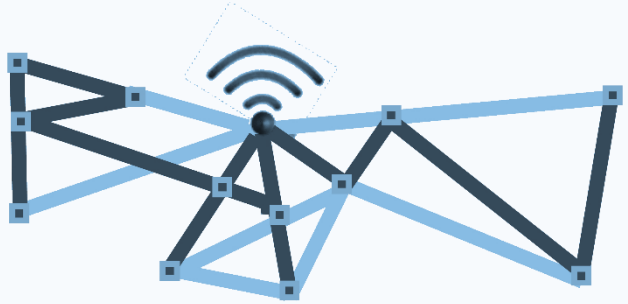
RTNS 2019



Reliable and Available Wireless

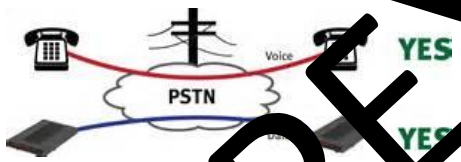
https://trac.tools.ietf.org/bof/trac/wiki/RAW

Pascal Thubert, Cisco Systems

Converging on IP => lower cost + distinct new Value

- Mail: slow, insecure

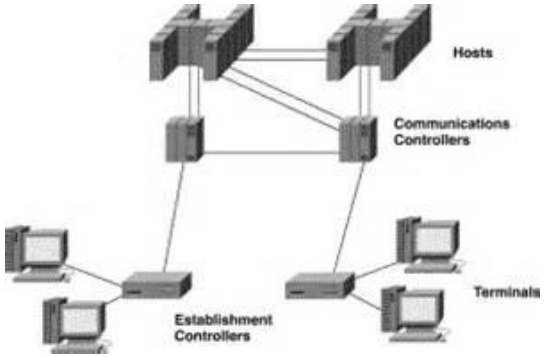
- Telephone: expensive for long distance



OPEX!!!

- TV: low quality, conflicting standards dedicated sets

- Data networks: limited



- email: free, high volumes, archives
- Skype, Webex: free, brings video and conferencing
- Netflix: on-demand, on-the-move, interactive/participative
- Internet: new breed of devices, for a new economy

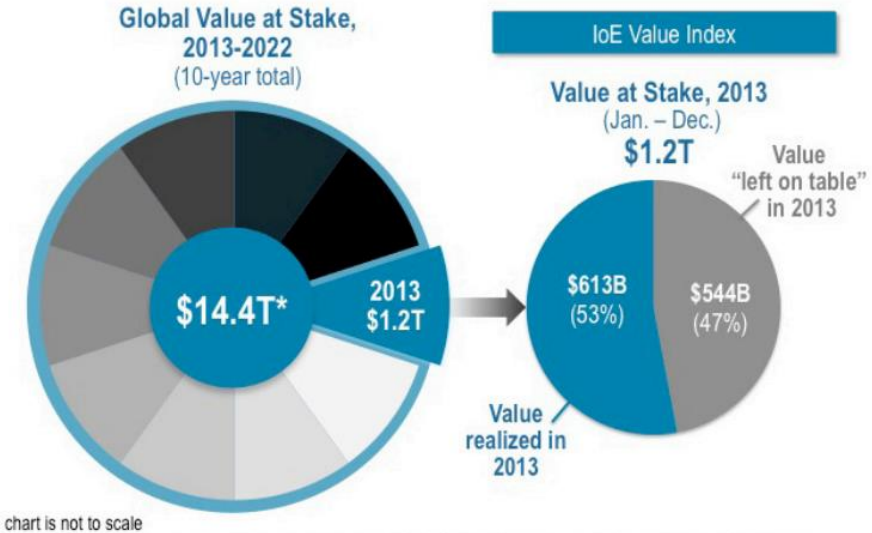
The Industrial Internet of Things

Converge Control Networks to IP

- Make IP networks “Deterministic”
- Emulating existing Industrial protocols

Beyond Control and Automation

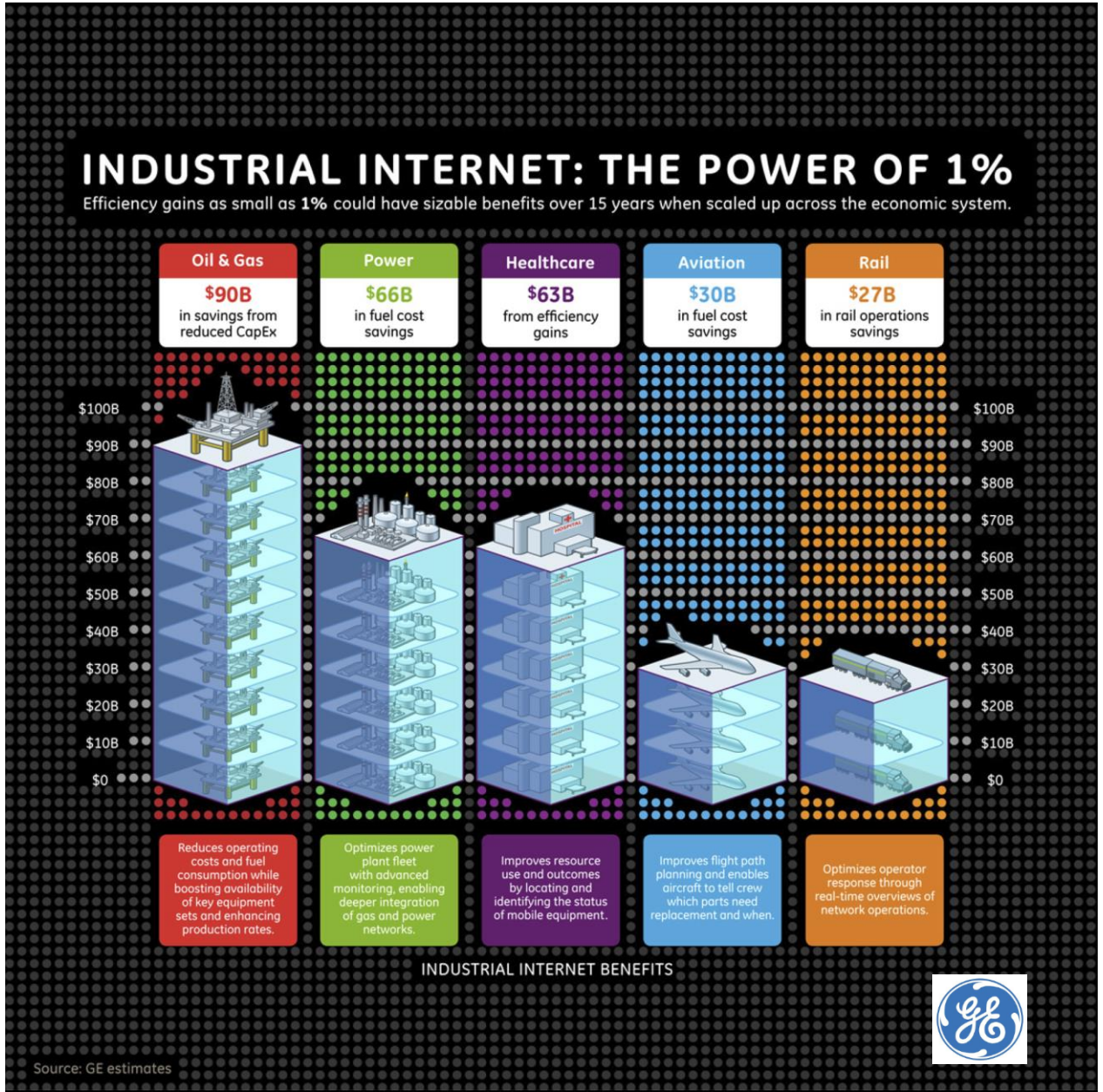
- Optimize processes (by 1%?)
- Leveraging IT, Live big data and Analytics



