UNIVERSITÀ DEGLI STUDI ROMA TRE
Dipartimento di Informatica e Automazione

Monitoring the Status of MPLS VPN and VPLS Based on BGP Signaling Information

Giuseppe Di Battista
Massimo Rimondini
Giorgio Sadolfo

IEEE/IFIP NOMS 2012
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MPLS VPN VPLS

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About MPLS VPNs/VPLS

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About MPLS VPNs/VPLS

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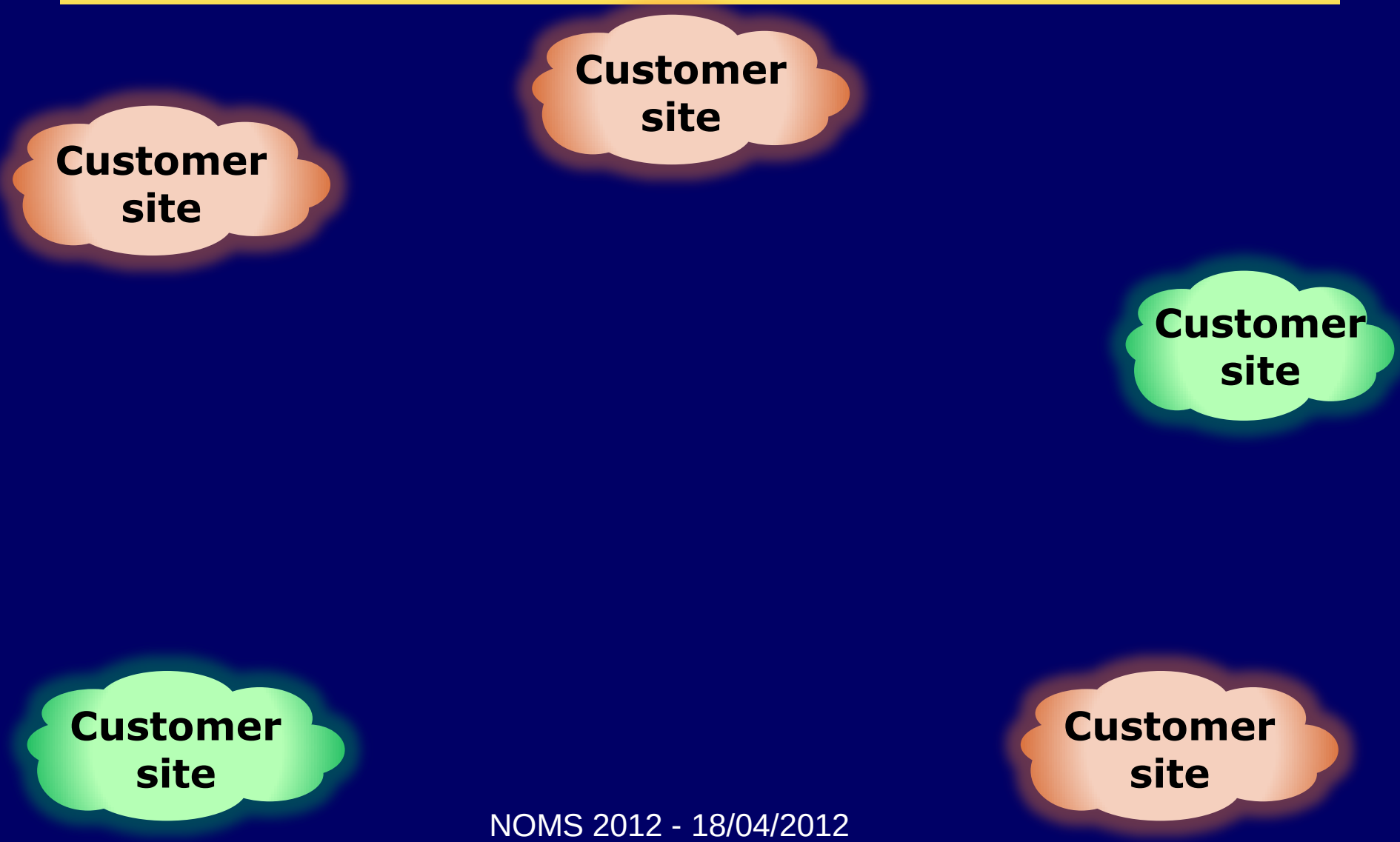

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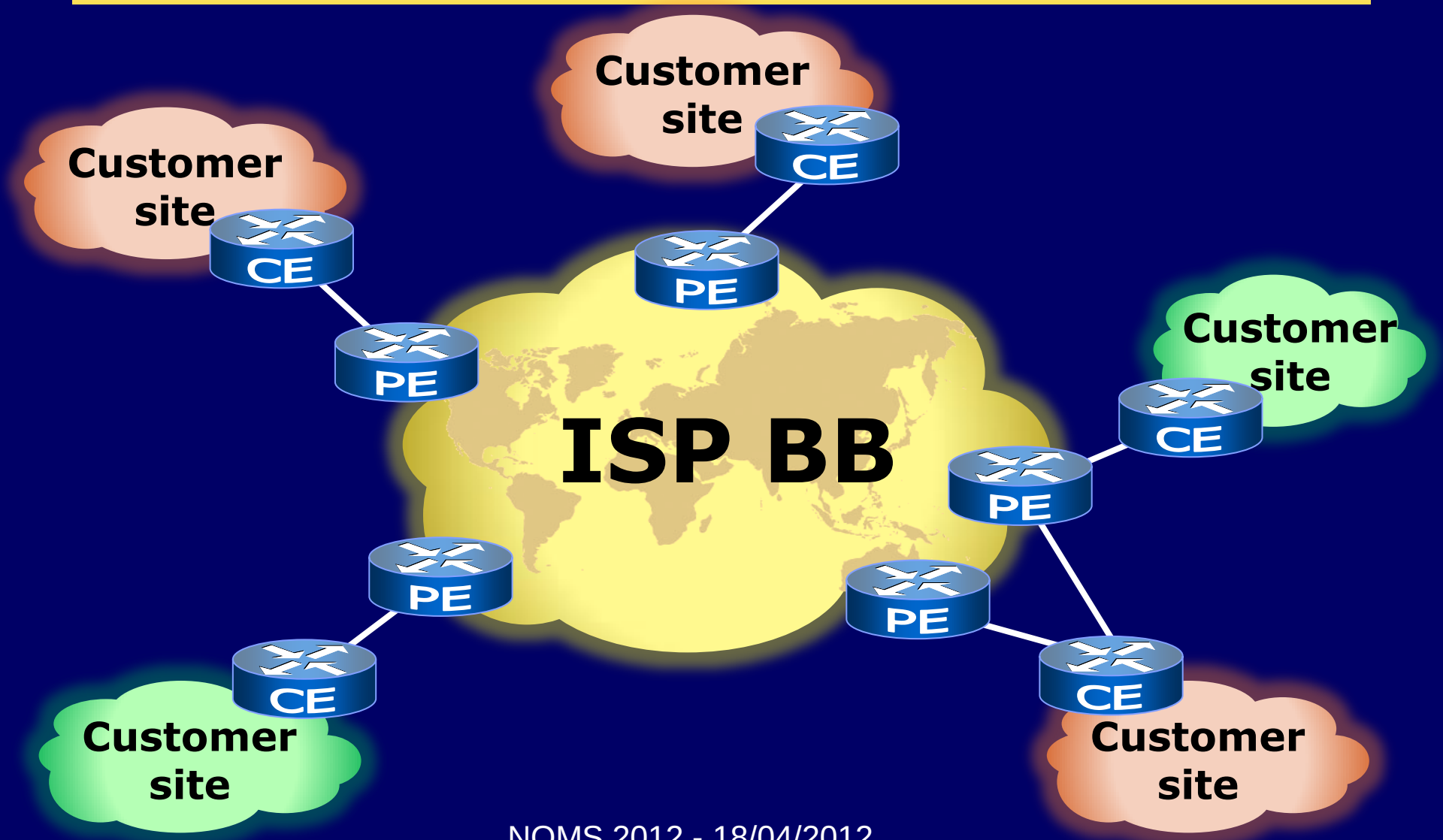

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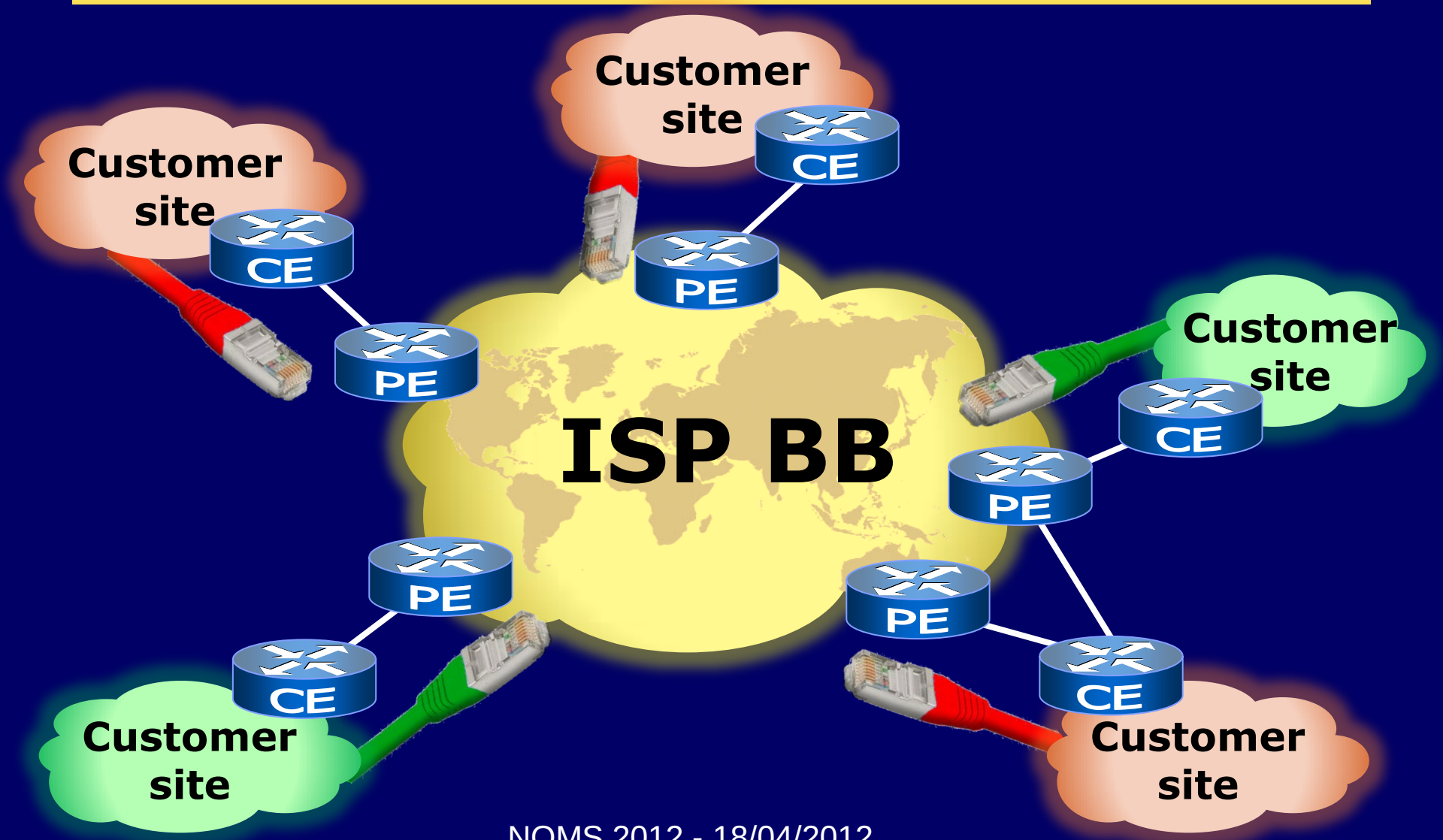

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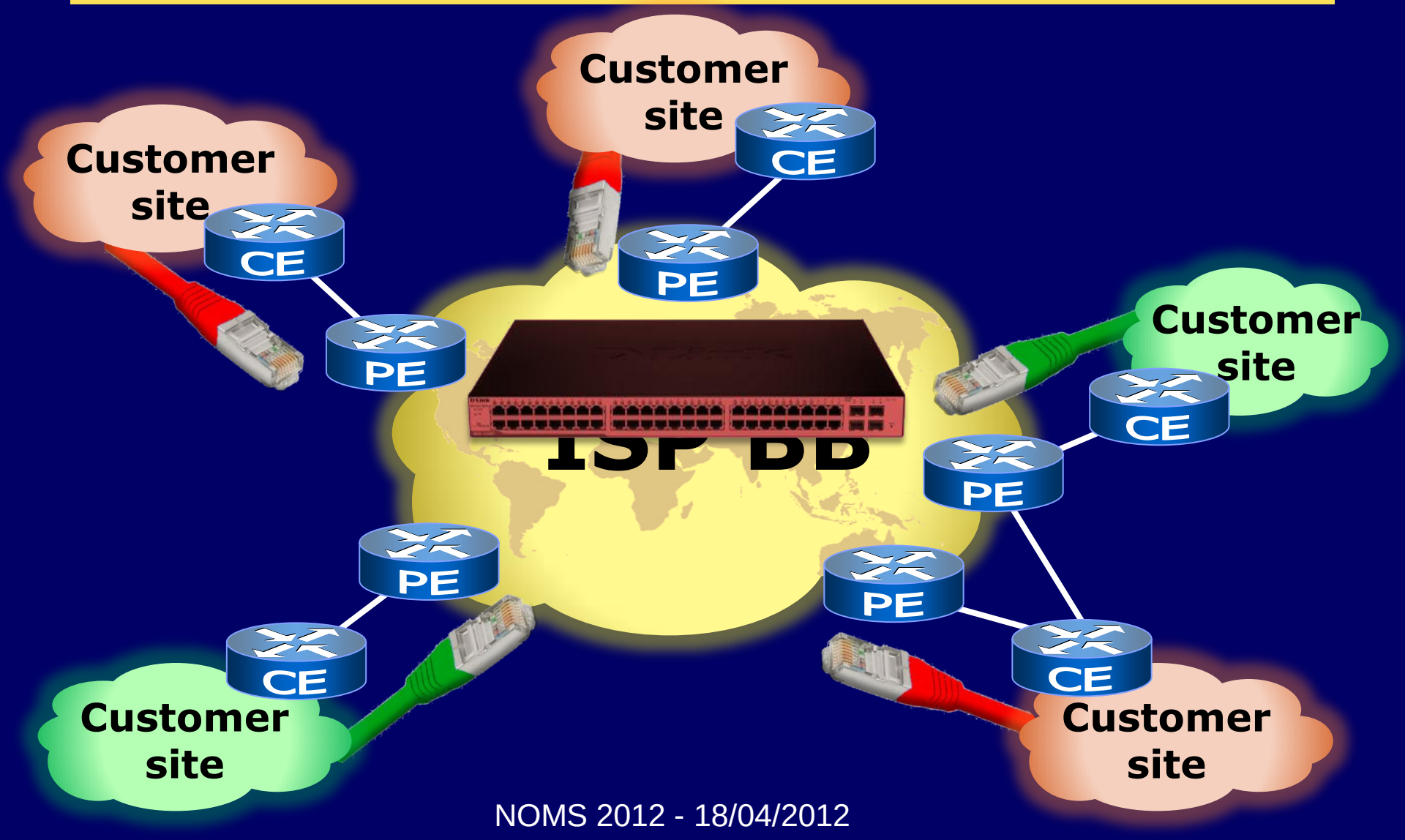

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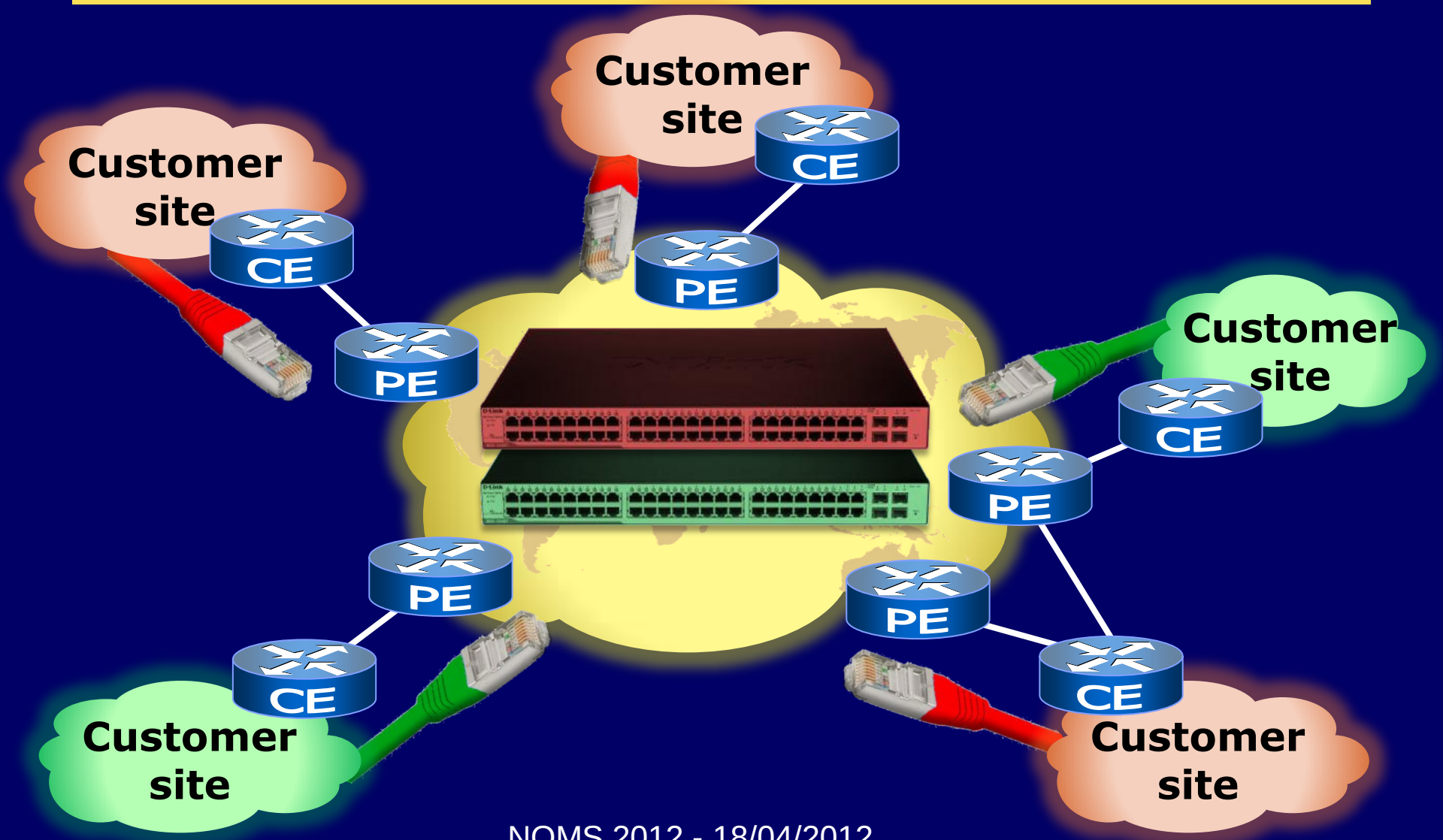

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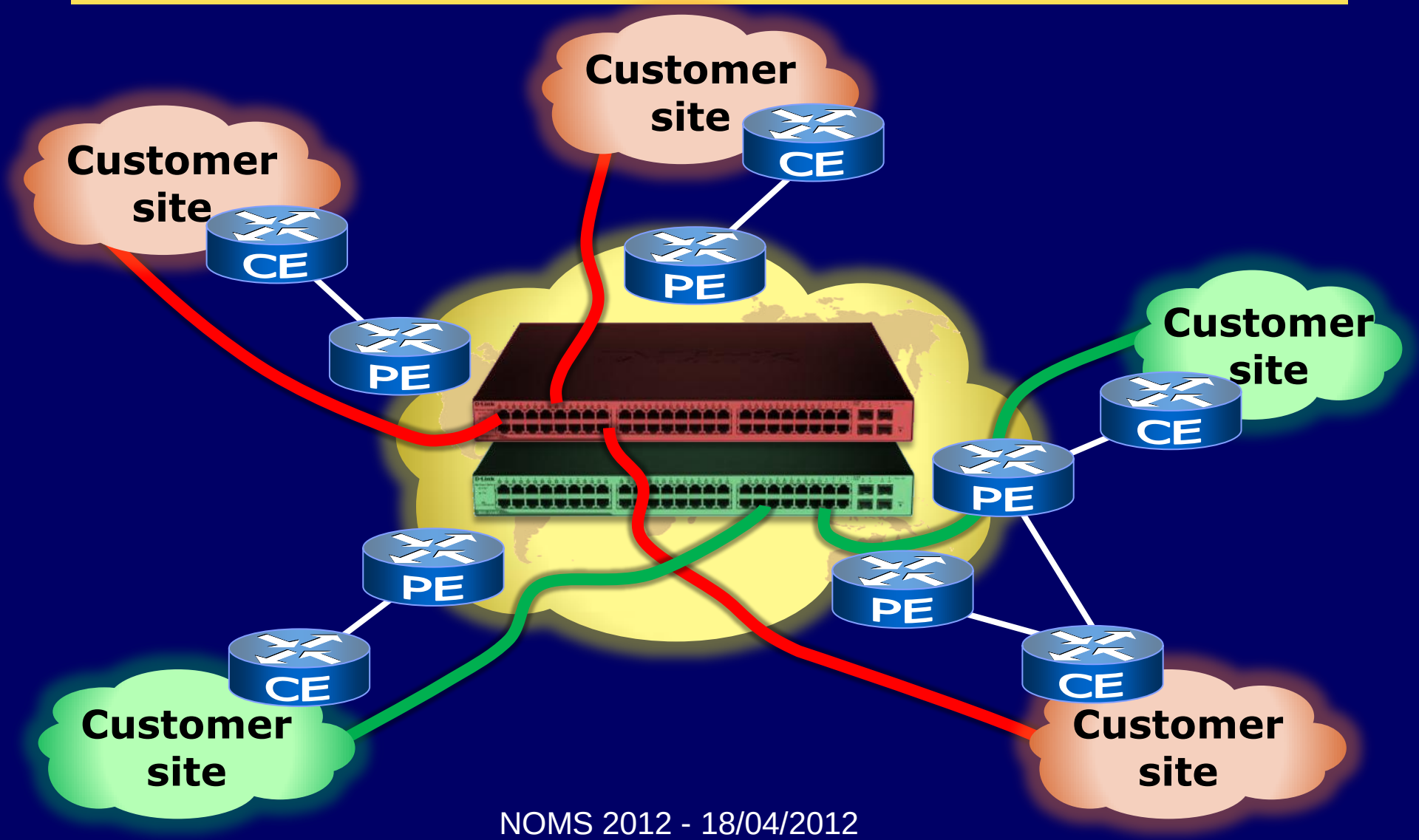

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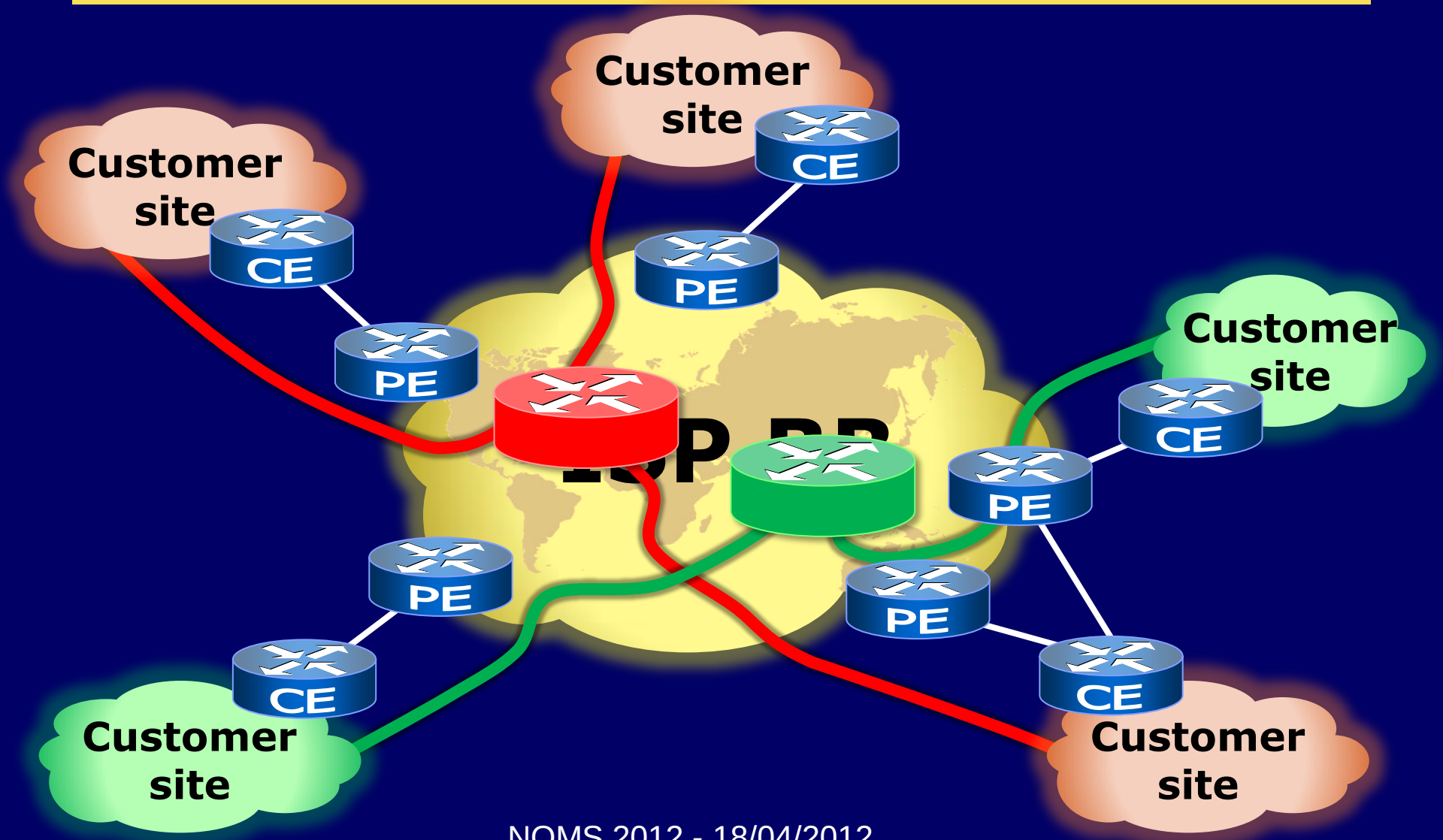

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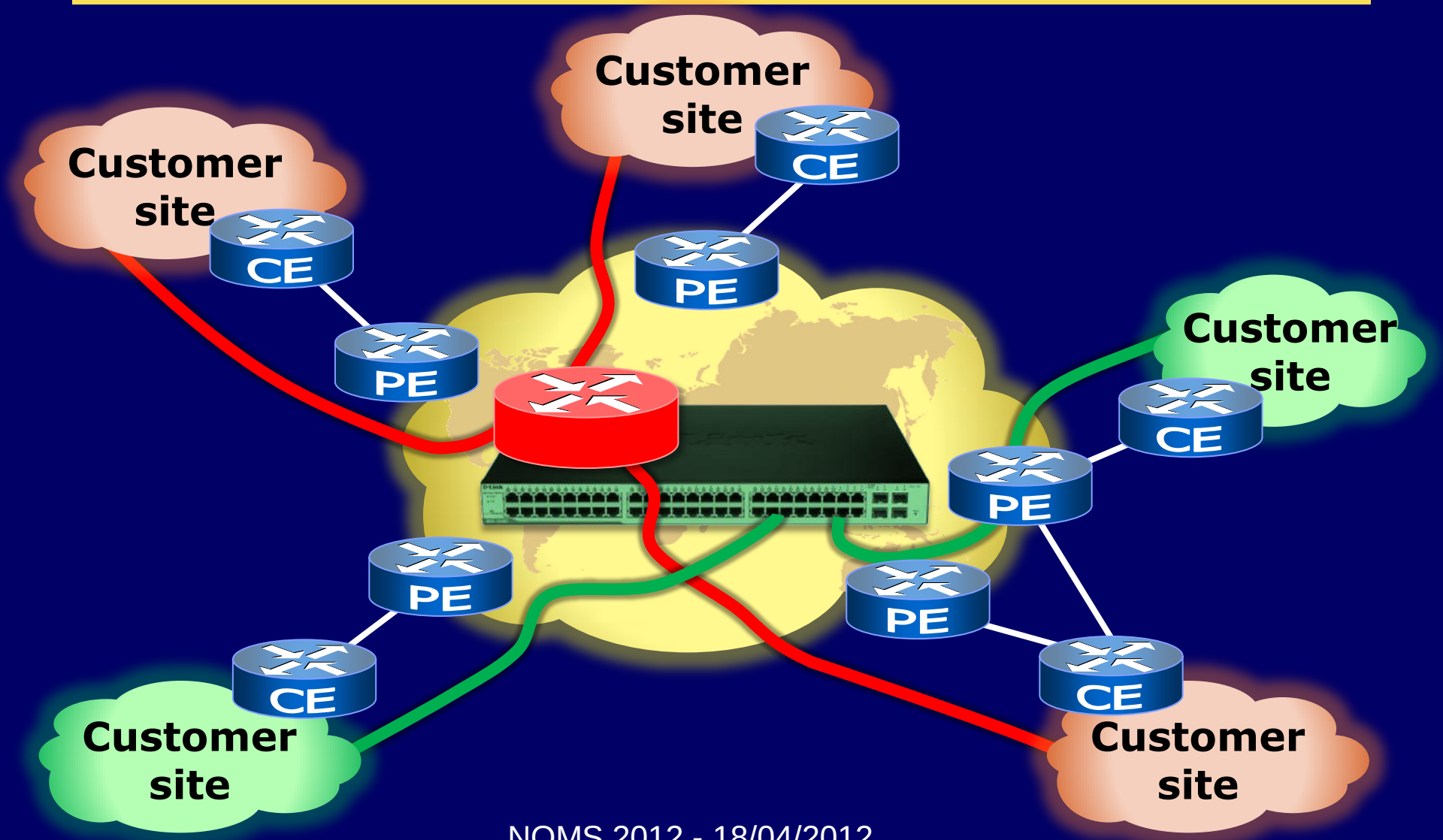

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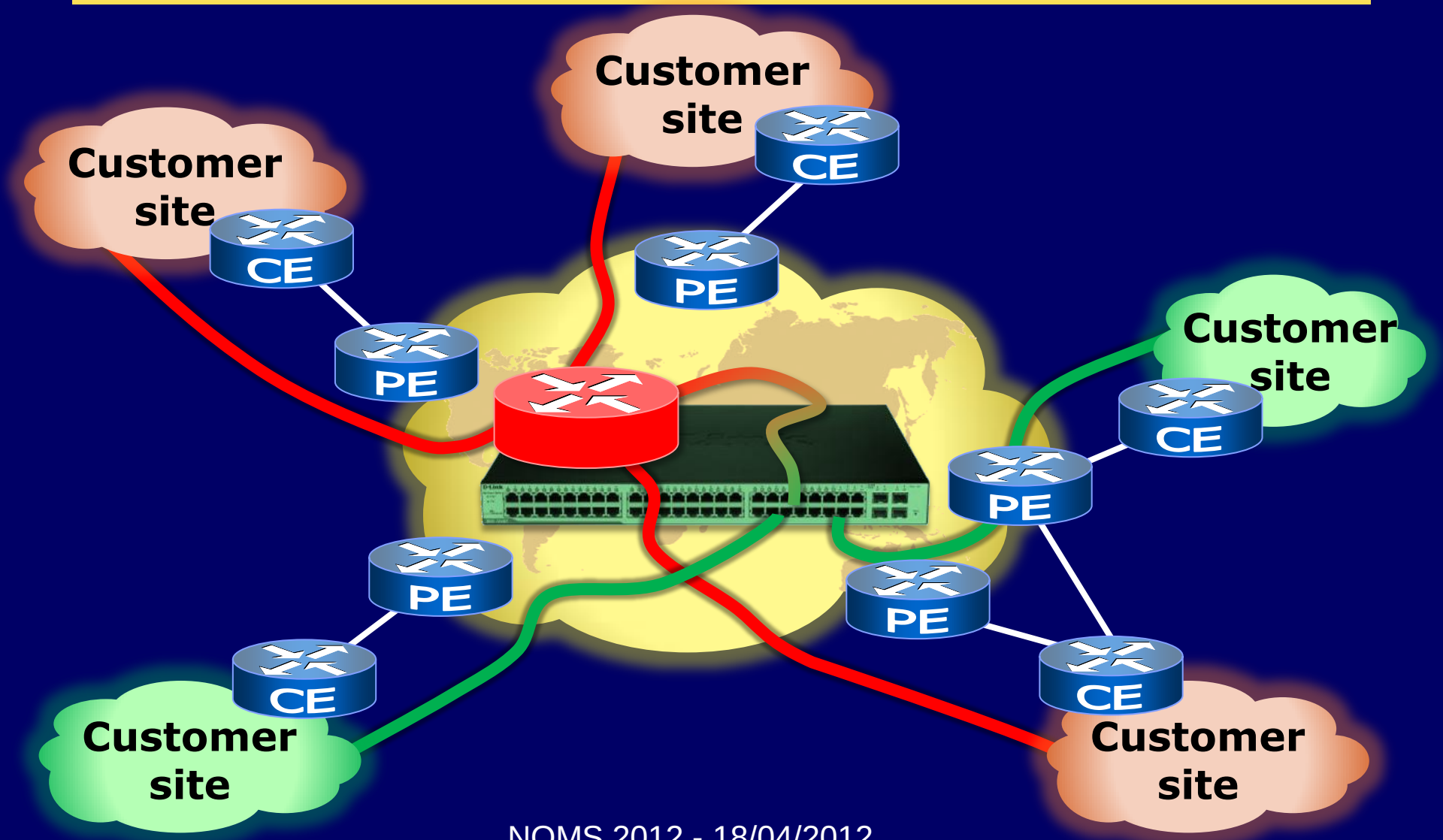

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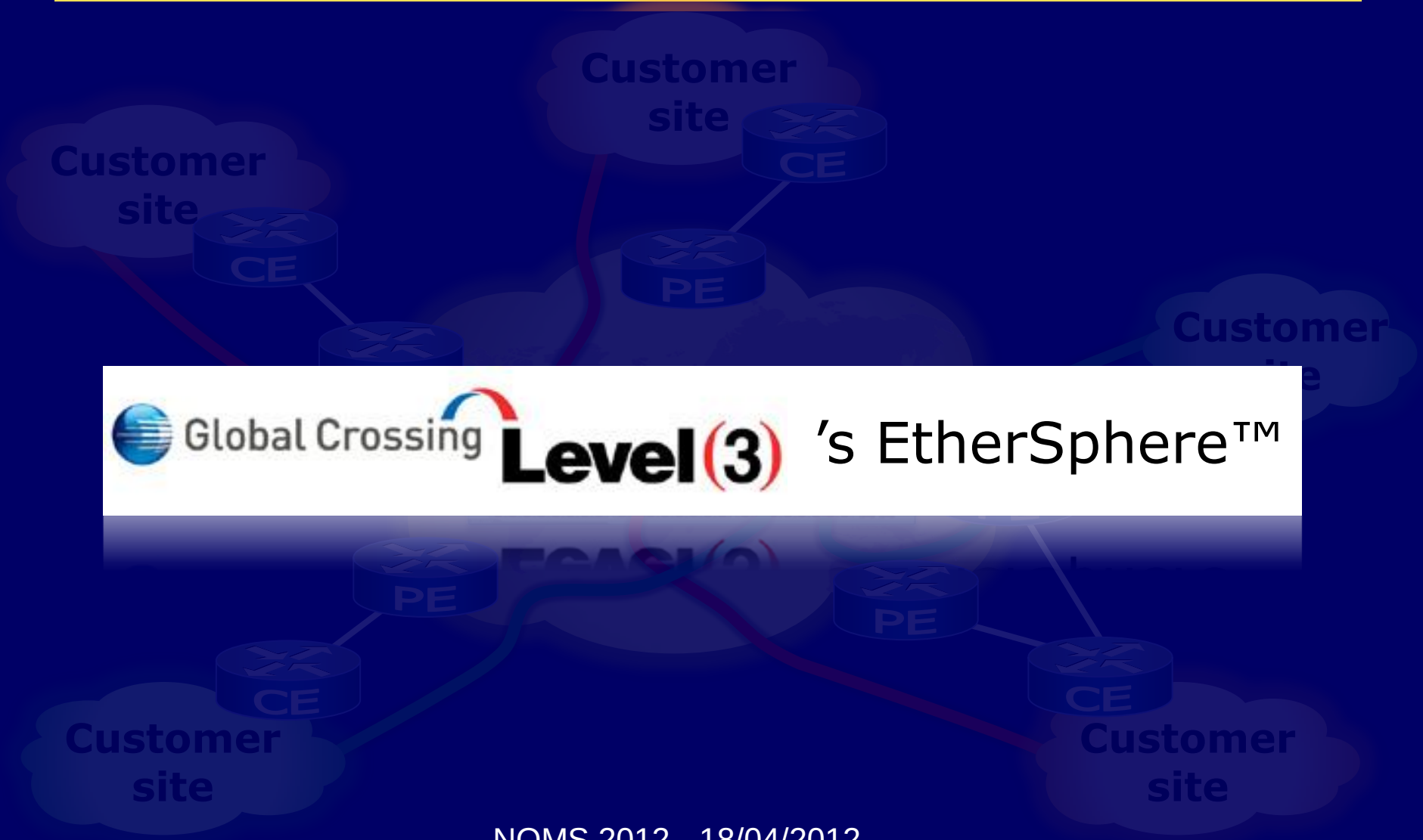

Global Crossing Level(3) 's EtherSphere™

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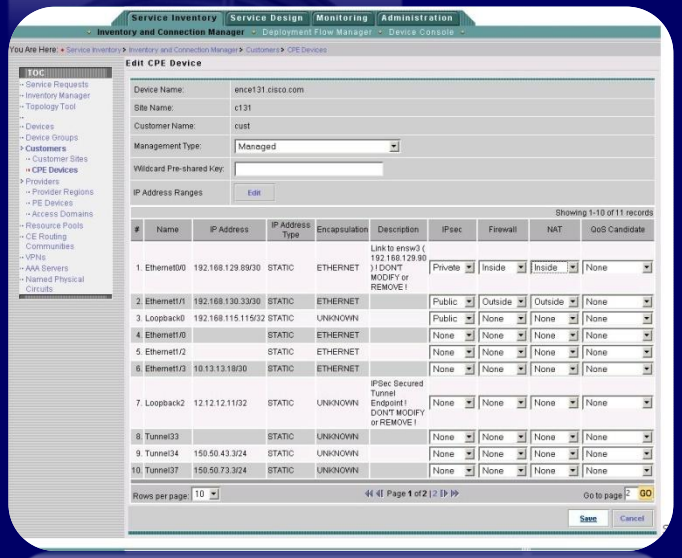

About MPLS VPNs/VPLS

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JUNIPER NETWORKS

CISCO

About MPLS VPNs/VPLS

juniper NETWORKS

CISCO

About MPLS VPNs/VPLS

JUNIPER NETWORKS

CISCO

192.168.0.4

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About MPLS VPNs/VPLS

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State of the Art (in MPLS/VPLS monitoring)

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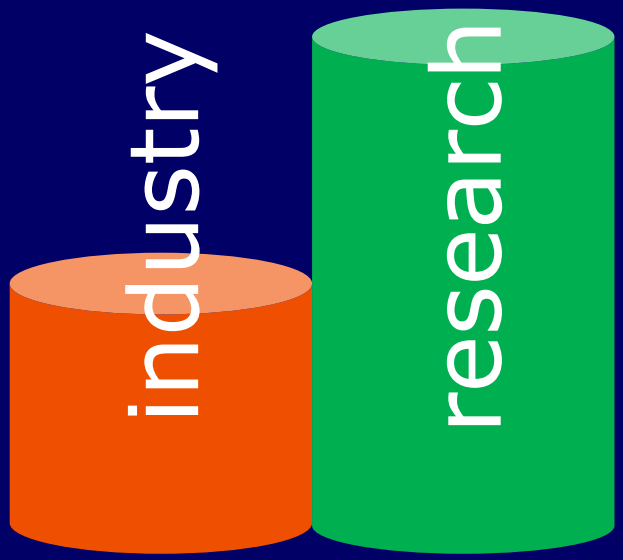

control plane monitoring

State of the Art (in MPLS/VPLS monitoring)

MPLS *and* VPLS control plane monitoring

State of the Art (in MPLS/VPLS monitoring)

industry

research

technology

State of the Art (in MPLS/VPLS monitoring)

industry

research

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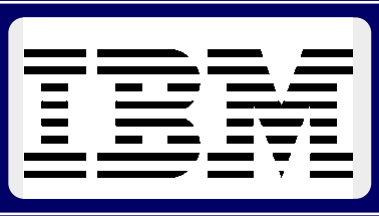


State of the Art (in MPLS/VPLS monitoring)

industry

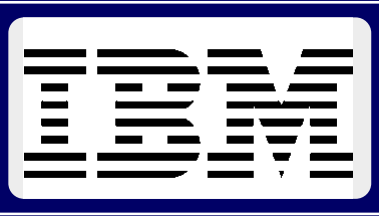
research

technology

IP Solution Center

Service Aware Manager

Service Activator Solution for VPN Services



Tivoli Network Manager

VPN Explorer

State of the Art (in MPLS/VPLS monitoring)

industry

research

technology

State of the Art (in MPLS/VPLS monitoring)

- Routing convergence
- Scalability
- Monitoring

industry
research
technology

State of the Art (in MPLS/VPLS monitoring)

industry

research

technology

- Routing convergence
  - D. Pei, J. Van der Merwe. BGP Convergence in Virtual Private Networks. Proc. IMC, 2006.
- Scalability
  - C. Kim, A. Gerber, C. Lund, D. Pei, S. Sen. Scalable VPN Routing via Relaying. Proc. SIGMETRICS, 2008.
- Monitoring
  - M. K. Thottan, G. K. Swanson, M. Cancone, T. K. Ho, J. Ren, S. Paul. SEQUIN: An SNMP-based MPLS Network Monitoring System. Bell Labs Technical Journal 8(1), 95–111, 2003.

State of the Art (in MPLS/VPLS monitoring)

industry

research

technology

State of the Art (in MPLS/VPLS monitoring)

- SNMP
- TIBCO Rendezvous Message Transport
- Oracle DBMS
- RCP, RSH
- Telnet, SSH
- TFTP, FTP

industry
research
technology

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industry
research
technology

Our Contributions

Our Contributions

- MPLS VPN/VPLS monitoring methodology

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- MPLS VPN/VPLS monitoring methodology
  - Focus on monitoring + provisioning

Our Contributions

- MPLS VPN/VPLS monitoring methodology
  - Focus on monitoring

Our Contributions

- MPLS VPN/VPLS monitoring methodology
  - Focus on monitoring
  - Observation of the network status

Our Contributions

- MPLS VPN/VPLS monitoring methodology
  - Focus on monitoring
  - Observation of effects of network events

Our Contributions

- MPLS VPN/VPLS monitoring methodology
  - Focus on monitoring
  - Observation of effects of network events
    - Reconfigurations
    - Failures

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✓ Exhaustive analysis of observable effects

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- MPLS VPN/VPLS monitoring methodology
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  - ✓ Exhaustive analysis of observable effects
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- MPLS VPN/VPLS monitoring methodology
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  - Additional technologies required

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  - Unobtrusive
  - Graphical visualization of VPN states

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- Extensive discussion on scalability vs visibility of (the effects of) network events

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- Architecture, prototype, experimentation in Junosphere

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- Graphical visualization of VPN states

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- Architecture, prototype, experimentation in Junosphere

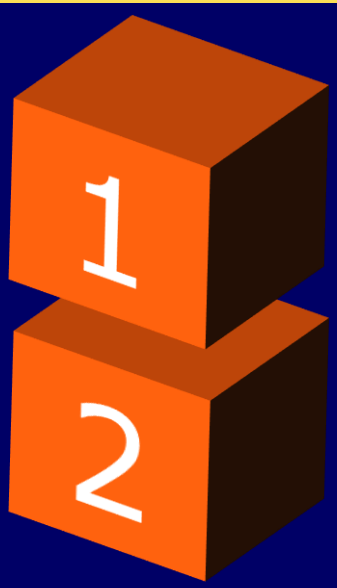
- Discovery of a subtle anomaly in the routing software, confirmed by Juniper

Methodology

Methodology

Collect signaling messages

Methodology



1. Collect signaling messages
2. Reconstruct visibility of VPNs at PEs

Methodology

Collect signaling messages

Reconstruct visibility of VPNs at PEs

Visualize VPN states

Methodology

Collect signaling messages

Reconstruct visibility of VPNs at PEs

Visualize VPN states

Methodology
1. Collection

Approach	Drawback(s)

Methodology
1. Collection

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Monitor network traffic	Undetermined in absence of traffic

Methodology
1. Collection

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- Actual propagation of information
- Routing decisions @ PEs

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Methodology
1. Collection

- VPN signaling
  - MPLS: BGP
  - VPLS:

	Autodiscovery	Signaling	Vendor
RFC 4762 (Kompella)	N/A	LDP	Cisco
RFC 4761	BGP	BGP	Juniper

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BGP-based VPLS Autodiscovery

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BGP-based VPLS Autodiscovery

LDP-BGP VPLS Interworking

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BGP-based VPLS Autodiscovery

LDP-BGP VPLS Interworking

BGP is also...

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BGP-based VPLS Autodiscovery

LDP-BGP VPLS Interworking

BGP is also...
- easy to set up
- scalable
- policy-aware

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BGP-based VPLS
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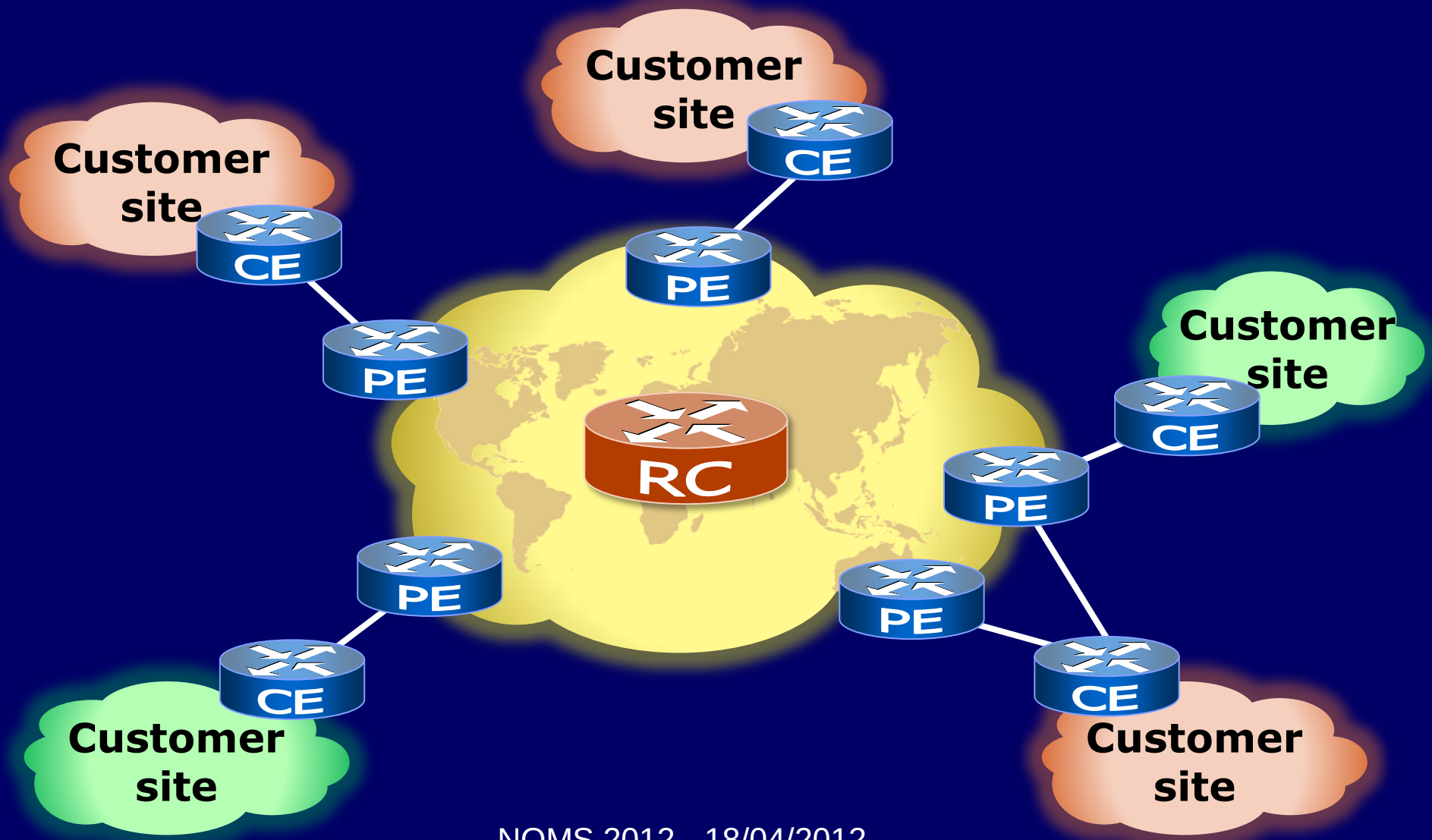

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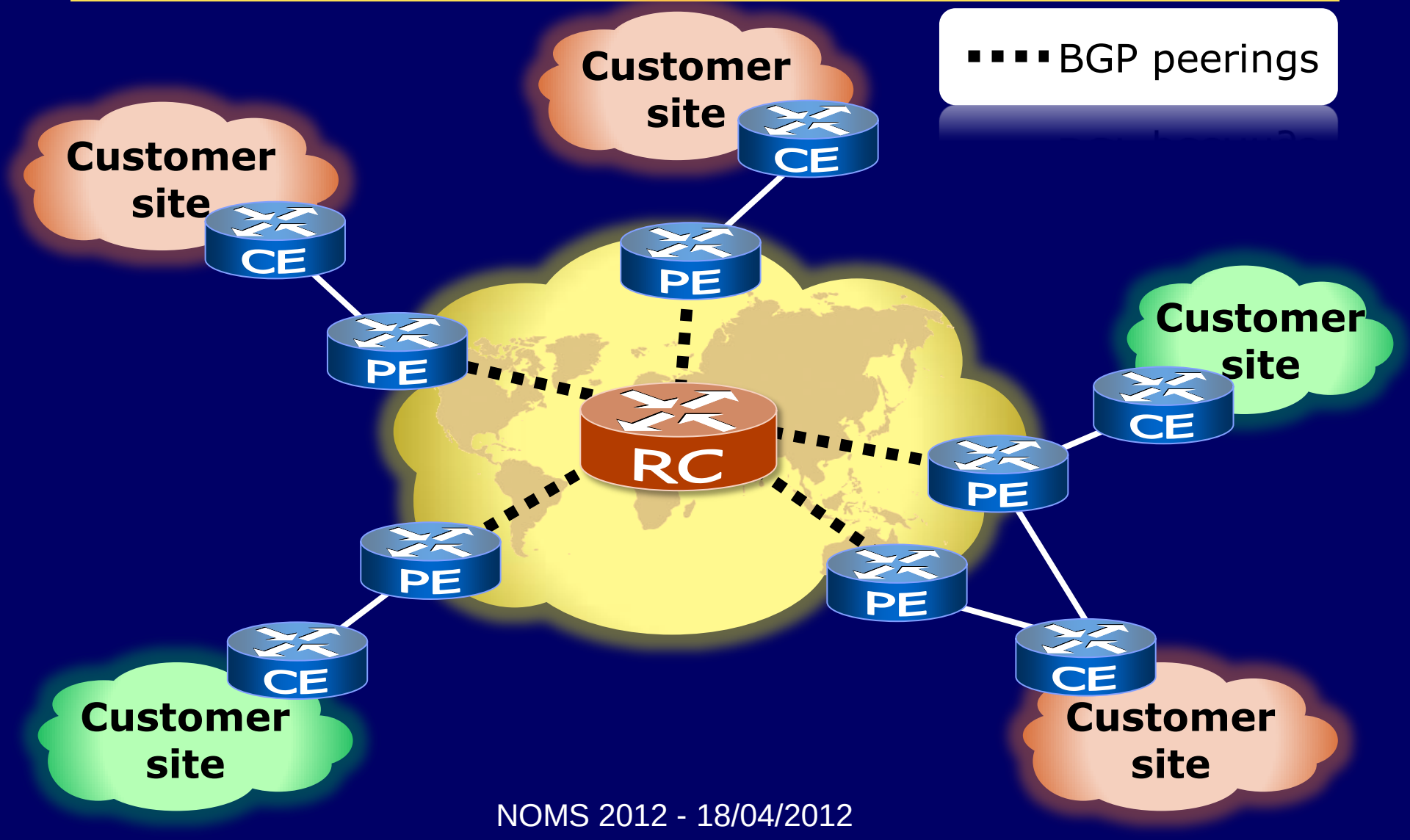

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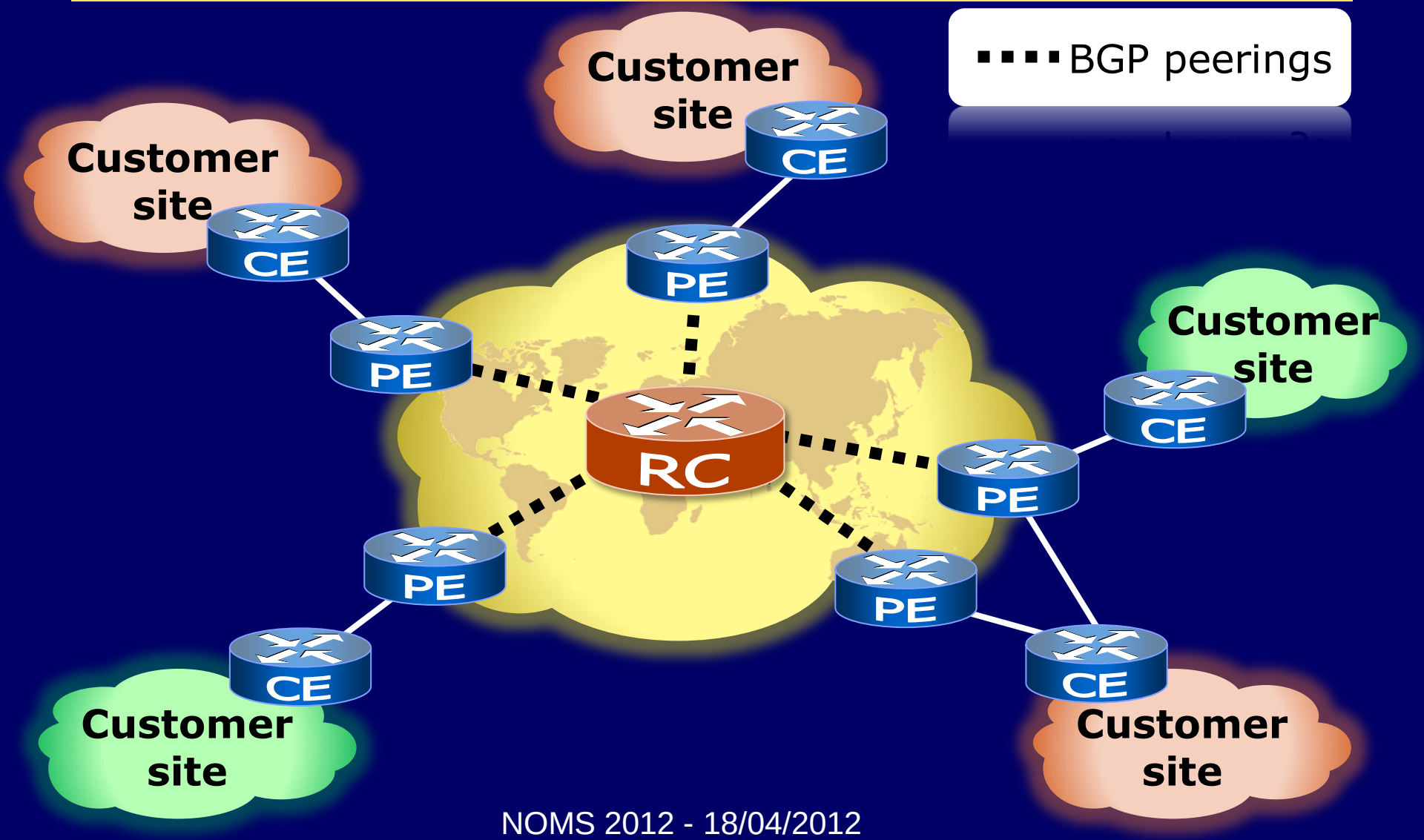

