ALBERT-LUDWIGS-
UNIVERSITÄT FREIBURG

Communication Systems

OSPF, BGP

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Open Shortest Path First (OSPF)

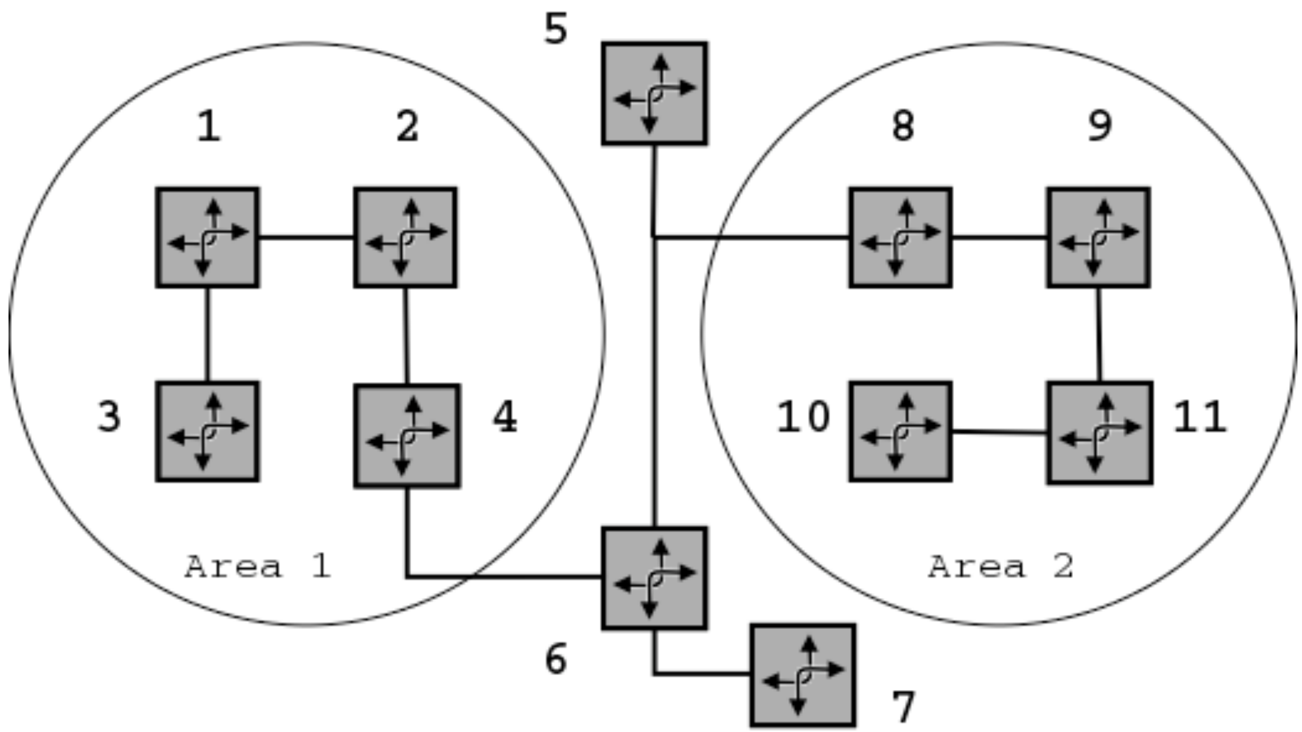
- Last lecture: OSPF as an example of Link State Routing algorithm
- Router contains a routing directory (called a "routing database").
- Exchange Link state advertisements
- Route computation using Dijkstra’s algorithm
- Advertisements disseminated to entire AS (via flooding explained before)
- Utilizes the Hello protocol for advertising state information between neighbors
- Neighbors exchange Hello packets periodically

OSPF – Hierarchy

- OSPF can cope with large networks (no restrictions as with RIP)
- Two-level hierarchy: local area, backbone
  - local area: aggregation of routers, hosts
  - backbone: distributes routing information between different areas
  - area border routers: advertise distances in own area to other area border routers
  - boundary routers: connect to other Autonomous Systems (talked about later on)

