The Wireless FRINGE

scal Thubert
vanced Architecture and Research

e 27th, 2013

Agenda

The Fringe of the Internet

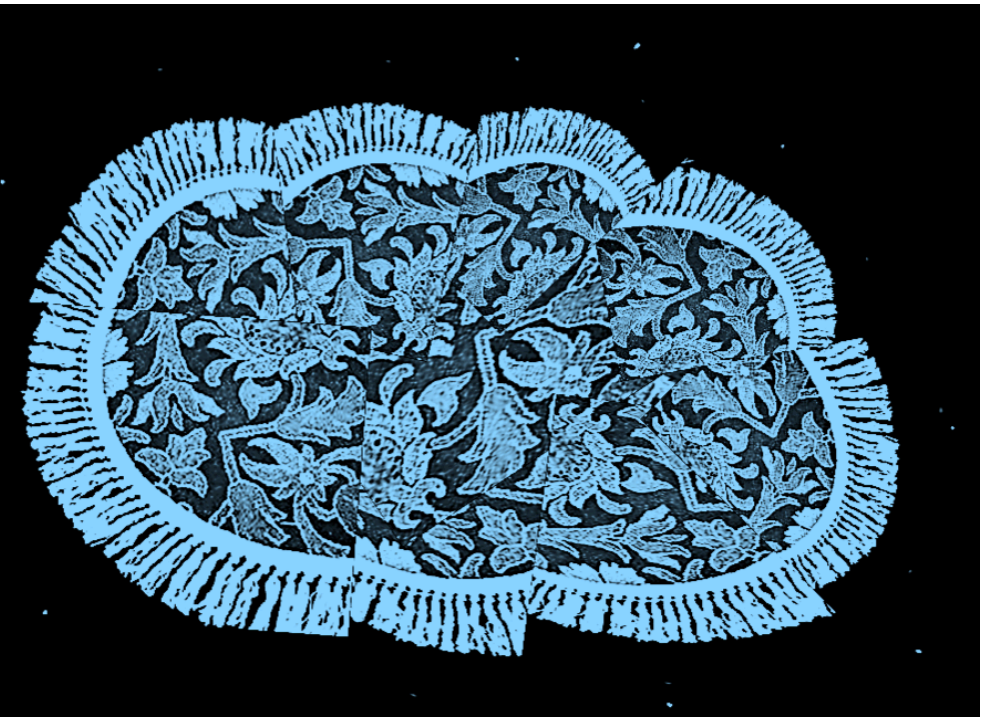
The Fringe backbone

The Deterministic Fringe

6TSCH

Polymorphic Flows

The routing infrastructure, today



The Internet

- Fully engineered
  - Hierarchical, Aggregations, ASs, Wire links
- Fully distributed States
  - Shows limits (BGP tables, addr. depletion)

⇒ Reached adult size, mature to aging

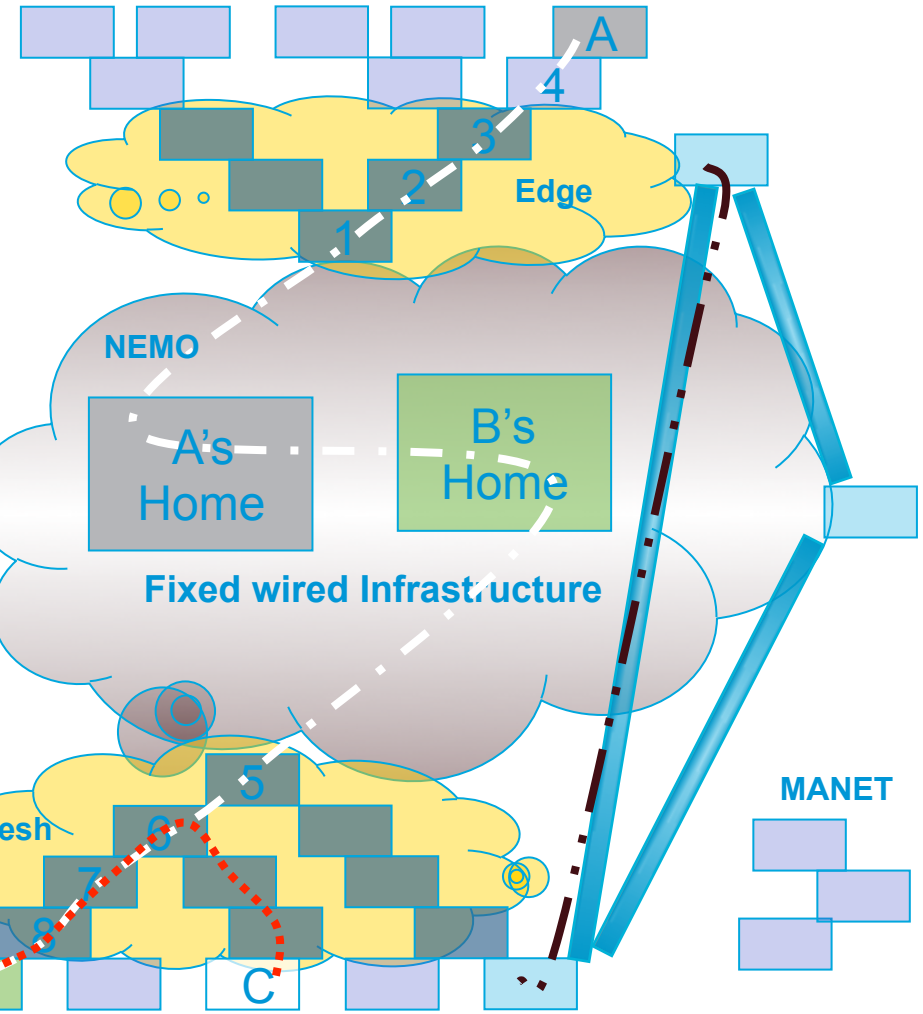
⇒ Conceptually unchanged by IPv6

IPv4 Intranets

- Same structure as the Internet
- Yet decoupled from the Internet
  - NAT, Socks, Proxies

⇒ First model for Internet extension

The emerging Fringe of the Internet



L2 mesh Under

Multi-hop Public Access Points,
Proprietary mission specific products
Getting Deterministic

L3 Route Over

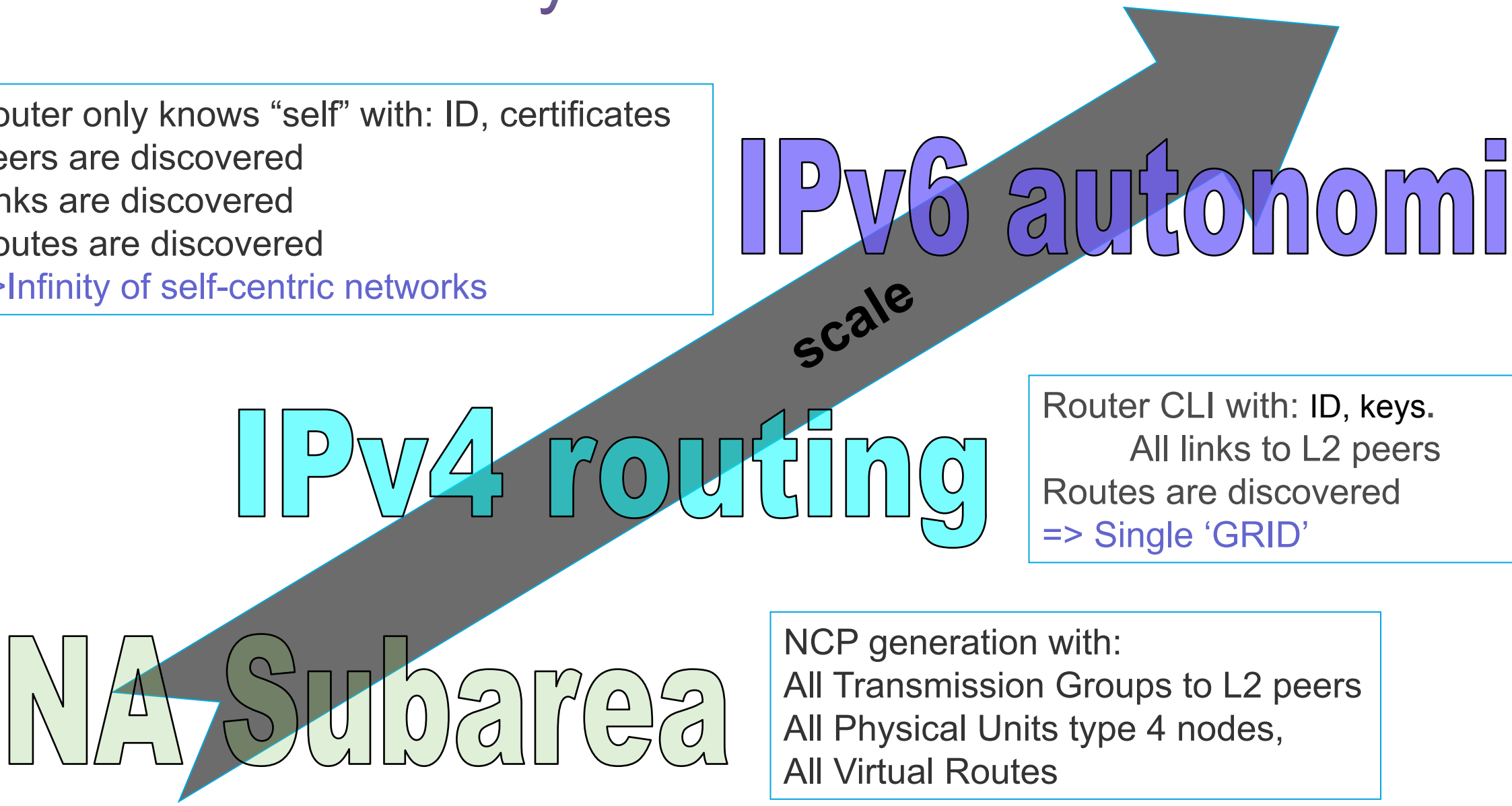
Migration to IETF Protocols (RPL)
Internet of Things (IOT, M2M)
Different IPv6 (6LoWPAN, SDN)

Mobile Overlays

Global reachability (NEMO, LISP, DMM)
DataCenter Network virtualization (NVO3, LISP
Route Projection

The Fringe DOES NOT LEAK into the Routing Infrastructure

A sense of history



Scaling to Pervasive IoE/T

000*scale => No leak in the Internet

=> Opaque Fringe operations

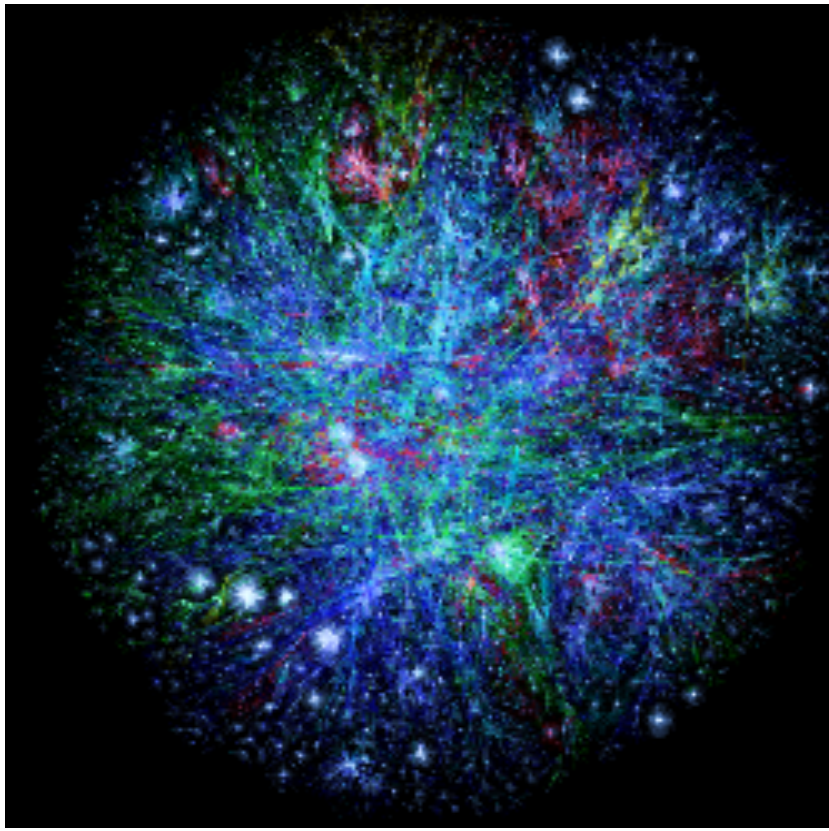
=> Federating backbone

Reachability => Radio

Addressing => IPv6

Density => spatial reuse

=> Routing

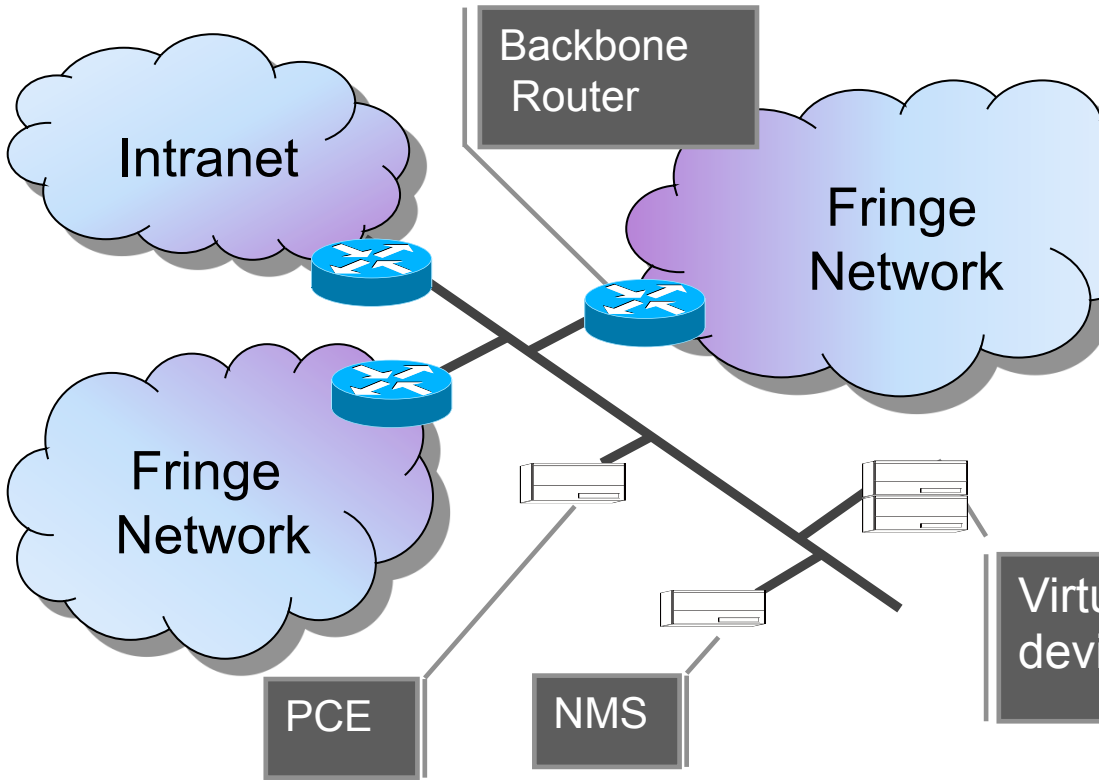


Agenda

- The Fringe of the Internet
- The Fringe backbone
- The Deterministic Fringe
- 6TSCH
- Polymorphic Flows

ackbone Devices

- Wired or Wireless
- Switches and Controllers
  - Wireless ND
  - Global Mobility integration
- Virtualized Functions
  - PCE for deterministic route computation
  - Legacy Appliances e.g. industrial PLC



