Bridges

- Bridges interconnect network segments at the link layer (layer 2)
- Handle any layer 3 protocol (including non-routable ones); some can interconnect different media
- Mostly for LANs, also used in WANs (2 “half bridges” on ends of pt-to-pt links)

Extended LANs

- Extending (interconnecting) multiple LANs. Appears as single LAN to layer 3.
- Essentially accepts and forwards all frames
- Benefits:
  - extend number of stations
  - extend size
  - limit interfering traffic

The “no-frills” Bridge

- Interconnect 2 or more LAN segments
- Listens in promiscuous mode, buffers packets and transmits them on other interfaces when able
- On average, still cannot exceed link bandwidth
  - bridge copies all traffic
  - small bursts accommodated in buffers

The “learning” Bridge

- Bridges “learn” which interfaces reach which end stations
  - could do this “by hand”, but a hassle
  - best if this happens transparently
- Learn by watching source addresses in frames
  - senders usually use their own addresses
  - (note that bridges don’t!)

Learning Strategy

- Listen promiscuously for all traffic
- Store (src addr, port) tuple in “station cache” for each new sender observed
- For each received frame:
  - try to match frame dest to cache src entry
  - not there -> send on all interfaces except rcv
  - is there > send on indicated, or filter if same as rcv interface
- Age cache entries
With redundant paths, bridges can loop traffic—can happen forever (example)

- with more than 2, can cascade

Cascade—each bridge with N interfaces may produce up to N-2 new copies!

Consider LAN a graph G = (E, V), with LANs as vertices, and bridges as edges (well, sort of... see footnote p.212)

- A spanning tree of an undirected, connected graph G is a subgraph which is both a tree and contains all vertices in G
- Thus, the ST will throw out some edges and be cycle-free

Spanning Tree

- Purpose will be to provide a single path to reach each network
- Generally, graphs have many STs (even several MST’s...CS 170)
- Must be a distributed algorithm
- Can result in some bridges not forwarding at all!

Spanning Tree Computation

- Each bridge will decide over which ports it will forward frames
  - bridges have unique addresses per port
  - ports are also numbered by each bridge
  - bridges have a single unique identifier e.g. the lowest address

Ouch... Loops Hurt

- With redundant paths, bridges can loop traffic
  - can happen forever (example)
  - with more than 2, can cascade

- each bridge with N interfaces may produce up to N-2 new copies!
Computation Outline
- Elect single bridge as root
- Calculate distance from each bridge to root bridge
- For each network, elect the bridge nearest the root to forward frames from that LAN to the root
- Choose a port on which to forward toward root (the root port)
- Select which ports are on the ST

Configuration Messages
- Root election and ST formation are accomplished by configuration messages
  - messages sent to "all bridges" multicast address, using bridge's src MAC address
  - Contents: Root ID, Bridge ID, Cost, [age]
    - Root ID: current assumed root ID
    - Bridge ID: sending bridge's ID
    - Cost: cost of best path to root from sender
    - messages are not forwarded between LANs

Election 1
- Bridges initially assume they are the root
  - Uses its own ID as root, with zero cost
- Bridges save "best" configs they hear on each port (or its own):
  - C1 > C2 if root(C1) < root(C2), otherwise
  - C1 > C2 if cost(C1) < cost(C2), otherwise
  - C1 > C2 if bridgeID(C1) < bridgeID(C2)
- Cost is # hops to root

Election 2
- Upon receiving "better" config message, bridge stops sending its own config messages (but continues to forward others' with a cost incremented by 1)
- Once stability is reached, only one bridge on each LAN (the designated bridge) is sending config messages on that LAN

Calculating Root, Cost, and Port
- Global root is MIN of local bridge ID and MIN of all received root IDs
- Distance to root will be smallest cost to global root plus one
- Root port is port on which message containing minimum cost to global root was received

Calculating Designated Bridge
- Once root, cost, and port are known, a bridge knows what its own config messages would contain
- It will transmit its own config messages on ports where it is "best"
Choosing Ports on the ST

- Put these ports in ST:
  - root port
  - all ports for which bridge is the designated bridge for the LAN
- Selected ports put into “forwarding” state (bridge will forward frames to/from)
- Other ports are “blocked” (no data, but configuration messages are processed)