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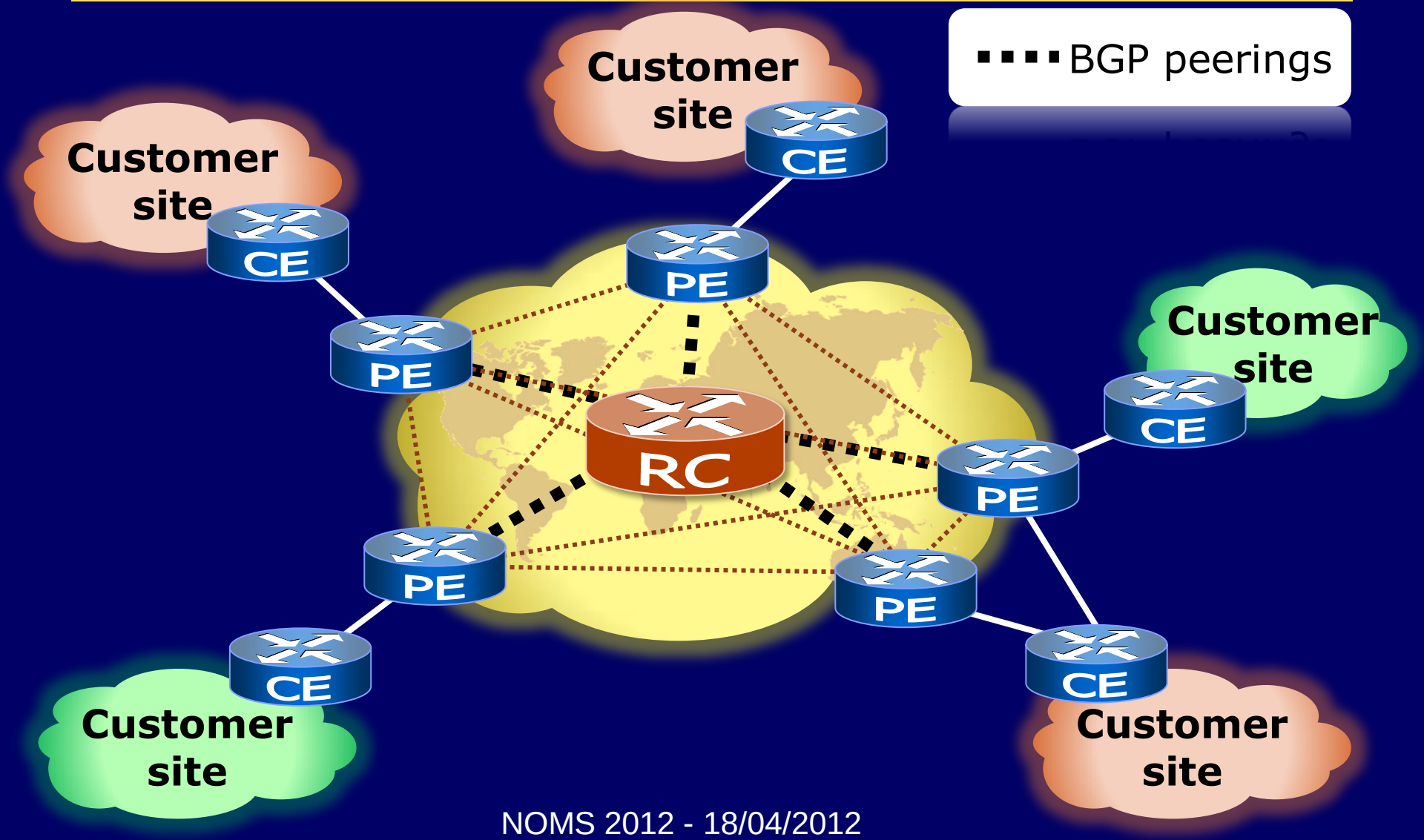

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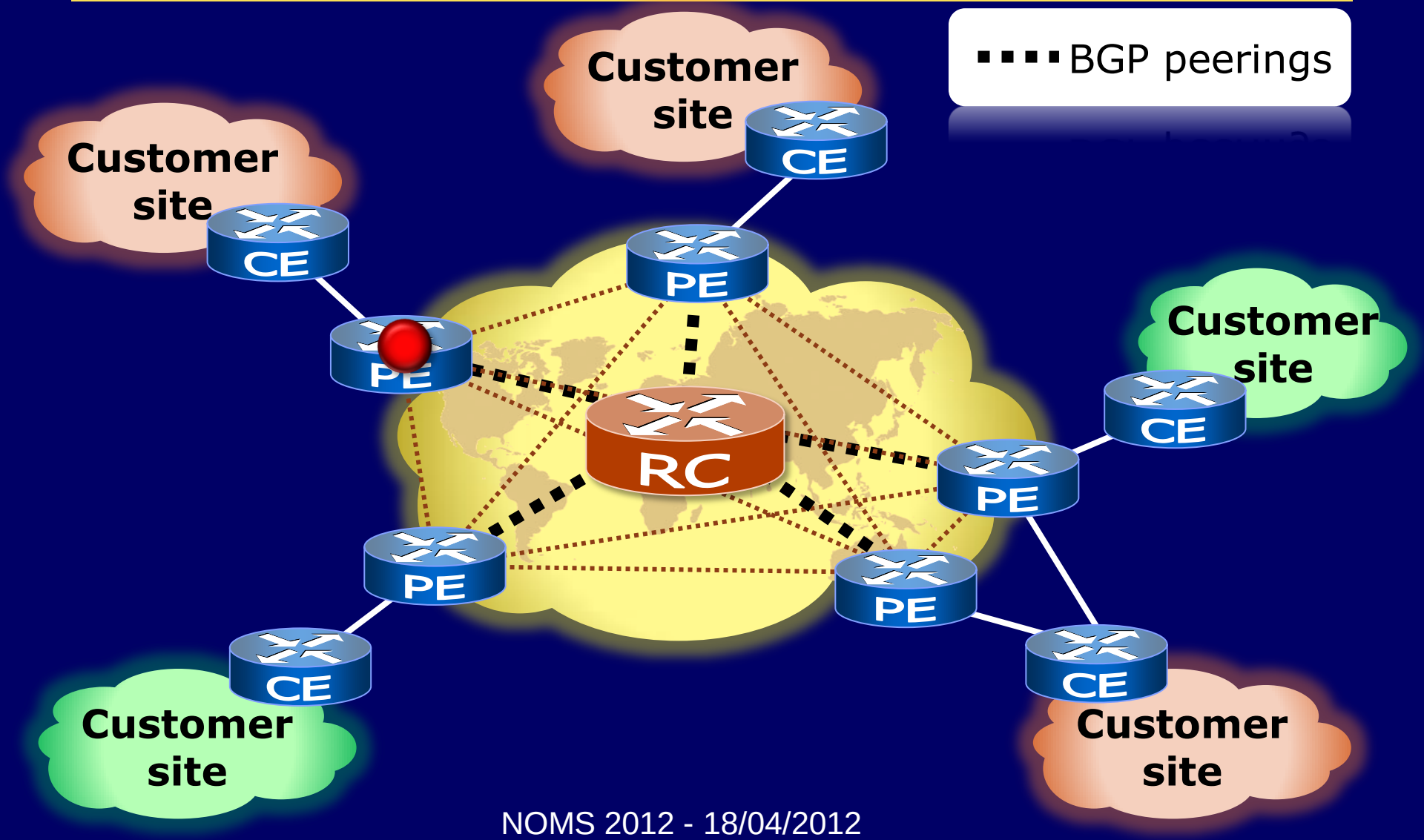

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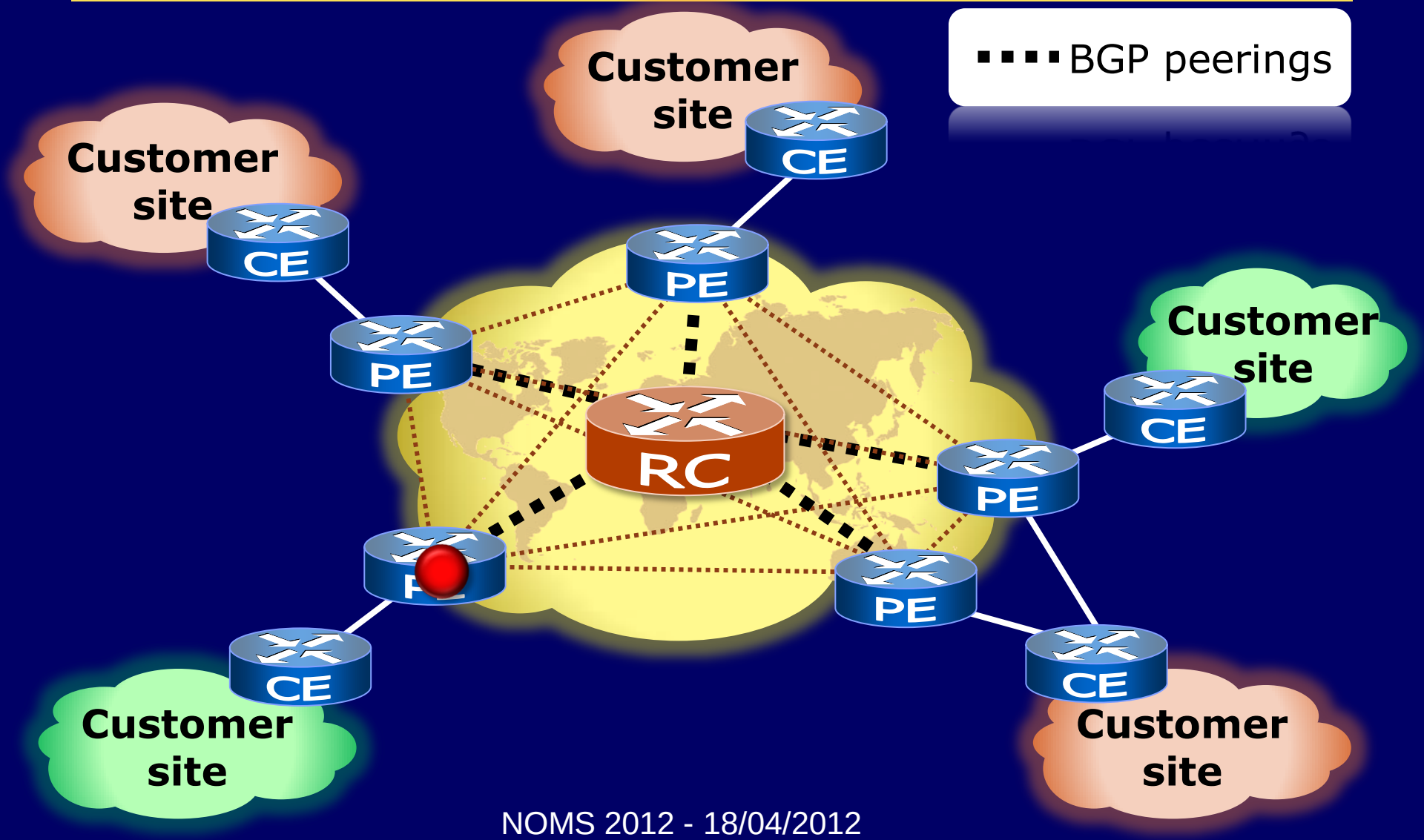

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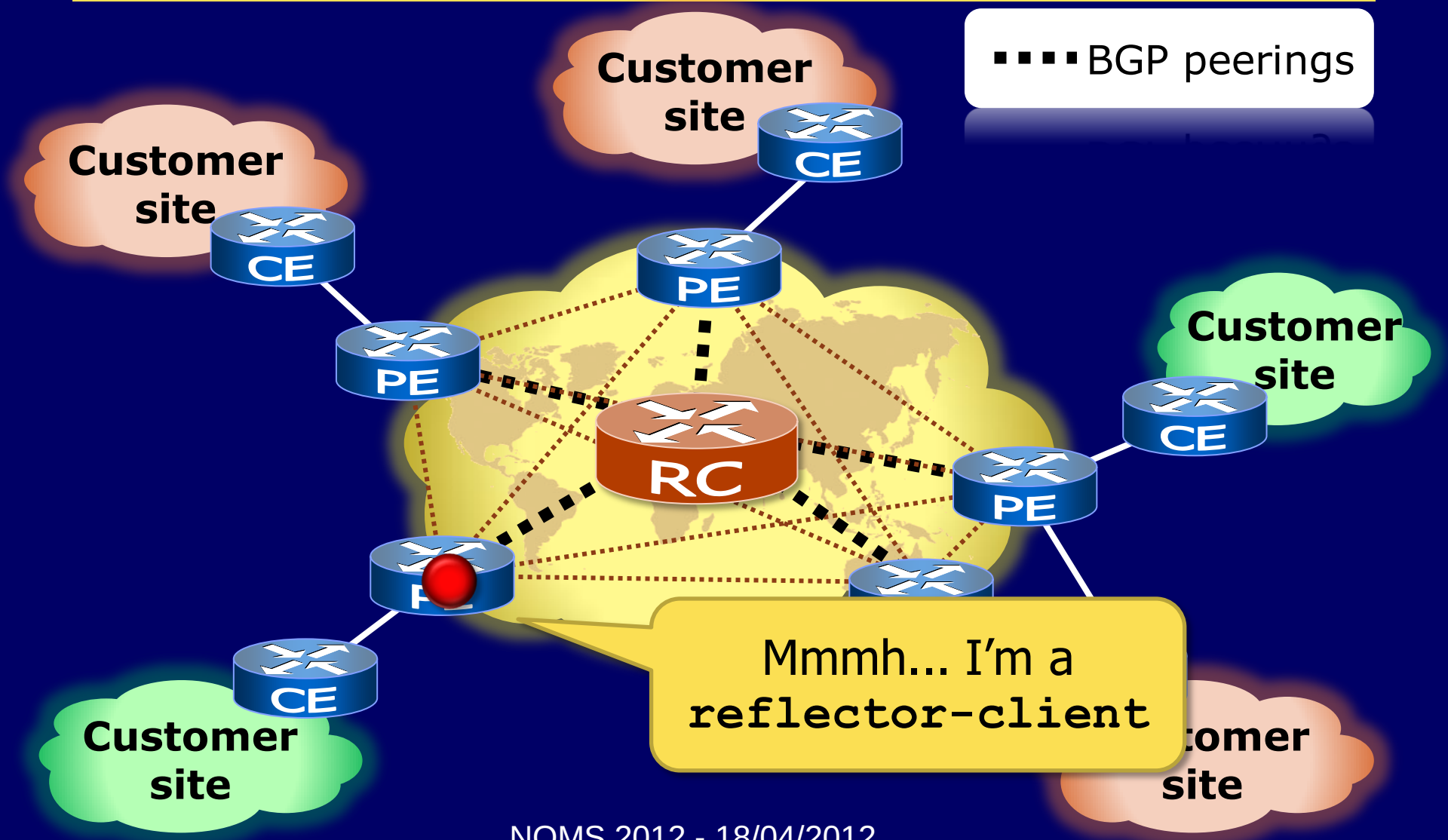

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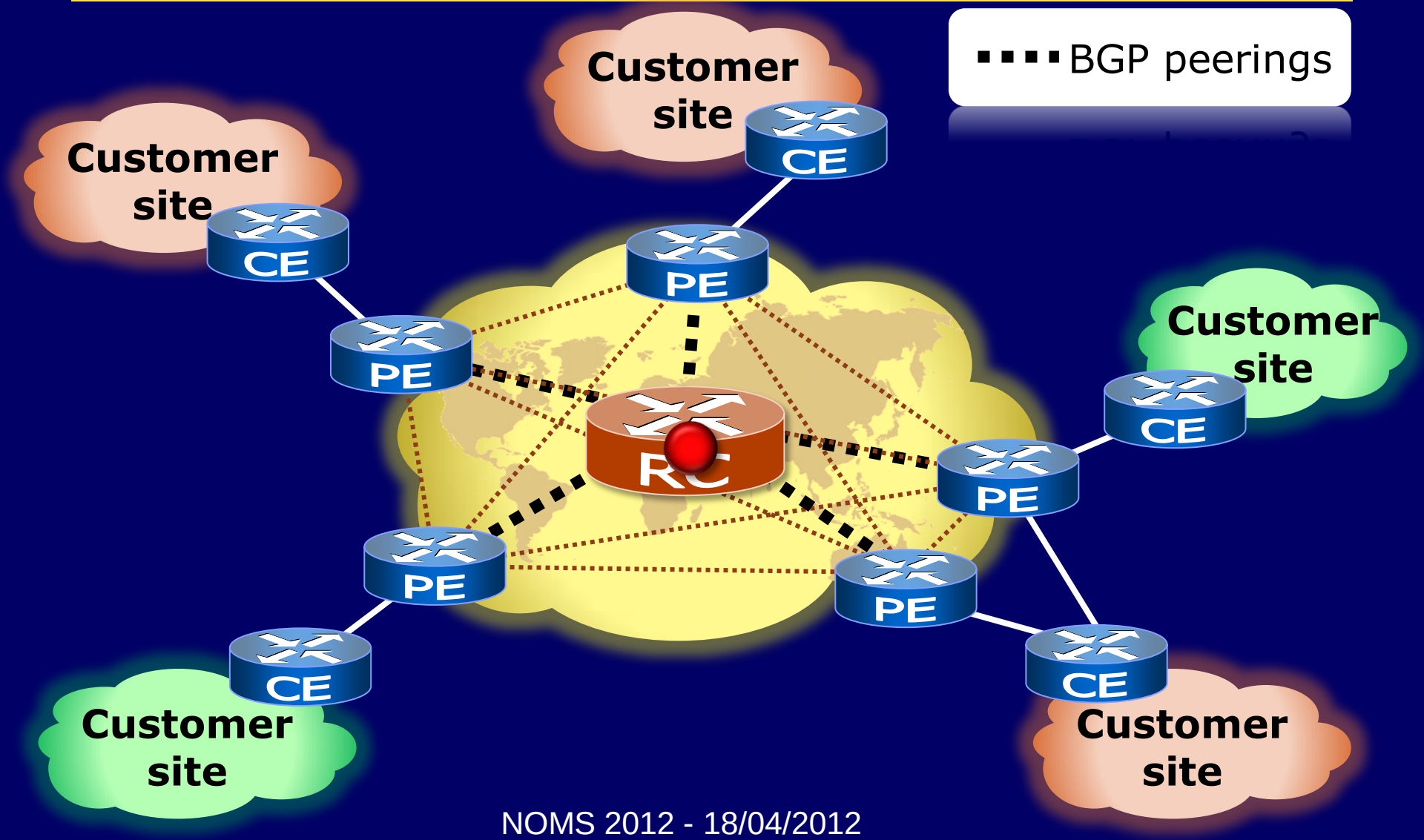

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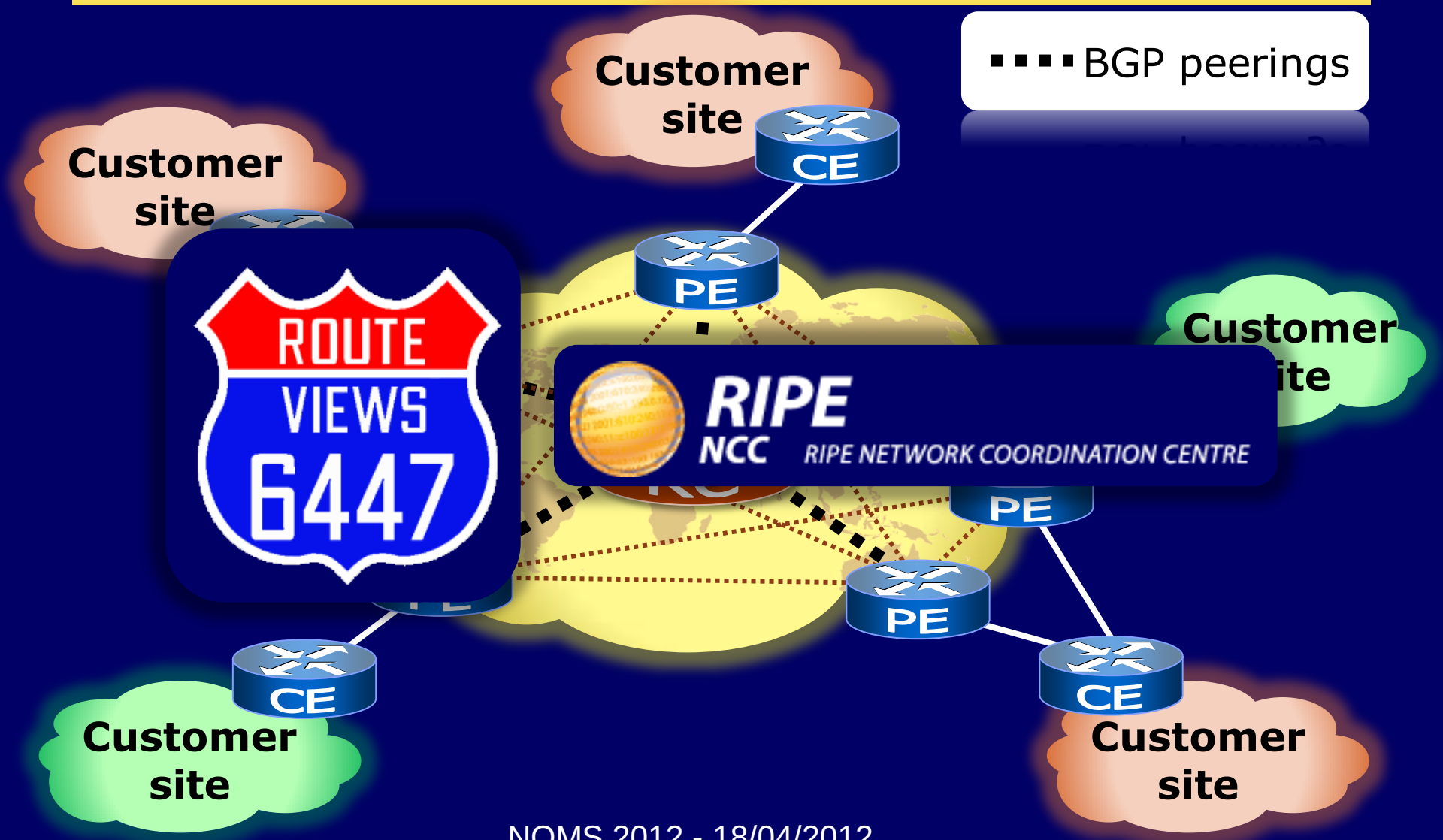

Methodology
1. Collection

Methodology
2. Reconstruction of VPN state

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type (A/W)

Methodology
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NLRI

Methodology
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type (A/W)

NLRI

Extended communities

Methodology
2. Reconstruction of VPN state

type (A/W)

NLRI

RD + prefix

Extended communities

Methodology
2. Reconstruction of VPN state

type (A/W)

NLRI

RD + prefix

CE ID

Extended communities

Methodology
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type (A/W)

NLRI

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CE ID

Extended communities

RT

Methodology
2. Reconstruction of VPN state

type (A/W)

NLRI

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Extended communities

RT

- Exhaustive comparison of information from different BGP updates

Methodology
2. Reconstruction of VPN state

- Example

Methodology
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Methodology
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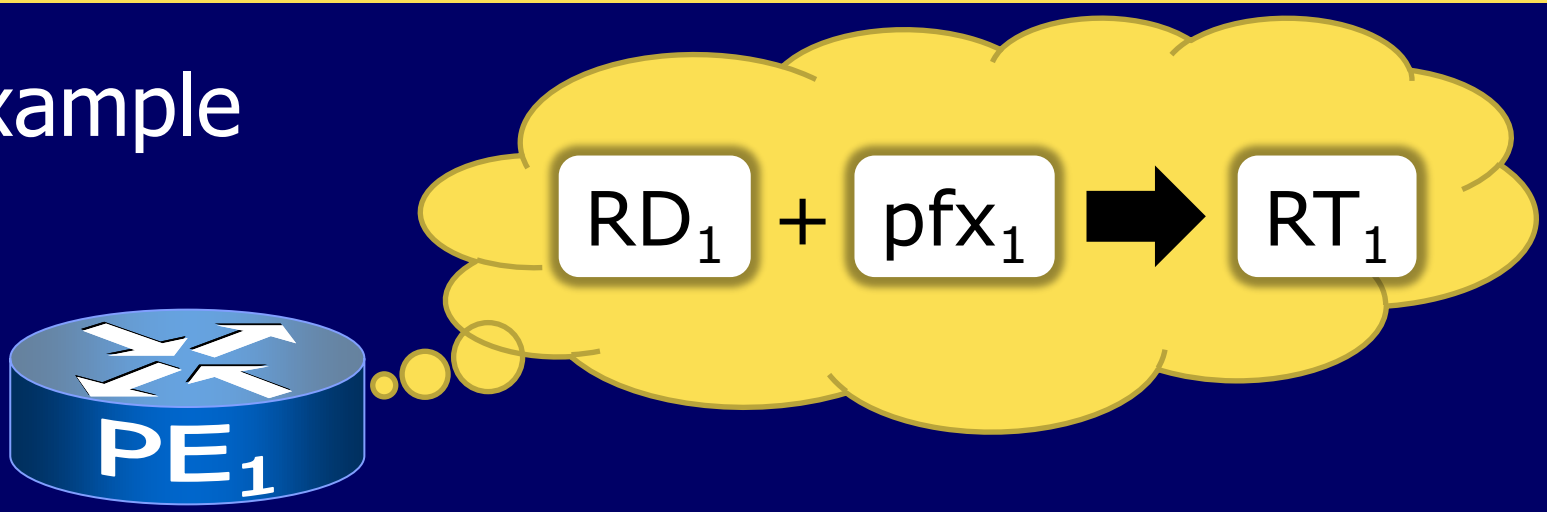
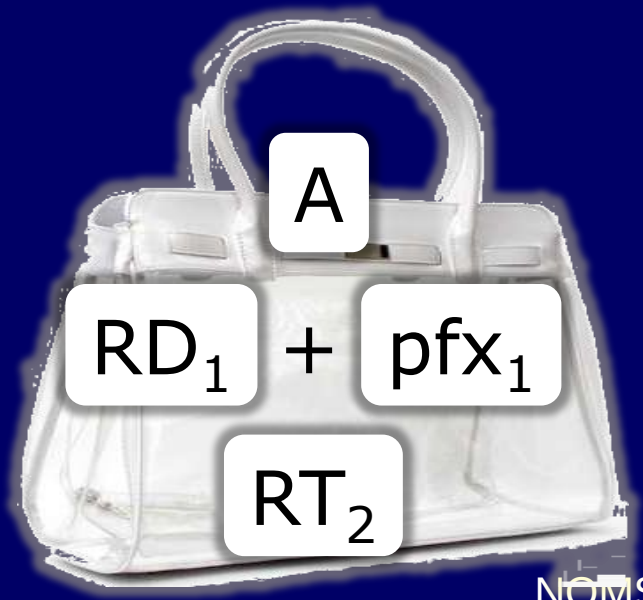


Methodology
2. Reconstruction of VPN state

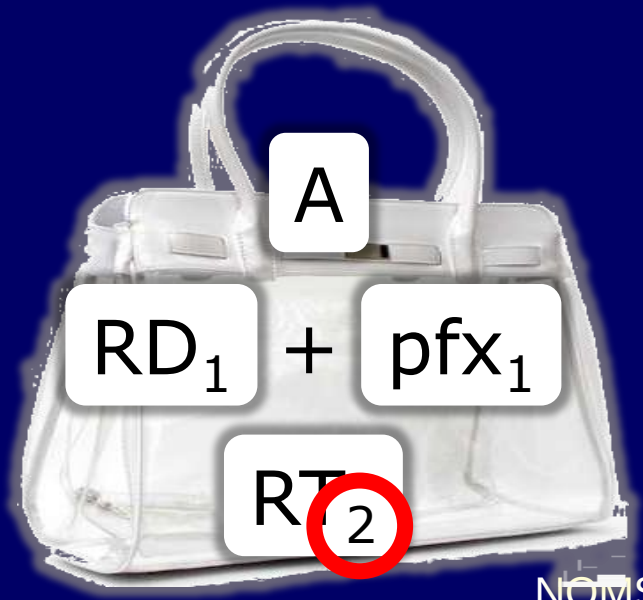
- Example



RD_1 + pfx_1 ➡ RT_1

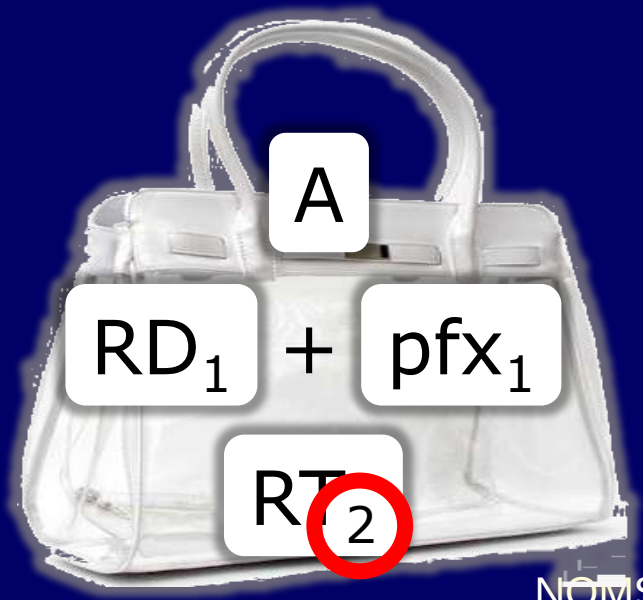
Methodology
2. Reconstruction of VPN state

- Example



Methodology
2. Reconstruction of VPN state

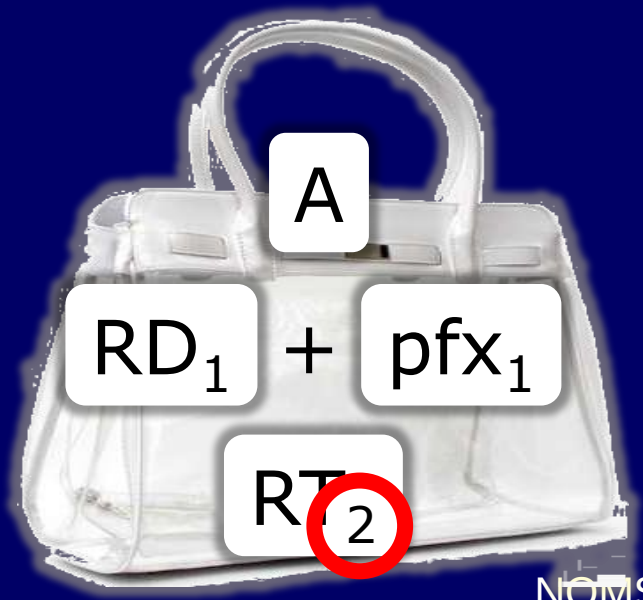
- Example



Methodology
2. Reconstruction of VPN state

- Example

RD_1 + pfx_1 ➡ RT_2



- Changed VPN?
- Reconfiguration?
  - Policy change?
  - Moved pfx_1 to a different VPN?

Methodology
2. Reconstruction of VPN state

- Apply the method to a sequence of BGP updates

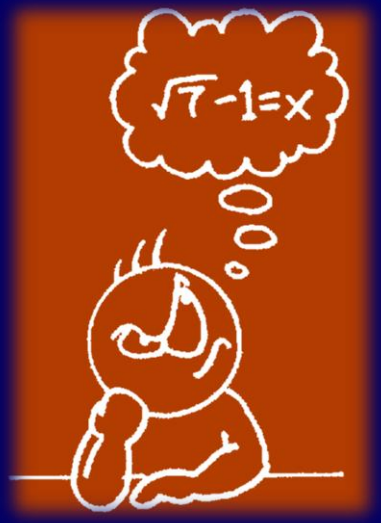
Methodology
2. Reconstruction of VPN state

- Apply the method to a sequence of BGP updates

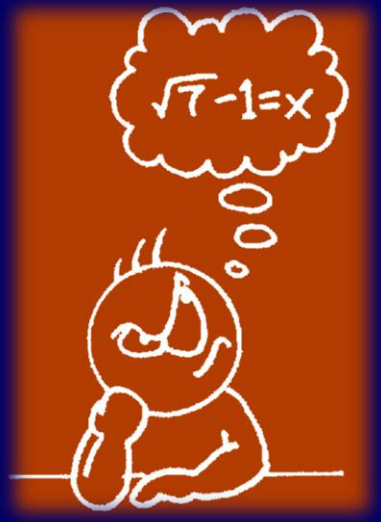
- Reconstruct history of VPN visibility at each PE

Methodology
2. Reconstruction of VPN state

- A few difficulties:



Methodology
2. Reconstruction of VPN state



- A few difficulties:
  - Investigation of the PE where the effect was first observed
  - Dealing with missing attributes in withdrawals
  - Inadmissible announcements [rfc4761]
  - Reannouncements
  - Synchronization with actual VPN states
  - Monitoring RC peering states

Methodology
3. Visualization

Methodology
3. Visualization

Query: visibility at each PE of

RD	12345:10011
prefix	172.16.110.0/30
RT	12345:111

Methodology
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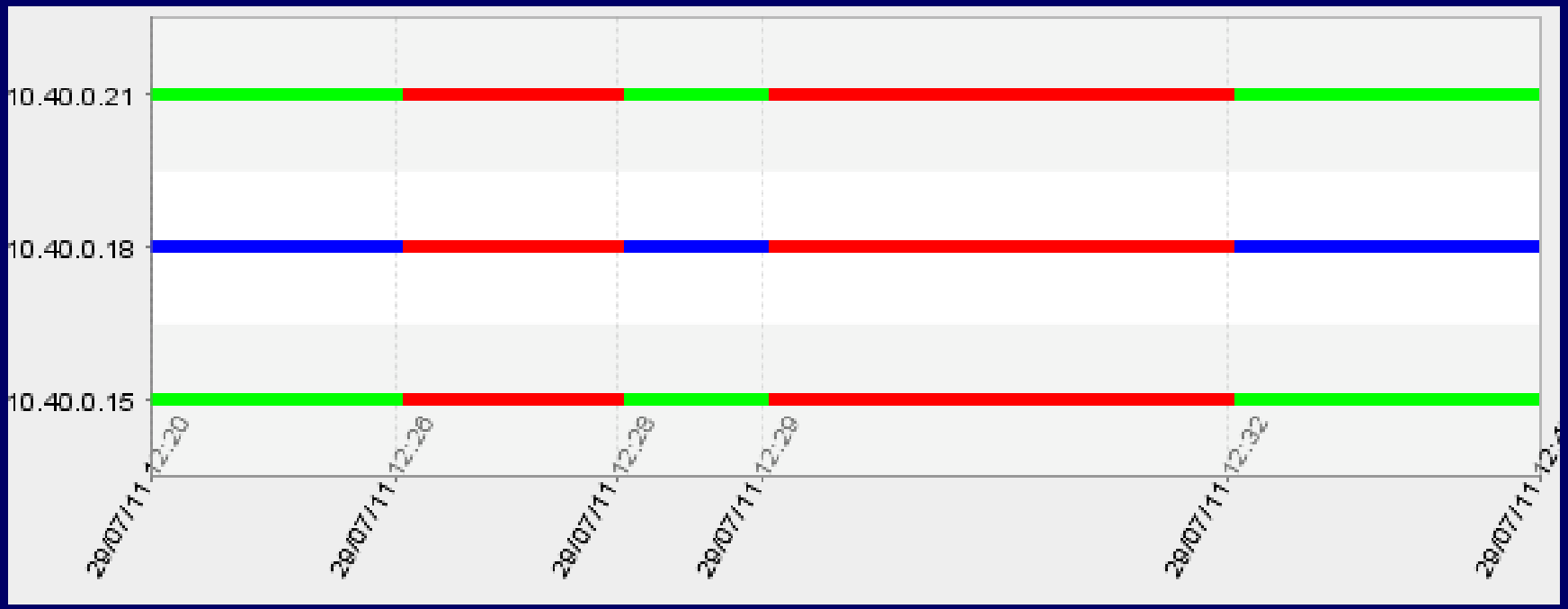

Methodology
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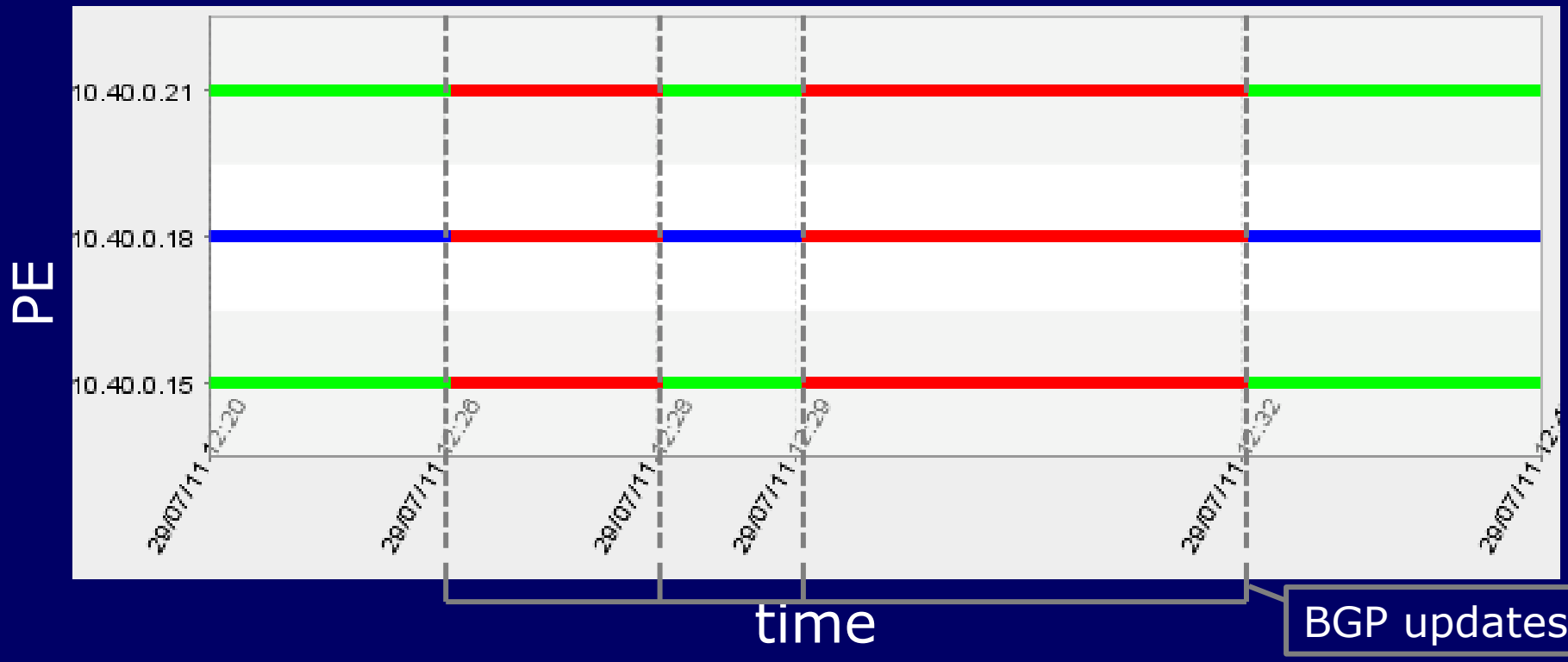

Methodology
3. Visualization

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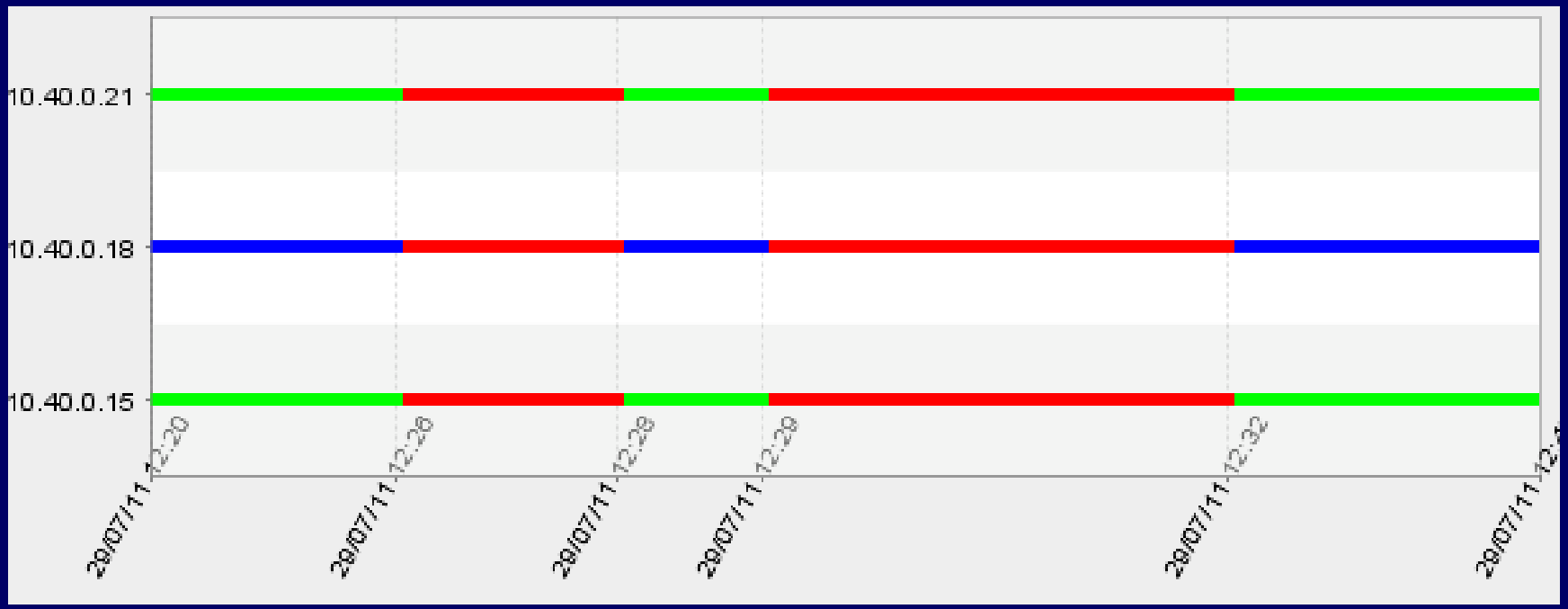
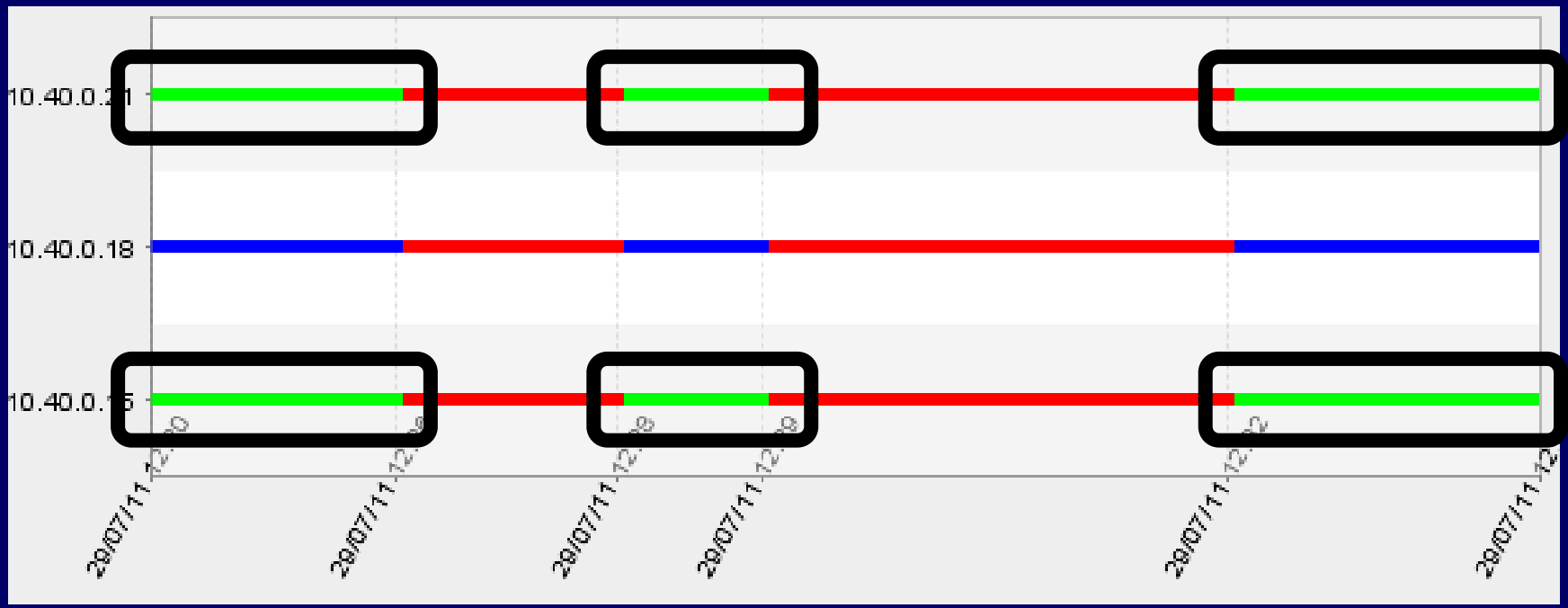


Methodology
3. Visualization

Query: visibility at each PE of
RD 12345:10011
prefix 172.16.110.0/30
RT 12345:111

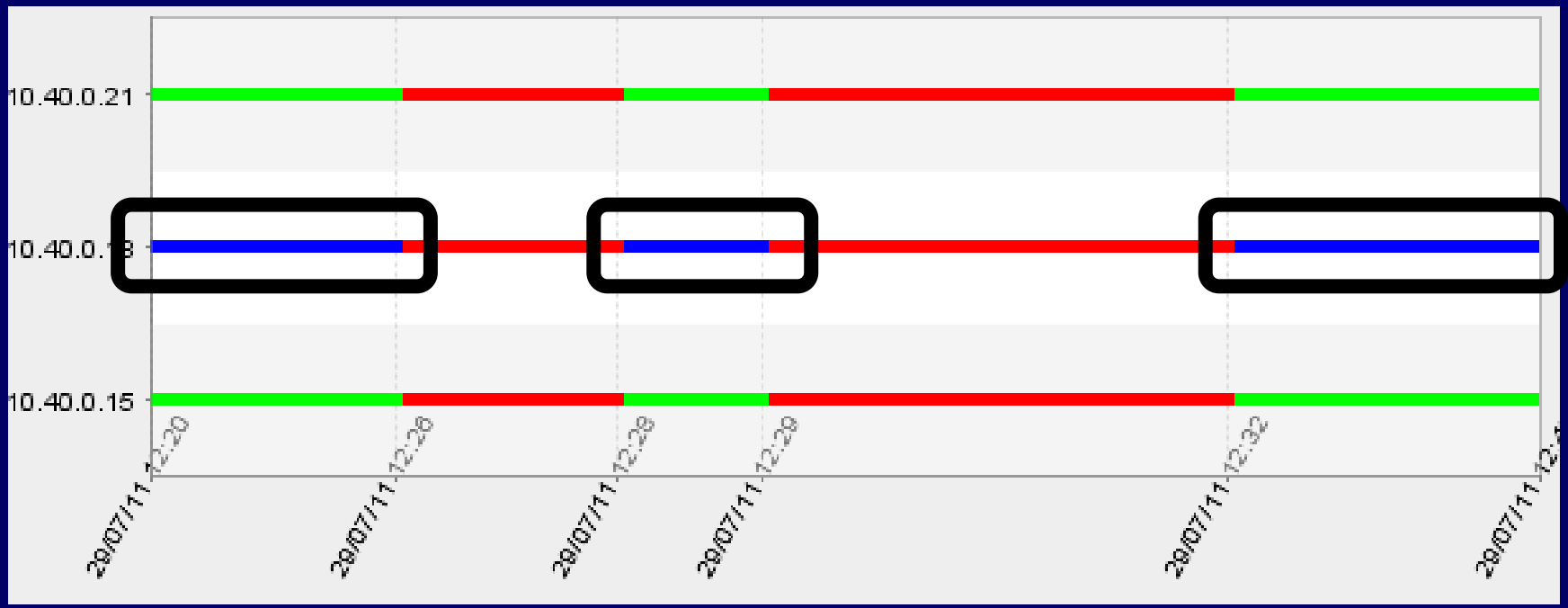
visible



Methodology
3. Visualization

Query: visibility at each PE of
RD 12345:10011
prefix 172.16.110.0/30
RT 12345:111

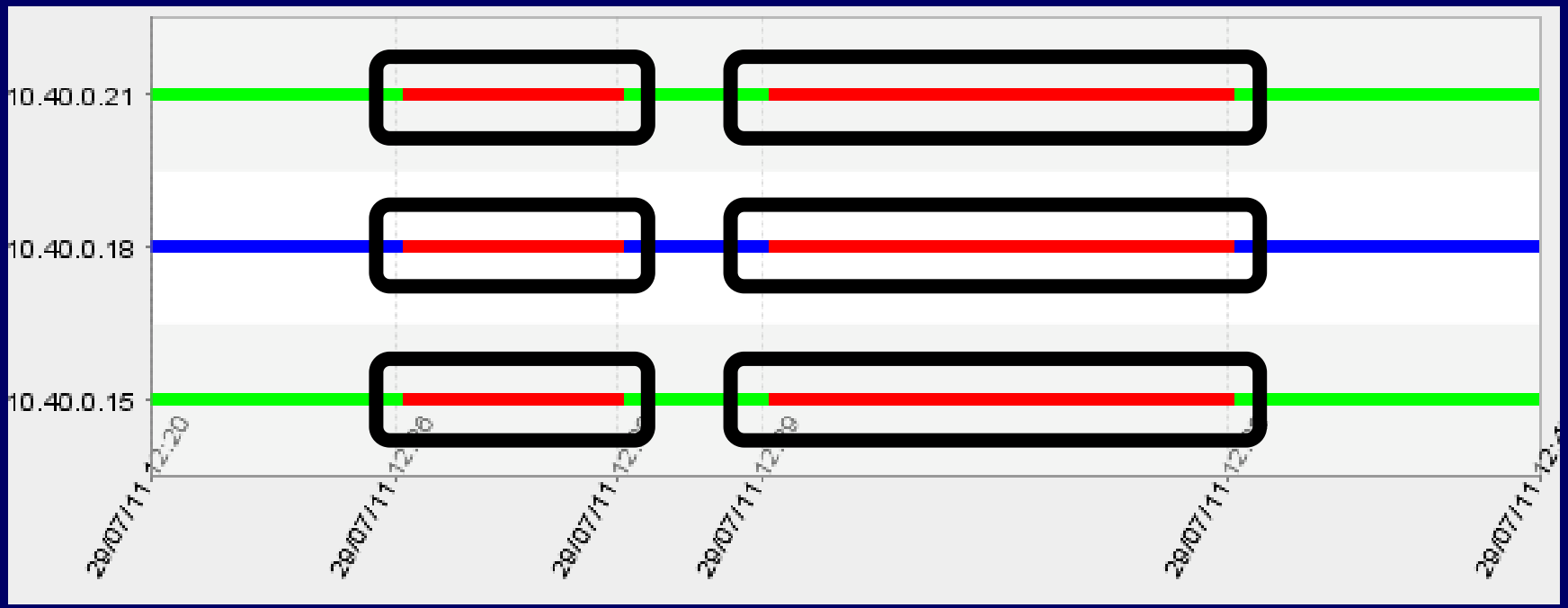
visible
originated



Methodology
3. Visualization

Query: visibility at each PE of
RD 12345:10011
prefix 172.16.110.0/30
RT 12345:111

visible
originated
not visible



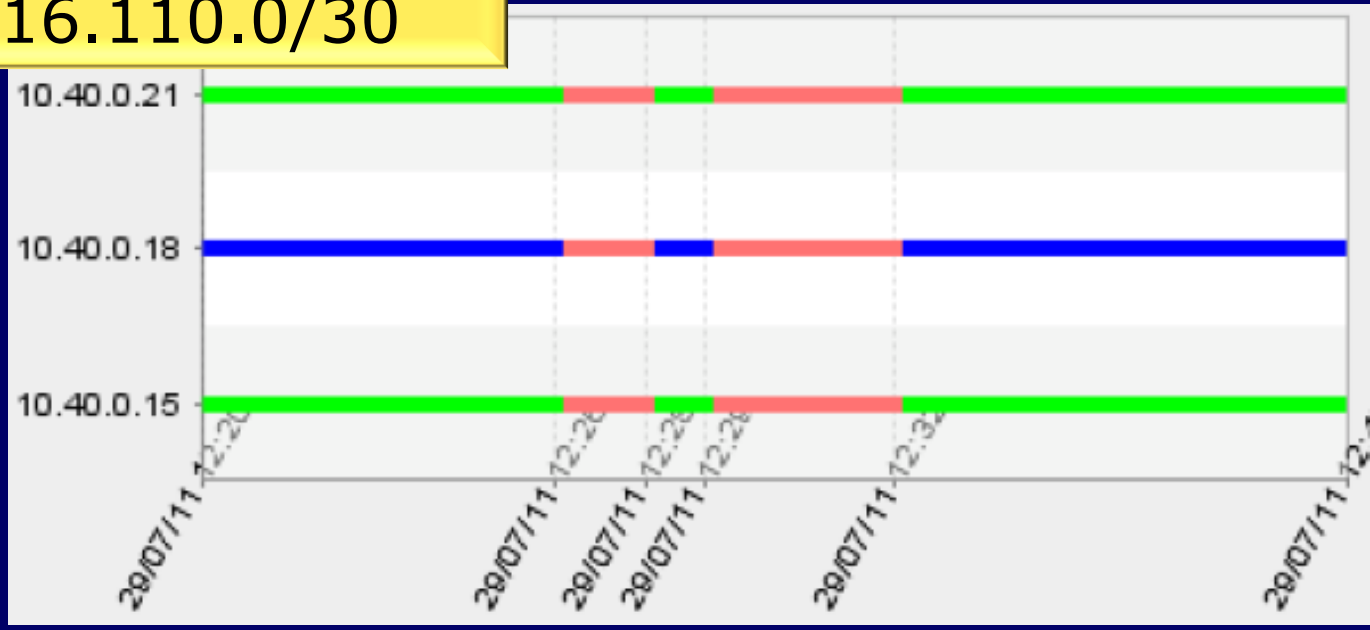
Query: visibility at each PE of

RD 12345:10011

prefix 172.16.110.0/30

Query: visibility at each PE of
RD 12345:10011
prefix 172.16.110.0/30

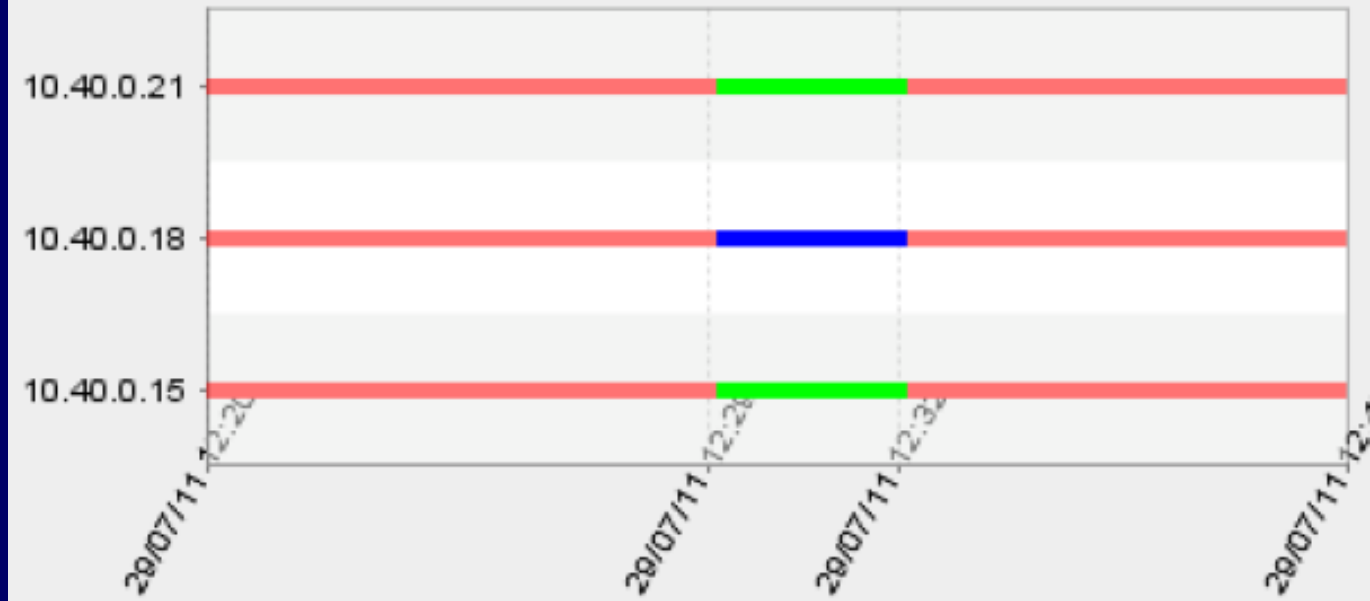
...with **RT** 12345:111



Query: visibility at each PE of
RD 12345:10011
prefix 172.16.110.0/30

...with **RT** 12345:111

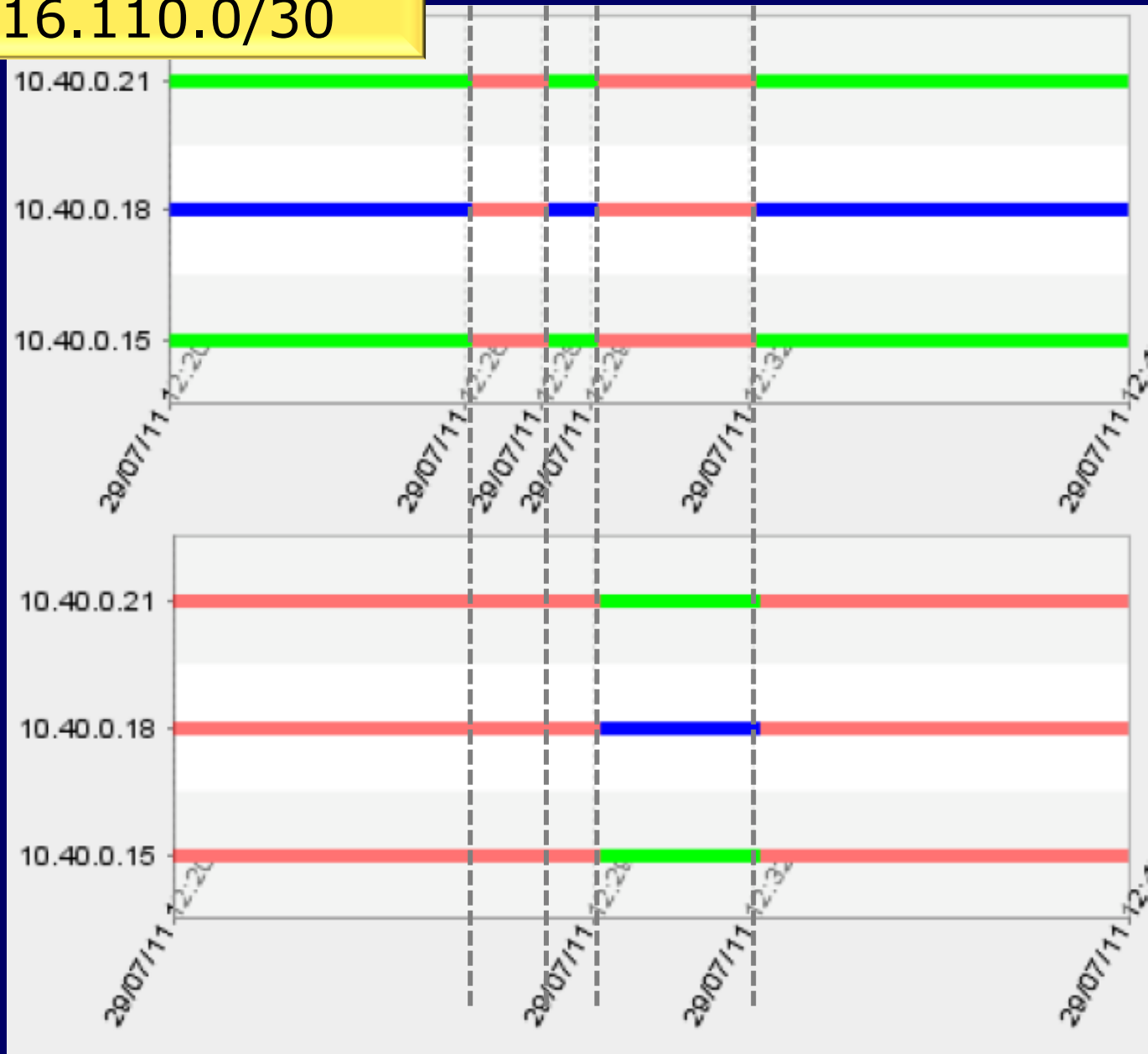
...with **RT** 12345:222



Query: visibility at each PE of
RD 12345:10011
prefix 172.16.110.0/30

...with **RT** 12345:111

...with **RT** 12345:222



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RD 12345:10011
prefix 172.16.110.0/30