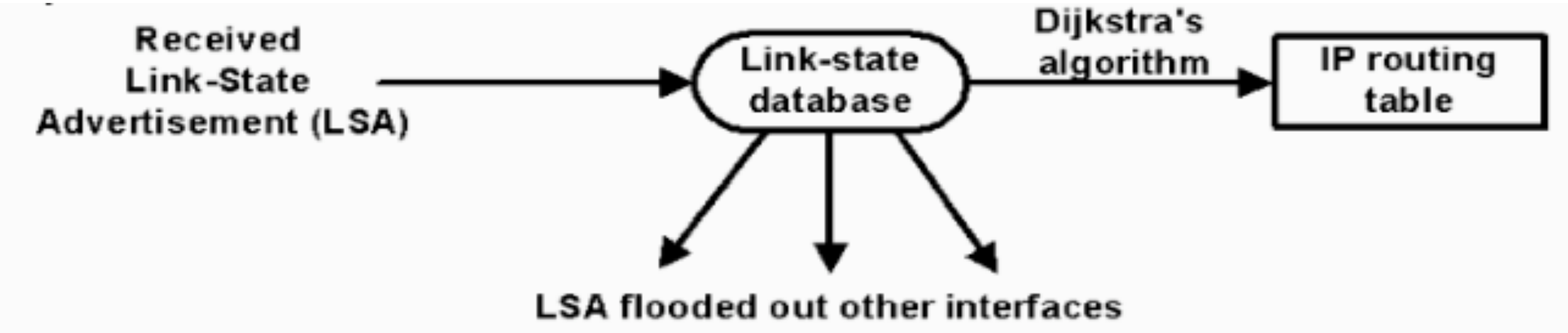
OSPF – Hierarchy (Example)

- Routers 1 – 4 and 8 – 11 are within the same area
- Routers 5,6,7 are backbone routers and form an additional area



OSPF – Protocol Operation

- Hello packets used to find adjacencies
  - Adding neighbours to the local list
  - Flood network with LSA (Link State Advertisement introduced beginnig of this lecure) to propagate information
  - Each router forwards only new information
  - Hello packets check state of neighbours
  - No response → router down → LSA flood → update of routing tables → fast convergence

