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Considerations in implementing routing algorithms

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Problems with Distance Vector

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- At the root of the problems is slow convergence (slower than LS)
- The major problem is the "count-to-infinity" problem

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DV "count to infinity" problem

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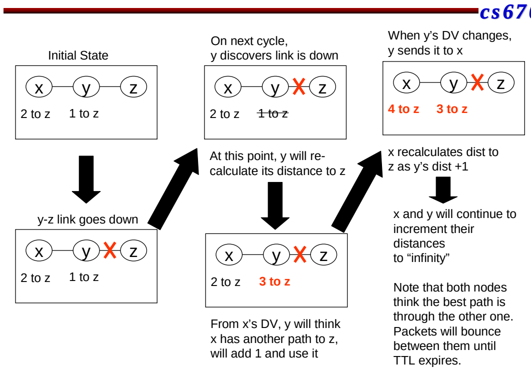

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Some ways to speed up convergence

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- Set a small "infinity"
- Report entire path
- Split horizon
- Split horizon with poison reverse
- Hold Down

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Set a small “infinity”

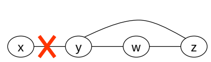
- The idea is to set a reasonably-sized number that you will consider to be “infinity” (say, the diameter of your network +1)
- This will bound the time lost in counting to infinity
- Problem: what happens when the network grows?

Report the entire path

- Instead of just advertising distances, routers advertise the entire path to the destination.
- If router A sees itself on router B’s path, it knows not to use that path.
- This fixes the problem, but it’s very expensive in terms of routing table storage and network bandwidth

Split Horizon

- Assume router A sends traffic to destination D through neighbor router B
- Under Split Horizon, when A sends its DV to B, it will not report its distance to D
- This cures some count-to-infinity problems, but not all. For example:



Split Horizon with Poison Reverse

- Instead of just not advertising distances to the neighbor node they came from, advertise ∞

Note: a similar-sounding thing

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- “Route poisoning”: when a link fails, advertise its cost as ∞

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Hold down

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- When a link goes down, neighboring routers advertise its cost as ∞ for some period of time (The “hold down interval”) before switching routes
- The idea is that the infinite cost will spread through the network so that the old distance will be dropped before the new one is advertised
- Problem: How well this works depends on the interval selected. AND, it slows down convergence instead of speeding it up.

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DV algorithm: the bottom line

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- Simple, easy to build, but slow convergence and count-to-infinity make it less favored than LS

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Considerations in implementing the Link State algorithm

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When is an LSP generated?

- When
  - Some refresh time has elapsed
  - The router detects a new neighbor
  - The router detects that a cost to a neighbor has changed
  - The router detects that a link has gone down

Some potential problems with LSP distribution (1)

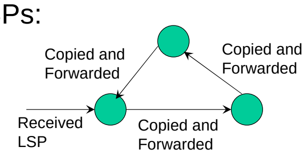
- Different routers have different LSPs
  - This is acceptable for transient states, but not for long-term states
- To avoid this, the distribution strategy must ensure that LSPs reach all routers, even if:
  - Links or routers are broken
  - A router needs this LSP to know how to route it

Some potential problems with LSP distribution (2)

- LSP distribution can overwhelm the network with LSPs to the point that nothing else can be processed.

Basic flooding

- Each router copies each received LSPs and forwards it on every link except the one the LSP was received on
- This can lead to exponential growth of LSPs:



Improved flooding

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- Each router keeps a copy of all received LSPs
- When a router receives a duplicate LSP, it does not forward it

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A problem with improved Flooding

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- Since LSPs can take different routes to get to another router, they can arrive out-of-order
- How does a router know that the most recent LSP it received is the latest one?

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LSP timestamping

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- We could timestamp LSPs to show which order to put them in
- A problem:
  - An error (or an intruder) could cause a timestamp to show a time that is a long time in the future – all succeeding LSPs would be ignored
  - We could do a sanity check of received timestamps if each router's clock was globally synchronized (or near-synchronized), but that might be harder than distributing LSPs

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Sequence numbering

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- The idea:
  - Each router gives a sequence number to the LSPs it generates. Numbers are assigned sequentially at each router
  - Receiving routers can detect outdated LSPs by comparing SN against the SN of the last-received LSP from that router

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Some problems with sequence numbering

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- Error can cause large SN
- Sequence number wrap-around can make newer LSP have smaller SN
- Router crash can make router forget next SN to use

- Need a fall-back method in case any of these problems happen

Sequence + Age schemes

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- In addition to sequence number, add an "age" field to LSP
- When router generates an LSP, it sets age to some max value
- As LSP sits in a receiving router's memory, the age field is continuously decremented
- An LSP with age=0 is replaced, regardless of sequence number
- LSPs with age=0 are not forwarded

That one has problems, too

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- Due to wraparound, if a router malfunctions, you can have:
  SN1 < SN2 < SN3 < SN1
  When this happens, every LSP will be replaced (and the new one will be propagated)
- If that happens and the network is flooded with LSPs (this is likely in the above case), LSPs may be replaced before they can time out

- This happened in the ARPANET and crashed the network

The fix

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- SNs do not wrap around, they are reset when they hit the max. Succeeding LSPs will be ignored by other routers until the previous LSP times out
- LSPs to be forwarded are buffered before queuing.
  - If an LSP is updated while it is in the buffer, it is overwritten – queues cannot fill with LSPs from one source
- LSPs are ACKed

- This method widely used (OSPF, PNNI, IS-IS)

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Summary: LS vs DV

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Comparing DV and LS: memory

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- Assume n neighbors and d destinations. Each router must store:
  - DV
    - Must keep a DV (length d) for each of n neighbors => ***O*(n*d)**
  - LS
    - Must keep an LSP (length n+) for each of d destinations (keep in mind that routers are addressable: "destinations" include routers) => ***O*(n*d)**

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Comparing DV and LS: bandwidth

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- Bandwidth usage is highly dependent on network topology
- Not a significant factor unless you are considering extreme situations

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Comparing DV and LS: processing

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- DV
  - All n DVs must be scanned => ***O*(n*d)**
- LS
  - Dijkstra's algorithm dominates
    - *O*(number_links * log d) => ***O*(n * d log d)**
- Both types can be sped up for cases where only a few states have changed since last calculation

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Comparing DV and LS: robustness

- Both DV and LS are vulnerable to some extent to problems and attacks
  - Router claims a link that doesn't exist
  - Router claims no link where one exists
  - Oddball sequence numbering
  - Incorrect or omitted LSP forwarding
  - Incorrect age handling
  - Failure to ACK LSPs
  - Incorrect path calculation

Comparing DV and LS: convergence

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- The principal performance difference
- When network situation changes, how long does it take for the information to be reflected everywhere?
- LS converges faster:
  - DV has looping problem – fixes are slower
  - DV must re-calc distances before passing along data (LS forwards immediately)

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