Some Lessons from History

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Lessons from History

- **There have been major Internet issues**
  - "Interesting" events in 1980's, 90's, 200x's
  - We didn't always know what we were doing
- **Some knowledge is in the mind of old folks**
- **I thought it would be wise to write some of these down**
- **Examples to follow**
  - I have tried to be fully vendor-neutral (eg, have not considered issues with proprietary protocols)

Arpanet Collapse (early 1980's)

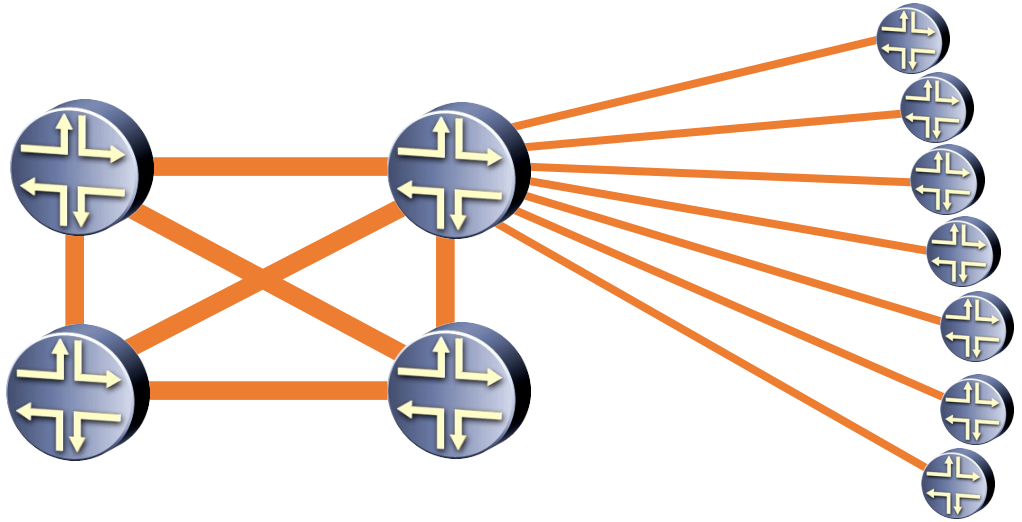
- **A switch crashed and restarted**
  - Forwarded old packets in output queue
- **Result: Old Route Update was propagated…**
  - While another update was in progress
  - Old update was exactly 1/2 way around circular sequence space (a>b; b>c; c>a)
  - Update A replaced Update B
  - Update B replaced Update C
  - Update C replaced Update A…

Arpanet Collapse (early 1980's)

- Problem: Three updates chased each other around the Arpanet for hours
- Solution: All but two packet switches had to be manually shut down
- (today, with hundreds of routers per network, this could be quite unpleasant)

OSPF Flooding Issue (early 1990's)

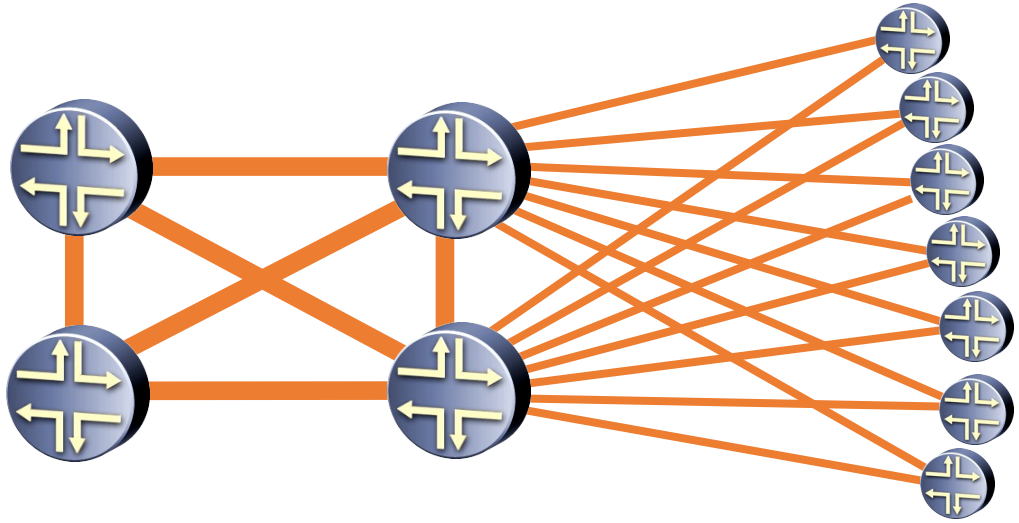
- Stable Network, Well-connected core with single-homed stubs



