Cloud Networking

Network Virtualization

Case Study: VL2

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Key Needs

Agility

Location independent addressing

Performance uniformity

Security

Network semantics

Case Study

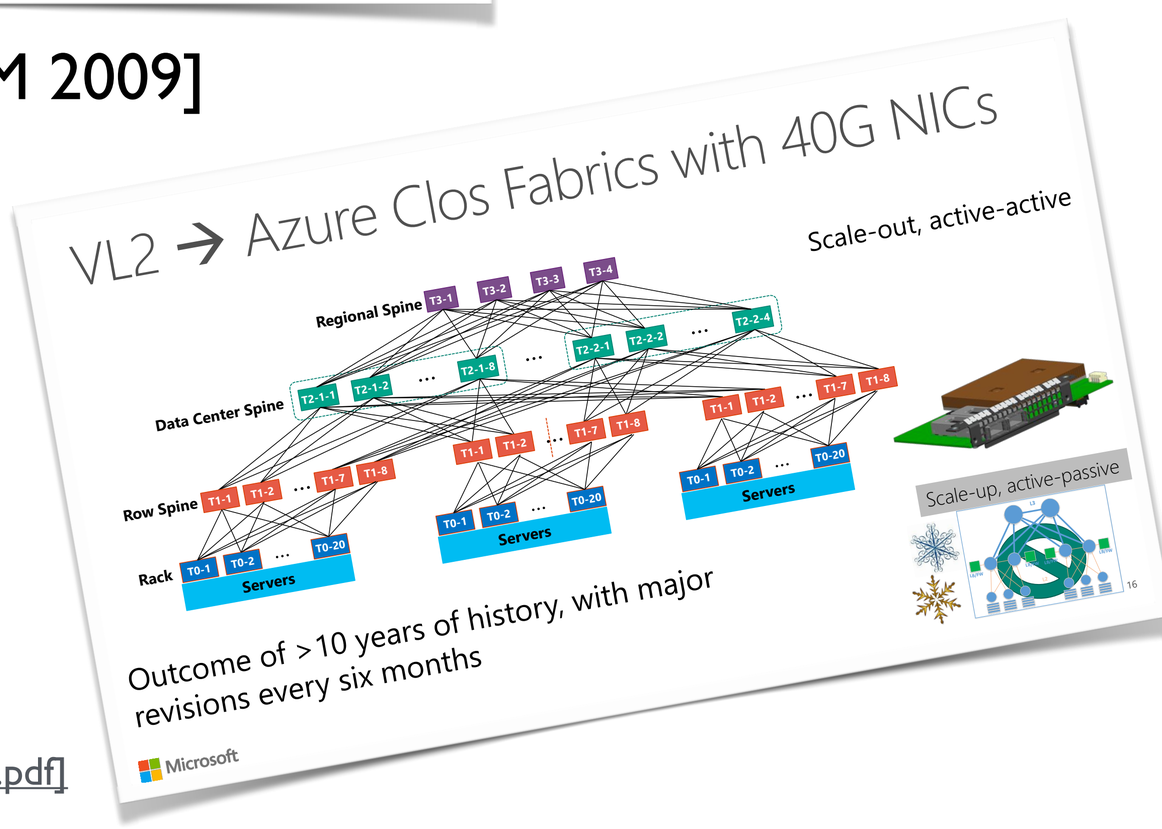
VL2: A Scalable and Flexible Data Center Network

Albert Greenberg, James R. Hamilton, Navendu Jain
Srikanth Kandula, Changhoon Kim, Parantap Lahiri
David A. Maltz, Parveen Patel, Sudipta Sengupta

Microsoft Research

[ACM SIGCOMM 2009]

Influenced architecture of Microsoft Azure



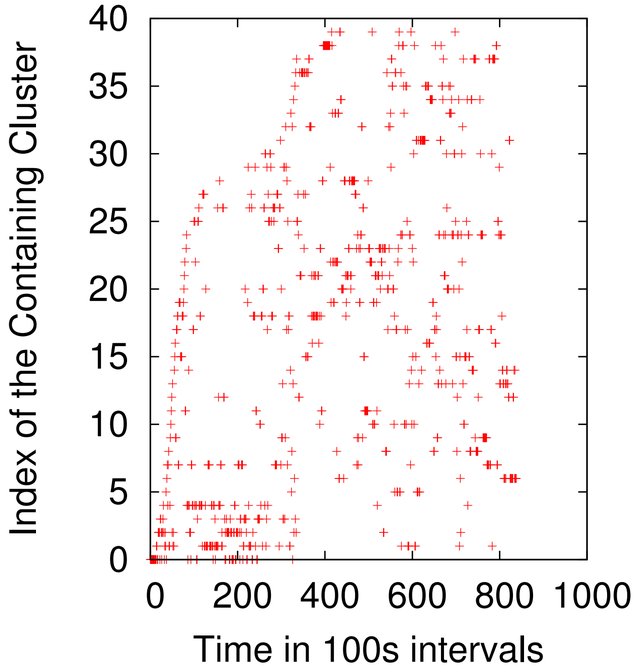
[From Albert Greenberg keynote at SIGCOMM 2015: http://conferences.sigcomm.org/sigcomm/2015/pdf/papers/keynote.pdf]