The IPv6 Neighbor Discovery (R)evolution

A new Efficient ND, aka WiND for Wireless ND

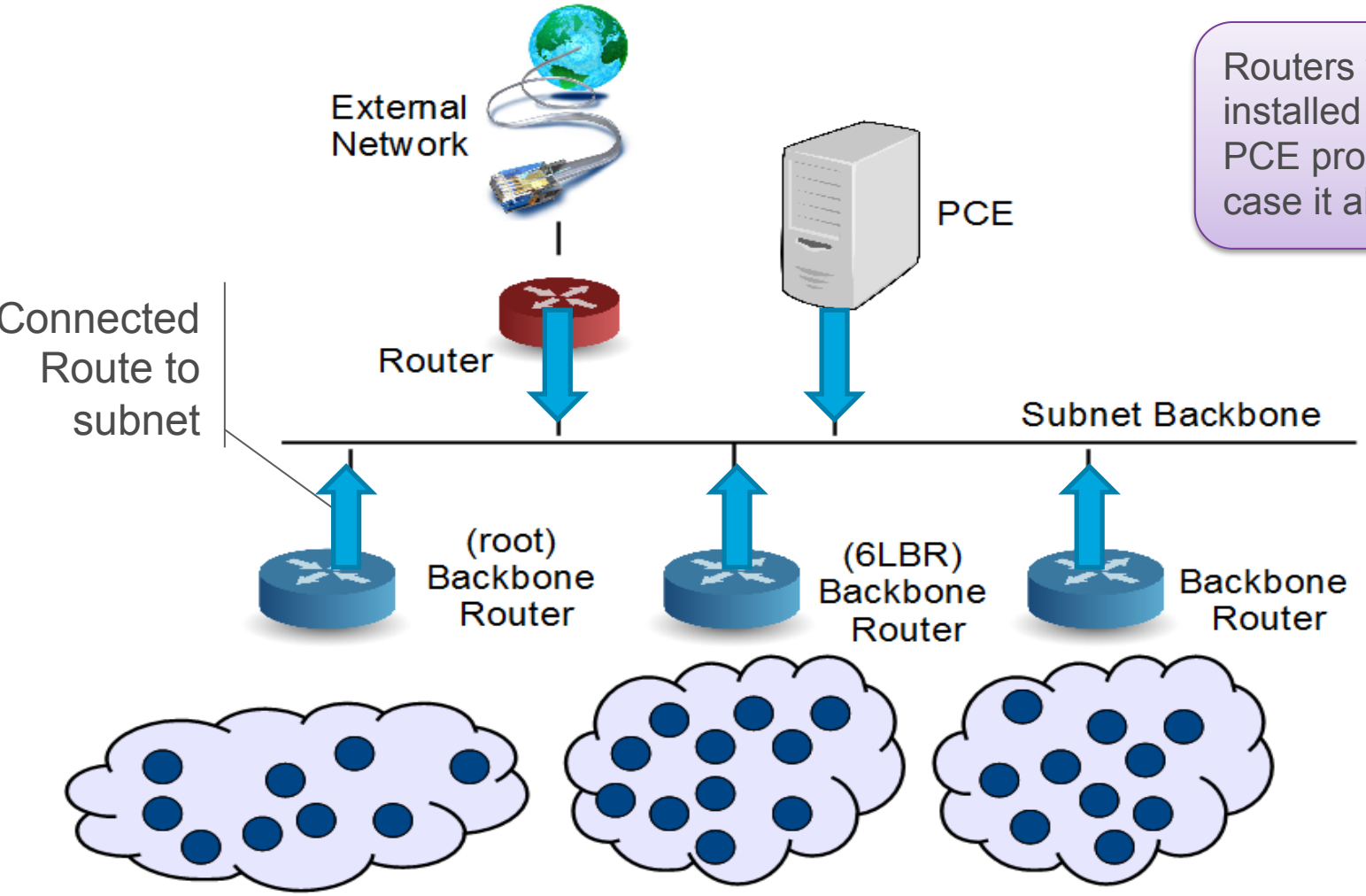
Registration and Duplicate Address Detection (DAD)

- extending 6LoWPAN ND over the backbone

Resolution

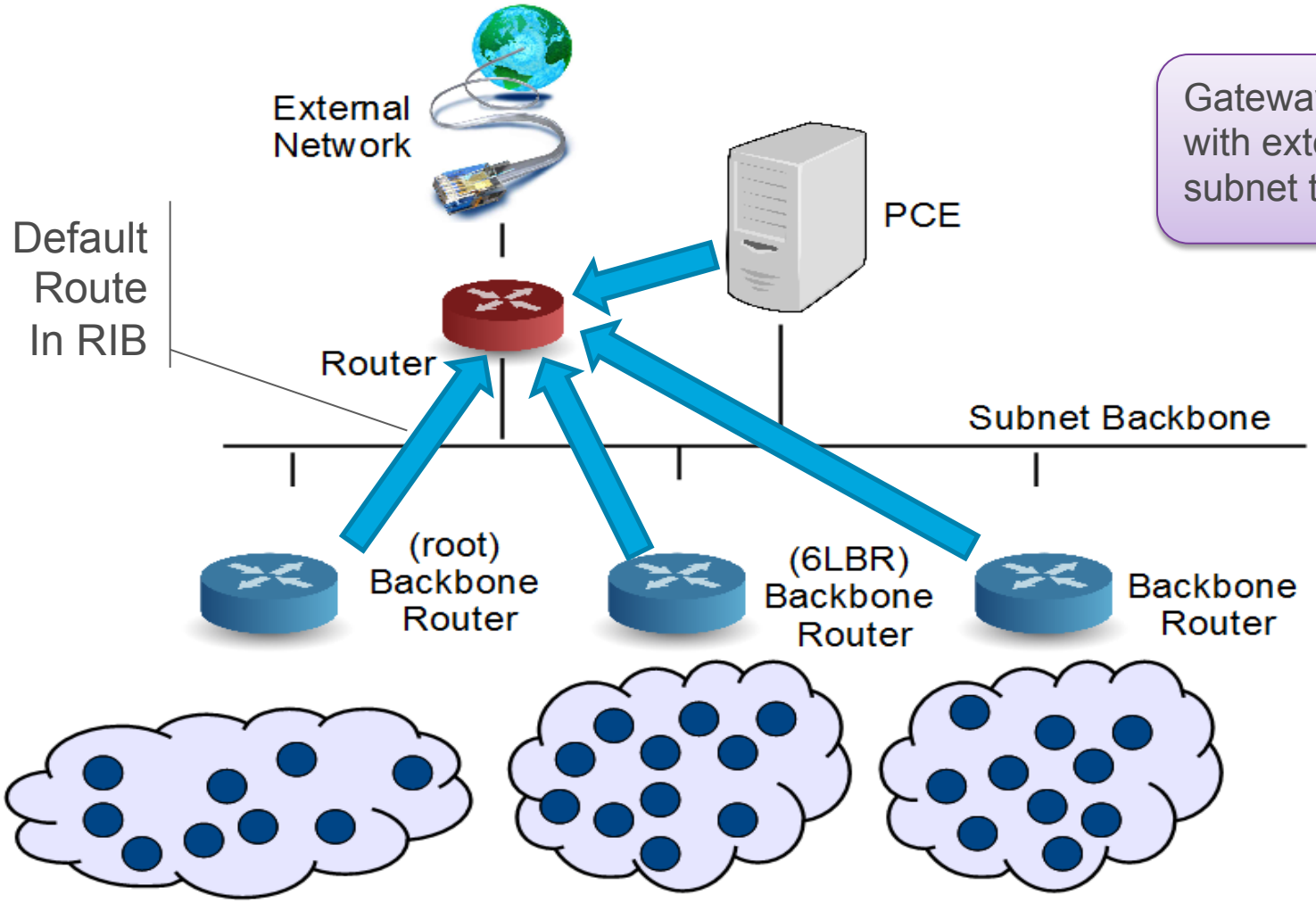
- Distributed through proxy-ND
- Routing in not-onlink mode

Initial time



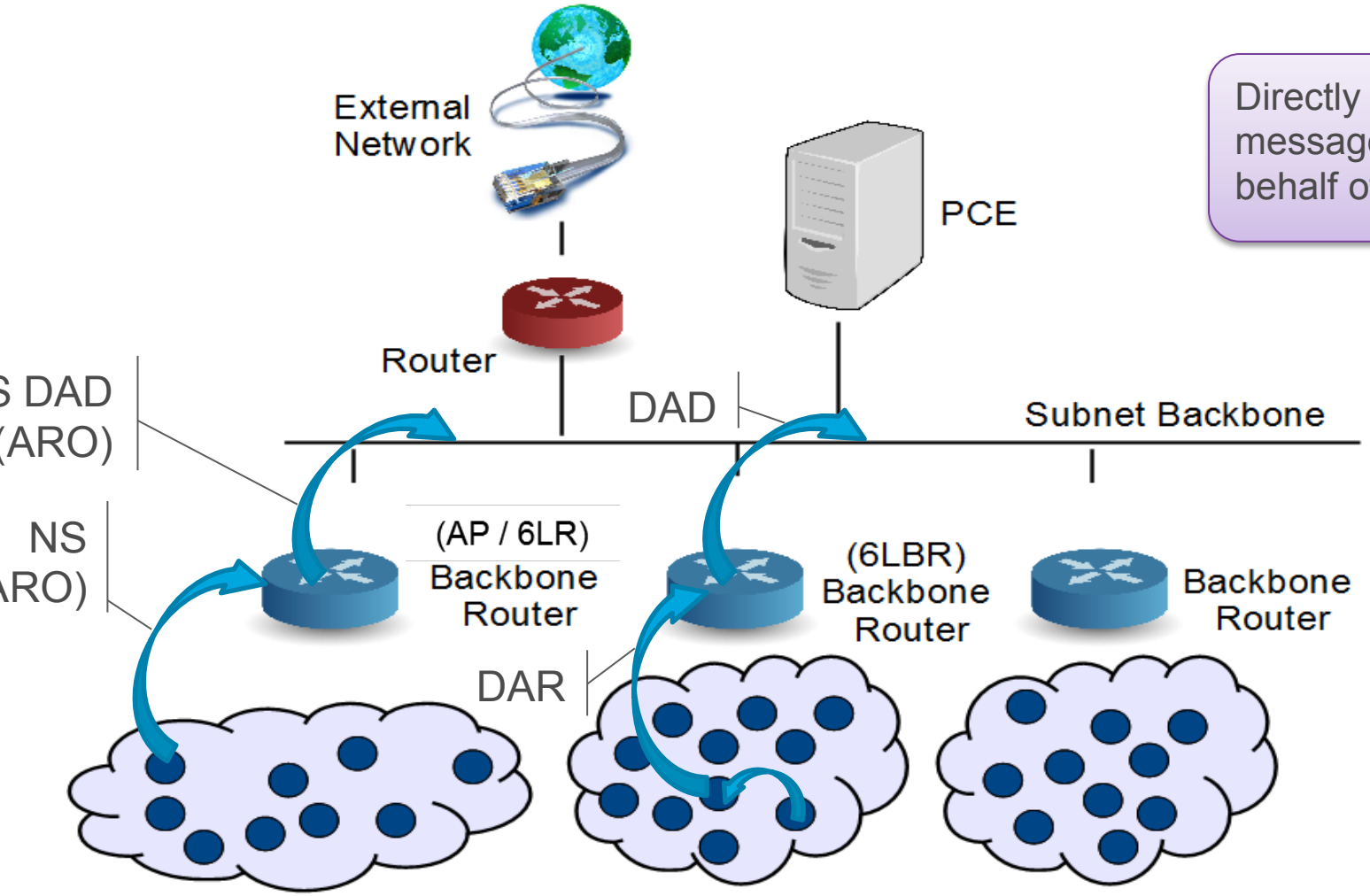
Routers within subnet have a connected route installed over the subnet backbone.
PCE probably has a static address in which case it also has a connected route

First advertisements from GW (RA, IGP, RPL)