- S.P. thought: I really care about reliability. Let's multi-home stubs…

OSPF Flooding Issue…

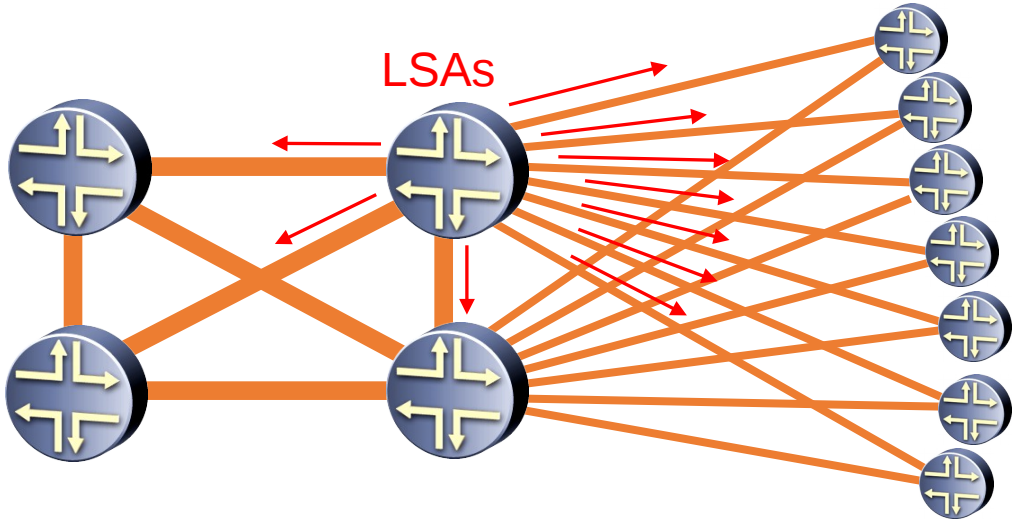
- **Redundancy added:**



- **Result: Collapse**
- **What happened?**

OSPF Flooding Issue…

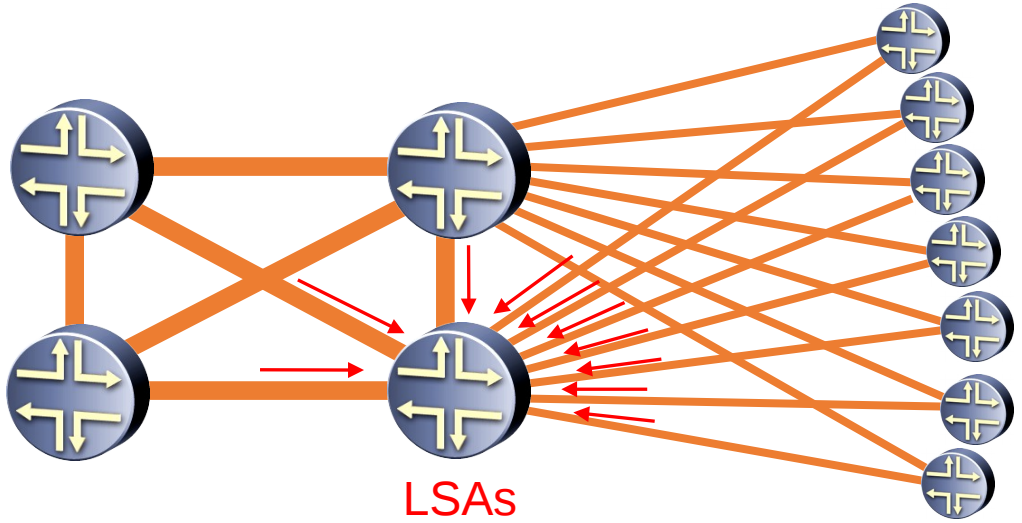
- **Core router had LSA to send out**
  - Transmitted to all adjacent routers