Note: chart is not to scale

* $14.4T is conservative because it is based on a set number (21) of private-sector use cases and discounts future cash flows due to uncertainty around privacy and regulatory issues.

RTN



What is Deterministic?

(per Wi

I know what, I control when, I can reproduce it every time, guaranteed

In mathematics and physics, a determi is involved in the development of future states of ways produce the same output ial state.

[In philo odel of the philosophical doctrine of determinism applied to g that has and will occur in the system, based on the physical outcomes of system, every action, or cause, produces a reaction, or effect, and every reaction, the cause of subsequent reactions. The totality of these cascading events can theoretically show exactly how the system will exist at any moment in time.

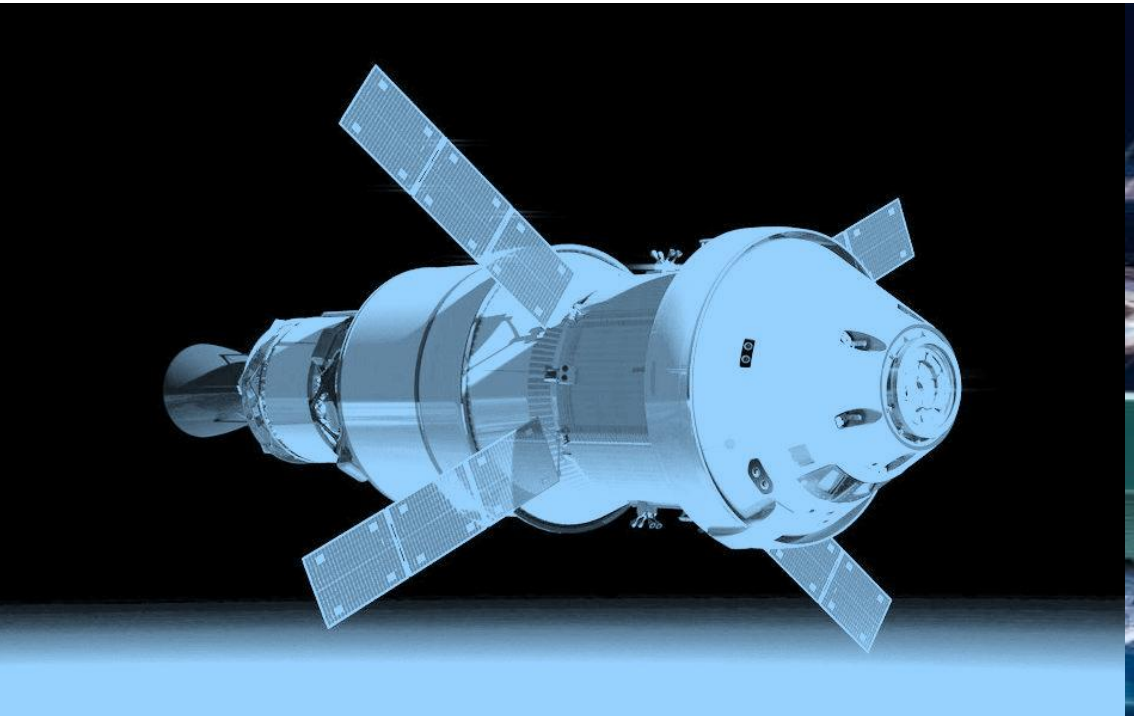
Key Take Aways on Deterministic Networking

Scheduling and Perfect timing for an optimum use of the medium.

=> Low loss / Hard bound latency. A new level of QoS guarantees for IT.

Sharing physical resources with classical best effort networking.

=> High ratio of critical flows for traffic known a priori.



Diverse TDM and Scheduling

Provides similar benefits to wired

⇒ High delivery ratio through path redundancy and collision elimination

⇒ High ratio of critical flows

⇒ Bounded maximum latency (and jitter)

Centrally scheduled operations bring [illegible] wireless

⇒ Medium usage optimizati[illegible]

⇒ Energy savi[illegible] transmission)

But **how th[illegible]y achieved is different** in wireless

⇒ All trar[illegible]ission opportunities **MUST** be scheduled (not just deterministic ones)