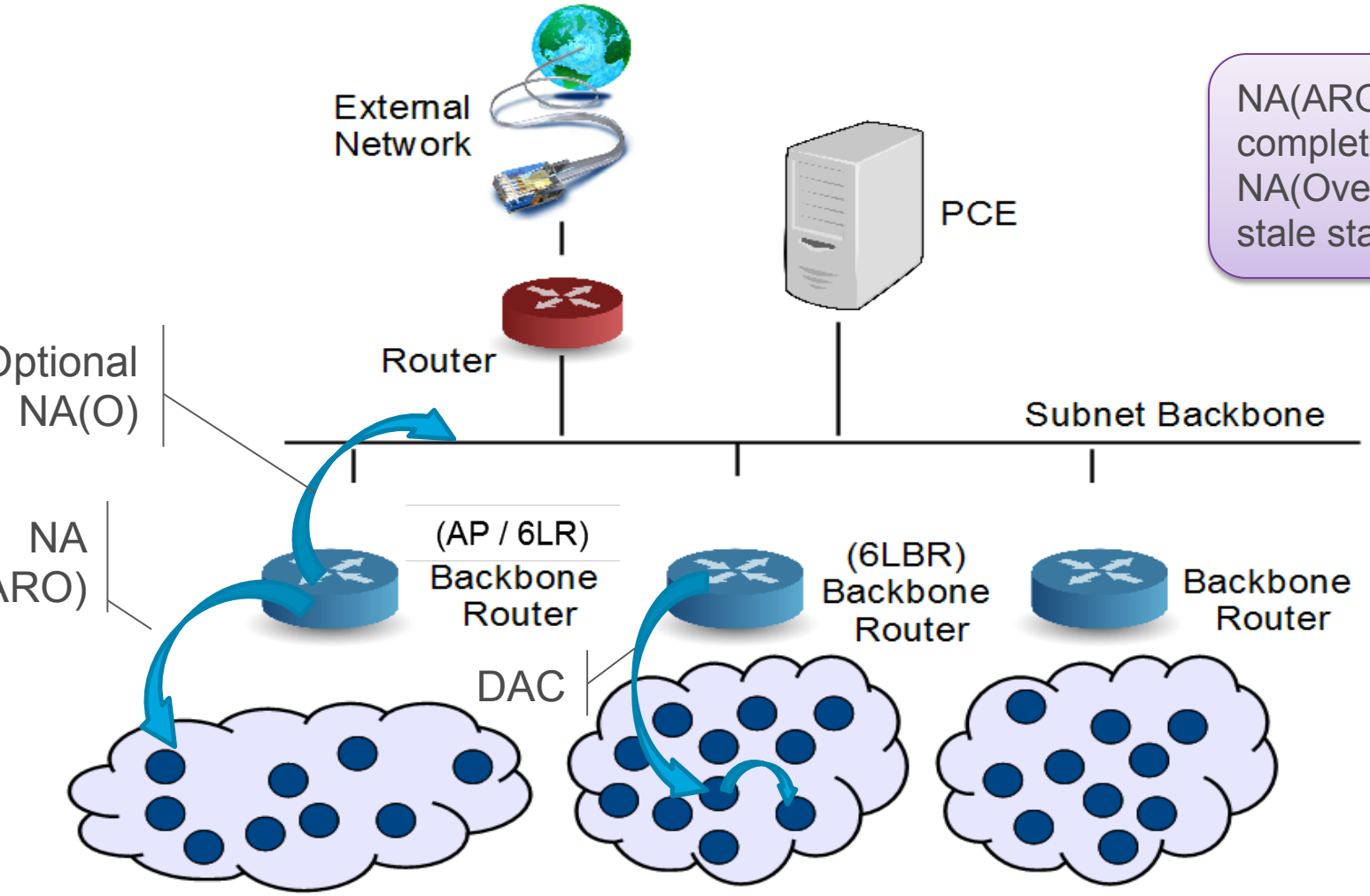
Gateway to the outside participate to some IG with external network and attracts all extra-subnet traffic via protocols over the backbone

IPv6 ND Registration to 6LR and 6LBR



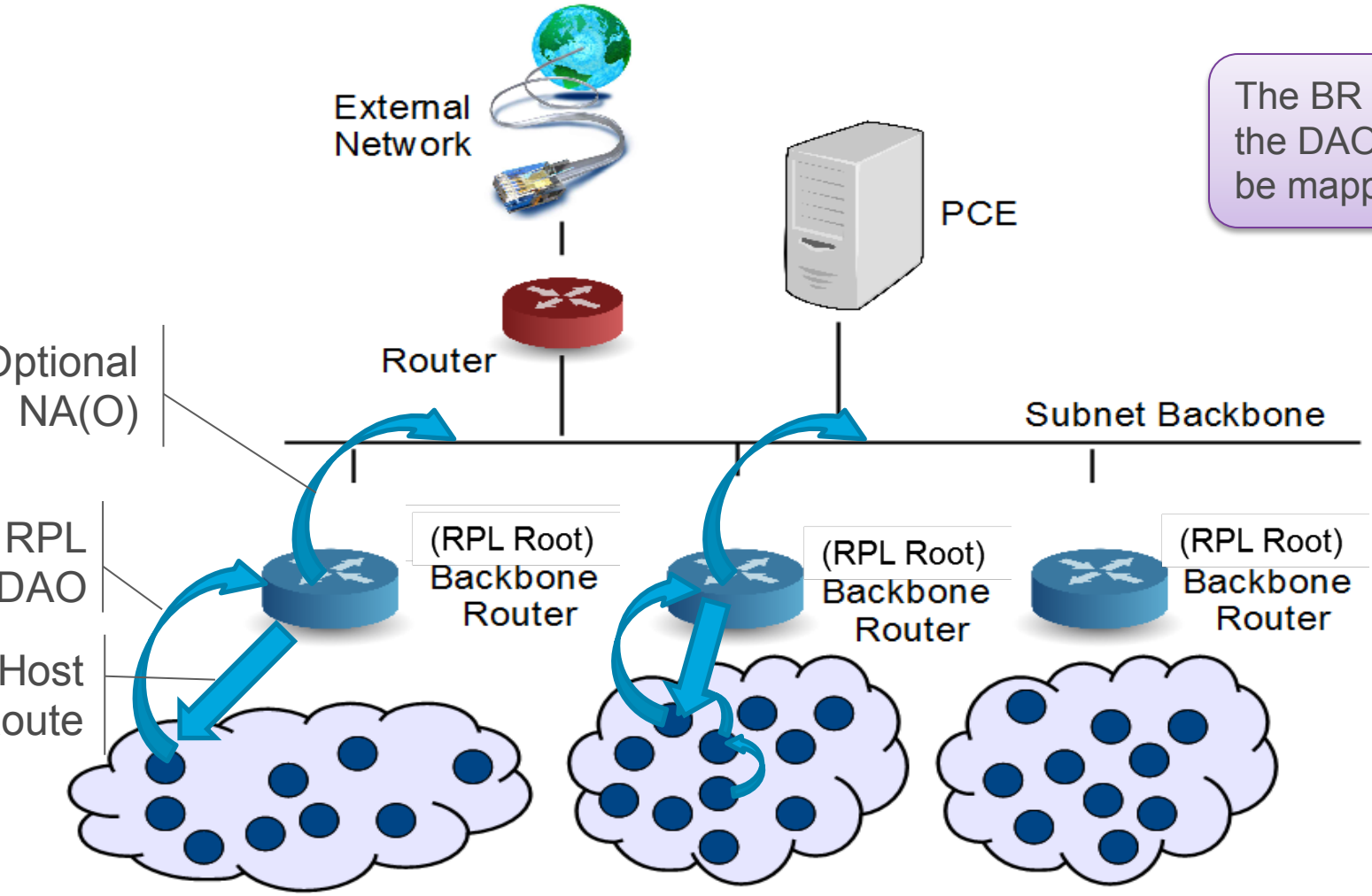
Directly upon NS(ARO) or indirectly upon DA message, the backbone router performs DAD behalf of the wireless device.

IPv6 ND Registration and Proxy for NS ARO



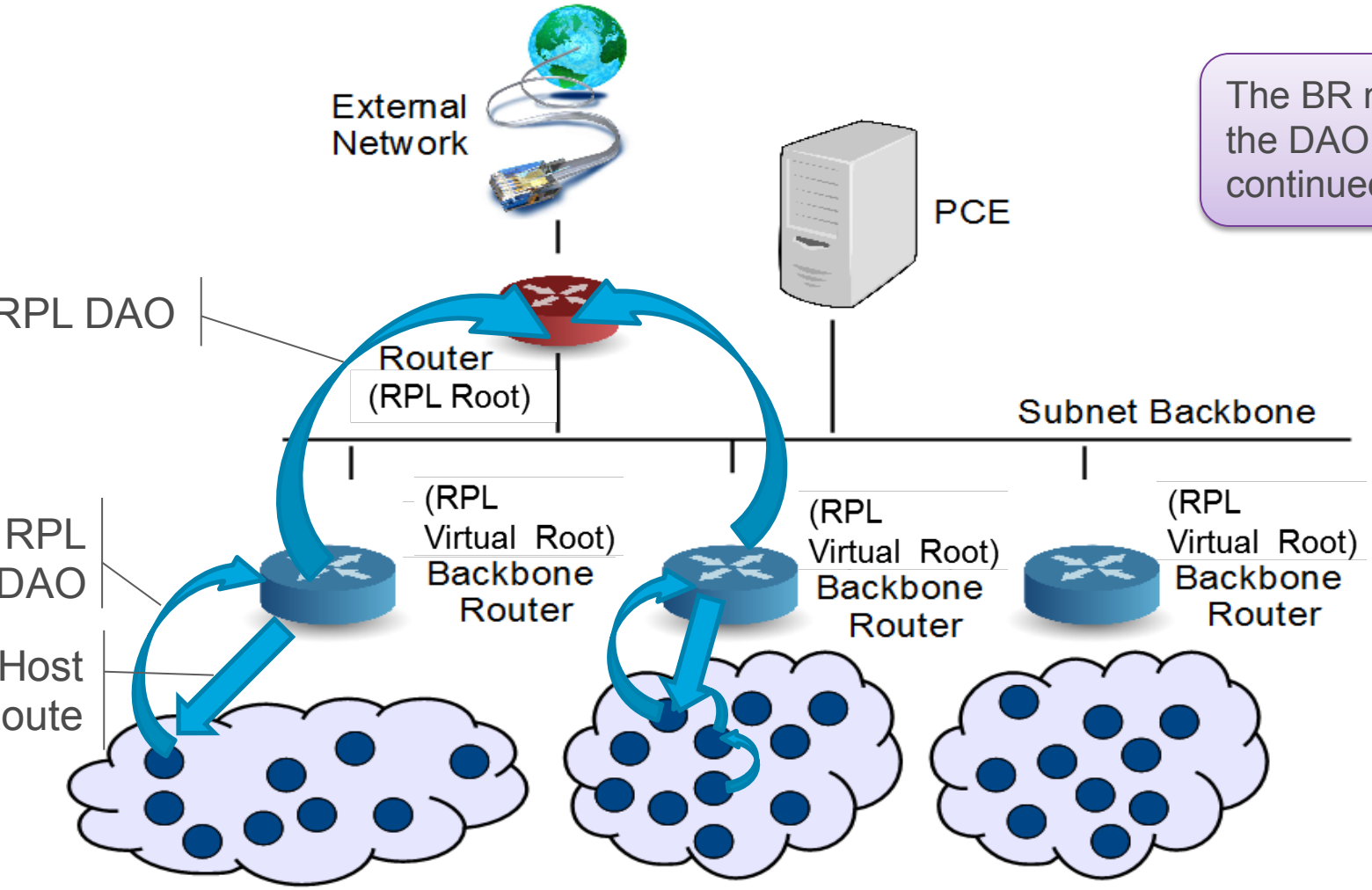
NA(ARO) or DAC message carry succeful completion if DAD times out.
NA(Override) is optional to clean up ND cach stale states, e.g. if node moved.

IPv6 ND Proxy for RPL



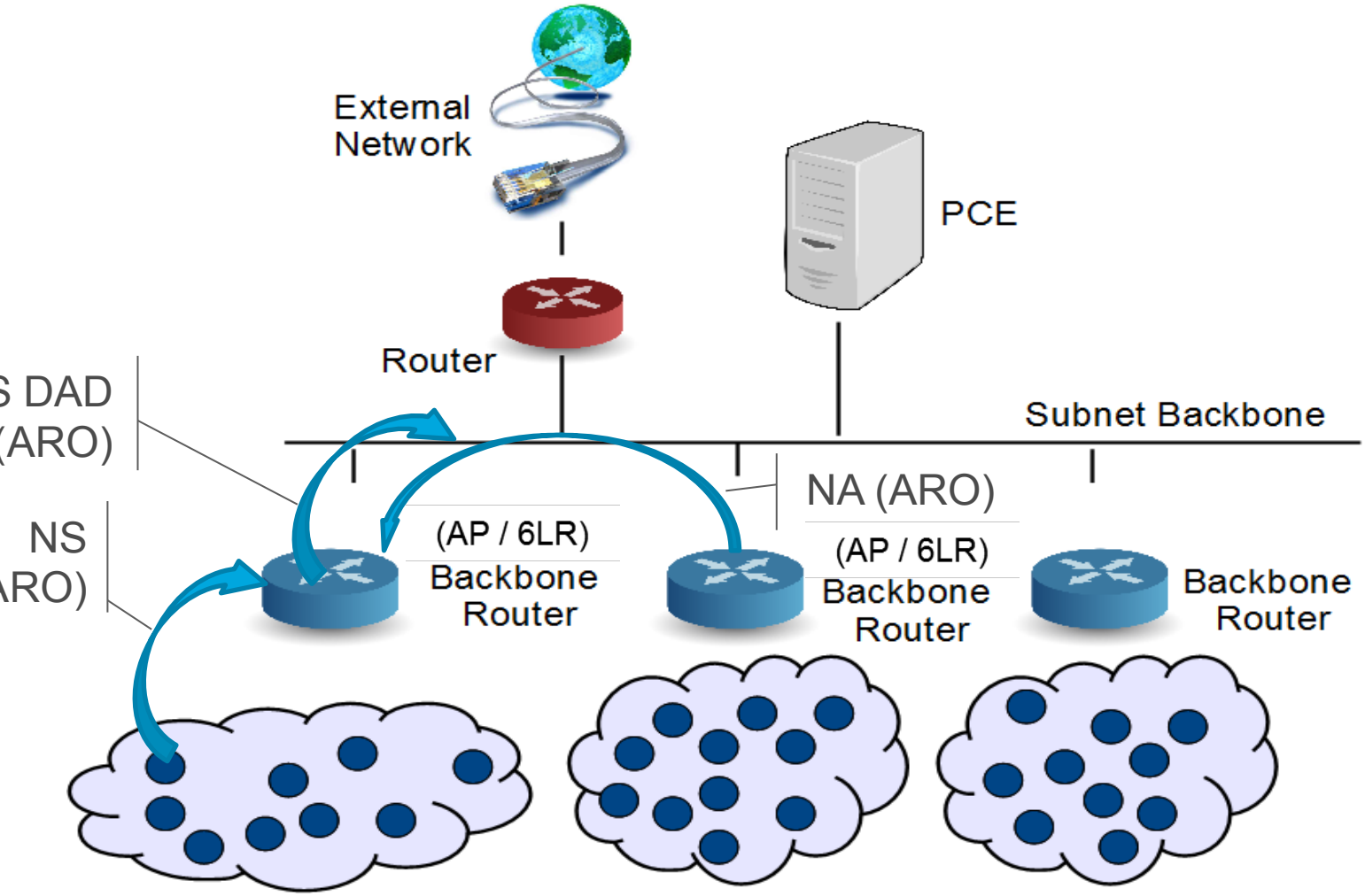
The BR maintains a route to the WSN node fo the DAO Lifetime over instance VRF. VFR ma be mapped onto a VLAN on the backbone.

RPL over the backbone



The BR maintains a route to the WSN node fo the DAO Lifetime over instance VRF that is continued with RPL over backbone.