- **Stub routers all forwarded the LSA to their neighbors…**

OSPF Issue…

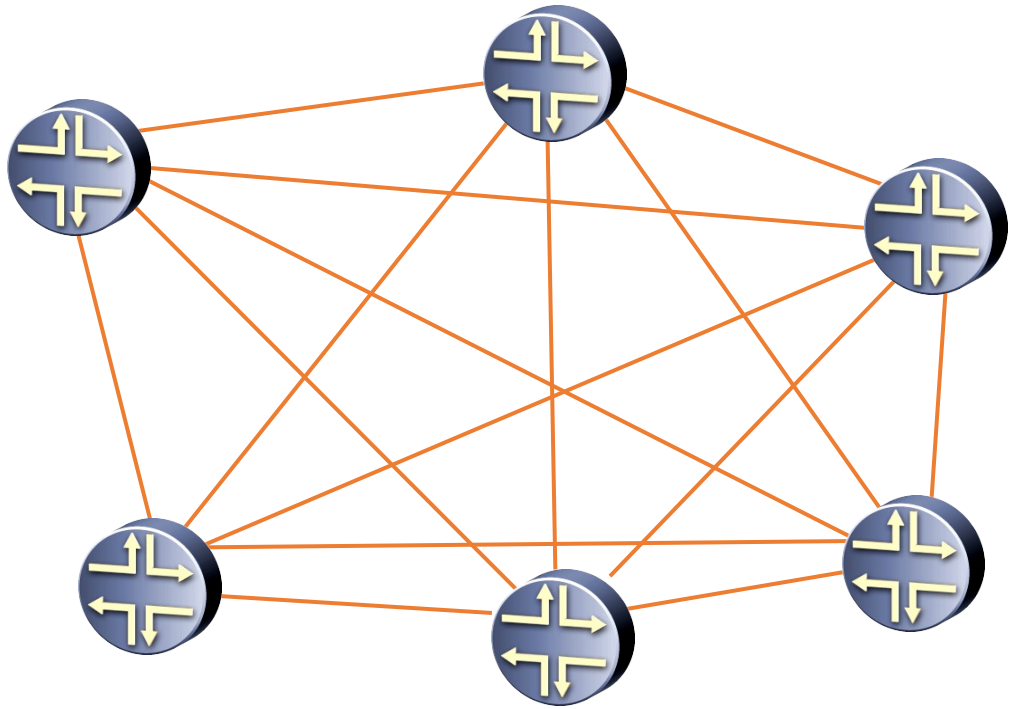
- **Result: Other core router was overwhelmed with LSAs forwarded by stub routers**



- **Lesson: Buffering and discarding duplicate LSAs is a difficult part of OSPF/IS-IS**
  - No one predicted this

Flooding Issue with IP over ATM

- Similar issue occur with full mesh of circuits over an ATM core
- Mesh groups added to deal with this



Lost Hellos (~1992)

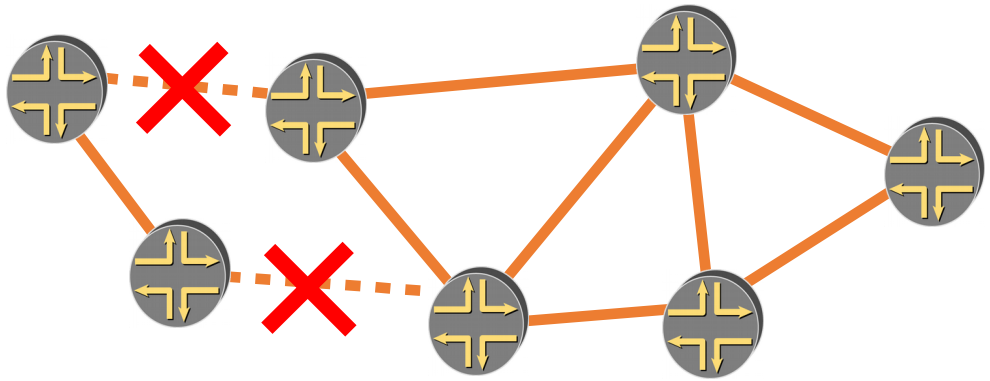
- **Network stable for long periods of time**
- **Multiple random changes in short order cause processor to fall behind**
  - Processor drops Hellos, adjacencies dropped
  - More routing updates transmitted
  - Widespread CPU congestion, more Hellos dropped
  - Entire network disconnects
  - Problem stabilizes, network recovers
  - ~20 minutes later, many LSAs are refreshed, problem repeats