Motivating Environmental Characteristics

Increasing internal traffic is a bottleneck

- Traffic volume between servers is 4x external traffic

Unpredictable, rapidly-changing traffic matrices (TMs)



[Greenberg et al.]

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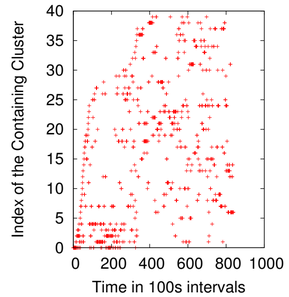

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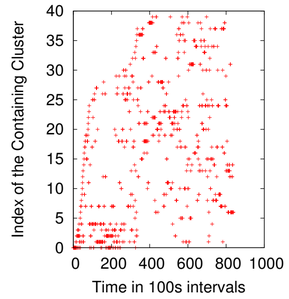


[Greenberg et al.]

Design result: Nonblocking fabric

- High throughput for *any* TM that respects server NIC rates

Motivating Environmental Characteristics

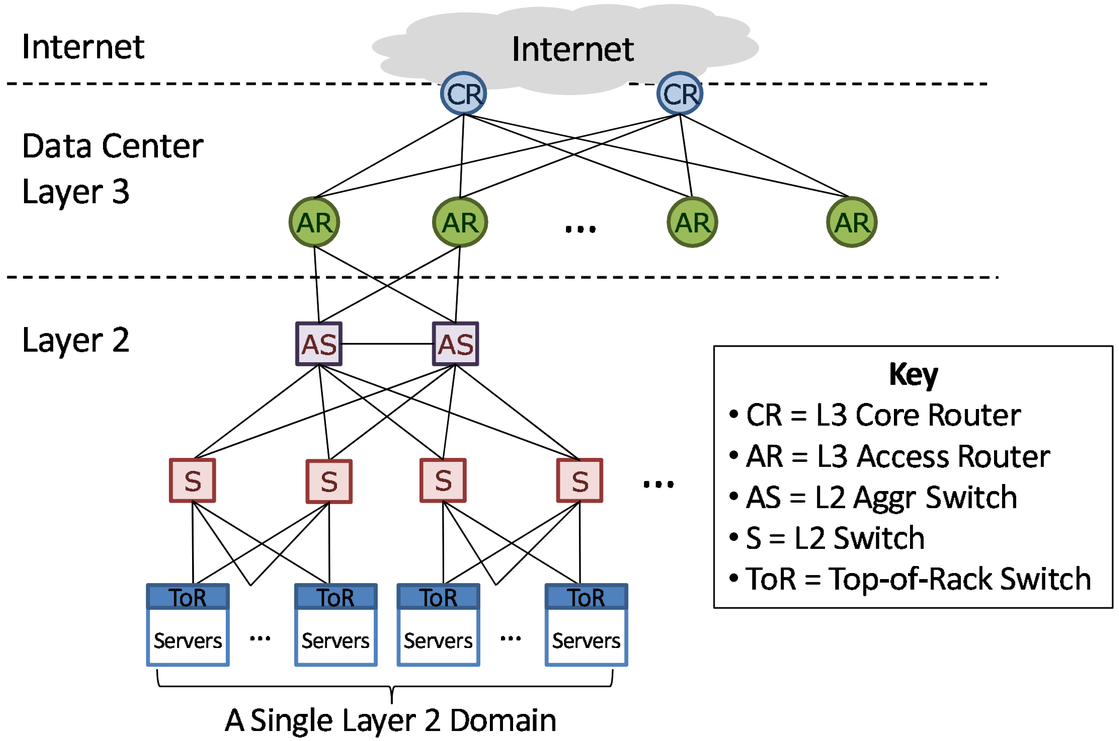
Failure characteristics

- Analyzed 300K alarm tickets, 36M error events
- 0.4% of failures were resolved in over one day
- 0.3% of failures eliminated all redundancy in a device group (e.g. both uplinks)