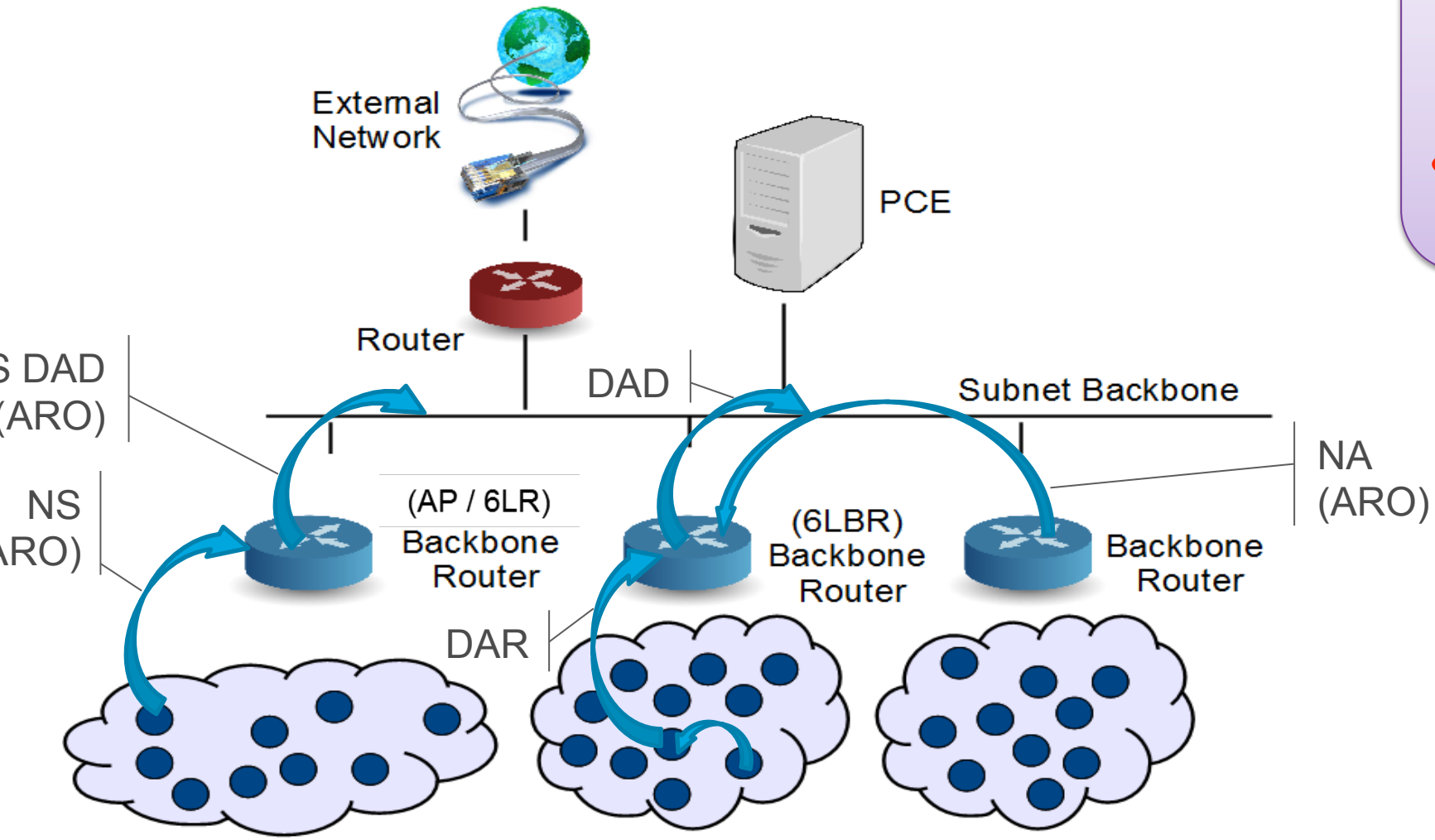
Duplication



DAD option has:
Unique ID
TID (SeqNum)

Defend with NA if:
Different OUID
Newer TID

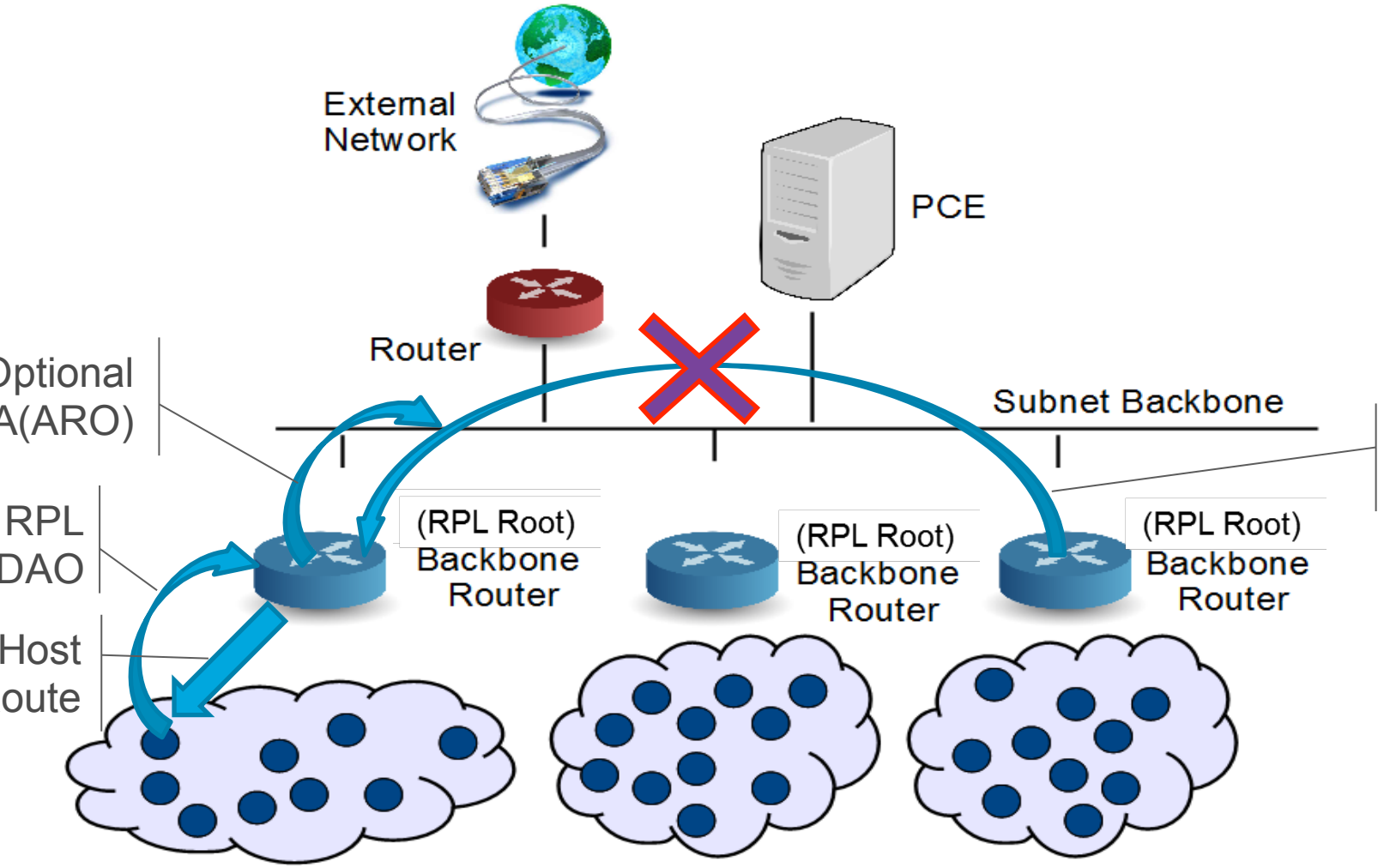
Mobility



DAD option has:
Unique ID
TID (SeqNum)

Defend with NA if:
Different OUID
Newer TID

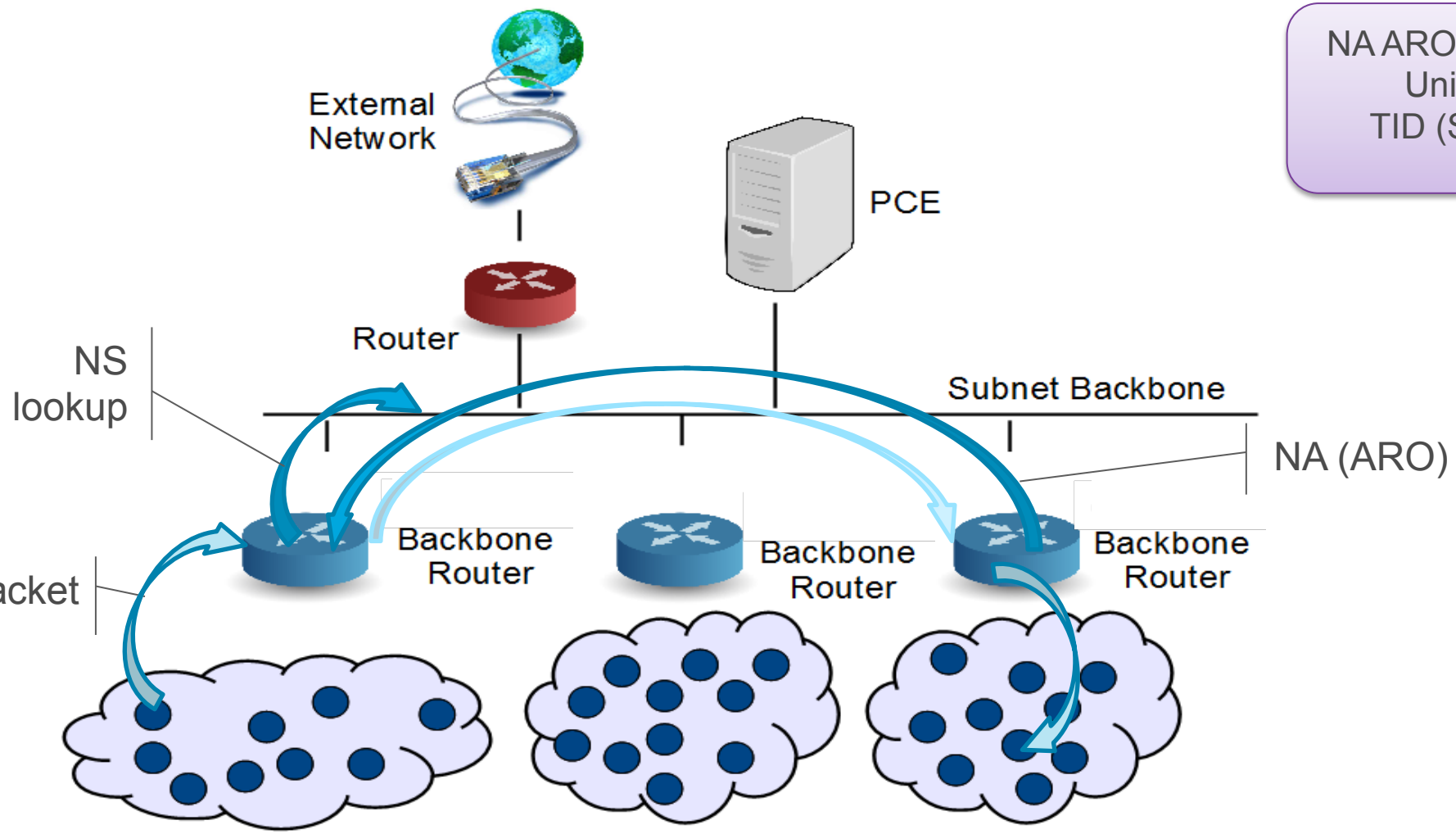
Mobility



DAD option has:
Unique ID
TID (SeqNum)

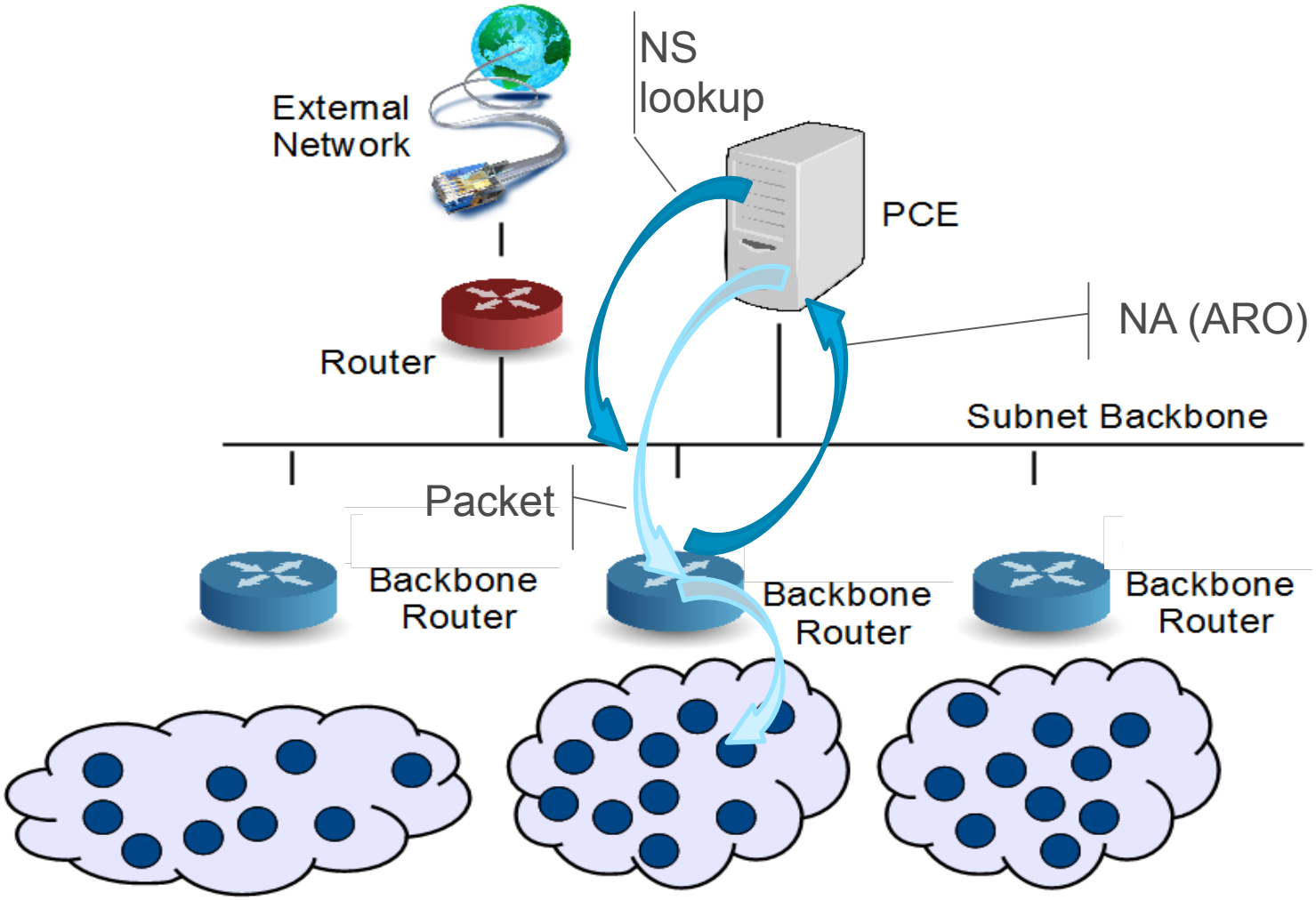
Defend with NA if:
Different OUID
Newer TID

