On 802.1 Time Sensitive Networking

Norm Finn
Cisco

Introduction to Deterministic Networking for Engineers

- This is an overview, with lots of pointers to more detailed documents. One slide has market justification. The rest of the deck is about making it happen, with an emphasis on standards.
- There are lots of hot links to the details.
- The outline:
  - What, Who, Why, and How. A 4-slide summary of Deterministic Networking
  - Terminology, history, and current state of the development of Deterministic Networking standards.
  - Deeper dive: Data plane
  - Deeper dive: Control plane

What is Deterministic Networking?

Same as normal networking, but with the following features for **critical data streams**:

1. **Time synchronization** for network nodes and hosts to better than 1 μs.
2. Software for **resource reservation** for critical data streams (buffers and schedulers in network nodes and bandwidth on links), via configuration, management, and/or protocol action.
3. Software and hardware to ensure **extraordinarily low packet loss ratios**, starting at 10^{-6} and extending to 10^{-10} or better, and as a consequence, a **guaranteed end-to-end latency** for a reserved flow.
4. **Convergence** of critical data streams and other QoS features (including ordinary best-effort) on a single network, even when critical data streams are 75% of the bandwidth.
5. **Ease of use** is inherent, in that configuration is minimal, and all per-flow configuration is done via protocols (not people) that use parameters meaningful to the users (bandwidth and latency).

Who needs Deterministic Networking?

- Two classes of customers, Industrial and Audio/Video. Both classes have moved into the digital world over the last 40 years, and some are using packets, but now they all realize they must move to Ethernet, and most will move to the Internet Protocols.

1. **Industrial:** process control, machine control, and vehicles.
   - At Layer 2, this is IEEE 802.1 **Time-Sensitive Networking (TSN)**.
   - Data rate per stream very low, but can be large numbers of streams.
   - Latency critical to meeting control loop frequency requirements.
2. **Audio/video:** streams in live production studios.
   - At Layer 2, this is IEEE 802.1 **Audio Video Bridging (AVB)**.
   - Not so many flows, but one flow is 3 Gb/s now, 12 Gb/s tomorrow.
   - Latency and jitter are important, as buffers are scarce at these speeds.

- (You won't find any more market justification in this deck.)

Why such a low packet loss ratio?

Back-of-the-envelope calculations:

1.Industrial (TSN):

- General Motors factory floor: 1000 networks • 1000 packets/s/network • 100000 s/day = 10^{11} packets/day.
- Machine fails safe when 2 consecutive packets are lost.
- At a random loss ratio of **10^{-5}**, 10^{-10} is chance of 2 consecutive losses.
- 10^{11} packets/day • 10^{-10} 2-loss ratio = **10 production line halts/day**.
- In some use cases, lost packets can damage equipment or kill people.

2.Audio video production (AVB): (not distribution)

- 10^{10} b/s • 10 processing steps • 1000 s/show = 10^{14} bits = 10^{10} packets.
- Waiting for ACKs and retries = too many buffers, too much latency.
- Lost packets result in a **flawed master recording**, which is the user's end product.

How such a low packet loss ratio?

1. **Zero congestion loss**.
   - This requires reserving resources along the path. (Think, "IntServ" and "RSVP") You cannot guarantee anything if you cannot say, "No."
   - This requires hardware in the form of buffers, shapers, and schedulers. Overprovisioning usually works, but the packet loss curve has a tail.
   - Heavyweight resource reservation is another word for "circuits".
   - Circuits only scale by aggregation in to larger circuits. (MPLS? LISP?)
2. **Seamless redundancy**.
   - Serialize packets, send on 2 (or more) fixed paths, then combine, re-order and delete extras. (Paths are seldom automatically rerouted.)
   - 0 congestion loss means packet loss is failed equipment or cosmic rays.
   - Zero congestion loss satisfies some customers without seamless redundancy. The reverse is not true in a converged network—if there is congestion on one path, congestion is likely on the other path, as well.

