Midterm week 5, review next week
Routing Protocol
- LSA flooding
- Shortest Path First
Path Vector
Link State
Some Review

- CIDRs, IP Prefix Routing, classification, Throughput, Linkspeed
Shortest Path First

- Need consistent results among routers or loops form
- Implement Dijkstra
- $N \log N$ complexity
Constrained SPF

- Take into account other factors than “shortest”
- Pruning Tree may make some nodes unavailable
- Develop hybrid “cost” for links
- Equal costing—packet order
- Traffic engineering
Routing Information Protocol (RIP)

- RIP 2 backwards compatible with RIP 1
- UDP port 520
- Command(8), version(8), Reserved(16) Address family(2=IPv4), Route tag(16)
- IP address
- Subnet Mask
- Next hop
- Metric
RIP

- No Support for unnumbered links
- Authentication
  - MD5 message digest--accurate message
  - Password--6 byte password
  - Message digest and SN into secret key table--AFI set to 0xffff
- RIP2 uses multicast
RIP Cont.

- RIP request multicast(224.0.0.9) on port 520
- Request for single IP or 0.0.0.0 for all
- Multiple routes on a single response message
- Infinity is still 16
- Diameter of a RIP network cannot exceed 15
- Silent mode
RIP Cont.

- Timers
  - Full table to each neighbor every 30 sec.
  - Triggered updates
    - If route change, update sooner
  - 180 second individual route timer
    - If it expires, route is no longer in use?
  - Advertise as down, remove in 120 sec.
RIP v1 vs v2

- No authentication in R v 1
  - Generally v1 will ignore v2 fields it does not understand
  - Packets are the same size
- Neither supports Multicast
- Support classless routing (CIDR)
RIP 2

- Good reason to use RIP is hosts come with it
  - Turn on RIP listener for reliable network support

RIP NG

- Very similar, but with IP V6 addresses
  - Recovery Cycle
  - Hold-Off Timer
LSA Flooding Process

- Generate new LSA
- Link failure, node failure, IP prefix reachability change, LSA refresh, Configuration Change
- Flooding Process
  - Is received LSA older than current LSA?
  - If so, don’t forward
LSA Flooding

- Is LSA same age?
  - Ack, but don’t forward

- Is LSA newer?
  - Ack, store in local DB (LSDB) flood to every neighbor

- Generally, flood before new SPF computation
LSA Flooding

- Packet queuing delays
- Over-provision and simple queueing
- Priority reliable queue
- Differentiated Services Code Point (DSCP)
- “ef” expedited forwarding
- Famine: limits
SP Route Computation

- LSA data on nodes and neighbors
- Compute paths with Dijkstra(1959)
  - Identify working node
  - Tentatively label all neighbor paths
  - Pick lowest cost neighbor, make permanent, examine its neighbors, etc.
SP Computation Triggers

- New LSA generally triggers new SP comp.
- New IP address may warrant only a partial route computation (IS-IS PRC)
- Too many LSA updates may trigger too many SP Comps, so delay computation according to difficulty and time for router
- Exponential backoff
Temporary Loops

- Network changes not yet distributed can cause loops
  - Loop example for failed link
  - Loop example for restored link
Load Balancing

- Per Packet load balancing
- Packet reordering issues
  - Application degradation at 0.1–1%
- Per-session load balancing
  - Hash on source and dest IP address
  - Avoid polarization by using different hash at each hop
Load Balancing (cont.)

- Reduce failure impact for symmetric mode
  - Route still exists
  - But may not be available if asymmetric
- Improve Convergence time
Widest Path First

- SPF assumes additive cost property
- Dynamic call routing with reservation
  - Not Additive, min{each link}
  - Dijkstra still works fine
    - May not be optimal
- Path caching
Widest Path First

- Bellman-Ford also works with Widest First
  - The same advantages and disadvantages
- K-shortest paths algorithm
  - Find multiple paths
    - Delete shortest path, calculate again
  - Disjoint paths require careful choice
Link State Routing Examples

- Open SPF
- OSPF provides intra-domain hierarch
- Divide network into areas
- Area-Border routers
  - The border between backbone low-level areas. Must have interface on backbone
- Internal Routers
  - Route inside numbered areas
OSPF Continued

- OSPF Router types
  - Backbone routers
    - Route inside the backbone (area 0)
  - AS Boundary Routers
    - Talks to BGP router out to Internet
OSPF Cont.

OSPF Network types

- Point-to-point links
- Broadcast networks (Ethernet)
- Non-broadcast multi-access (ATM, FR)
- Point-to-multipoint networks
- Virtual Links -- transit links through other networks, or other areas
OSPF Flooding

- In-network flooding
  - Depending on link type
    - Multicast on broadcast and IP ptp
  - OSPF sits on IP, so implements its own TCP
    - resend unicast until Ack(imp or exp) received
- LSARefresh-30 min, MinLSInterval-5 sec, MinLSArrival-1 sec
Link State Advertisements

- Router LSA (type=1) -- Ptp links, most basic
- Network LSA (type=2) -- Multicast networks DR
- Network Summary (type=3) --
- AS Border Router (type=4) between areas
- AS External LSAs (type=5) external destinations
OSPF Subprotocols

- In addition to LSA
  - Hello Protocol—find adjacencies and DR and BDR routers on broadcast networks
- Database Sync Process
  - Exchange LSA headers only
  - Stateful conversation between routers
Equal Cost Multipath

- If two paths have the same lowest cost, both paths can be listed and traffic split between them.