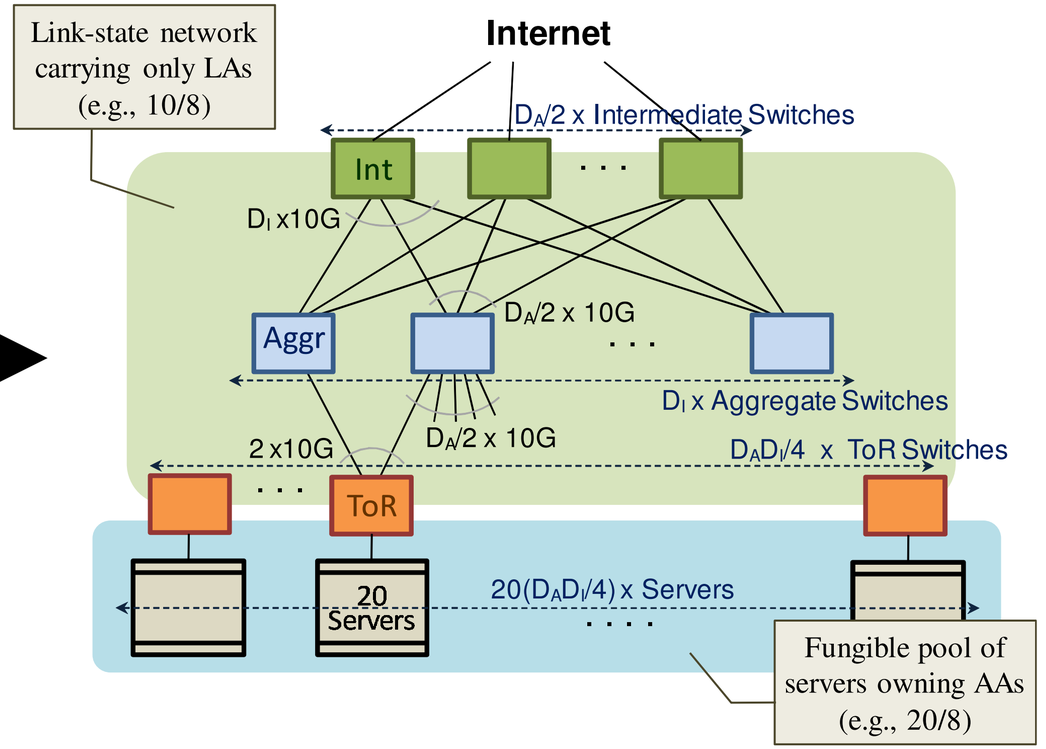
Design result: Clos topology

- “Scale out” instead of “scale up”

VL2 physical topology



Traditional



VL2

[Figures from Greenberg et al.]

