Real-time networks and preemption

More to it than latency

Rev. 1

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What is a real-time network?

- In a real sense, all networks are “real-time” except for simulations of networks.
- Video or voice data is certainly a kind of “real-time”
- Priority, resource reservation, and other methods work for many networks that have tight latency and/or jitter requirements.
- In this slide deck, “real-time” means a guaranteed response time to any given input or combination of inputs. **No excuses, no exceptions**.
- Typical examples are automatic automobile braking systems and robot control.

What do real-time networks lack?

- Some excellent presentations have been made this year on requirements from users and designers of real-time automotive and industrial networks.
- There are common threads that we can address:

  Topology

  Delivery

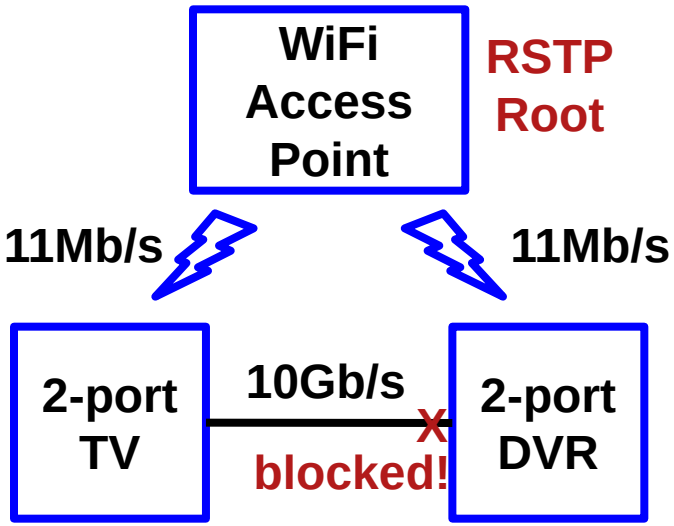
  Predictability

- But, we cannot address them in isolation, either from each other, or from more general uses of Ethernet networks.

Topology

Topology

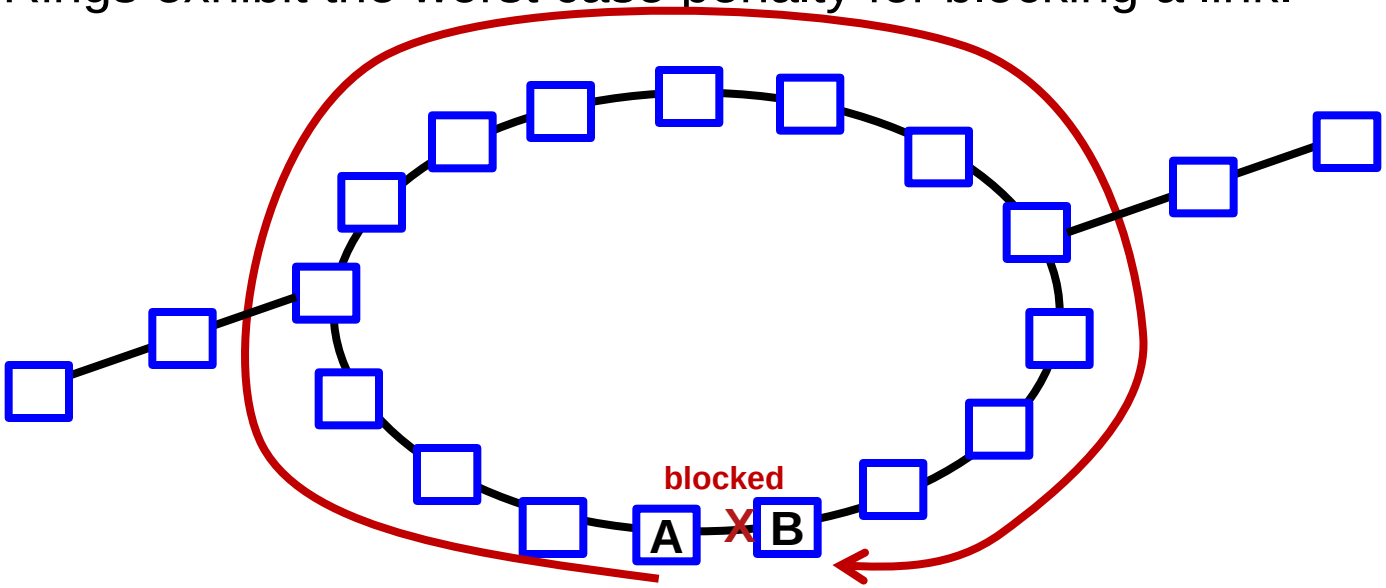
- As has been known for a long time, spanning tree has issues in simple networks with links of widely disparate data rates.



- This diagram illustrates the problem in the home.

Topology

- Similarly, large rings, as are common in automobiles and industrial networks, are the least-favored topology for spanning tree.
  - Rings (with tails) exhibit the worst case reconfiguration times.
  - Rings exhibit the worst case penalty for blocking a link.



Topology

- We could build on spanning tree. But ...
  - Bridges running MSTP lack a view of the whole network, and this may useful information to applications.
  - Using MSTP requires that MSRP or similar protocols must converge *after* MSTP converges, instead of simultaneously.
- For these reasons, and because the blocked-link problems in the previous slides are solved, this author believes that a **link-state protocol should be the basis for real-time networks**.