Lost Hellos…

- **Solution**
  - Optimize protocol processing
  - Prioritize Hello processing
  - Randomize timers
  - (Apply to all routing protocols)
- **This was known in early 90's**
- **But…**

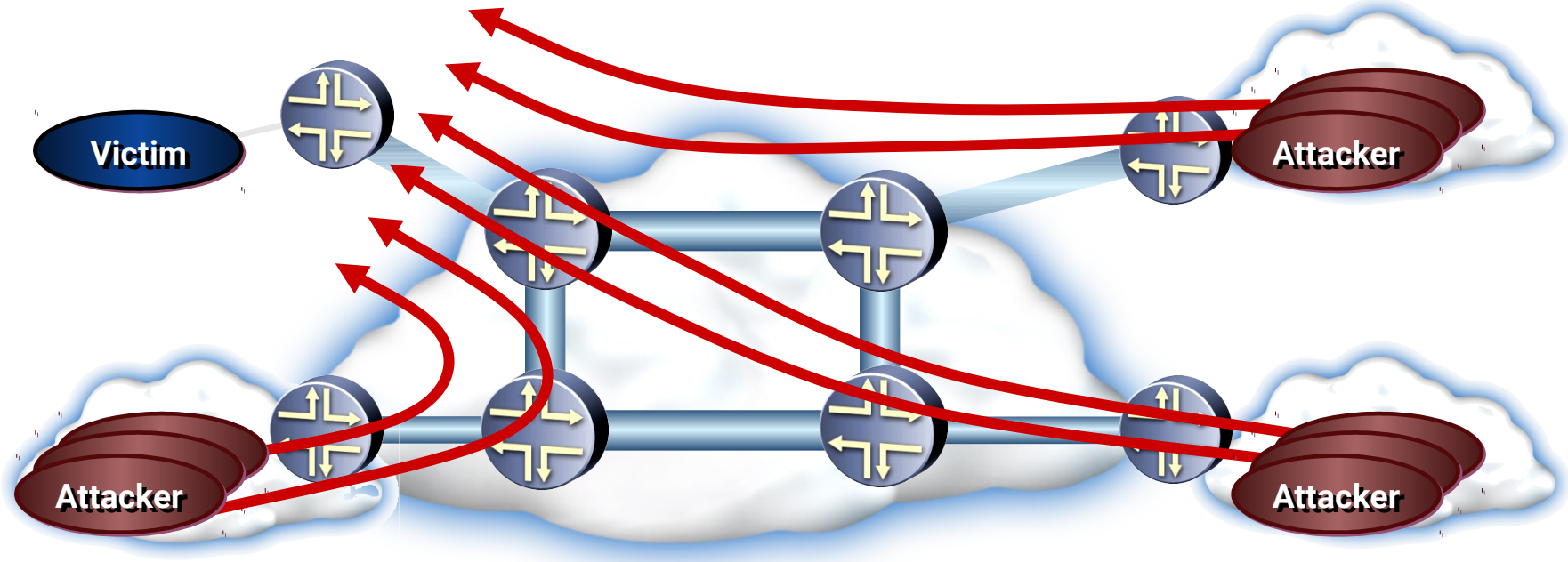
ATM Switches, mid 1990's

- ATM Network partitions, re-connects



- New updates flooded between partitions
- CPUs congest, drop Hellos
- Adjacencies dropped, Network Disconnects
- ('Prioritize Hellos' wasn't well enough known)

IP Nets: DDoS Attacks



- Attacker compromises many hosts, uses them to launch a coordinated attack
- Result: Link Congestion

Slammer, January 2003

- **Slammer worm**
  - Very rapid propagation (doubles in ~8sec)
  - Widespread congestion in IP networks worldwide
- **Result**
  - Routers drop Hellos, Adjacencies dropped
  - Network disconnects
  - (not clear if result of link or CPU congestion)
  - Issue getting management plane to respond

Solution: Prioritize Hellos + …

- **Give priority, guaranteed resources for real time protocol functions**
- **Prioritized queues**
  - Inside router, and on egress