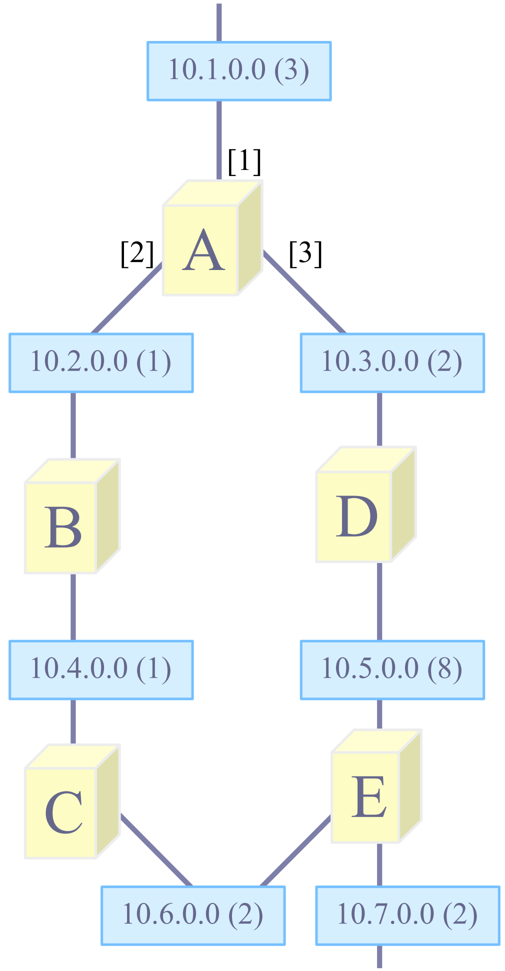


OSPF – routing tables

- **Steps for building routing table for Router A:**

Step	Confirmed	Tentative
1	A (0)	10.1.0.0 [1] (3)
		10.2.0.0 [2] (1) *
		10.3.0.0 [3] (2)
2	A (0)	10.1.0.0 [1] (3)
		10.3.0.0 [3] (2) *
	10.2.0.0 [2] (1)	10.4.0.0 [2, B] (1 + 1 = 2) *
3	A (0)	10.1.0.0 [1] (3)
	10.2.0.0 [2] (1)	10.4.0.0 [2, B] (1 + 1 = 2) *
	10.3.0.0 [3] (2)	10.5.0.0 [3, D] (2 + 8 = 10)
4	A (0)	10.1.0.0 [1] (3) *
	10.2.0.0 [2] (1)	
	10.3.0.0 [3] (2)	10.5.0.0 [3, D] (2 + 8 = 10)
	10.4.0.0 [2, B] (2)	10.6.0.0 [2, B, C] (1 + 1 + 2 = 4)

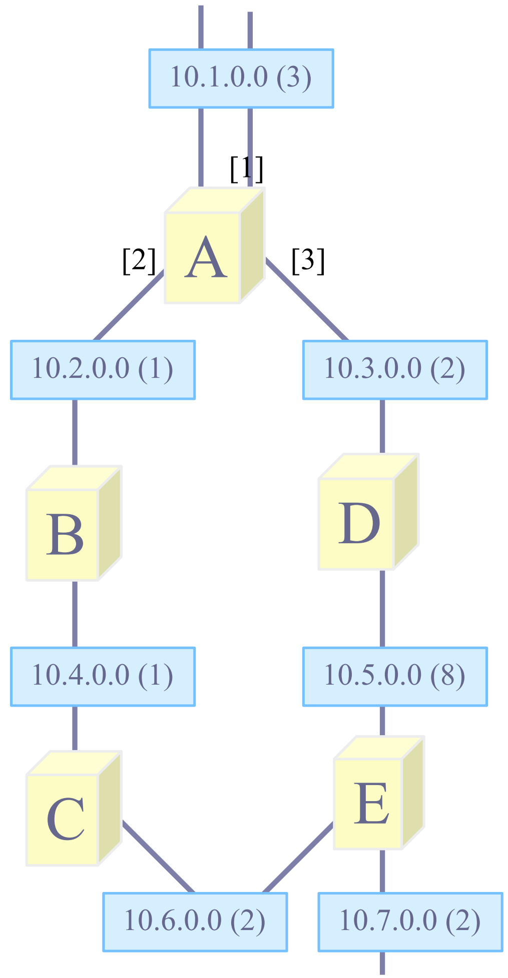
* represents tentative entries that are lowest cost; one of these is moved to confirmed list at end of each step.



Routing Algorithms – Routing Mechanisms

Router A's final routing table

A (0)
10.2.0.0 [2] (1)
10.3.0.0 [3] (2)
10.4.0.0 [2, B] (2)
10.1.0.0 [1] (3)
10.6.0.0 [2, B, C] (4)
10.7.0.0 [2, B, C, E] (6)
10.5.0.0 [3, D] (10)



Typology: Routing Strategies – (non)adaptive Routing

- Routing algorithms are grouped into two major classes
- **Nonadaptive** routing algorithms do not base their routing decisions on (continuous) measurements or estimates of current bandwidth usage and topology
  - no need for specific measurement service run continuously or scheduled
- The routes to use are computed in advance, off-line and downloaded to routers when network is coming up
- That is the typical scenario for networked end systems – normally the system administrator provides the routes during machine setup
- Or the routing information is transferred via DHCP (centralized setup of networking resources)