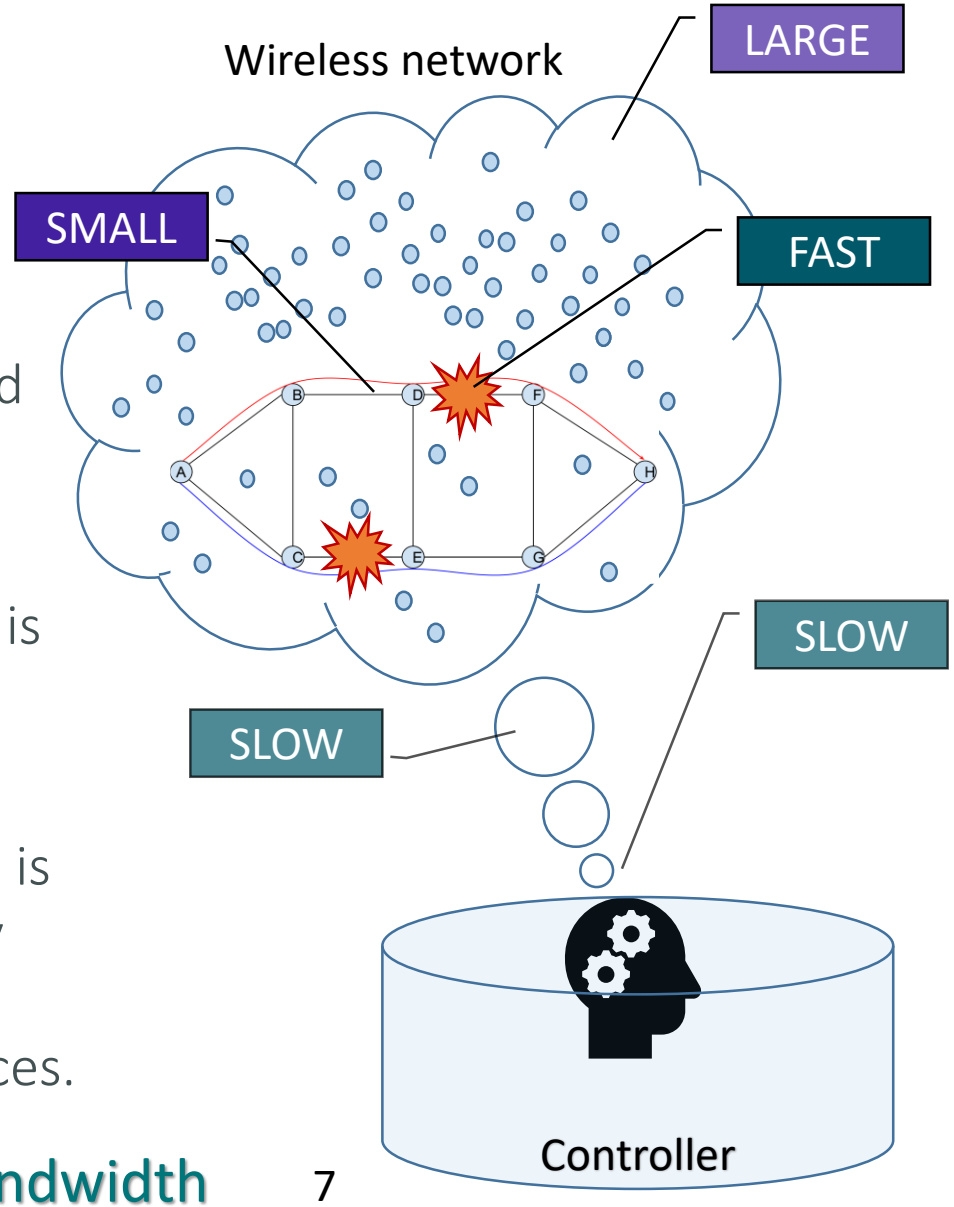
⇒ Reserved scheduled transmission opportunities for critical traffic

⇒ Shared scheduled transmission opportunities & dynamic allocation for best effort

Diversity, Diversity, Diversity

The RAW Problem

- Due to uncontrolled interferences, including the self-induced multipath fading, deterministic networking can only be approached on wireless links.
- The radio conditions may change -way- faster than a centralized routing can adapt and reprogram, in particular when the controller is distant and connectivity is slow and limited.
- RAW separates the routing time scale at which a complex path is recomputed from the forwarding time scale at which the forwarding decision is taken for an individual packet.
- RAW operates at the forwarding time scale. The RAW problem is to decide, within the redundant solutions that are proposed by the routing, which will be used for each individual packet to provide a DetNet service while minimizing the waste of resources.



Terms

- **Reliability**: Reliability is a measure of the probability that an item will perform its intended function for a specified interval under stated conditions. For RAW, the service that is expected is delivery within a bounded latency and a failure is when the packet is either lost or delivered too late. RAW expresses reliability in terms of Mean Time Between Failure (MTBF) and Maximum Consecutive Failures (MCF).
- **Availability**: Availability is a measure of the relative amount of time where a path operates in stated condition, in other words (uptime)/(uptime+downtime). Because a serial wireless path may not be good enough to provide the required availability, and even 2 parallel paths may not be over a longer period of time, the RAW availability implies a path that is a lot more complex than what DetNet typically envisages (a Track)
- **PAREO**: Packet (H)ARQ, Replication, Elimination, and Ordering

=> Includes wireless specific techniques such as Overhearing and Constructive Interference

Status

WG Forming BoF at IETF 106

https://ietf.org/how/meetings/106/

https://trac.tools.ietf.org/bof/trac/wiki

Tentative Charter

https://trac.tools.ietf.org/bof/trac/wiki/RAW

RAW will initially

⇒Document schedulable radio technologies and the basic RAW problem

⇒Provide in-band signaling to control PAREO functions based on specific OAM

Available drafts

Generic info

https://tools.ietf.org/html/draft-thubert-raw-technologies

https://tools.ietf.org/html/draft-bernardos-raw-use-cases

https://tools.ietf.org/html/draft-maeurer-raw-ldacs

Problem statement and requirements

https://tools.ietf.org/html/draft-pthubert-raw-problem-statement

https://tools.ietf.org/html/draft-papadopoulos-raw-pareo-reqs

https://tools.ietf.org/html/draft-theoleyre-raw-oam-support

Externally sponsored solution drafts

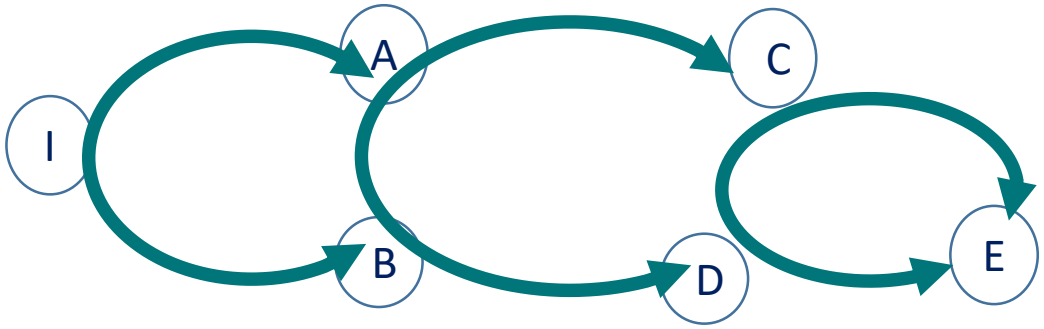
https://tools.ietf.org/html/draft-ietf-roll-nsa-extension

https://tools.ietf.org/html/draft-thubert-bier-replication-elimination

RAW: Forwarding plane optimization

Radios are lossy, but they are also inherently broadcast:
Use that latter property as a compensation for the former

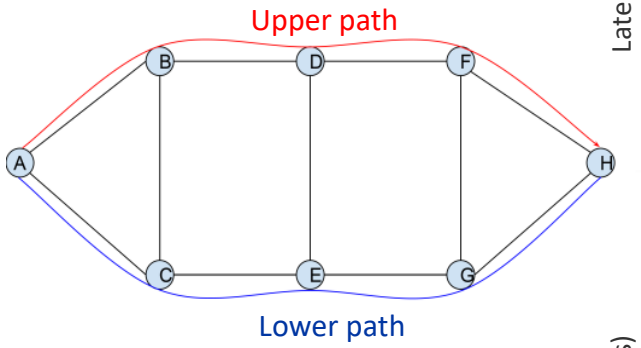
1. Multipath Tracks with the general shape of a cord ladder