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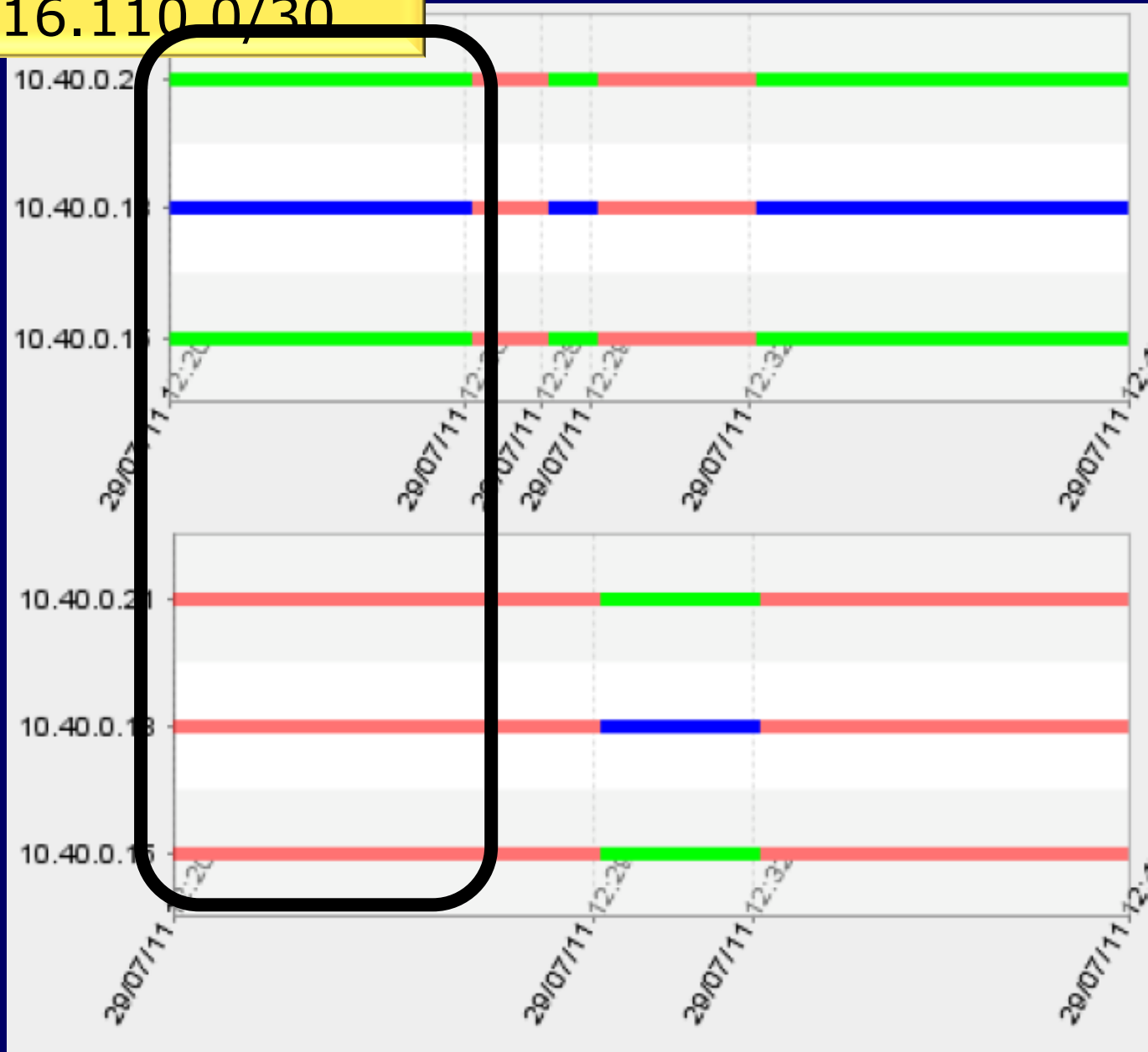
...with **RT** 12345:222



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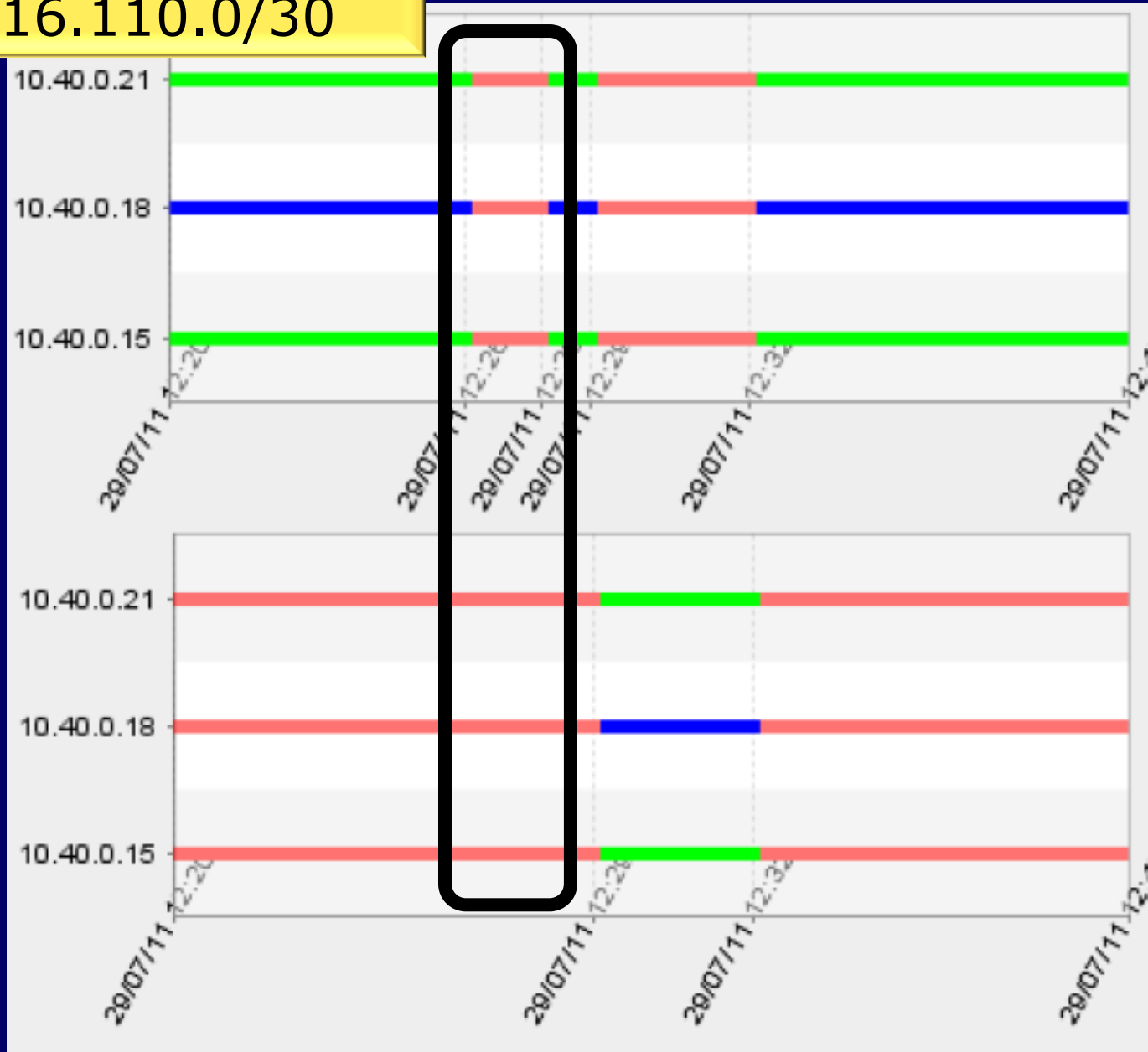
RD 12345:10011
prefix 172.16.110.0/30

...with **RT** 12345:111

...with **RT** 12345:222



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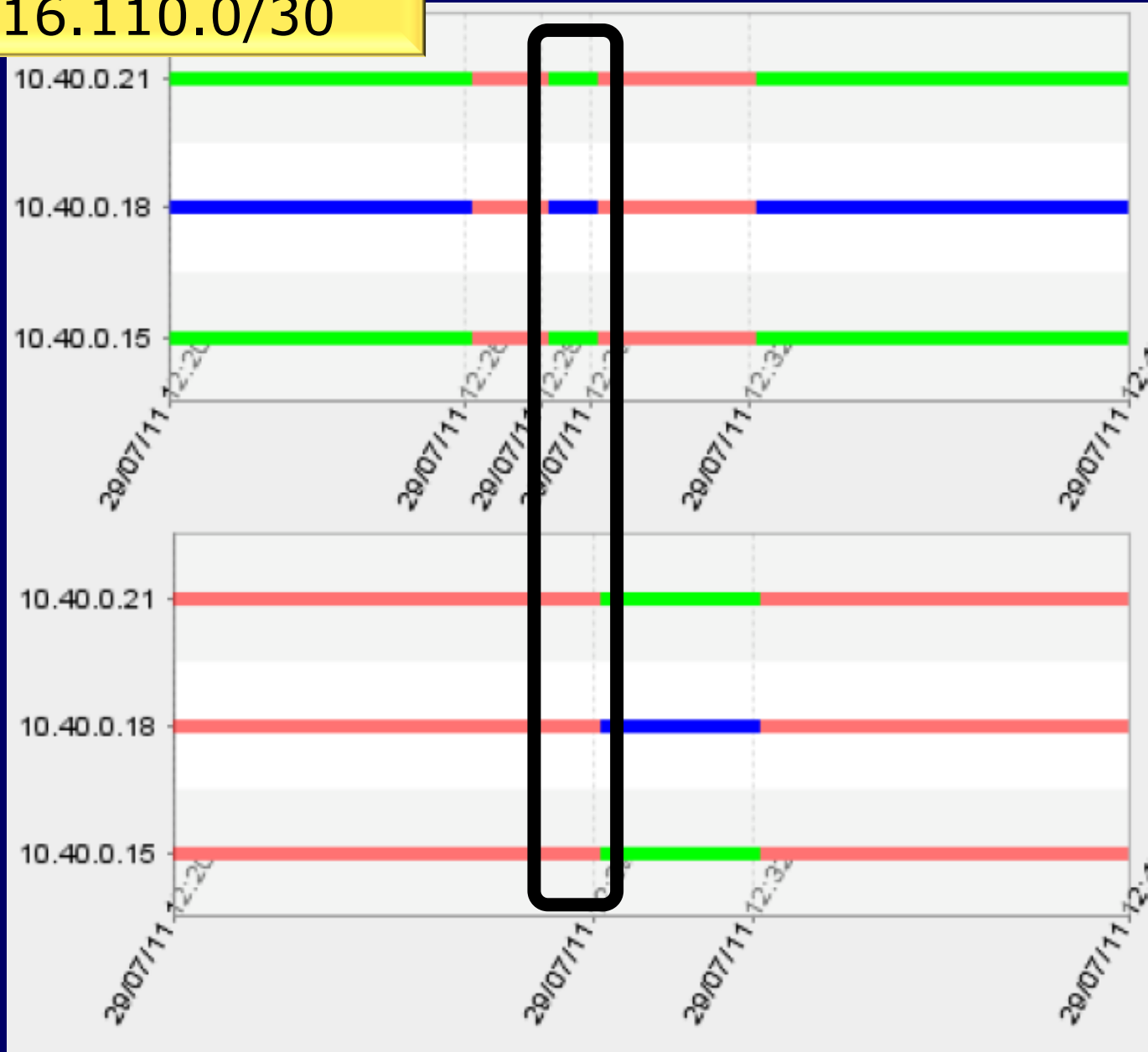
RD 12345:10011
prefix 172.16.110.0/30

...with **RT** 12345:111

...with **RT** 12345:222



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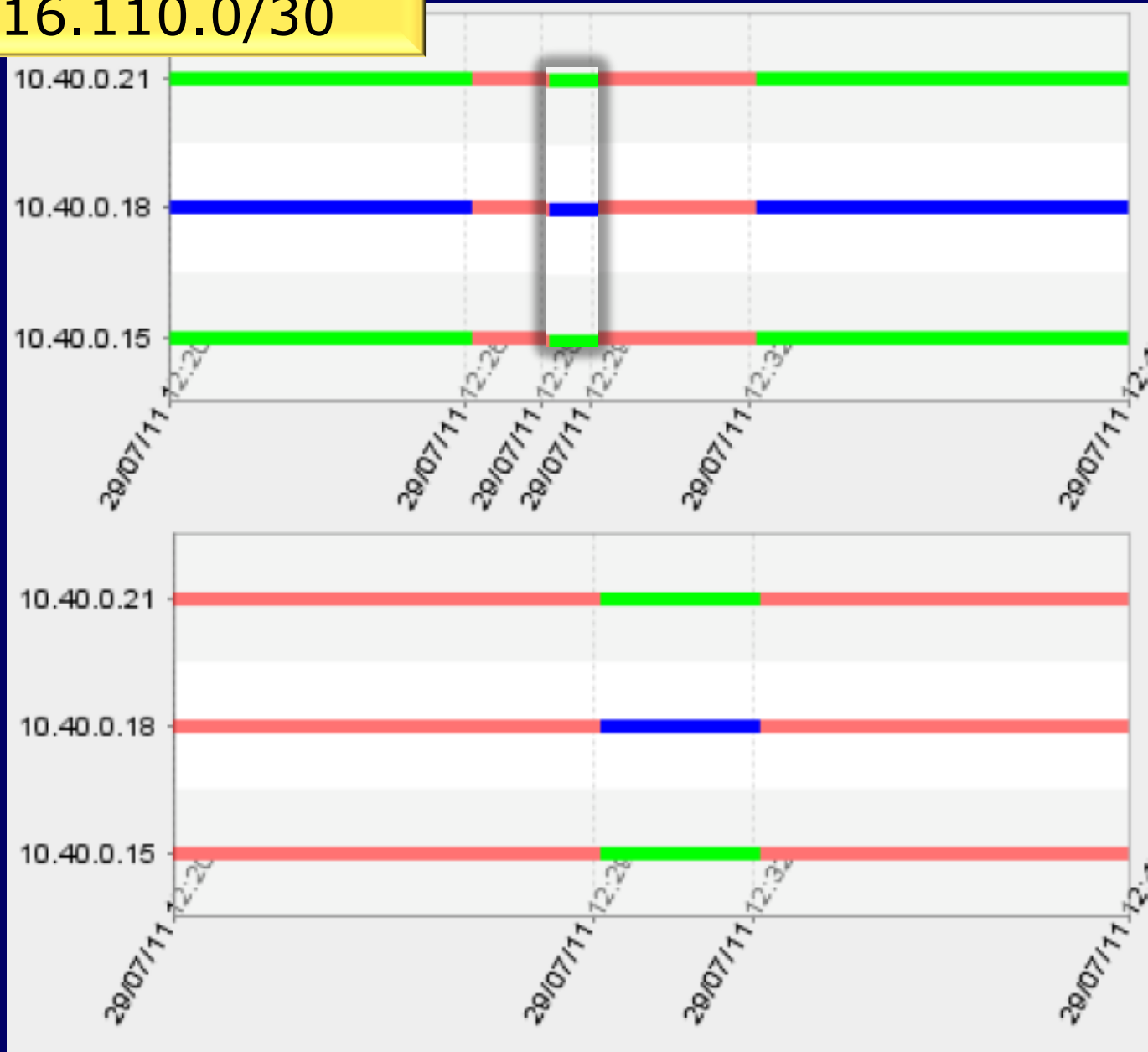

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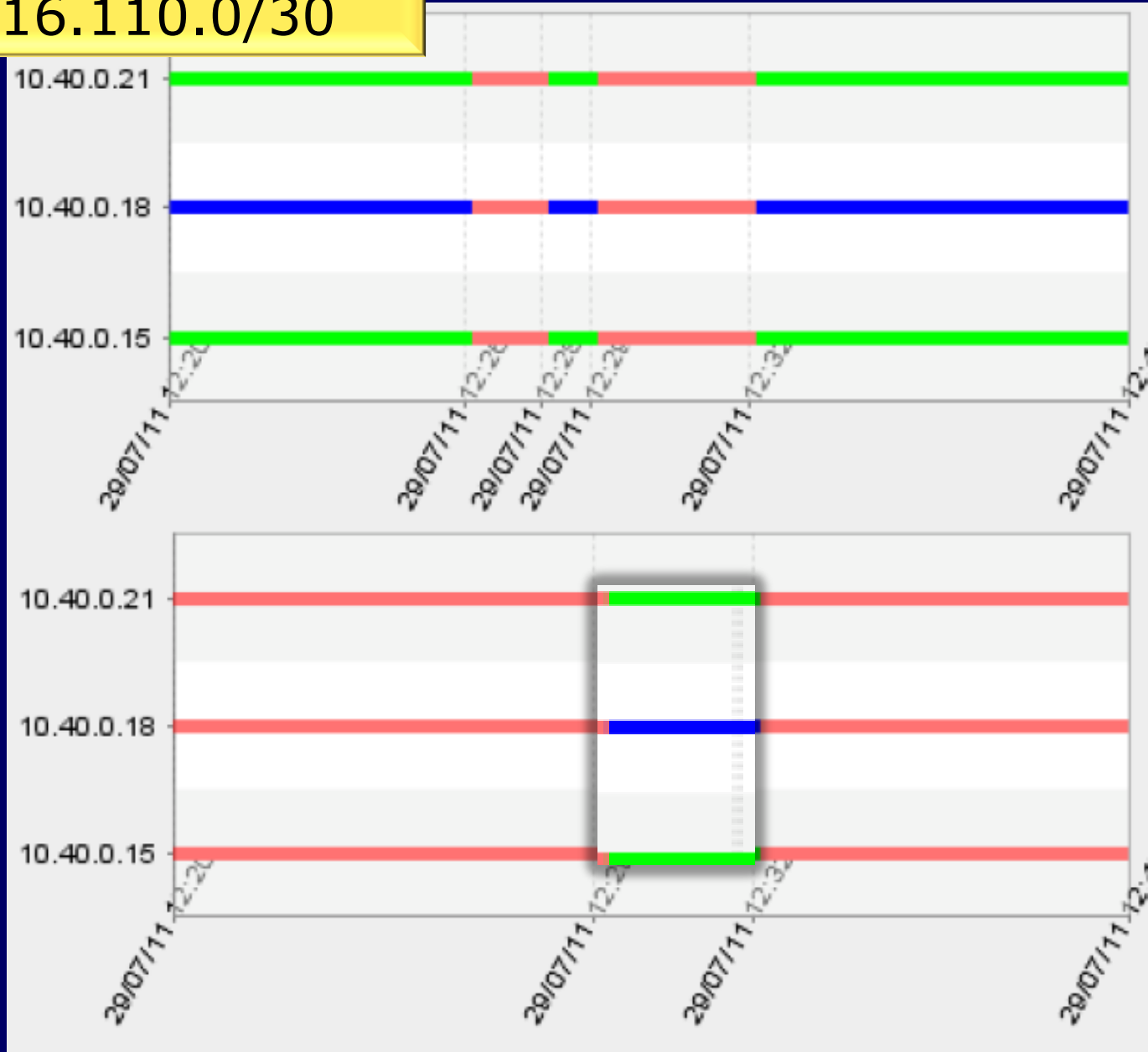

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RD 12345:10011
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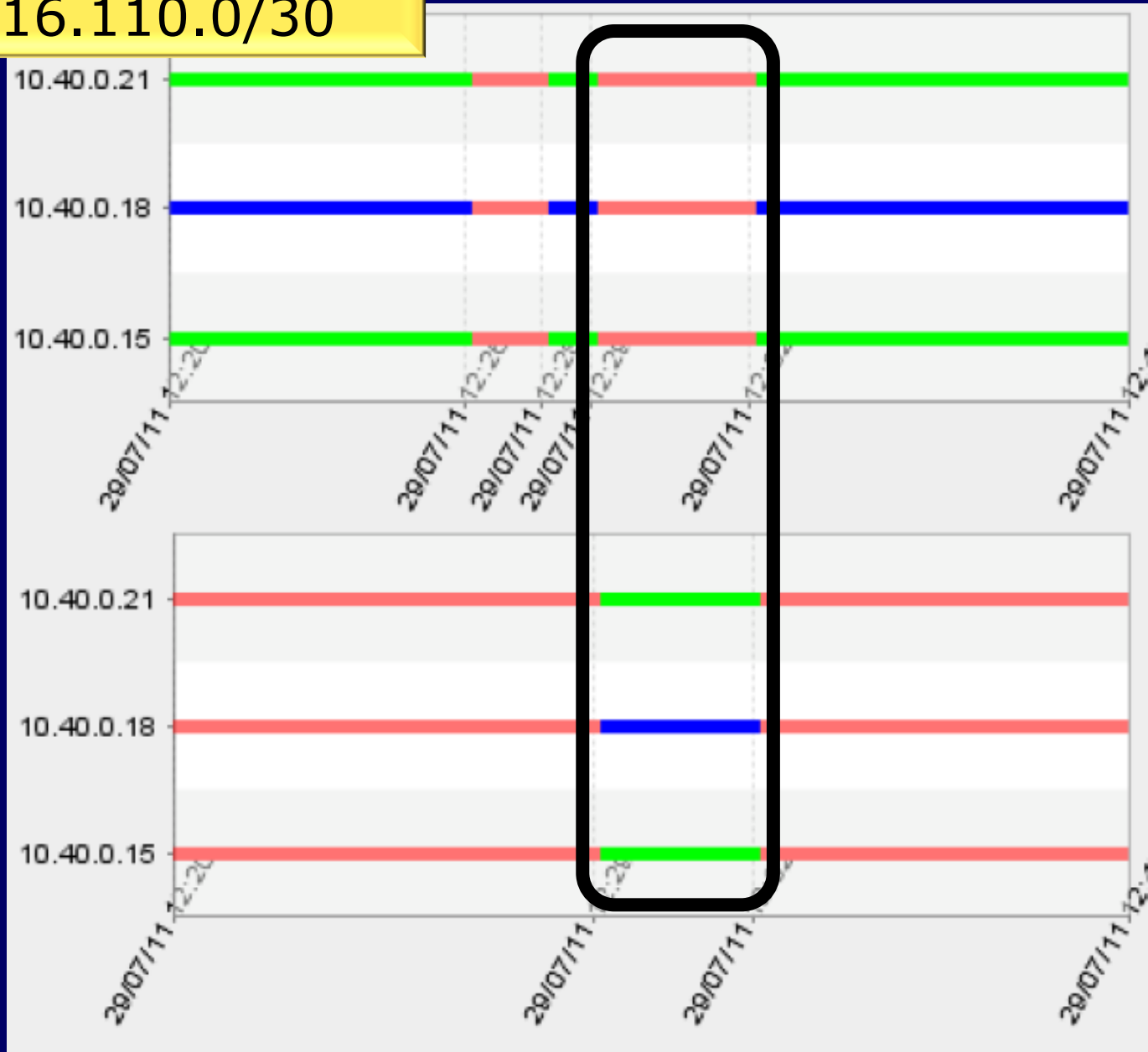

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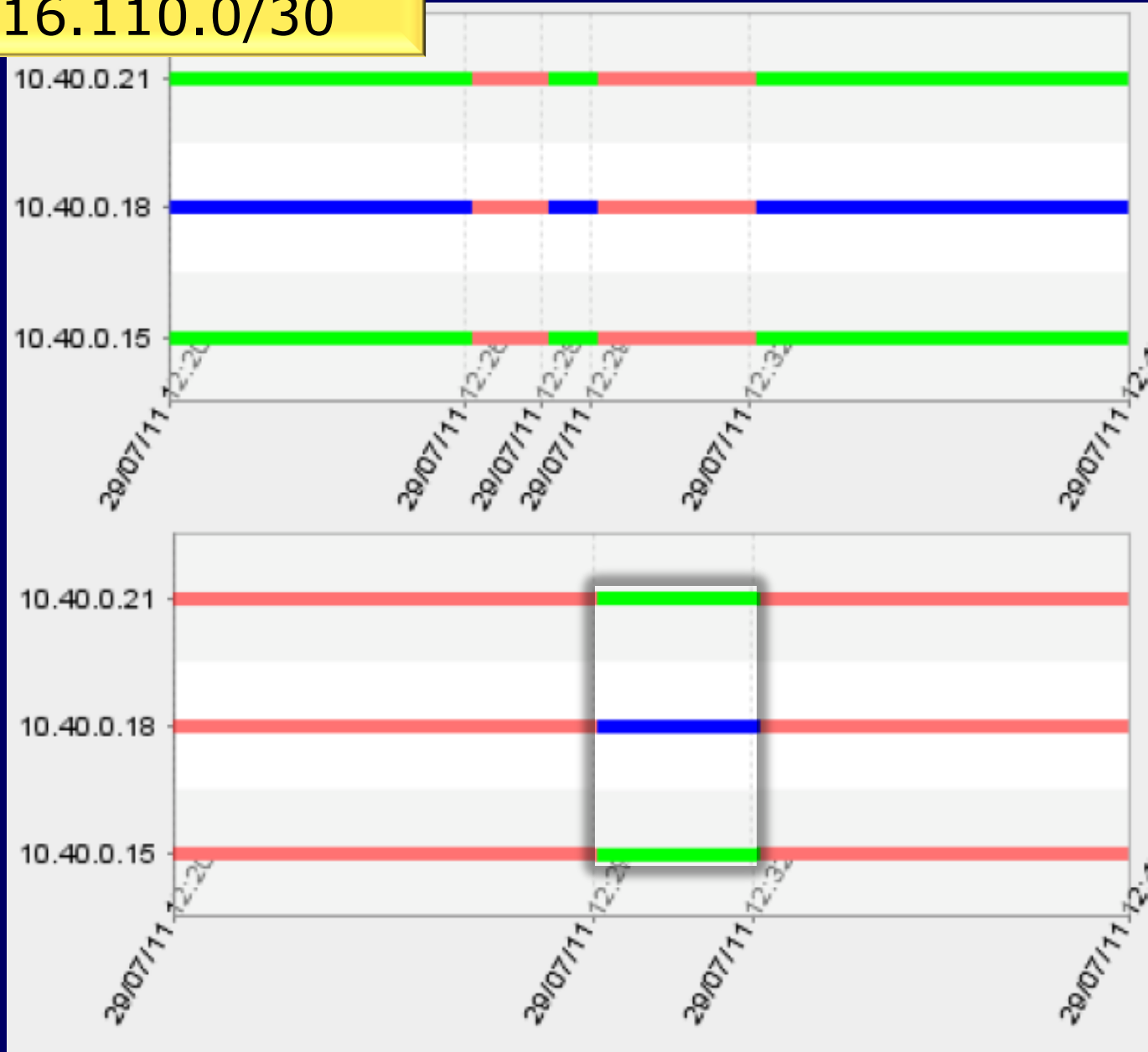

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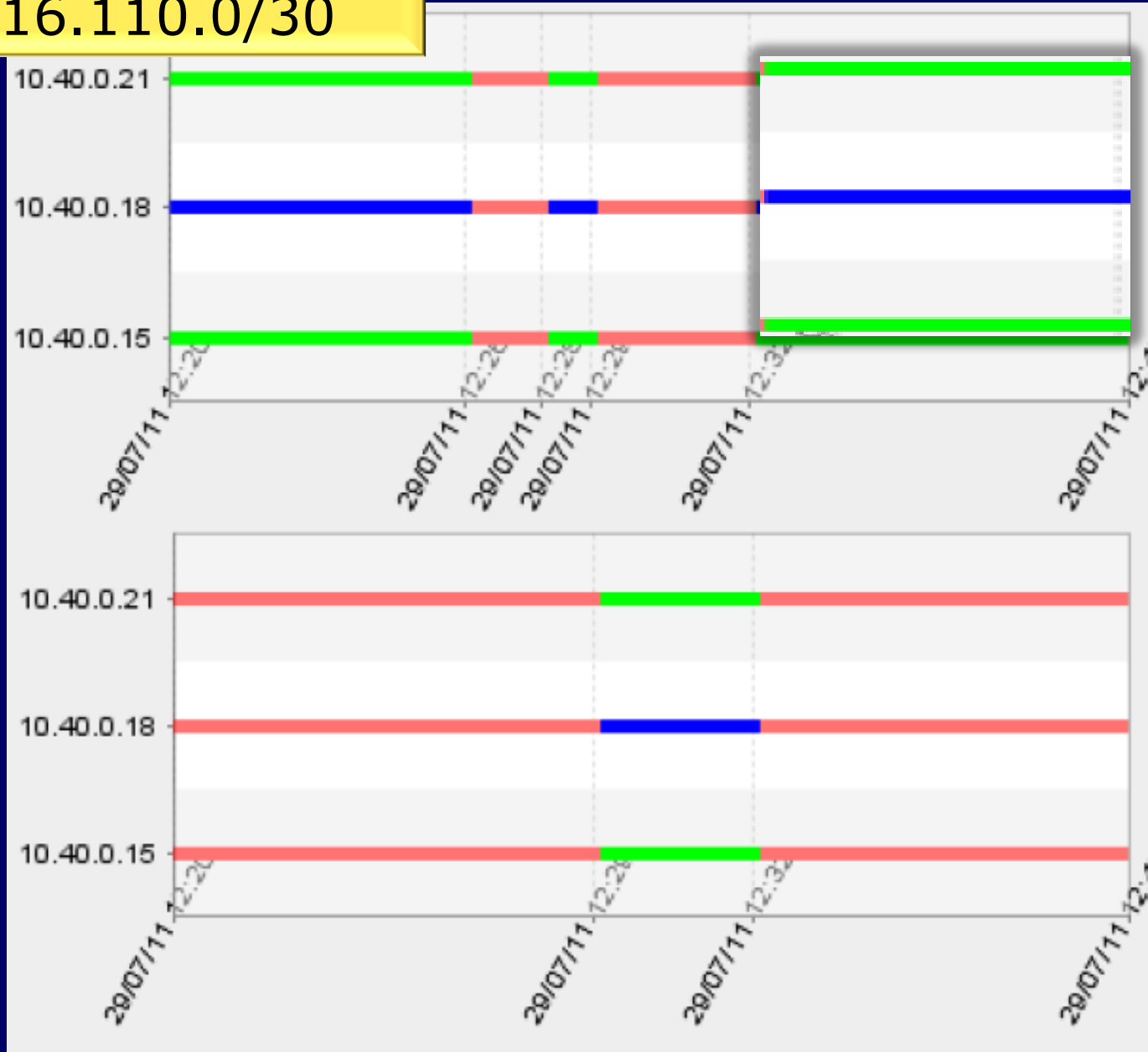

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RD 12345:10011
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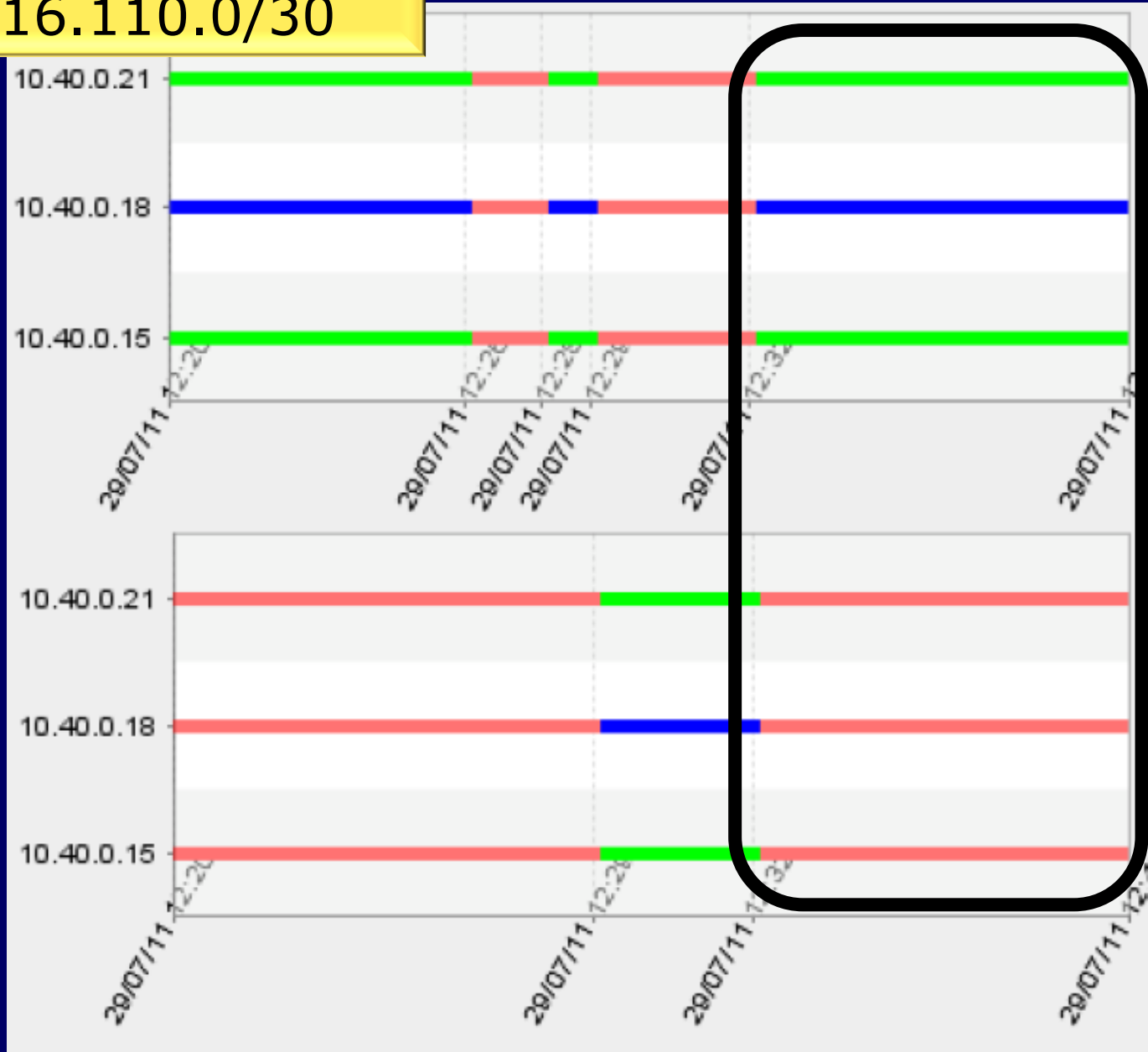

Methodology
3. Visualization

- Queries

Methodology
3. Visualization

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility from all PEs

Methodology
3. Visualization

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility from all PEs
  - Check a PE's visibility of a specific VPN
    - Input: RT, PE
    - Output: Visibility of all RD+{prefix,CE ID} with that RT at that PE

Methodology
3. Visualization

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  - Check information propagation
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  - Check a PE's visibility of a specific VPN
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    - Output: Visibility of all RD+{prefix,CE ID} with that RT at that PE
  - Highlight belonging of a prefix to a VPN
    - Input: RD+{prefix,CE ID}
    - Output: Visibility of that RD+{prefix,CE ID} from all PEs, with each seen RT

Methodology
3. Visualization

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility from all PEs
  - Check a PE's visibility of a specific VPN
    - Input: RT, PE
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  - Highlight belonging of a prefix to a VPN
    - Input: RD+{prefix,CE ID}
    - Output: Visibility of that RD+{prefix,CE ID} from all PEs, with each seen RT
  - Highlight participation of PEs in VPNs
    - Input: RT
    - Output: Visibility of that RT at each PE

Methodology
3. Visualization

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility from all PEs
  - Check a PE's visibility of a specific VPN*
    - Input: RT, PE
    - Output: Visibility of all RD+{prefix,CE ID} with that RT at that PE
  - Highlight belonging of a prefix to a VPN*
    - Input: RD+{prefix,CE ID}
    - Output: Visibility of that RD+{prefix,CE ID} from all PEs, with each seen RT
  - Highlight participation of PEs in VPNs*
    - Input: RT
    - Output: Visibility of that RT at each PE

Methodology
3. Visualization

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility from all PEs
  - Check a PE's visibility of a specific VPN*
    - Input: RT, PE
    - Output: Visibility of all RD+{prefix,CE ID} with that RT at that PE
  - Highlight belonging of a prefix to a VPN*
    - Input: RD+{prefix,CE ID}
    - Output: Visibility of that RD+{prefix,CE ID} from all PEs, with each seen RT
  - Highlight participation of PEs in VPNs*
    - Input: RT
    - Output: Visibility of that RT at each PE

* VPN≡RT

Methodology
3. Visualization

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility[#] from all PEs
  - Check a PE's visibility of a specific VPN[*]
    - Input: RT, PE
    - Output: Visibility[#] of all RD+{prefix,CE ID} with that RT at that PE
  - Highlight belonging of a prefix to a VPN[*]
    - Input: RD+{prefix,CE ID}
    - Output: Visibility[#] of that RD+{prefix,CE ID} from all PEs, with each seen RT
  - Highlight participation of PEs in VPNs[*]
    - Input: RT
    - Output: Visibility[#] of that RT at each PE

Methodology
3. Visualization

* VPN≡RT
# over time

- Queries
  - Check information propagation
    - Input: RD+{prefix,CE ID}, RT
    - Output: Visibility# from all PEs
  - Check a PE's visibility of a specific VPN*
    - Input: RT, PE
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    - Input: RD+{prefix,CE ID}
    - Output: Visibility# of that RD+{prefix,CE ID} from all PEs, with each seen RT
  - Highlight participation of PEs in VPNs*
    - Input: RT
    - Output: Visibility# of that RT at each PE

Scalability

- Amount of routing updates

Scalability

- Routing table size
- Amount of routing updates

Scalability

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- Amount of routing updates

Scalability

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  - ☹ >> #Internet prefixes: ~ $k \times 10^5$ [Ben-Houidi et al. 07]
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[Ben-Houidi et al. 07] Z. Ben-Houidi, R. Teixeira, and M. Capelle, "Origin of route explosion in virtual private networks," in Proc. CoNEXT, 2007.

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  - ☺ Our prototype works even for M/L ISPs

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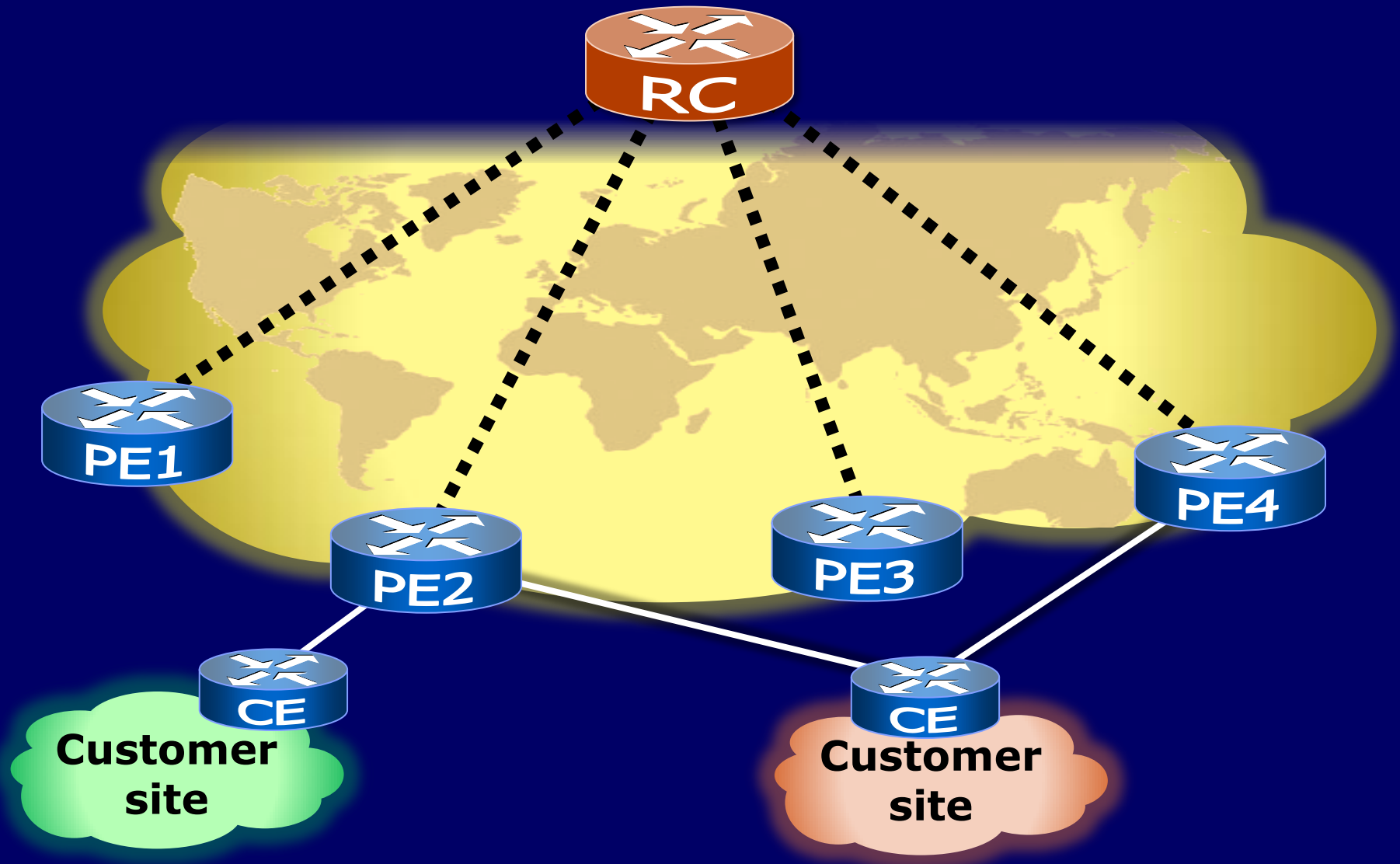
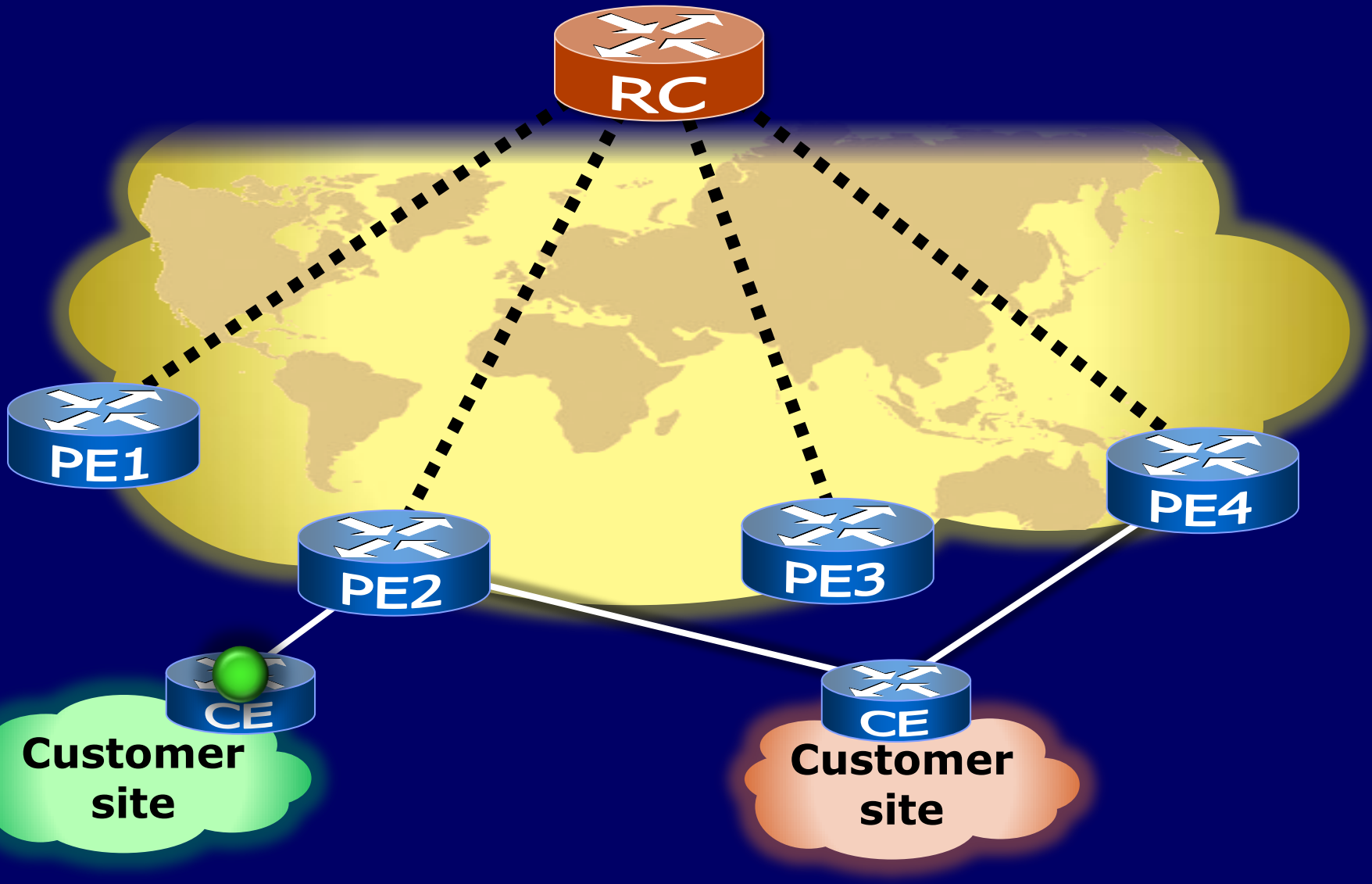
Scalability vs Visibility



Scalability vs Visibility



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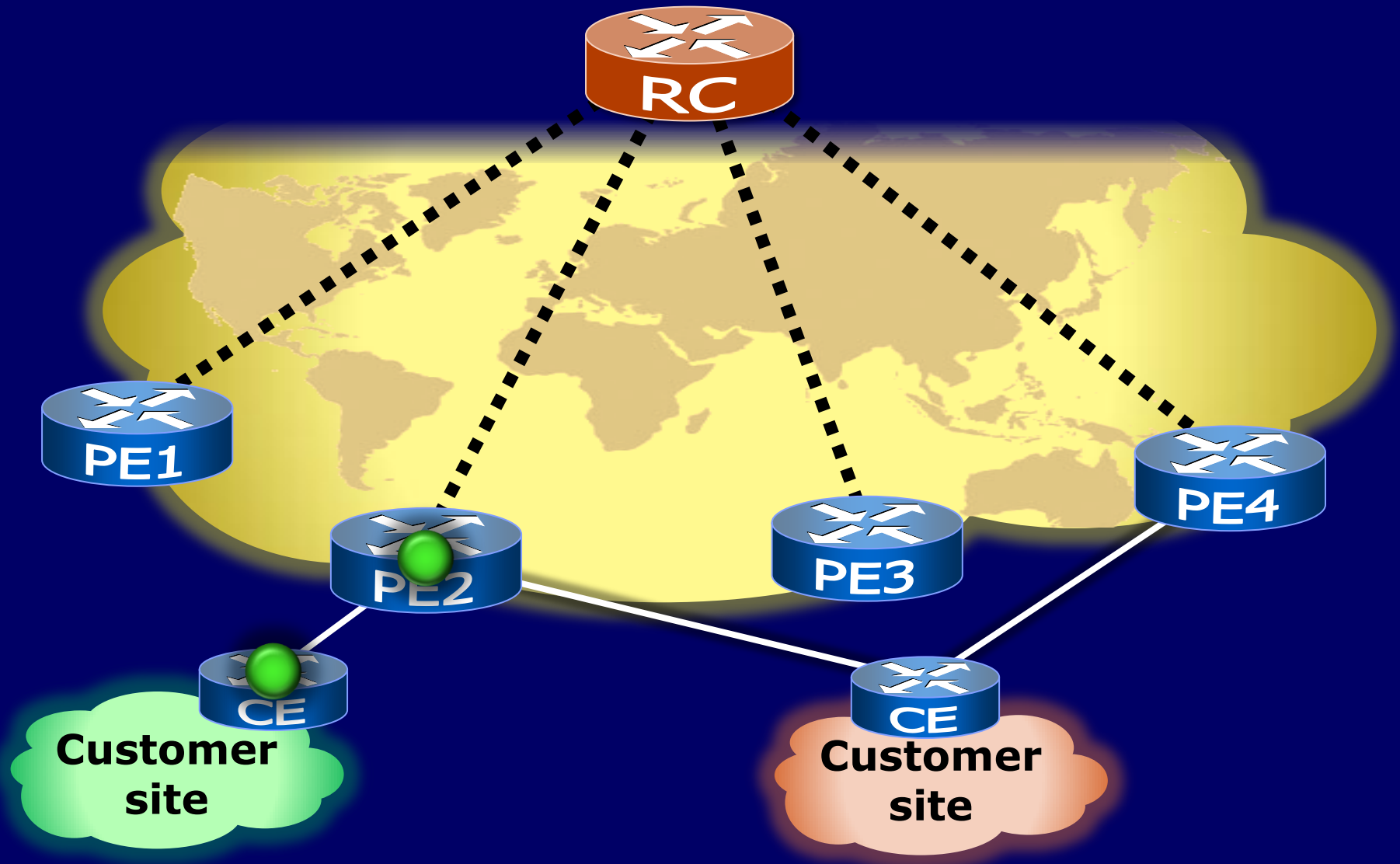
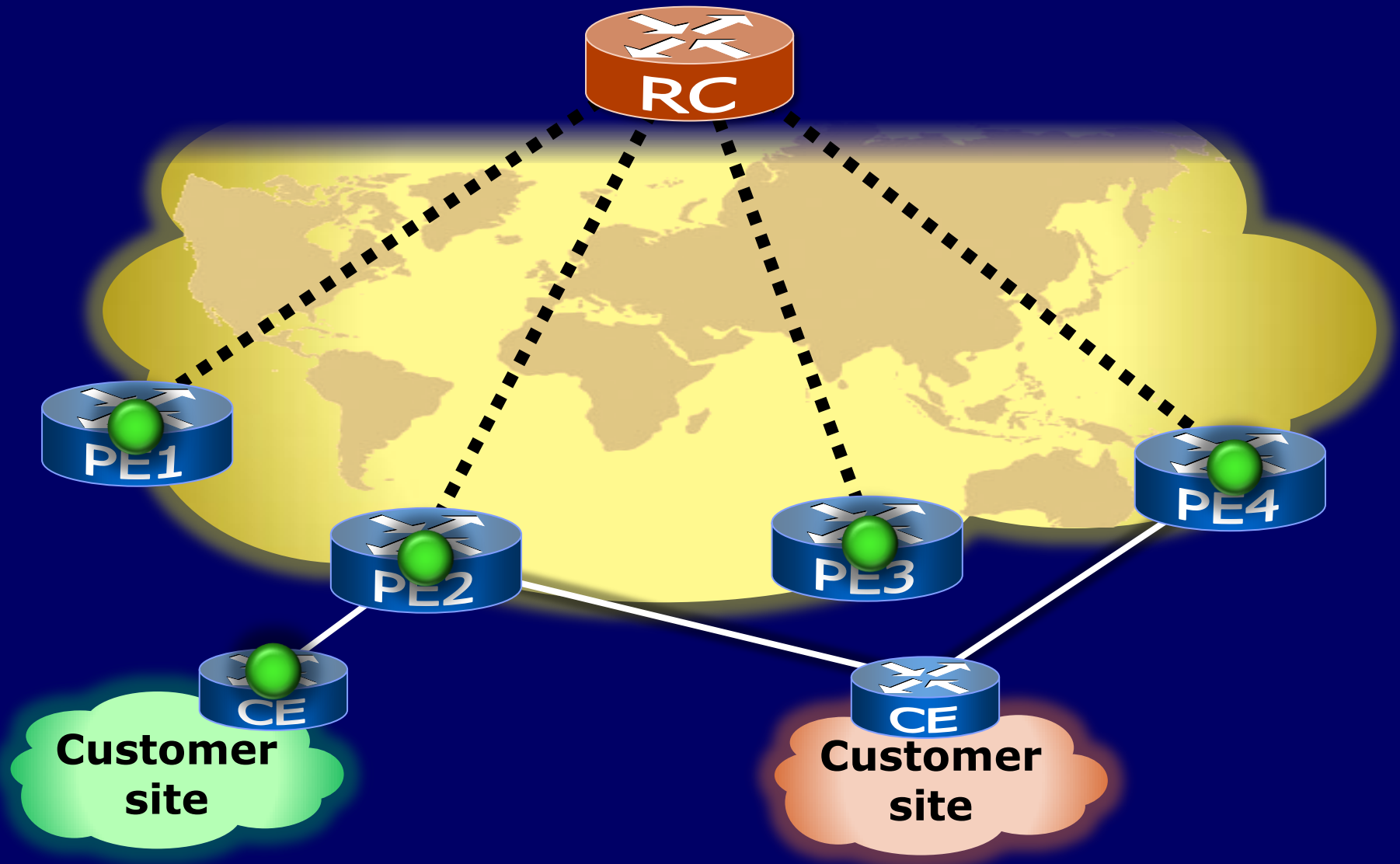


Scalability vs Visibility



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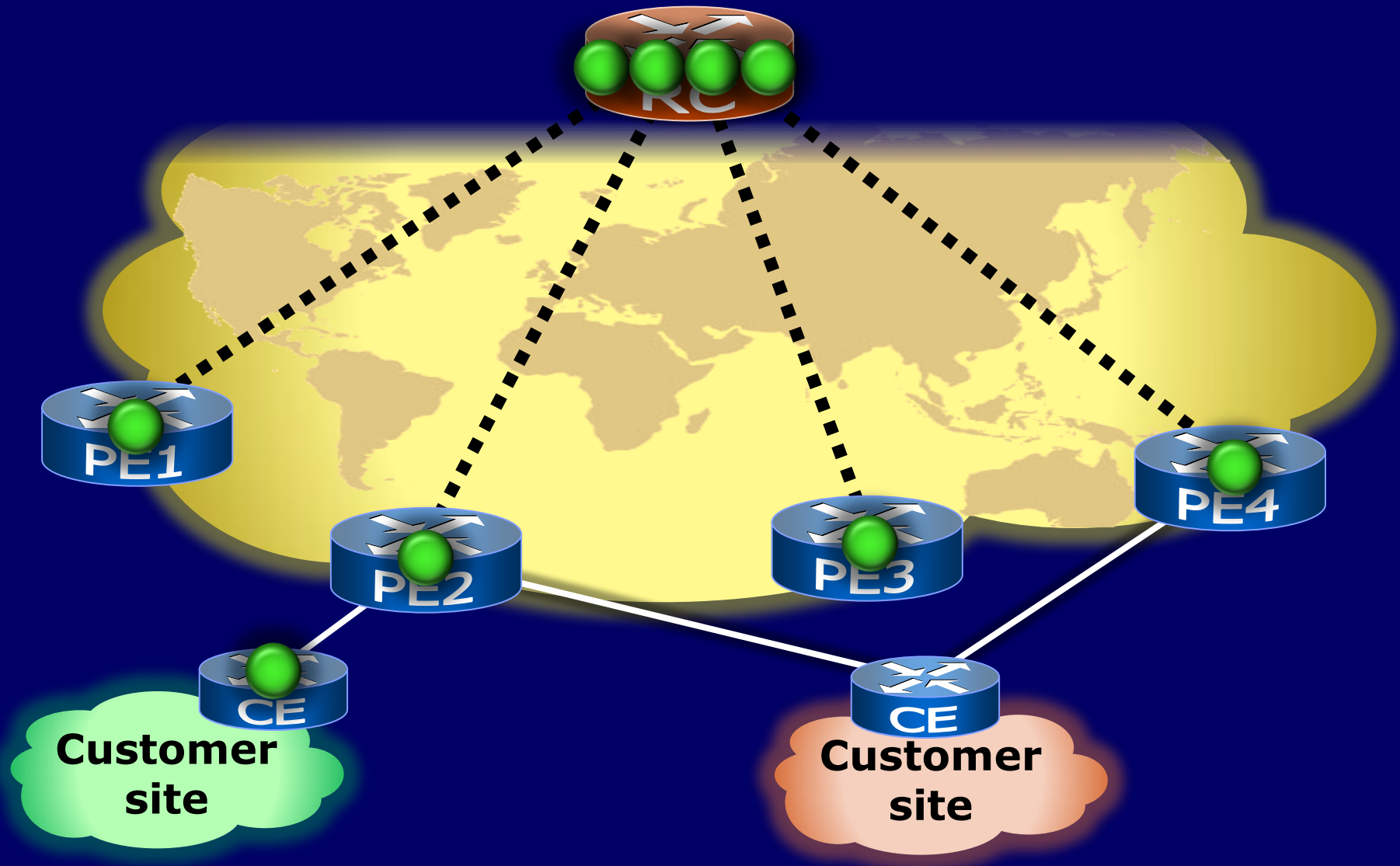

