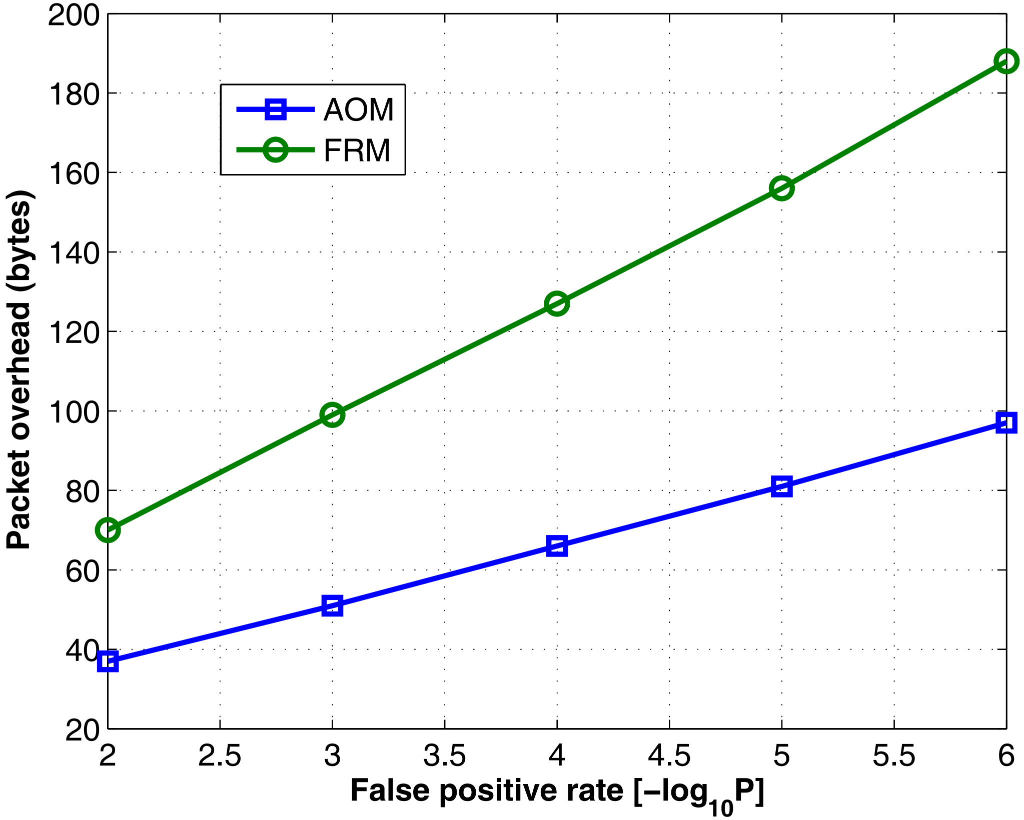
- Forwarding FALSE Positive Rate
  Binary tree topology with different tree heights

H	AOM		FRM	
2	4	2.6934×10^{-53}	6	5.4875×10^{-50}
3	8	1.4433×10^{-15}	14	2.5713×10^{-11}
4	16	2.3242×10^{-10}	30	2.8203×10^{-6}
5	32	6.6281×10^{-6}	62	0.0085
6	64	0.0111	126	0.4172
7	128	0.4358	254	0.9658

S. Ratnasamy, A. Ermolinskiy and S. Shenker, “Revisiting IP Multicast,” in *Proc. ACM SIGCOMM*, Sept. 2006.

Performance evaluation

- Packet Overhead



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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