Routing in VL2

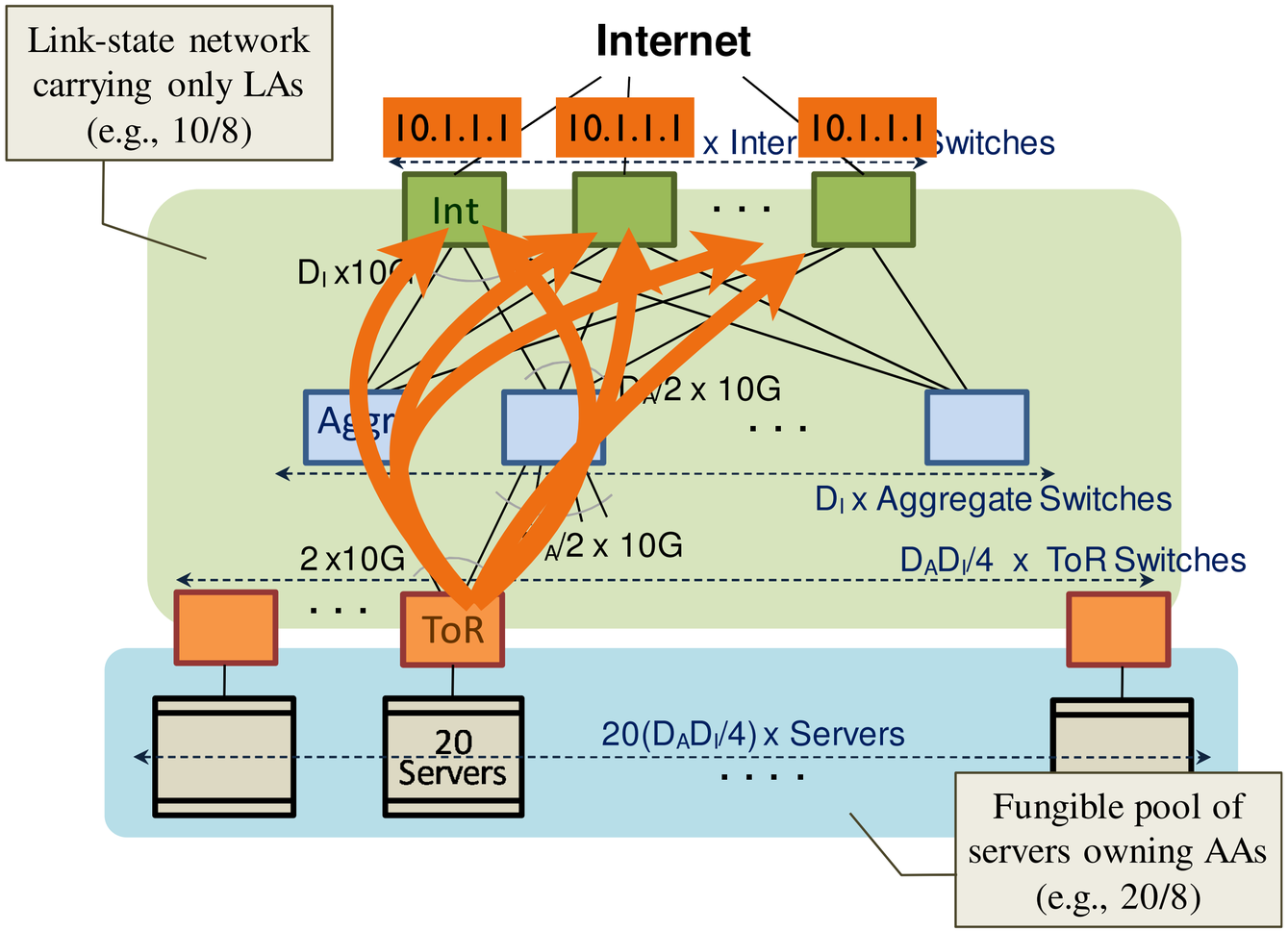
Unpredictable traffic

- Difficult to adapt

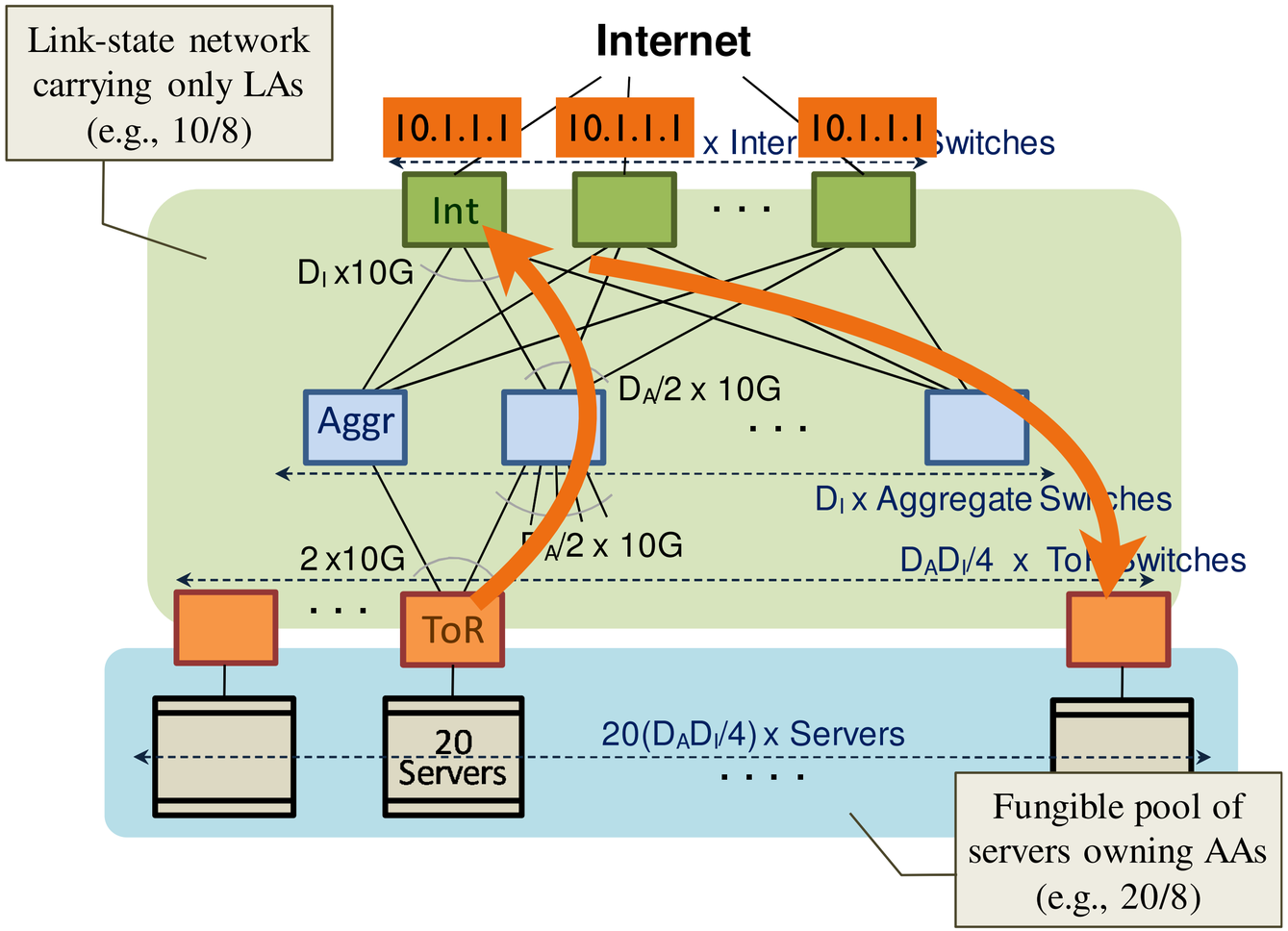
Design result: "Valiant Load Balancing"