Terminology

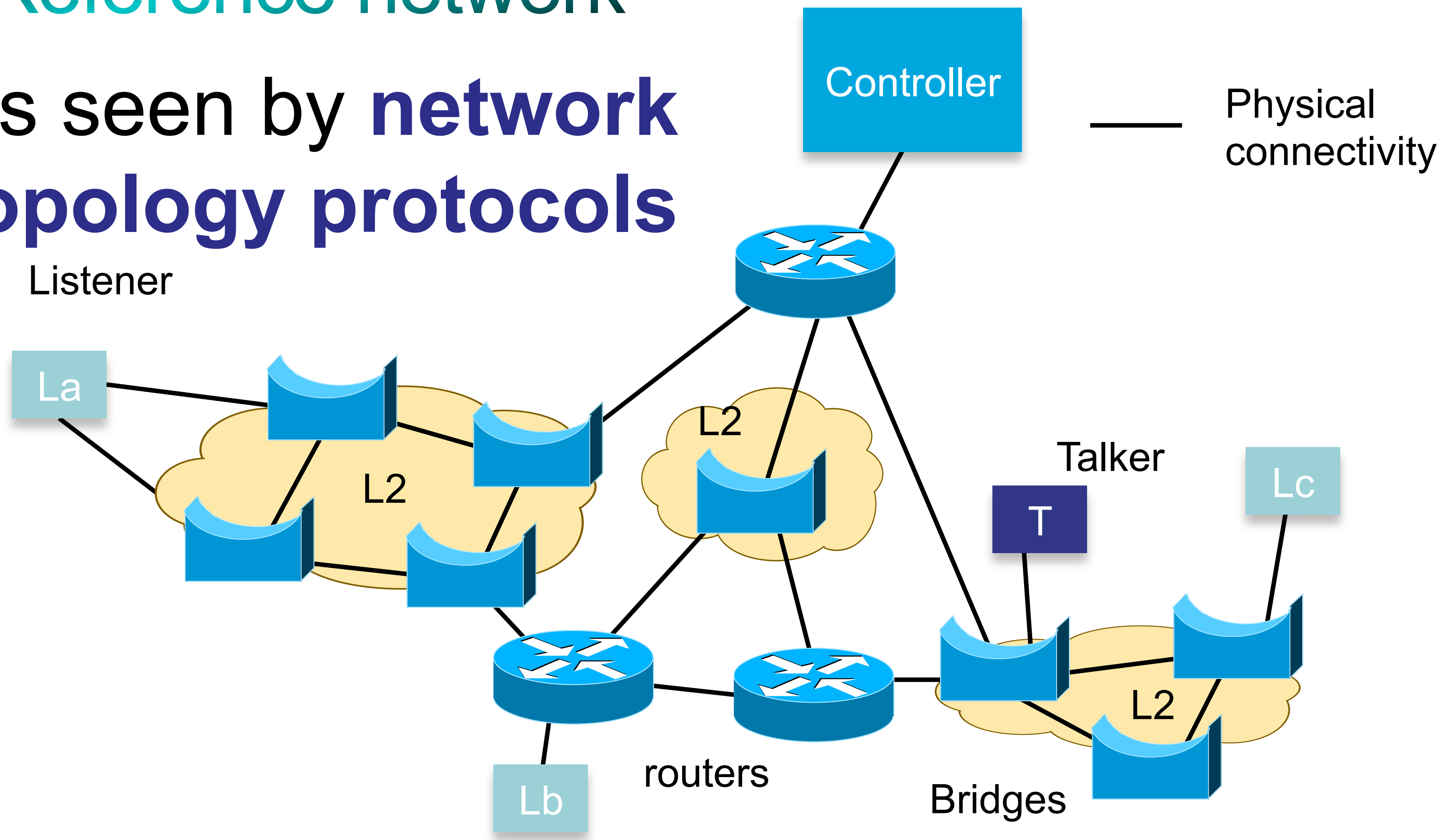
- **IEEE 802.1Q** defines the standard for "Virtual Bridged Networks". That means **VLAN bridges**.
- The term "**switch**" is not used by 802.1, or in this presentation.
- "**Deterministic Ethernet**" is a term used by some. It has no strict definition, but is usually meant to mean "all that stuff IEEE 802.1 AVB and TSN Task Groups have done and are doing."
- "**Deterministic Networking (DetNet)**" is another term used by some, but with no strict definition. This author uses it to mean, "The principles of Deterministic Ethernet, reworked somewhat to be a Quality of Service available to any data stream on any network, whether L2, L3, or mixed."
- An "**AVB Device**" is a device conforming to IEEE Std 802.1BA.