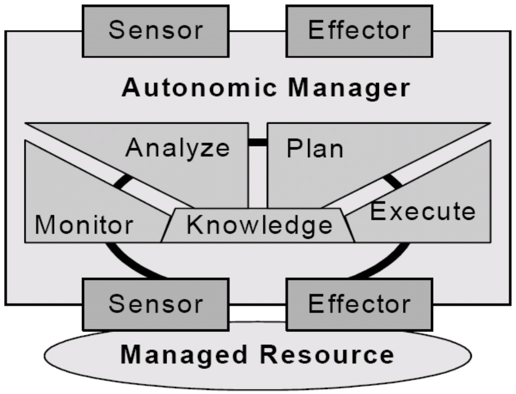
- Implementing the service broker
  - The universal description, discovery, and integration UDDI approach
  - Broker overlay network
    - How to organize the overlay
    - How to search a set of correlated services
    - How to negotiate SLAs in a distributed approach
- Dependable and automatic service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

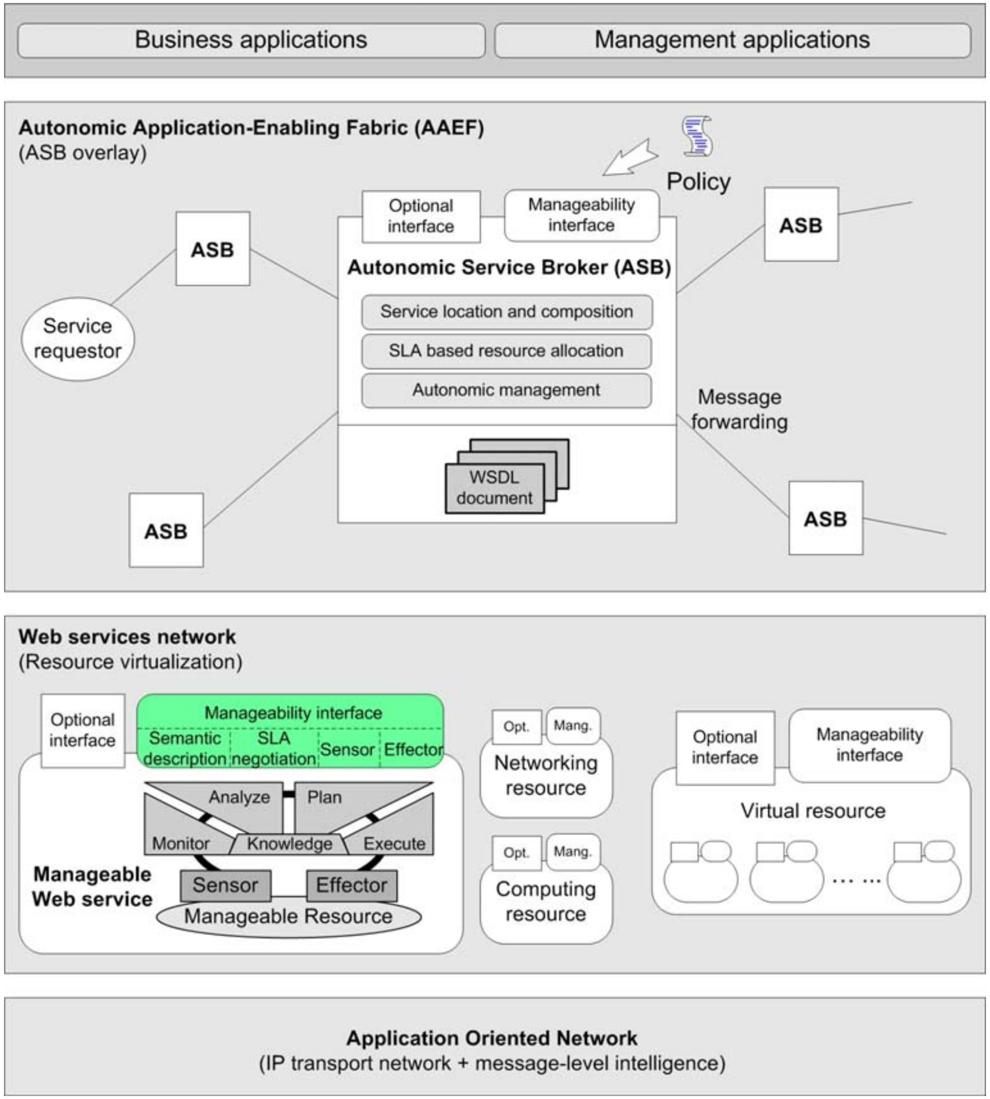
Autonomic computing

- 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



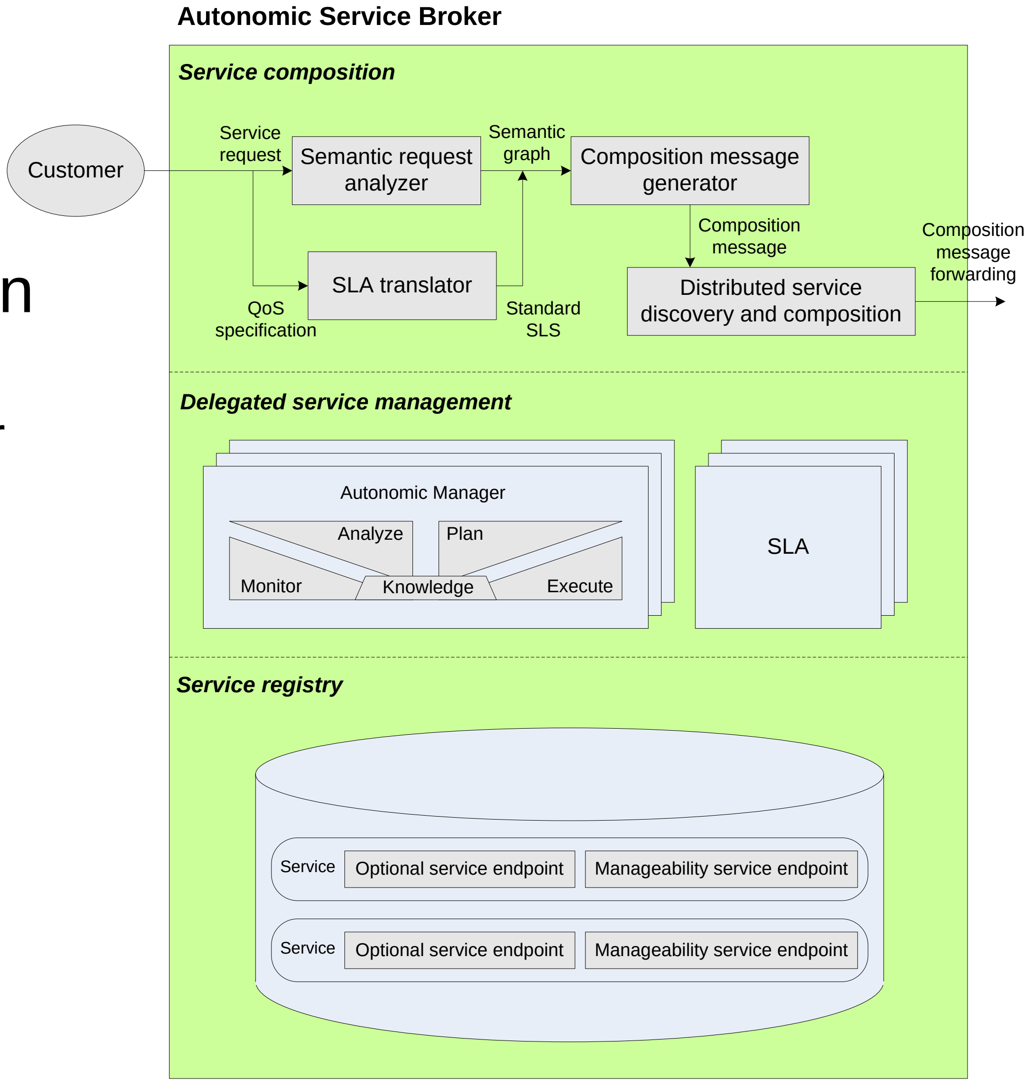