- Route traffic independent of current traffic matrix
- Spreads arbitrary traffic pattern so it's uniform among top layer switches

Routing Implementation



Routing Implementation



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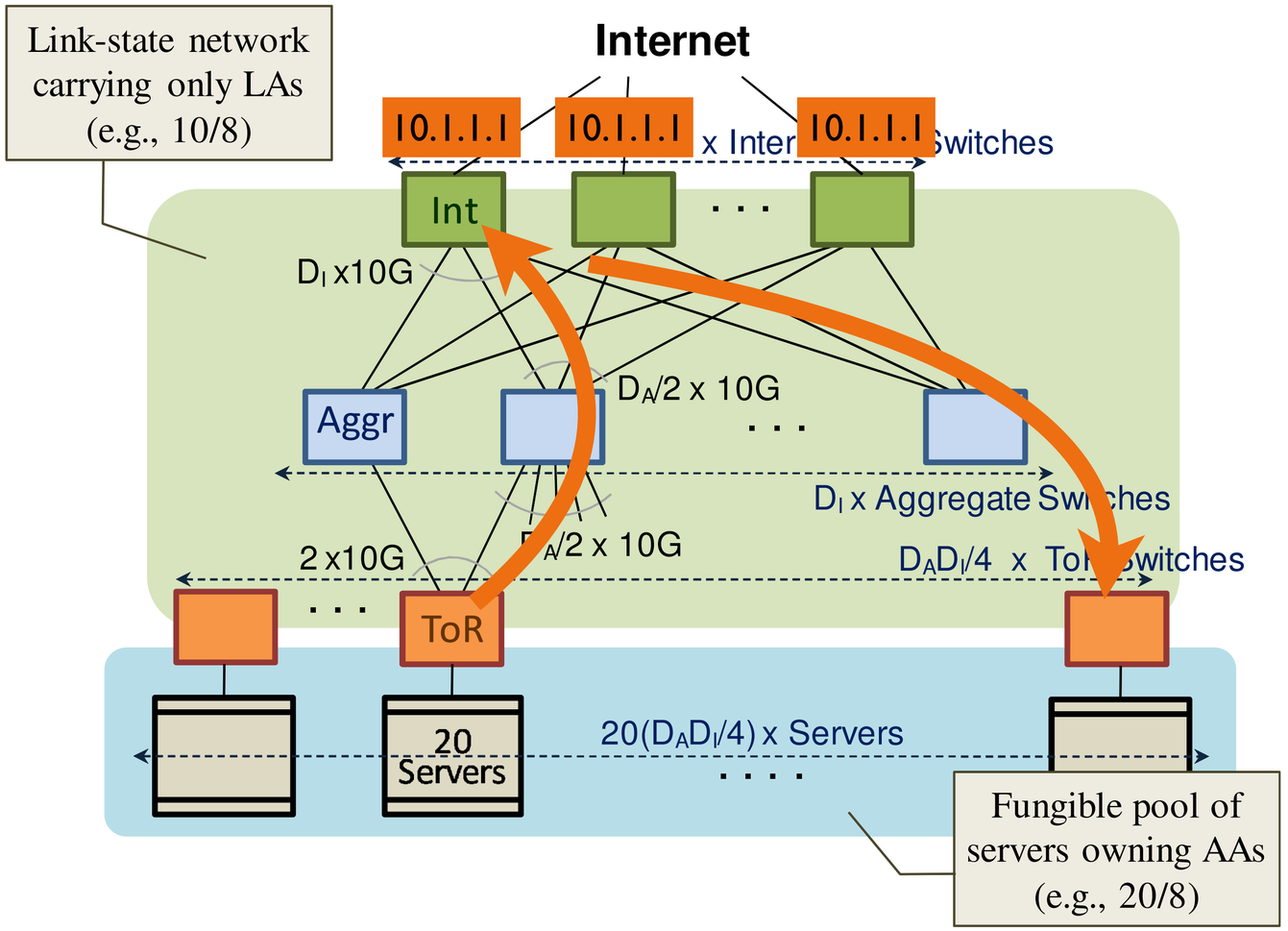


