TDC 375
Network Protocols

Routing Overview

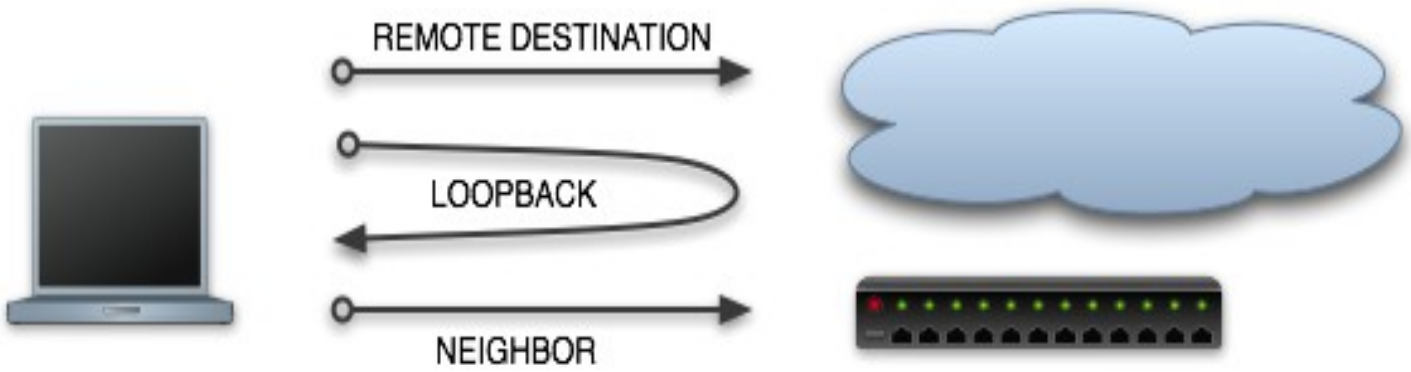
One of two critical systems

Routing (BGP) and naming (DNS) are, by far, the two most critical subsystems of the Internet infrastructure. In the case of BGP, participation in and access to the routing system itself is generally, or rather should be, limited to a subset of trustworthy nodes and admins.

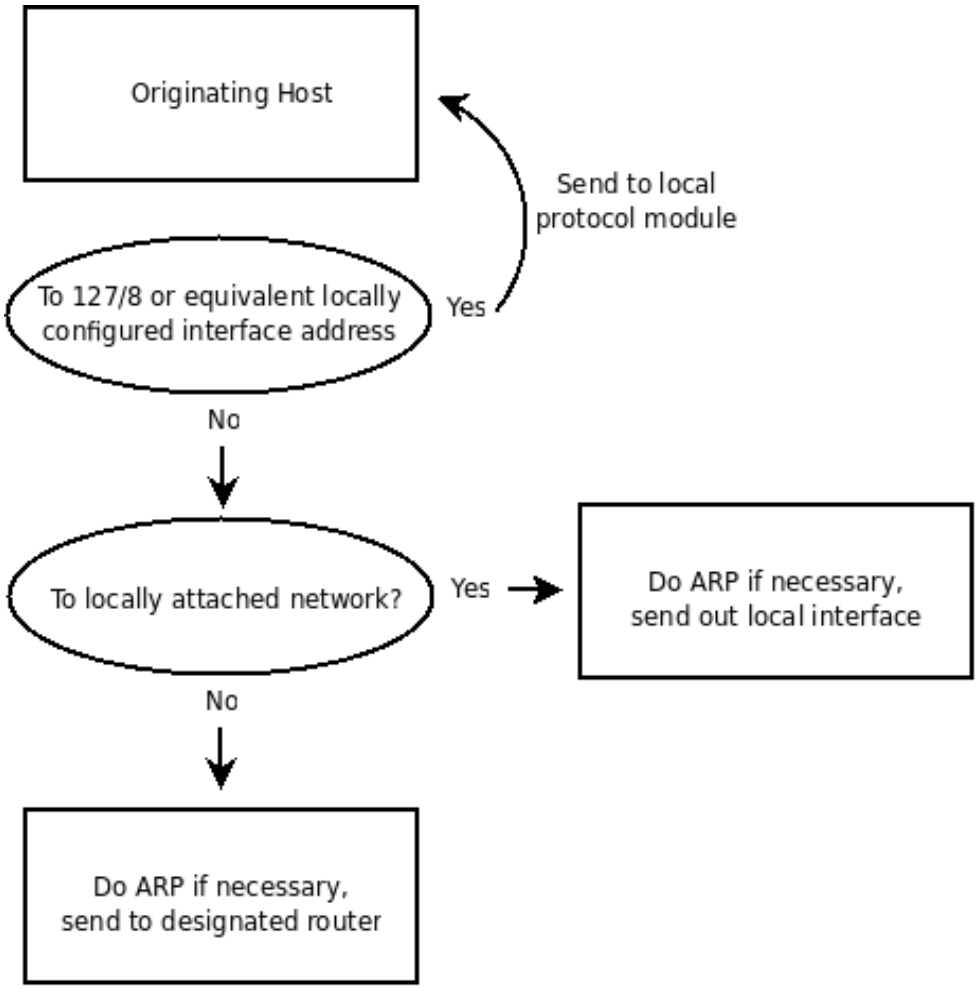
Do all IP hosts route? Yes.