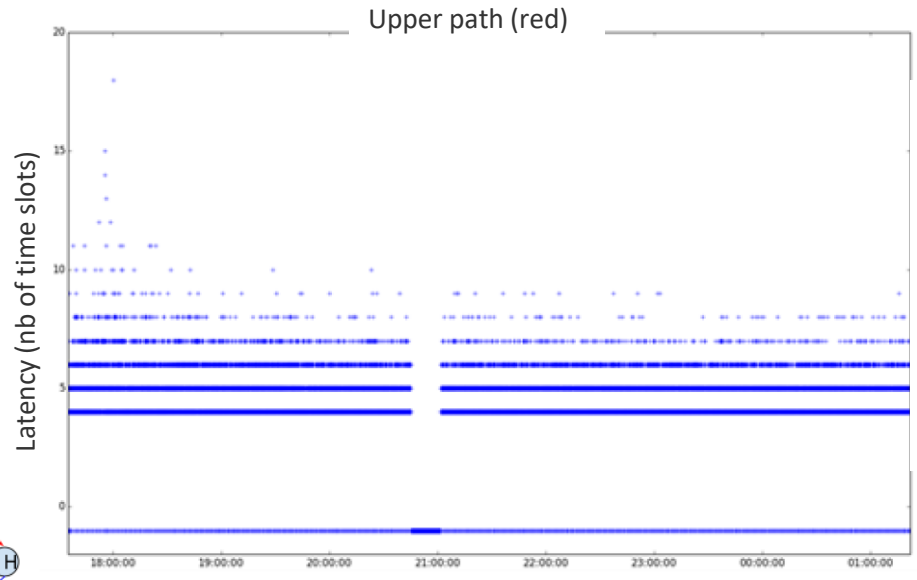


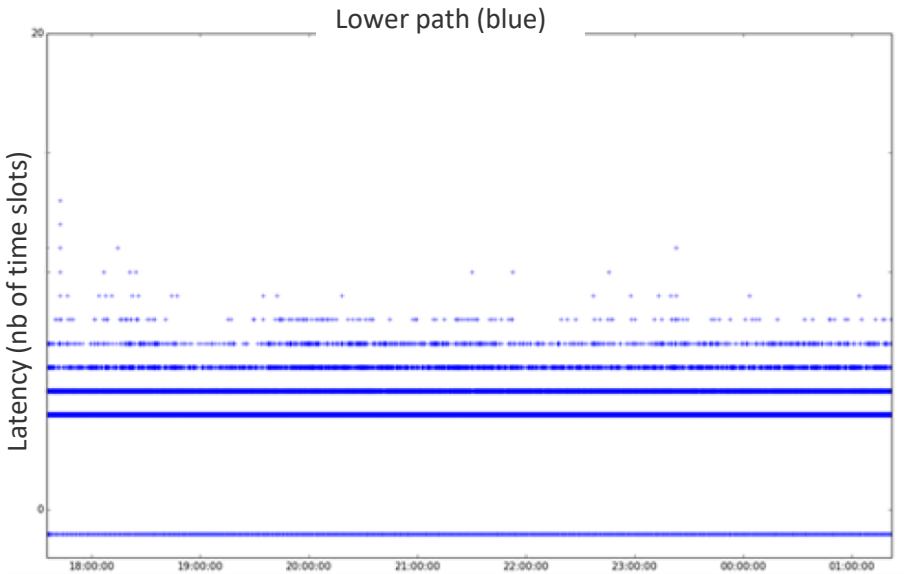
2. Control the replication and elimination to save energy
3. Use intelligent flooding leveraging broadcast properties

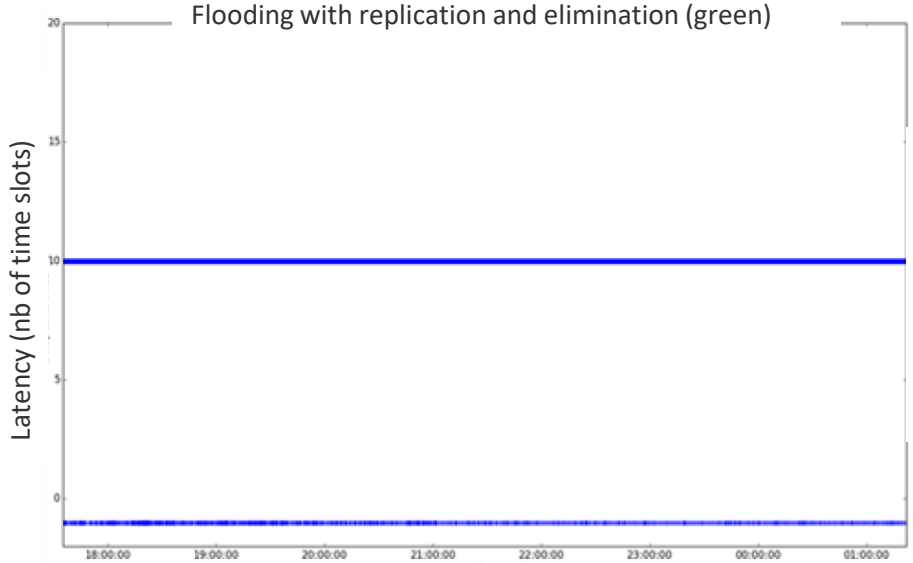
Goals: minimize energy, minimize latency, optimize delivery and avoid 4 losses in a row

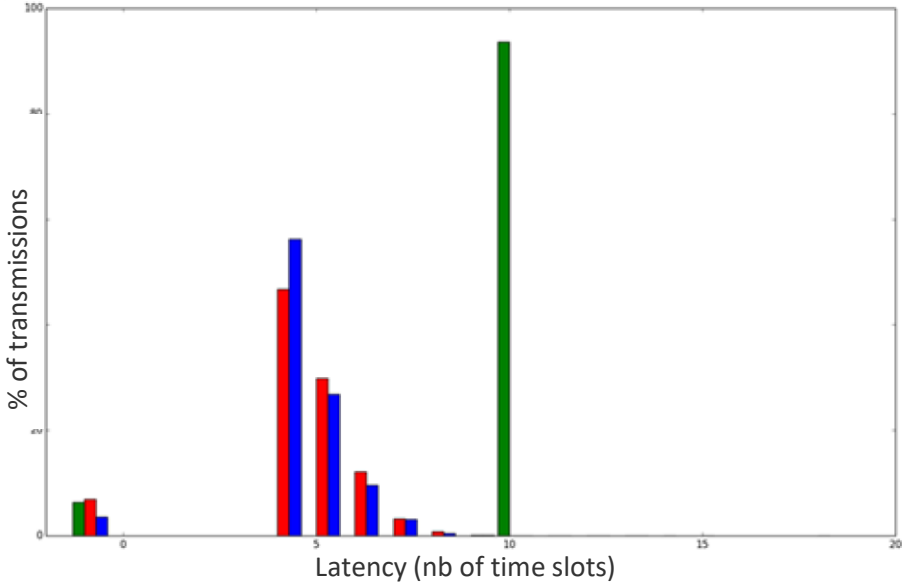
Replication and Elimination vs. Serial Path