Resolution



NA ARO option has:
Unique ID
TID (SeqNum)

Resolution (2)



Mixed mode ND
BBR proxying over
the backbone

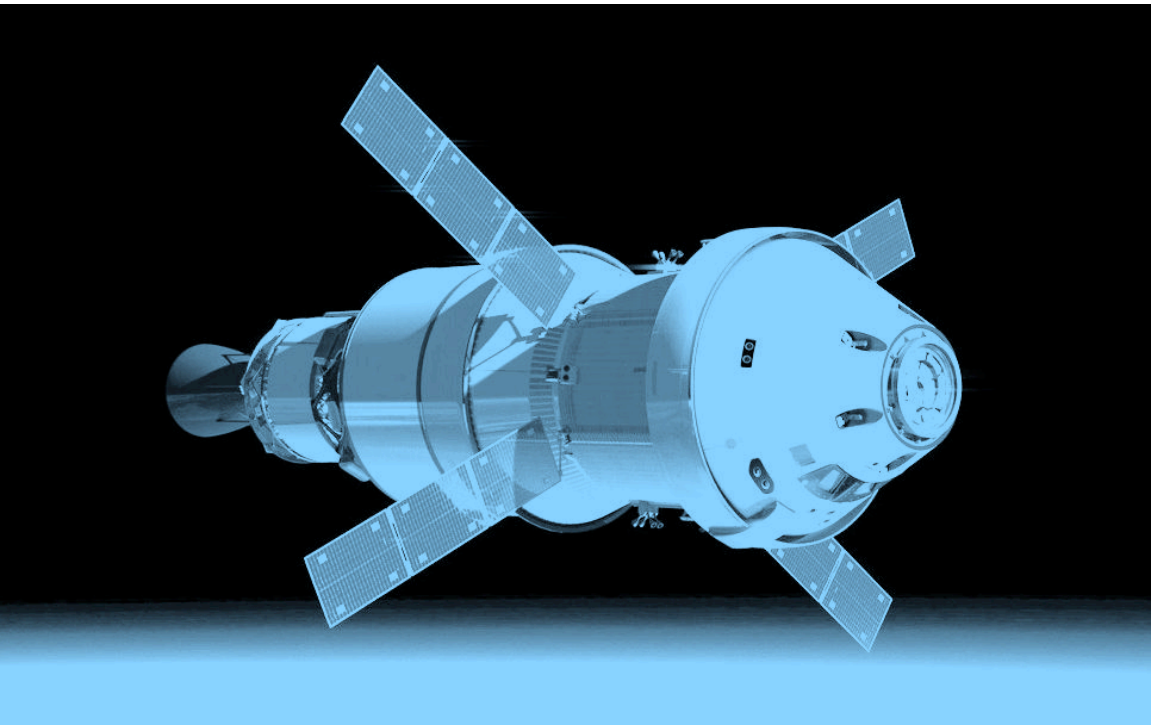
Agenda

- The Fringe of the Internet
- The Fringe backbone
- The Deterministic Fringe
- 6TSCH
- Polymorphic Flows

eterministic Networking

ew level of guarantees

- For deterministic traffic (known a priori)
- Network synchronization and Timely transmission
- Centralized routing and scheduling optimization



Cleveland, Columbus & Cincinnati R

SPECIAL TIME SCHEDULE

FOR THE TRAIN CONVEYING THE

REMAINS OF ABRAHAM LINCOLN, LATE PRESIDENT OF THE U.S., AND

FROM WASHINGTON, D. C., TO SPRINGFIELD, ILL.

Cleveland to Columbus, Saturday, April 29th, 18

Leave Cleveland	12.00	Midnight.
Berea	12.43	A. M.
Olmsted	12.51	"
Columbia	1.02	"
Grafton	1.23	"
La Grange	1.37	"
Wellington	2.00	"
Rochester	2.17	"
New London	2.36	"
Greenwich	2.59	"
Shiloh	3.19	"
Shelby	3.39	"
Crestline	4.07	"
Galion	4.23	"
Iberia	4.41	"
Gilead	5.05	"
Cardington	5.20	"
Ashley	5.43	"
Eden	5.55	"
Berlin	6.19	"
Lewis Centre	6.32	"
Orange	6.37	"
Worthington	6.56	"
Arrive Columbus	7.30	A. M

This Train will have exclusive right to the Road against all other
A Pilot Locomotive will be run ten minutes in advance of th
whole time.

E. S. FLINT, Superinte

Process Control example: a refinery

- Sensors and actuator usually close: <100m
  - Elements of critical loops can be wire-interconnected
  - Low-quality (noisy, intermittent) field power often available
- Control room typically 500m to 2km distant
  - Wired: power + signal carried together on one twisted pair
    - Designed to meet intrinsic safety regulations: ~40mW/pair
    - Typically 25-pair to 100-pair wire bundles in buried conduit
- Wireless is most attractive for this long, costly link
  - Primary requirement is ≥ 5yr battery life for field devices
  - Battery replacement is often very costly or impractical
  - Environmental power harvesting strongly desired

"Courtesy of Emerson Process Manag

- e.g. ExxonMobil Baytown refinery near Houston (Texas)
  - 100 hectares (40 sq. miles) with 12 control rooms (CRs): 10 refining CRs localized to a few hectares each,
  - 2 CRs that span the plant and interact with the other 10; large chemical plant adjacent to refinery

What’s specific

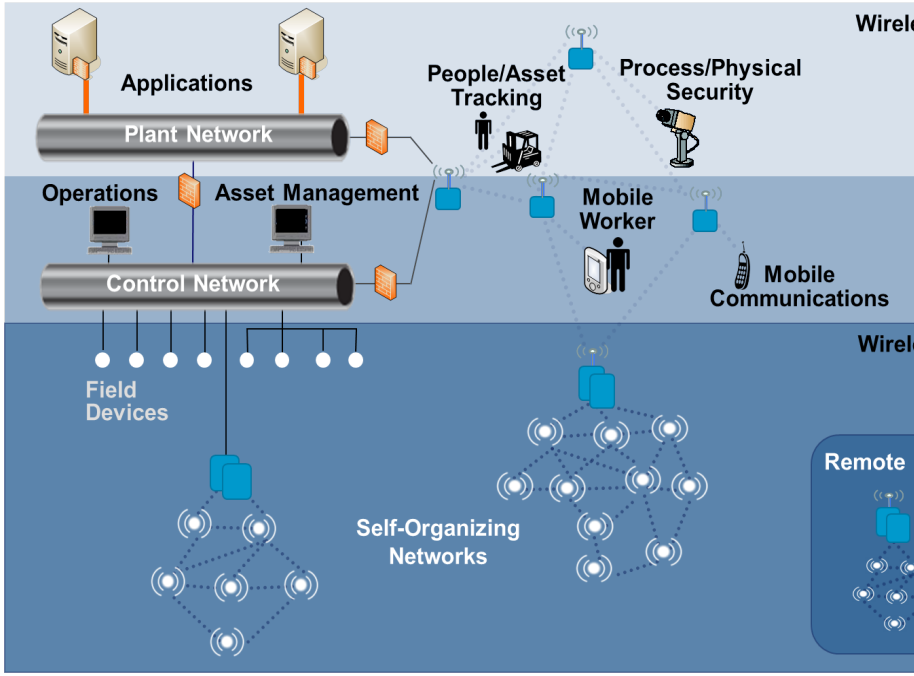
ustrial networks evolved concurrent with IP

cess Control and Factory Automation goals
iffer from those of IT => schism

ed low latency and high cyclic determinism

her reliability, faster repair, lesser maintenance

gest plants potentially reap the most profit from small productivity improvements
thus more willing to innovate (in stages) and to fund proven new technology



Agenda

- The Fringe of the Internet
- The Fringe backbone
- The Deterministic challenge
- 6TSCH
- Polymorphic Flows

6TSCH: standardizing IPv6 over TSCH MAC

Align existing standards

(RPL, 6LoWPAN, PANA, RSVP, PCEP, MPLS) over 802.15.4e TSCH

Support Mix of centralized and distributed deterministic routing

Design 6TUS sublayer for L3 interactions

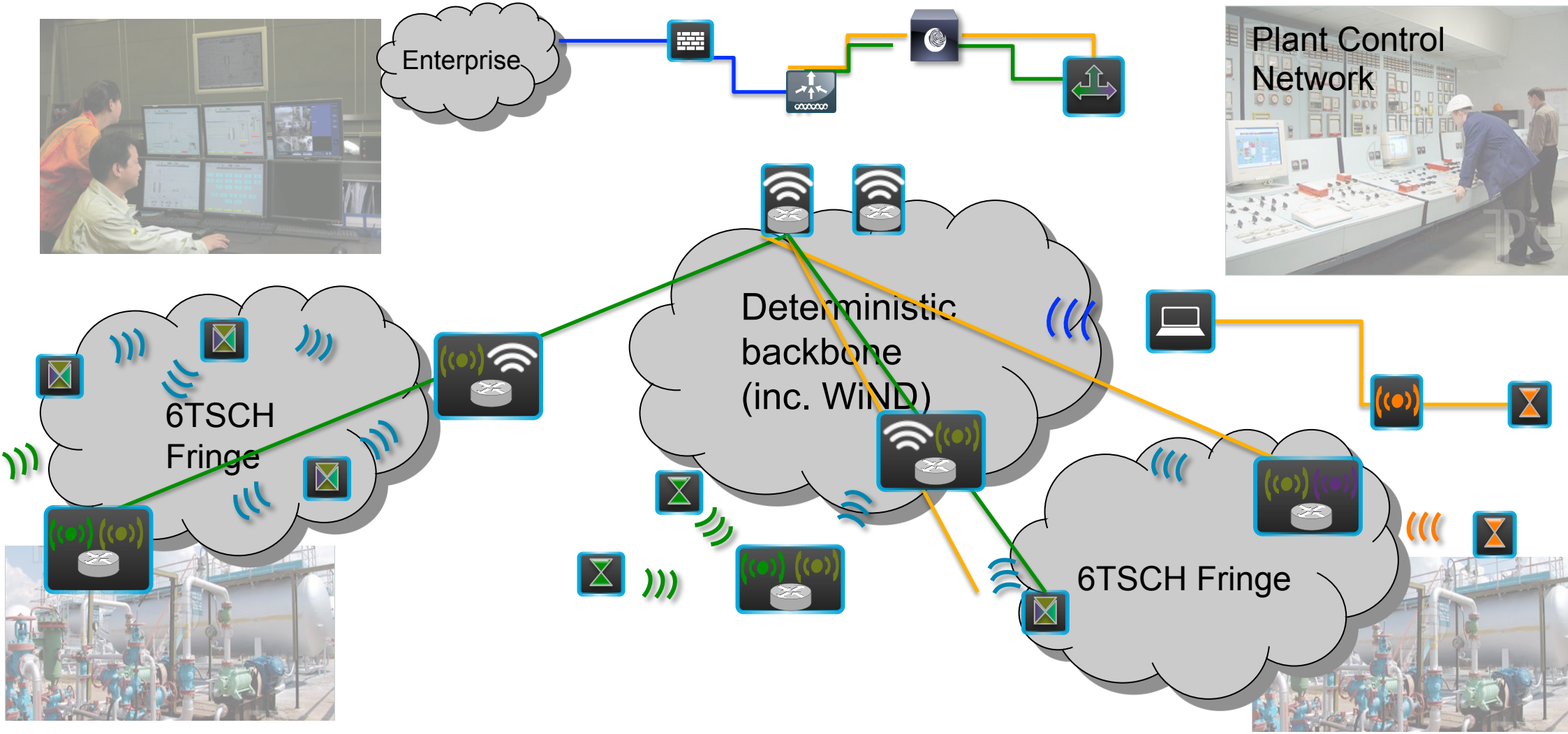
Open source implementations (openWSN…)

Build Ecosystem (DUST, NIVIS, IoT6, uni.lux, uni.bari, Berkeley…

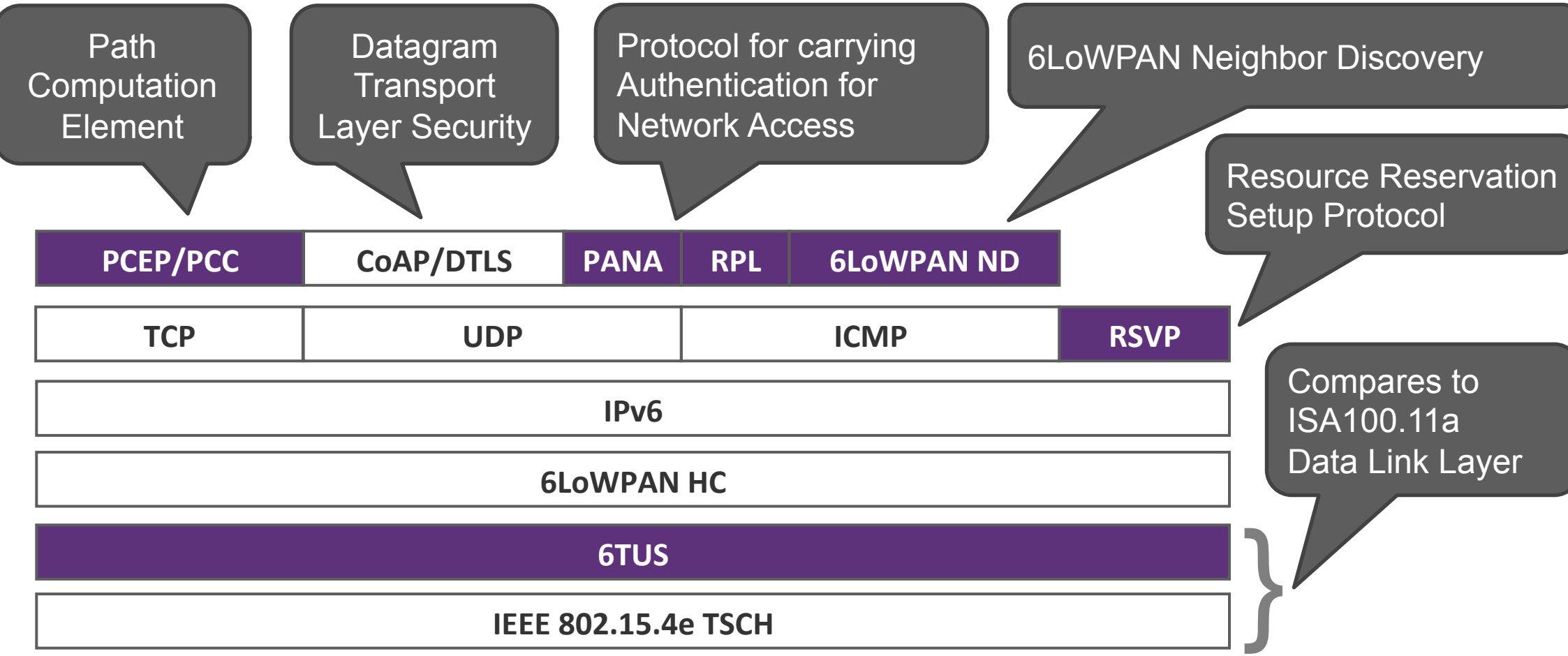
6 active drafts (Archi, 6TUS, …)