Most hosts make one of three routing decisions:

1) send packet to another via a relay
2) send packet to itself
3) send packet to a directly attached neighbor



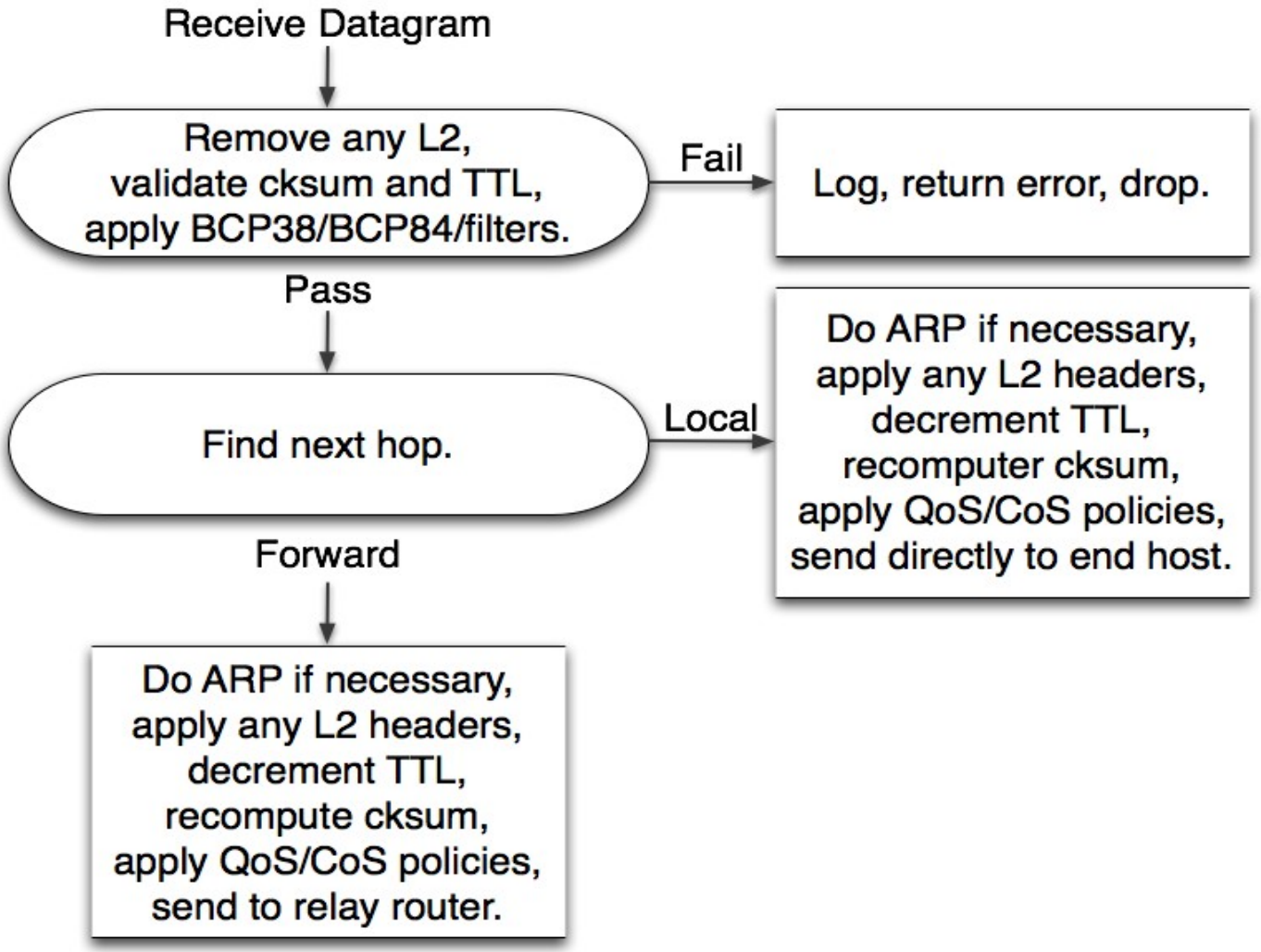
Simplified routing decision tree



Your end host != router

- Need to know your address, network and gateway
  - not so much a “routing system” process
  - this is your host's bootstrap challenge
- We don't tend to think of end hosts as routers
- How do they differ then?
  - network / interface attachments
  - distributed routing algorithms
  - forwarding packets on another's behalf

Real routers work more like this



Best match forwarding

- Forward packet via the “most specific” route
- Most specific to least specific (IPv4 example):
  - host (/32) route, /31, /30, /29, ... default (/0)
- If no route, drop and return ICMP error to source

Routers as signposts

How do routers build a signpost?