Similar effect to ECMP to each rack

Smaller forwarding tables at most switches

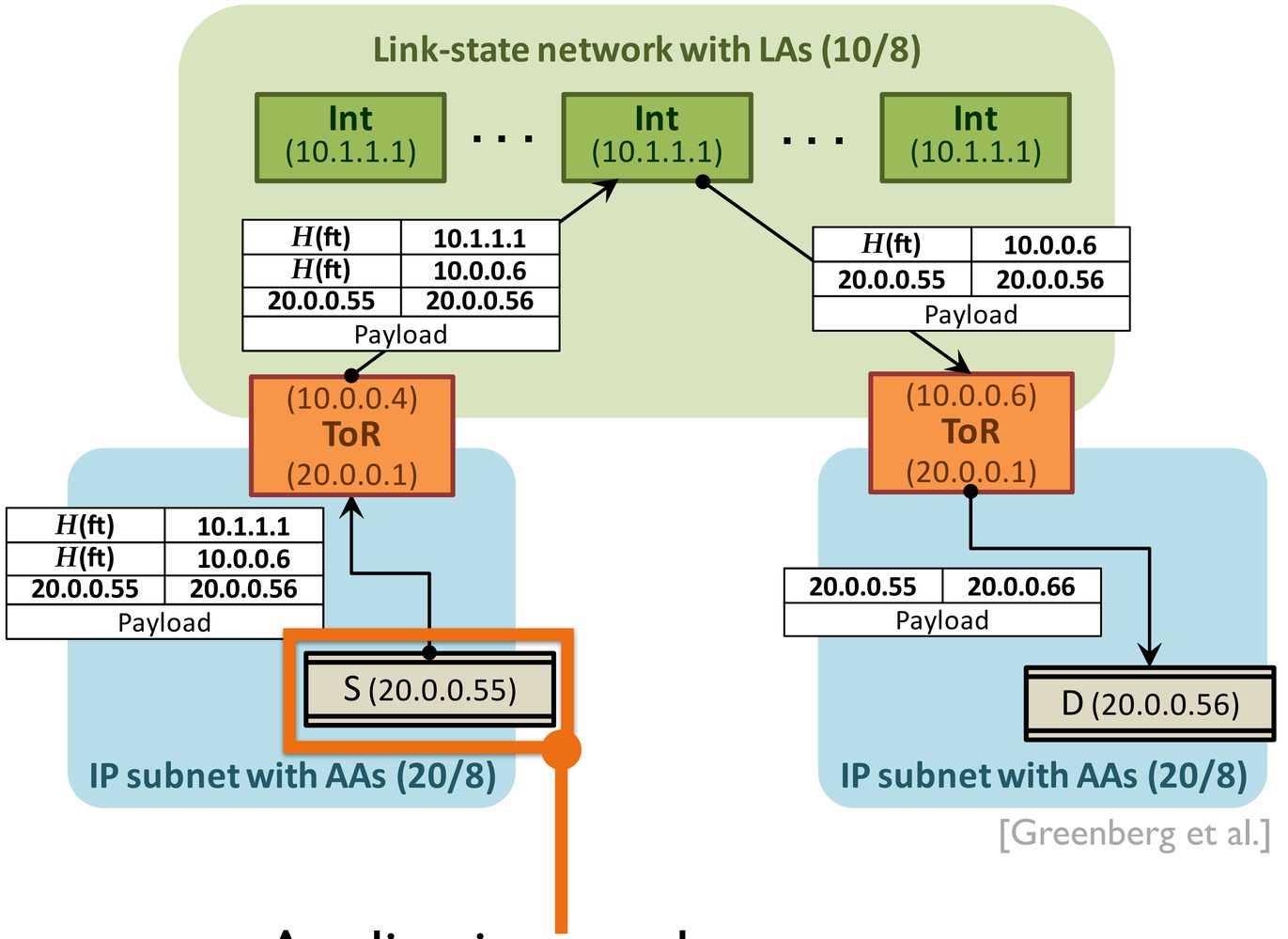
Virtualization

"All problems in computer science can be solved by another level of indirection."

– *David Wheeler*

App / Tenant layer	• Application Addresses (AAs): Location independent • Illusion of a single big Layer 2 switch connecting the app