Adaptive Routing

- Routing done that way often named static (type of routing discussed yet falls into that category)
- **Adaptive** algorithms change their routing decisions to reflect changes in traffic/bandwidth usage and topology
- Algorithms differ in where they get their information ...
  - Locally from own measurements or from adjacent routers
  - Or (globally) from all routers
- ... and when changes are executed
  - Every ΔT seconds when network load changes
  - Or changes in topology occur
  - Or event driven ...
- Last two lectures examples of main dynamic routing concepts

Link State versus Distant Vector – Comparison

- Principle: Periodic advertisement of the routes in their routing tables
- Example: RIP (II)
- Advantages
  - Simpler - Easy to configure
- Disadvantages
  - Large routing tables
  - High network traffic overhead
  - Does not scale (very well), maximum of 15 hops
  - High convergence time

Link State versus Distant Vector – Comparison

- Principle: exchange link state advertisements (LSAs)
- LSAs are advertised upon startup and when changes in the internetwork topology
- Advantages
  - Smaller routing tables
  - Low network overhead
  - Ability to scale
  - Lower convergence time
- Disadvantages
  - Complex
  - More difficult to configure

Routing Protocols – IGP / EGP

- After theoretical introduction and some practical experiments
  - We know by now: Different implementations for dynamic LAN routing
- Taxonomy – dynamic routing could be divided into
  - Interior Gateway Protocols (IGP)
  - Exterior Gateway Protocols (EGP)
- Autonomous system (AS definition) - unit of routing policy, either a single network or a group of networks that is controlled by a common network administrator on behalf of a single administrative entity (such as a university, a business enterprise, or a business division)
- AS is also sometimes referred to as a routing domain

Routing – Interior Gateway Protocols

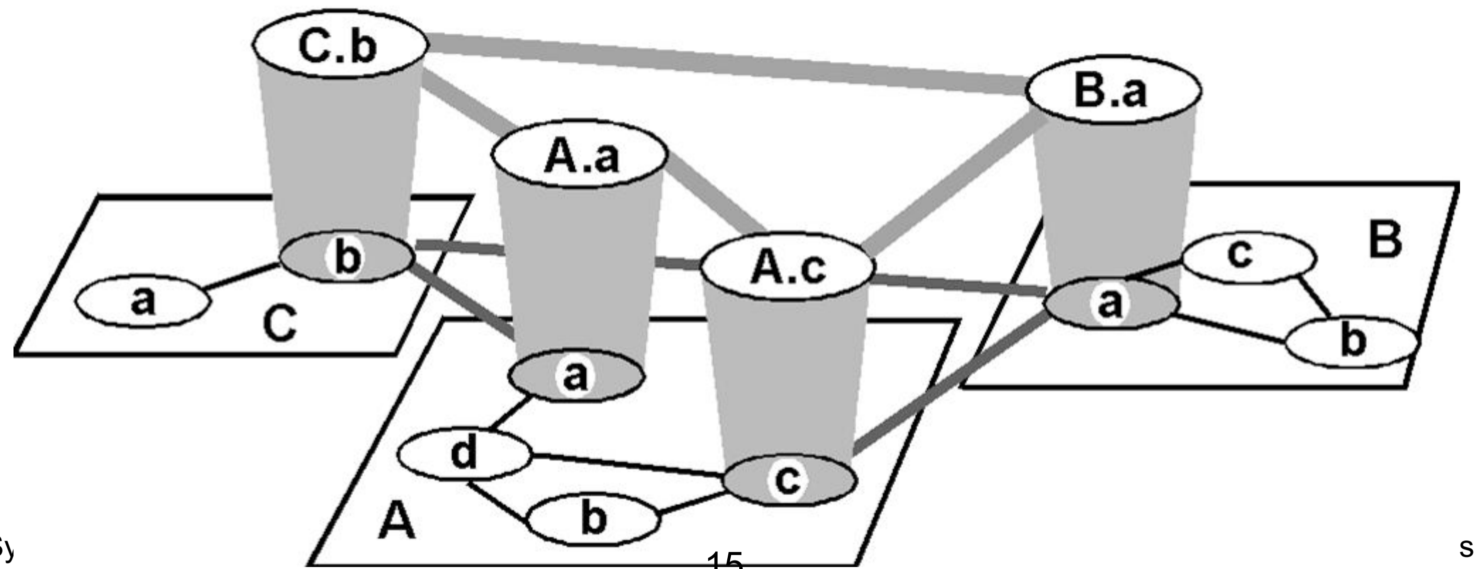
- Routing within Autonomous System (AS)
- Always finds shortest path within AS
- Most common IGPs:
  - RIP (II)
  - OSPF (just introduced)
  - ISIS (Intermediate System to Intermediate System)

