Announcements

Lectures 1-9 are available.
Homework 3 is out. Due 10/10 at 3am.
Submit only plain ASCII or PDF!
No class on Thursday 10/3 (inauguration).
Still looking for a TA.
Have you been thinking about your project?
OSPF

• More accurately: OSPFv2.
  – v1 was never really deployed.
• Link-state IGP, “open”, based on Dijkstra’s SPF algorithm.
• RFC2328 (and many others).
• Recommended IGP, esp. in a multivendor environment.
• Several features in common with other LS protocols
  – IS-IS, NLSP, PNNI.
  – We may look into IS-IS if time permits.
  – We’ll point out some things that other protocols do better.

• Basis for other IETF LS protocols:
  – MOSPF.
OSPF Properties

• Reduced LSA distribution overhead.
  – **Areas** limit the extent of flooding.
  – Multicast limits impact on broadcast networks.
  – OSPF goes quiet when there are no route changes.
• 16-bit dimensionless metric.
• Equal-cost load balancing.
• Route aggregation.
  – CIDR, VLSM, etc.
• Route tagging.
• Authentication.
OSPF Overview

• Neighbor discovery:
  – **Hello** packets sent on all OSPF-enabled interfaces.
  – **Neighbors**: routers on same link that agree on certain hello parameters.
  – **Adjacencies**: virtual point-to-point links between certain neighbors.

• Link State Advertisements (**LSAs**):
  – Multiple LSA types.
  – Sent over all adjacencies.
  – List all of router’s interfaces and the state of all links.
  – Flooded throughout an area.
  – Recorded in Link State Database and forwarded to neighbors.
OSPF Overview (cont’d)

• Designated Router / Backup Designated Router.
  – Two of the routers on a multiaccess link.
  – Used to reduce overall traffic on the link.
• When LSDB is complete:
  – Shortest Path Tree is computed on each router
    • (using Dijkstra’s SPF algorithm).
  – Forwarding table built from SPT.
• Keep quiet:
  – Hellos are exchanged as keepalives.
  – LSAs are retransmitted every 30 minutes.
OSPF Network Types

- Point to point links.
  - High and low speed PPP links.
- Broadcast networks.
  - Ethernet-like.
- Non-Broadcast Multiple Access (NBMA) networks.
- Point-to-multipoint.
  - Really, special configuration of NBMA networks.
- Virtual links.
  - OSPF-specific meaning of the term.
  - Effectively, unnumbered point-to-point links.
Some Multicast Addresses

- 224.0.0.5   AllSPFRouters OSPF-ALL.MCAST.NET
- 224.0.0.6   AllDRouters OSPF-DSIG.MCAST.NET

- FF02::5 and FF02::6, respectively for OSPFv3.

- While we are at it:
  - 224.0.0.1   ALL-SYSTEMS.MCAST.NET
  - 224.0.0.2   ALL-ROUTERS.MCAST.NET
  - 224.0.0.9   RIP2-ROUTERS.MCAST.NET
  - 224.0.0.10  IGRP-ROUTERS.MCAST.NET

- Look up some more (with `dig -x address`).
Destination Addresses Used

- On point-to-point networks:
  - No need to elect a DR.
  - Neighbors always become adjacent.
  - All OSPF packets except retransmitted LSAs sent to AllSPFRouters (224.0.0.5).

- On Broadcast networks:
  - DR and BDR are elected.
  - Packets sent to AllSPFRouters (224.0.0.5):
    - Hello packets.
    - All packets originating from the DR and BDR.
  - Packets sent to AllDRouters (224.0.0.6):
    - All packets sent by the rest of the routers.
    - Since these should only go to the DR/BDR.
Destination Addresses Used (cont’d)

• On NBMA networks:
  – DR and BDR are elected.
  – Extra configuration is needed to acquire neighbors.
  – All packets are unicast (no point in multicasting them).

• On Point-to-Multipoint networks:
  – These are treated as a collection of point-to-point links.
  – No DR/BDR are elected.
    • no need to.
  – Packets are multicast.
    • This way you don’t have to find the address of the machine on the other side of the link.