Preparing for BoF in Berlin this summer

uture Industrial Architecture with unified wireless



TSCH: Architecture



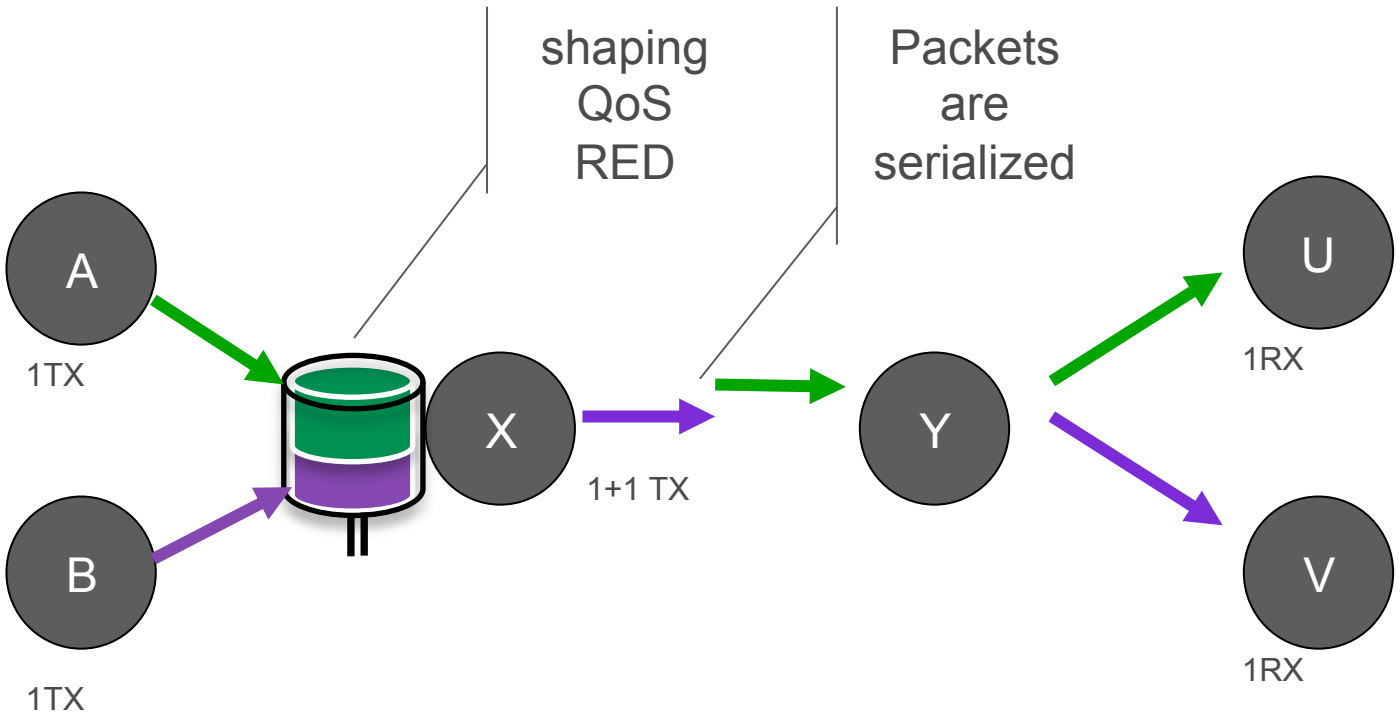
Centralized vs. Distributed routing

Centralized	Distributed
God's view optimization	Autonomic & Mobile
Multipath redundancy	Highly available (DARPA)
Deterministic (optimized)	Deterministic
Virtualization	Scalability

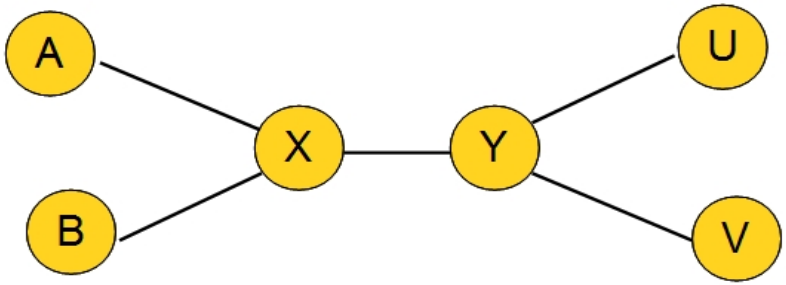
Routing With RPL

Low Power Lossy Nets	Addressed in RPL ?
Dynamic Topologies	✓ Distance Vector + stretch
Peer selection	✓ Peer only with parents
Constrained Objects	✓ DV + Non-storing mode
Fuzzy Links	✓ Lazy Update & datapath valid
Routing, local Mobility	✓ Constrained instances, TID
Global Mobility	✗ Req coupling with LISP/NEM