Other Routing Protocols

- **ISIS** - Intermediate system to intermediate system
  - Link-state routing protocol invented by DEC, standardized in 1992
  - Operates by reliably flooding topology information throughout a network of routers
  - Each router then independently builds a picture of the network's topology
  - IS-IS uses Dijkstra's algorithm
- Enhanced Interior Gateway Routing Protocol (**EIGRP**) - Cisco proprietary routing protocol deploying multiple metrics
  - Diffusing Update Algorithm (DUAL) for guaranteed loop-free operation and a mechanism for fast convergence
- Others, like OLSF (check online and the literature)

Routing – Exterior Gateway Protocols

- What happens in large scale: Routing between different AS
- Routing protocols and tables may differ between different AS
- Most common EGP: BGP(4) (Border Gateway Protocol)
- Example: A,B,C autonomous systems - C.b, A.a, A.c and B.a EGP routers – small letters IGP routers



Exterior Gateway Protocols – Principles

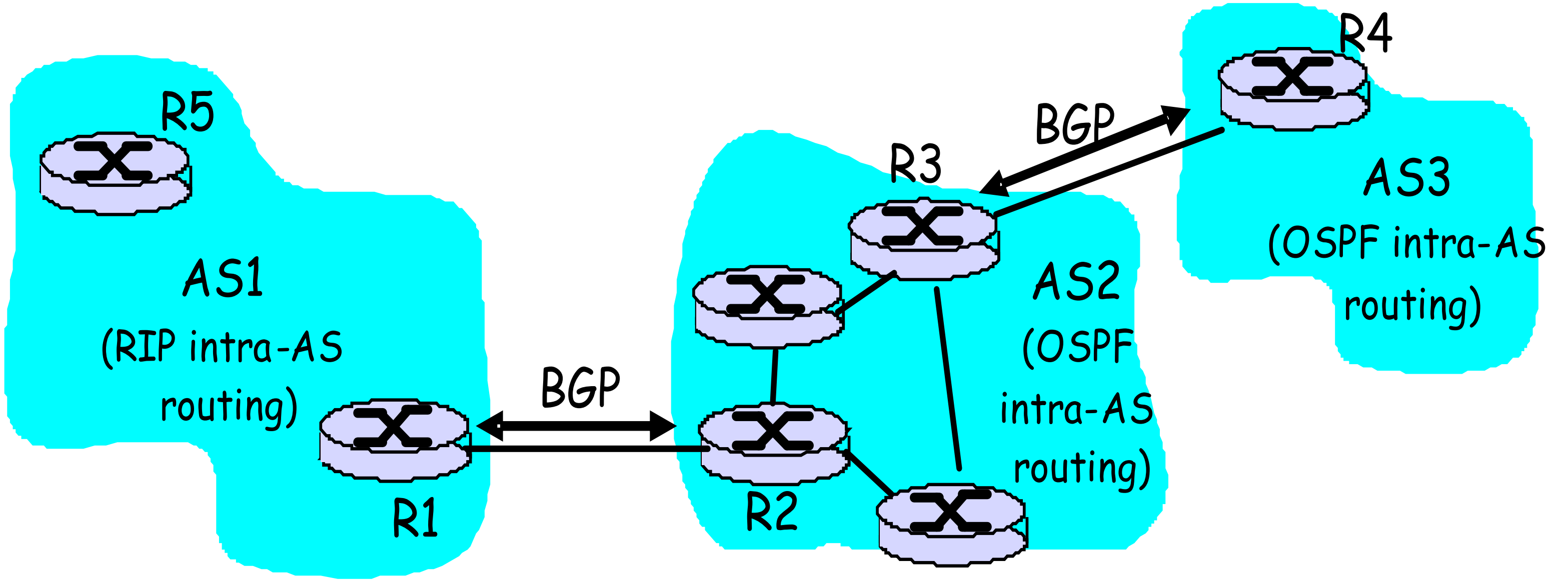
- You tell me all the address prefixes you can reach, but don't tell me the path you use to get there
  - I'll tell you the same
- If anything changes, please let me know
- If you tell me an address I'll send you traffic destined to that address.
  - If I tell you an address I will accept traffic destined to that address
- Beside that: Hide network internal topologies