- Per-node, ie based on number of outgoing interfaces at a specific router. (multiple-multiple example.)

- Type of Service (TOS) option also available
Stub Areas

- "Regular" areas support all LSA types
- "Stub" areas use default route to area border router
- "Not-so-stubby-area (NSSA)" a stub where AS routes need to be imported to a connected AS
- "Totally-stubby-area (TSA)
- "Stub Network" has just one router
OSPF Cont

- Inter-area Routing Computation
  - Dijkstra is applied in each area, with DR and BDR routers handling traffic between areas
  - This looks like distance vector routing
- MD5 or password authentication
- Stub areas: no external routers, use default
OSPF packet Format

- Version(1B)=2, Type(1B)=1-5, packet Len(2)
- Router ID (4B)
- Area ID (4B)
- Checksum(2B), Auth Type (2B)
- Auth (8B)
OSPF Packet Format

- Type=1 (Hello packet)
- network Mask (4B)
- Hello interval(2B), Options(1B), Priority(1B)
- Router Dead Interval(4B) -- typ 4x hello int.
- Designated Router (4B)
- Backup Designated Router (4B)
- Neighbors (4B)........
OSPF Type=2 DB

- Interface MTU(2B), options (1B), I, M, MS bits
- DD Sequence number(4B)
- LSA headers
OSPF Type=3 Link State Request Packet

- Link State Type (4B) (router or network)
- Link State ID (2B)
- Advertising Router (2B)
- (repeat)
OSPF Type=4 Link State Update Packet

- Number of LSAs (4B)
- LSAs
OSPF Link State Acknowledgment

- Age, Options, Type, Link State ID, Advertising Router, Sequence number, Checksum and Length
- Checksum over entire packet except age
IS-IS

- Another Link State SPF protocol
- Two level area protocol like OSPF
- Pseudonodes for different network types
- Dijkstra SPF calculations
IS-IS Similarities

- Two level areas
- Both use Hello
- Can do summarization between areas
- Link state database and SPF with Dijkstra
- Designated Router election
IS-IS Differences

- Border routers are inside an area in IS-IS
- IS-IS packets between routers are link level, i.e. not IP
- Safer from spoofing attacks
Border Gateway Protocol

- BGP facilitates exchange of information between Autonomous Systems on the Internet
- An Inter-AS routing protocol
- Path Vector based
- TCP port 179 with open TCP connection
- BGP Requires TCP connectivity to operate
Why use BGP?

- Multi-Homing
- Multiple ISPs
- Can have multiple links without BGP, but not multiple ISPs.
BGP Setup

- Peering connections between autonomous systems
  - Two party config
  - Three party config
  - ISP level multi connections
BGP Messages

- OPEN
  - Started between BGP speakers
  - Usually configured in advance
- UPDATE
  - New IP IP Prefixes
- KEEPALIVE
BGP Messages

- UPDATE
  - Graceful close on error or exit
- ROUTE-REFRESH--pull
- Timers
  - ConnectRetryTimer, Hold Timer, (90 sec.)
  - KeepAlive, MinRoute, MinASO (anti-flap)
BGP Initialization

- Bringing up Neighbor
  - Single, use IP address
  - Multiple, use loopback
BGP State Diagram
Internal BGP (IBGP)

- Useful for multiple connections between stub BGP networks.
- Same ASN number
BGP Routing Decisions

- Route Import policy
- Policy based routing
- Route Export policy
- Full-Mesh BGP
- Use Route Reflectors to reduce mesh
- Cluster ID defines cluster
BGP Routes

- Route Reflectors must maintain their own full mesh.
- Some delay in delivery of updates, but less processing per router.
BGP Confederation

- Break network into multiple sub-ASN
- Full Mesh inside AS with exterior IBGP sessions.
- Multiple public or private space ASNs
- Need to watch for loops with hierarchical approach
BGP Aggregation

- Aggregate routes into one prefix
- Multiple ASN involved
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Example BGP Networks
Hierarchical Networks

- 3 Layer network
  - Summarization to the Core
  - Common Service Area
  - Summarization to the leaves
  - Stubs--don't advertise dynamic routes
Hierarchical Networks

- 2 Layer Networks
- Summarization from the core, but not in
- Third Party Next Hop in EIGRP
- Avoid extra hop with 3 nodes
Why Corporate BGP?

- Not useful for single vendor backup
- Use pooled connections, “dark fiber”
- Very Useful for multi-vendor Internet backup
- Many pitfalls
  - Don’t become a carrier
  - Matching dissimilar speed links
More Corporate Internet

- Connecting Distributed offices to the Internet
  - Central connection
  - Regional non-BGP connections
  - Fail-over procedure
  - Multiple BGP connections
  - Use care with policy advertisements