Normal L3 operation



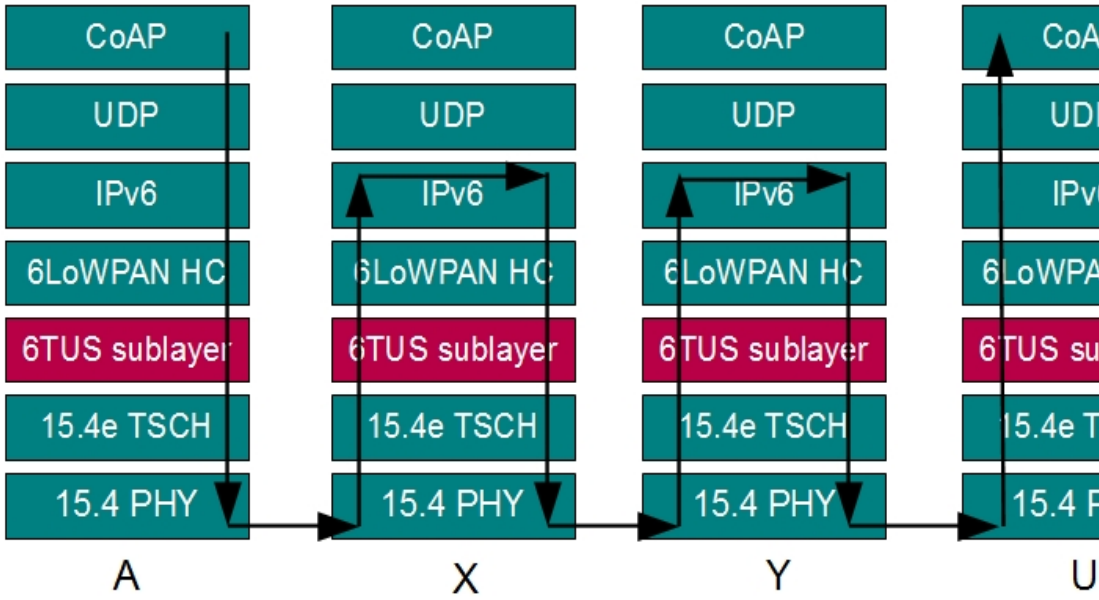
Best effort routing



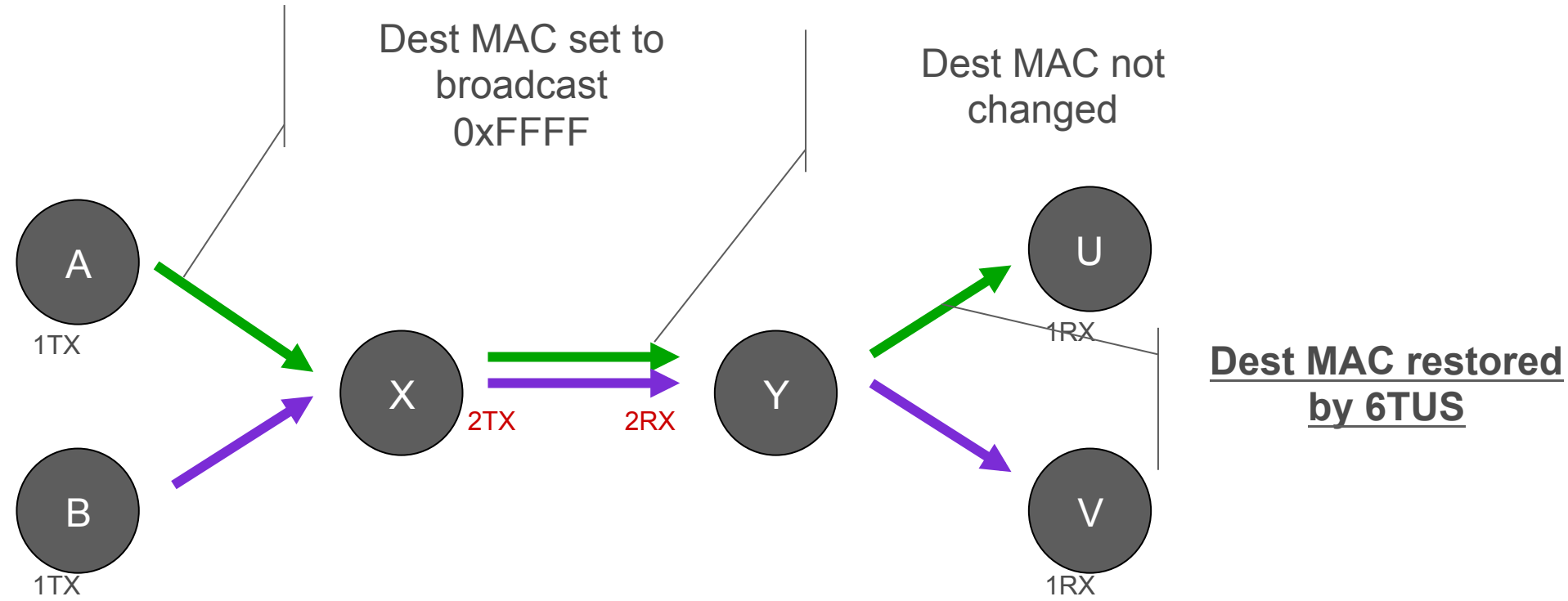
Bundle

			X → Y			Y → V	
A → X					X→ Y		Y → U
	B → X						

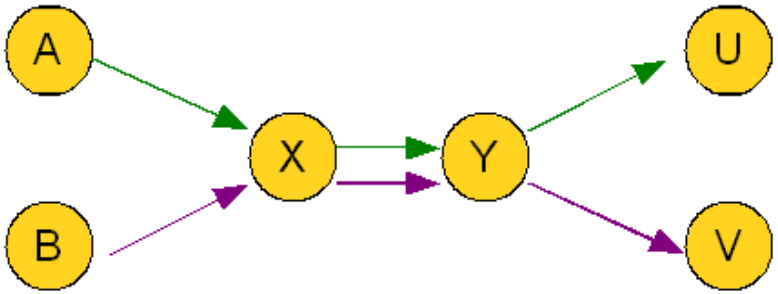
slotOffset

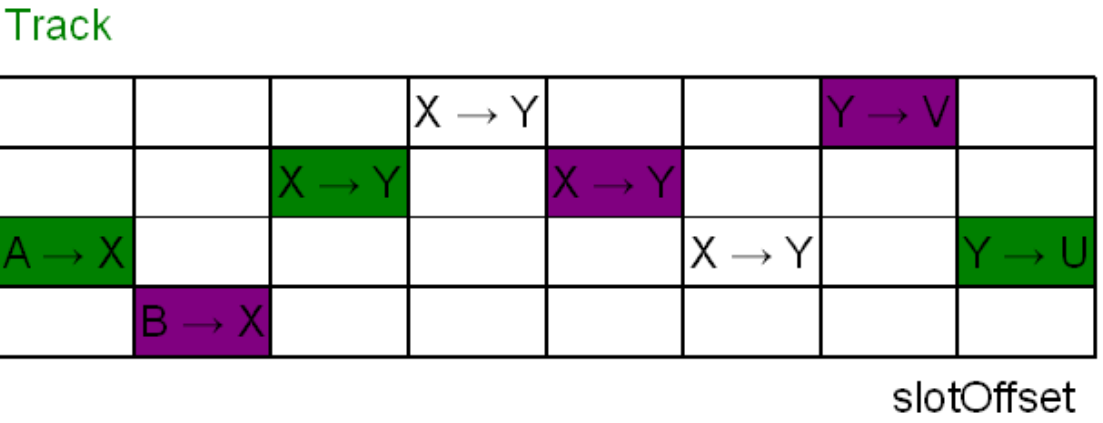


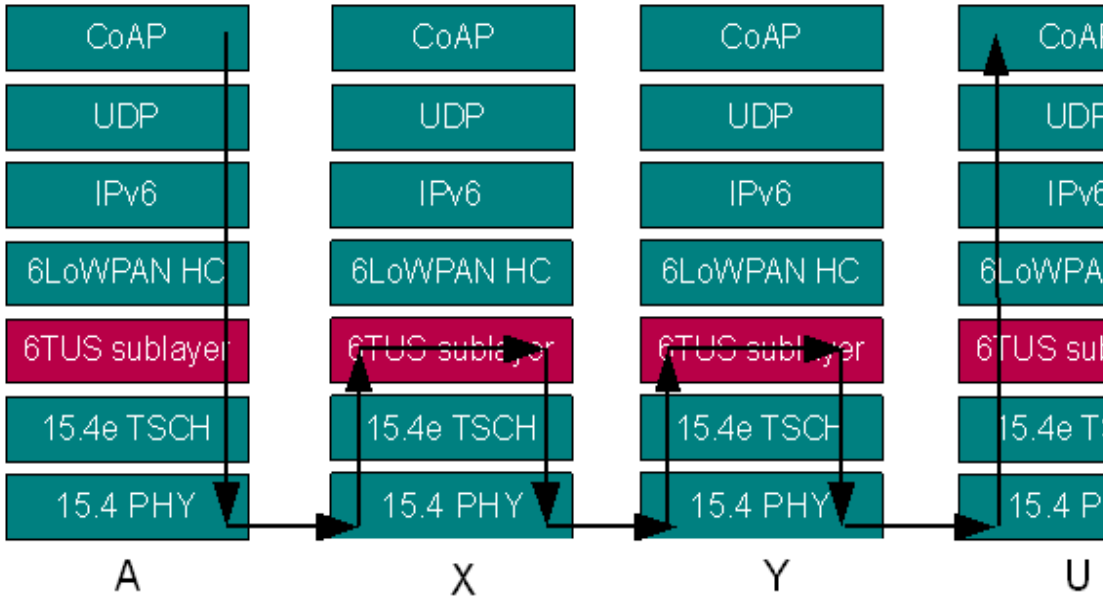
Normal Track operation



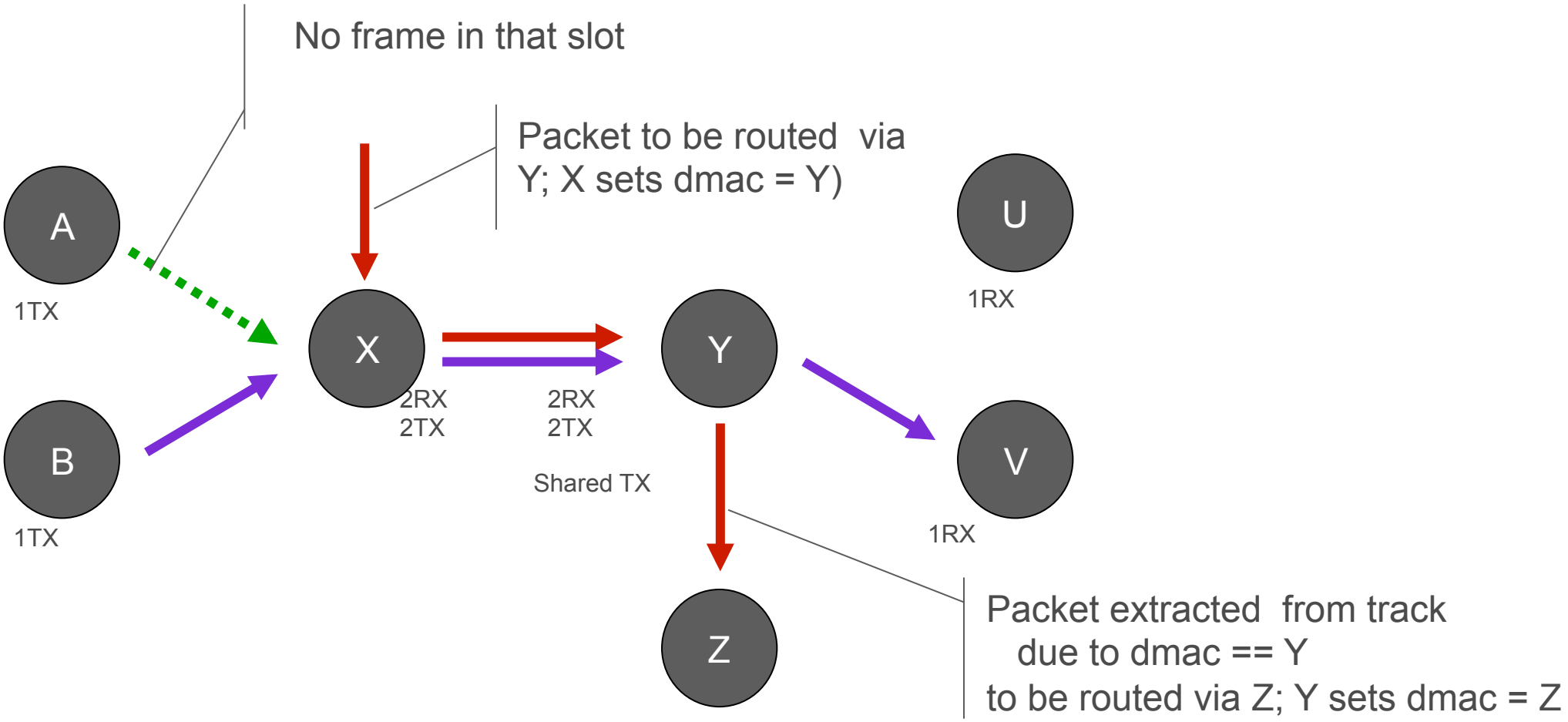
Track Switching (G-MPLS)



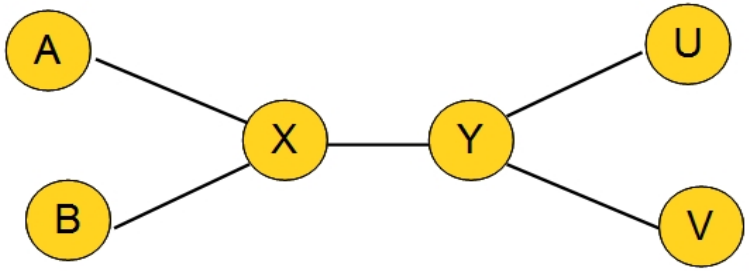




Opportunistic track slot reuse



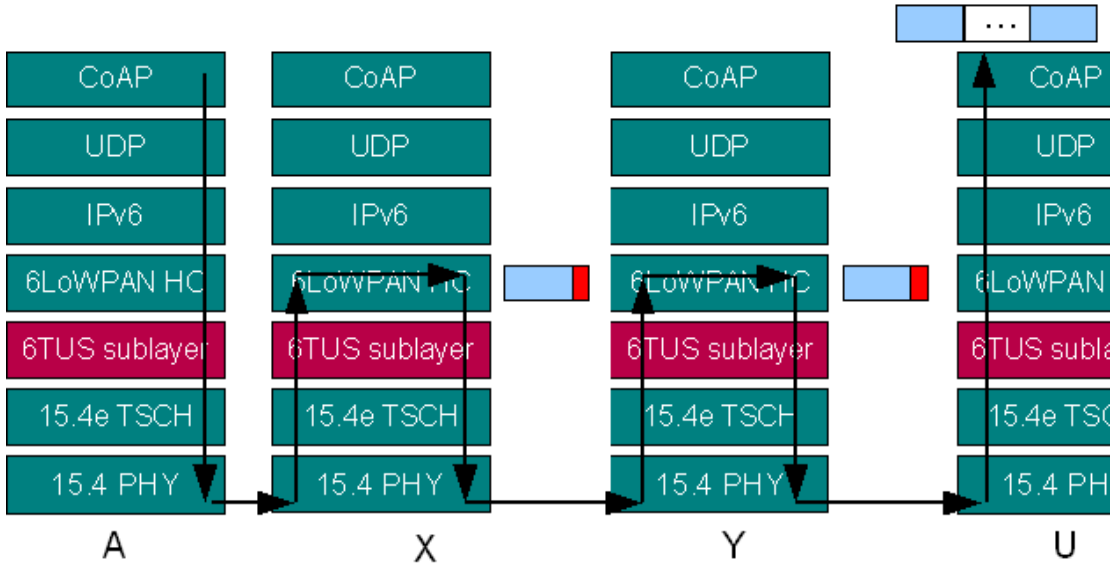
6LoWPAN Fragment forwarding

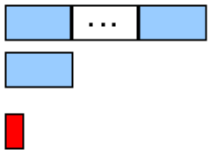


Bundle

			X → Y			Y → V	
A → X					X→ Y		Y → U
	B → X						

slotOffset





packet, composed by N fragments

i-th fragment of the packet, with i > 1

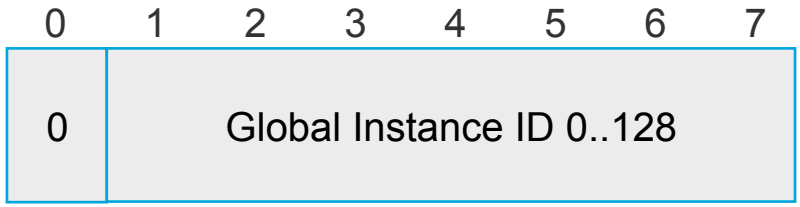
state installed in a single fragment

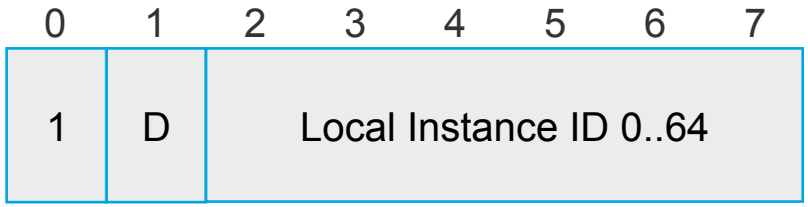
Agenda

- The Fringe of the Internet
- The Fringe backbone
- The Deterministic challenge
- 6TSCH
- Polymorphic Flows

RFC 6550: RPL Instance ID

The RPL instance ID allows different routing optimizations, constraints and policies.





The RPL instance ID is encoded in 1 octet. The first bit indicates whether Global or Local.

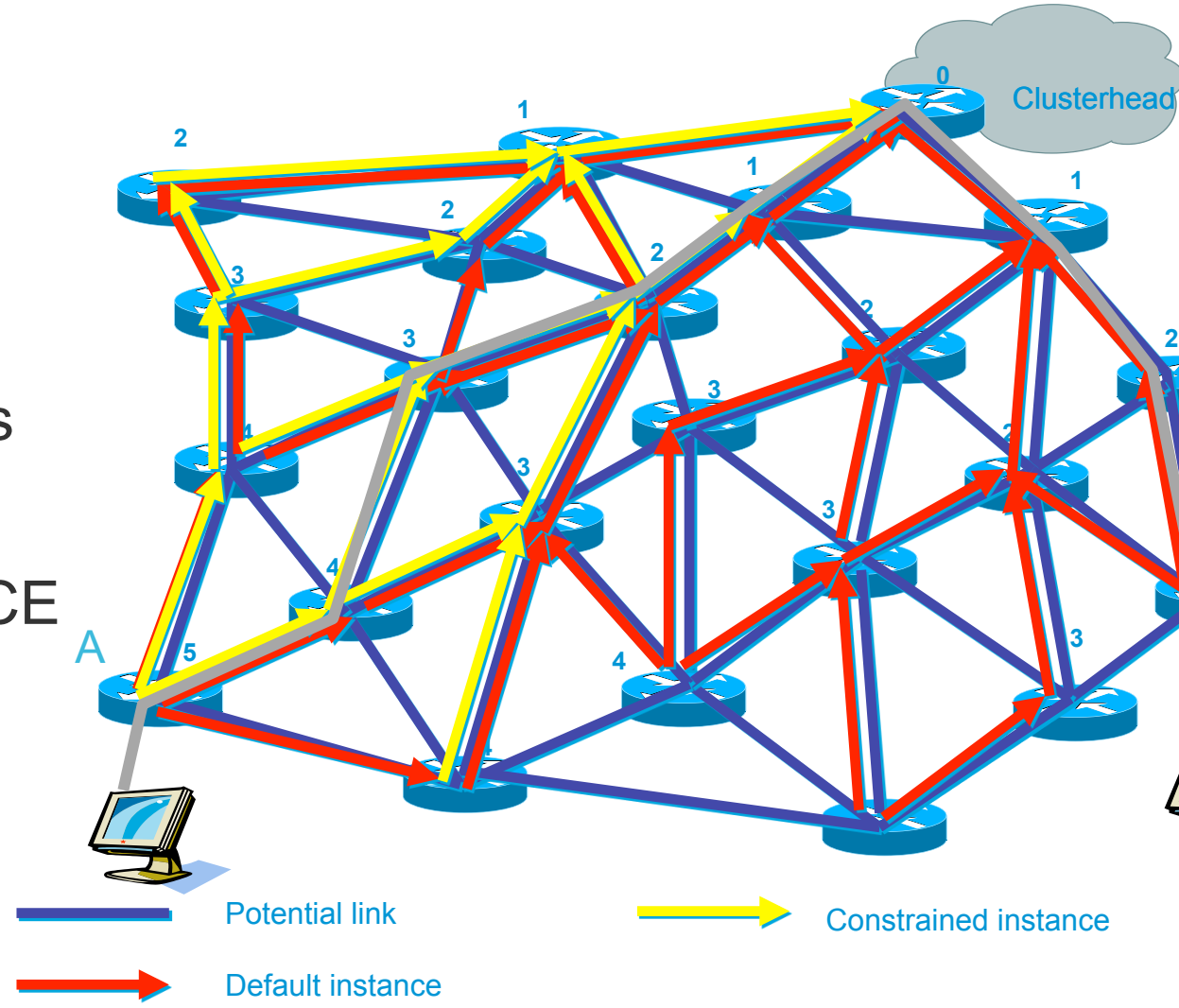
"A local RPLInstanceID is autoconfigured by the node that owns the DODAGID and it MUST be unique for that DODAGID. The DODAGID used to configure the local RPLInstanceID MUST be a reachable IPv6 address of the node, and it MUST be used as an endpoint of all communications within that Local instance."

Inside a packet: "If the 'D' flag is set to 1, then the destination address of the IPv6 packet MUST be the DODAGID. If the 'D' flag is cleared, then the source address of the IPv6 packet MUST be the DODAGID."

6TSCH extends RPL's language of DODAGID to route (reservation) endpoint.