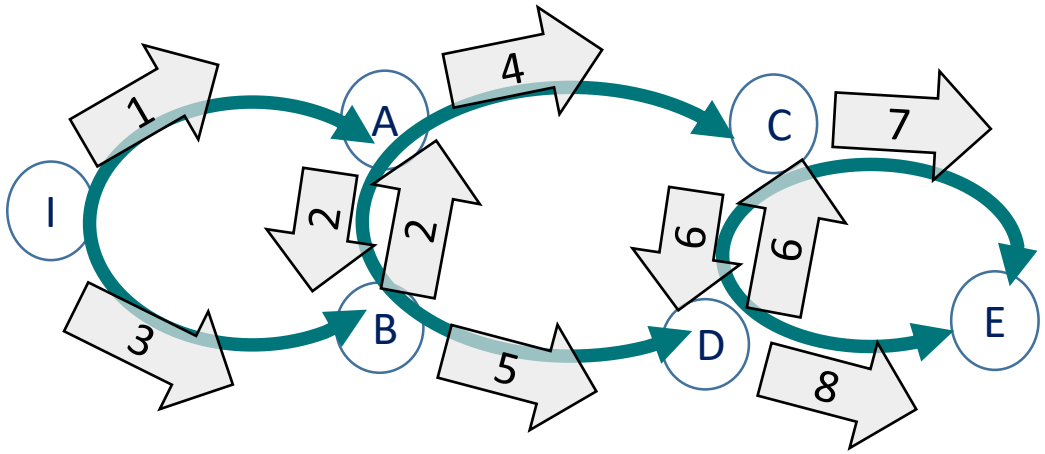






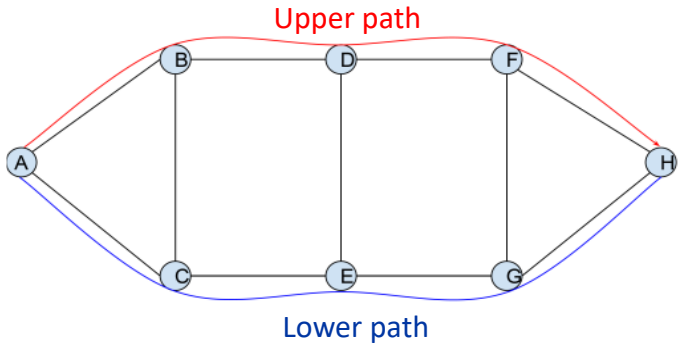


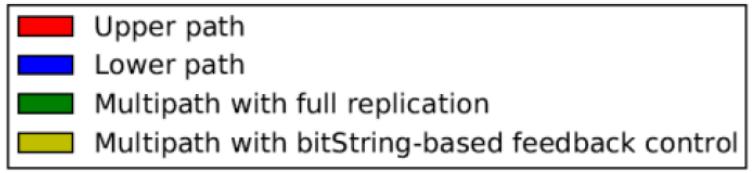
Detecting and routing around errors

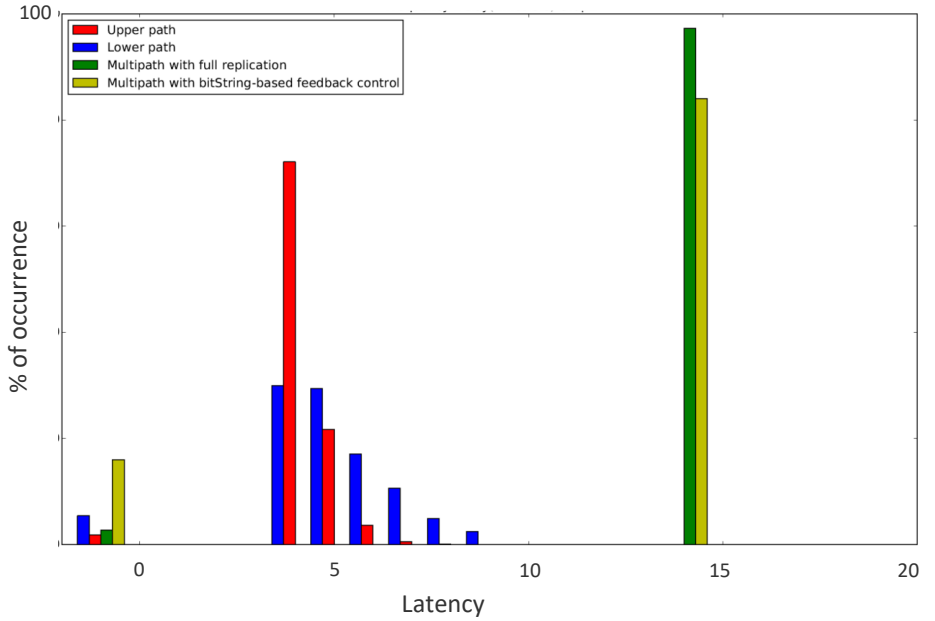


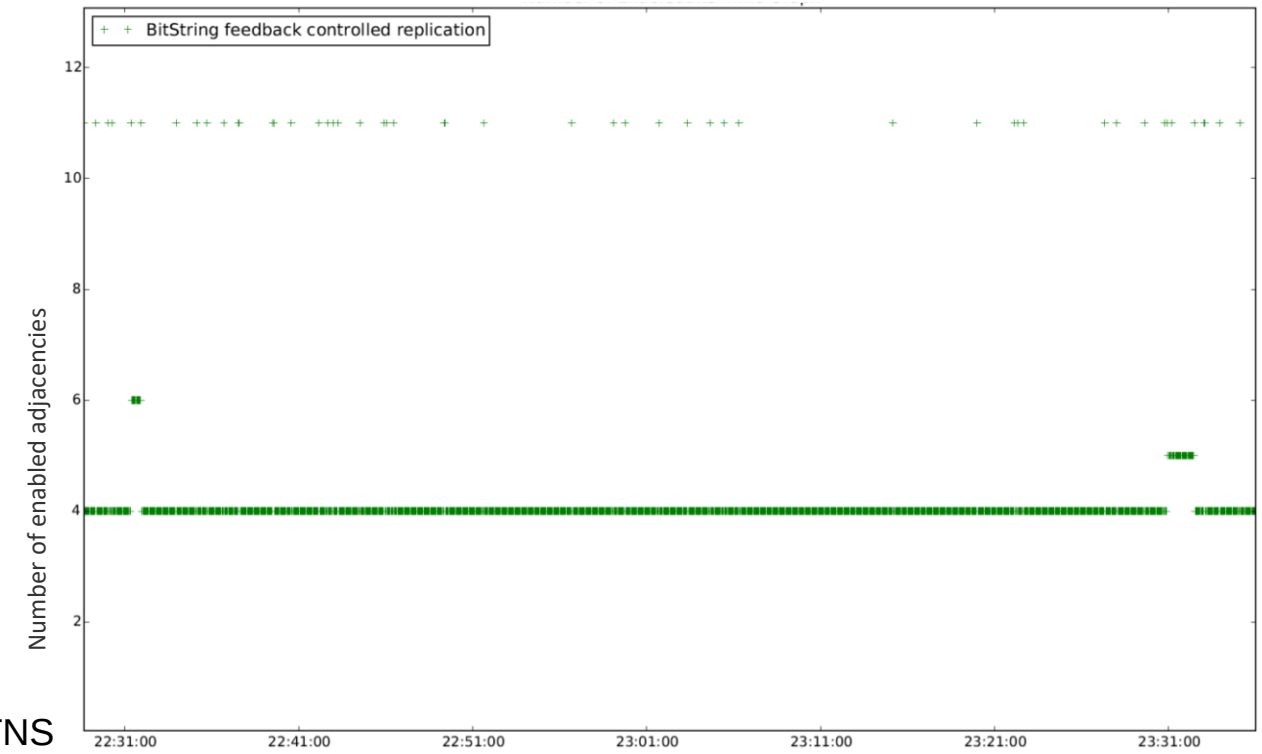
Failing Adjacency	BIER BitString at Egress
I->A	Frame Lost
I->B	Not Tried