Example [Perlman, p 58]

1. (81,0,81)
2. (41,12,315)
3. (41,13,90)
4. (41,12,111)
5. (41,12,315)

(root ID, cost, bridge ID): best received messages

Example (chooses 41 as root)

1. (41,13,92)
2. (41,12,111)
3. (41,12,315)
4. (41,13,90)
5. (41,13,92)

(root ID, cost, bridge ID) best current messages

Example (becomes designated bridge for 1,2)

1. (41,13,92)
2. (41,13,92)
3. (41,12,315)
4. (41,13,90)
5. (41,13,90)

Best cost to root is 12 (from port 4) + 1 = 13

Example (becomes designated bridge for 1,2)

1. (41,13,92)
2. (41,13,92)
3. (41,12,315)
4. (41,13,90)
5. (41,13,90)

Example (root bridge 15)

1. (15,0,15)
2. (15,0,15)
3. (15,0,15)
4. (15,0,15)
5. (15,0,15)

• No ports blocked, designated bridge on all ports

• Ports 3,5 are blocked (ST still runs, no data forwarding)
• Ports 1,2,4 are on the Spanning Tree (forwarding)
Station Cache
- Bridges learn and cache locations of stations.
- Stations may be moved, so bridges should “forget” about them.
- Use a time-out on station cache info.
- Not so easy to choose a suitable value.

Station Cache Timeout
- Too large: traffic destined to moved node will be lost.
- Too short: unnecessary flooding (lots of traffic).
- So, if stations moving were the only concern, could use a timer on order of minutes.

Spanning Tree Recalculation
- ST recalculation can change active ports and associated station caches.
- ST recalculation takes < minutes.
- So, want small timeout (say, 15 secs).
- Standards committee could not make a establish a definitive value.

Spanning Tree Recalculation
- Two admin-set values used:
  - long value, used in normal case.
  - short value, used after ST recompute.
- Which to use? (how to detect ST recomput):
  - can bridges just detect this?
  - Some can, some can’t.

Topology Change
- Want to inform all bridges, but without having traffic scale as # of bridges.
- Operation:
  - Bridges noticing change send message on root port toward root.
  - Root config messages subsequently contain “topology changed” flag.
  - A simple ACK scheme is used (Perlman92 for details).

Failures
- Algorithm so far doesn’t detect or adapt to failures.
- Approach:
  - Each per-port stored config message gets a message age field.
  - If max age reached, bridge recalculates.
  - Root bridge periodically transmits config message with age zero; these trigger designated bridges to send their config msgs.
A Small Snag...
• designated bridges receiving 0-age message from root send their own messages with age zero
• if that were the only time, no reason to include age info in config message
• new bridges’ messages generate responses, but with aged value for root info; allows for discovery of failed root

Spanning Tree Recalculation
• Recalculation on two events:
  - receipt of config message on port X
    • if better than current stored message for X, recalculate root, root path cost, and root port
  - timer tick
    • if the age in any stored config message expires, discard message and recalculate root, root path cost, and root port

Temporary Loops
• during a topology change (new link/bridge starting or failing), time for info to propagate (esp. with congestion)
• Inconsistent data can cause:
  - loss of connectivity
  - temporary loops (worse!)

Limiting Temporary Loops
• Probability is minimized by requiring bridge to wait before changing ports from blocking to forwarding state
• Wait time should be long enough for topology information to spread through the network
• ---> should be at least 2x max transit time across network

Why is this? [2]
• Suppose new root is B2
• Suppose 1st config message from B2 is delayed by X before reaching B1’s area
• Then bridges near B1 will “hear” about new topology X time later
• Upshot: bridges near B1 could be up to 2X time out of date

Why is this?
• Assume bridges B1 and B2 are maximally distant from each other. B1 is root.
• B1 sends config message, not delayed. Sends another, very delayed (X secs), then B1 crashes.
• Bridges near B1 recompute, those near B2 wait >= max age + X sec to recompute
Bridge Limitations

- Scale: not very realistic to interconnect more than 10's of LANs
- Heterogeneity: really works best for homogeneous systems
- All broadcasts and multicasts are flooded