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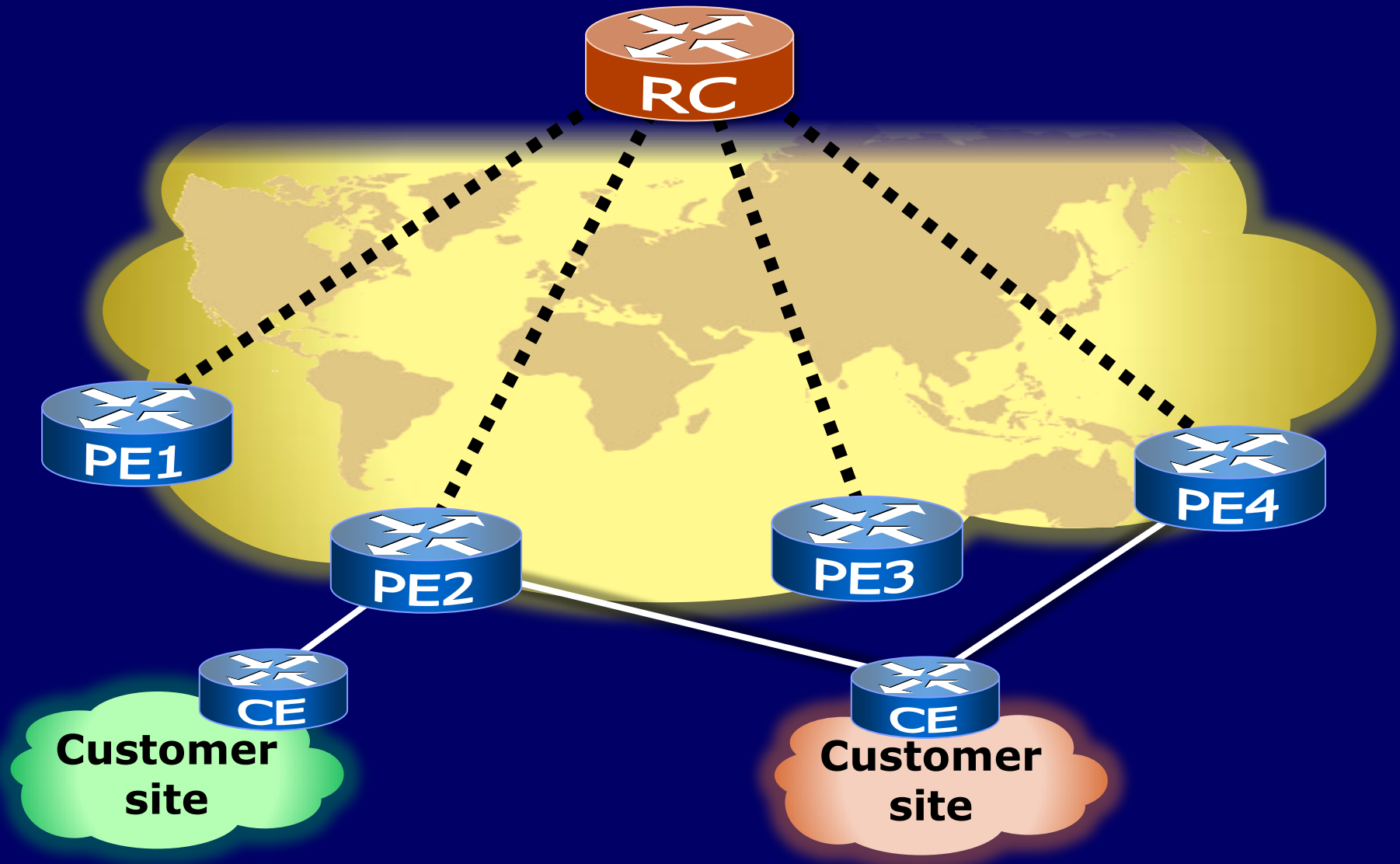

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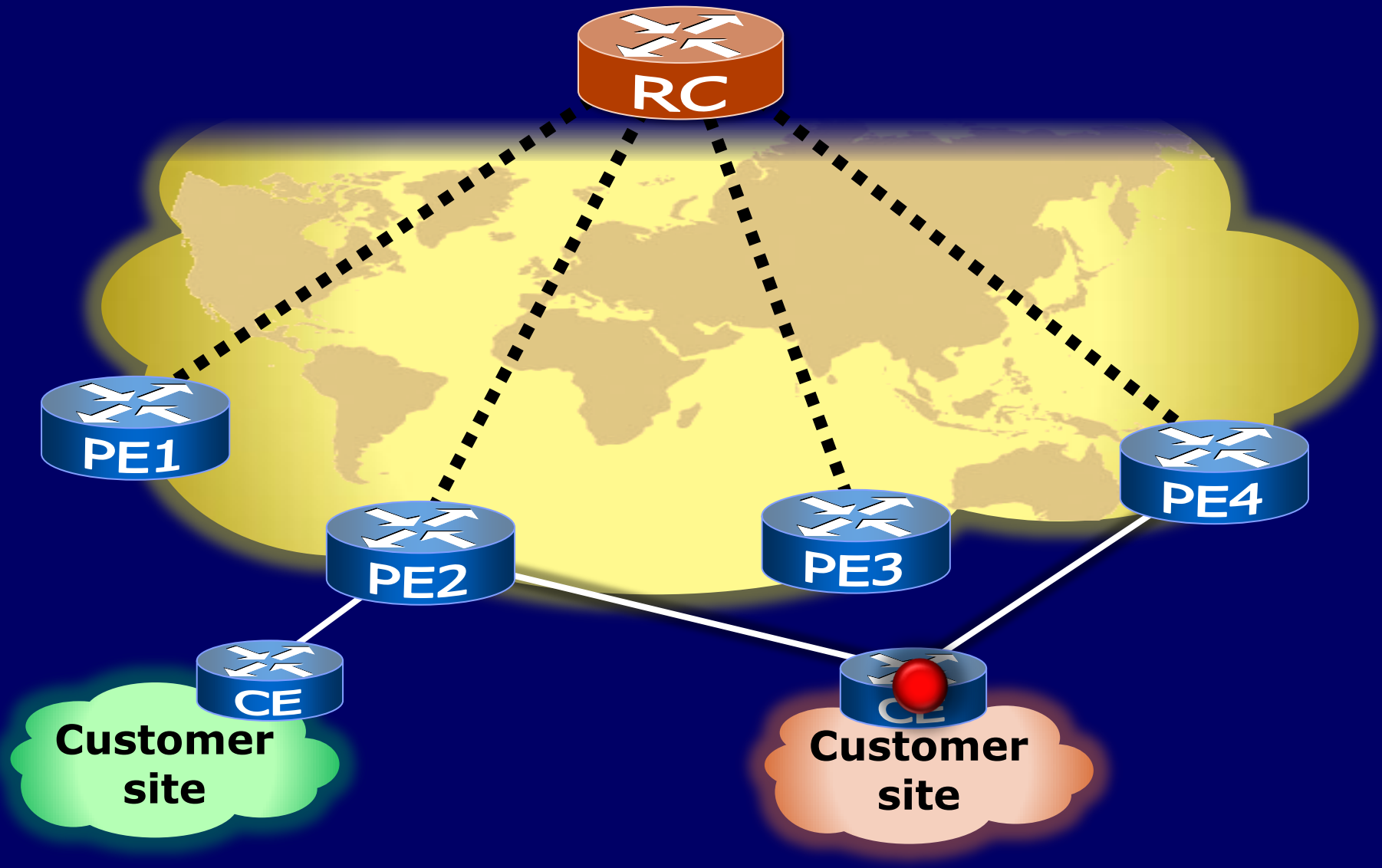

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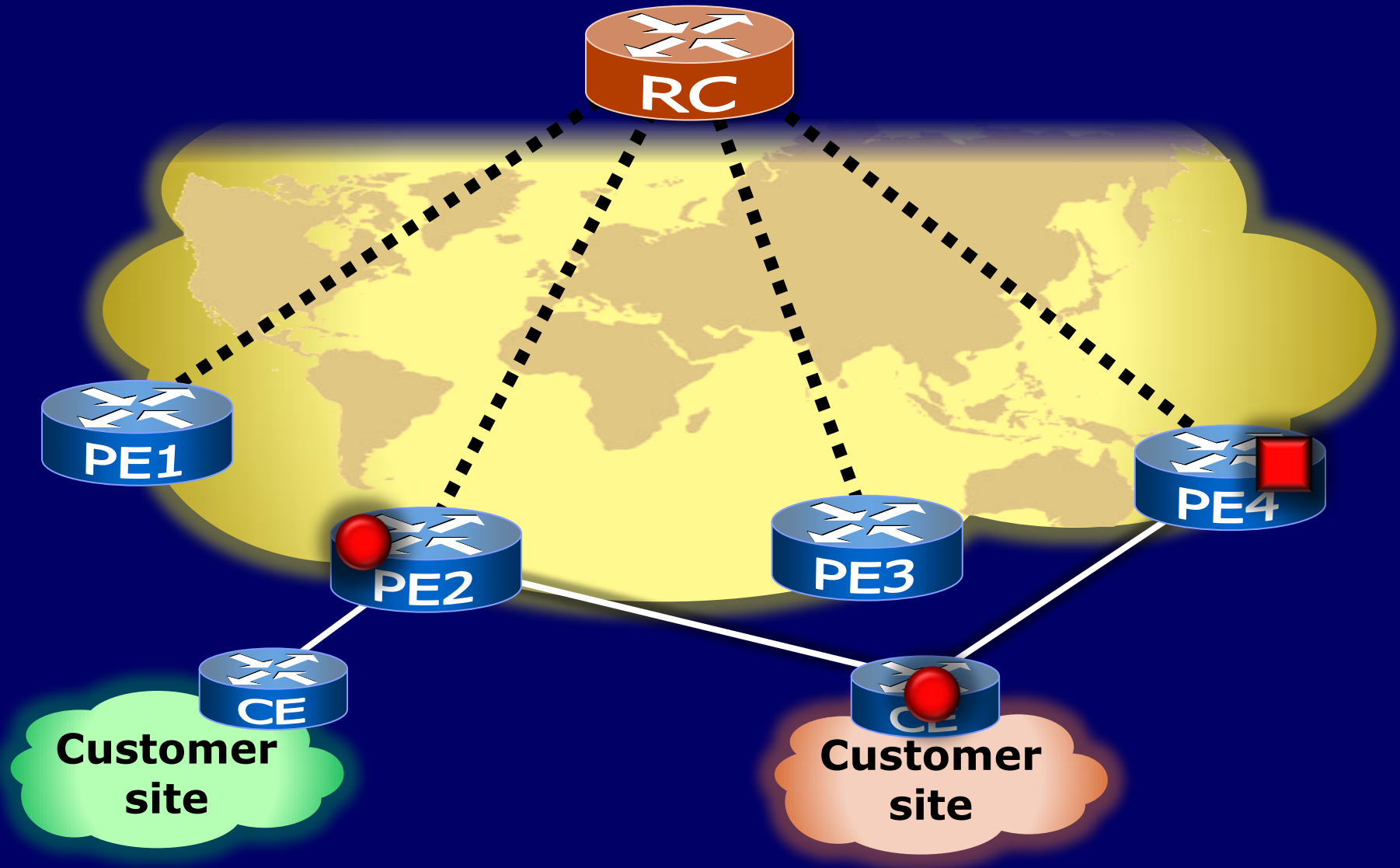

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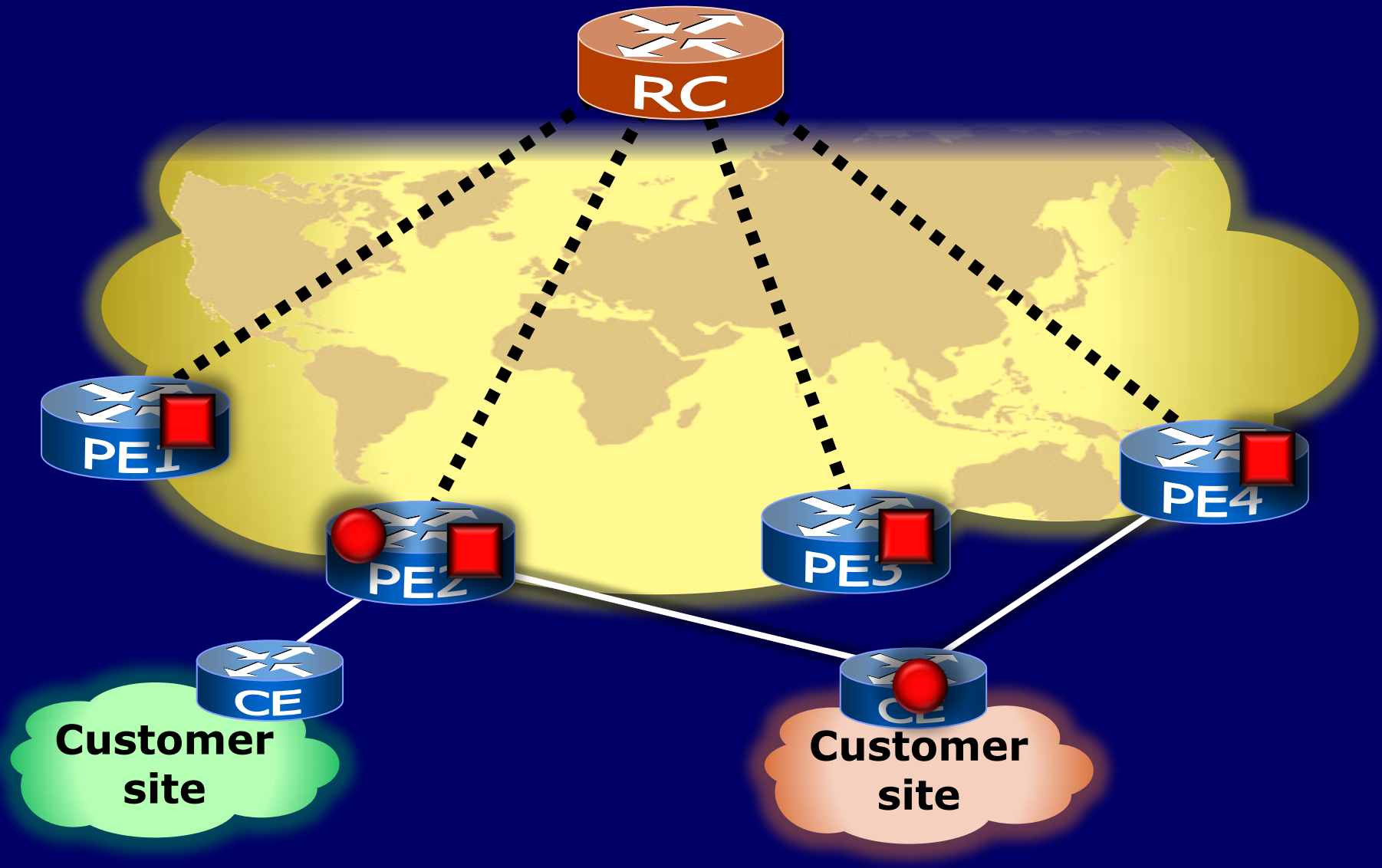
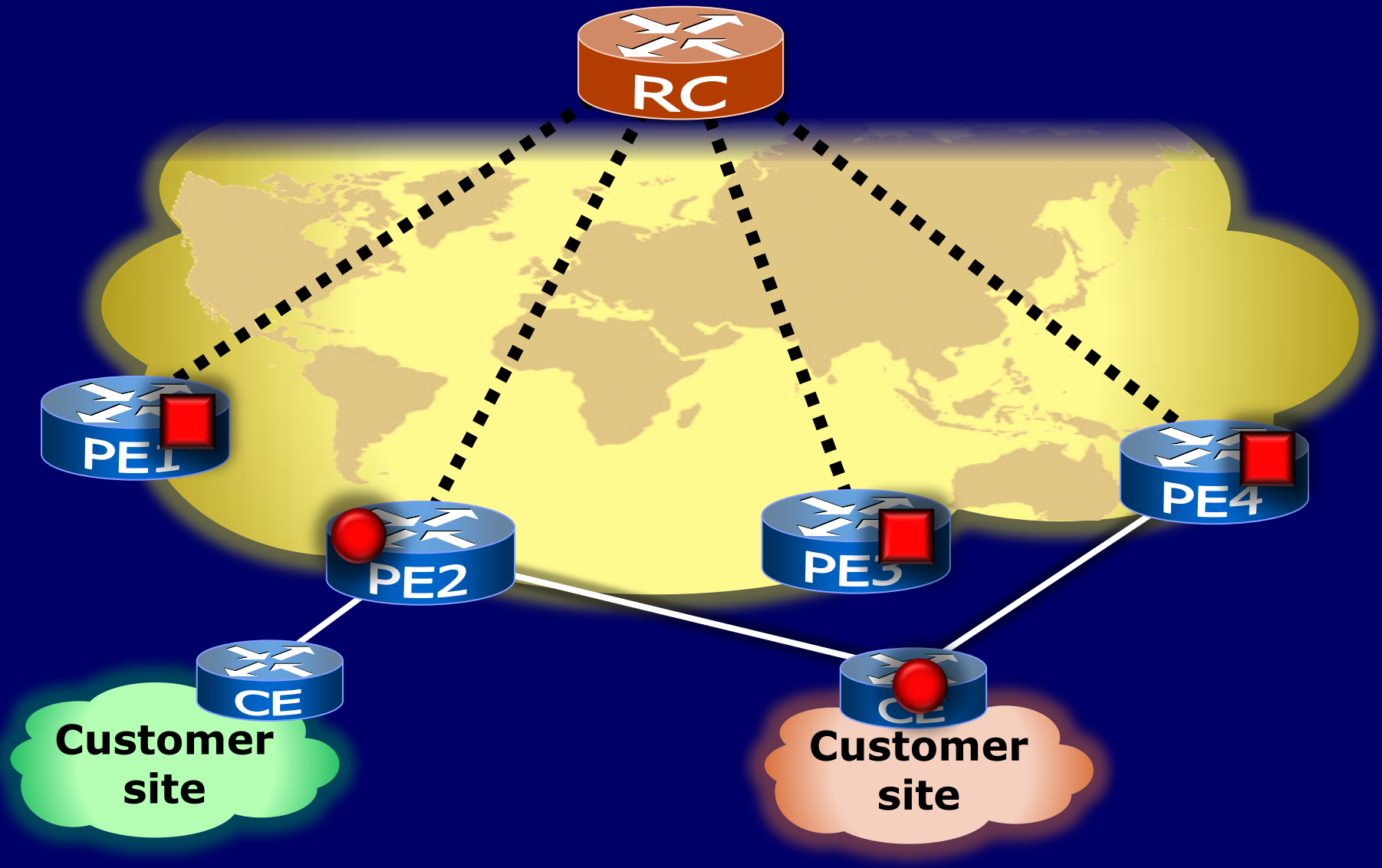


Scalability vs Visibility



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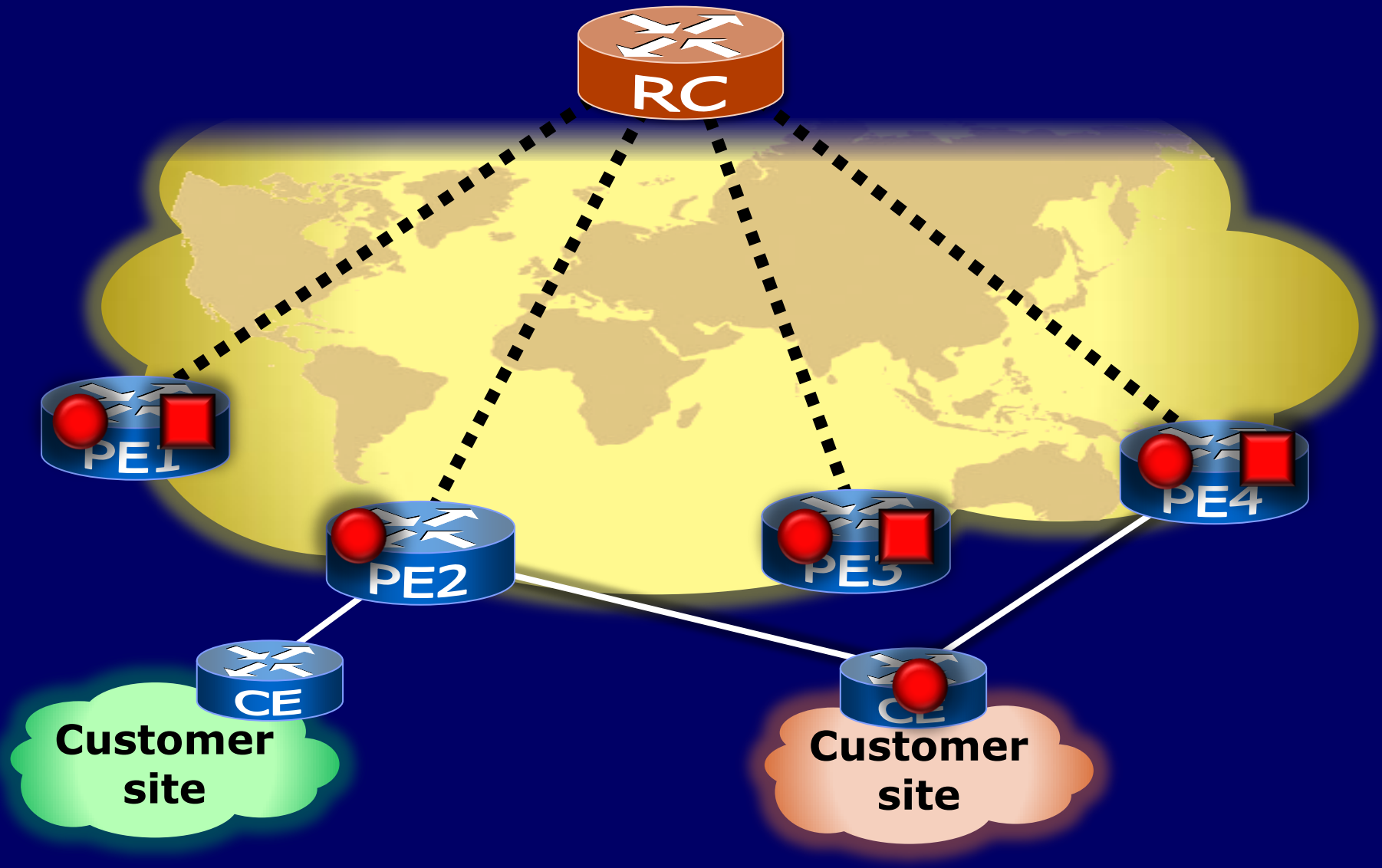

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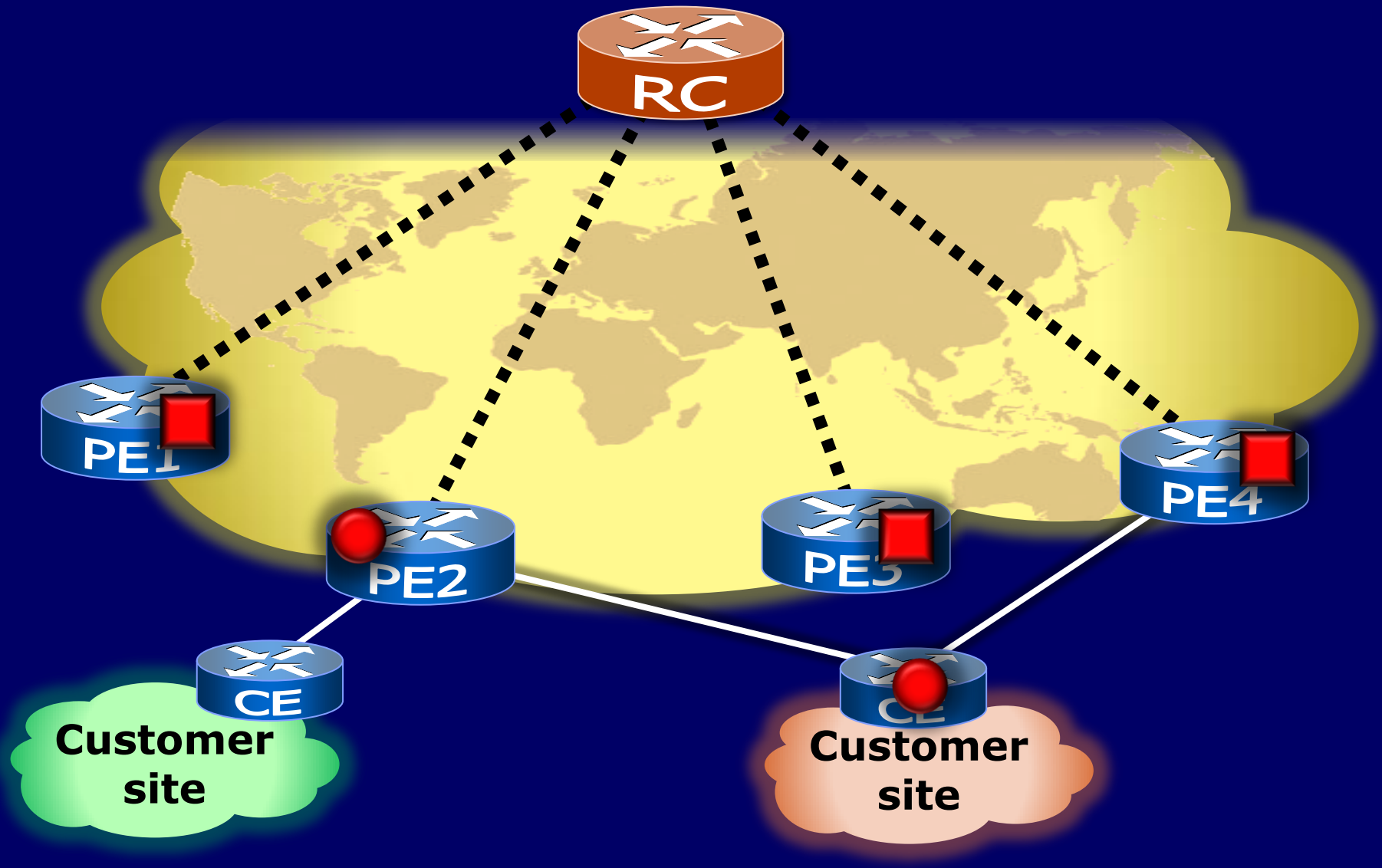

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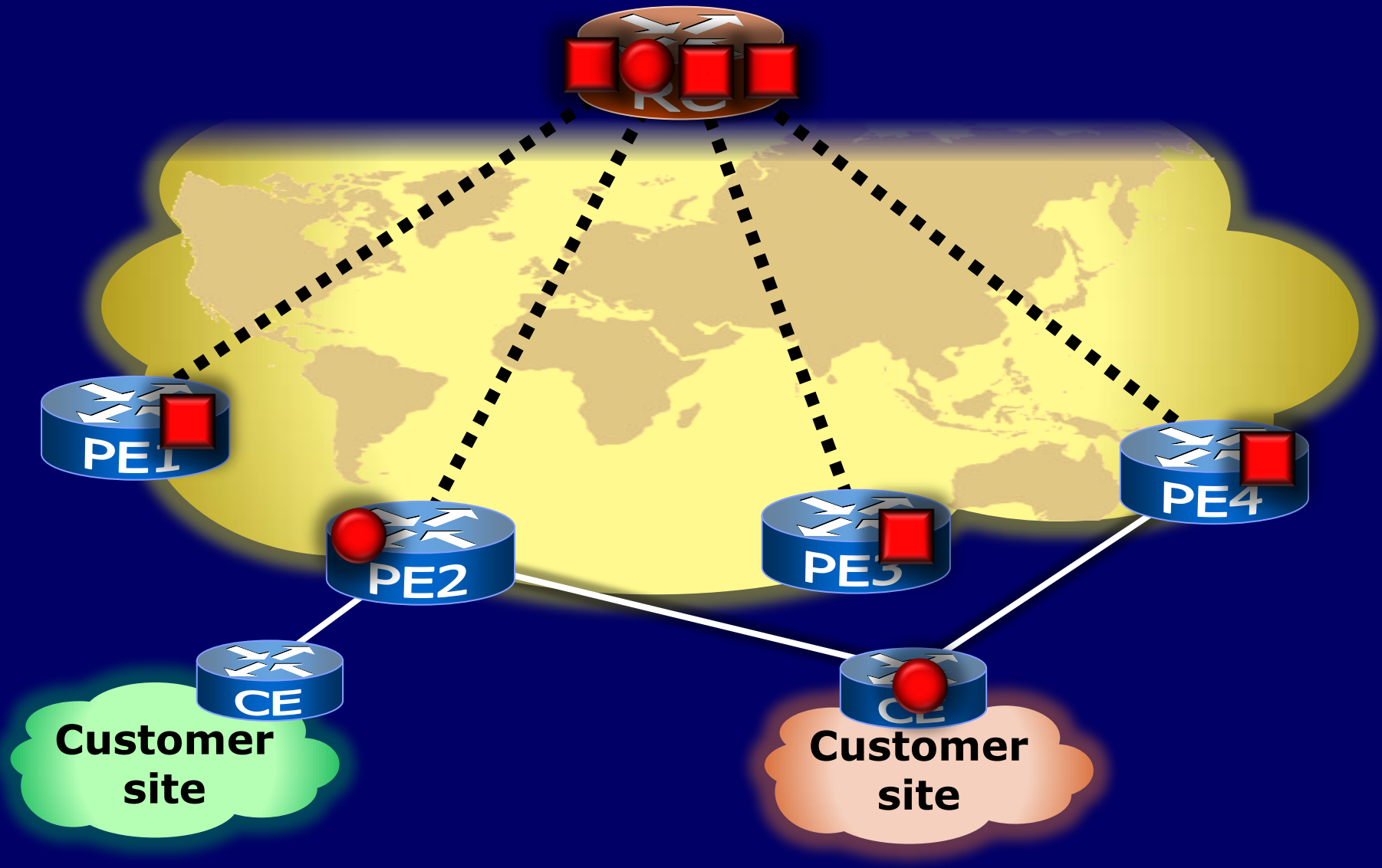

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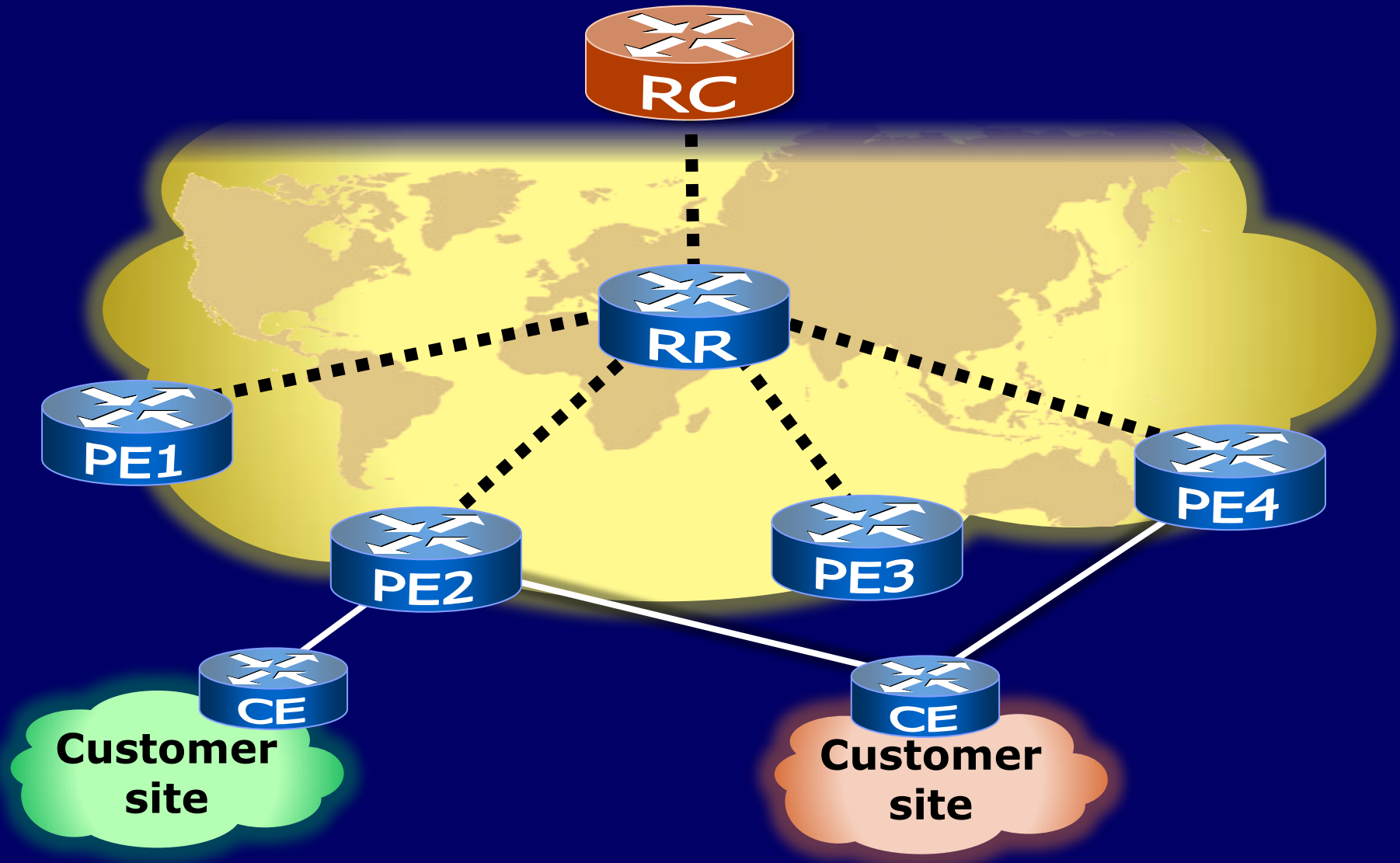

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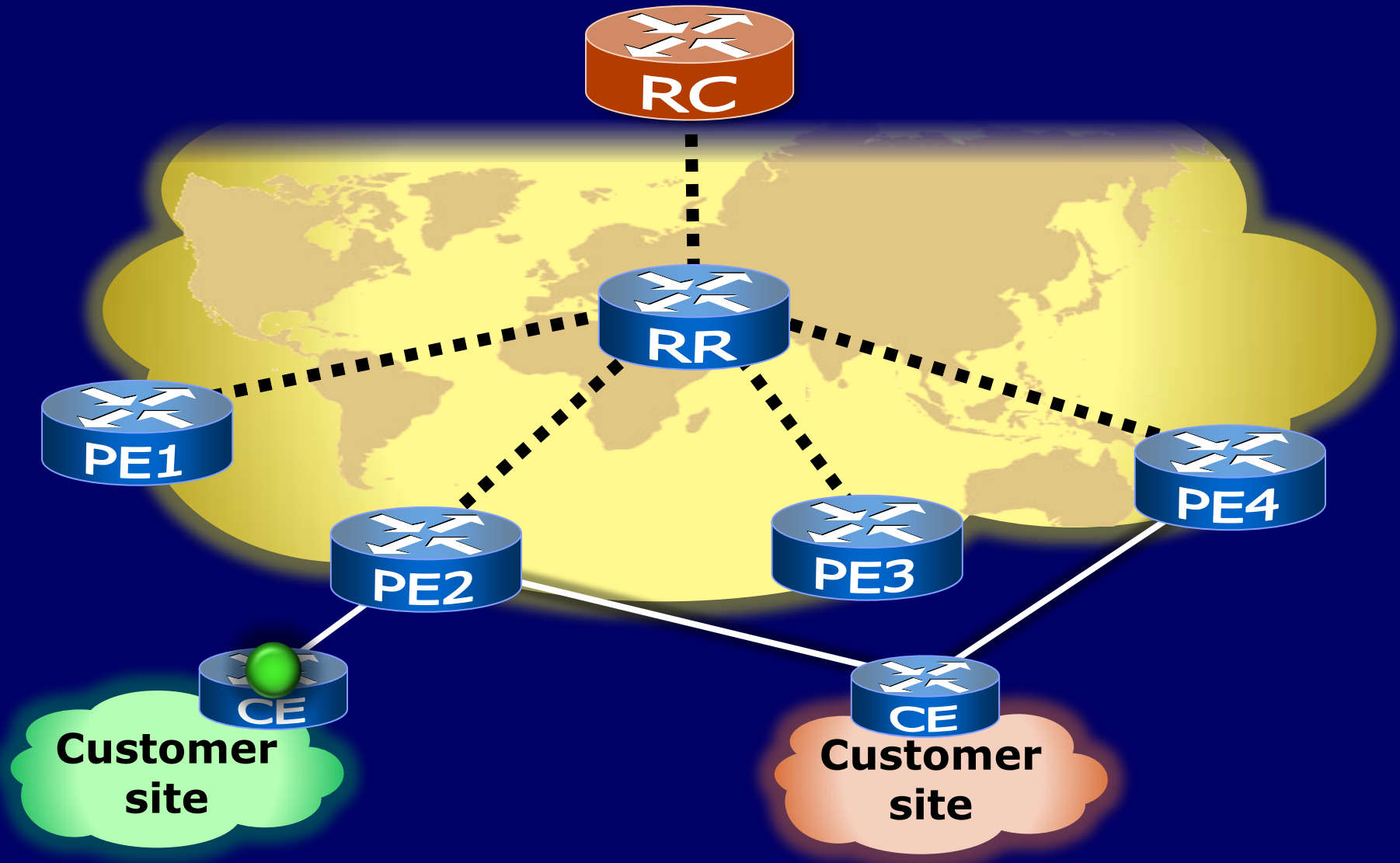

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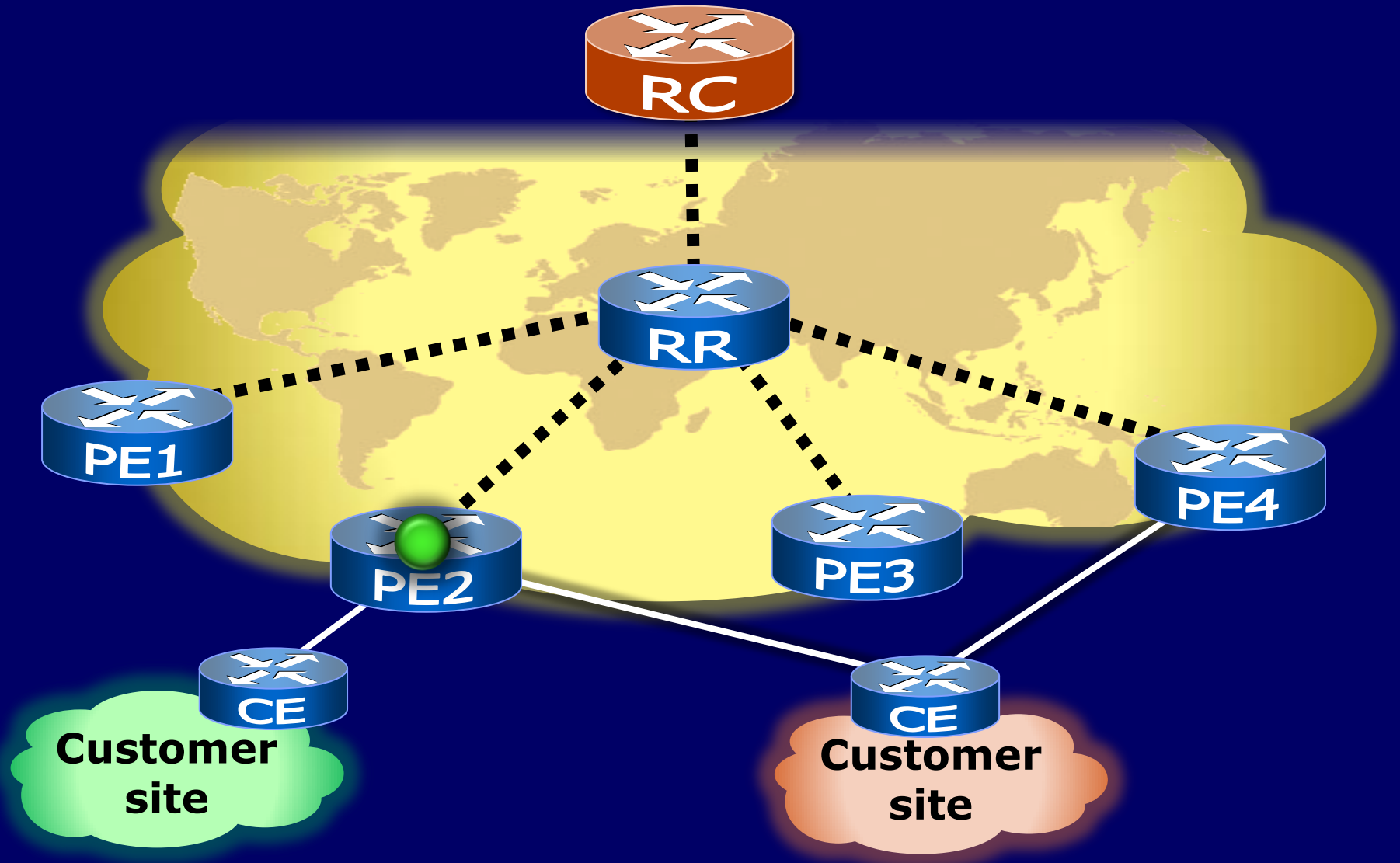

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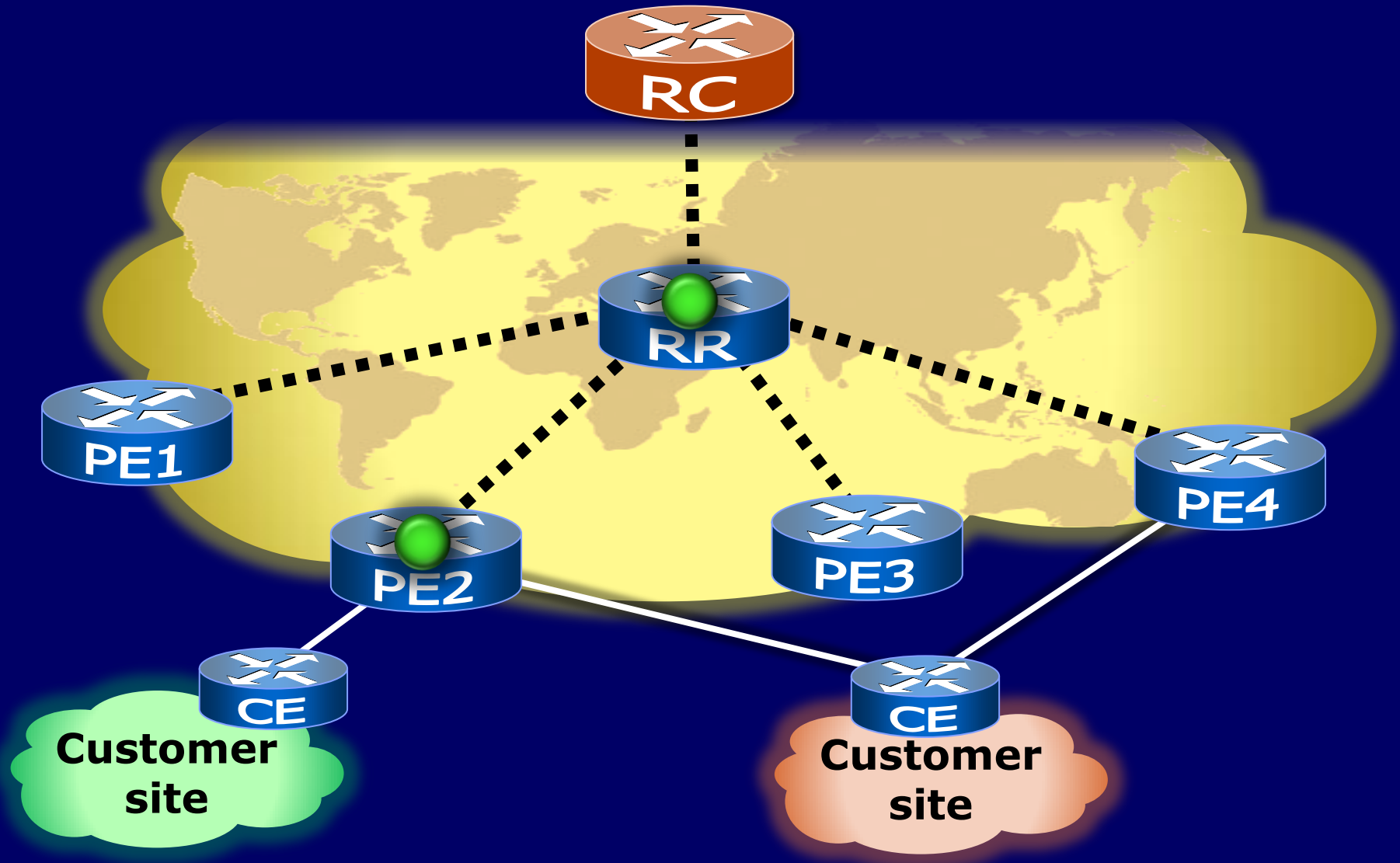

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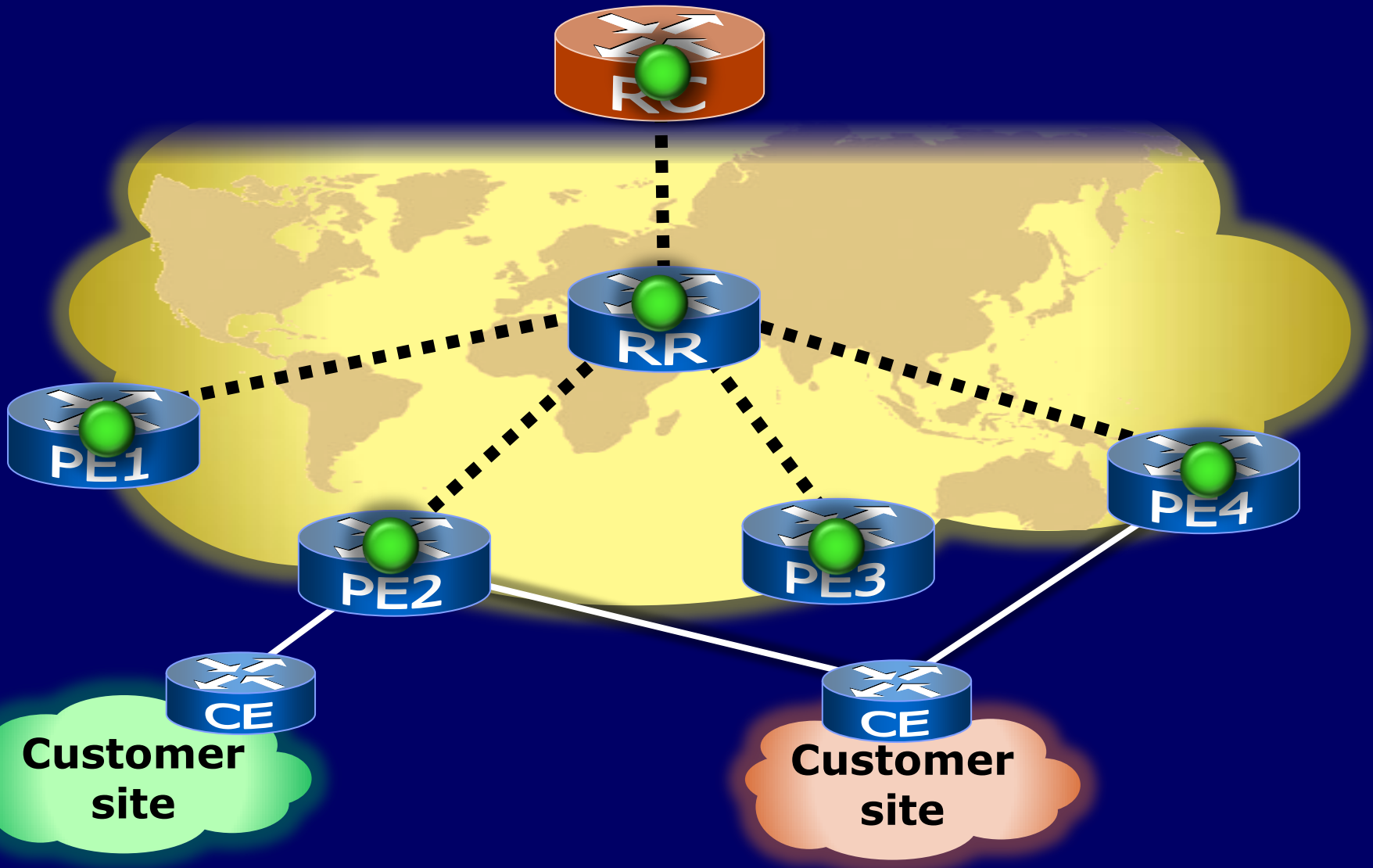

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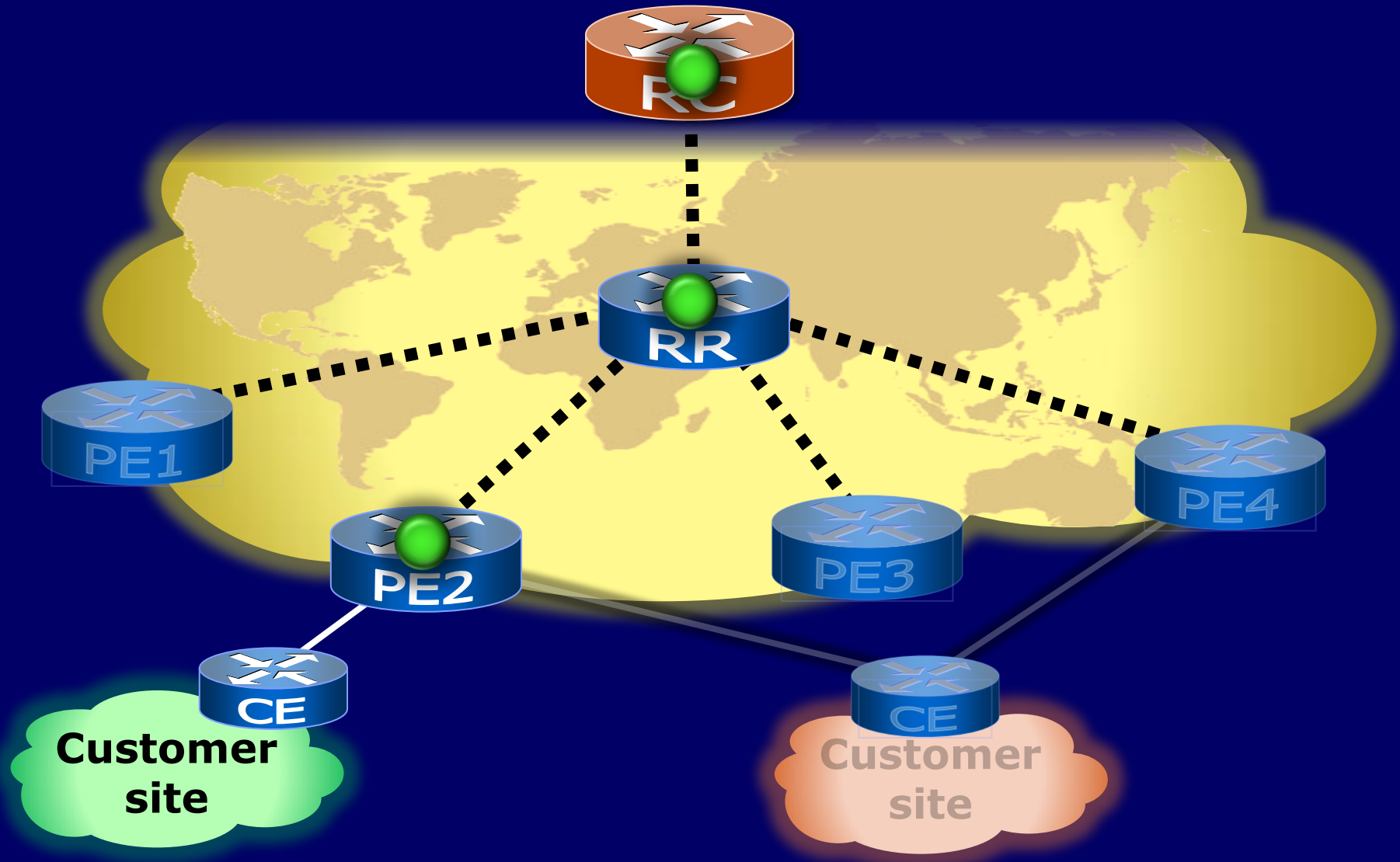

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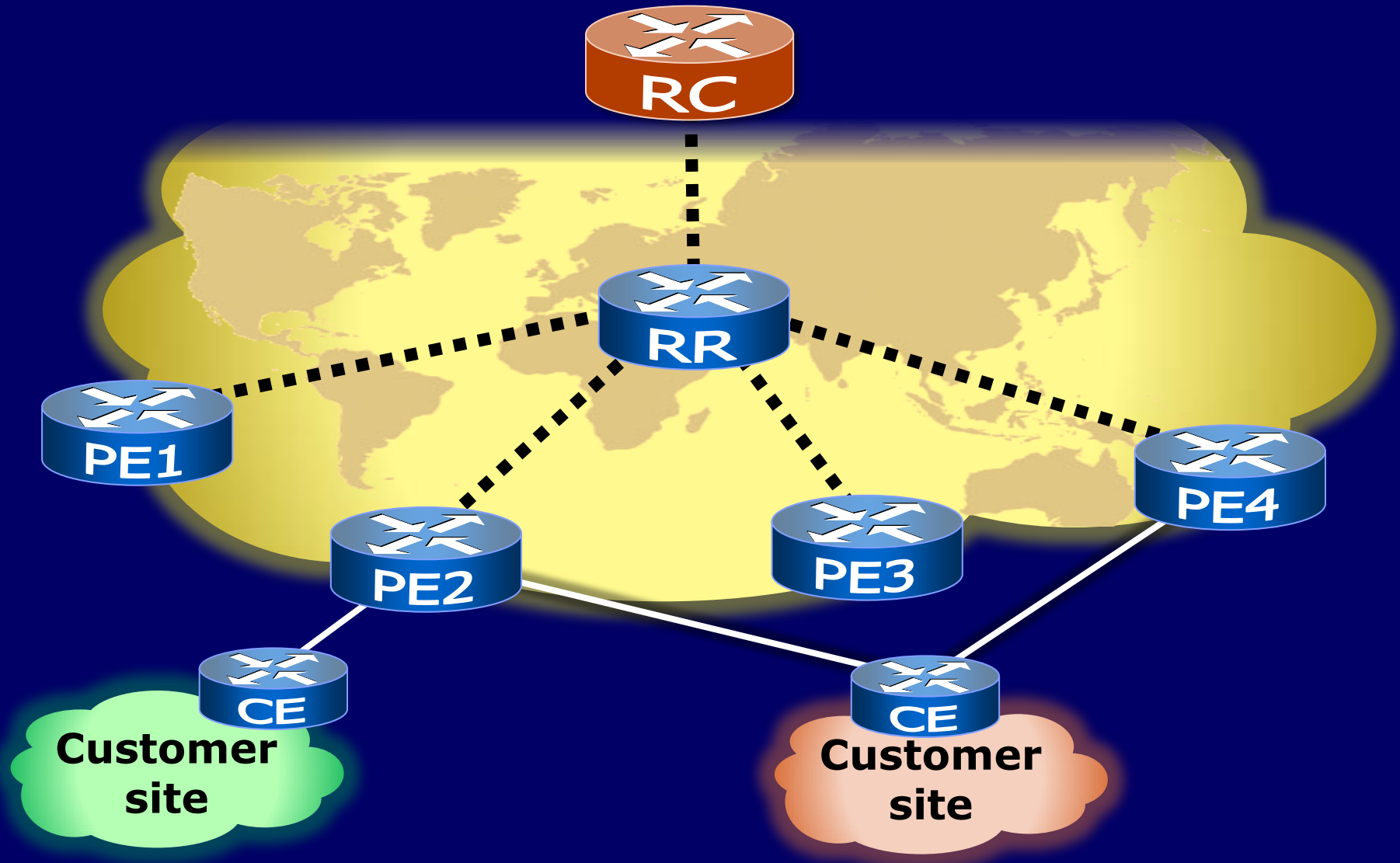

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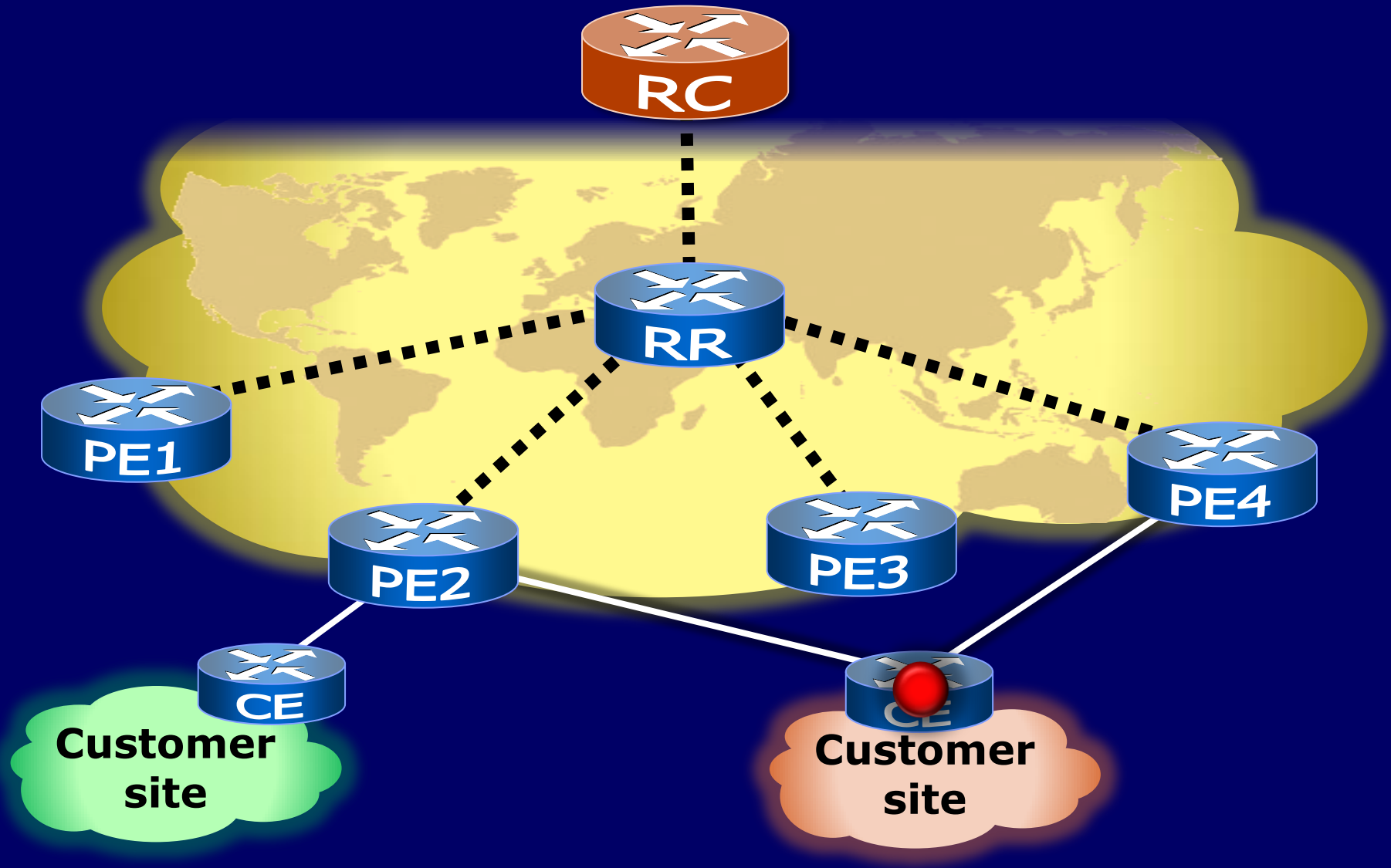