Autonomic Service Management Framework

- 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



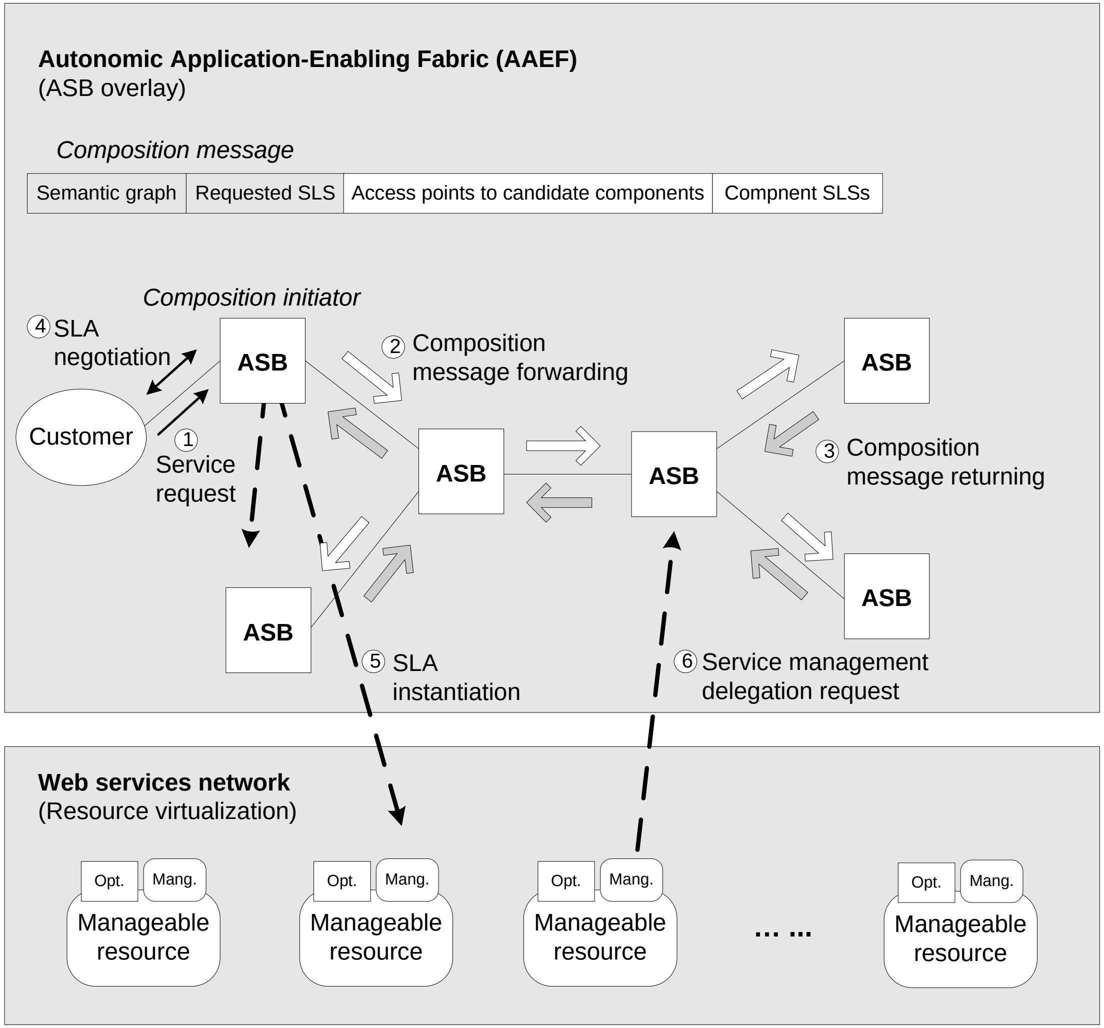
ASB Overlay

- 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

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