- Maybe manually configured, but that doesn't scale
- Routers gossip amongst themselves
- Well defined “gossip” protocols are used
  - e.g. RIP, EIGRP, OSPF, IS-IS, BGP
  - a bootstrap configuration is generally required
- Reachability information associated with all routes
  - e.g. distance, cost, preference, policy

Key IPv4 field for routing: TTL

- More apt name today would be hop count
  - in fact, that is just what it is called in IPv6 now
- This field prevents packets looping forever
- Other uses are secondary to this
  - traceroute
  - source OS fingerprint and distance detection
  - BGP peering hack (aka GTSM, RFC 3682)

Key IP field for routing: Destination Address

- Consists of both a...
  - host/interface identifier (usually unique) and
  - a network identifier (also usually unique)
- Combined, the daddr helps hosts and routers
  - get the packet to the correct network
  - and to the specific host on the correct network

BGP Overview

- The routing protocol for connecting *domains*
- Besides the *network prefix* the path is the key component of a BGP route
- Autonomous system numbers (ASNs) define path
  - generally an ASN == domain
    - NOTE: this is not a reference to DNS!
- Even if you don't use it for actual Internet routing, it might be handy for other things (e.g Team Cymru bogon route server, IP addr to ASN mapping)

IS-IS/OSPF Overview

- Widely used *intradomain* routing protocols
- *Link state* database of entire routed network built by all routers
- Each router can make an optimal forwarding decision, because it has a complete view of all the routers and their attached networks
- Relatively simple idea, but is a bit more complex to implement – i.e. database synchronization issues

A real Internet BGP route entry

```
route-views.oregon-ix.net>sh ip bgp 68.22.187.0/24
BGP routing table entry for 68.22.187.0/24, version 543323
Paths: (34 available, best #7, table Default-IP-Routing-Table)
  Not advertised to any peer
  8075 2828 23028
    207.46.32.34 from 207.46.32.34 (207.46.32.34)
      Origin IGP, localpref 100, valid, external
  3333 3356 2828 23028
    193.0.0.56 from 193.0.0.56 (193.0.0.56)
      Origin IGP, localpref 100, valid, external
  4513 13789 3561 23028 23028 23028 23028
    209.10.12.125 from 209.10.12.125 (209.10.12.125)
      Origin IGP, metric 4103, localpref 100, valid, external
```

An example routing table

```
route-views.oregon-ix.net>show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF
       IA - OSPF inter area,  N1 - OSPF NSSA external type 1
       N2 - OSPF NSSA external type 2, E1 - OSPF external type 1
       E2 - OSPF external type 2, E - EGP i - IS-IS
       su - IS-IS summary, L1 - IS-IS level-1
       L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 128.223.51.1 to network 0.0.0.0

B    216.221.5.0/24 [20/489] via 208.51.134.254, 18:06:49
B    210.51.225.0/24 [20/0] via 12.0.1.63, 18:07:52
B    210.17.195.0/24 [20/0] via 216.218.252.164, 18:08:11
B    209.136.89.0/24 [20/0] via 216.218.252.164, 18:08:21
B    209.34.243.0/24 [20/0] via 157.130.10.233, 17:59:49
B    205.204.1.0/24 [20/0] via 157.130.10.233, 18:00:57
B    204.255.51.0/24 [20/0] via 157.130.10.233, 17:59:44
B    204.238.34.0/24 [20/0] via 157.130.10.233, 18:00:28
```

Want router access?

- Telnet to route-views.routeviews.org
- Browse to http://routerproxy.grnoc.iu.edu/
- Go easy, don't ruin it for the rest of us please
  - notwithstanding potential bugs or attacks, by default access it intended to be limited (sorry, no “enable”), but they can still be **very** helpful for remote analysis and troubleshooting

You do have enable, kind of

- On Unix, Linux, Mac OS X
  - `netstat -arn`
- On Microsoft Windows
  - `route print`

There is router security and there is route security

- Few serious network engineers use HTTP
  - “That's probably a good thing!” you say
- Many Cisco networks still use Telnet
  - this is where you security people go “WTF!?!?”
- Many networks have SNMPv1 write enabled
  - then you go “OMFG!?!”
- Almost nobody watches out for more specifics
  - “Specifics smurifics, whoop-dee $#!&@”

Au contraire

- Router security
  - authentication, filtering, crypto... DONE!
  - uhm, no
- Route security
  - this is the old, “my security, depends on your ability to do security” problem
  - say you have and announce a /16
  - someone announces /24's in that /16.
  - uh-oh

Examine your own router

- Microsoft Windows
  - ipconfig /all
  - route print
- UNIX (varies depending on flavor)
  - ifconfig
  - netstat -arn (or route -n)
  - cat /etc/dhcp*/dhclient.conf (or something like it)
  - cat /etc/resolv.conf
- Mac OS X
  - like UNIX, but also check Sys prefs → Network