IEEE Time-Sensitive Networking (TSN)

- The AVB standards attracted the attention of industrial and automotive communities, both for the manufacturing floor and for use in automobiles, themselves: General Electric, Siemens, Hyundai, Audi, General Motors, BMW.
- Due to this interest, the AVB TG changed its name to the **Time-Sensitive Networking (TSN) Task Group** in 2013. It is still a task group within the IEEE 802.1 Working Group.
- A second round of standards has been started by the TSN TG. These fall into two broad categories:
  - **AVB Gen2**. Improvements and enhancements to the AVB suite aimed at the original markets.
  - **TSN**. Extensions to AVB, primarily for industrial and vehicular systems.

Reference network

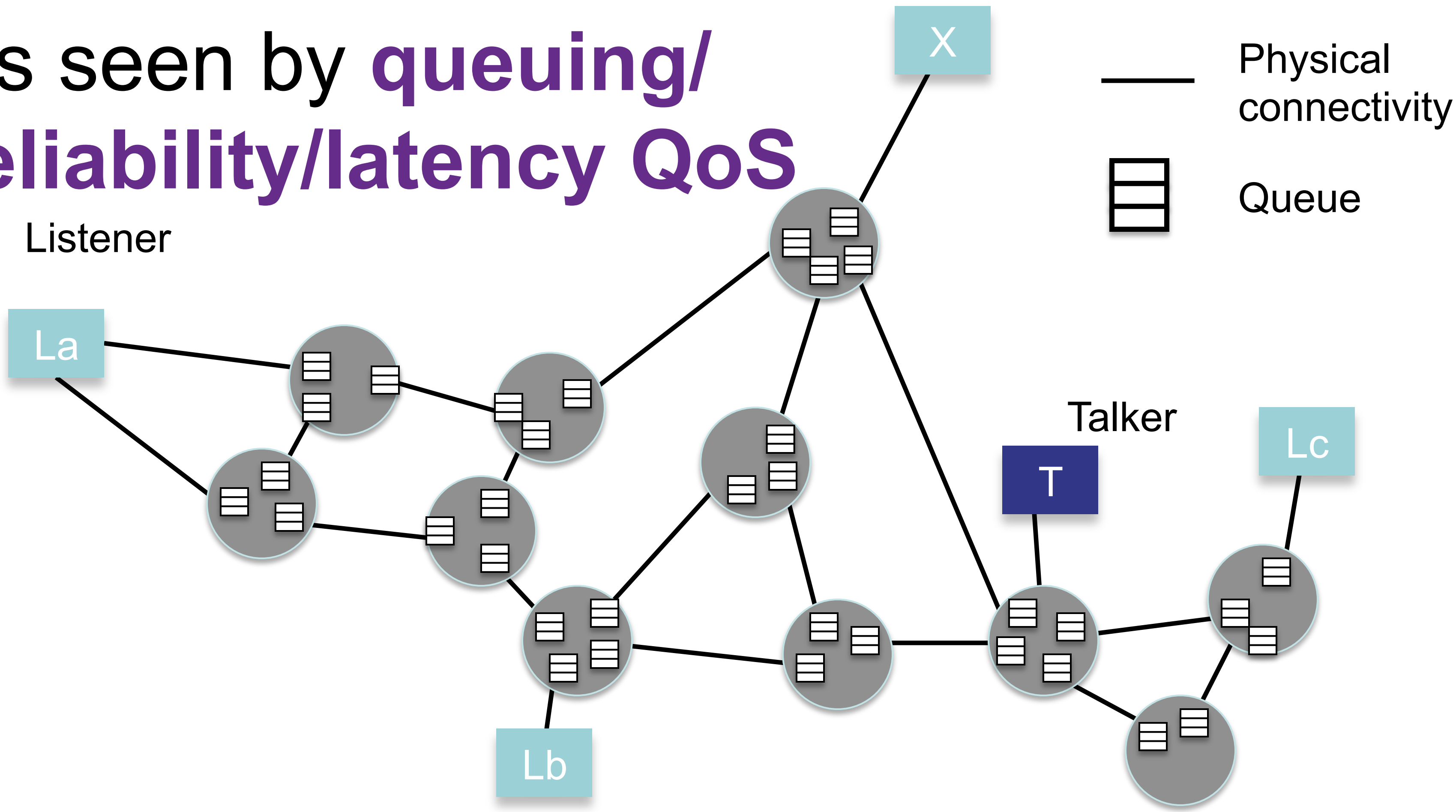
