Deploying OSPF

Session RST-207

Agenda

- Link State Protocol Refresher
- OSPF Concepts, Structure and Operation
- Deploying OSPF
- OSPF Implementation
- OSPF Design Practices
What Is a Link State Protocol?

Finding the Way Using Dijkstra

Link State Protocols

- Based on Dijkstra (Shortest Path First) Pathfinding Algorithm
- Dijkstra is one of many pathfinding algorithms (ie. Best-First, A*, etc.)
- Pathfinding algorithms are used in many modern applications:
  - Dijkstra—Networking
  - A*—Gaming AI
  - Dijkstra—Mapping/Direction Calculation
Dijkstra Concepts (Cont.)

• How?
  We create a protocol

• What does it do?
  Creates and maintains the link-state and path databases
  Populates the forwarding table

Dijkstra Protocols

• CLNS/DECnet phase 5
• IS-IS
• OSPF
• NLSP
Deploying OSPF

Concepts, Structure, and Operation

OSPF History

- Development began 1987 by IETF
- OSPFv2 established in 1991 with RFC 1247
- Goal—a link state protocol more efficient and scaleable than RIP
- Latest revision is RFC 2328 April 1998
OSPF Benefits

• Uses metrics—path cost
• Typically faster convergence than DVRPs
• Support for CIDR, VLSM, authentication, multipath, and IP unnumbered
• Relatively low steady state bandwidth requirements

Cost = Metric

• Cost applied on all router link paths
• 16-bit positive number 1–65,535
• The lower the more desirable
• Relevant going out an interface only
• Route decisions made on total cost of path
OSPF Metric

- Derived from bandwidth
  
  \[
  \frac{108}{\text{bandwidth}} \quad \text{56-kbps serial link} = 1785
  \]
  
  \[
  \text{Ethernet} = 10 \quad \text{64-kbps serial link} = 1562
  \]
  
  \[
  \text{T1 (1.544-Mbps serial link)} = 64 \quad \text{Fast Ethernet/FDDI} = 1
  \]

- Bandwidth dividend is user configurable:

- Configured via:
  
  - Interface subcommand: `bandwidth`
  - Interface subcommand: `ip ospf cost`
  - Router subcommand: `ospf auto-cost reference bandwidth`

Router ID

- Routers are identified by a unique ID

- RID: highest IP address from any loopbacks

- RID: if no loopback exists, highest IP address configured to a physical interface

- Can be forced with:
  
  `router-id <ip address>`
Areas

- OSPF uses a 2 level hierarchical model
- Areas defined with 32 bit number
  - Defined in IP address format
  - Can also be defined using single decimal value (ie. Area 0.0.0.0, or Area 0)
- 0.0.0.0 reserved for the backbone area
- All areas must connect to area 0.0.0.0

OSPF Areas—Example
Virtual Links

- Not recommended
- So what’s it for?
  - Tunnel ABR summaries to area 0
  - Allow areas to connect to areas other than 0
  - Repair a discontinuous area 0

Virtual Links (Cont.)

- May be required in backup scenarios
- Configured at each ABR
- Should use loopback interfaces
  area <area id> virtual-link <router-ID>
Virtual Links—Example 1

Area 0

Area 1

Area 2

Area 3
Virtual Links—Example 1

Router A (RID 171.0.1.7)
router ospf 100
area 2 virtual-link 171.0.1.5
Router B (RID 171.0.1.5)
router ospf 100
area 2 virtual-link 171.0.1.7

Different Types of Routers

- Internal routers (inside an area)
- Backbone routers (inside area 0)
- Area Border Routers (ABR)
  An ABR sits between two or more areas
  Must touch backbone area (area 0)
- Autonomous System Boundary Routers (ASBR)
  Redistribution makes a router an ASBR
**Location of Different Routers**

- Internal Area 10
- LAN
- Area 11
- Internal
- ASBR
- Backbone Area 0
- ABR
- Area 12
- Internal
- LAN
- RIP/RIPv2 World
- ABR
- ABR
- ABR
- ABR

**OSPF Algorithm**

- Network changes generates link-state advertisements (LSA)
- All routers exchange LSAs to build and maintain a consistent database
- The protocol remains relatively quiet during steady-state conditions
  - Periodic refresh of LSAs every 30 minutes
  - Otherwise, updates only sent when there are changes
Routing Protocol Packets