• Virtual Links:
  – Packets are multicast.
Reminder: Transit vs. Stub Networks

Transit networks

Transit ISP

ISP A

Customer A

Customer B

Customer C

ISP B

Customer D

Customer E

Stub networks
Hello Protocol

• Sent every *HelloInterval* (default: 10s).
• Neighbor discovery.
• Parameter announcement/discovery.
  – No negotiation!
• Used as keepalive.
  – Dead after *RouterDeadInterval* (default: 4*HelloInterval).
• Establishes bi-directional communication.
• On broadcast and NBMA networks:
  – Elects DRs and BDRs ([Backup] Designated Routers).
Hello Packet Contents

- **Router ID** of originating router (32 bits):
  - Highest IP address on loopback interfaces.
  - If no lb, highest IP address on regular interfaces.
  - Unchanged even if interfaces go down.

The rest of the fields pertain to the originating *interface*.

- **Area ID** (32 bits):
  - Area ID 0 is the *backbone* area.

- Checksum (16 bits).

- Authentication type (16 bits) and information (64 bits).
  - None, cleartext (bad!), or keyed hash.
  - The hash is appended to the packet and is not considered part of the packet for checksumming purposes.
Hello Packet Contents (cont’d)

- **HelloInterval** (16 bits).
- **RouterDeadInterval** (32 bits).
- Options (5 of 8 bits).
- Router Priority (8 bits).
- DR and BDR (32 bits each).
- List of neighbors.
Hello Packet Processing

- Receiving routers (on same link) check:
  - AreaID, Authentication, Netmask, HelloInterval, RouterDeadInterval, and Options.
  - If they don’t match its own, packet is dropped.
- If RouterID is known to the receiving interface:
  - RouterDeadInterval timer is reset.
  - RouterID is added to the table of known neighbors.
- If receiving router sees its own ID in the list of neighbors in the hello packet, it knows that it has bi-directional communication with the sender.
- Adjacencies may now be formed, if appropriate.
  - Depends on network type.
Adjacencies on Broadcast Networks

- If n routers are on a bc link, n(n-1)/2 adjacencies could be formed.
- n^2 LSAs would be originating from this network (why?).
Adjacencies, cont’d

- If routers formed pairwise adjacencies:
  - Each would originate \((n-1)+1=n\) LSAs for the link.
  - Out of the network, \(n^2\) LSAs would be emanating.
- Routers would also send received LSAs to their adjacencies.
  - Multiple \((n-1)\) copies of each LSA present on the network.
  - Even with multicast, \((n-1)\) responses would still result.

- To prevent this, a Designated Router is elected.
  - Routers form adjacencies only with DR.
  - Link acts as a (multi-interface) virtual router as far as the rest of the area is concerned.
Adjacencies, cont’d

- One router is selected as the DR.
- Actually, another is selected as the BDR.
  - If the DR fails, we want the BDR to take over within RouterDeadInterval rather than go over a new election.
    - During which no traffic would be forwarded.
- Routers form adjacencies with both DR and BDR.
- DR and BDR also form adjacencies with each other.
DR Election

• When router joins in:
  – Listen to hellos; if DR and BDR advertised, accept it.
  • This is the case if all Hello packets agree on who the DR and BDR are.
  • Unlike IS-IS, status quo is not disturbed!
• If there is no elected BDR, router with highest priority becomes BDR.
• Ties are broken by highest RouterID.
  – RouterIDs are unique (IP address of lb if).
• If there is no DR, BDR is promoted to DR.
• New BDR is elected.
DR Election Details

• Routers who believe can be BDRs or DRs put their own IDs in their Hello packets.
• Once 2-way communication has been established, all routers know who the candidates are.
• They can now all pick a BDR.
  – Highest priority, then Router ID.
• And then a DR.
• If only one router claims he’s the DR, he becomes the DR.
• First two routers to come up become the DR and BDR.
OSPF Interface Data Structure

- IP Address and Mask
- Area ID
- Router ID
- Network Type
- Cost
- Interface Transit Delay
- State
- Priority
- DR
- BDR

- Hello Interval
- Hello Timer
- Router Dead Interval
- Wait Timer
  - Before DR selection
- Rxmit Interval
  - Ack packets
- Neighbors
- Auth type
- Auth key
OSPF Interface State Machine

- point to point
- down
- waiting
- Election
- BDR
- DR
- loopback
- DROTHER