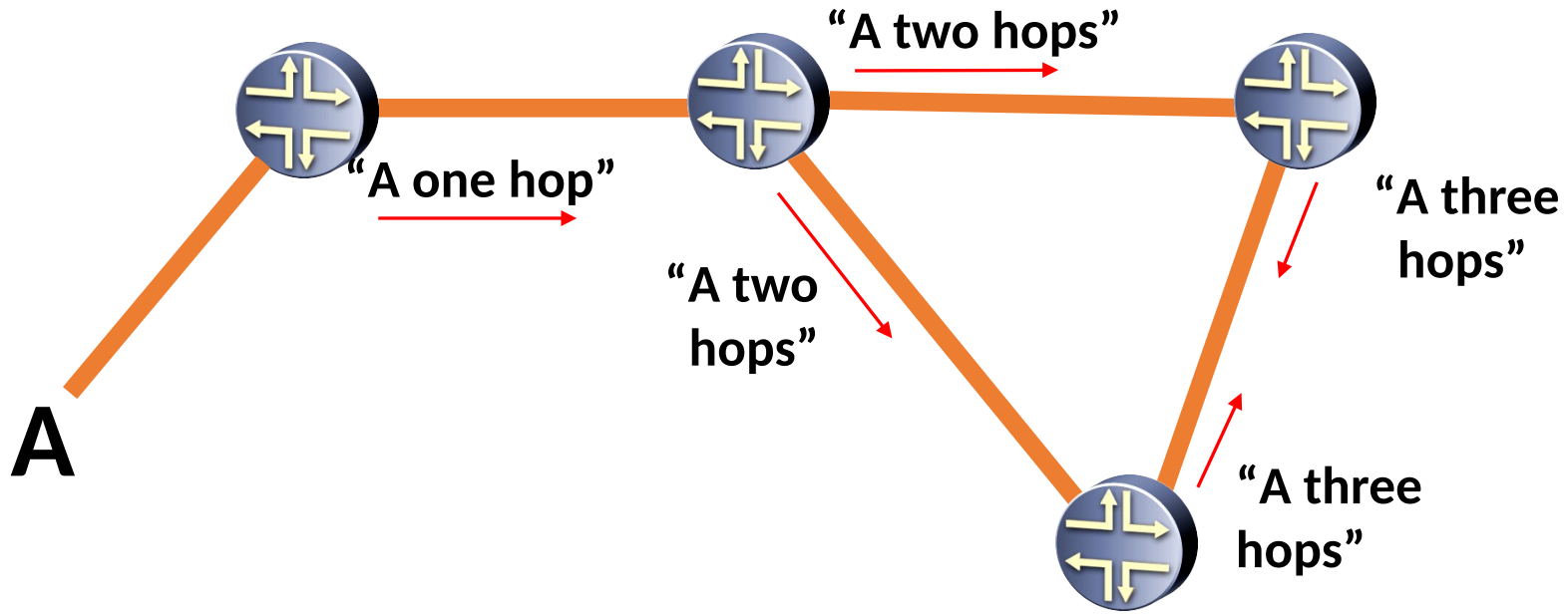
Invalid Update Issue

- **IS-IS (and OSPF) defined in mid 1980's**
  - Smaller CPUs, which also forwarded packets
  - ⇒ Original spec minimizes CPU strain
  - In forwarding IS-IS updates: Check outer wrapper, forward, then check internals
- **IS-IS & OSPF were widely deployed, interworked well**
  - IS-IS was solid for several years