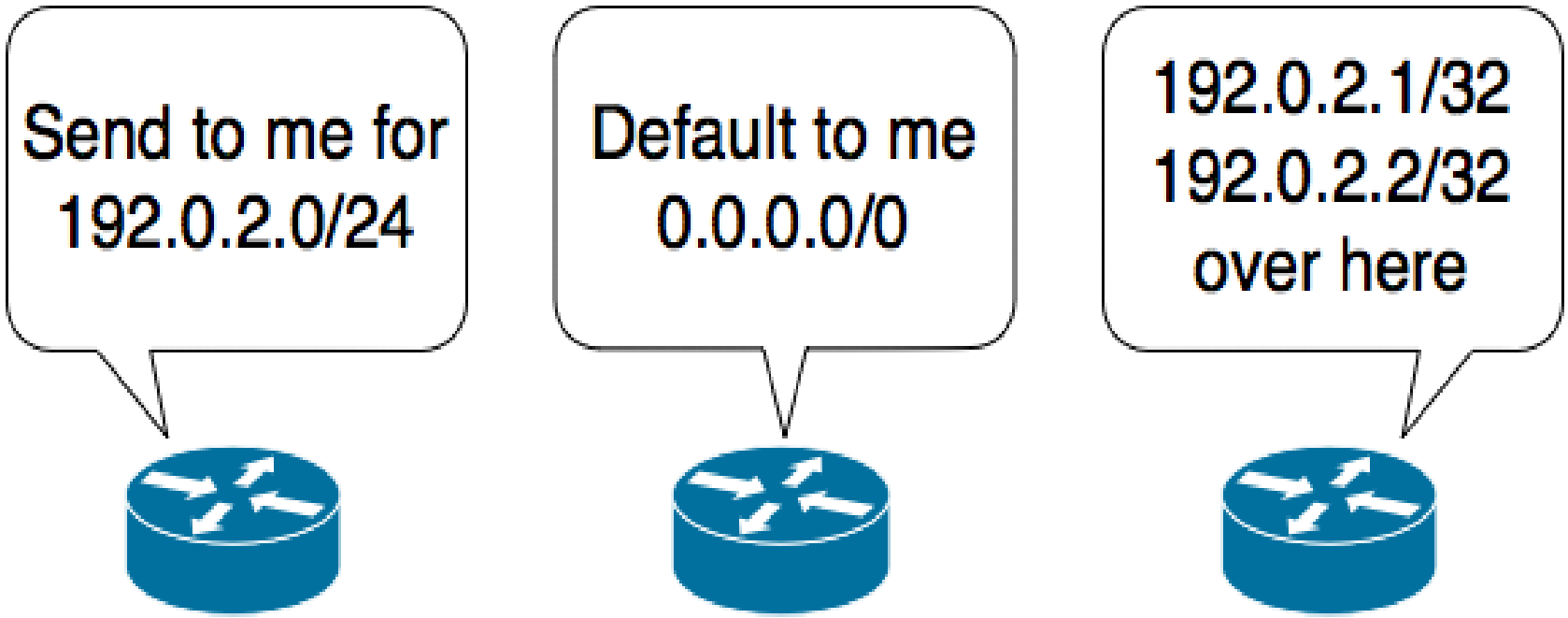
Determine your...

- IPv4/IPv6 address(es). More than one?
- Net mask – in dotted decimal (IPv4) and / notation
- ARP cache
- Default route, default router
- Network interface list
- Recursive/caching name servers
- MAC address and OUI assignment

Recall...

Routers as signposts...
Best match forwarding...