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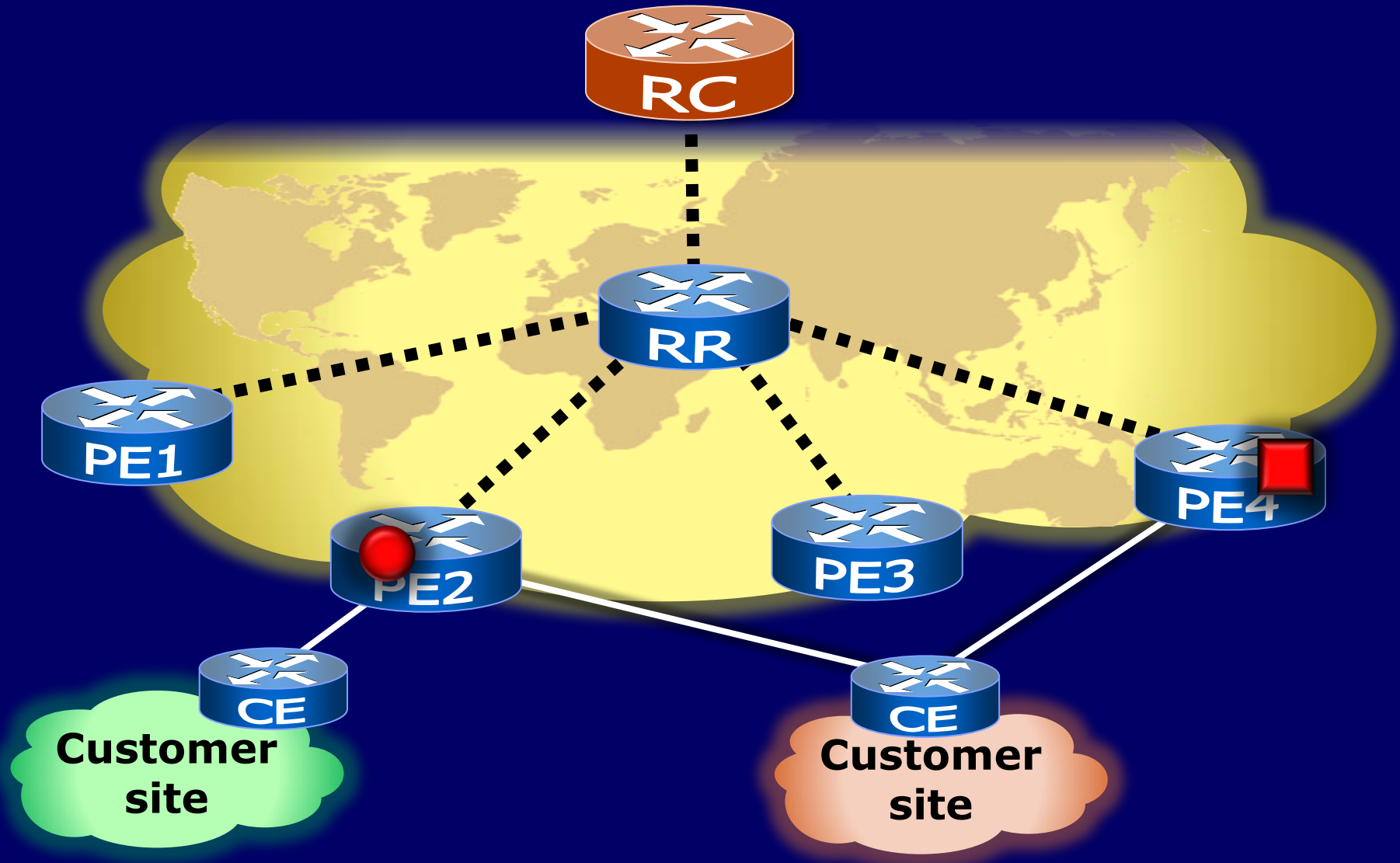

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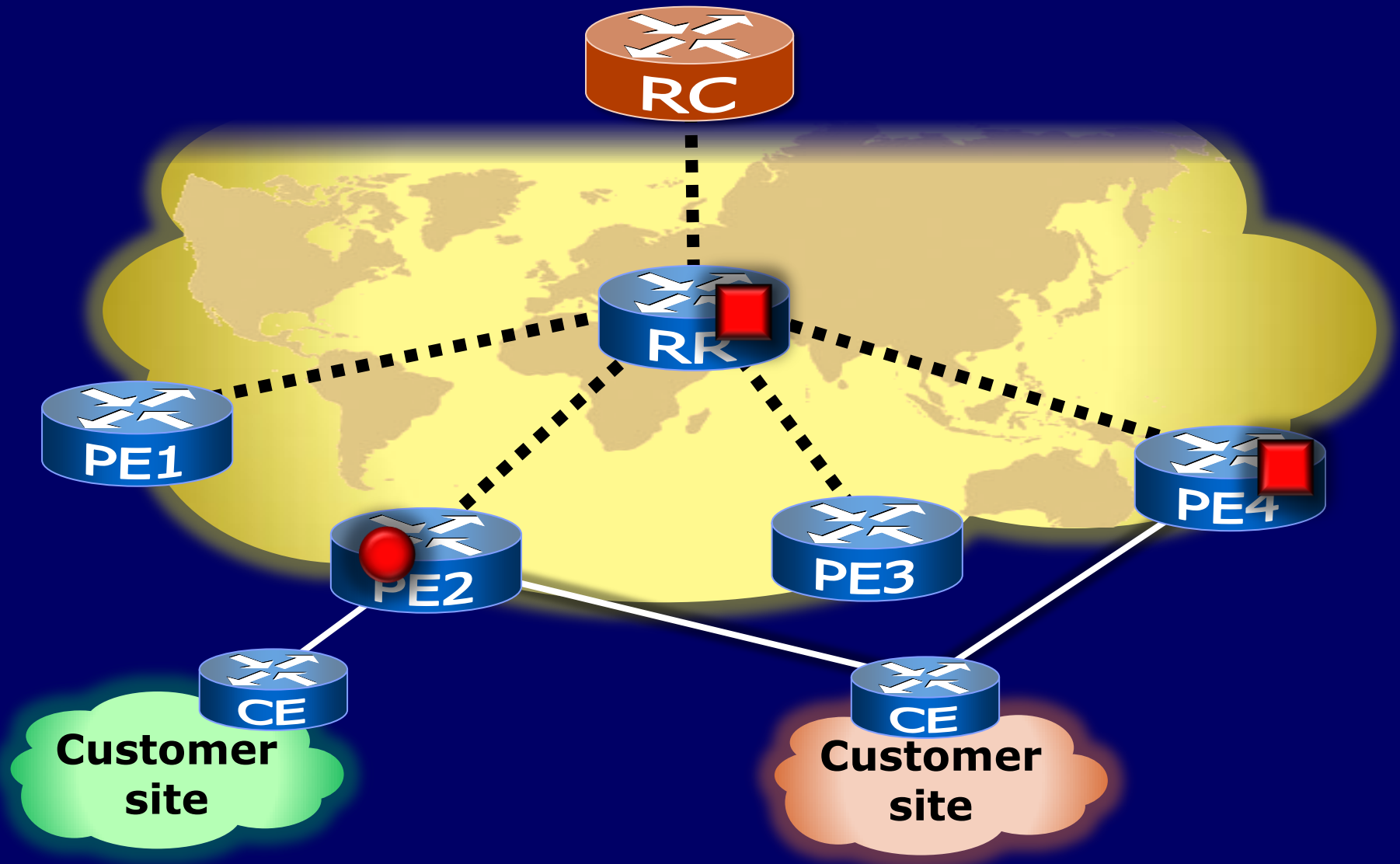

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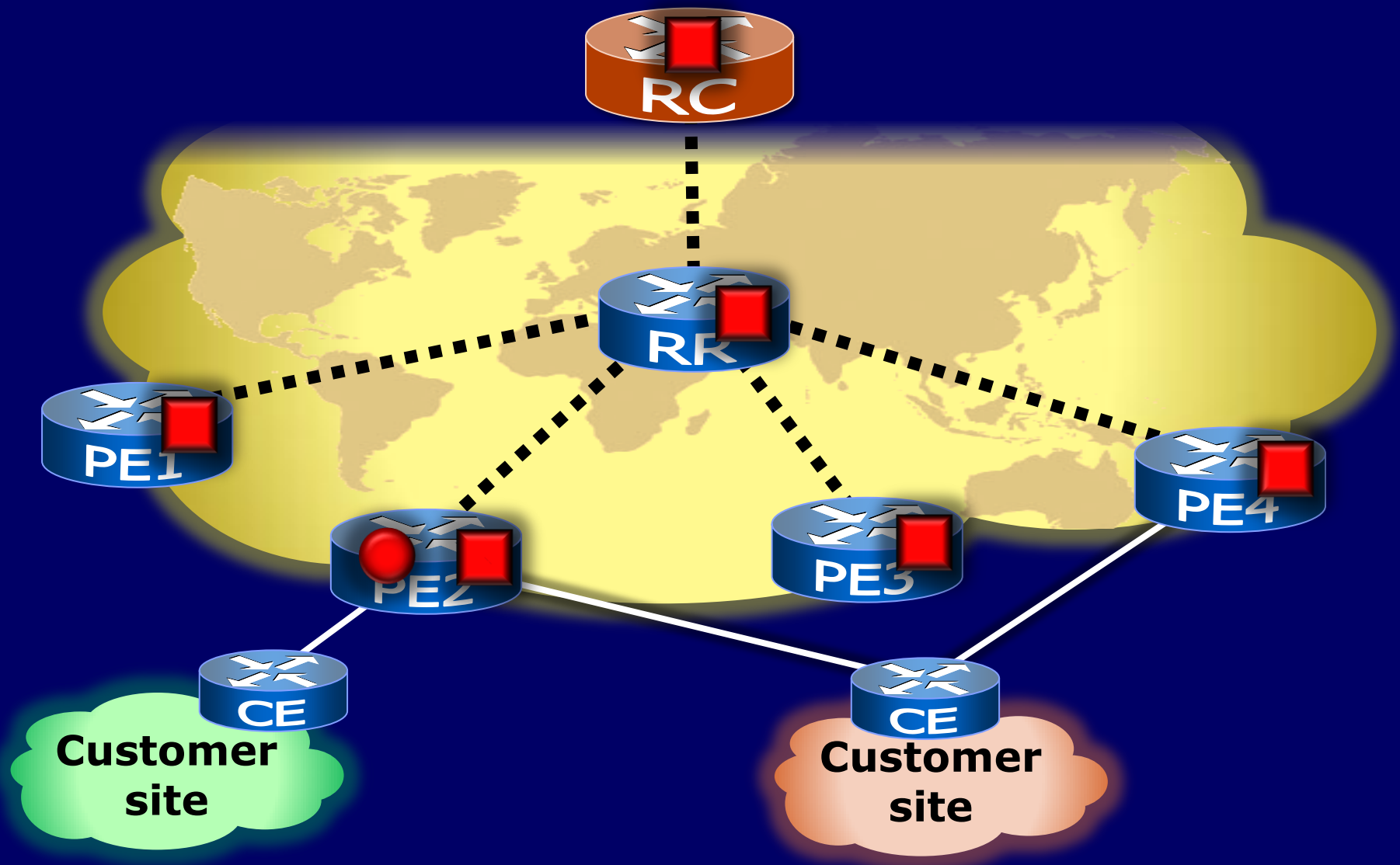

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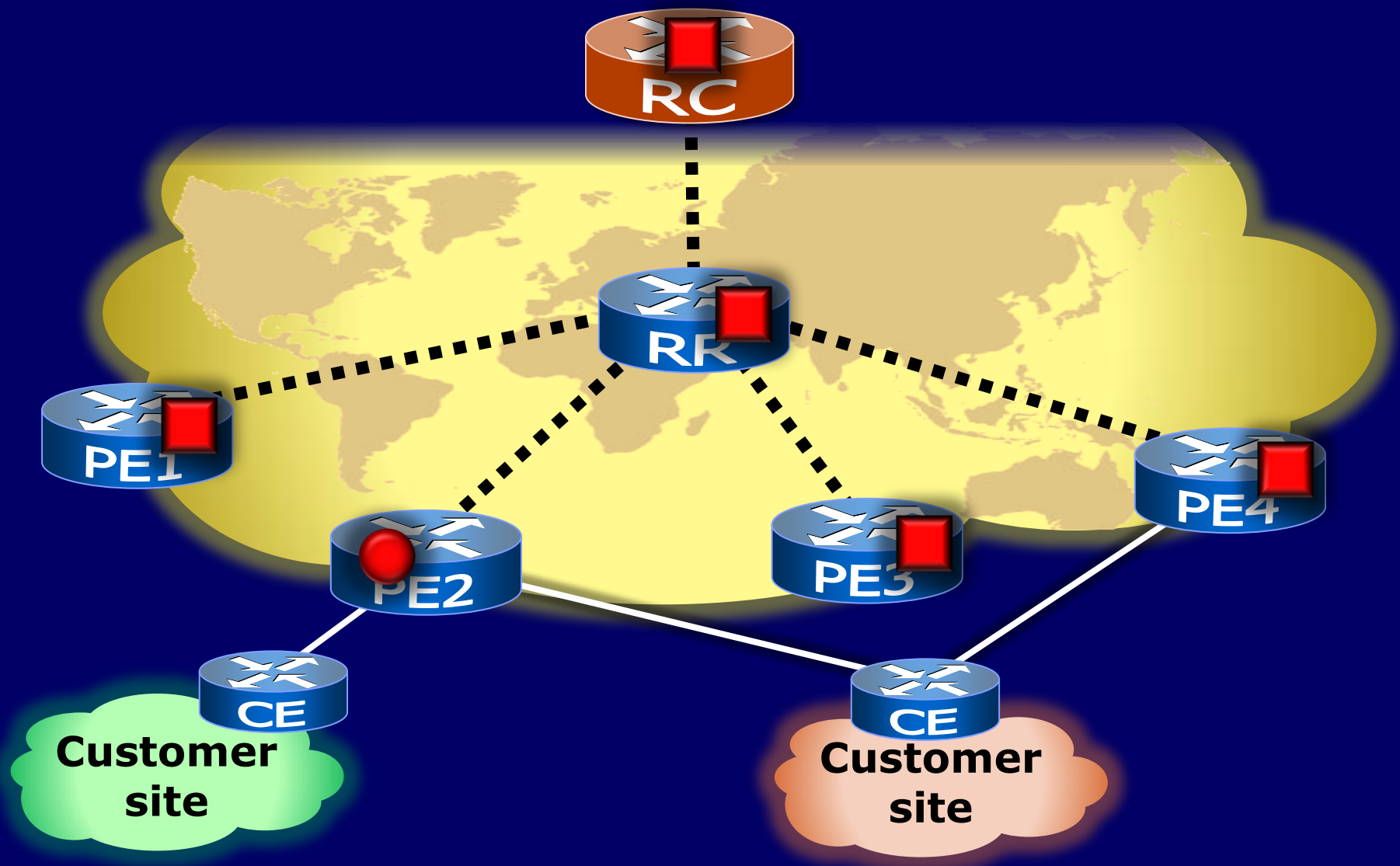

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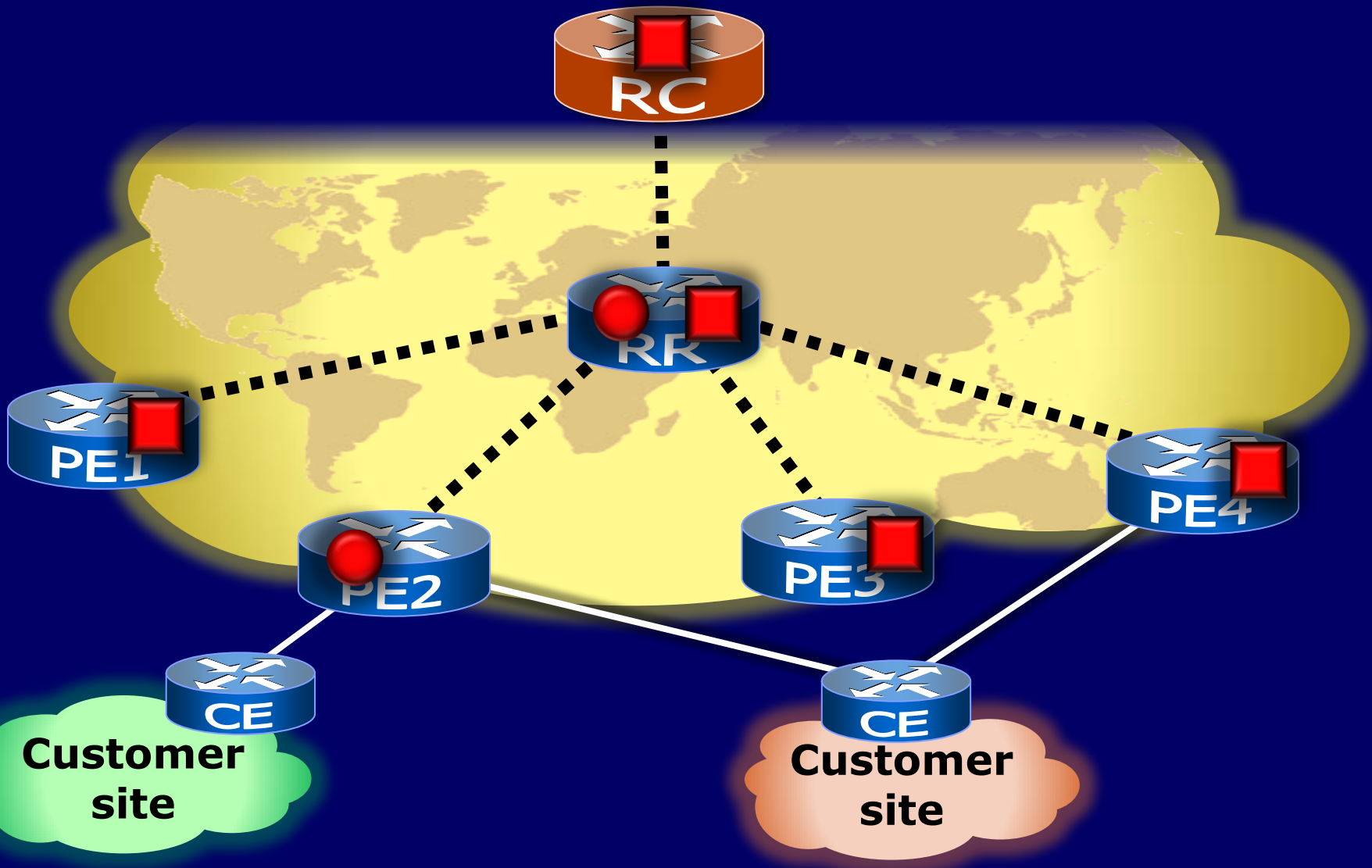

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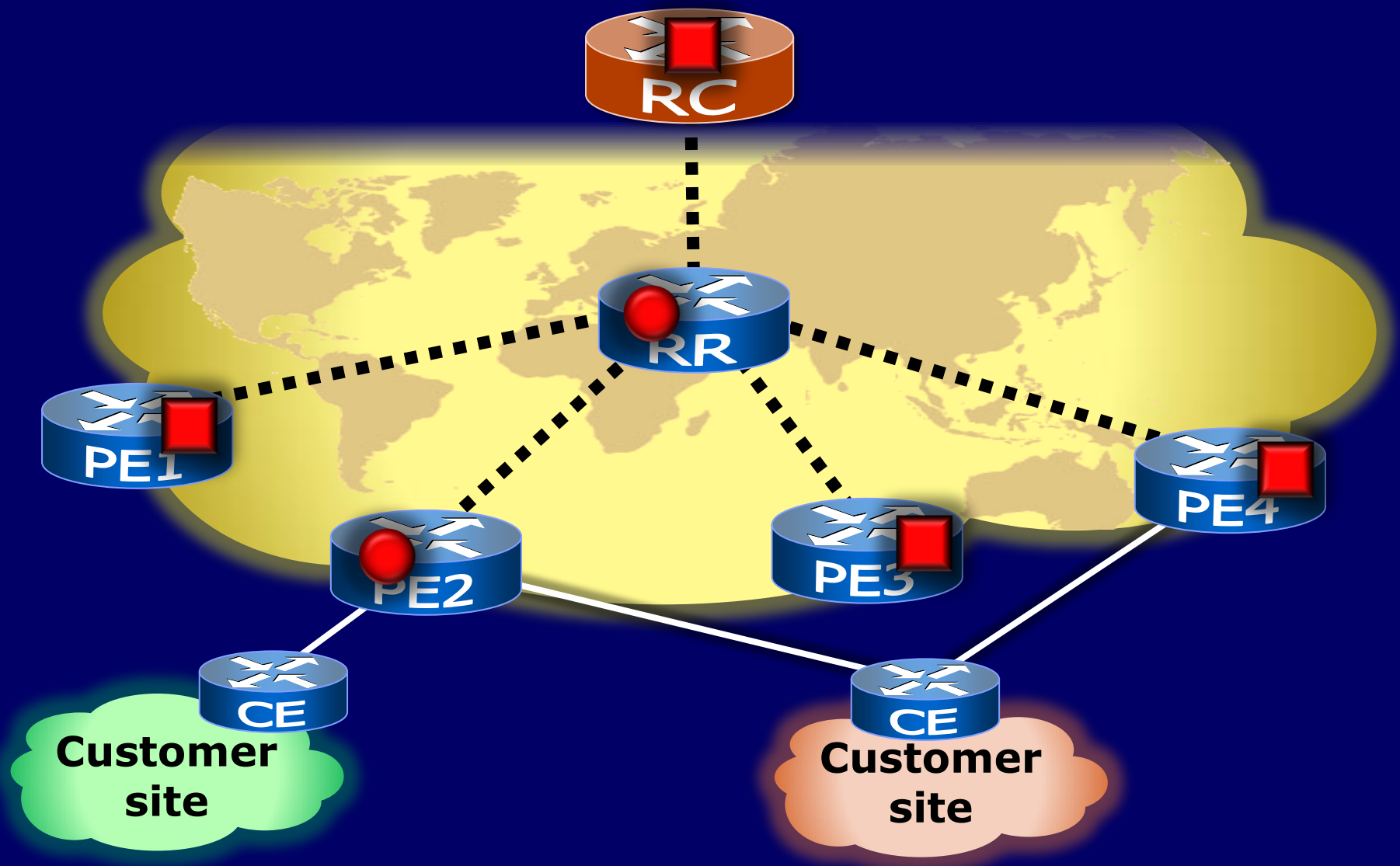

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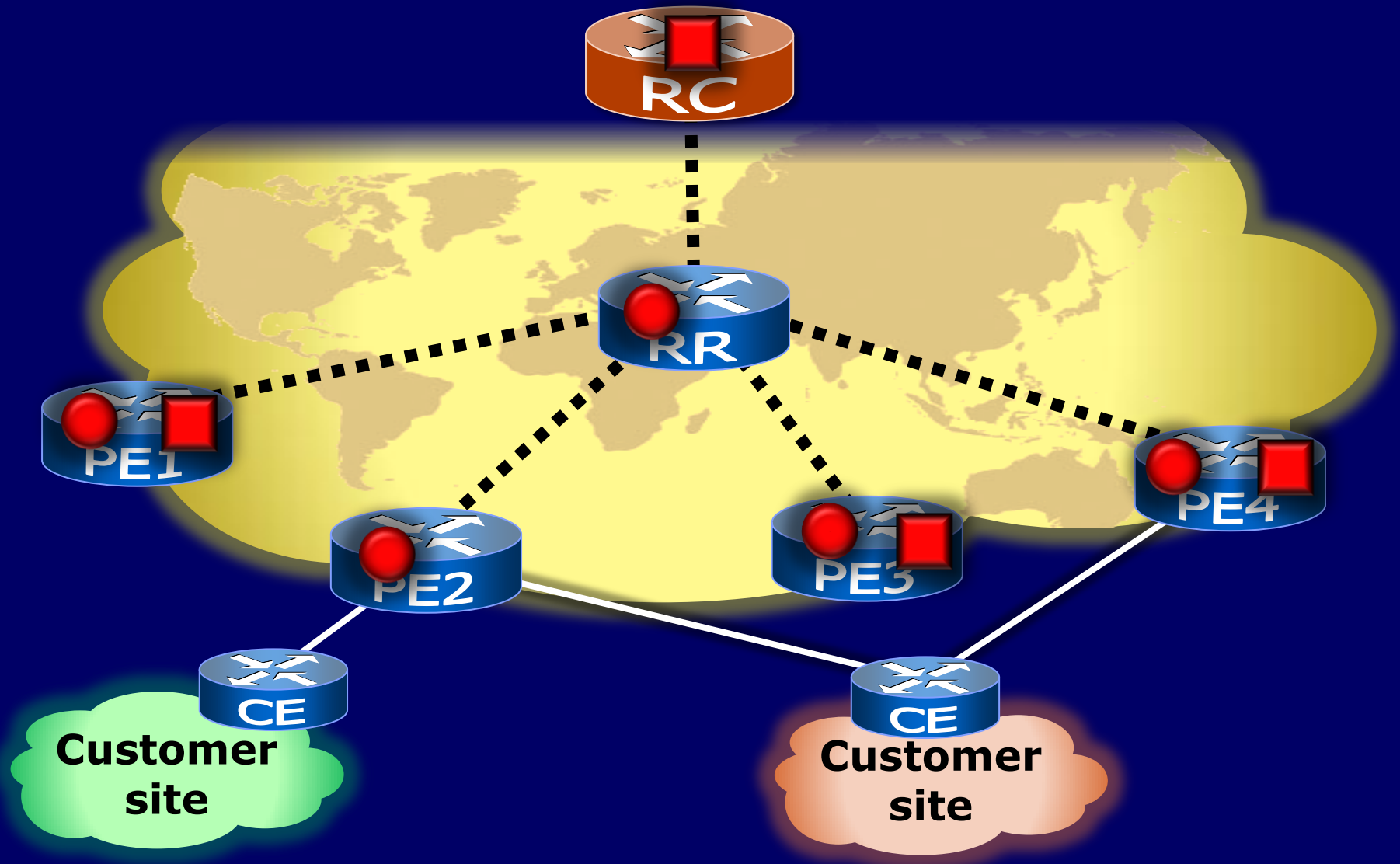

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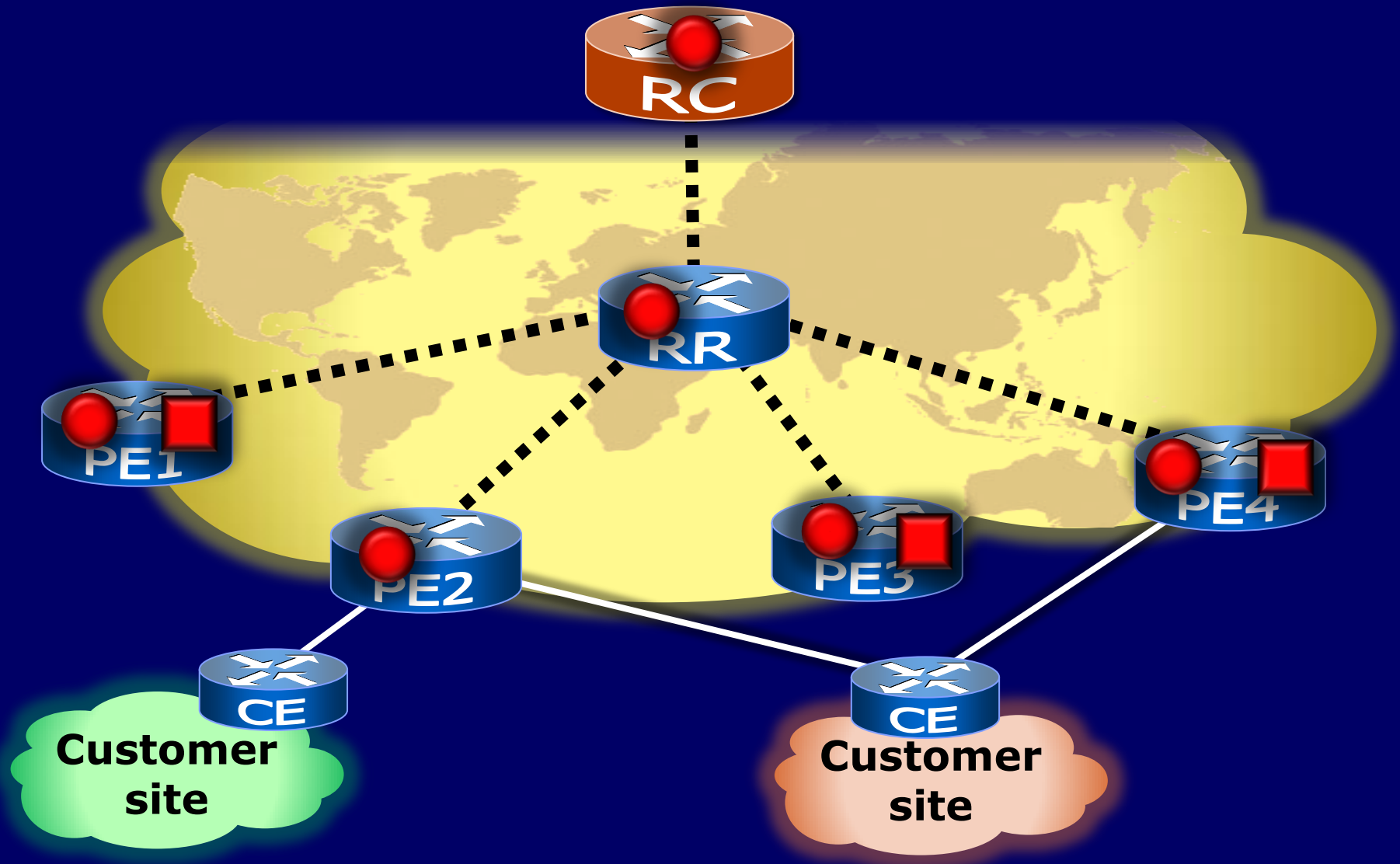

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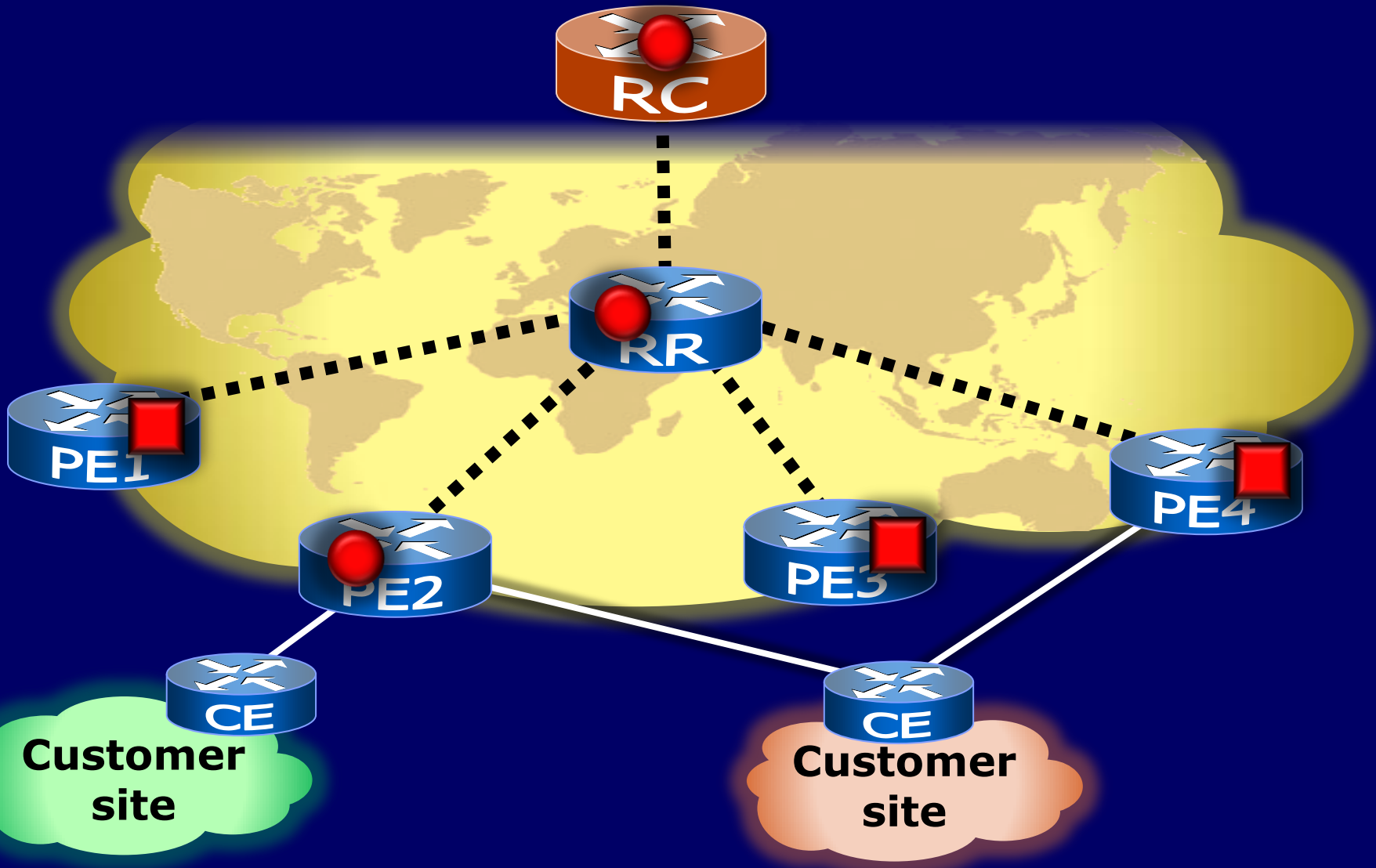

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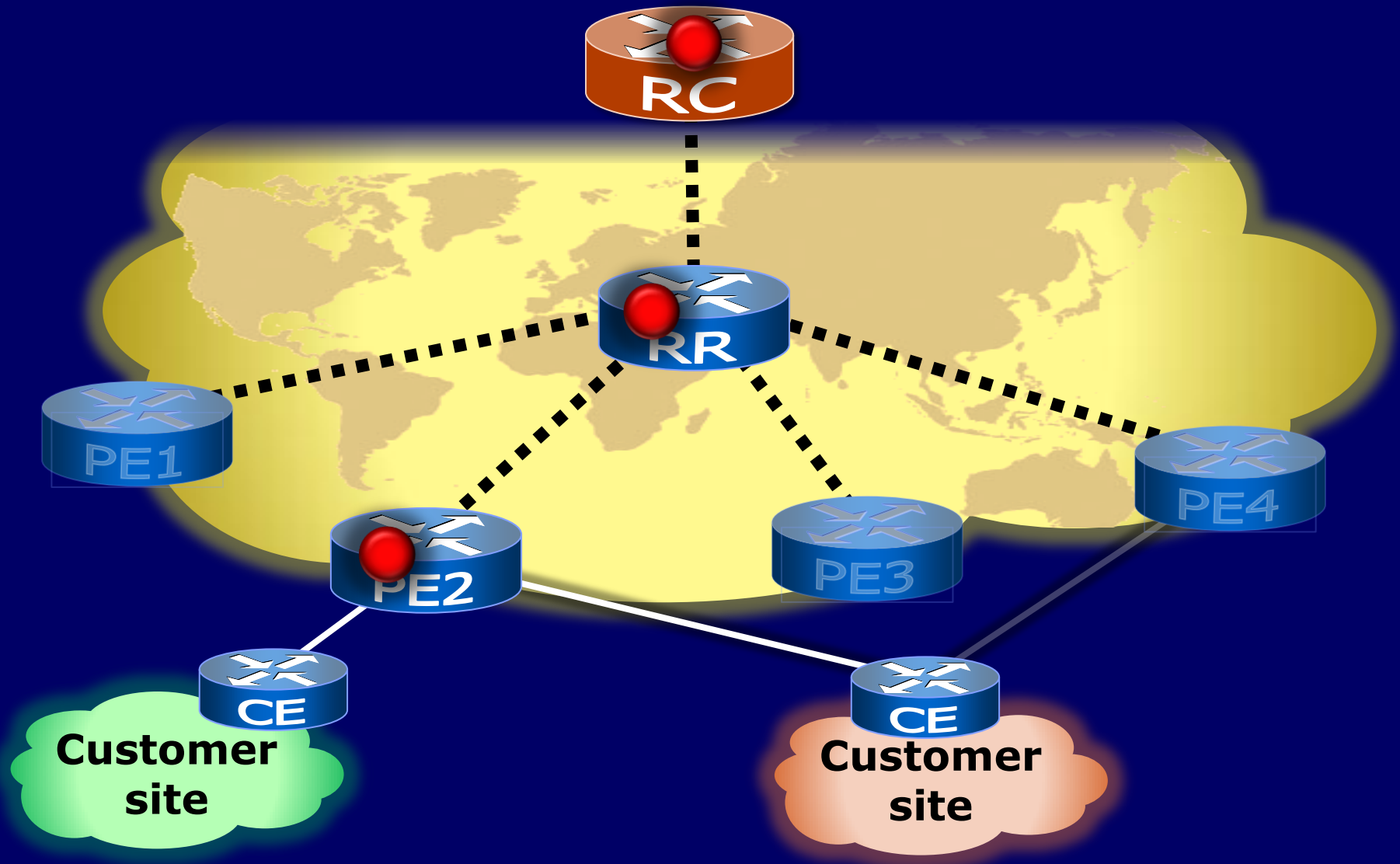

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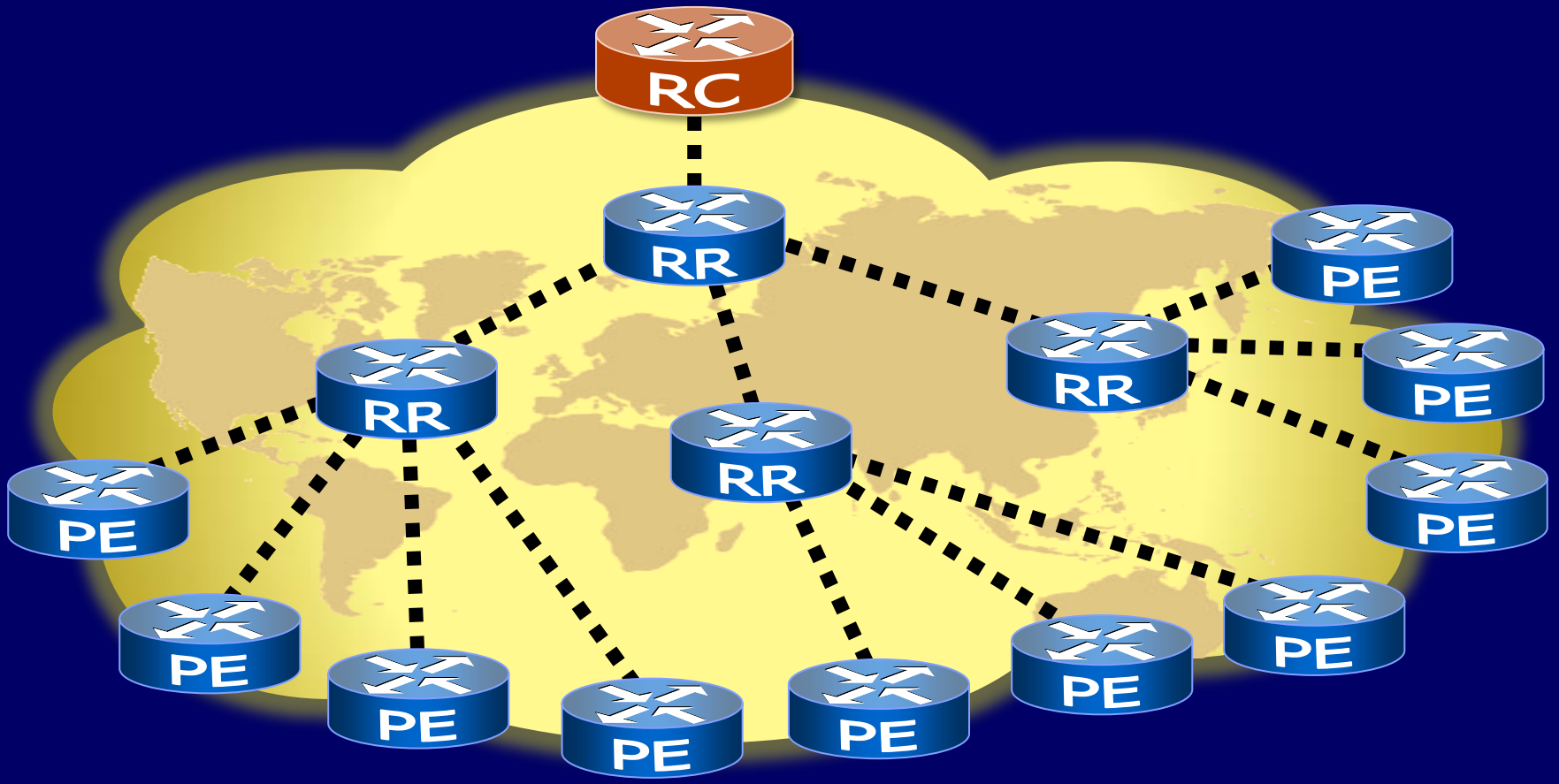

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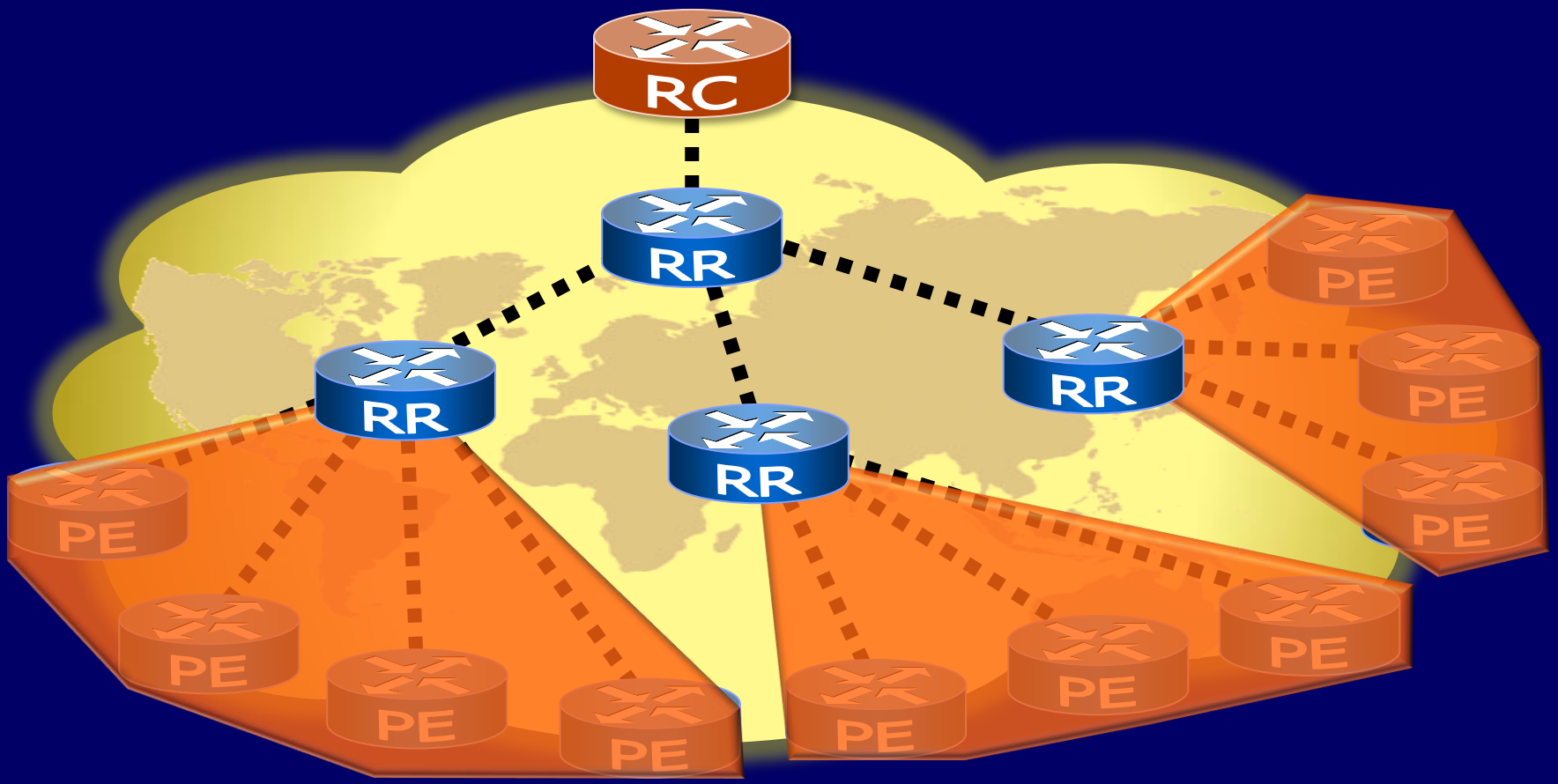

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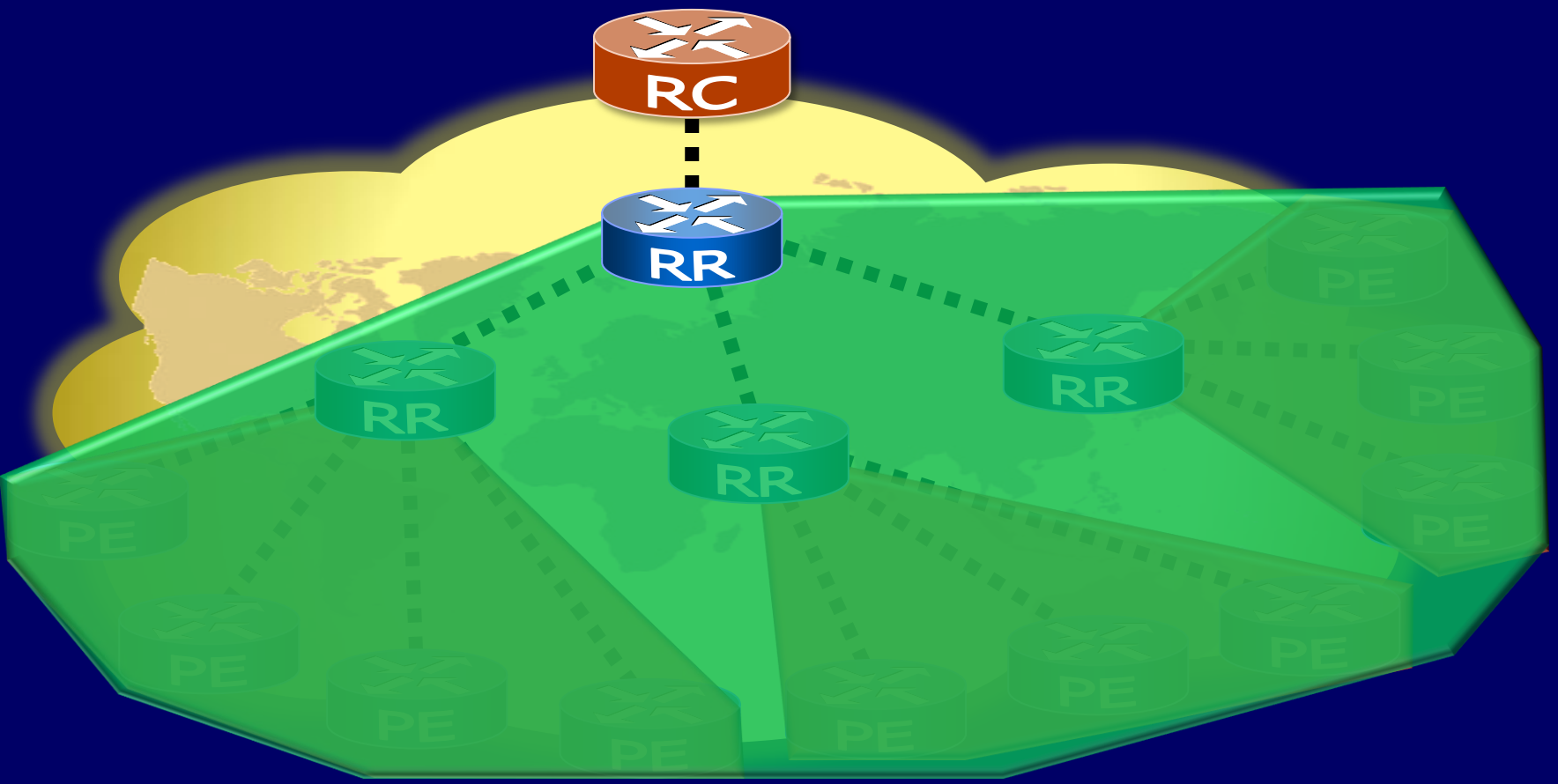

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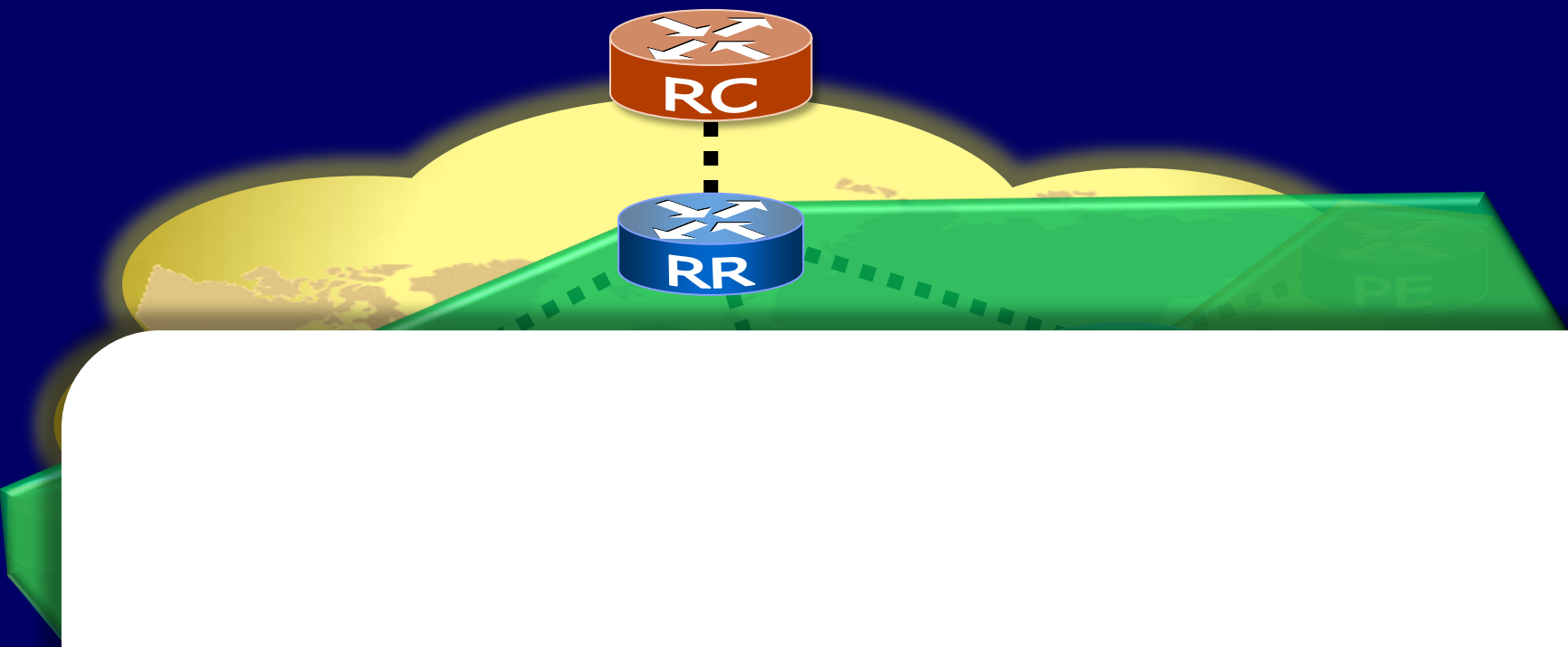

