SC/CSE 3213 Winter 2014

L4: Internet Routing and Controls

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Outline

- Routing
- Error Detection
- Retransmission
- Congestion Control
- Flow Control
- Medium Access Control

Forwarding Tables

- How do routers know what to do with their packets?
- Their forwarding tables tell them:
- Forwarding: The process of taking a packet from an input and sending it out the appropriate output
- Forwarding tables need to contain every detail of a link

Destination	Interface	MAC Address
128.208.128.0/17	if0	8a:0c:1f:e4:6b:1c
128.208.0.0/18	if0	8a:0c:bb:e4:3b:a1
128.208.96.0/19	if2	8a:0c:7b:a9:b2:fc

- They are often implemented in VLSI hardware
  - high-speed memories

Routing Tables

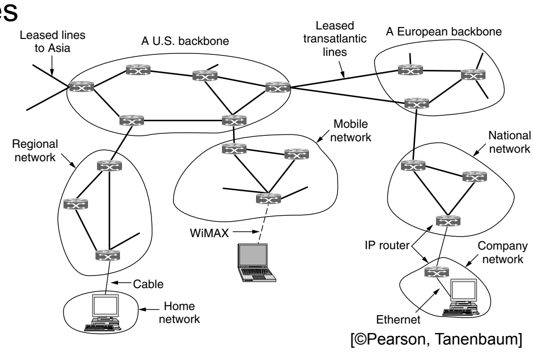
- Where do forwarding tables come from?
- From routing tables:
- Routing: The process of building the tables that determine the correct destinations for packets

Destination	Next Hop
128.208.128.0/17	171.69.245.10
128.208.0.0/18	171.69.245.10
128.208.96.0/19	178.45.23.124

- Simpler than forwarding tables
  - typically just a data structure in a computer

Routing

- How do you build routing tables? How do you route?
- Routers run algorithms that update their knowledge of the network every few seconds to hours
- They do this by sending out queries for information and by responding to queries
- Routing seeks to find the cheapest path from any source to any destination
- Minimize link costs



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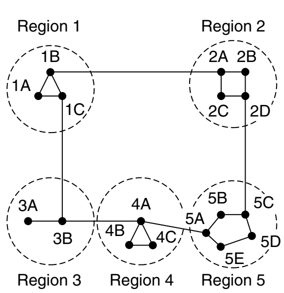
Hierarchical Routing

- Routing over two-levels substantially cuts on complexity
  – Within AS
  – And between them
    - Region-region comms condensed to single router
    - Increased path length a common penalty (e.g. 1A to 5C)



1A: Full Table

Dest.	Line	Hops
1A	–	–
1B	1B	1
1C	1C	1
2A	1B	2
2B	1B	3
2C	1B	3
2D	1B	4
3A	1C	3
3B	1C	2
4A	1C	3
4B	1C	4
4C	1C	4
5A	1C	4
5B	1C	5
5C	1B	5
5D	1C	6
5E	1C	5

1A: Hierarchical Table

Dest.	Line	Hops
1A	–	–
1B	1B	1
1C	1C	1
2	1B	2
3	1C	2
4	1C	3
5	1C	4

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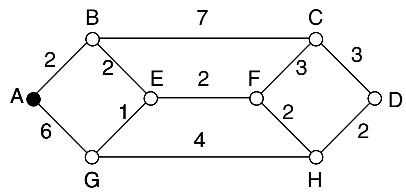
Link Metrics (Costs)

- Routing often seeks to identify the shortest path between destinations in a graph, the smallest link metric
- Easiest is to just treat all links the same and just count hops (RIP: Routing Information Protocol, does this)
- But many options exist
  - mean delay (latency)
  - distance
  - bandwidth
  - average traffic
  - communication cost
  - political/economic policy



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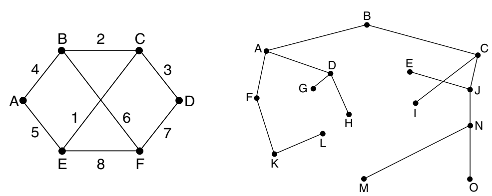
Routing Types