Virtualization layer	• Directory server: Maintain AA to LA mapping • Server agent: Query server, wrap AAs in outer LA header
Physical network layer	• Locator Addresses (LAs): Tied to topology, used to route • Layer 3 routing via OSPF

End-to-end example



[Greenberg et al.]

Application sends to AA 20.0.0.56

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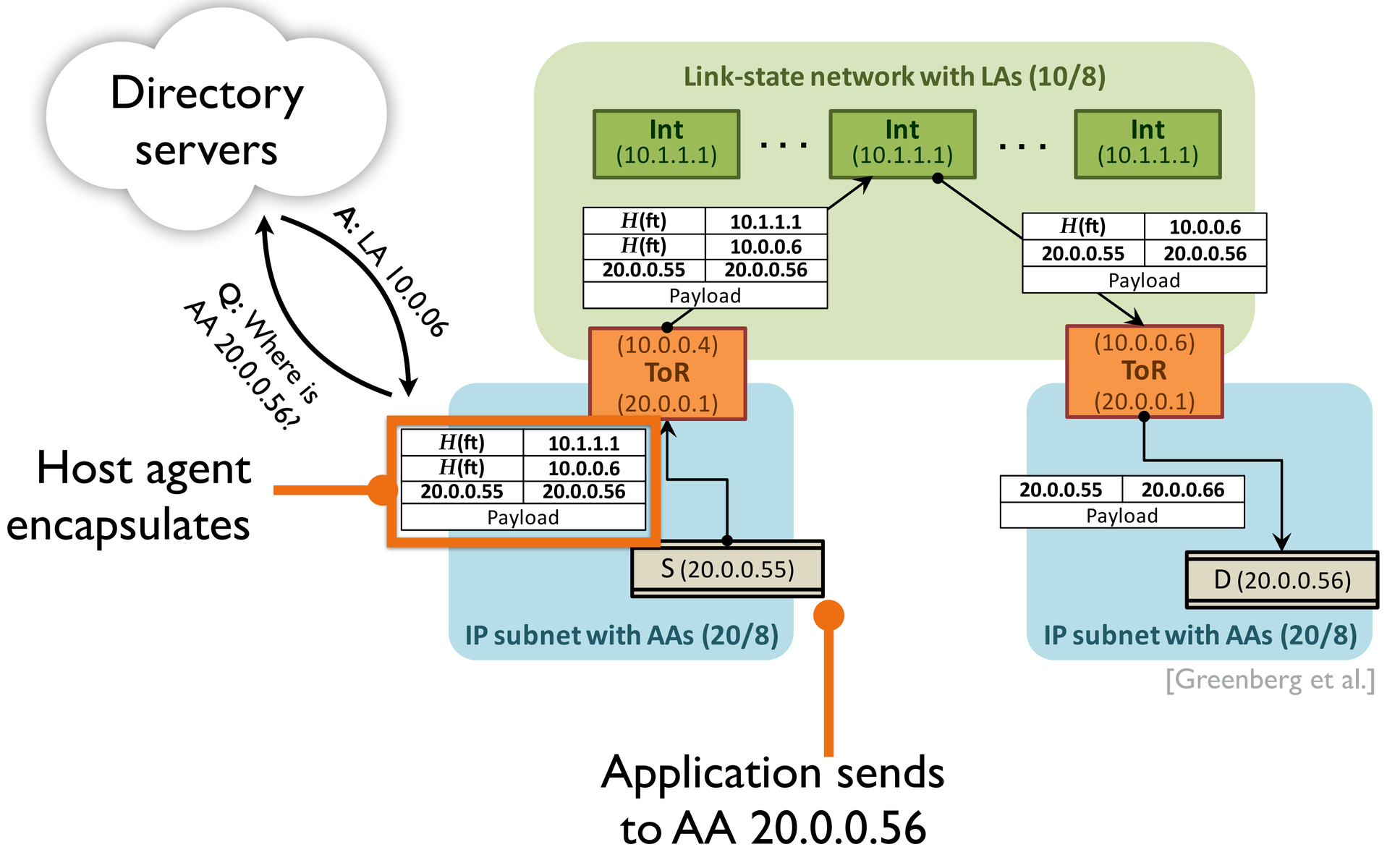