- They share a common protocol header
- Routing protocol packets are sent with type of service (TOS) of 0
- Five types of OSPF routing protocol packets
  - Hello
  - Database description
  - Link-state request
  - Link-state update
  - Link-state acknowledgment

OSPF Hello Packets

- Multicast 224.0.0.5 on all router interfaces
- Hello interval 10 sec. LAN, 30 sec. NBMA
- Used to form adjacencies between routers
- Describes the optional capabilities
Different Types of LSAs

- Router link (LSA type 1)
- Network link (LSA type 2)
- Network summary (LSA type 3)
- ASBR (LSA type 4)
- External (LSA type 5)
- NSSA external (LSA type 7)

Opaque LSAs

- RFC 2370
  Used for distribution for applications
- Opaque link-local (LSA type 9)
- Opaque area-local (LSA type 10)
  First Cisco implementation with RSVP
- Opaque AS (LSA type 11)
  Similar to type 5
Different Types of LSAs

• Router LSA (type 1)
  
  Describes the state and cost of the router’s links to the area

  All of the router’s links in an area must be described in a single LSA

  Flooded throughout the particular area and no more

  Router indicates whether it is an ASBR, ABR, or end point of virtual link

• Network LSA (type 2)

  Generated for every broadcast network

  Describes all the routers attached to the network

  Only the designated router originates this LSA

  Flooded throughout the area and no more
Different Types of LSAs

- **Summary LSA (type 3 and type 4)**
  - Describes the destination outside the area but still in the AS
  - Flooded throughout a single area
  - Originated by an ABR
  - Only intra-area routes are advertised into the backbone
  - Type 4 is the information about the ASBR

- **External LSA (type 5)**
  - Defines routes to destination external to the AS
  - Default route is also sent as external
  - Two types of external LSA:
    - **E1**: Consider the total cost up to the external destination
    - **E2**: Considers only the cost of the outgoing interface to the external destination
Location of Different LSAs

LSA Types
1) Router  2) Network  3) Summary  4) ASBR Summary  5) External

Topology/Link State Database

- A router has a separate LS database for each area to which it belongs
- All routers belonging to the same area should have identical databases
- SPF calculation is performed independently for each area
- LSA flooding is bounded by area
- Router ID unique identifier within OSPF domain
When a Link Changes State

- Every router in area hears a specific link LSA
- Each router computes shortest path routing table

Router 1, Area 1

Router 2, Area 1

Link State Table

Dijkstra Algorithm

Old Routing Table

New Routing Table

OSPF Media Options

- Point-to-Point
- Non-Broadcast Multi-Access (NBMA)
- Multi-access media
- Demand circuits (11.2)
Multi-Access Media

- Gig/Fast/Ethernet, FDDI, Token Ring
- Multicast
- DR and BDR

Designated Routers

- Reduce OSPF traffic on multiaccess links
- Store and distribute neighbors LSDBs
- Backup DR for redundancy
- OSPF priority used in DR selection
- Range 1–255 default 1, 0 for noncandidate
Point-to-Point Media

- Serial links
- Multicast used
- No DR or BDR

Non-Broadcast Multi-Access Media (NBMA)

- Frame Relay (multipoint), X.25

  Several possibilities: point-to-point, broadcast, point-to-multipoint, or nonbroadcast
Dealing with NBMA

• Point-to-point model
  Benefits: Individual costs can be configured; Can be simple, treated like standard point-to-point links
  Drawbacks: Complex to configure if the NBMA network is big or redundant; Wastes address space

• Broadcast model
  Benefits: Simple to configure; Treated like a Multi-Access network
  Drawbacks: Must maintain an L2 full-mesh at all times; One one metric for all VCs
Dealing with NBMA

• NBMA model:
  Benefits: Only one IP subnet used
  Drawbacks: Complex to configure and scale;
           Need to manually configure each neighbor

• Point-to-Multipoint model:
  Benefits: Simple to configure; No neighbor
           configuration (unless you want individual costs);
           No requirement for a full mesh at L2
  Drawbacks: Compared to other choices—none

• This is the recommended method of dealing
  with NBMA networks
OSPF Demand Circuits

• OSPF demand circuit
  Additional option in LSAs:
  Do not age bit
  Suppresses hellos exchange
  Suppresses DB synchronization

• All new LSA still have to be transmitted in the area

Scaling OSPF

Leveraging OSPF Components
Using Areas

- The tool to make OSPF scale
- One SPF per area, flooding done per area
- Different types of areas do different flooding
  - Normal areas
  - Stub areas
  - Totally stubby (stub no summary)
  - Not so stubby areas (NSSA)