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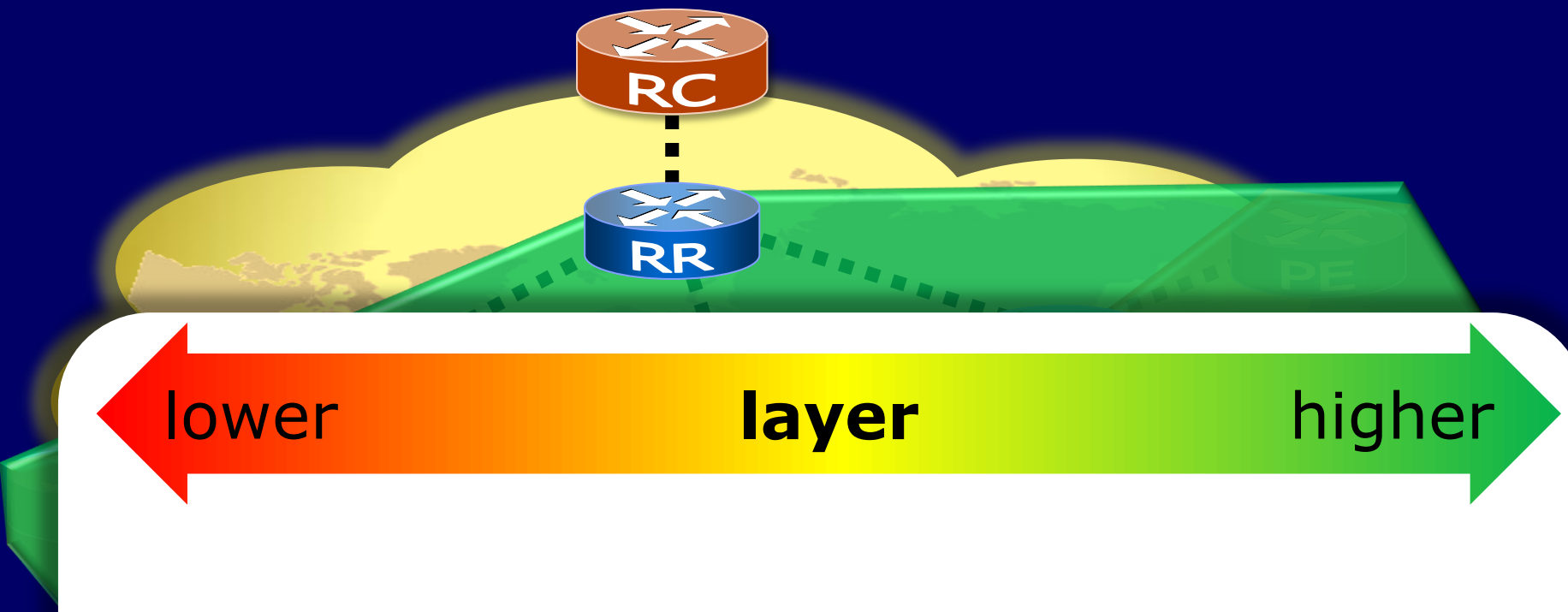
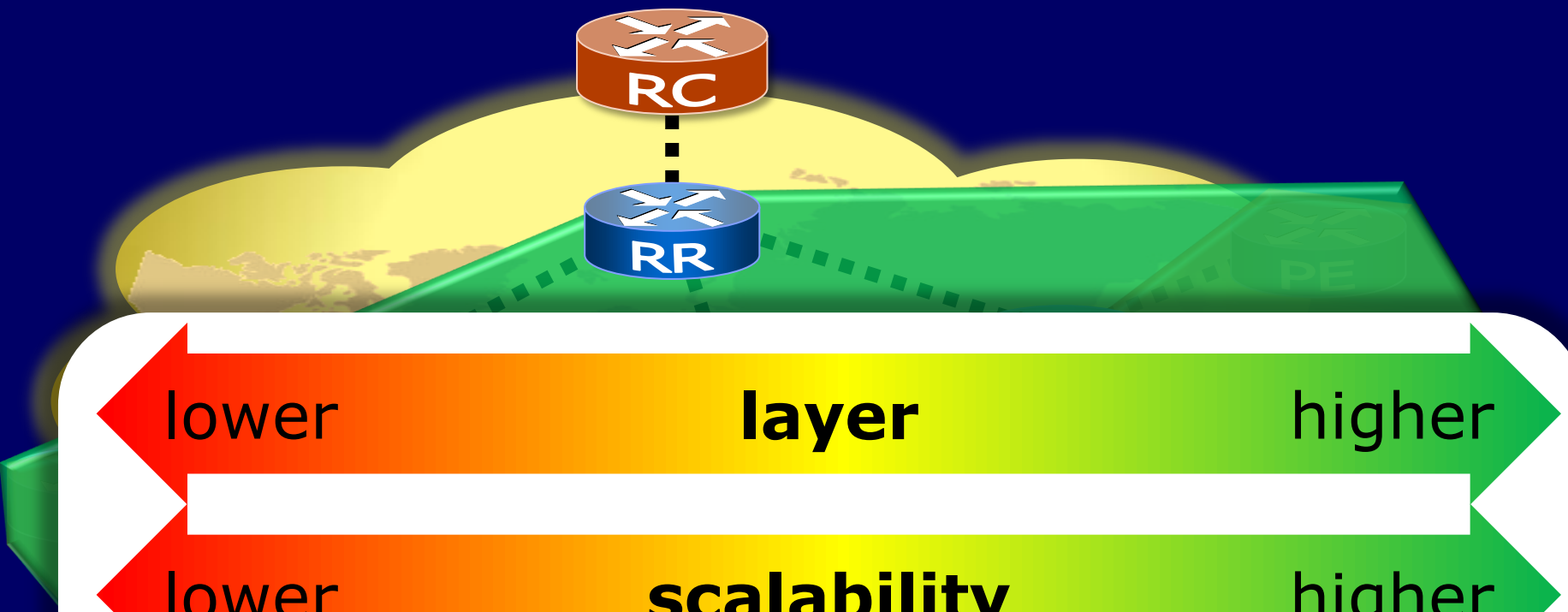


lower **layer** higher

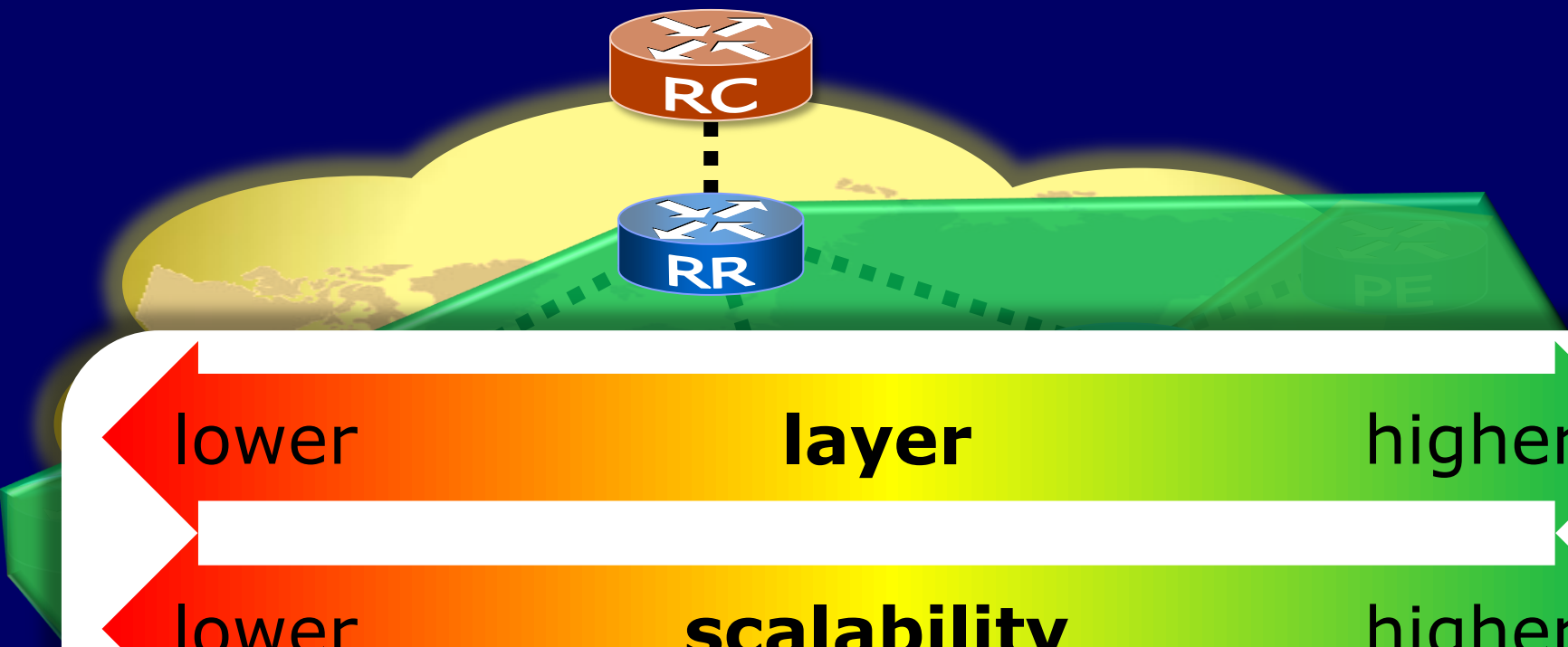
Scalability vs Visibility



lower **layer** higher

lower **scalability** higher

Scalability vs Visibility

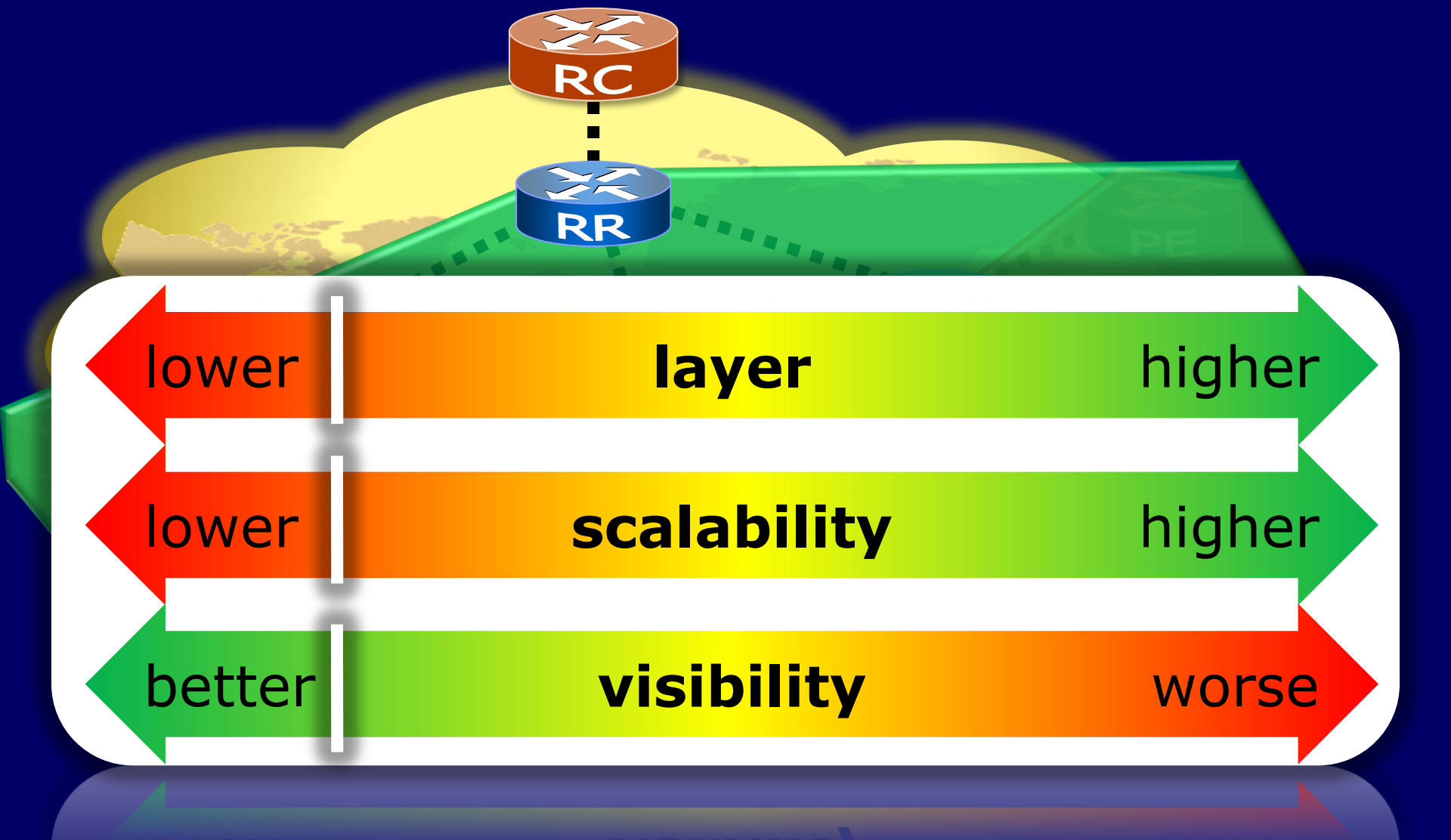


lower **layer** higher

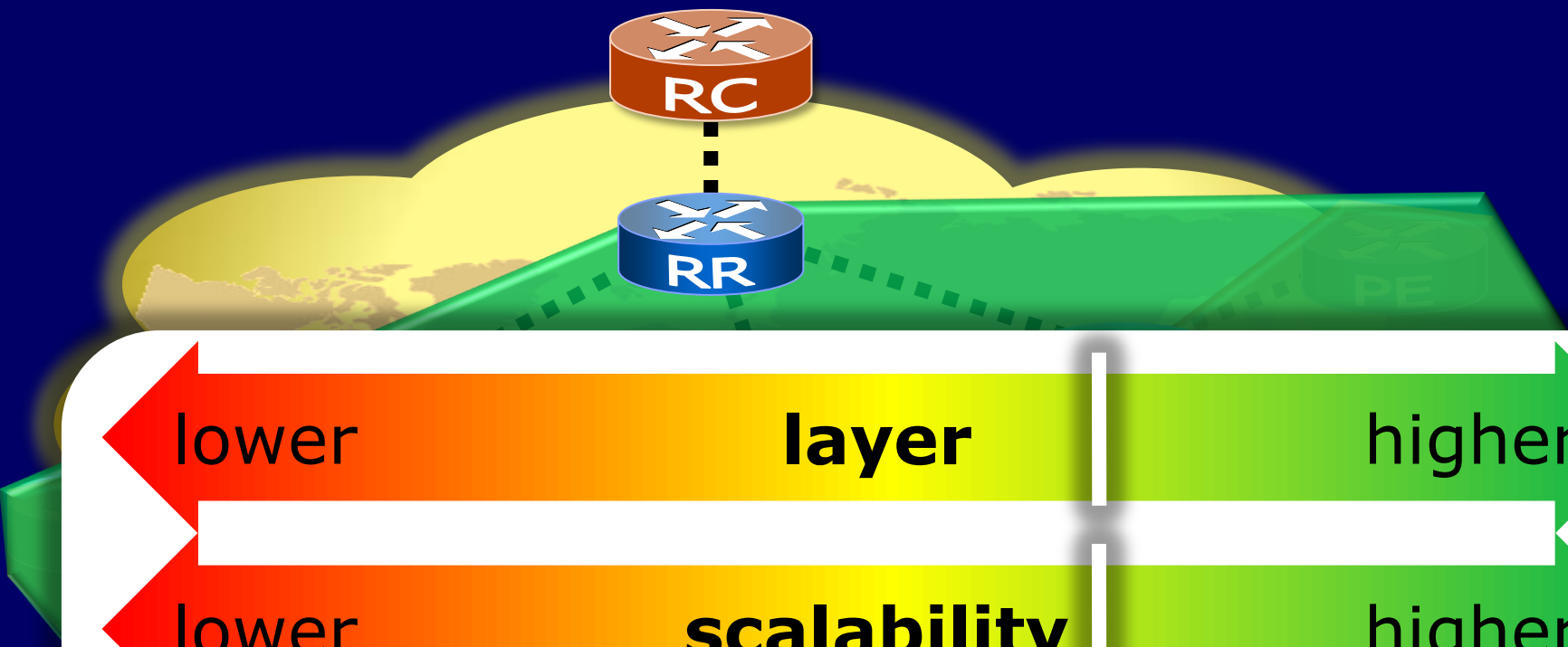
lower **scalability** higher

better **visibility** worse

Scalability vs Visibility



Scalability vs Visibility

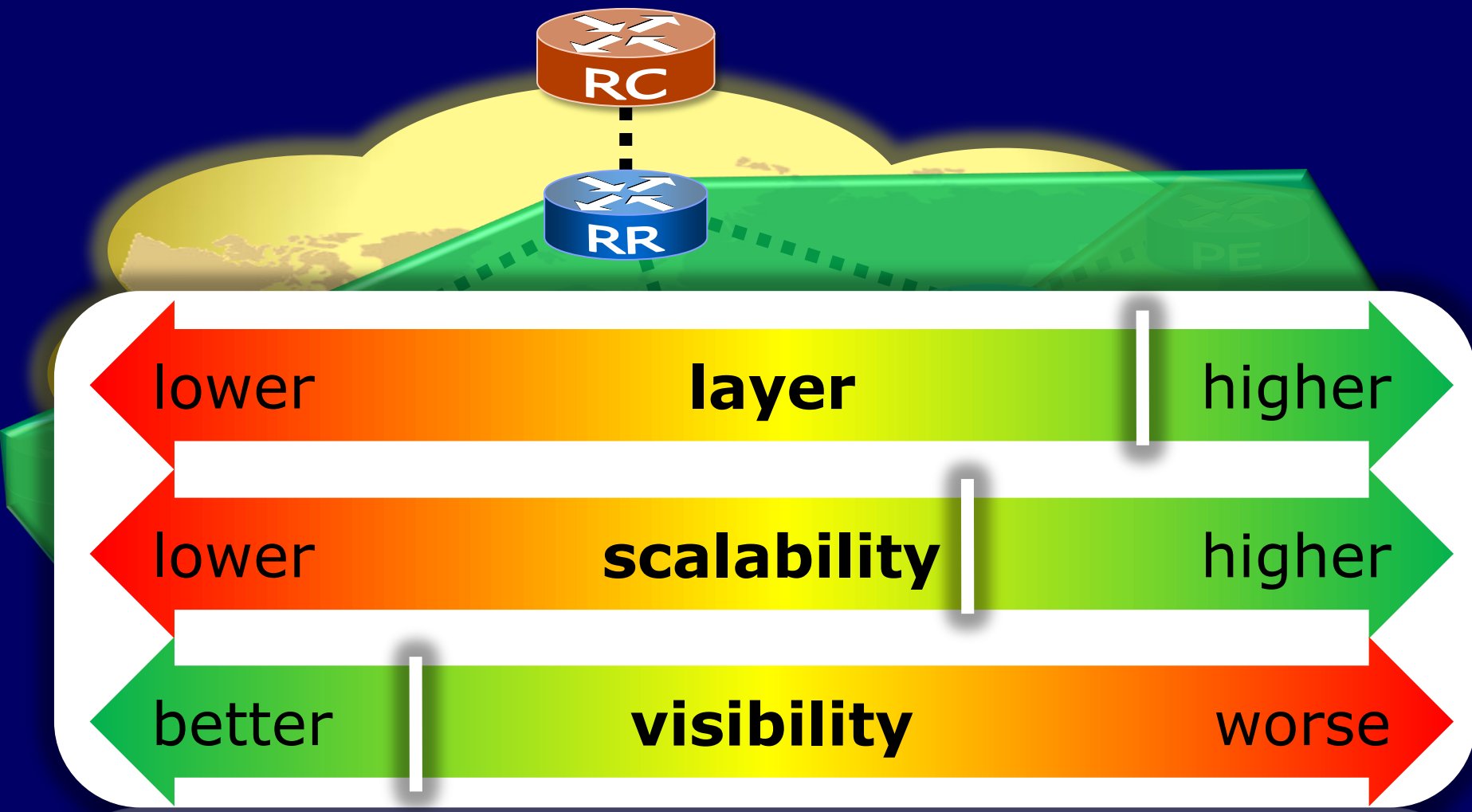


lower **layer** higher

lower **scalability** higher

better **visibility** worse

Scalability vs Visibility



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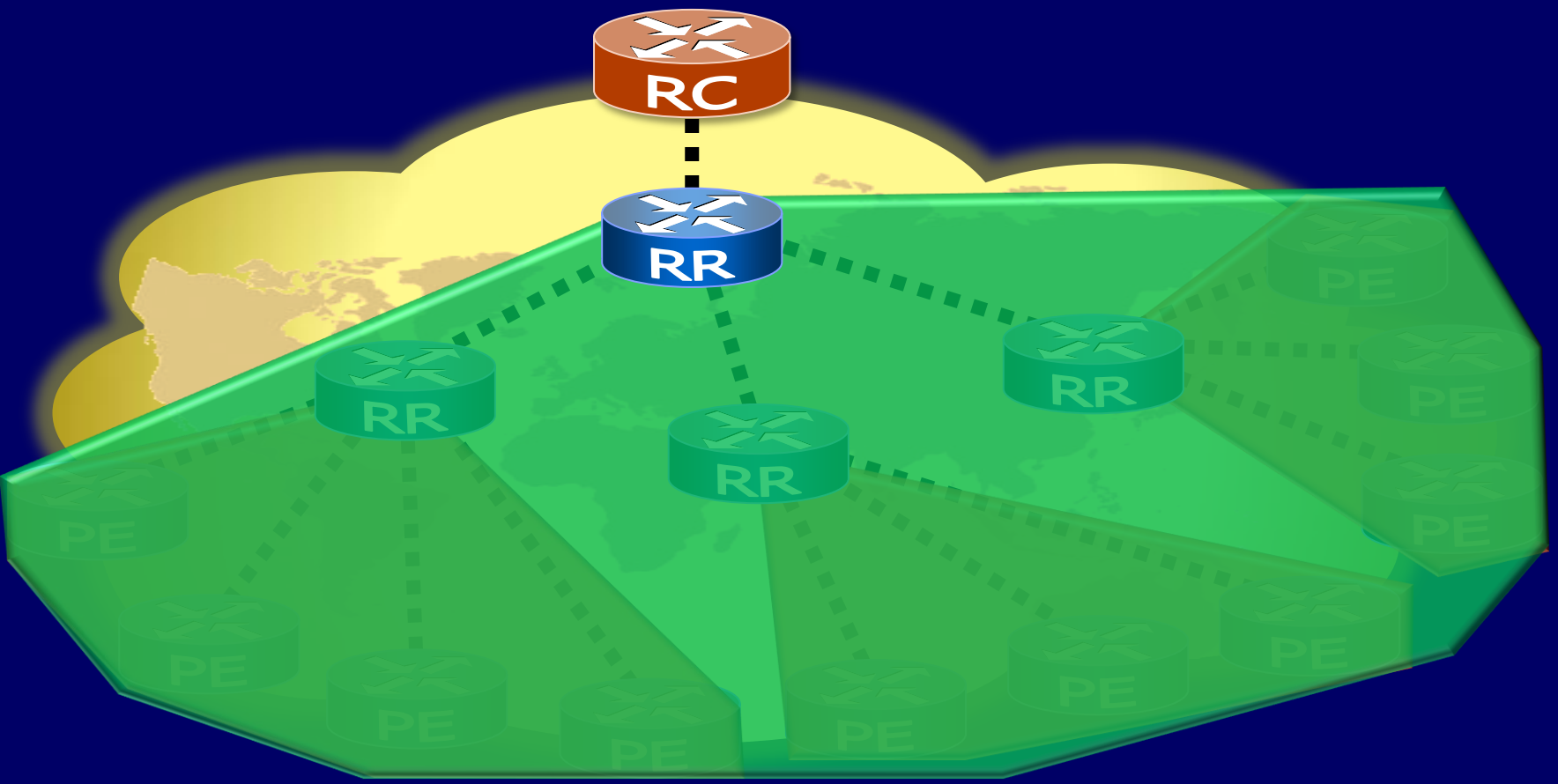

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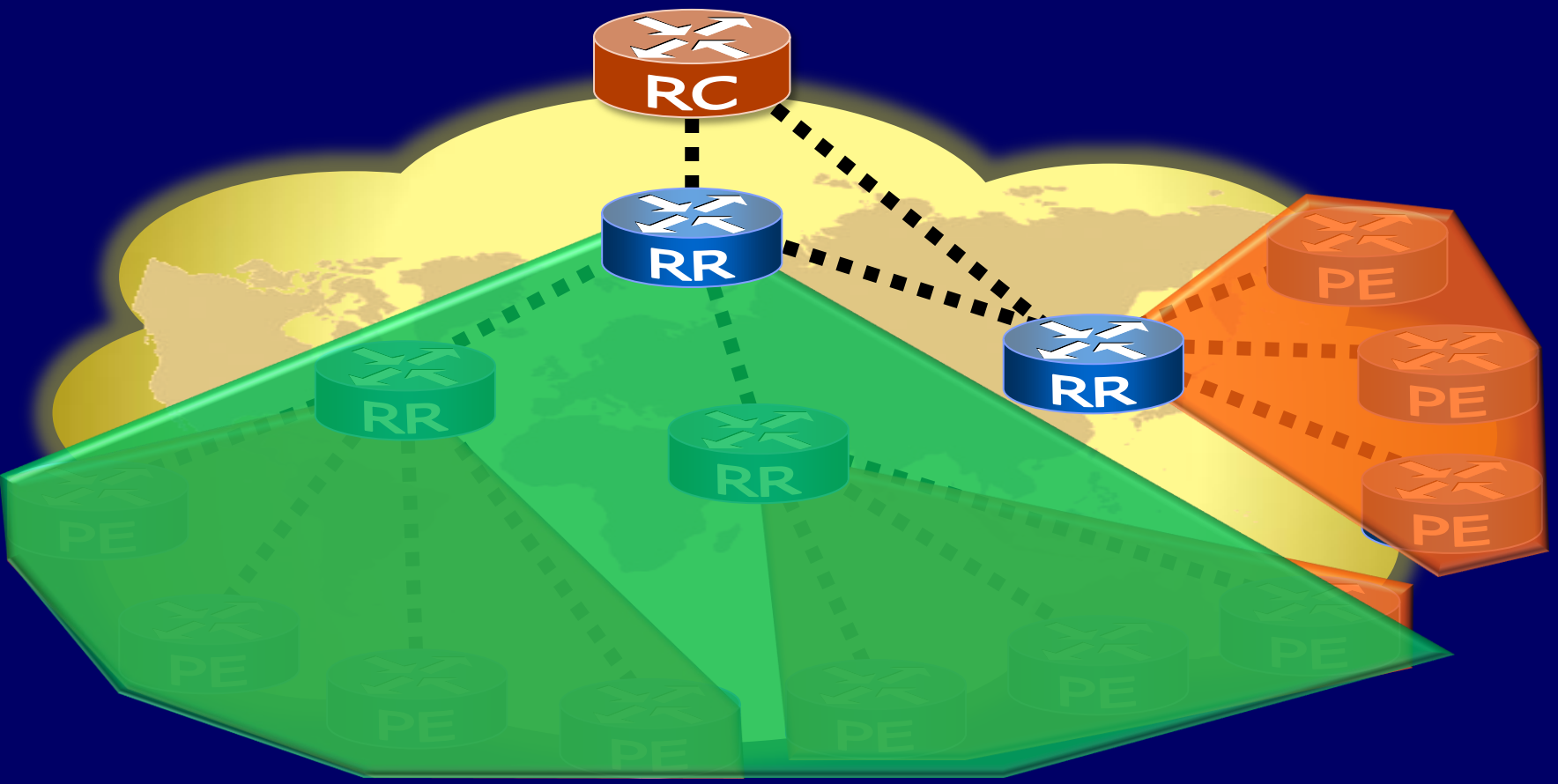
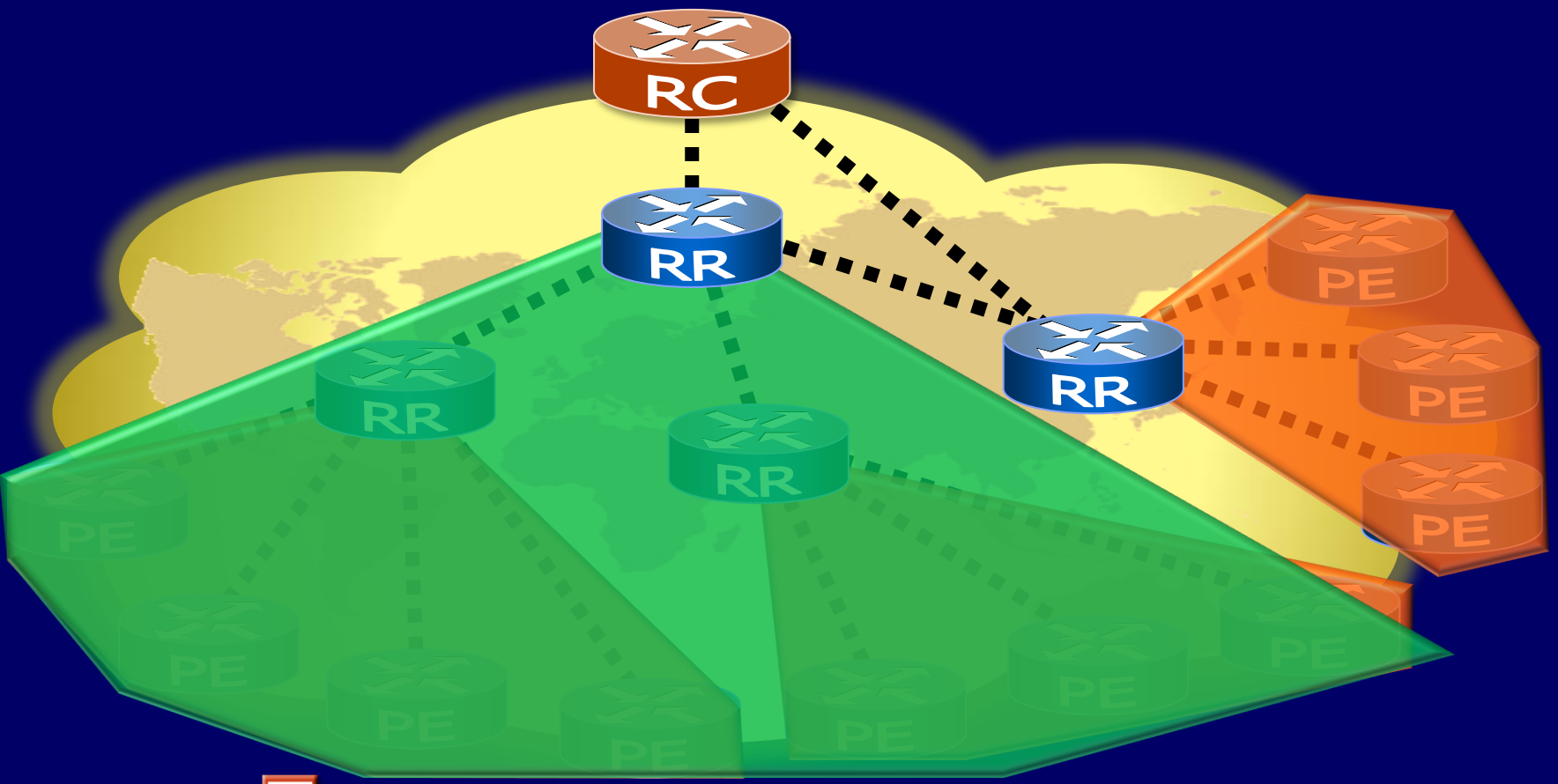


Scalability vs Visibility



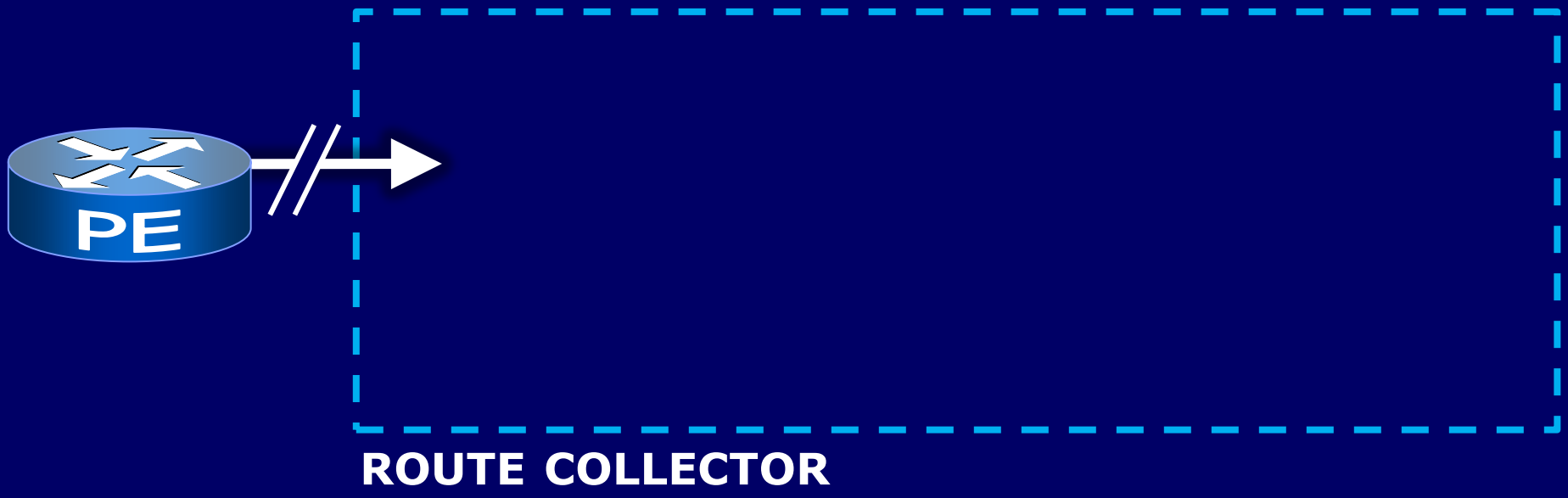
beware of matching updates

Experimental Scenario

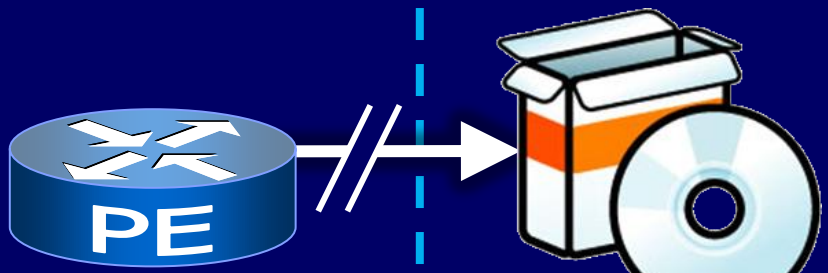
Experimental Scenario

ROUTE COLLECTOR

Experimental Scenario



Experimental Scenario



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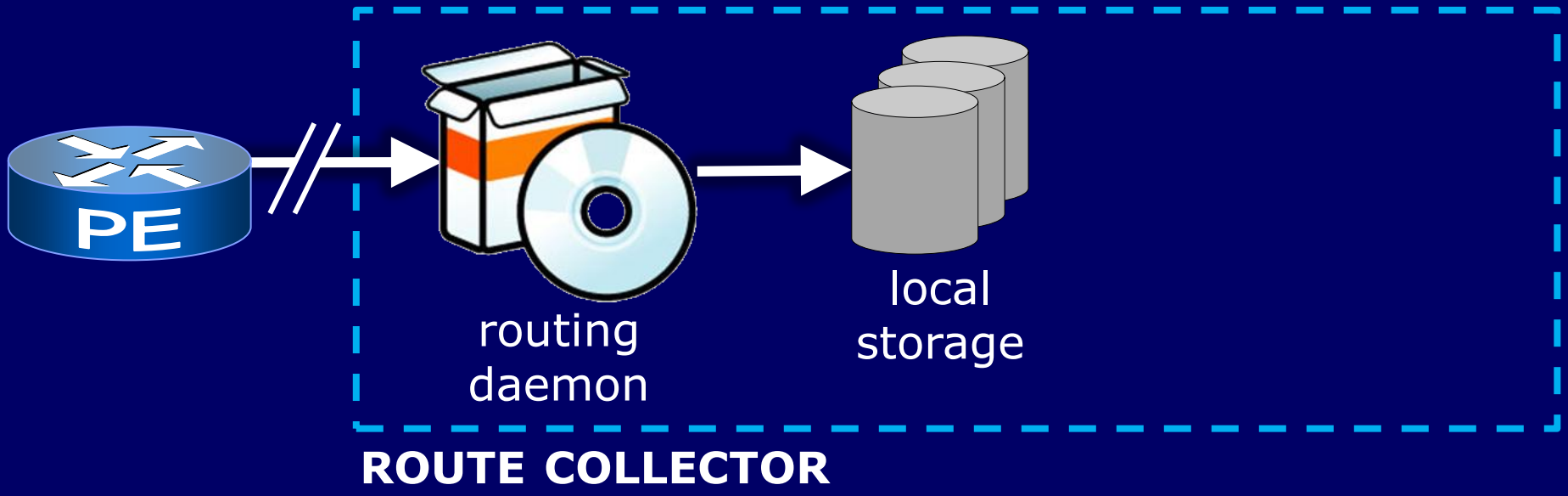
ROUTE COLLECTOR

Experimental Scenario



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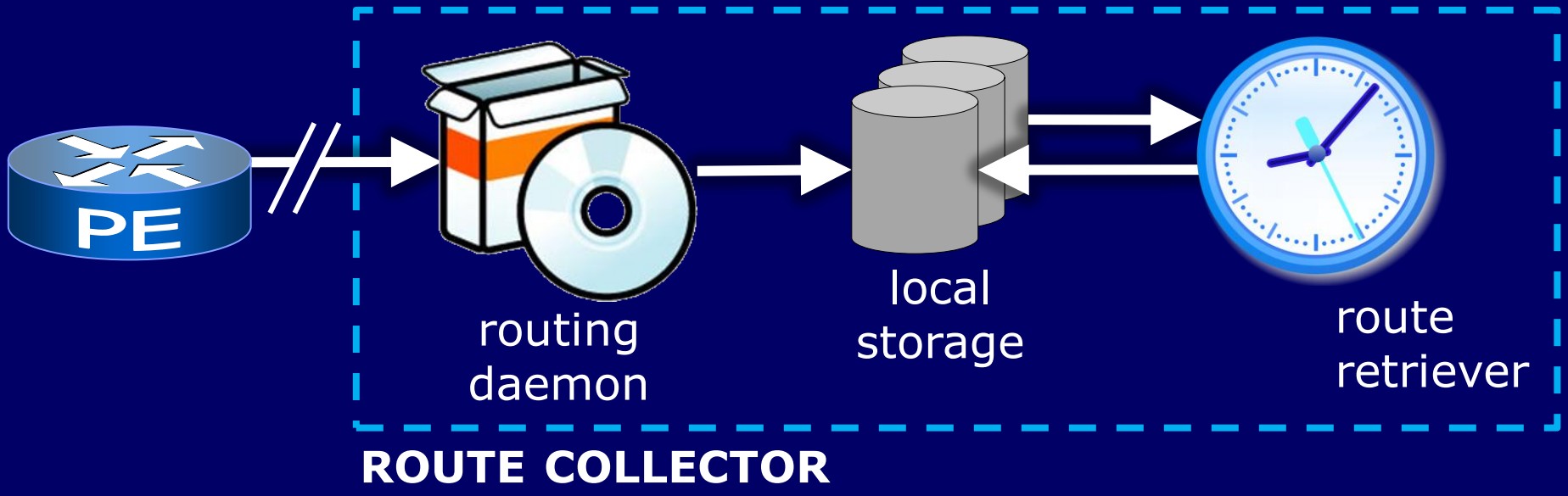

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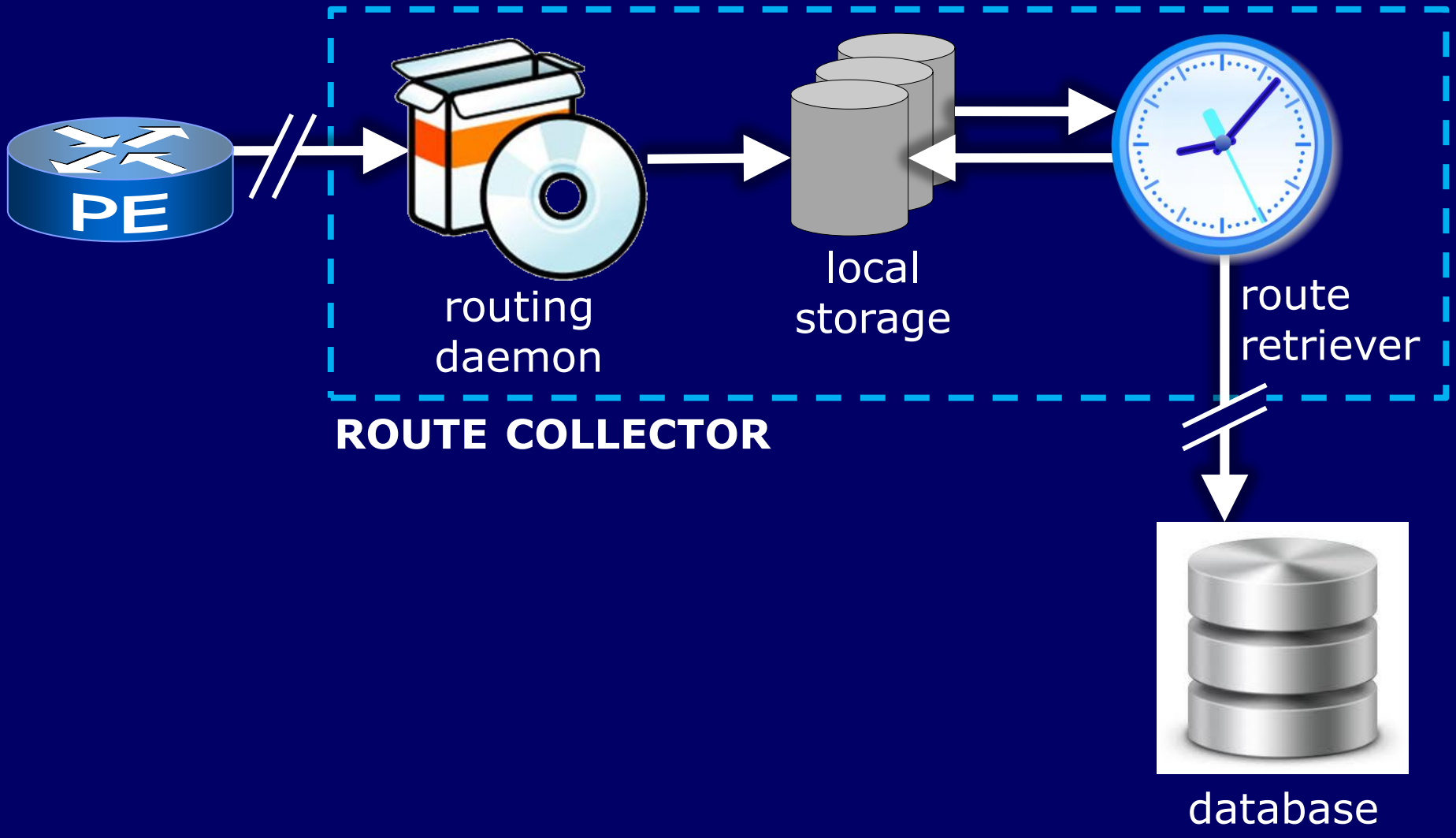

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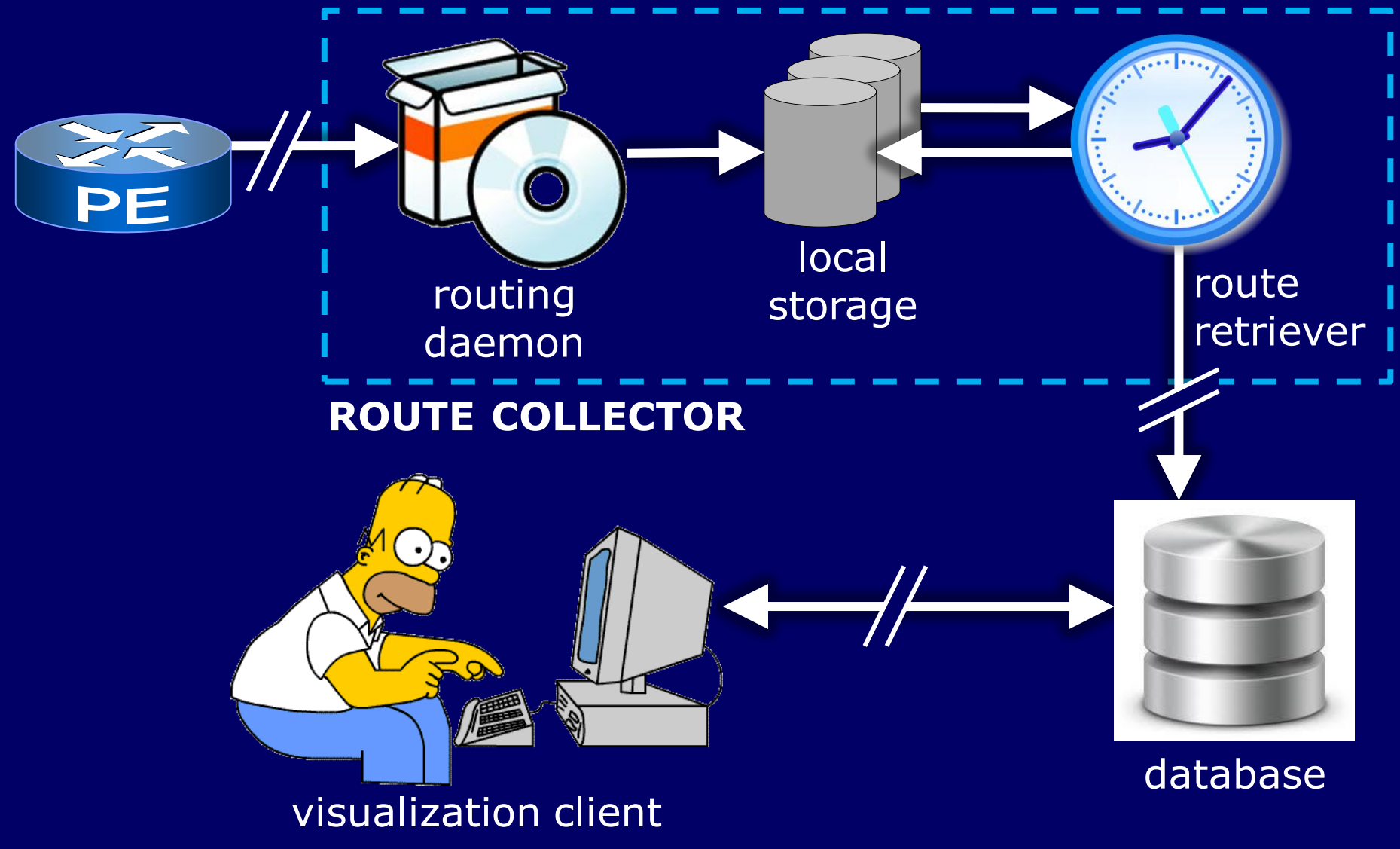

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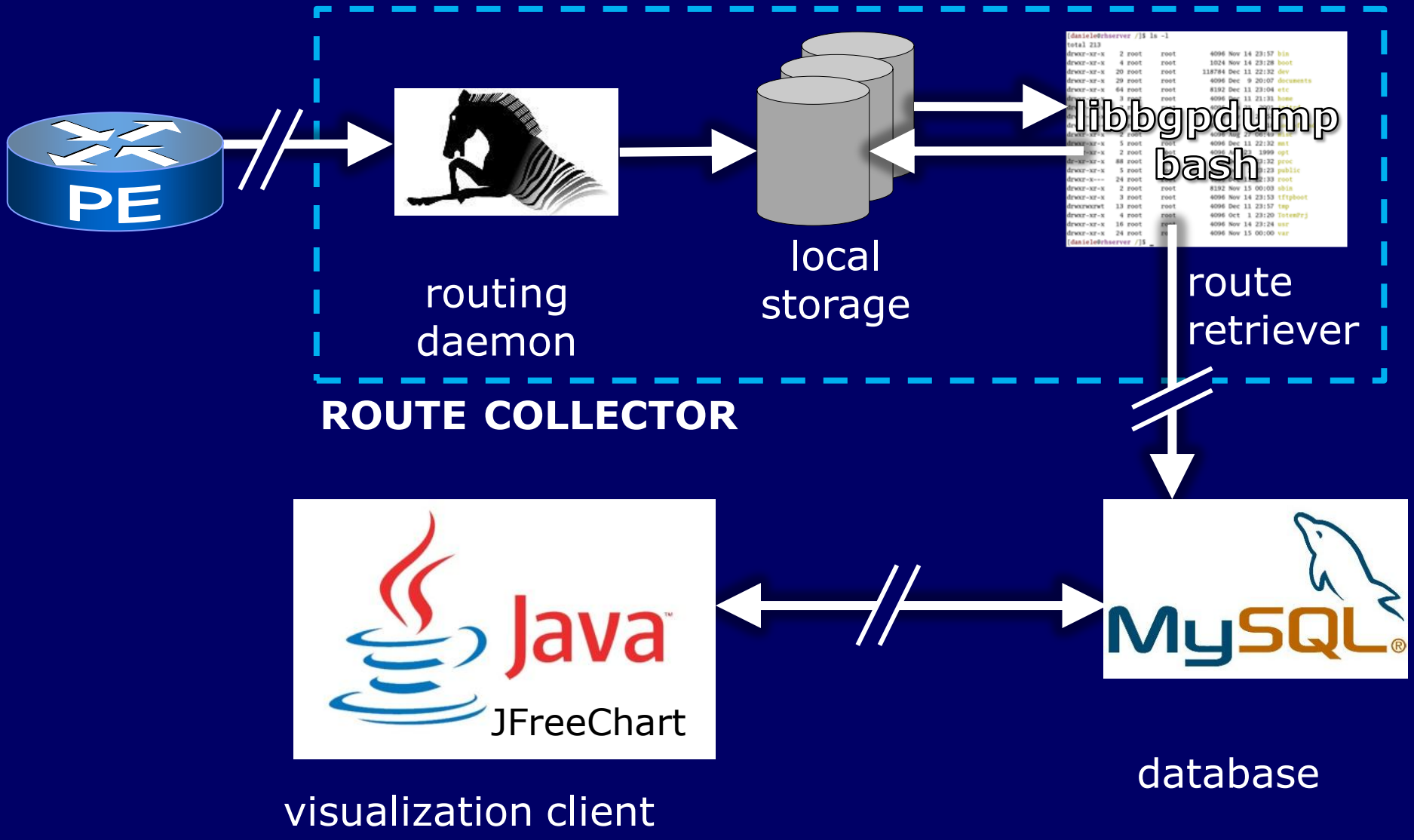

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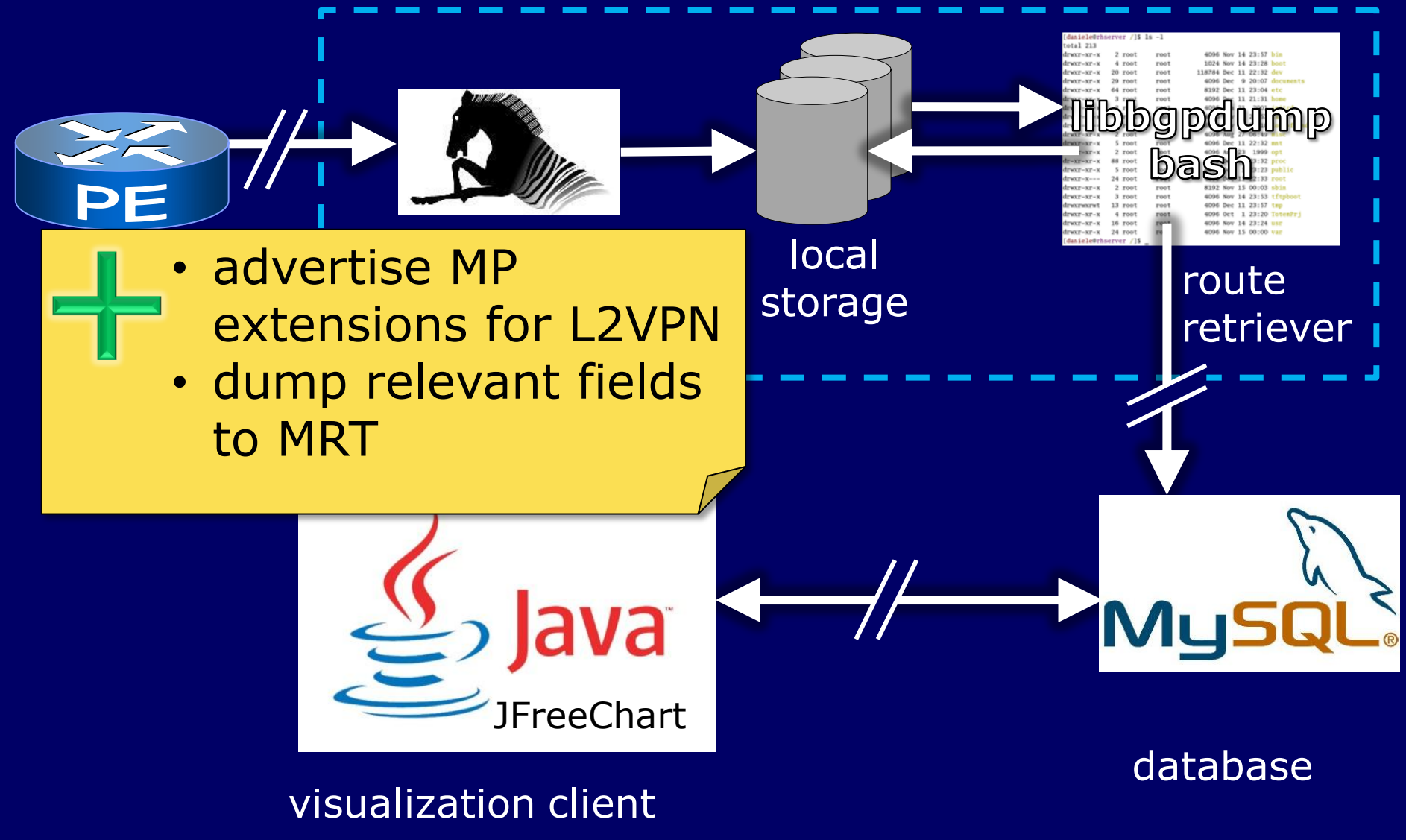

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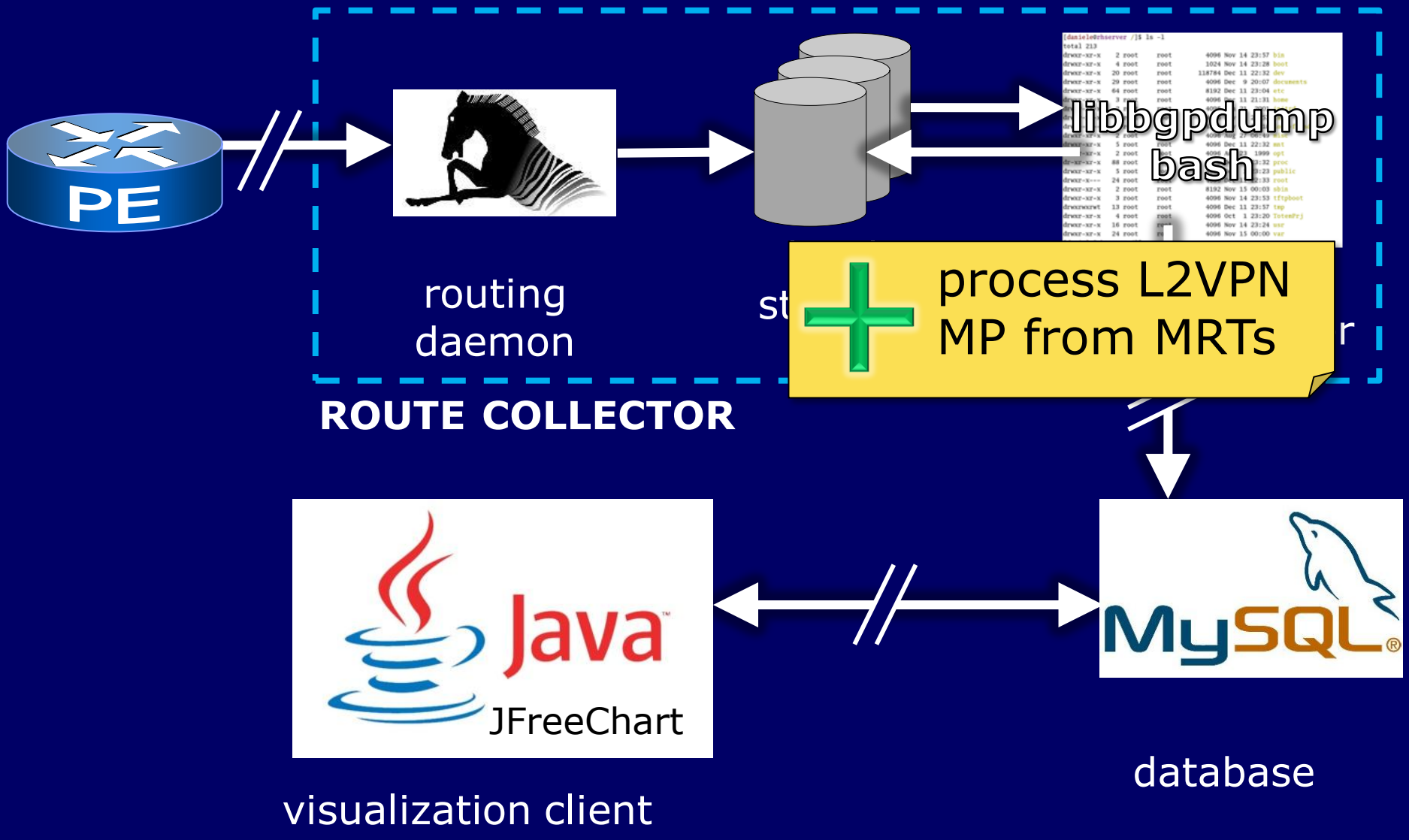