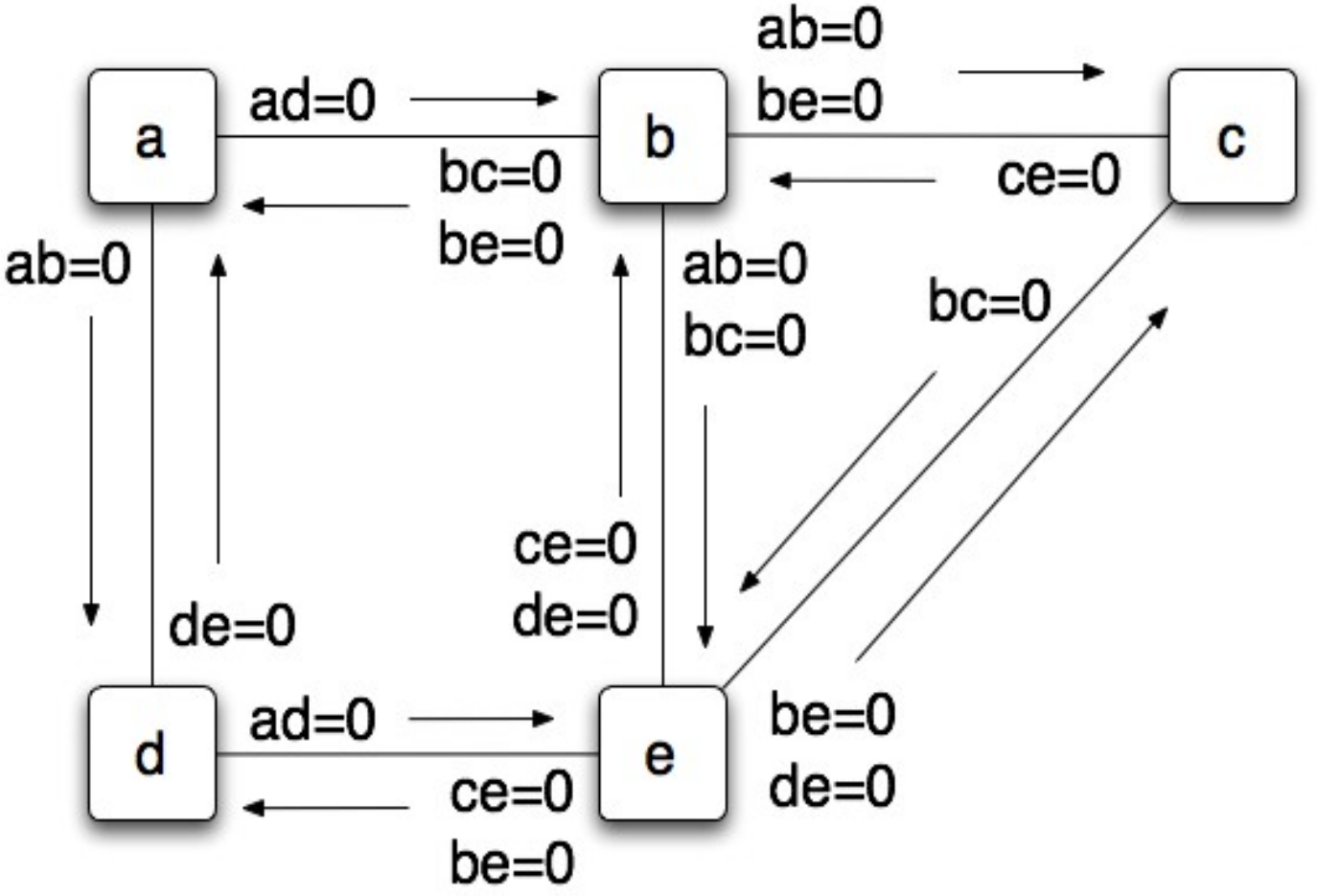
Route announcements



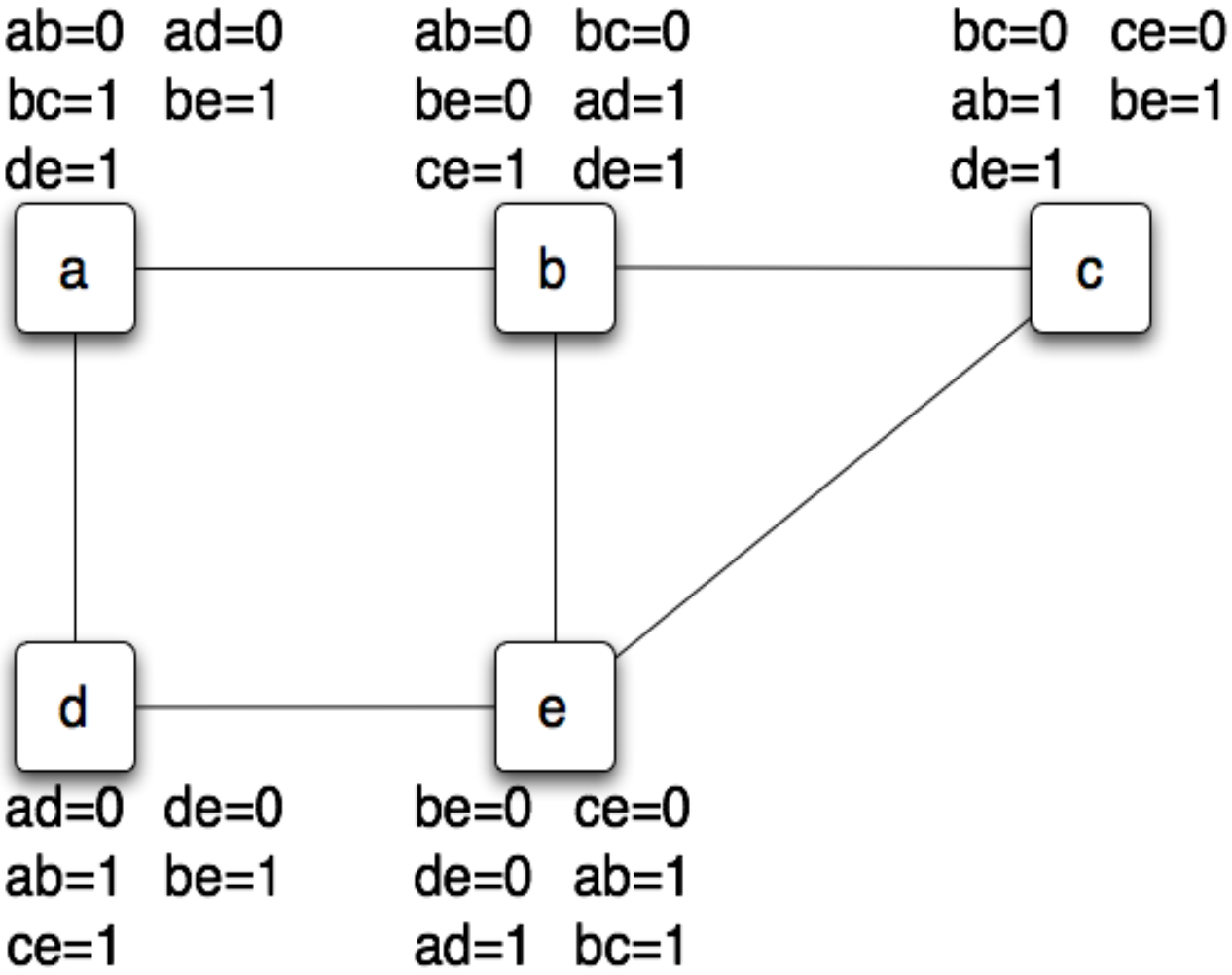
Distance Vector (DV) Routing

- Algorithm known as Bellman-Ford
- Routers gossip amongst themselves
  - kind of like the “telephone game”
- As announcement propagates, distance increases