A->C	00010000
A->B	01001100
B->D	
D->C	
C->E	Frame Lost
D->E	Not Tried

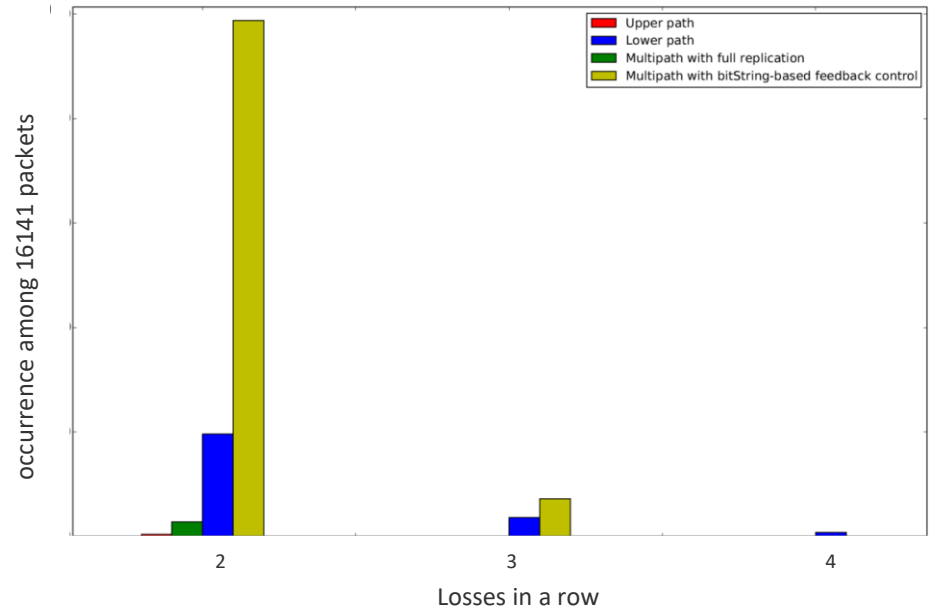
Energy Saving







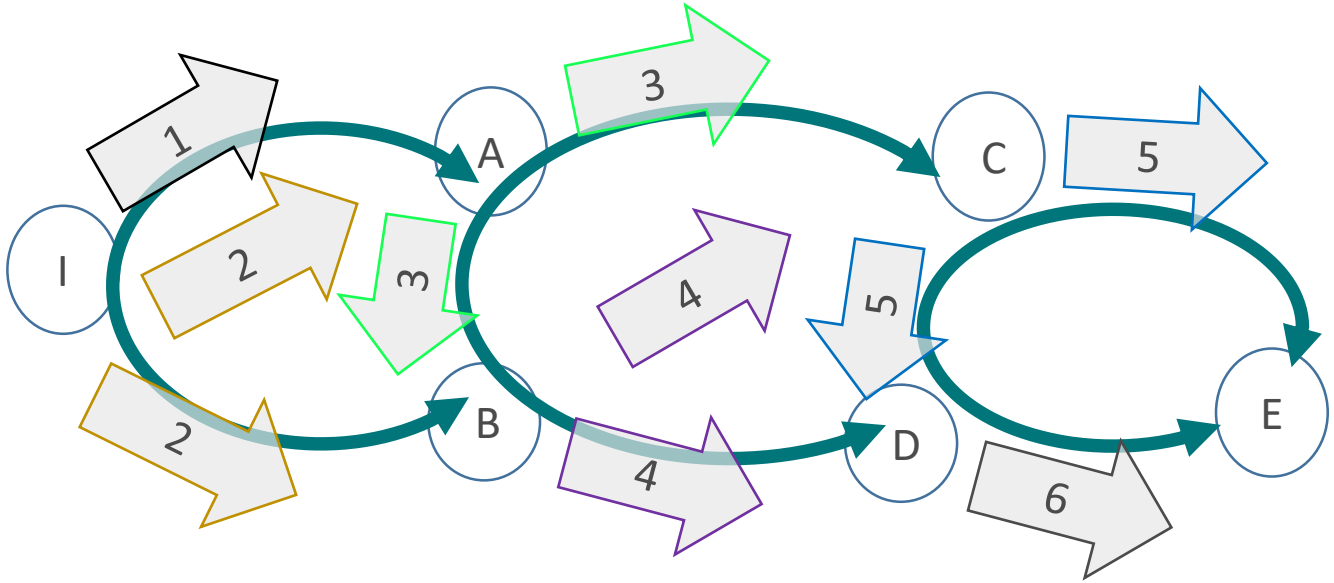




Controlling Xcasting along the Track

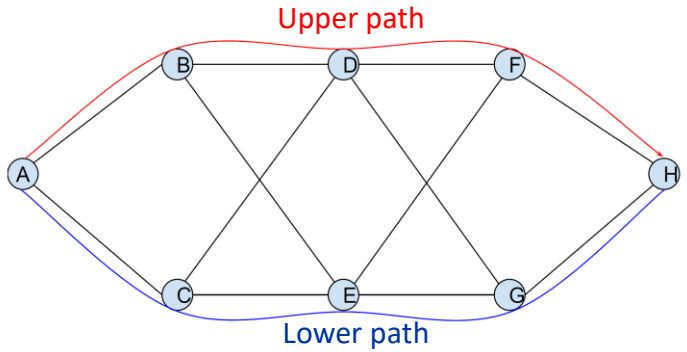
Novelty: Collaborative overhearing to improve latency while preserving energy