Regular Area

- Regular areas
  - Summary LSA from other areas injected
  - Specific links from other areas injected
  - External links injected
Regular Area

- Backbone Area 0
- Area Border Router
- Area 51

- ABRs forward all LSAs from backbone

Stub Area

- Stub area
  - Summary LSAs from other areas injected
  - LSA type 5 not injected
  - Default LSA injected into area as summary LSA
  - Define all routers in area as stub
  - External link flaps will not be injected
**Stub Area**

- Consolidates specific external links—default 0.0.0.0

**Totally Stubby Area**

- Totally stubby area
  - Default LSA injected into area
  - Represents all external links
  - Represents all summarized internal links
  - Represents non-summarized internal links
  - Very stable, small LSDB, fewer routes
**Totally Stubby Area**

- Use this for stable—scalable internetworks

**Not So Stubby Areas (NSSA)**

- Benefits of stub area, but ASBR is allowed
- New type external LSA (type 7)
  - Type 7 LSAs flooded throughout the area
  - No type 5 external LSAs in the area
  - Type 7 LSAs will be converted into type 5 LSAs when flooded into area 0 by ABRs
- Filtering and summaries allowed at ABRs
NSSA

- Backbone Area 0
- ABR—Type 7 --> Type 5
- NSSA 51
- ASBR Injects LSA Type 7

An Area Forwards the Following
Summary LSAs
Specific LSAs
Default External 0.0.0.0

Summarization

- Routing is by longest prefix match
- Instead of advertising many more specific prefixes, advertise only one summary prefix
  - Area-range on ABR to summarize type 3 LSAs
  - Summary-address on ASBR to sum type 5s
- Not only smaller, but also more stable
- Drawback is possible suboptimal routing
Not Summarized: Specific Links

- Only summary LSA advertised out
- Link-state changes do not propagate

Summarized: Summary Links

- Only summary LSA advertised out
- Link-state changes do not propagate
Summarization (Cont.)

Configure on Both ABRs
Area-Range 11.1.0/17
Area-Range 11.1.128/17

Cost to Range 1:
Via ABR1: 30
Via ABR2: 80

Cost to Range 2:
Via ABR1: 80
Via ABR2: 30

Design Practices
Defining the Logical Layout
OSPF Design

• Attack addressing first
  Create address hierarchy to match topology
  Can be geographic or organizational

• Examine physical topology
  Is it meshed or hub and spoke?

Meshed

• OSPF may not be the right choice
  We only get a two-layer hierarchy
  Using Virtual Links for a fix is bad

• However we can engineer anything
  Pruning some links
  Adding a few
Meshed (Cont.)

- Try to use as stubby an area as possible
  It reduces overhead and LSA counts
- Push the creation of a backbone
  Reduces mesh and promotes hierarchy

Example Network

![Example Network Diagram]

- R200
  172.16.7.2
  172.16.3.1
  172.16.1.1
  172.16.2.2
  172.16.12.1
  64 Kb

- R300
  172.16.8.1
  172.16.1.2
  172.16.5.1
  172.16.5.2
  172.16.6.2
  172.16.6.1
  172.16.10.1

- Cen
  172.16.4.1

- Rem
  172.16.2.1
  172.16.11.1
  172.16.4.2

- Trans
  172.16.11.2
  172.16.1.1
  172.16.2.1

- Frame Relay
  172.16.3.2

- T-1
  64 Kb
  172.16.9.1
Hub and Spoke

- **Scalability**
  
  But any dynamic routing protocol is unnecessary if there is only one path and no dial backup

  ODR/static?

- **Hub routers are the ABRs**
  
  Spoke routers are totally stubby wherever possible
Hub and Spoke (Cont.)

- Group branch offices by capability for
  Totally stubby, stub, NSSA and regular
- Define area’s and addressing to these groups
- How big:
  Hard to answer; Depends on a lot of factors
  (i.e. Number of routes, efficiency of design, router platforms, etc.)