Exterior Gateway Protocols – BGP

- Protocol to connect different AS
  - Exterior Gateway Protocol
  - Specified in RFC 1771
  - Extension mBGP (multiprotocol BGP)
- Mostly used by ISPs not in local LAN/MAN
- TCP for delivery (less bandwidth needed)
- Distance vector approach
- Allows policy-based routing

Shortest Path Routing

- Inter-AS routing with BGP:



BGP – Vector Protocol

- Each Gateway broadcasts entire path (sequence of AS identified by a 16-bit number) to destination to peers
- Operates on a path vector protocol:
  - Similar to Distance Vector protocol
  - Each Border Gateway broadcast to neighbors (peers) entire path (i.e., sequence of AS's) to destination
  - BGP routes to networks (ASs), not individual hosts
  - E.g., Gateway X may send its path to dest. Z:
  - Path (X,Z) = X,Y1,Y2,Y3,…,Z
- Initially whole routing table exchanged

BGP – Vector Protocol

- Incremental updates exchange
- Keepalive messages to neighbors
- Four basic components in a BGP system
  - Speakers
  - Peers
  - Links
  - Border routers
- Receiving and filtering route advertisements from directly attached neighbors

Shortest Path Routing

- Do a route selection
- Send route advertisements to neighbors
- BGP uses TCP for message exchange
- Messages
  - Open: opens TCP connection to peer and authenticates sender
  - Update: advertises new path (or withdraws old)
  - Keepalive: keeps connection alive in absence of UPDATES; also ACKs OPEN request
  - Notification: reports errors in previous msg; also used to close connection

Shortest Path Routing

- BGP reduces transit traffic
  - Types of traffic for BGP routers
    - Local traffic: origin or destination in AS
    - Transit traffic: all other traffic
- AS classification:
  - Stub - only single connection to another AS
  - Multihomed - multiple connections, no transit traffic
  - Transit - connections to several other AS, designed to carry both local and transit traffic

Shortest Path Routing

- Implications
- You have control over policy settings
  - what is advertised to your immediate peers
  - what you accept from your immediate peers
  - what transits you will accept (send traffic)
- But you cannot control
  - transit path of received traffic
  - symmetry of transit policy
- Thus “peering” between different providers is a complicated issue (estimation of traffic (asymmetries), contracts and handling)

Decision on Routing Protocols

- Different routing policies depending on type of network
  - Inter-AS: admin wants control over how its traffic routed, who routes through its net
  - Intra-AS: single admin, so no policy decisions needed
- Scale
  - hierarchical routing saves table size, reduced update traffic
- Performance
  - Intra-AS: can focus on performance
  - Inter-AS: policy may dominate over performance
- Special routing scenarios e.g. for distributed WLANs (z.B. Berlin freifunk.net)
  - OLSF (Optimized Link State Routing Protocol, RFC3536)

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