As seen by network topology protocols



- Gazillions of complex protocols

Reference network

As seen by **queuing/ reliability/latency QoS**



- Just nodes, queues, and wires!!

Just nodes, queues, and wires

- This is why the emphasis on:
  - An L2/L3 “UNI” for requesting bandwidth.
  - Extending the PCE concept to L2.
  - Extending the Deterministic Ethernet queuing mechanisms to L3.

Proposed LLN Diffserv Recommendation

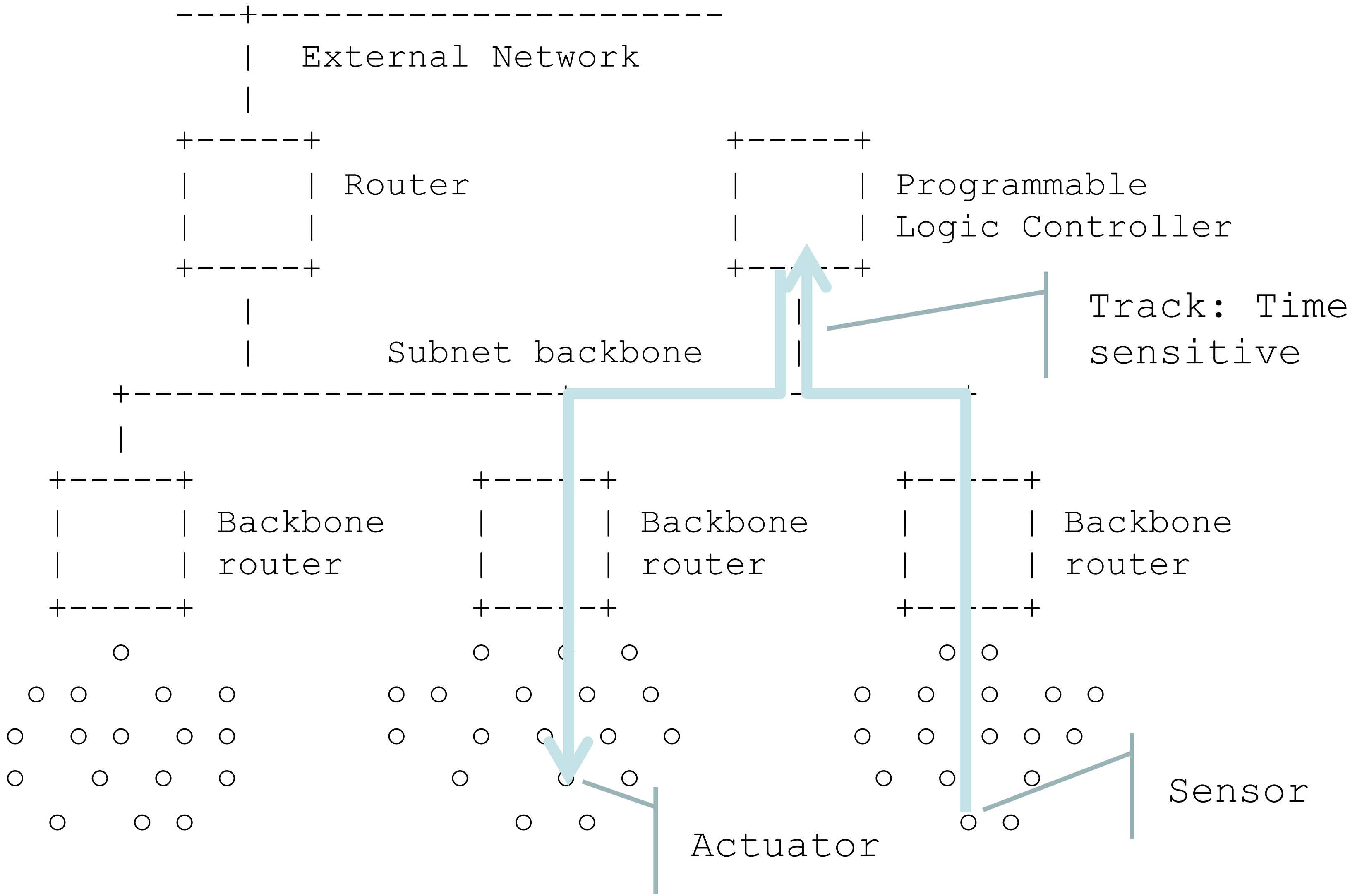
- Alert Signals	CS5
- Control Signaling	CS5
- Deterministic (closed-loop) control-signals	~~EF~~ DF (Deterministic PHB)
- Video broadcast/feed	CS3
- Query-based data	AF2x
- Assured monitoring data (high throughput)	AF1x
- Best effort monitoring, periodic reporting	BE