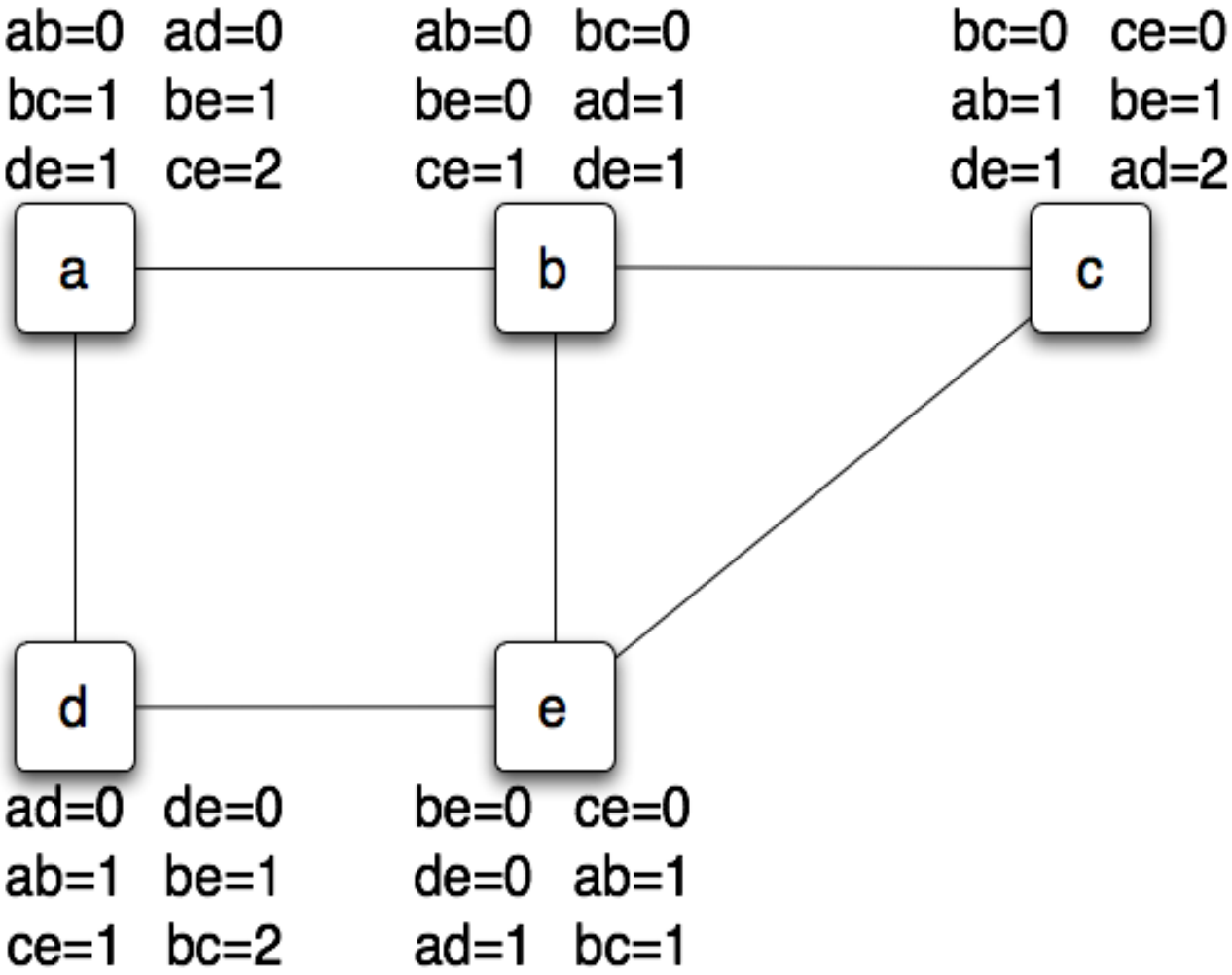
DV bootstrap 1



DV bootstrap 2



DV converged



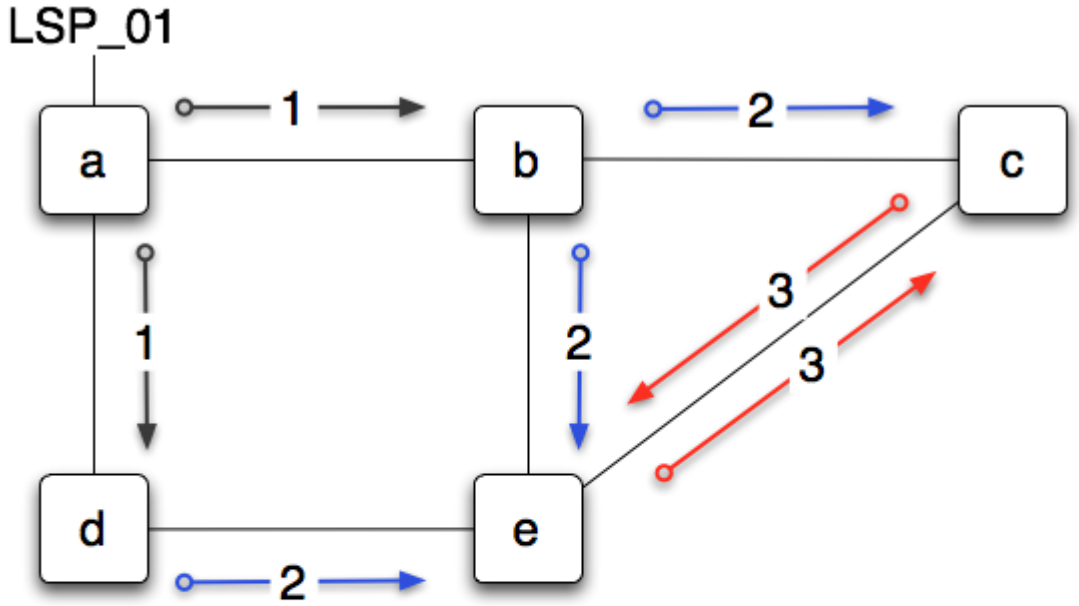
DV Summary

- Simple distance calculation determines path
- Periodic route updates sent to neighbors
- Convergence time can be slow
- Updates can be “triggered” upon a metric change
- Loop avoidance optimizations delay convergence
- Examples:
  - RIP (IP/IPX), RIPv2, RIPng, IGRP (cisco)

Link-state (LS) routing

- Algorithm known as Dijkstra
- Routers exchange their connectivity in a LSP
  - LSP = link state packet
  - as opposed to exchanging the routing table
- A LSP includes:
  - router id
  - sequence number
  - links and costs for each link
  - time-to-live (TTL)

LS bootstrap



NOTE: sequence of events an example only

1) a floods LSP_01 to b and d
2) b floods LSP_01 to c and e
2) d floods LSP_01 to e, e ignores duplicate LSP
3) c or e flood LSP_01 to the other, whoever is faster

LS summary

- Each router builds their own map from LSPs
- Good convergence time
- Good loop avoidance
- Can be more complex and resource intensive
  - not really an issue these days in practice
- Generally preferable over distance vector
- Examples:
  - OSPF, IS-IS