Dial-on-Demand

- Dial-on-Demand Techniques:
  Use virtual profiles
  Virtual interface gets assigned to the area associated with the calling router
  Area configuration and IP address for virtual interface are dynamic
Dial Backup and OPSF

Virtual Profiles

Area 0
Area 3
Area 4

Virtual Interface
AAA Server
NAS

--- Dial Backup
--- Primary Link

Deployment Tips
Enterprise Deployment Characteristics

- Can have multiple ‘islands’ of IGPs
- Islands tied together by a BGP core
- May be a requirement for redistribution

Dealing with Redistribution

- The number of redistribution boundaries should be kept to a minimum
  Why?
  Because you have better things in life to do besides; build access lists
- When redistributing try to place the DR as close to the ASBR as possible to minimize flooding
Dealing with Redistribution

- Be aware of metric requirements going from one protocol to another
  - RIP metric is a value from 1-16
  - OSPF Metric is from 1-65535
- Include a redistribution default metric command as a protection
  
  ```
  router ospf 1
  network 130.93.0.0 0.0.255.255 area 0.0.0.0
  redistribute rip metric 1 subnets
  ```

Dealing with Redistribution

- Redistribute only what is absolutely necessary
  - Don’t redistribute full Internet routes into OSPF
- Default route into BGP core; Let the core worry about final destination
Service Provider Deployment Characteristics

- SPs will have only one instance of IGP running throughout network
- BGP carries external reachability

Dealing with Redistribution

- Don’t do it!
- If you’re an SP you shouldn’t be carrying external information in your IGP
- Let BGP take care of external reachability
- Use OSPF to carry internal connectivity and next-hop information—ie. Loopbacks, internal links
- Don’t redistribute connected interfaces either; Doing so creates type 5 external LSAs which propagate across the network
Using OSPF Authentication

- Use authentication! Too many people overlook this basic feature
- When using authentication, use the MD5 feature
  
  area <area-id> authentication message-digest (whole area)

  ip ospf message-digest-key 1 md5 <key>

- Authentication can selectively be disabled per interface with:

  ip ospf authentication null

General Ground Rules

- Addressing should be contiguous with respect to topology
  
  Not just network topology but routing protocol topology

  Allows for summarization

  If you’ve any piece of a classfull protocol left, you must keep major network prefixes contiguous and non-VLSM
Preparation

- **Accurate topology maps**
  - Layout new protocol areas
  - Identify redistribution points

- **Create new configs**
  - New configs are simply *installed* during the change window, not created

- **Proof of concept**
  - Lab work with real routers
  - Netsys modeling

Validation

- **All networks should have an acceptance test**
  - What constitutes up?
    - A green network management map is not sufficient

- **Are the route ages appropriate?**
  - If the protocol is periodic, routes should never be older than the update time
  - If the protocol is update based, routes should get old
Validation (Cont.)

• Is the number of routes stable?
  • If you have the luxury, fail a link, allow the network to converge then restore the link and let the network converge
    Are convergence times appropriate for the protocol
    Remember to account for differentials in convergence time

Validation OSPF

• Do I have all the neighbors I should?
  Show ip ospf neighbors

• Are routes getting old
  Show ip route
  Look at the age of the route
Migration Tips

Migration Approaches

- Technique 1: Run only 1 IGP in any given part of the network; Redistribute between other IGP and OSPF
- Techniques 2: Run two IGPs concurrently, giving OSPF a higher admin distance and then cutting over
Migration via Redistribution

- **Benefits:** Requires less router resources
- **Drawbacks:** Becomes complex very quickly; Requires careful redistribution with potentially lots of filters
- **Not really a great choice for migration, but ok for small implementations**

Migration via Ships in the Night

- **Benefits:** Cleaner process not requiring redistribution points in the network; Easier to verify validity before making major change; Easier to back out of
- **Drawbacks:** Requires more router resources, particularly RAM
- **The recommended method of migrating to OSPF; Simpler, cleaner, safer, plus RAM is cheap these days**
Migrating

• Start by building out the backbone area
• Migrate additional areas in incrementally

Tuning OSPF
Available “Nerd-Knobs”

• **Hello/Dead Timers**
  
  `ip ospf hello-interval 3` (default 10)
  
  `ip ospf dead-interval 15` (default is 4x hello)

  This allows for faster network awareness of a failure, and can result in faster reconvergence, but requires more router CPU and generates more overhead

• **LSA Pacing**

  `timers lsa-group-pacing 300` (default 240)

  This is a great feature; Allows grouping and pacing of LSA updates at configured interval; Reduces overall network and router impact

Available “Nerd-Knobs”

• **DR/BDR Selection**

  `ip ospf priority 100` (default 1)

  This feature should be in use in your OSPF network; Forcibly set your DR and BDR per segment so that they are known; Choose your most powerful, or most idle routers; Try to keep the DR/BDR limited to one segment each