draft-svshah-tsvwg-lln-diffserv-recommendations

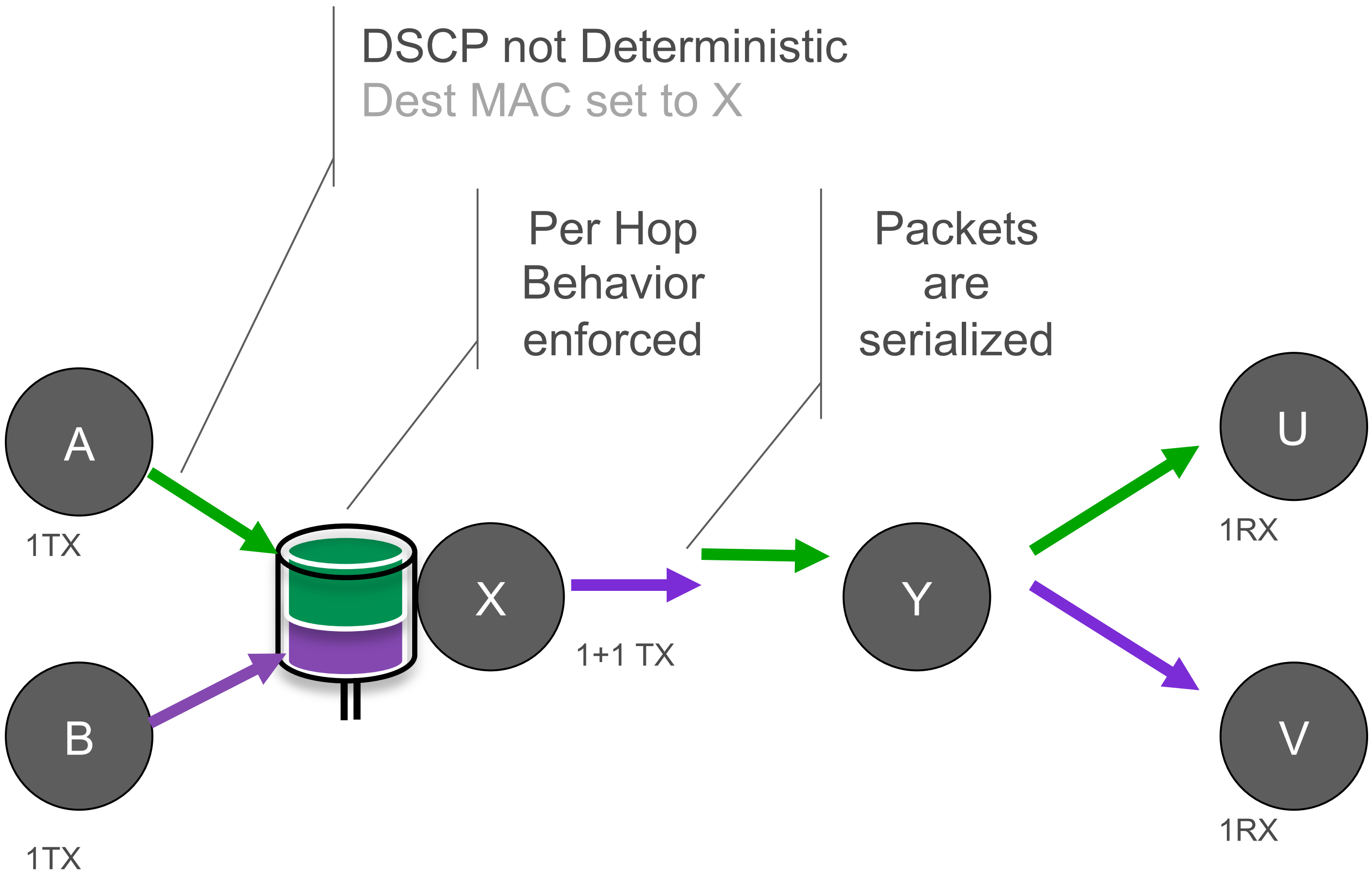
Deterministic Forwarding

IPv6 over the TSCH