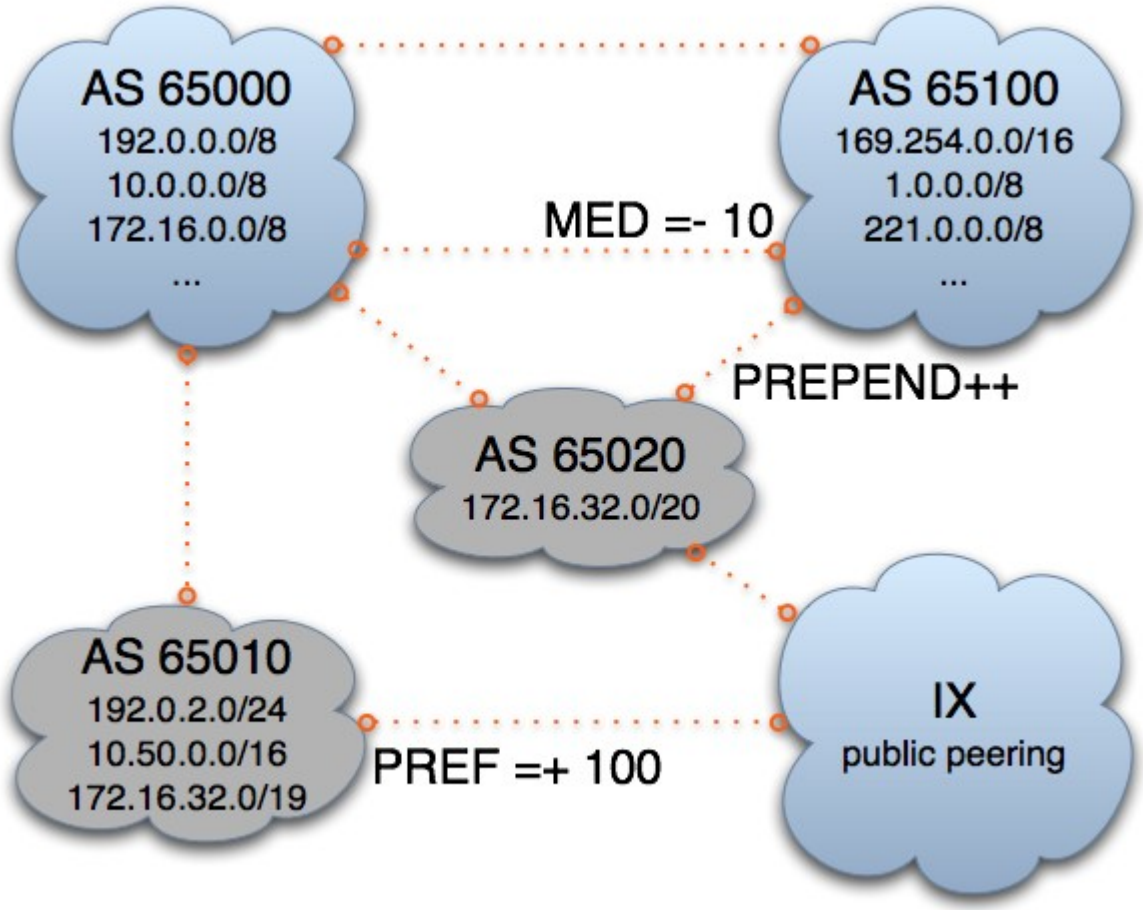
Path vector (PV) routing

- More similar to DV than LS
  - like DV, routes are exchanged, not connectivity
- Each hop appends itself to the path of a route
- A “hop” is an Autonomous System (AS)
  - an AS is roughly an Autonomous ISP/network
- Path policy & preferences influence route selection
  - i.e. paths can be altered, routes can be rejected
- Examples: BGP

Influencing BGP route selection

- Most specific prefix (best match) still matters most
- Highest local preference value associated w/ route
- Shortest AS path length (a weak form of distance)
- Origin type (e.g. IGP versus EGP)
- Lowest MED, a peer announced parameter
- Prefer external over internal route
- ...first received route, lowest router id, etc.
- Use of community strings (policy) changes things

IPv4 BGP Topology Example



Protocol encapsulation

- RIP uses UDP port 520 via IP broadcast/multicast
- IS-IS runs directly over layer 2 multicast
- OSPF is IP protocol 89, via IP multicast
- BGP uses TCP port 179, unicast of course

Example Implementations

- Cisco IOS
- Juniper JunOS
- Zebra and derivatives
  - Quagga, Vyatta
- BIRD Internet Routing Daemon
- OpenBGPD
- MikroTik RouterOS

BGP Remote Triggered Blackhole

- Goal: Have remote router /dev/null certain traffic
- Trick: use next-hop address that points to /dev/null
- Trick: Using policy, set next-hop for matching traffic
- Team Cymru bogon route server does this
- Many ISPs offer this as a DDoS relief service
- IPaddr getting packeted? Have upstream null it
- Also see IETF RFC 5635

unicast Reverse Path Check (uRPF)

- Goal: mitigate source address spoofing
- Trick: Validate source address to ingress interface
  - is there a route back via that interface?
- Loose versus strict mode
- Easier than ACLs (filters)? Maybe
  - doesn't work for everyone
- What do you do if you have a default route?

NetFlow

- Key router technology for analysis and monitoring
- NetFlow is not like pcap
- A unidirectional summary of traffic for a “flow”
- Flow is a unique tuple of addrs, proto, ports
- Router “exports” flows at timer, RST, FIN, etc
- Data may be limited due to sampling
- Scales very well and is very popular

NetFlow

- Need NetFlow v9 for IPv6
- saddr/daddr and netmasks
- Next hop address
- ingress/egress interface id
- Total bytes/packets in a flow
- Flow start/end time
- Protocols, ports, type/code, TCP flags, ToS bits
- src/dst ASN (peer or origin)

NetFlow illustrated

- http://flows.is-net.depaul.edu

Flow specification (flow-spec)

- Using BGP, exchange “flow-spec” to act on
- Largely used as a distributed firewall filter
- Can be more precise than a BGP RTBH
- Besides filtering, you can rate limit, log, pass
- Not widely implemented

Exchanges and Peering

- Networks need to connect to each other
- Question: Who pays who?
- Question: Where do they physically connect at?
- Peering is an entire “ecosystem” unto itself
- Paid versus settlement-free peering
- Transit versus peering and exchanges
- Peering requirements and network types

Overflow slide

- Other router management tools and processes
- Example routing configurations
- “traffic engineering”
- Class-of-service / quality of service
- Avoiding network capacity collapse
- Anycast - services on shared unicast addresses
- Mapping public Internet exchanges