- Methods of building routing tables?
- They do this by sending out queries for information and by responding to queries
  - Intradomain Routing
    - Routing within an AS
    - OSFP (Campus), IS-IS (ISPs)
  - Interdomain Routing
    - Routing between AS
    - BGP

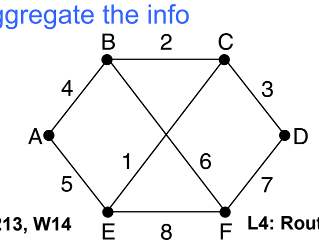
Intradomain Routing

- OSPF: Open Shortest Path First
  - Link-state routing
  - Every router builds up a knowledge of the whole network topology
    - Find link quality to all next-hop neighbors (local view formed)
    - Send this information throughout the whole network (global view formed)
    - Compute shortest path to every router (Dijkstra's algorithm)
- Details…



Intradomain Routing: Building Link States

- Learning about neighbours
  - When router is introduced it sends out HELLO packet on each line
  - Router on other line sends back its name
- Setting link costs
  - Connecting routers can construct costs by sending their bandwidth limits
  - Delay can also be constructed by sending ECHO packets
- Building link state packets
  - Aggregate the info



Link State Packets

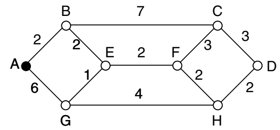
A	B	C	D	E	F
Seq.	Seq.	Seq.	Seq.	Seq.	Seq.
Age	Age	Age	Age	Age	Age
B 4	A 4	B 2	C 3	A 5	B 6
E 5	C 2	D 3	F 7	C 1	D 7
	F 6	E 1		F 8	E 8

Intradomain Routing: Distributing Link States

- Trickiest part
  - All routers must get packets quickly and reliably
  - If routers have different versions of topology odd behaviour will result
- Use flooding to distribute link state packets
- Every incoming packet is sent out on every outgoing line
  - Except the one it arrived on
  - How do you keep from swamping the network?
- Packets have **sequence numbers**
  - Each time you (the source) send out a new packet increment its sequence number, k
  - Routers keep track of (*source router*, $k_{largest}$) pairs
  - If incoming packet has $k < k_{largest}$ discard it
  - 32-bit k's would take 137 years to loop at 1 packet per second
  - **Age field** is decremented in case router goes down

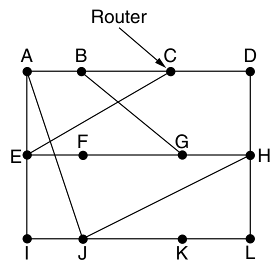
Shortest-Path Finding

- Now apply Dijkstra's algorithm to find shortest path



Interdomain Routing

- BGP: Border Gateway Protocol
  - Path vector routing (a form of distance vector routing)
  - Exchanging data with neighbours to incrementally form a global view of the network



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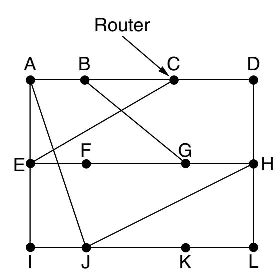
Vector Tables

- Each router maintains a vector table (e.g. J)
  - For each router (destination) in the network keeps track of…
    - The next hop it should take
    - The total (estimated) distance to the destination

Destination	Next Hop	Total Distance

- It can start a basic network table by talking to its neighbours
  - JA=8, JI=10, JH=12, JK=6



Vector Table Updates

- Every period T each router shares its vector table with each of its neighbours, X, and their distance to destination Y
  - Looks at their distance, estimates XY
    - Make mine…
    - Mininmum of RX+XY (over all neighbour vectors)
- For example what vector table do I generate for J from my X (neighbour) info with…
  - JA=8, JI=10, JH=12, JK=6