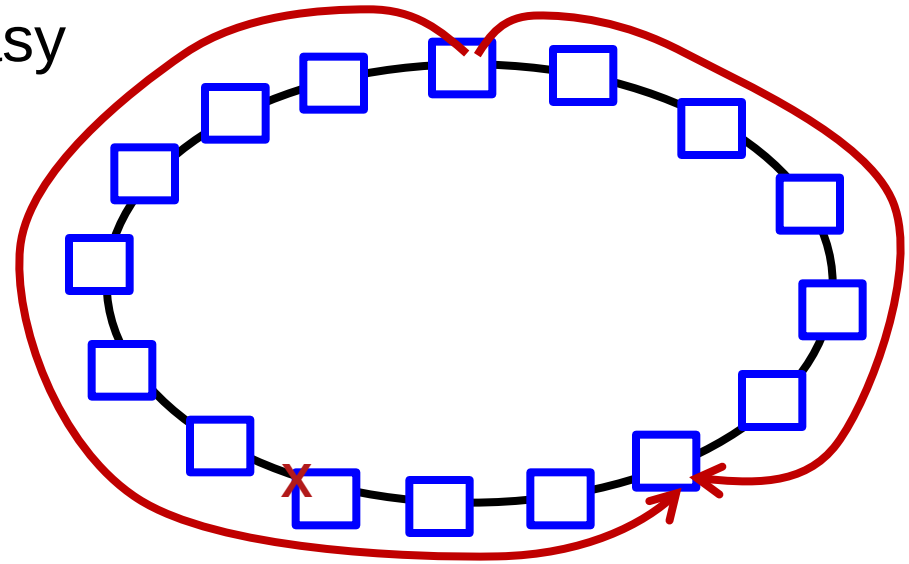
Shortest Path Bridging

- Coincidentally, SPBV (VLAN-mode Shortest Path Bridging) can be made plug-and-play for networks in the size range we're interested in.
- Some work would still be needed:
  - We must balance the number of VLANs against number of bridges ([number of bridges] * [number of VLANs] < 4096).
  - Learning MAC address can preclude the use of two paths between two stations.
- It is true that SPBV is more complex than alternatives that are based on a fixed topology. But, not all real-time networks are rings, and one must ask whether the topology is *really* fixed.

Delivery

Delivery

- For ultra-reliable communications between consenting stations, delivery of frames along two paths would be very helpful, and there are documented methods for it.
- This cannot be easily done by current bridging/routing protocols: paths are not equal cost, overriding the topology to slip past blocked links breaks address learning, and it is not easy to discovery maximally-disparate paths.
- But, if we can do it, the value will be significant!



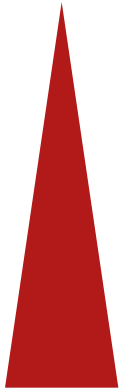
Predictability

Predictability

- Preemption certainly reduces the latency for at least one flow.
- But, improving one flow's latency generally makes all other flows' latency and jitter even worse.
- As soon as you have two preemptive flows, collisions between those flows put you in the same place you were in before you introduced preemption.
- Cut-through forwarding of preemptive frames would improve best-case latency. Is this improvement also necessary?
- So, there is more to the predictability problem than latency or preemption.

Improving one hurts all others

- The work on 802.1Qat and .1Qav showed that the biggest impacts on the latency and jitter of a reserved stream (or the highest-priority non-reserved stream) are, in increasing importance:



1. The largest conflicting lower-priority frame.
2. The fan-in at each bridge to a controlled queue.
3. The percentage of bandwidth reserved for this level of controlled traffic.
4. The percentage of bandwidth reserved for higher-priority controlled traffic.

- Preemption eliminates 1. 2 is not a concern for networks that are mostly rings. Preemption has a major impact on other, lower-priority bandwidth-reserved flows.

Impact of uncontrolled preemption

- If two preemptive frames collide, one must lose, and its latency goes up. Furthermore, the latency of the next-lower priority (presumably MSRP reserved) goes up dramatically.
- You could rate-control the preemptive traffic, but rate limiting outside the view of the application could easily result in unacceptable latency.
- If preemption is utilized, cut-through forwarding of preemptable frames must not be used, as this leads to uncontrolled fragmentation and/or poor goodput. Cut-through is only applicable to preemptive frames.

Time synchronization

- There is a long history of real-time networking, especially in the aerospace industry.
- In this world, “real time” does not mean interrupts and preemptive process scheduling. It does not mean “best effort delivery.”
- “Real-time” means scheduling: scheduling processes within a station, scheduling communications between stations, and coordinating the stations’ schedules.
- Scheduling guarantees that all processing and communications happen within the required time limits.

Real-time networks: 3 networks in 1

- Three levels of service: **Critical**, **Reserved**, and **Best-Effort**.
- **Critical** traffic uses preemption (and perhaps cut-through forwarding) so that other classes do not disturb it.
- **Critical** traffic uses time synchronized transmissions to ensure that critical flows do no interfere with each other, and do not overly disrupt Reserved traffic.
- **Reserved** traffic uses bandwidth reservation to meet audio/video requirements.
- **Best-effort** traffic gets what's left.

Preemption

Preemption

- Theoretically, it is possible to define preemption in 802.1.
- Practically, this function will be done at a very low level in the port ASICs, and should be defined where the expertise lies – in 802.3 – with support from 802.1 as necessary.
- Political opinion: If 802.1 has its ducks in a row with regards to the whole picture of real-time networks, getting 802.3 buy-in is much more likely. Simply presenting “we need better latency” will not overcome antipathy to an oft-presented idea.
- Assessing the impact of preemption on enterprise and provider networks is also required to overcome worries within 802.1, itself.