Experimental Scenario

max lag: 3mins

libbgpdump

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JFreeChart

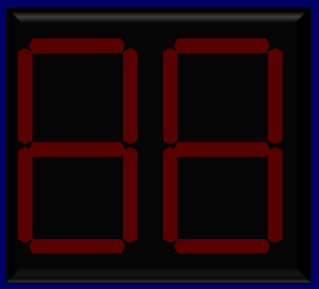
visualization client

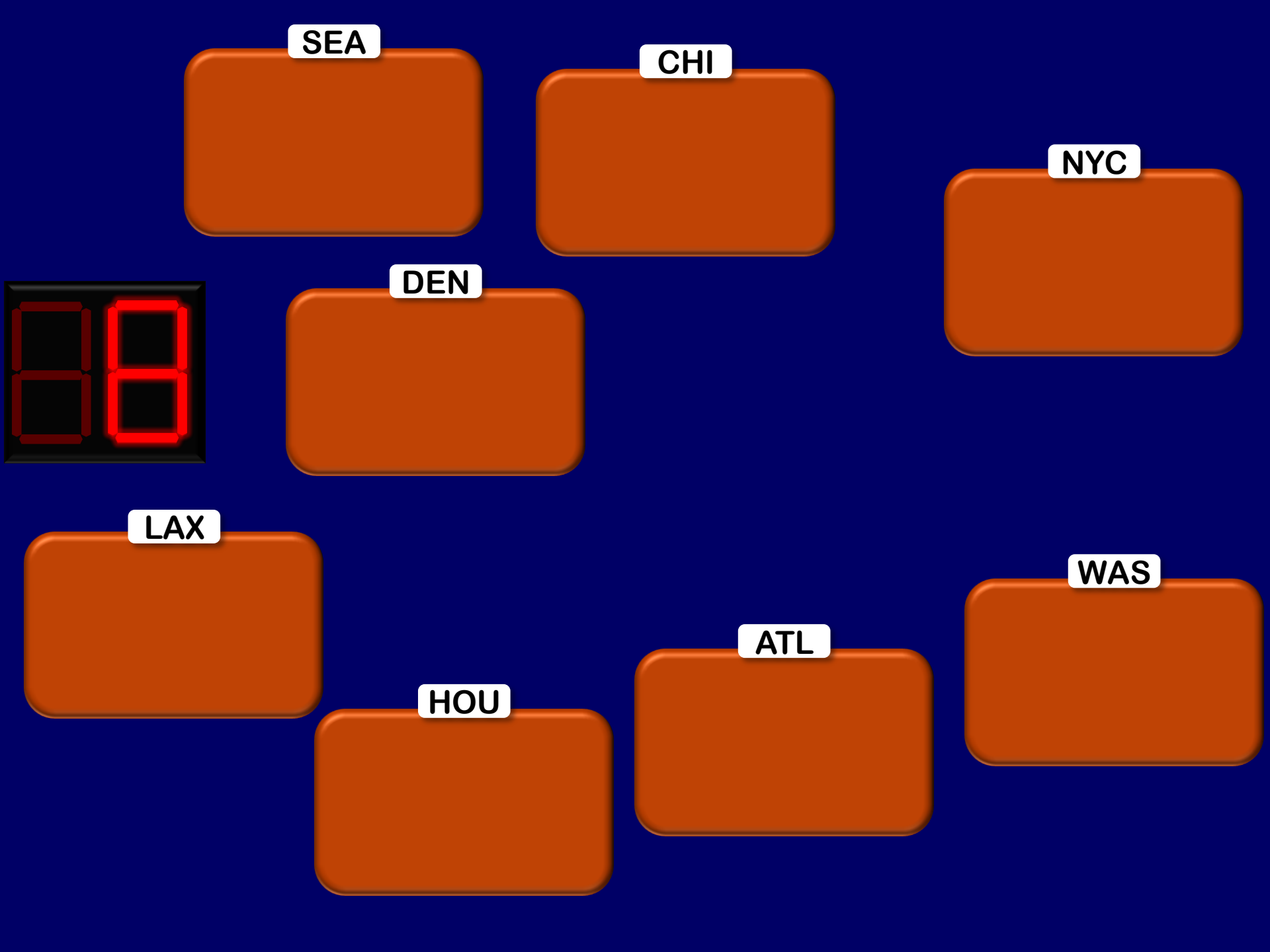
database

Experimental Scenario

max lag: 3mins

preliminary tests on Cisco routers

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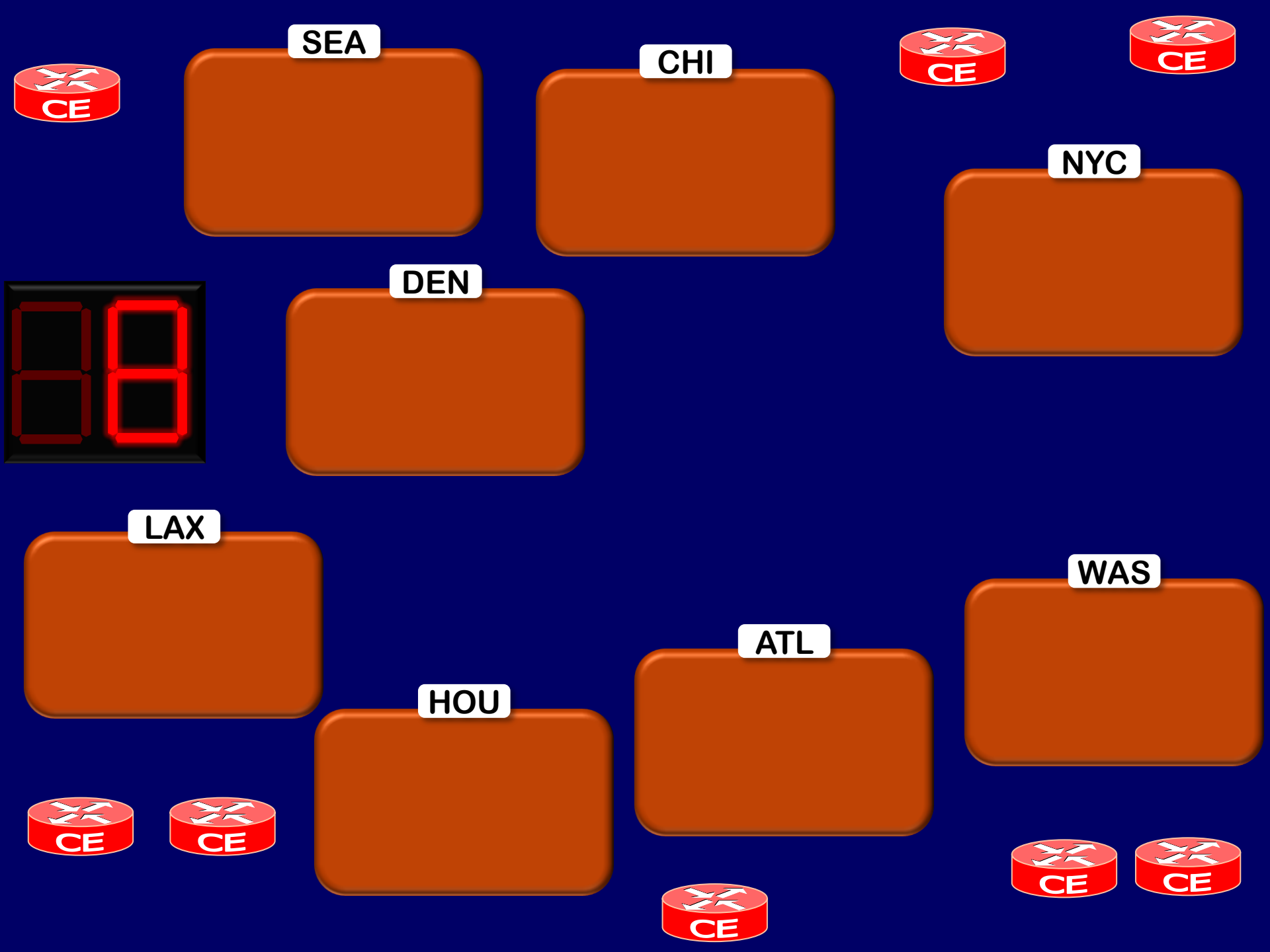
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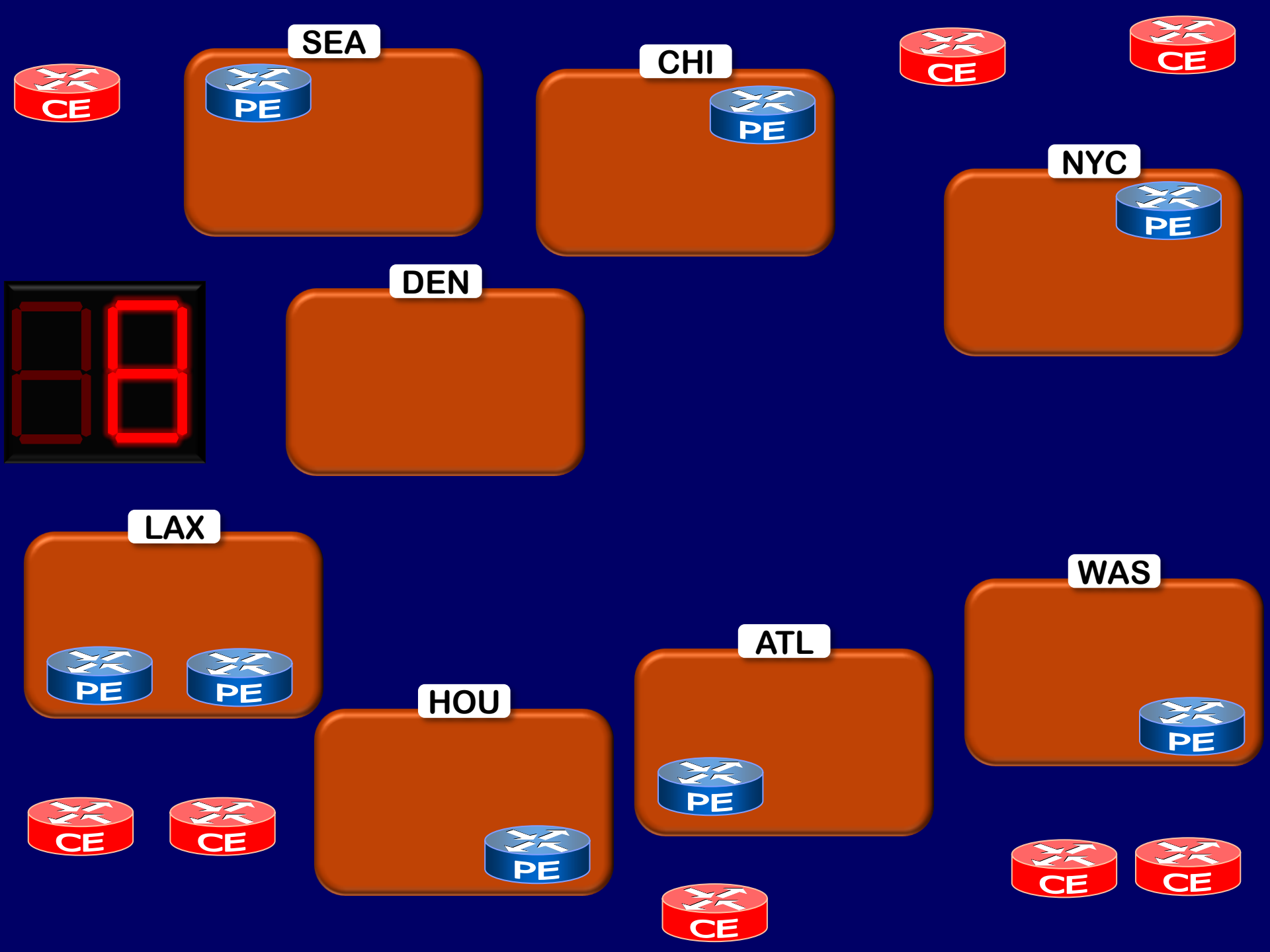
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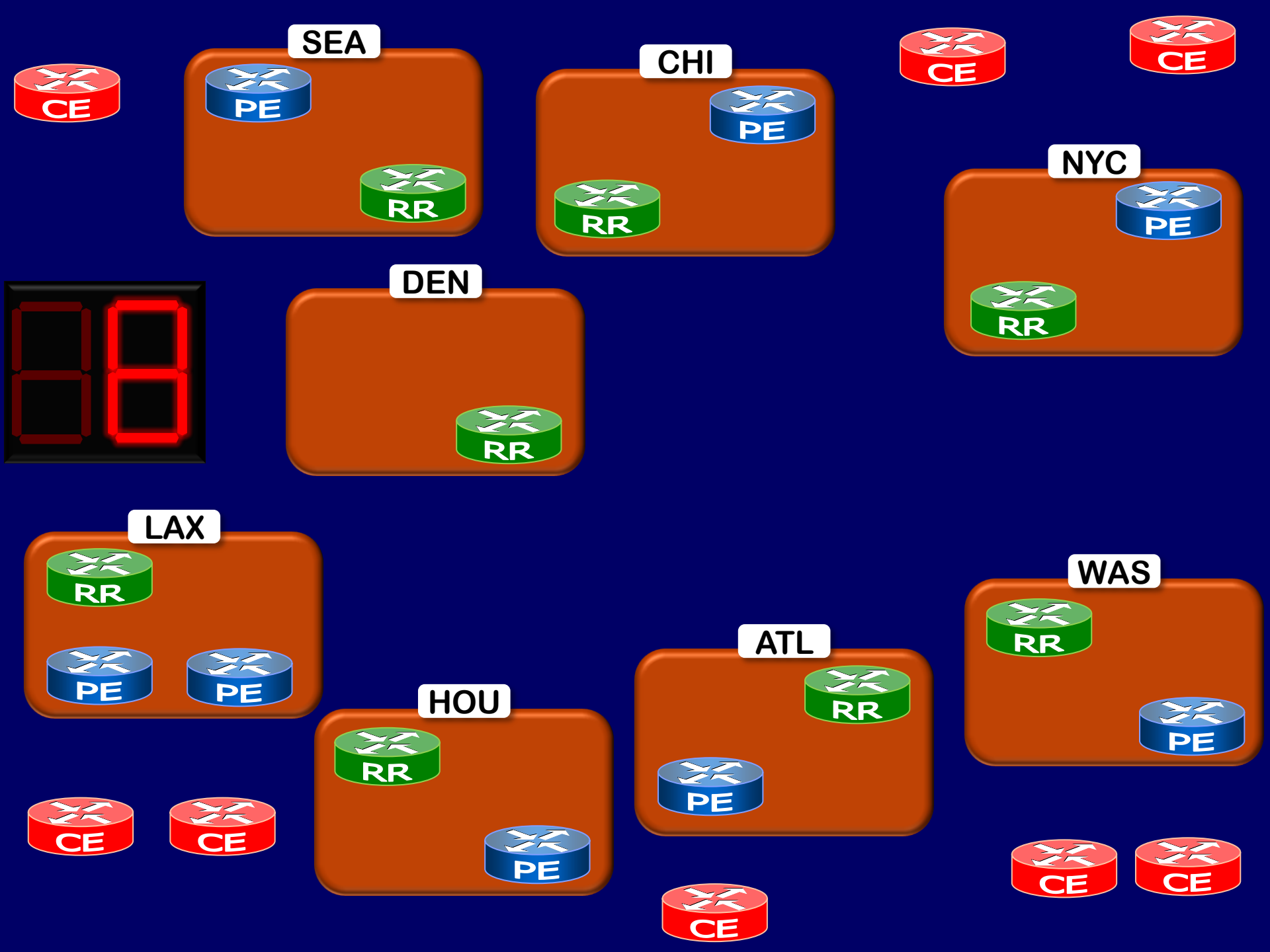
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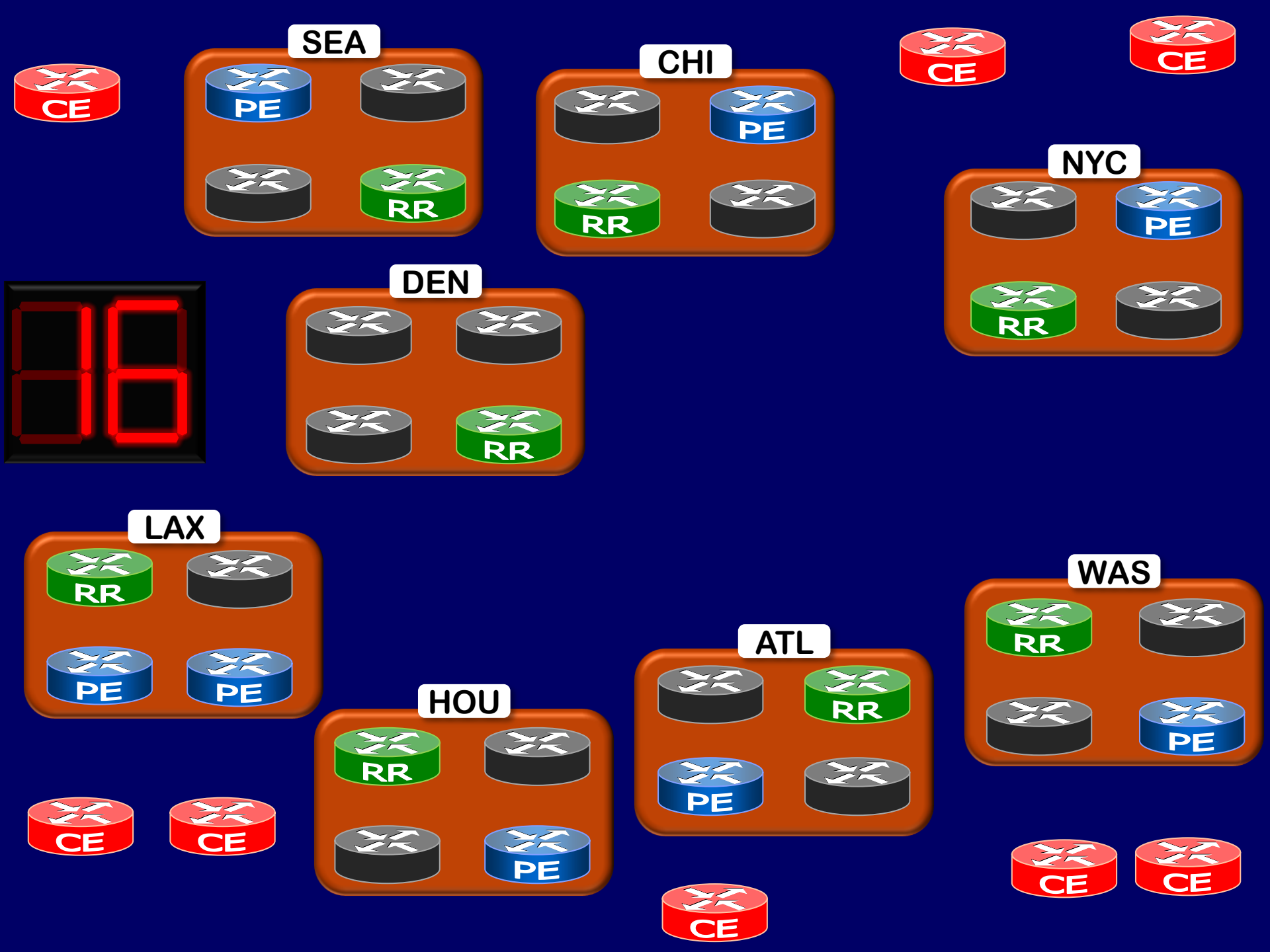
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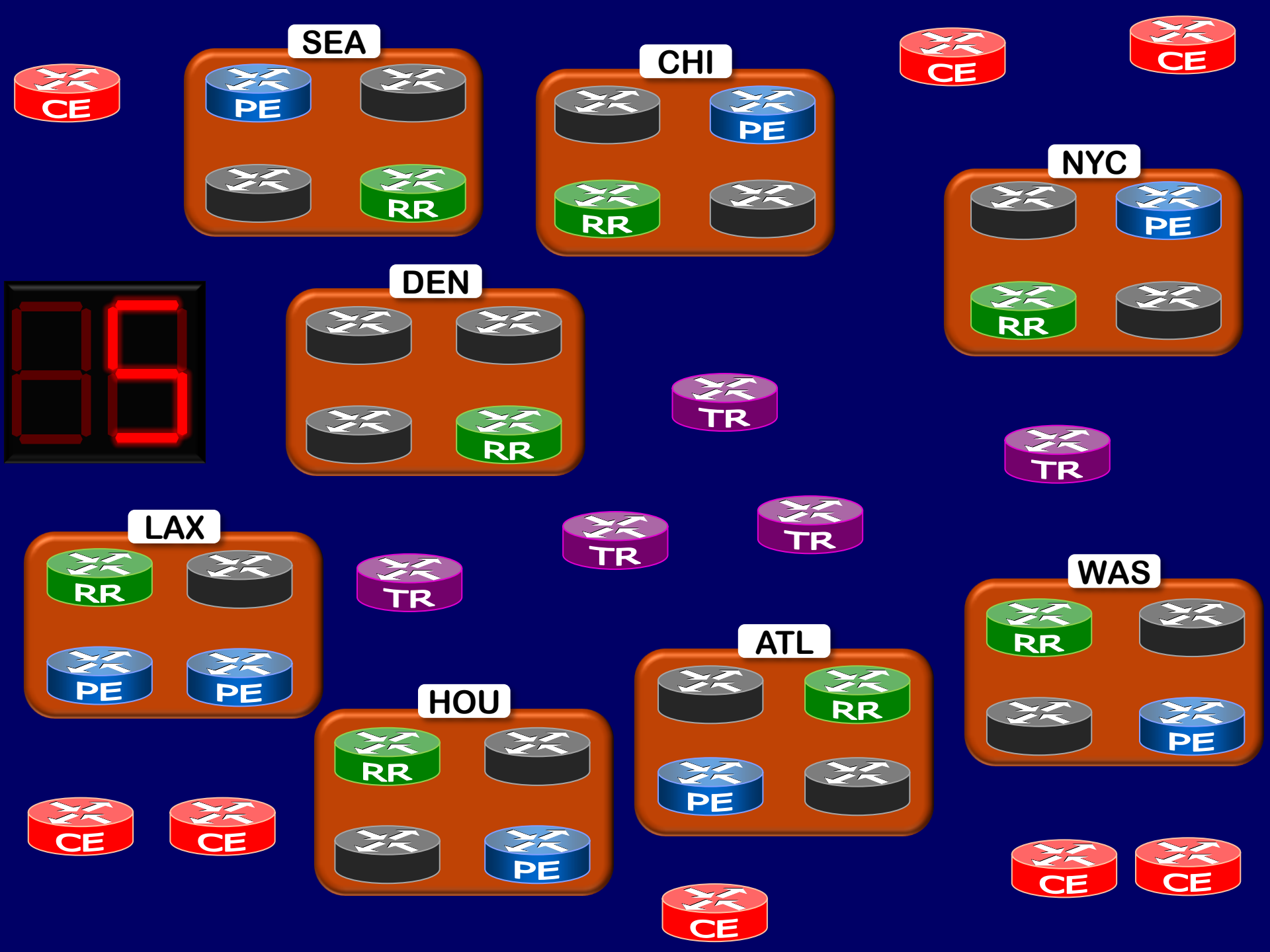
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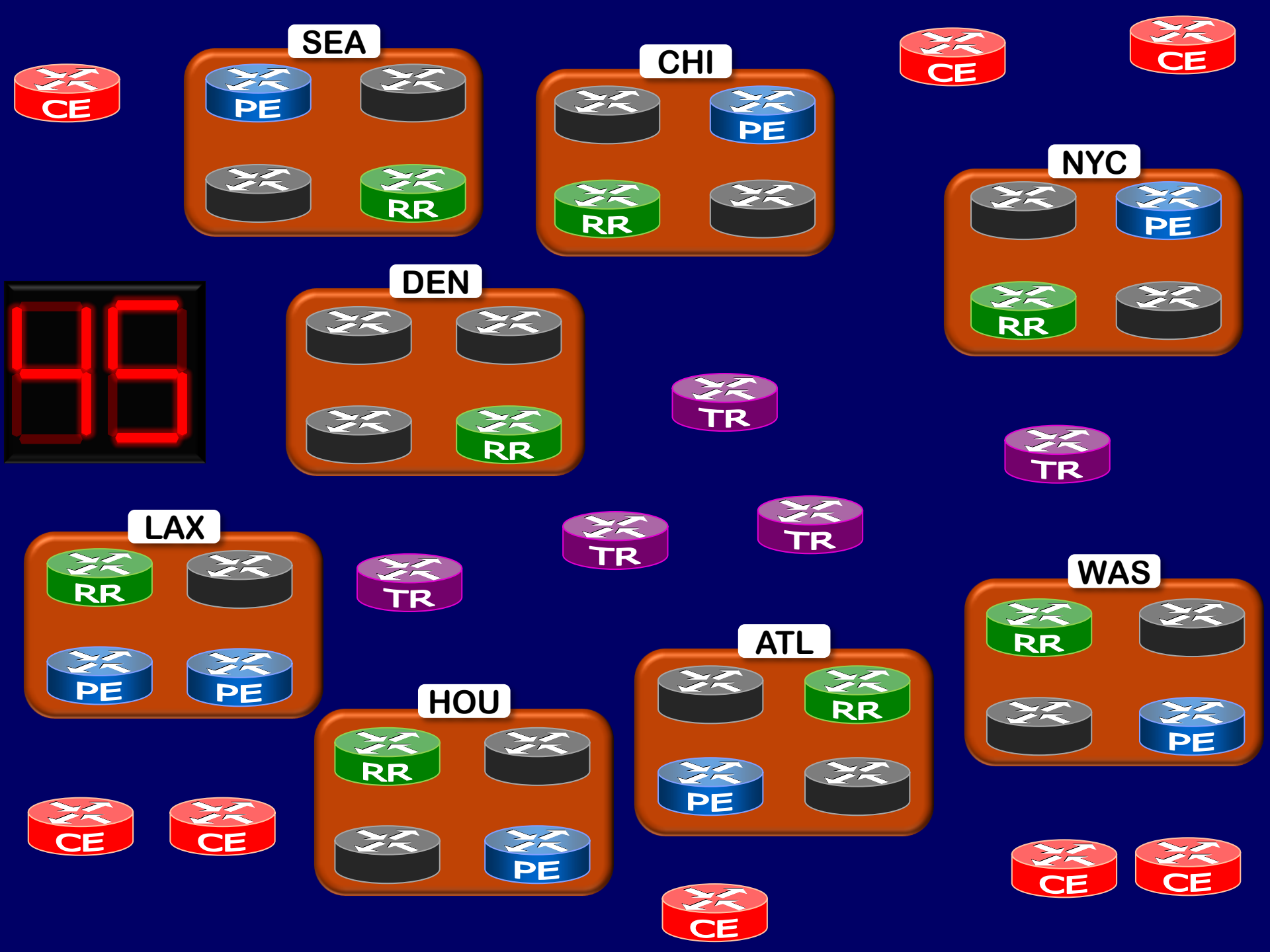
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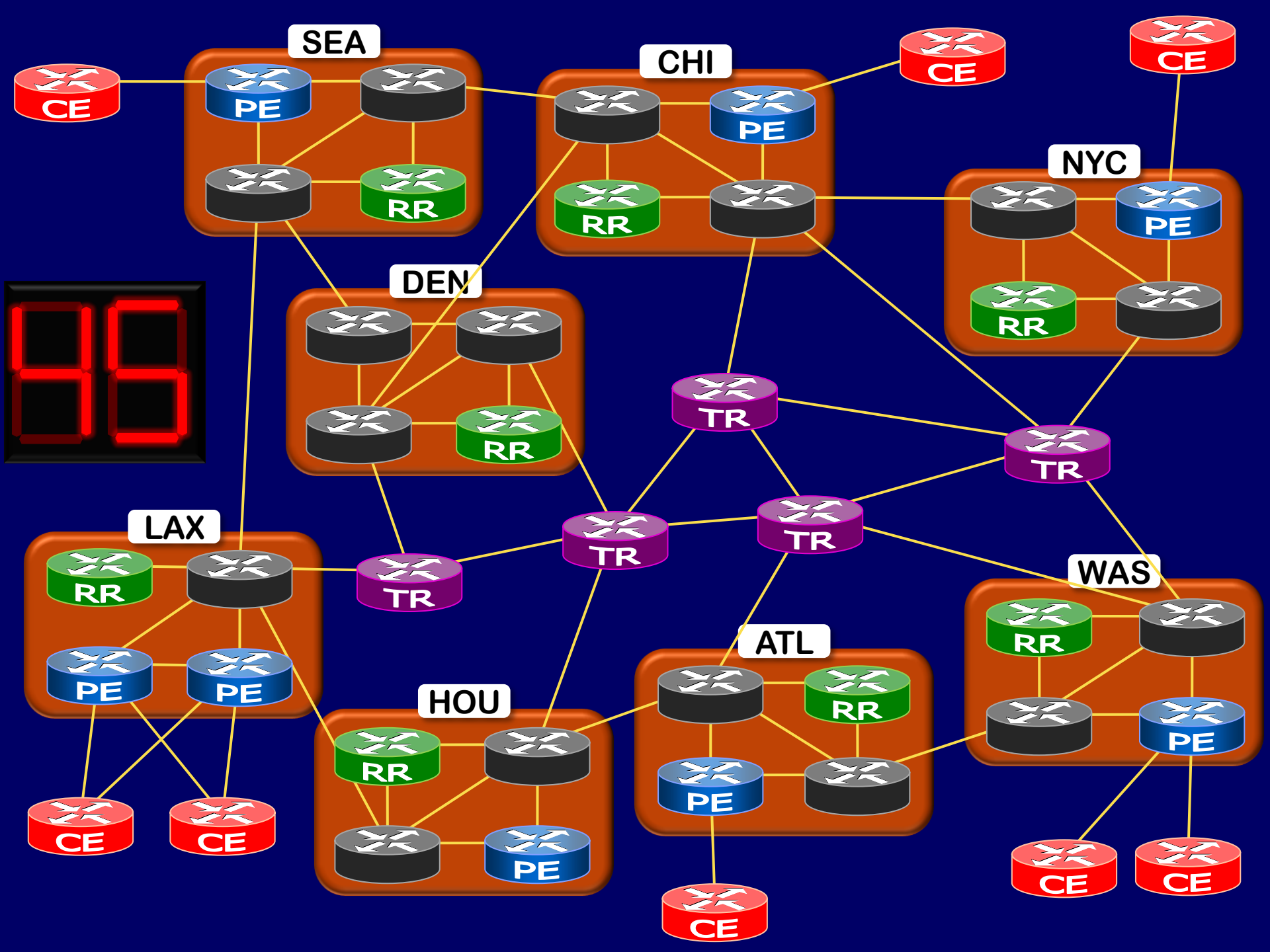
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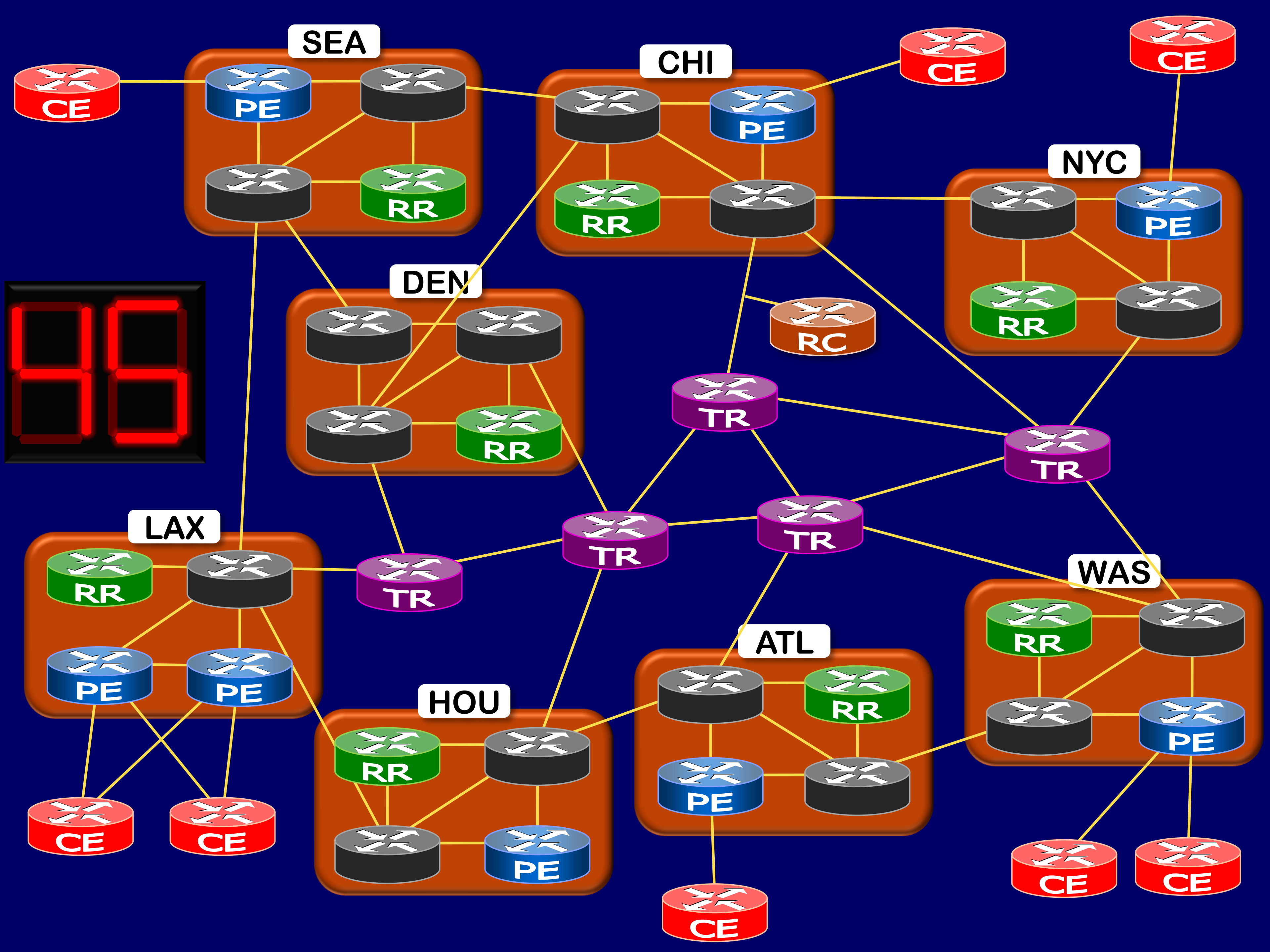
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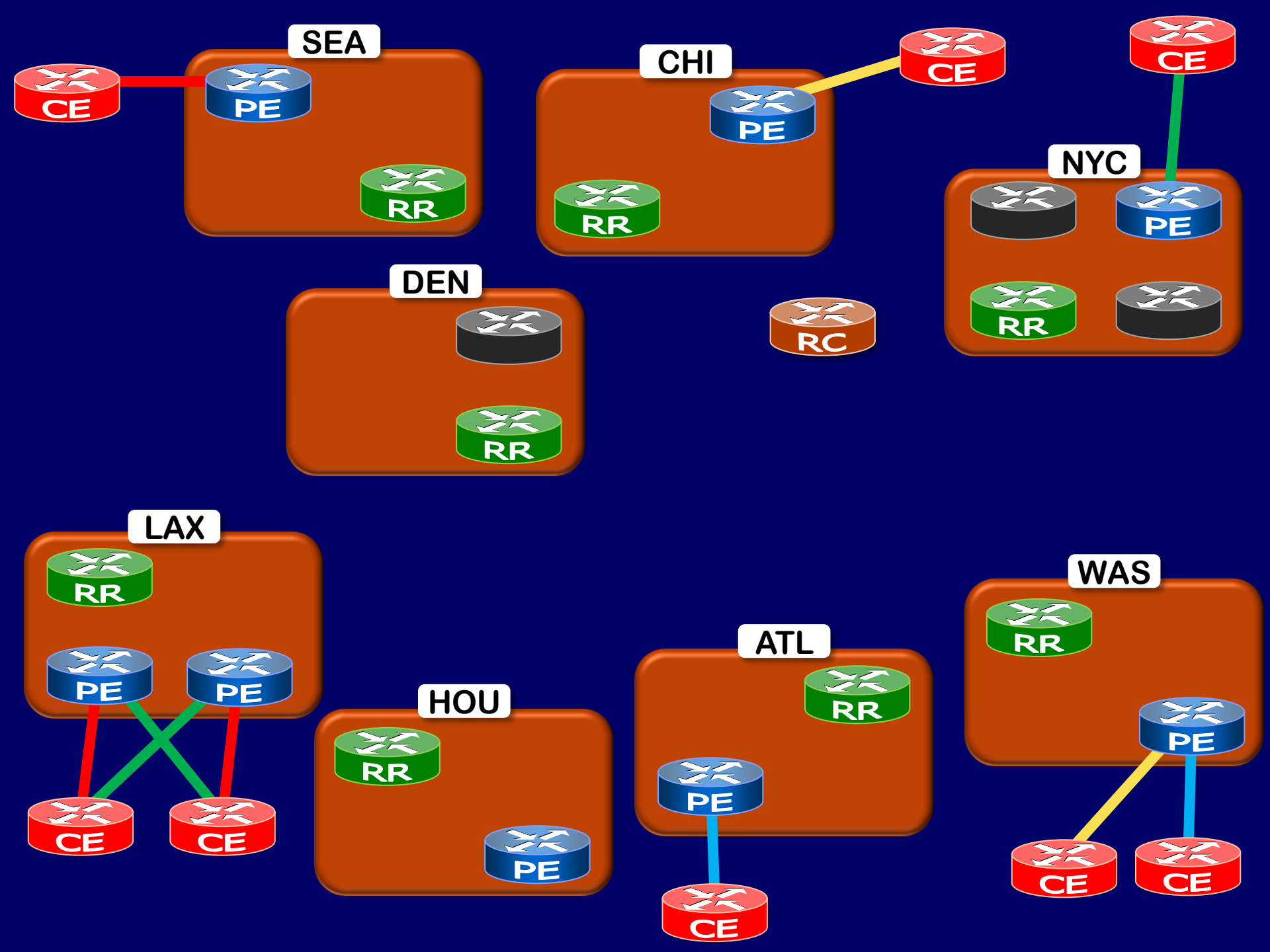
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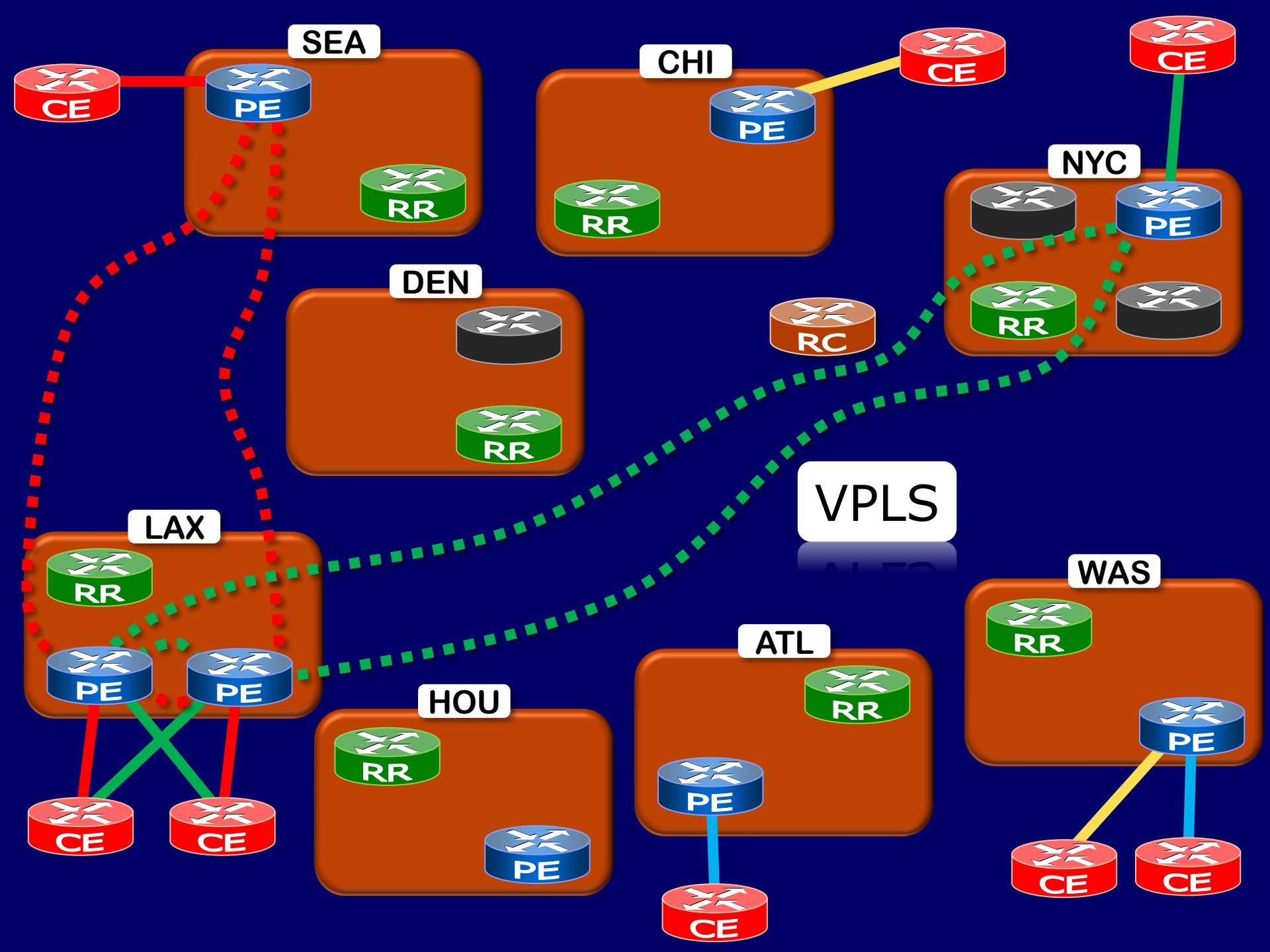
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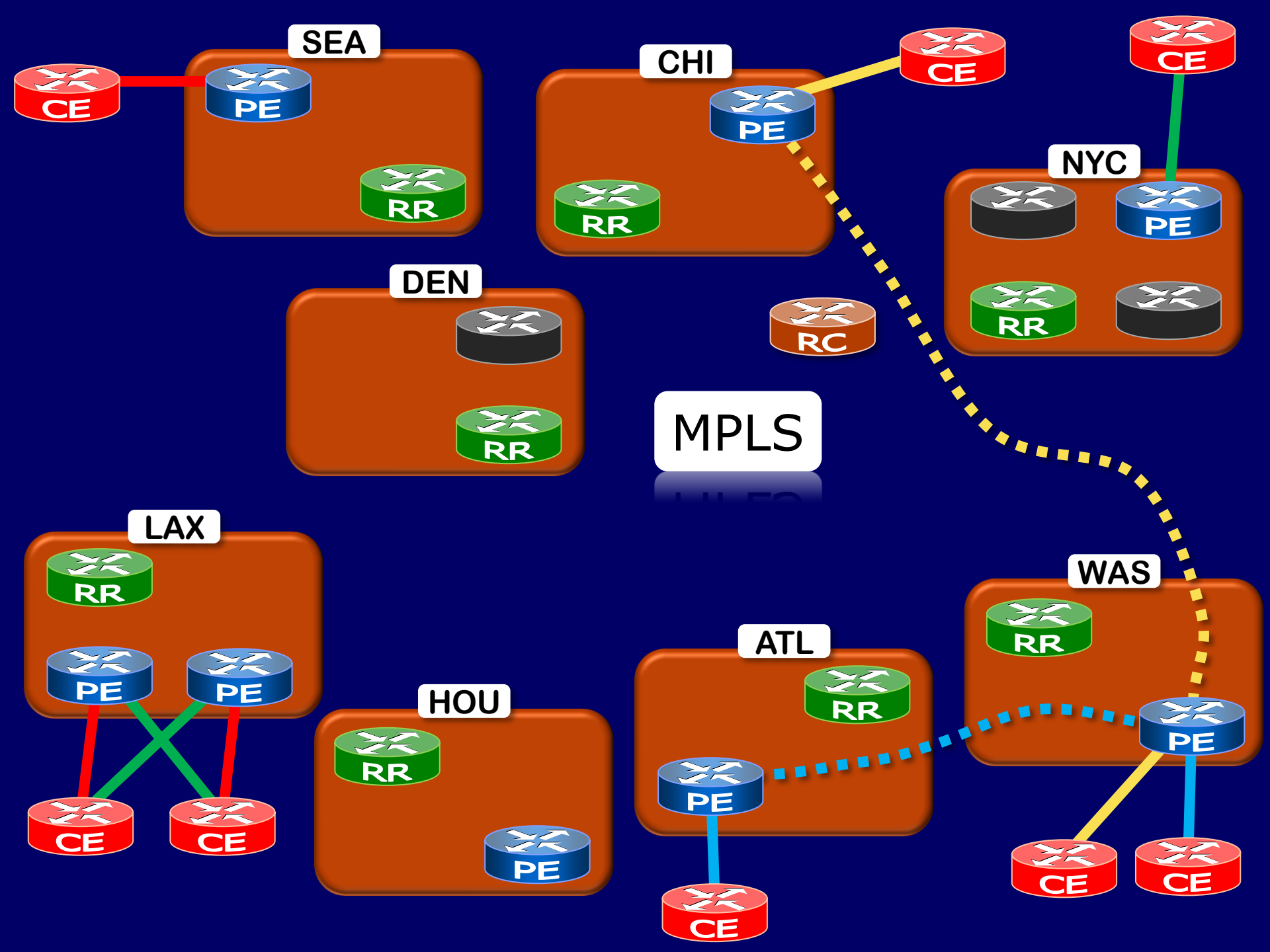
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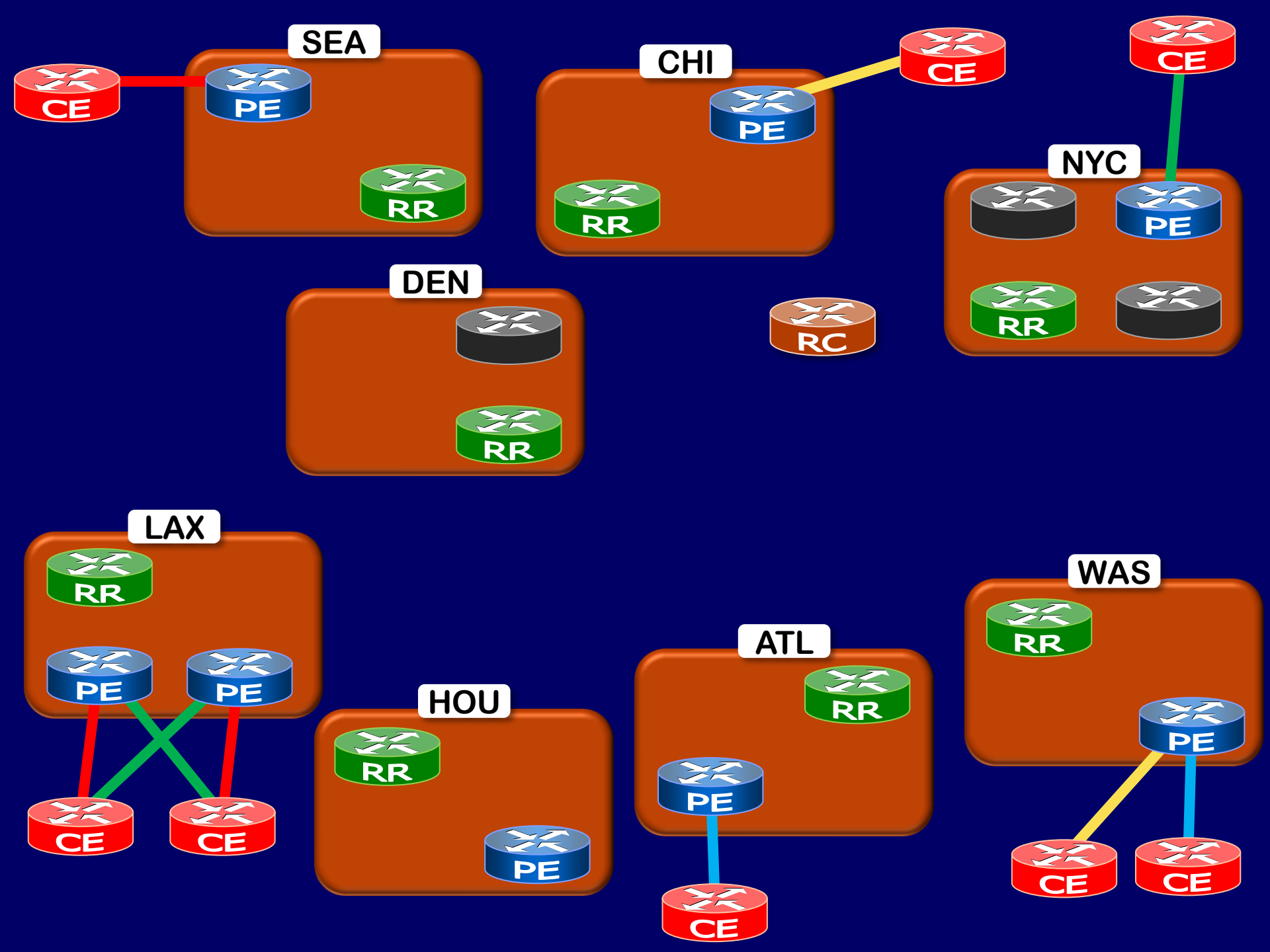
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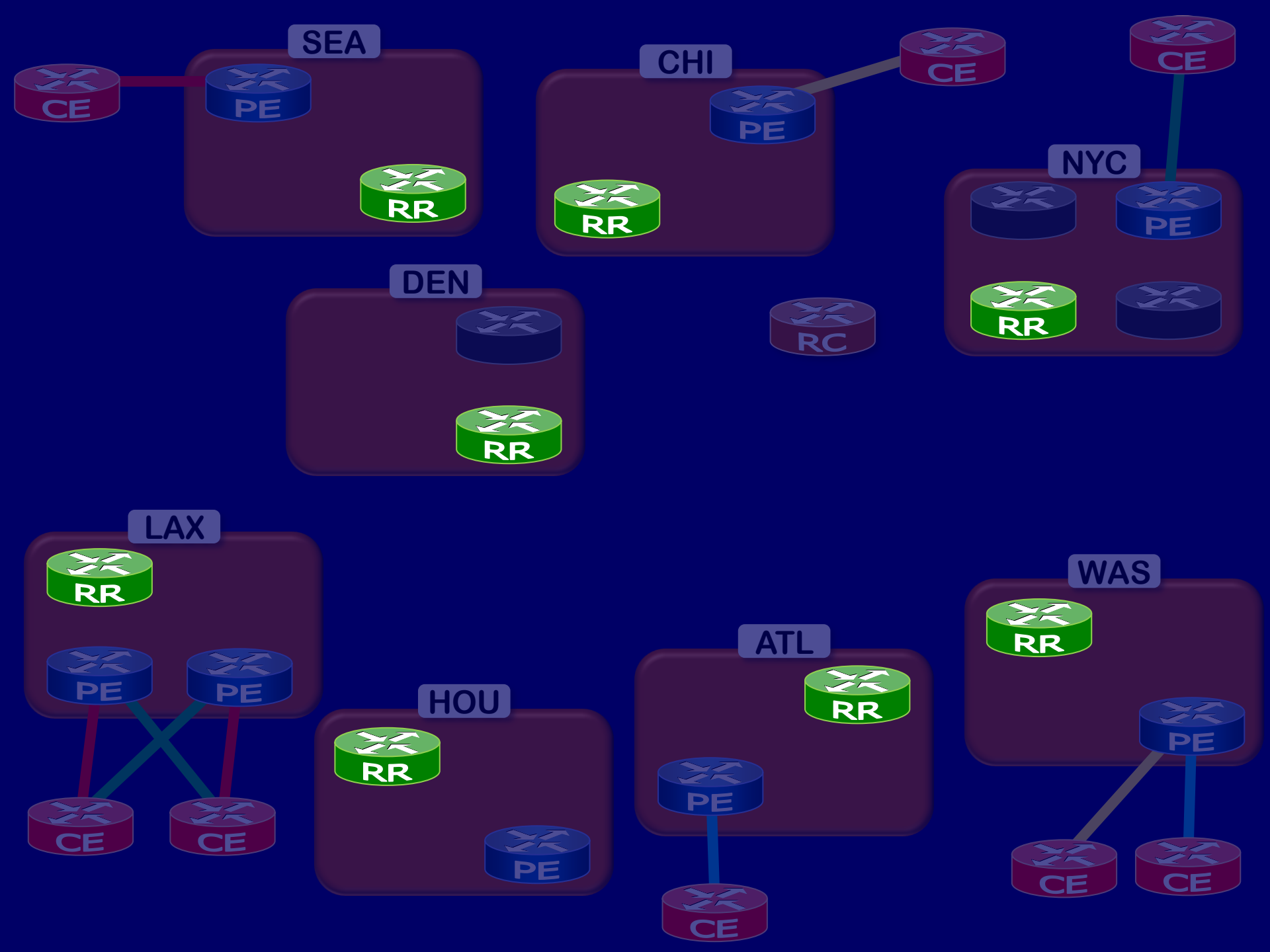
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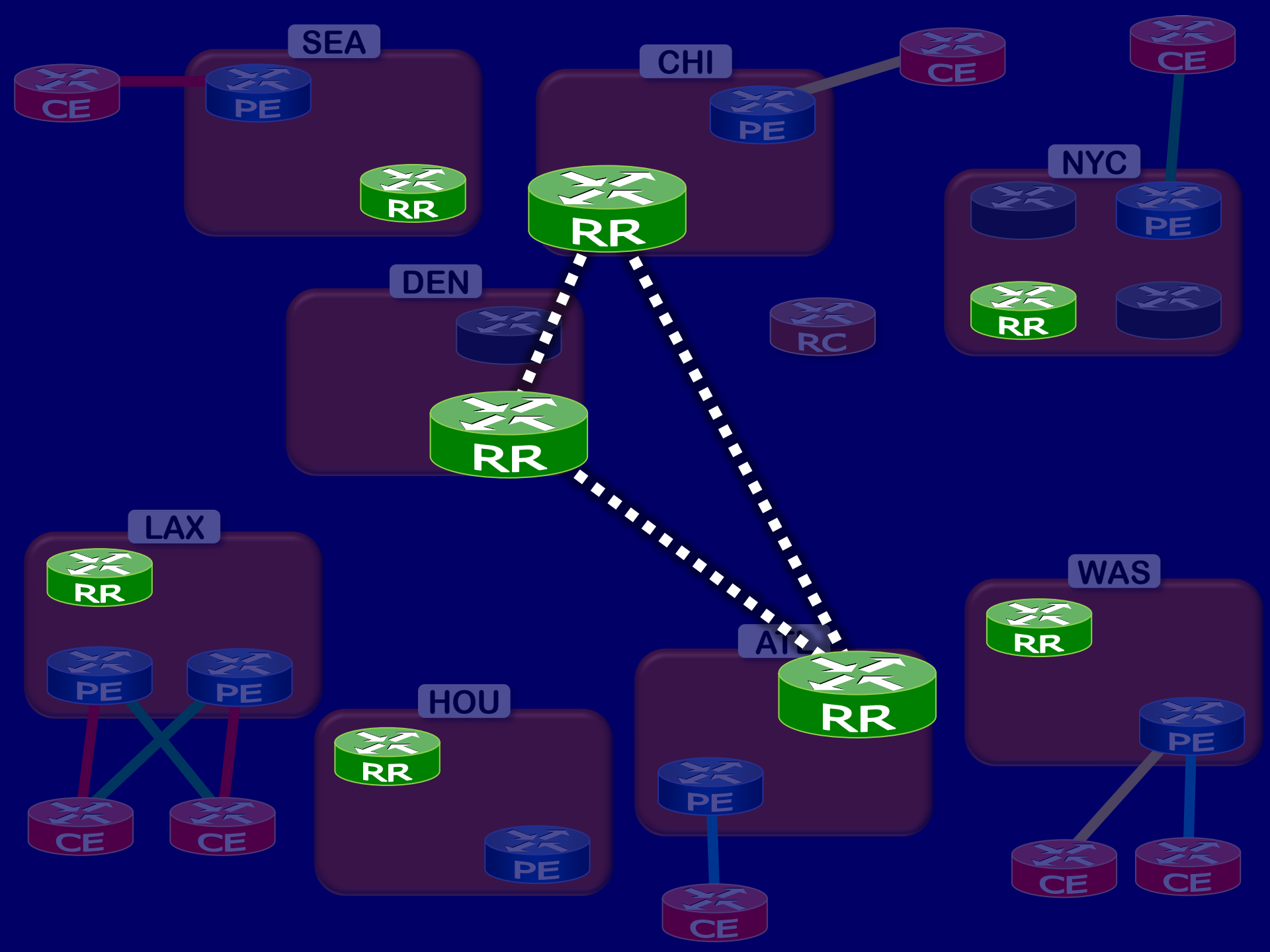
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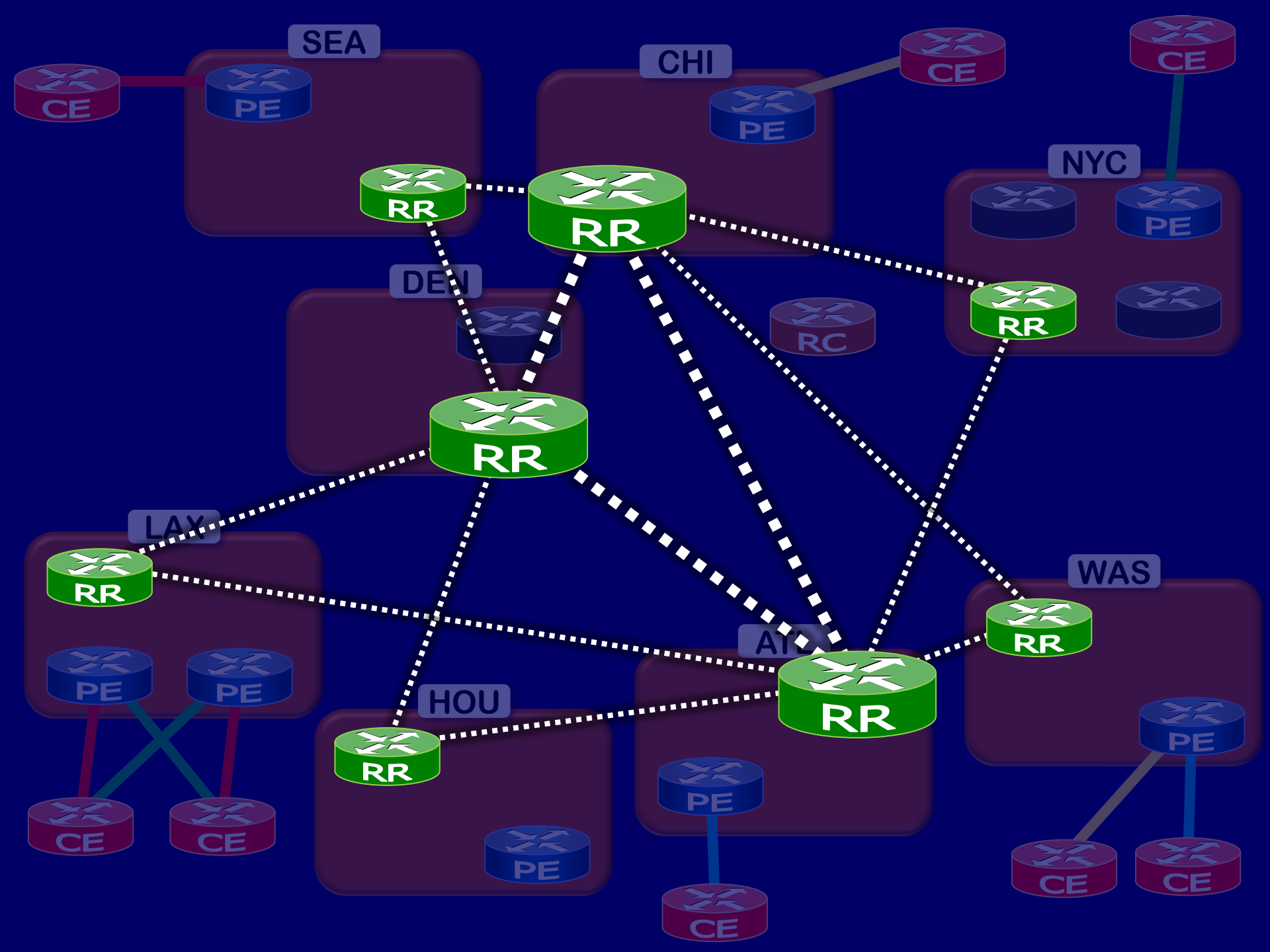
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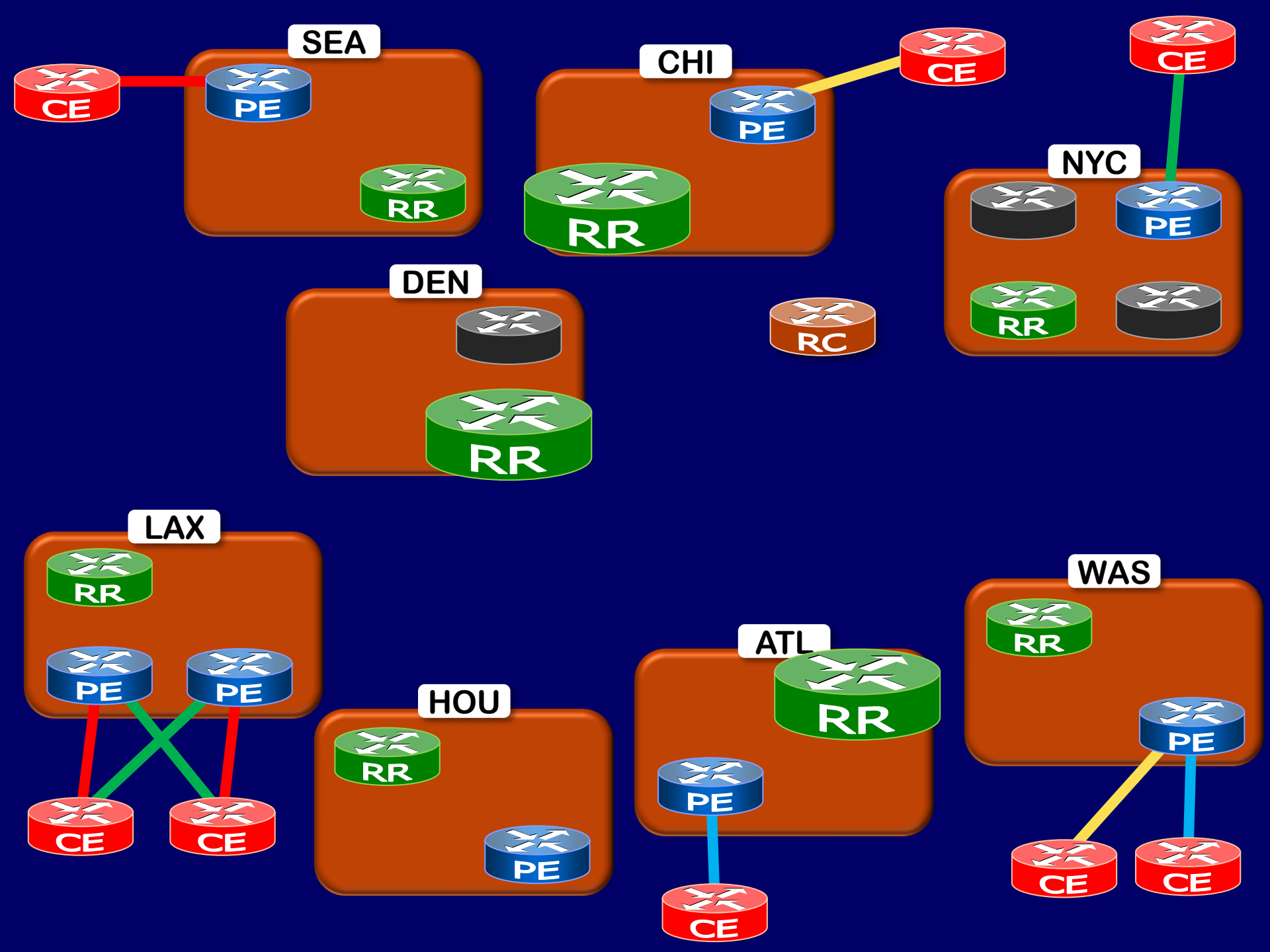
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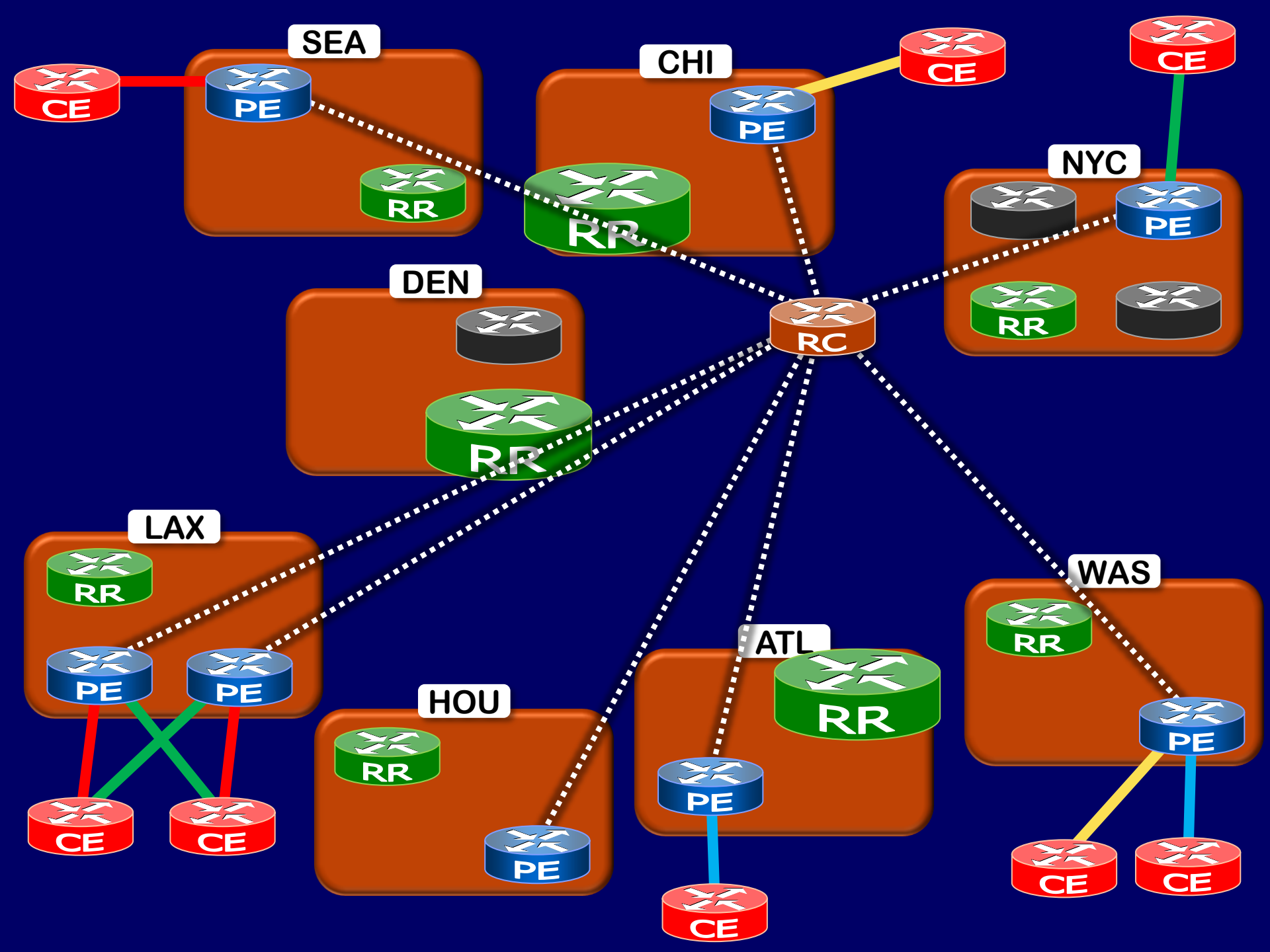
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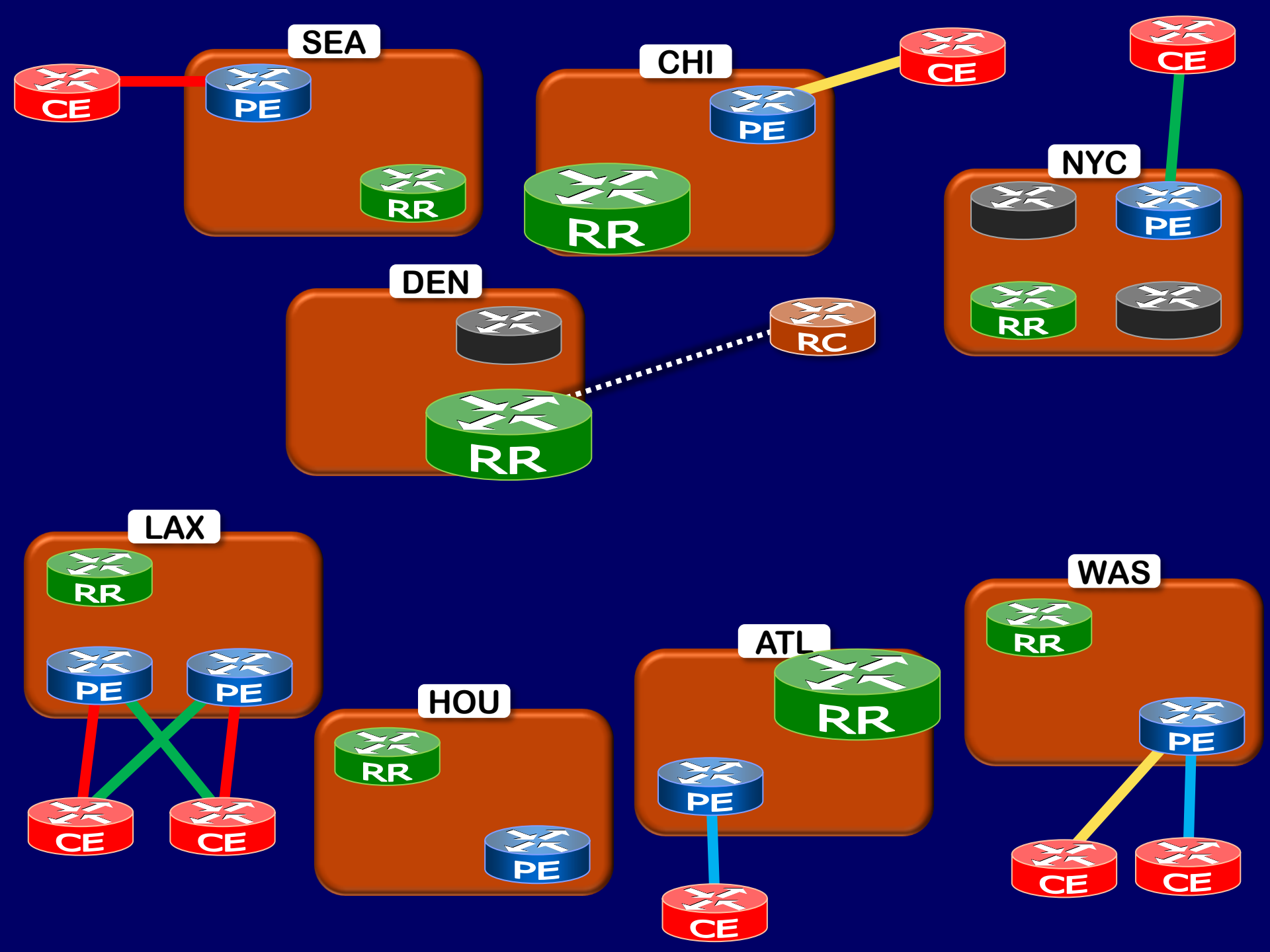
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Experiments