Invalid Update Issue,…

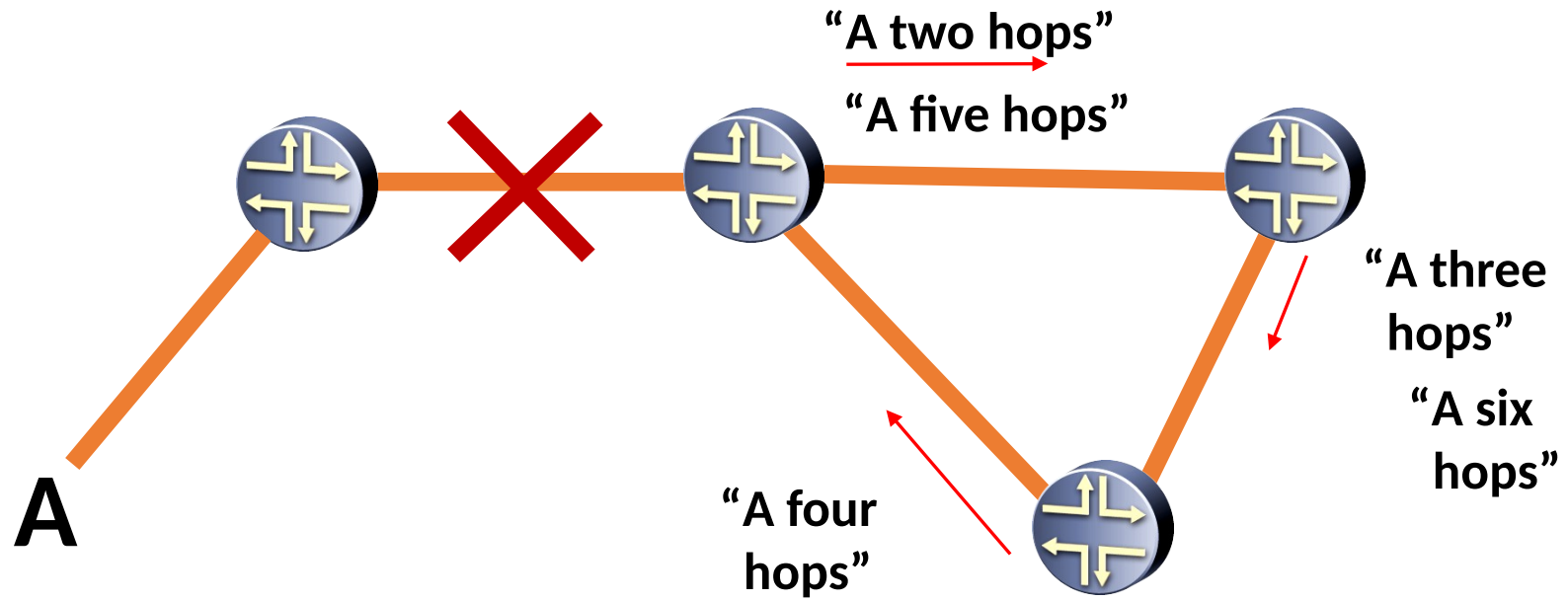
- **Bad interface trashes update**
  - One in ~65,000 have checksum which passes
  - Check outer wrapper (OK)
  - Forward (OK)
  - Check internals: Field out of range, Crash
- **Result: Entire area crashes**
  - Many rtrs, multiple vendors

Distance Vector (RIP) Count to Infinity



- Distance vector count to infinity is fairly well known

Distance Vector (RIP) Count to Infinity



- Many fixes have been proposed, some deployed
- There was an interesting "augmenting" to this problem in the early NSFnet…