To	A	I	H	K
A	0	24	20	21
B	12	36	31	28
C	25	18	19	36
D	40	27	8	24
E	14	7	30	22
F	23	20	19	40
G	18	31	6	31
H	17	20	0	19
I	21	0	14	22
J	9	11	7	10
K	24	22	22	0
L	29	33	9	9

- This technique is called the distributed Bellman-Ford algorithm

Distance Vector Convergence

- Good news travels fast
  - Delay metric is number of hops
  - A is down initially
  - But when it comes up…
  - …each exchange propagates the news in a linear fashion
- Bad news travels slow
  - A suddenly goes down
  - B does not hear from A…
  - …but C thinks it is 2 hops away
    - B thinks it can get to A from C
  - But B & D think they are 3 away
    - So C updates to 4, etc., etc.
  - Distance = 1 + min(neighbour)
    - Slow count to infinity

A	B	C	D	E	
	•	•	•	•	Initially
	1	•	•	•	After 1 exchange
	1	2	•	•	After 2 exchanges
	1	2	3	•	After 3 exchanges
	1	2	3	4	After 4 exchanges

A	B	C	D	E	
	1	2	3	4	Initially
	3	2	3	4	After 1 exchange
	3	4	3	4	After 2 exchanges
	5	4	5	4	After 3 exchanges
	5	6	5	6	After 4 exchanges
	7	6	7	6	After 5 exchanges
	7	8	7	8	After 6 exchanges

Routing Summary

- Intradomain
  - OSPF
  - link-state
    - global communication
    - local computation
  - Runs in network layer
    - acknowledged IP
  - Tends to have high memory requirements
    - Keeping track of each router's link state
  - More computation in implementing graph search

- Interdomain
  - BGP
  - distance vector
    - local communication
    - global computation
  - Runs in application layer
    - utilizes TCP
  - Slow at pruning out bad links
    - Bad news travels slowly (count-to-infinity problem)

Error Detection

- Physical links, router and host hardware can corrupt messages
- Routers should have the ability to detect errors
- Many approaches are used at many levels
  - Line coding at the physical layer (will discuss layers in L4)
    - Turbo codes
    - Reed-Solomon codes
    - LDPC codes
- At the data link and network layers
  - Use header checksums
  - A parity scheme

Retransmission of Erroneous Information

- What do you do when you detect an error?
- You can just forget about the erroneous packet
  - System doesn't breakdown, but information is lost
- Or you can request that the same packet be retransmitted
  - Foundation of a reliable delivery service
  - Such a scheme is called: Automatic Repeat reQuest (ARQ)
    - Units send messages and expect acknowledgments
    - A number of strategies are employed to make this approach reliable and efficient
  - Present in both the data link and transport layers
  - In the Internet this is typically carried out by the hosts not the routers

Congestion Control

- What happens if many hosts send packets through one link?
- Router buffer is overwhelmed and must start discarding packets
- Hosts don't get acknowledgments and thus slow down the rate at which they send information

Flow Control

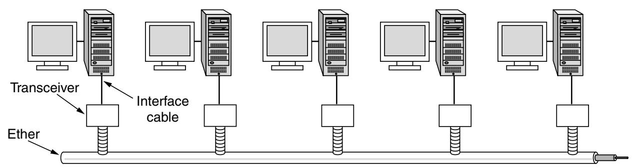
- A fast transmitter can overwhelm a slow receiver
- In this case receiver indicates (in acknowledgments) to the transmitter how much buffer space it has remaining
- Transmitter doesn't send unless it is aware of enough buffer space in receiver
  - Implemented within ARQ

Congestion & Flow Control Summary

- Congestion Control
  - Prevents overflowing the router buffers
  - Concerned with network internals
- Flow Control
  - Prevents overflowing the destination buffer
  - Concerned with end-to-end operation

Medium Access Control (MAC)

- Multiple hosts try to communicate over one medium
  - one wire
  - one radio channel
- How do the units organize their behaviour in order to achieve useful communication?
  - This is the job of the MAC
- This is more the job of LAN and less a specific Internet function



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