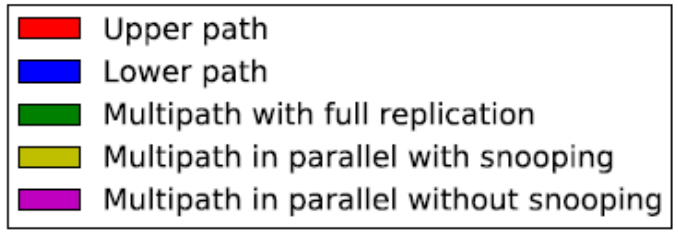
Use RPL non storing mode to expose topology
Enables and schedules >1 downstream listeners



ctrl #	Adjacency	Owner
1	I->A(,B)	I
2	I->B,A	I
3	A->C,B	A
4	B->D,C	B
5	C->D,E	C
6	D->E	B

Optimizing use of Track





Multipath with full replication:

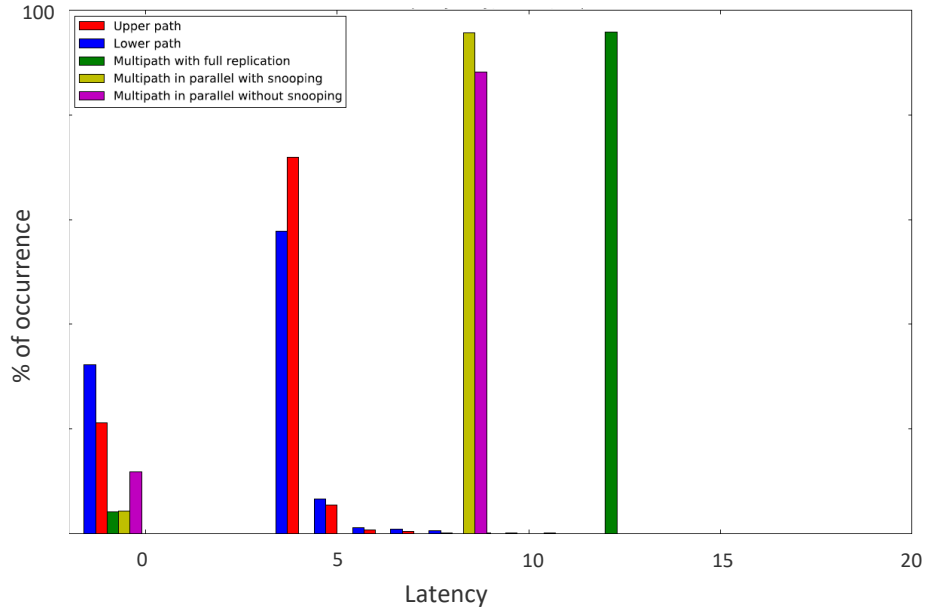
0	1	2	3	4	5	6	7	8	9	10	11
A --> B	A --> C	B --> E	B --> D	C --> E	C --> D	D --> G	D --> F	E --> G	E --> F	F --> H	G --> H

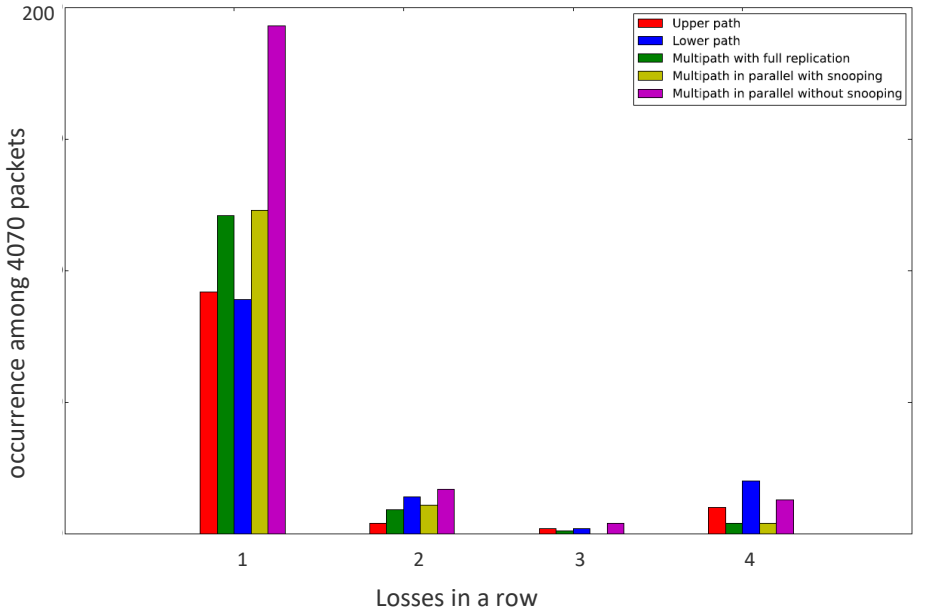
Multipath in parallel with snooping:

0	1	2	3	4	5	6	7	8	9	10	11
A --> B,C	A --> C,B	B --> E,D	C --> E,D	D --> G,F	E --> G,F	F --> H	G --> H				

Multipath in parallel without snooping:

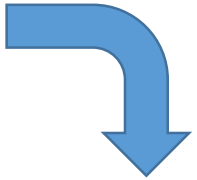
0	1	2	3	4	5	6	7	8	9	10	11
A --> B	A --> C	B --> D	C --> E	D --> F	E --> G	F --> H	G --> H				





Questions

More details if time permits ☺



Benefits of scheduling in wired networks

- Eliminate congestion loss
  - ⇒ Controlled amount of traffic
  - ⇒ Available Resources (bandwidth and buffers) guaranteed
- Guaranteed latency
  - ⇒ Deterministic Progress along Scheduled path
  - ⇒ Nor ARQ: Forward Error correction, Network coding
- (Nearly) Eliminate equipment failure losses
  - ⇒ Frame/Packet Replication and Elimination