- Injected events:
  - (De+re)activation of customer sites
  - RT change
  - (De+re)activation of multihoming
  - Local preference change in a multihoming configuration

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  - (De+re)activation of customer sites
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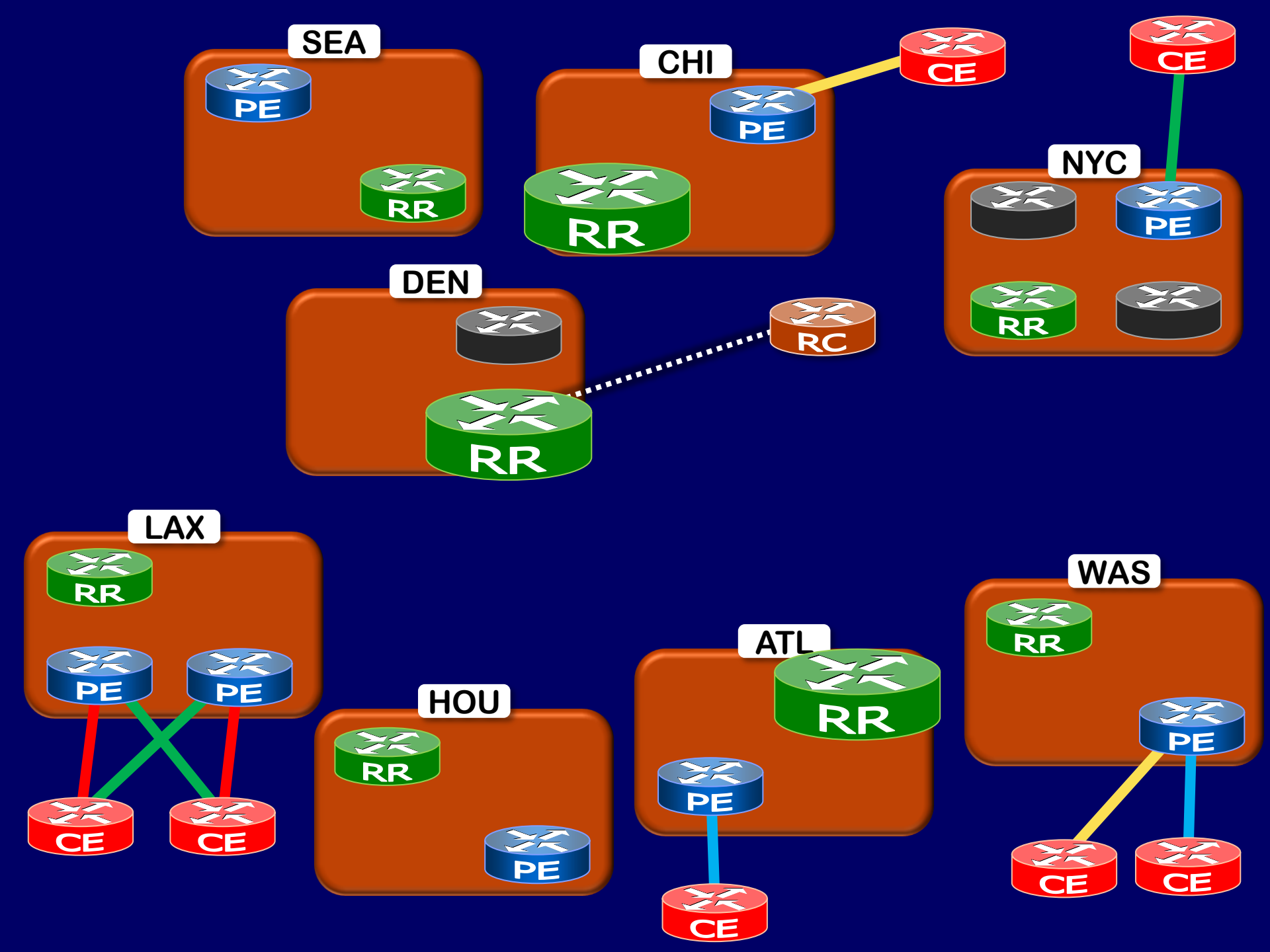
- Timing
  - Random order
  - Varying rate ([1/hr...100/min])

Experiments

- Injected events:
  - (De+re)activation of customer sites
  - RT change
  - (De+re)activation of multihoming
  - Local preference change in a multihoming configuration
- Timing
  - Random order
  - Varying rate ([1/hr...100/min])
- > 150,000 collected BGP updates
  - Processing time: < 20s, without optimizations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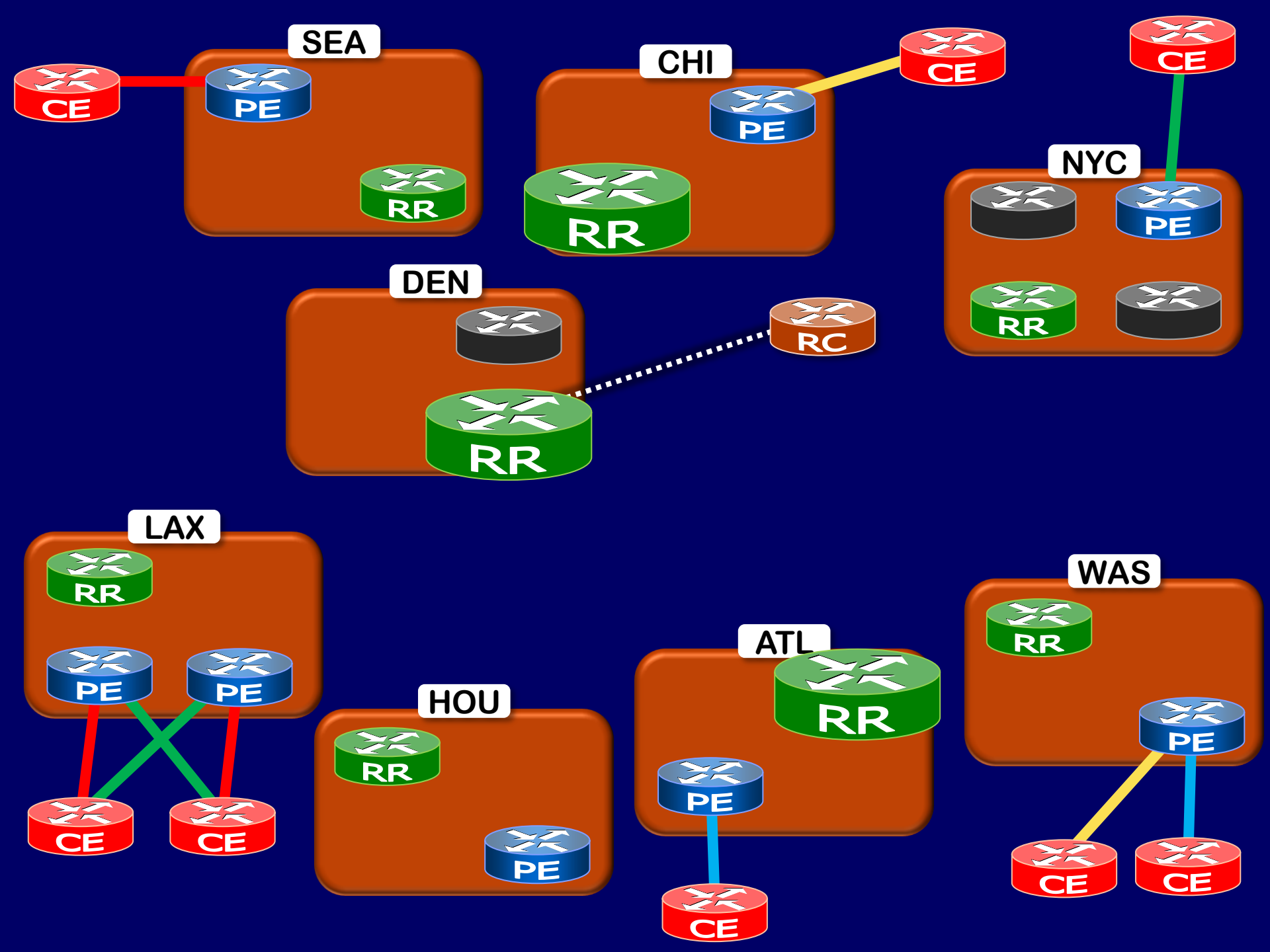
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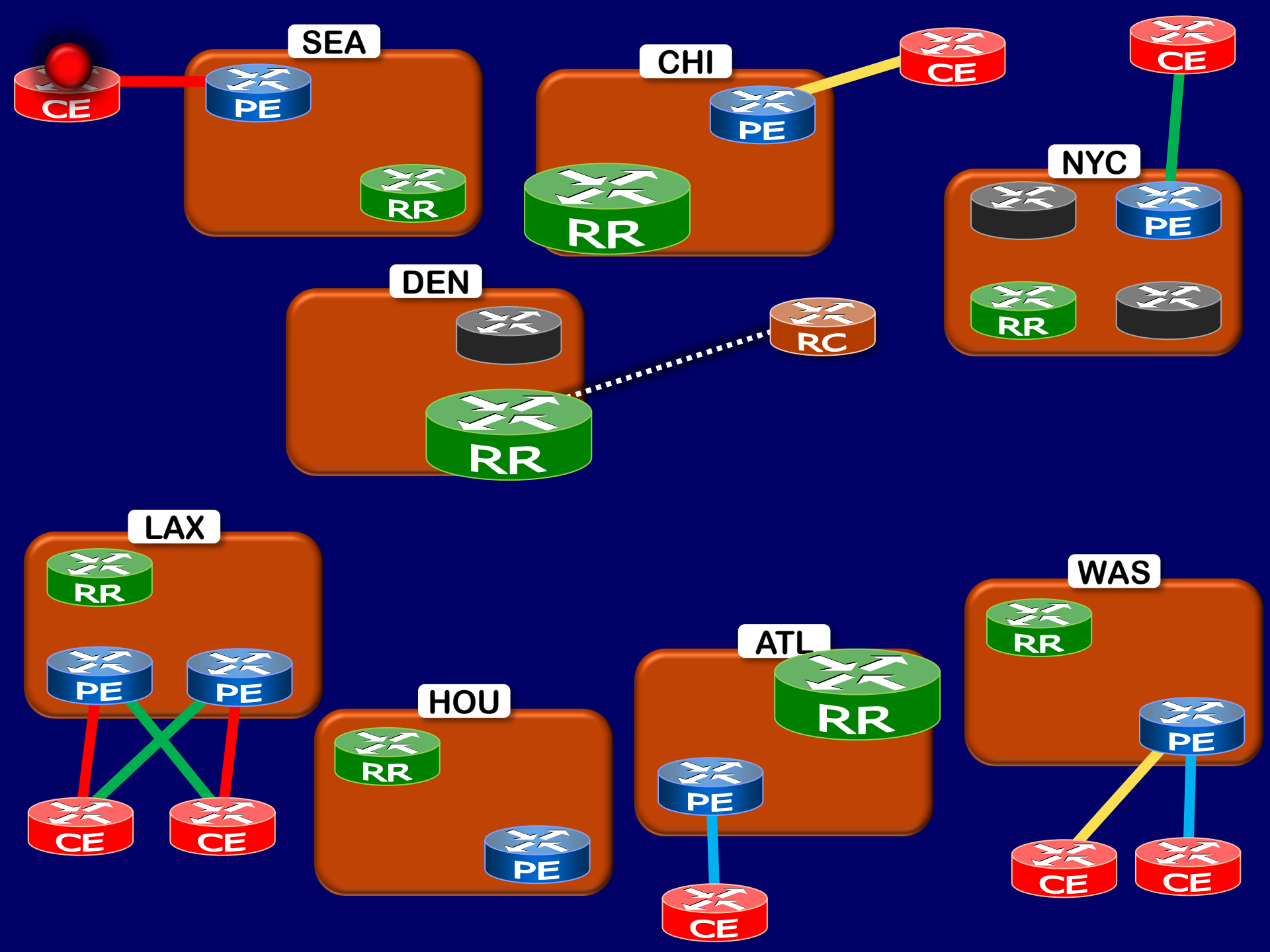
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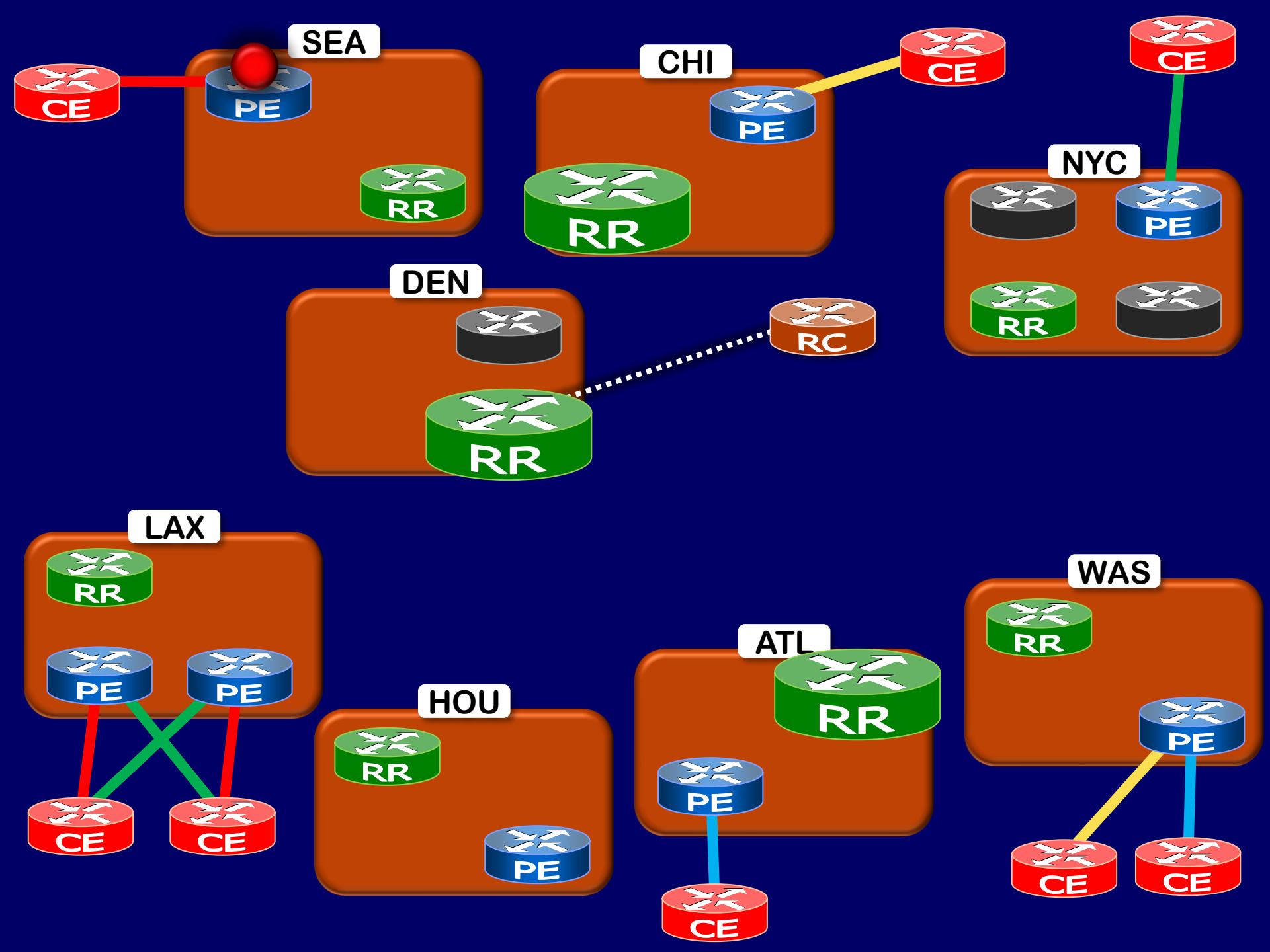
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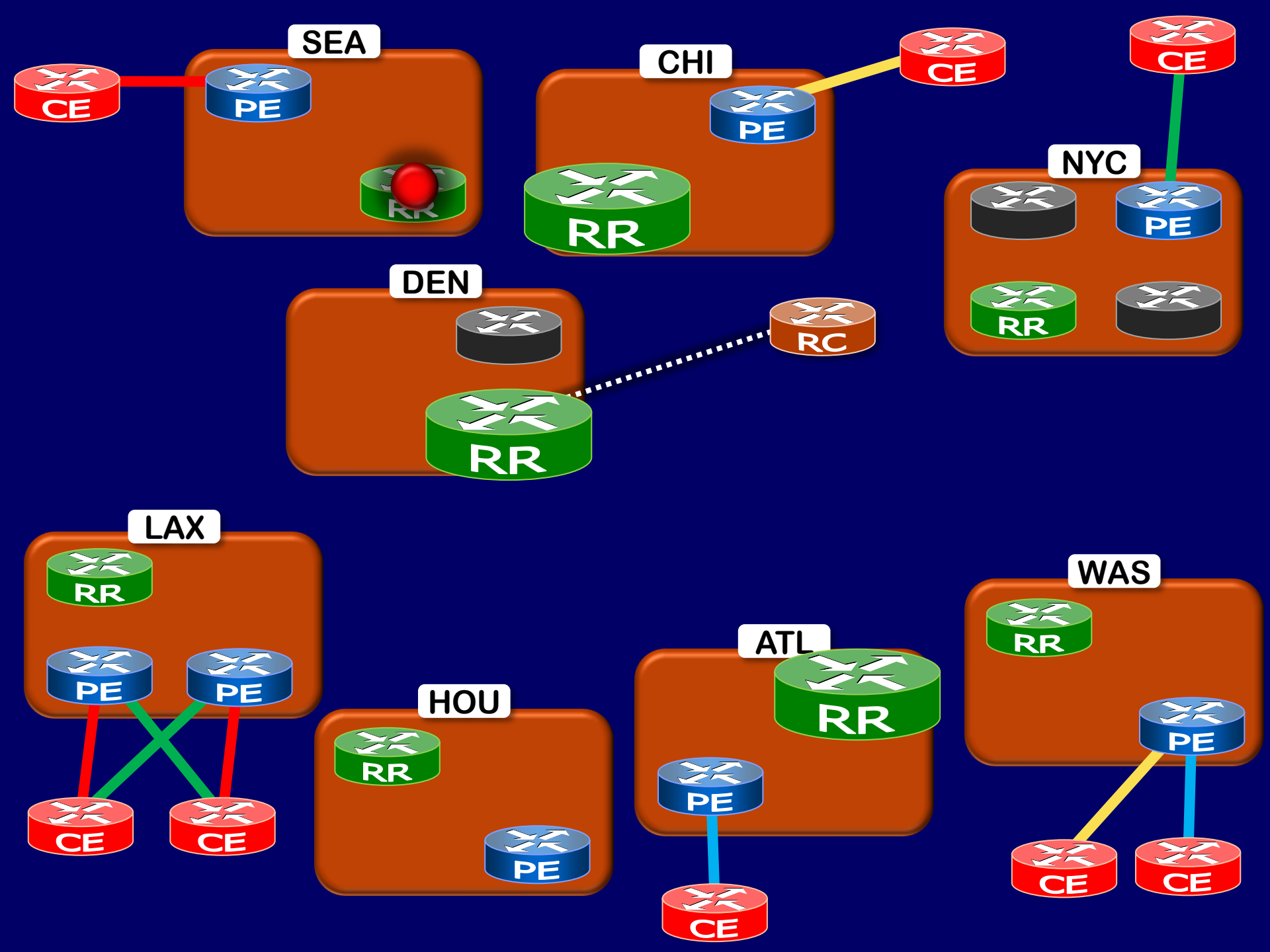
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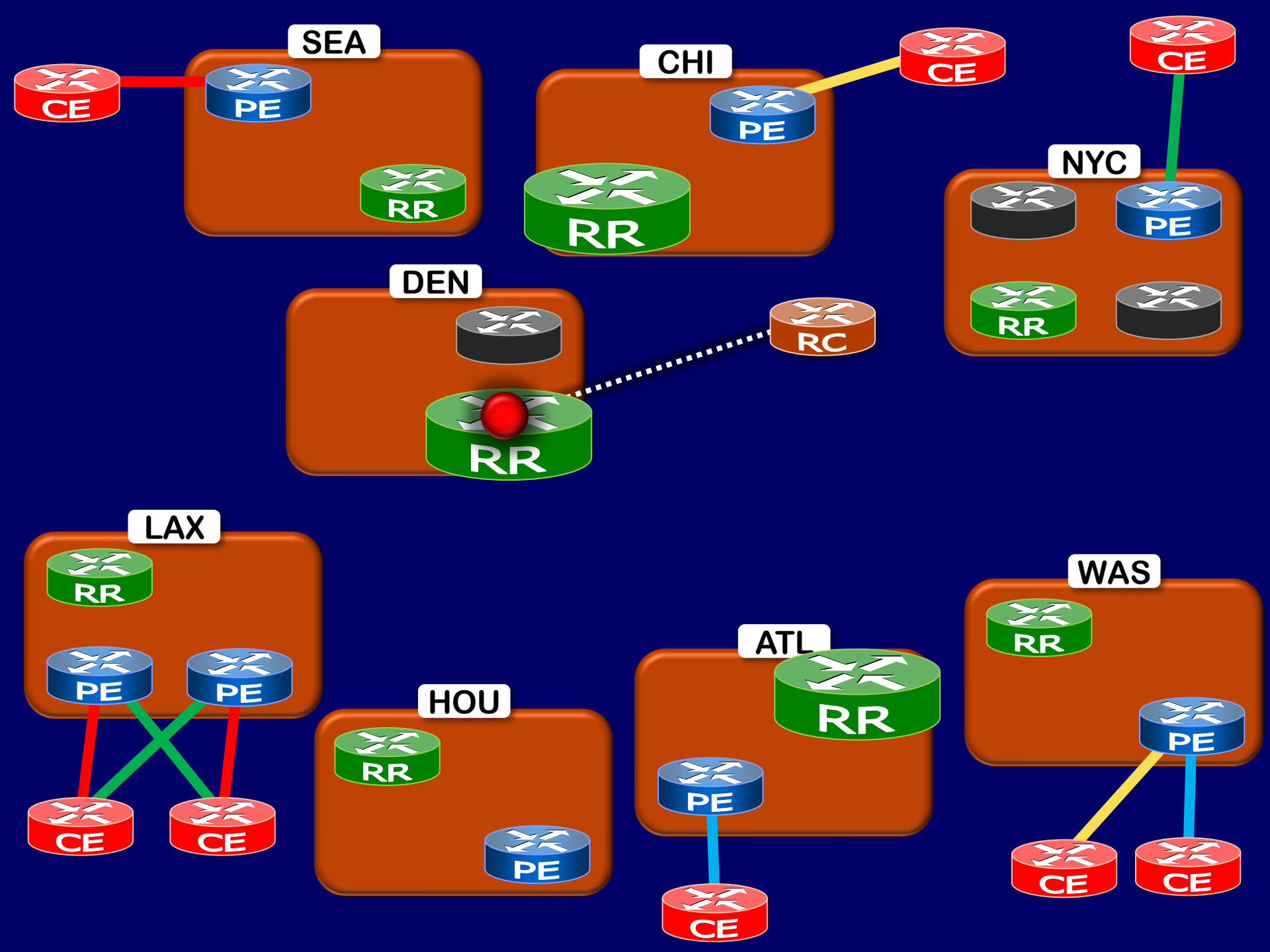
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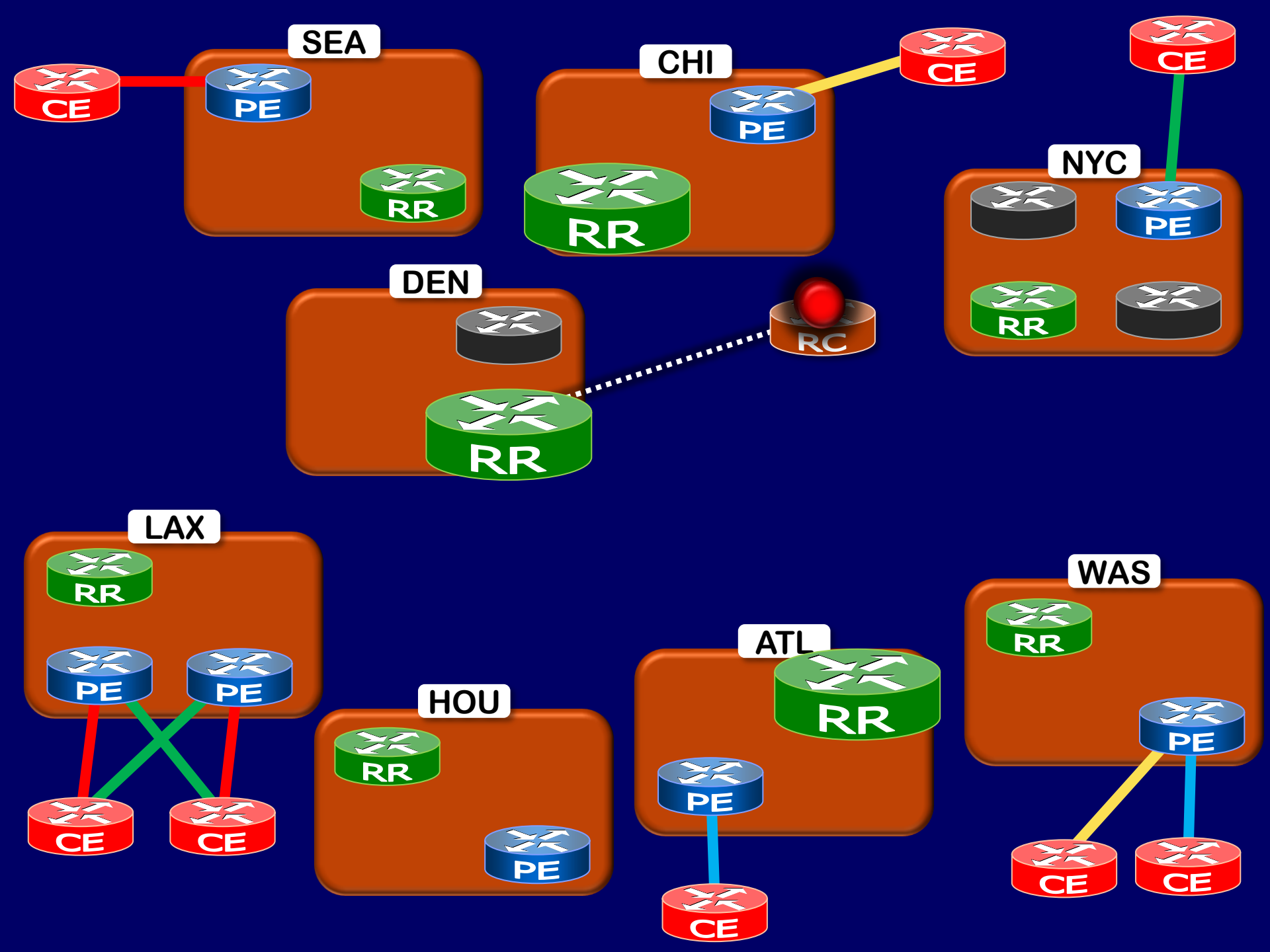
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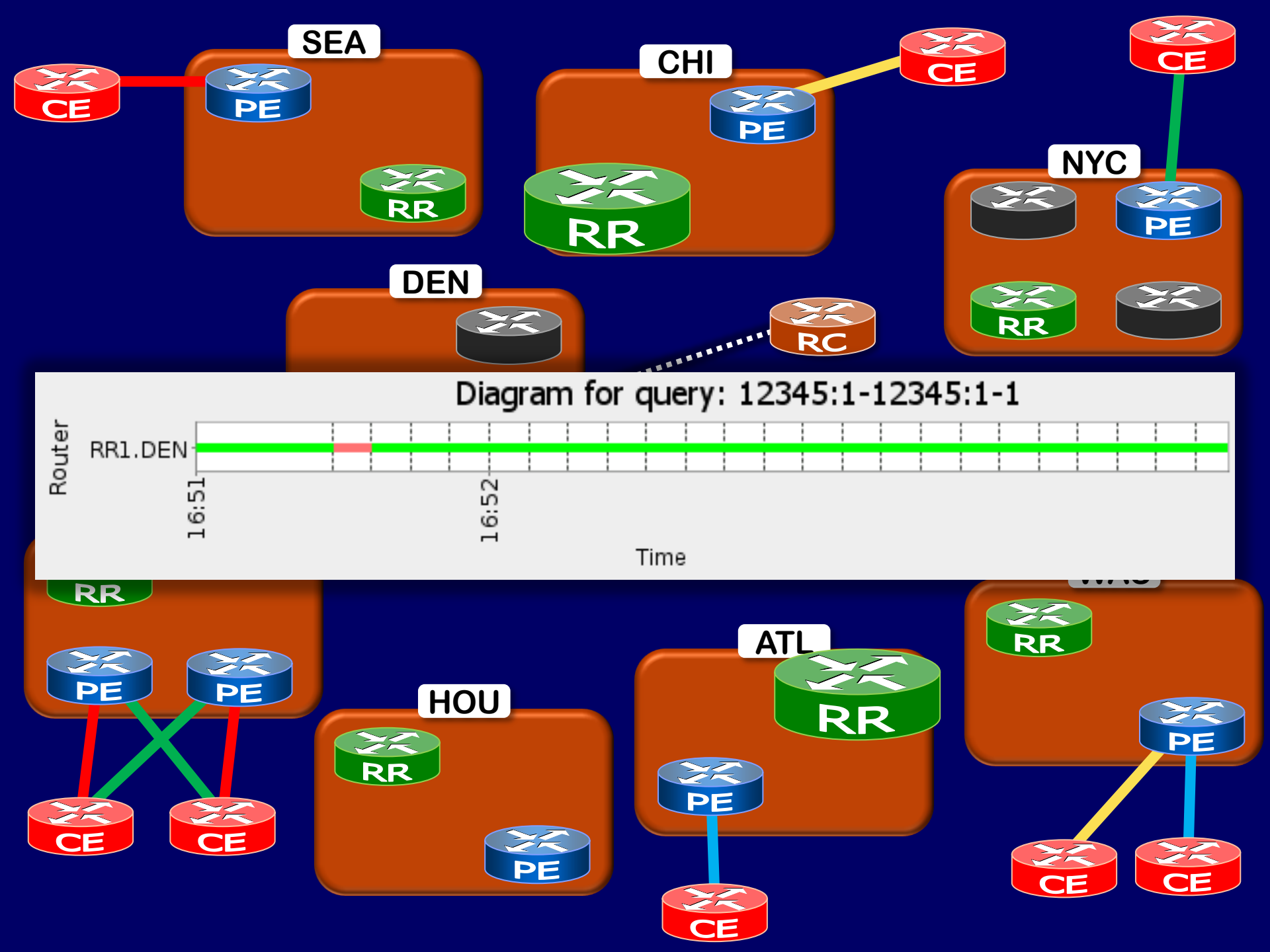
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Diagram for query: 12345:1-12345:1-1
Router
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16:52
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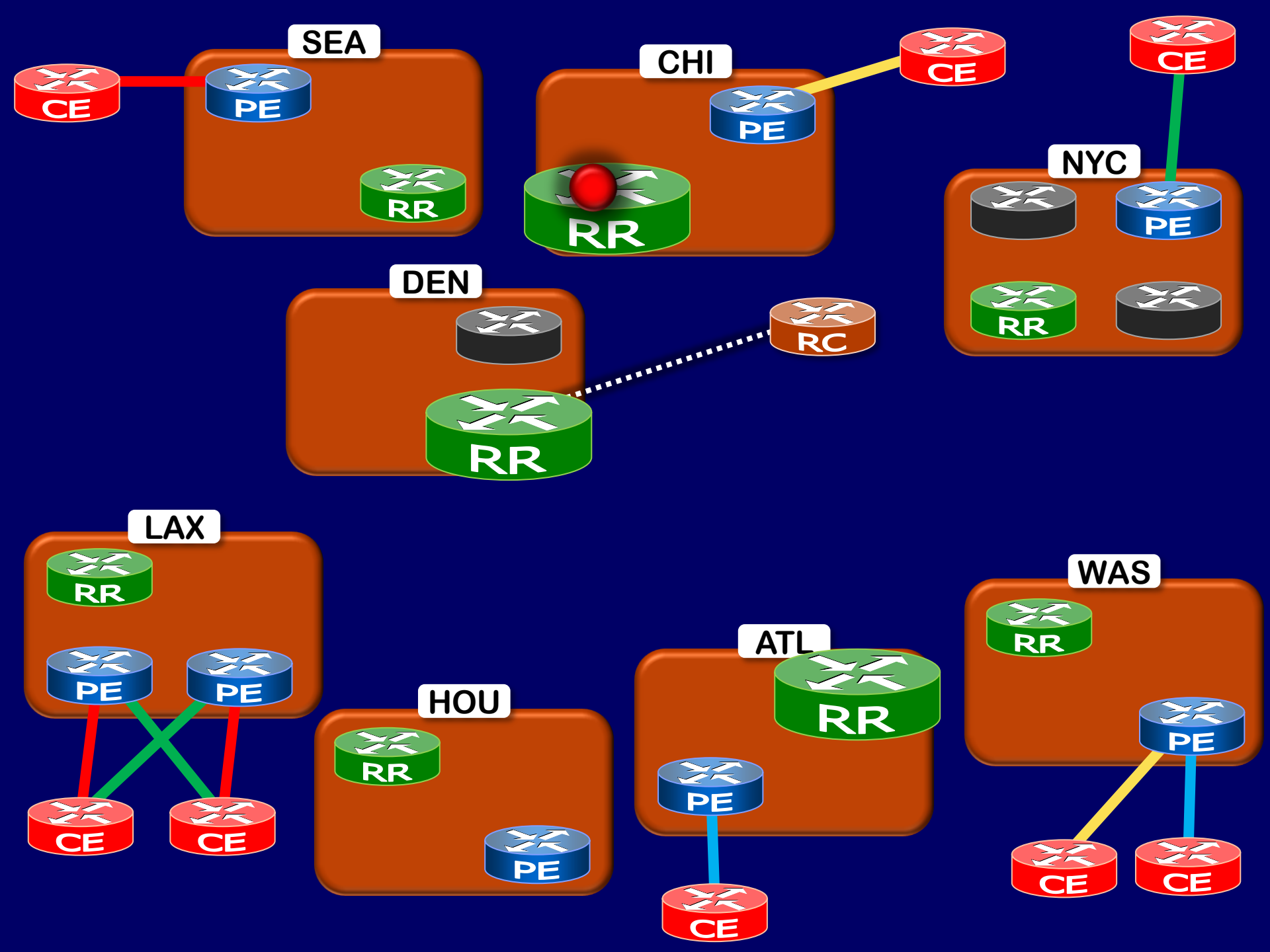
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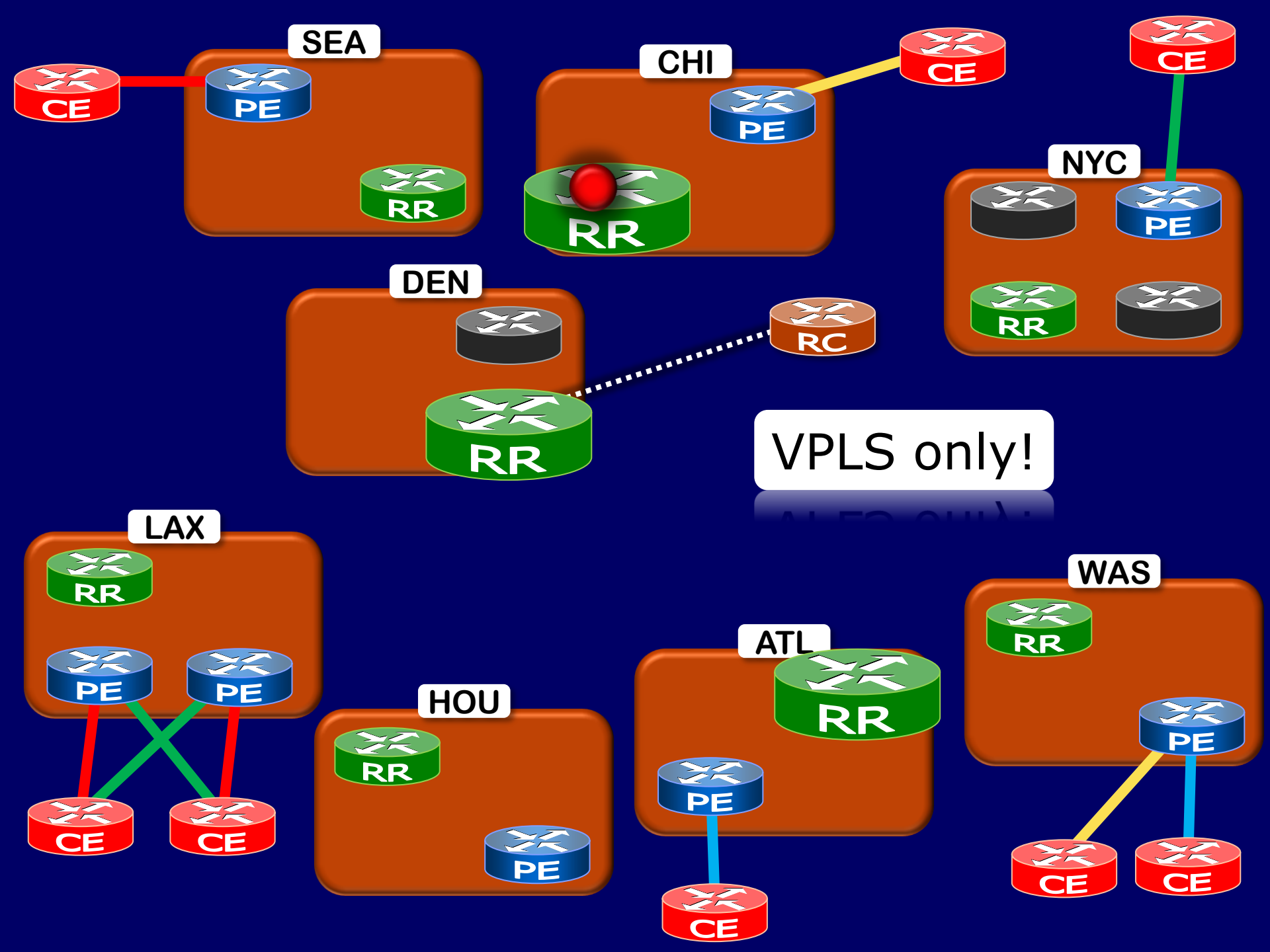
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VPLS only!
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The Oscillation Problem

- Did not affect forwarding

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- Investigation with Juniper

The Oscillation Problem

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- Best route selection in VPLS only considered
  - VPLS control flags
  - site preference
  - PE router ID

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- DISAGREE [Griffin et al. 02]

[Griffin et al. 02] T. Griffin, F. B. Shepherd, and G. Wilfong, "The stable paths problem and interdomain routing," IEEE/ACM Transactions on Networking, vol. 10, no. 2, pp. 232–243, 2002.

The Oscillation Problem

- Did not affect forwarding
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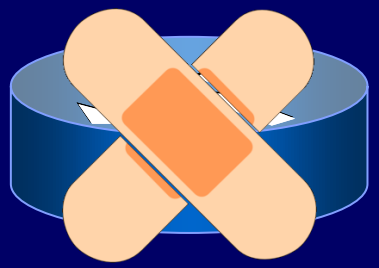
  - site preference
  - PE router ID
  - ties were broken on most recent announcement (could carry updated labels)
- DISAGREE [Griffin et al. 02]
- Fix (being) released



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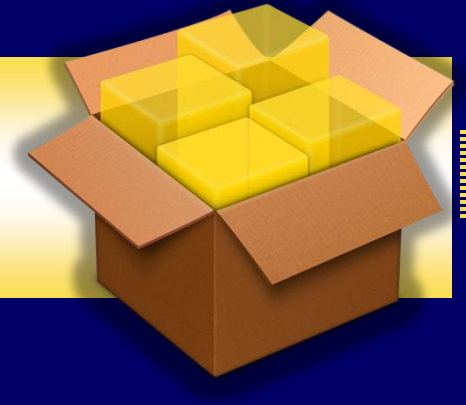
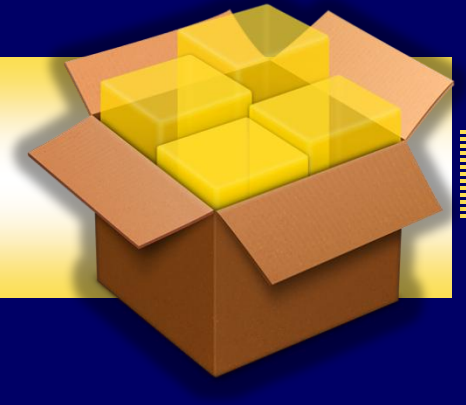
Wrapping Up

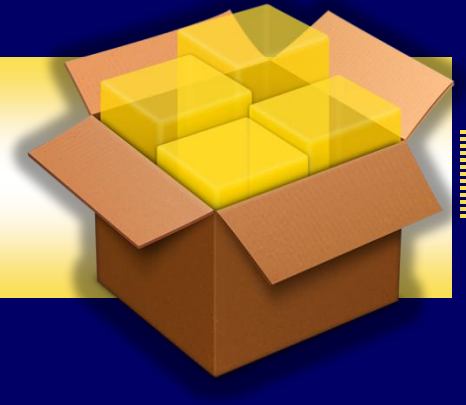


Wrapping Up



- A monitoring methodology

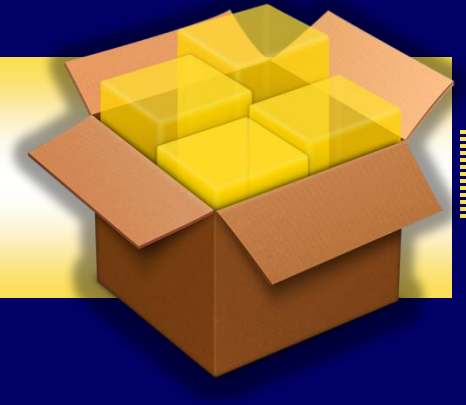
Wrapping Up



- A monitoring methodology

Effects

Wrapping Up



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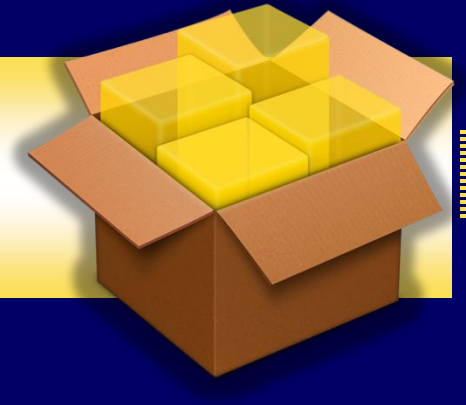
Effects

Signaling

Wrapping Up



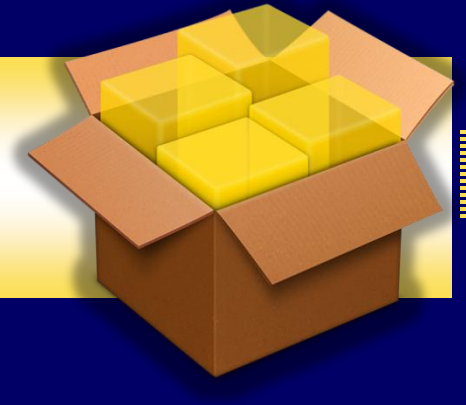
- A monitoring methodology

Effects

Signaling

MPLS+VPLS

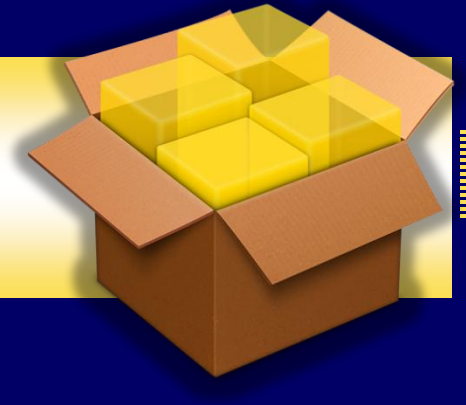
Wrapping Up



- A monitoring methodology

Effects | Signaling | MPLS+VPLS | Visualization

Wrapping Up



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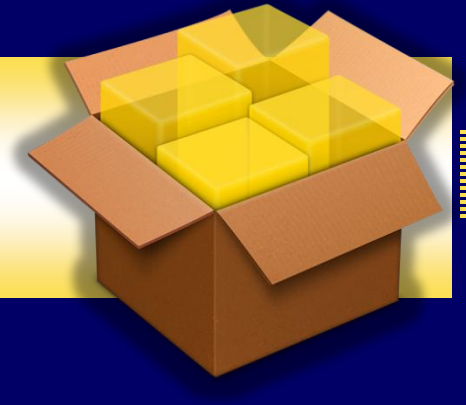
Operation

Wrapping Up



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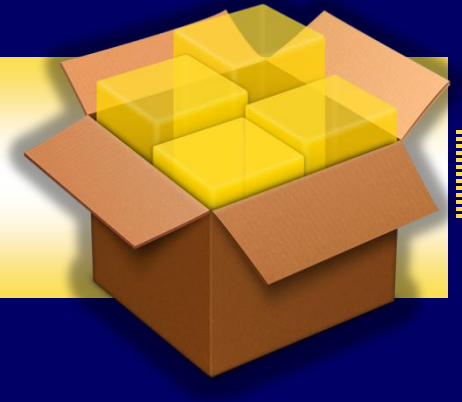
Effects | Signaling | MPLS+VPLS | Visualization

Operation → Reconfiguration

Wrapping Up

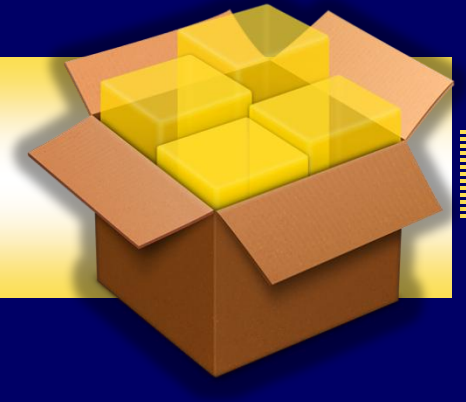


- A monitoring methodology

Effects | Signaling | MPLS+VPLS | Visualization

Operation → Reconfiguration → Troubleshooting

Wrapping Up



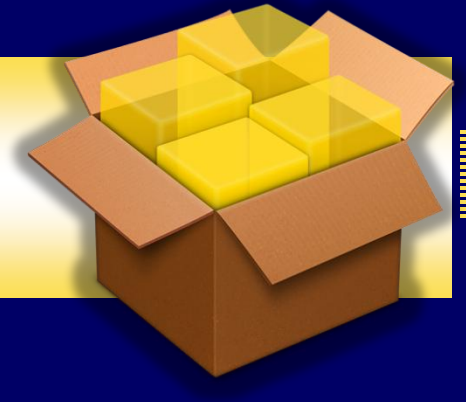
- A monitoring methodology

Effects | Signaling | MPLS+VPLS | Visualization

Operation → Reconfiguration → Troubleshooting

- Discussion on scalability vs visibility

Wrapping Up



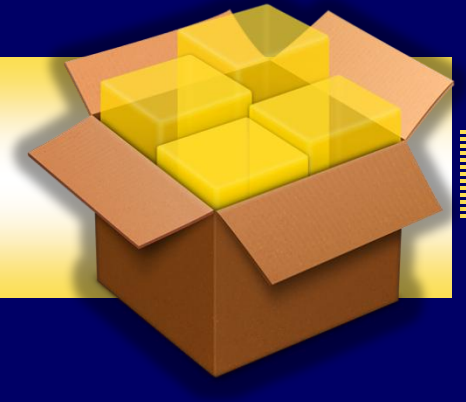
- A monitoring methodology

Effects | Signaling | MPLS+VPLS | Visualization

Operation → Reconfiguration → Troubleshooting

- Discussion on scalability vs visibility
- Architecture & prototype implementation

Wrapping Up



- A monitoring methodology

Effects | Signaling | MPLS+VPLS | Visualization

Operation → Reconfiguration → Troubleshooting

- Discussion on scalability vs visibility
- Architecture & prototype implementation
- Experimentation revealing routing anomaly

Future Work/Open Problems

- Monitor other protocols/kinds of information
- Collect non-best routes
- Improve the visualization
- Trigger alarms
- Improve inference of event causes

Acknowledgments to

Thank you