mode of IEEE 802.15.4e

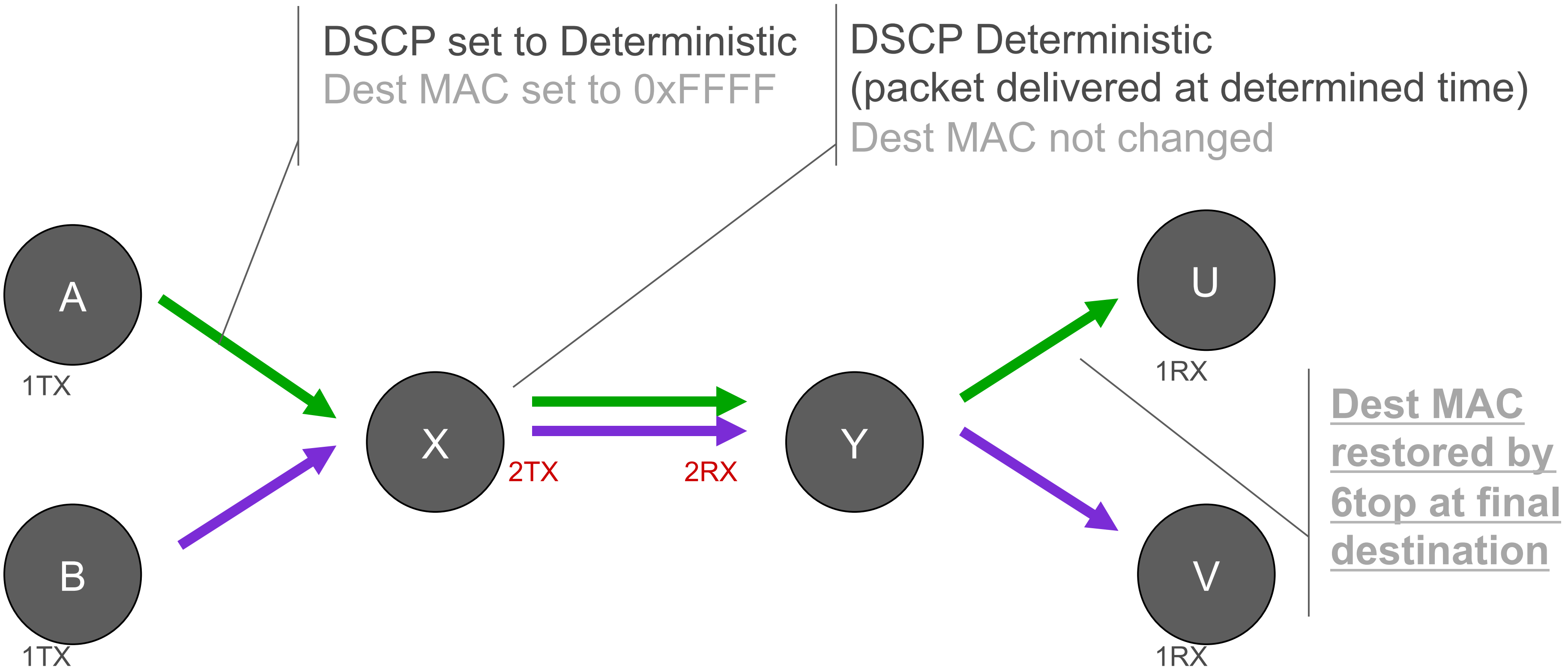
Basic topology



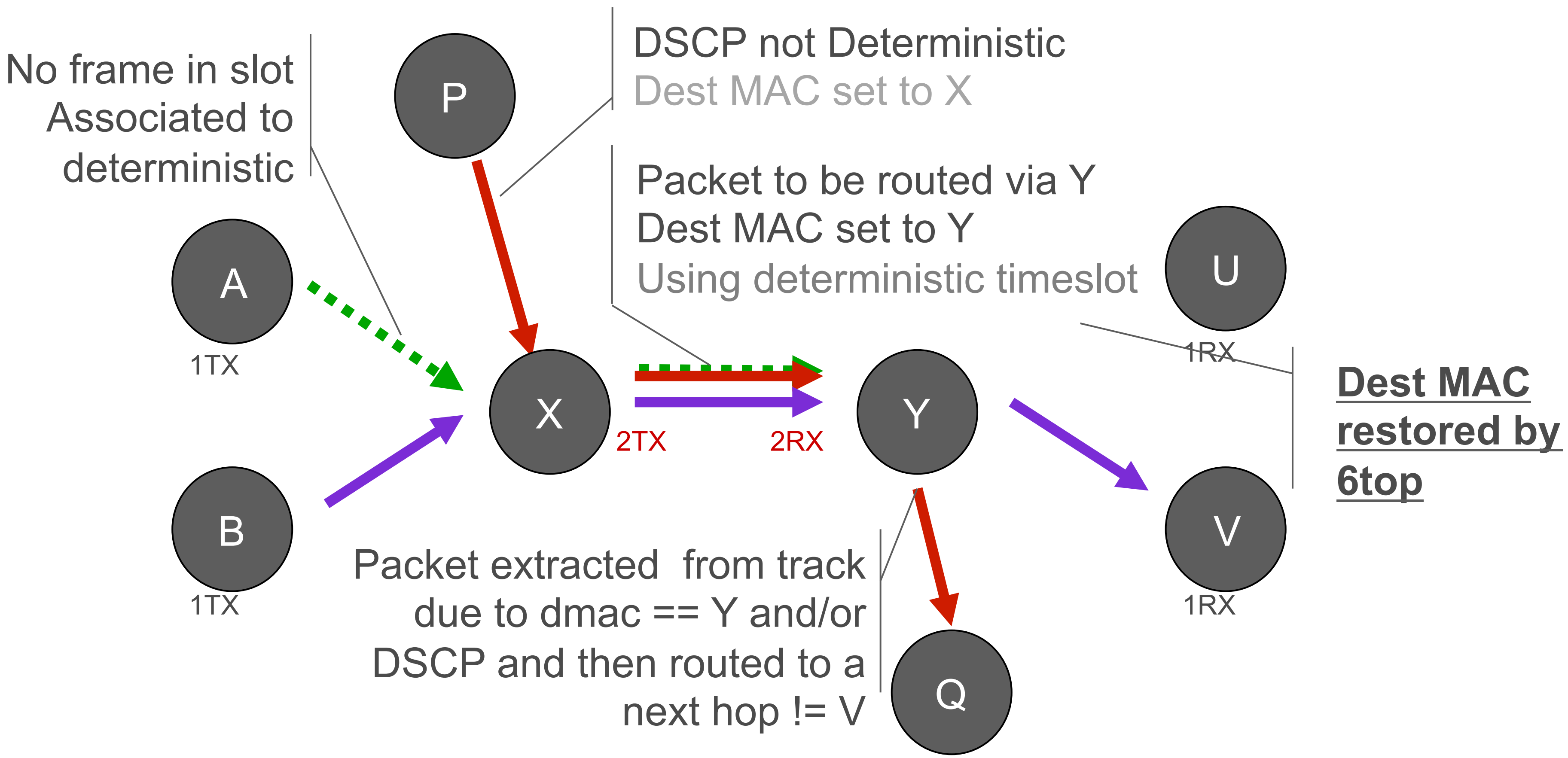
Normal L3 operation



Normal Track operation



(Existing) Opportunistic track slot reuse



(New) Retracking after recovery