Towards Highly Reliable Wireless

Controlling time of emission

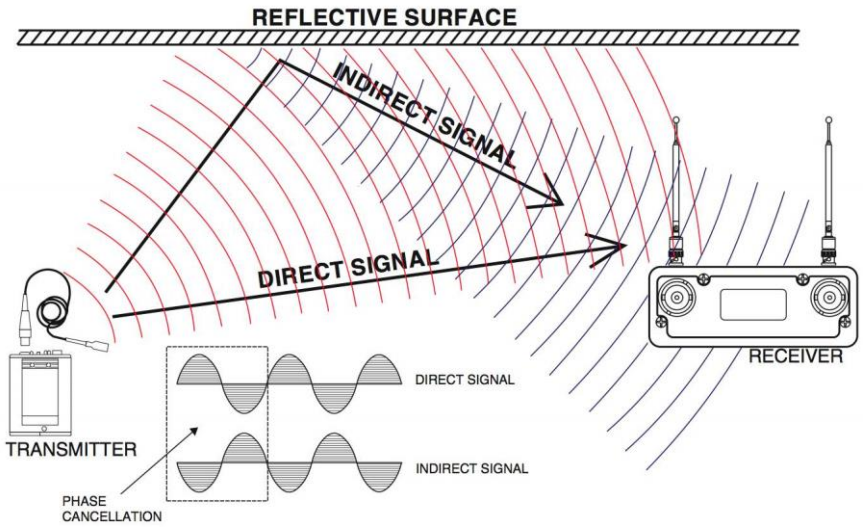
- Can achieve ~10µs sync on 802.15.4
- Can guarantee time of delivery

Protection the medium

- ISM band crowded, no fully controlled
- all sorts of interferences, including self
- Can not guarantee delivery ratio

Improving the Delivery ratio

- Different interferers => different mitigations
- Diversity is the key



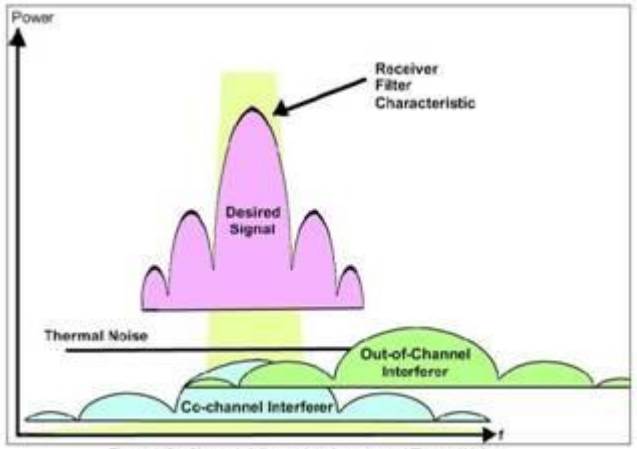


Figure 1. Co-Channel, Adjacent Interference, and Thermal Noise
All signals are referenced to zero power level.

The bus analogy (to deterministic circuit switching)

A bus every T. minutes => guaranteed latency max_wait + travel

Reserved bus lanes => no interaction with other traffic

Switching buses => Lower complexity but increased latency

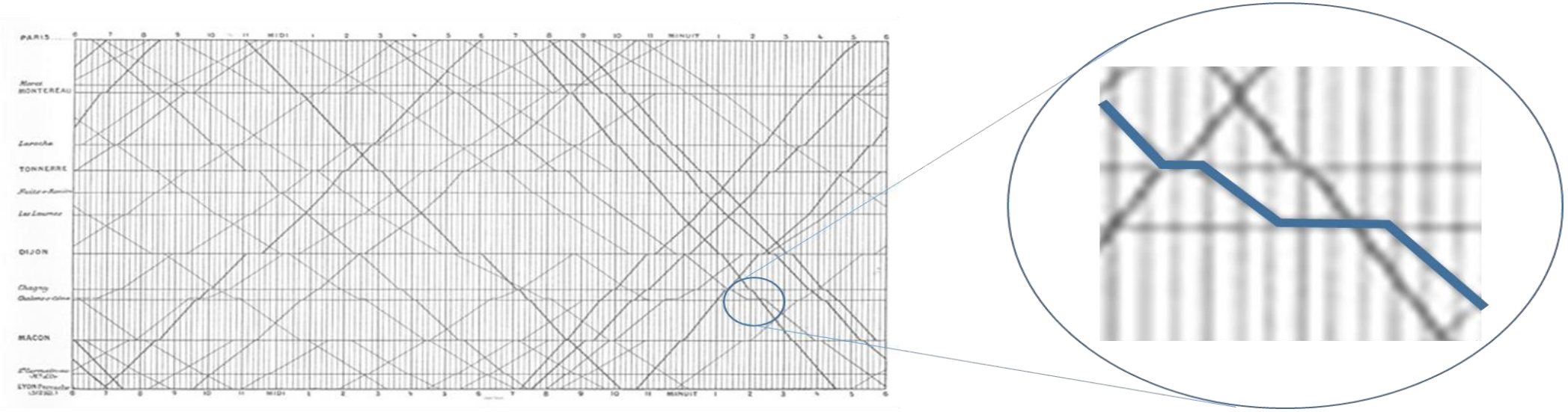
Towards a perfect emulation of a serial cable over a switched network

The Train Analogy (to control loop traffic)

Periodic trains along a same path and same schedule (time table)

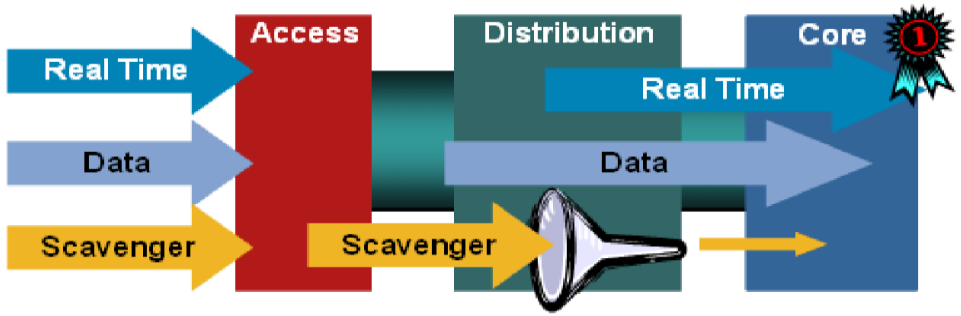
Collision avoidance on the rails guaranteed by schedule

End-to-End latency enforced by timed pause at station



Typical deterministic flows incur a higher latency than “hot potato”

The casino analogy (to statistical effects)



The Law of large numbers says:

Long term, the casino **will** win.

Long term, for any value of *X*, some player will win **more** than *X*.

- That's in theory an unbounded peak

The object of DetNet is to remove chance from the picture.

We have always been in the business of optimizing average throughput and latency. (The law of large numbers.)

- => A deterministic flow must traverse the network in the same predictable fashion every time, regardless of the load of the network.