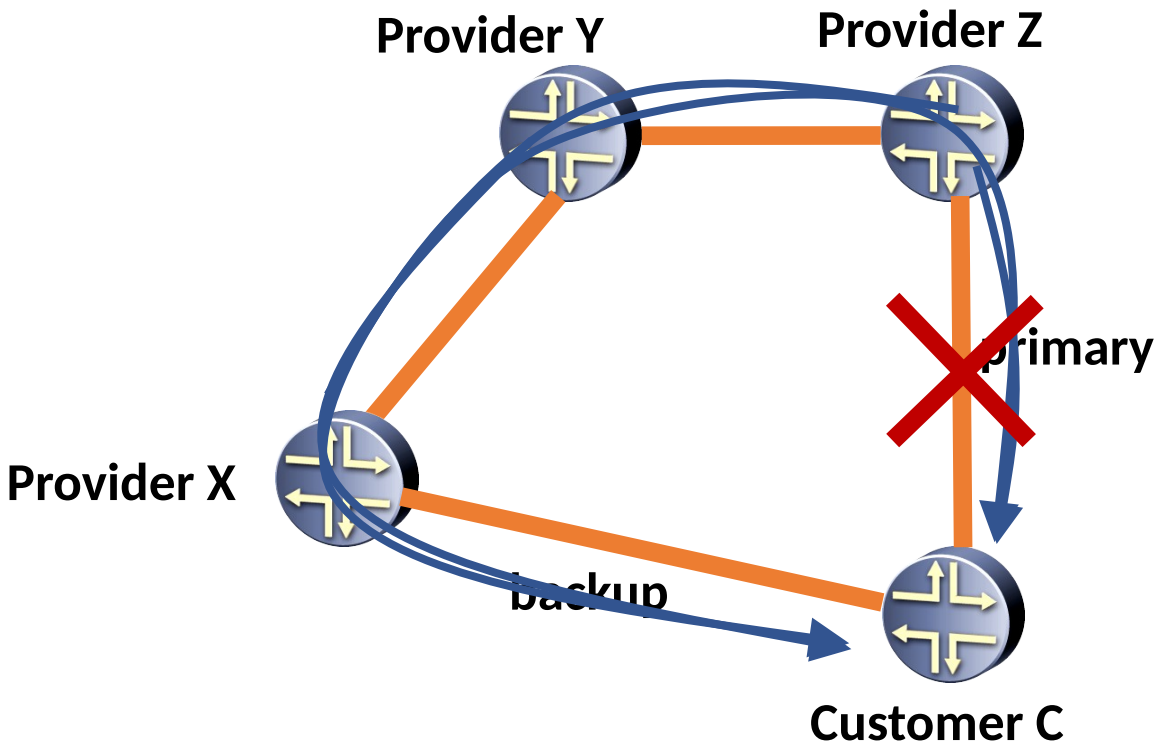
Delay Based Routing

- **There have been multiple “interesting” experiments with routing based on real time (queuing) delay**
- **Early NSFnet “Fuzzball” routers had delay based “Hello” protocol in the core, mapped to RIP around the edges**
  - Delays vary dynamically, feeding unstable metrics into RIP
  - This was not pretty
- **An Arpanet variant used a linear combination of hop count and real time delay, carefully overdamped**
  - When delays grew (congestion), it became under-damped

Non-deterministic routing

- **”BGP wedgies” are a well-documented example.**
- **One set of policy configurations can result in multiple different stable forwarding topologies (“multistable”), depending on timing.**
  - Because policies are local, but forwarding is global.
- **Much more detail in RFC 4264.**

BGP “wedgies” simple example



- C uses BGP community to tell X “use this link as a last resort only”
- When primary fails, all is well.
- But when primary is restored, forwarding topology has a new stable state. (And not what C intended.)

BGP MED Oscillation

- **Actually, BGP isn't even always multistable.**
- **The BGP MED path attribute can cause persistent oscillations (see RFC 3345).**
- **How did this happen?**
  - BGP route selection assumes total order.
  - MED gives only a partial order (MED is only comparable if source AS is the same).
- **Protocol was designed to be correct with a flat IBGP**
  - MED wasn't considered when designing route reflection, which does data hiding.
  - Even if it had been, not clear there would have been a solution.

Optional Transitive BGP Attributes

- **Some BGP data is opaque to routers handling it, and can transit across them.**
  - Optional Transitive Path Attributes, most famously.
- **When the data is handled by a router that does understand it, the router says "oh my goodness my peer has sent me a bad update it must be insane" and resets the session.**
  - But the peer didn't misbehave. Some router far across the Internet did.
  - This means one naughty router can cause a very large number of sessions to reset.
- **Best intentions by protocol designers, but a terrible outcome.**
- **Fixed by RFC 7606 (keep the session up but delete the malformed routes, don't assume the peer has gone insane).**

BGP – a few lessons

- Simple protocols have complex behaviors when assembled into large systems.
- Extensible protocols lead to small extensions that have surprising consequences when they interact.
- If you serve several masters (protocol correctness, business reality) something has to give.
- Data that is sometimes opaque leads to results that are sometimes surprising.
- The worse-is-better design philosophy is powerful.

Other examples…

- **Operator errors**
- **Distribution of full BGP routes into IGP (IS-IS, OSPF, …)**
- **Scaling**
- **Signaling System 7 (SS7) failure**
- **Rumors of other issues**
- **And note, I have not mentioned multicast…**
  - Eg, “multicast grenades” are in principle possible

What To Do With This Information?

- **I had been intending to write an Internet Draft (to RFC)**
  - This isn't going to happen (I am retired, and like it that way)
  - Adding more detail and additional examples would be useful
- **"Those who cannot remember the past are condemned to repeat it"**
  - Old saying (possibly originally by George Santayana)
- **Today, repeating these failures is not acceptable**
  - We all depend upon a stable and reliable Internet
- **Hopefully, this presentation can be helpful**