Global Instances

- 28 global instances per network
  - Indexed by tuple (IPv6, InstanceID)
  - Running as Ships-in-the-night
  - 1 instance = 1 VRF = 1 « L3 vlan »
- Serving different Objective Functions
  - Using different metrics
- Can be shared between RPL and PCE
  - RPL along a DODAG
  - PCE adding orthogonal shortcuts



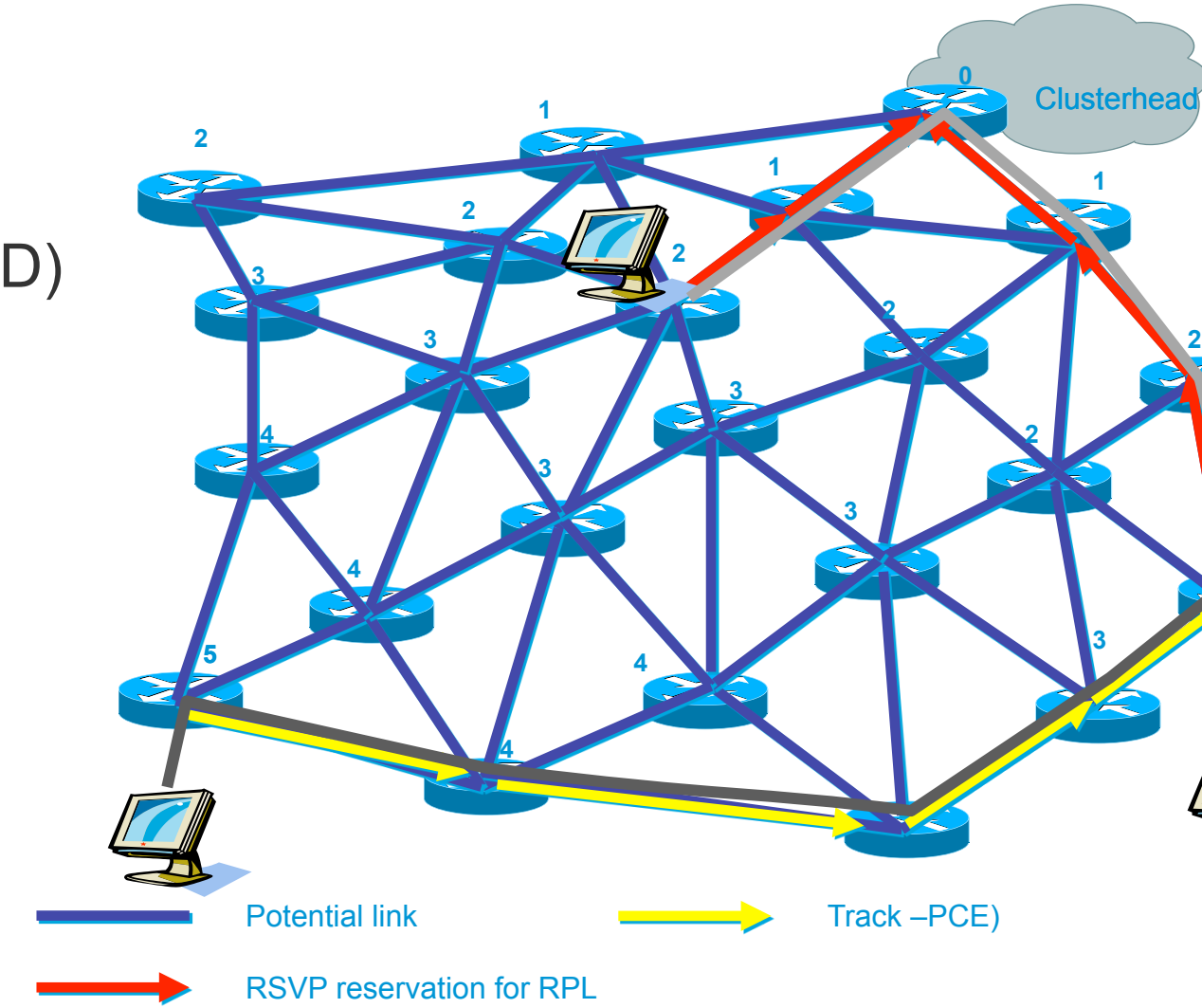
Local instances

64 local Instances

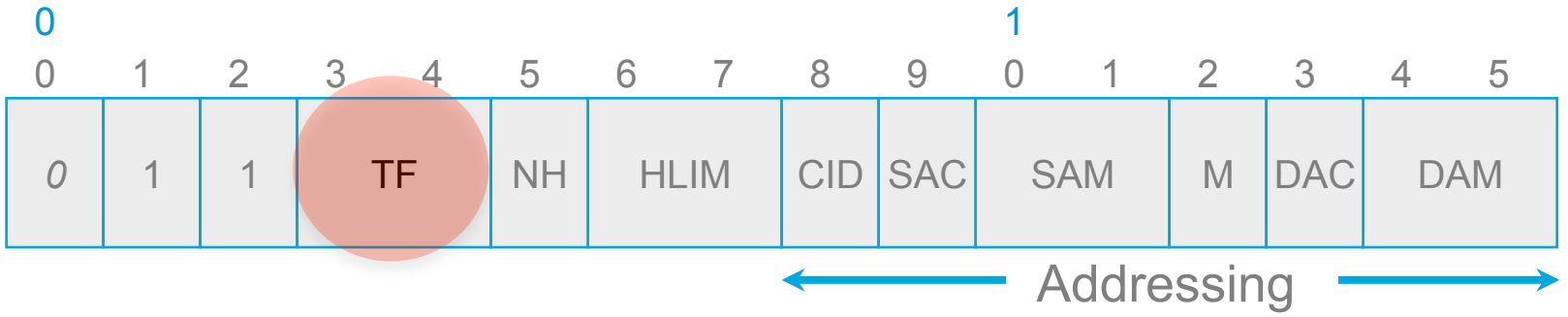
- per IPv6 source address
- Indexed by tuple (IPv6, InstanceID)

Used by RPL or PCE

- RPL: for P2P applications
- RPL: to index RSVP path
- PCE: Serves as Track ID,
  - included in PCEP request
  - from the source device

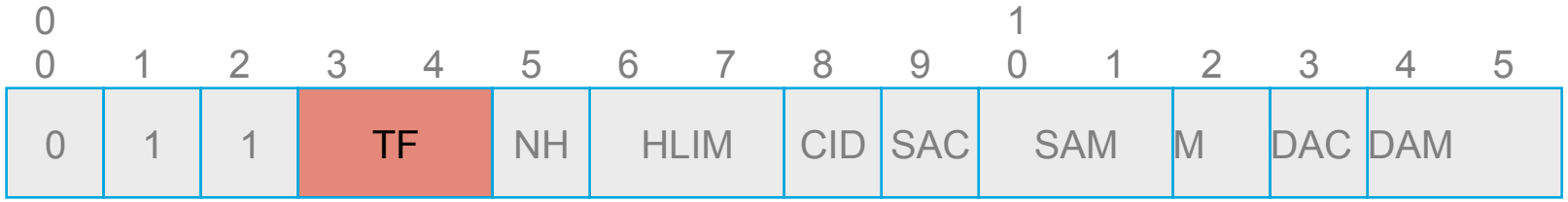


RFC 6282: 6LoWPAN IPv6 Header Compression

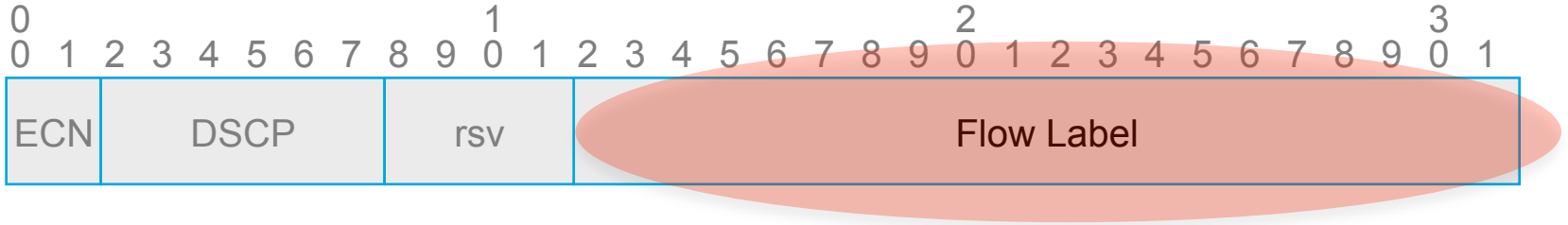


TF	2 bits	Traffic Class and Flow Label
NH	1 bit	Next Header
HLIM	2 bits	Hop Limit
CID	1 bit	Context Identifier Extension
SAC	1 bit	Source Address Context
SAM	2 bits	Source Address Mode
M	1 bit	Multicast Address Compression
DAC	1 bit	Destination Address Context
DAM	2 bits	Destination Address Mode

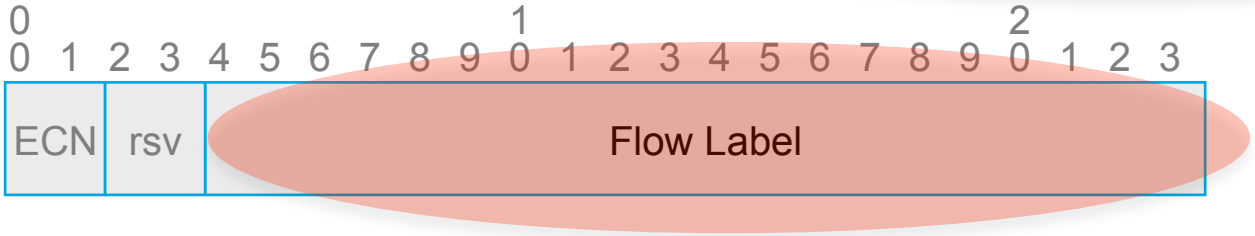
6LoWPAN: Traffic Class & Flow Label



TF = 0



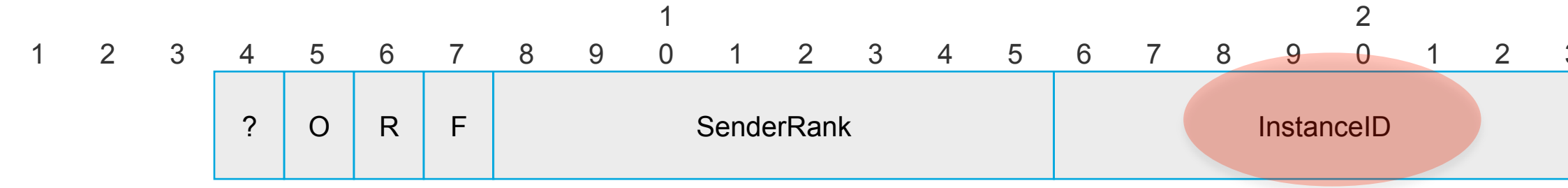
TF = 1



TF = 2

TF = 3 Traffic Class and Flow Label elided.

draft-thubert-roll-flow-label



aces in Flow Label the RPL Packet Information is defined in RFC 6550 Section 11.2

ave extra HbH header bytes incurred in RFC 6553 AND eventual IPinIP tunneling

"When the router is the source of the original packet and the destination is known to be within the same RPL Instance, the router SHOULD include the RPL Option directly within the original packet. Otherwise, routers MUST use IPv6-in-IPv6 tunneling [RFC2473] and place the RPL Option in the tunnel header."

iscussed with Brian Capenter on the ROLL ML

http://www.ietf.org/mail-archive/web/roll/current/msg06967.html

eed to take to 6MAN to resolve violation of RFC6437

Agenda

- The Fringe of the Internet
- The Fringe backbone
- The Deterministic challenge
- 6TSCH
- Polymorphic Flows

T/OT Network Convergence

Control anything from the network

- Learn from Industrial.
- Replicate and generalize with open standards

A converged network provides

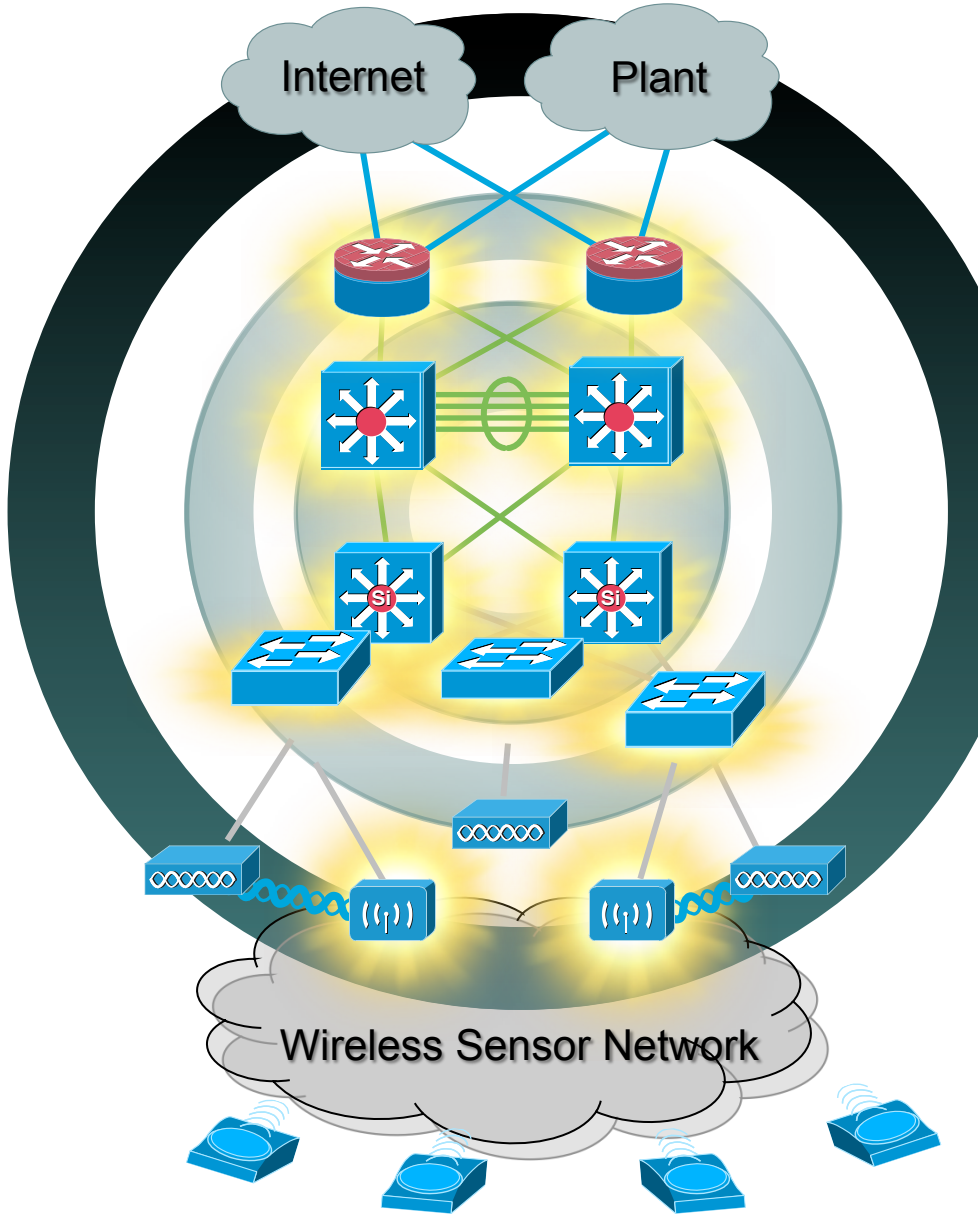
- high availability, flow isolation, security,
- Guaranteed bandwidth and **Determinism**

Coexistence involves:

- Location and Scheduling
- At L2 and L3, for wired and wireless.

New, higher end paradigm

- Reaching more devices and data, farther, cheaper, with better guarantees



Thank you.