• **OSPF Internal Timers**

  `timers spf 2 8` (default is 5 & 10)

  Allows you to adjust SPF characteristics; First number sets wait time from topology change to SPF run; Second is hold-down between SPF runs; BE CAREFUL WITH THIS COMMAND; If you’re not sure when to use it, it means you don’t need it; Default is 95% effective
Available “Nerd-Knobs”

- **LSA Filtering/Interface Blocking**
  
  **Per interface:**
  
  `ip ospf database-filter all out (no options)`
  
  **Per neighbor:**
  
  `neighbor 1.1.1.1 database-filter all out (no options)`
  
  OSPF router will flood an LSA out all interfaces except the receiving one; LSA filtering can be useful in cases where such flooding unnecessary (ie. NBMA networks), where the DR/BDR can handle flooding chores
  
  `area <area-id> filter-list <acl>`
  
  Filters out specific Type 3 LSAs at ABRs
  
- **Improper use can result in routing loops and black-holes that can be very difficult to troubleshoot**

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Example Network

[Diagram of a network with areas and protocols like RIP and OSPF represented.]
Addressing

- Loopbacks are /32 out of 172.168.1.0
- WAN links are /30 out of 172.168.2.0
- Area 1 subnet: 172.168.6-7.0/24
- Area 2 subnet: 192.64.48-63.0/24
- Area 3 subnet: 64.78.134-170.0/24
- Area 4 subnet: 64.78.180-183/24
- Area 51 subnet: 173.45.12-26.0/24

Design Plan

- Make Area 2 totally stubby
- Make Area 51 a stub
- Make Area 3 an NSSA
- All other areas are regular areas
- Summarize where possible
- Make router A the DR for the LAN in Area 1
Example Configs—Area 1

Router A
int lo0
  ip address 172.168.1.1 255.255.255.255
  
  int se0
  ip address 192.145.100.235 255.255.255.252
  
  int eth0
  ip address 172.168.6.1 255.255.255.0
  ip ospf priority 20
  ip ospf message-digest-key 1 md5 mykey
  
  router ospf 1
  network 172.168.6.0 0.0.0.255 area 0.0.0.1
  redistribute rip subnets metric-type 2 metric 100
  area 0.0.0.1 authentication message-digest
  
  router rip
  network 192.145.100.0
default metric 5
  
end

Router B
int lo0
  ip address 172.168.1.2 255.255.255.255
  
  int se0
  ip address 172.168.2.3 255.255.255.252
  ip ospf authentication-key mykey
  
  int eth0
  ip address 172.168.6.2 255.255.255.0
  ip ospf message-digest-key 1 md5 mykey
  
  router ospf 1
  network 172.168.6.0 0.0.0.255 area 0.0.0.1
  area 0.0.0.1 range 172.168.6.0 255.255.254.0
  area 0.0.0.1 authentication message-digest
  area 0.0.0.0 authentication message-digest
  
end

Example Configs—Area 2

Router H
int lo0
  ip address 172.168.1.8 255.255.255.255
  
  int se0
  ip address 172.168.2.6 255.255.255.252
  ip ospf authentication-key mykey
  
  int se1
  ip address 172.168.2.9 255.255.255.252
  ip ospf authentication-key mykey
  
  int se2
  ip address 172.168.2.17 255.255.255.252
  ip ospf authentication-key mykey
  
  int eth0
  ip address 192.64.60.1 255.255.255.0
  ip ospf message-digest-key 1 md5 mykey
  
  router ospf 1
  network 172.168.2.0 0.0.0.255 area 0.0.0.0
  network 192.64.60.0 0.0.0.255 area 0.0.0.2
  area 0.0.0.2 range 192.64.48.0 0.0.15.255

Router H (cont.)
  area 0.0.0.2 stub no-summary
  area 0.0.0.0 authentication message-digest
  area 0.0.0.2 authentication message-digest
  
end

Router K
int lo0
  ip address 172.168.1.11 255.255.255.255
  
  int eth0
  ip address 192.64.60.34 255.255.255.0
  ip ospf priority 20
  ip ospf message-digest-key 1 md5 mykey
  
  router ospf 1
  network 192.64.60.0 area 0.0.0.2
  area 0.0.0.2 stub no-summary
  area 0.0.0.0 authentication message-digest
  
end
Recommended Reading

- RFC 2328 and others
- and of course: http://www.cisco.com

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