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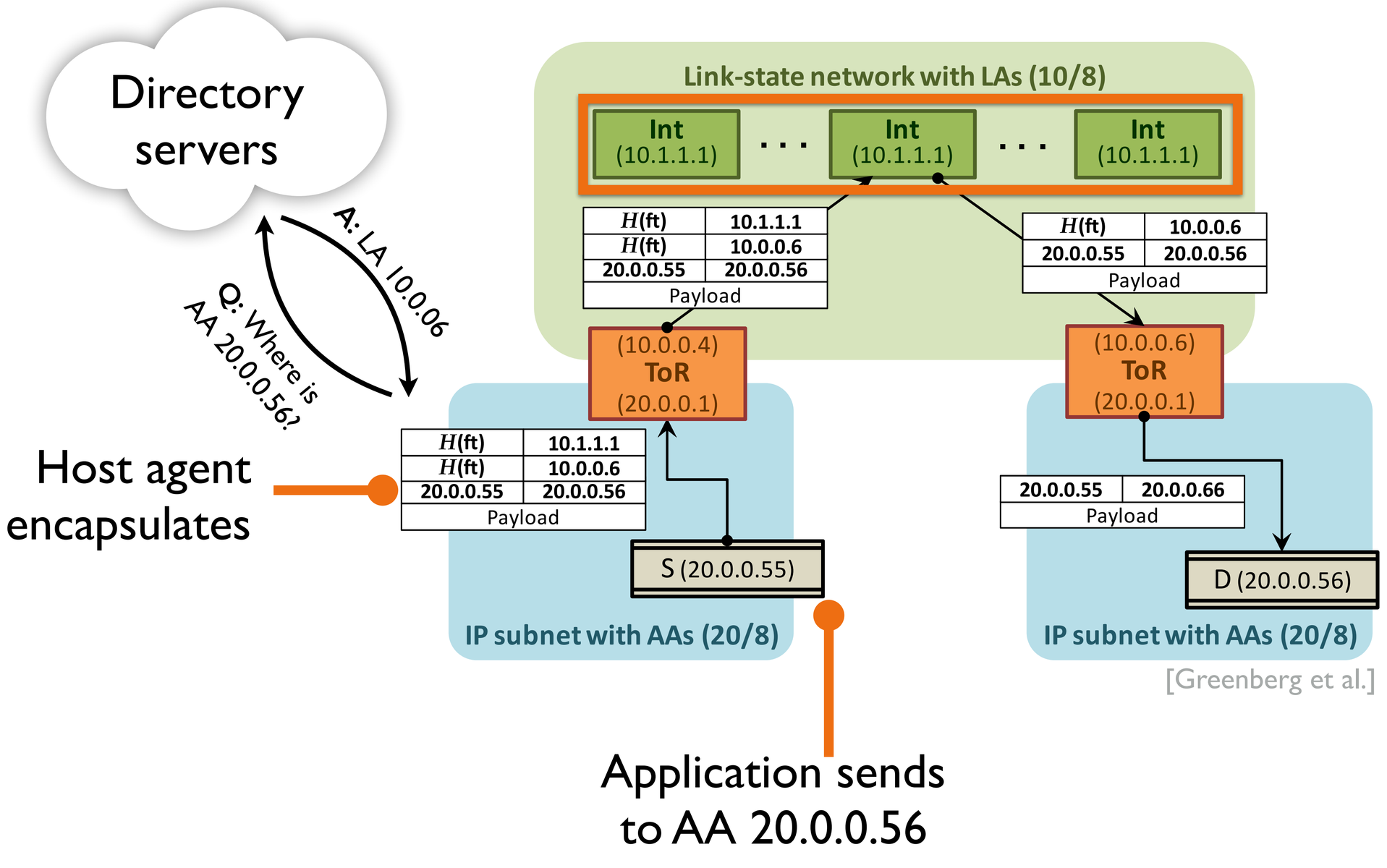

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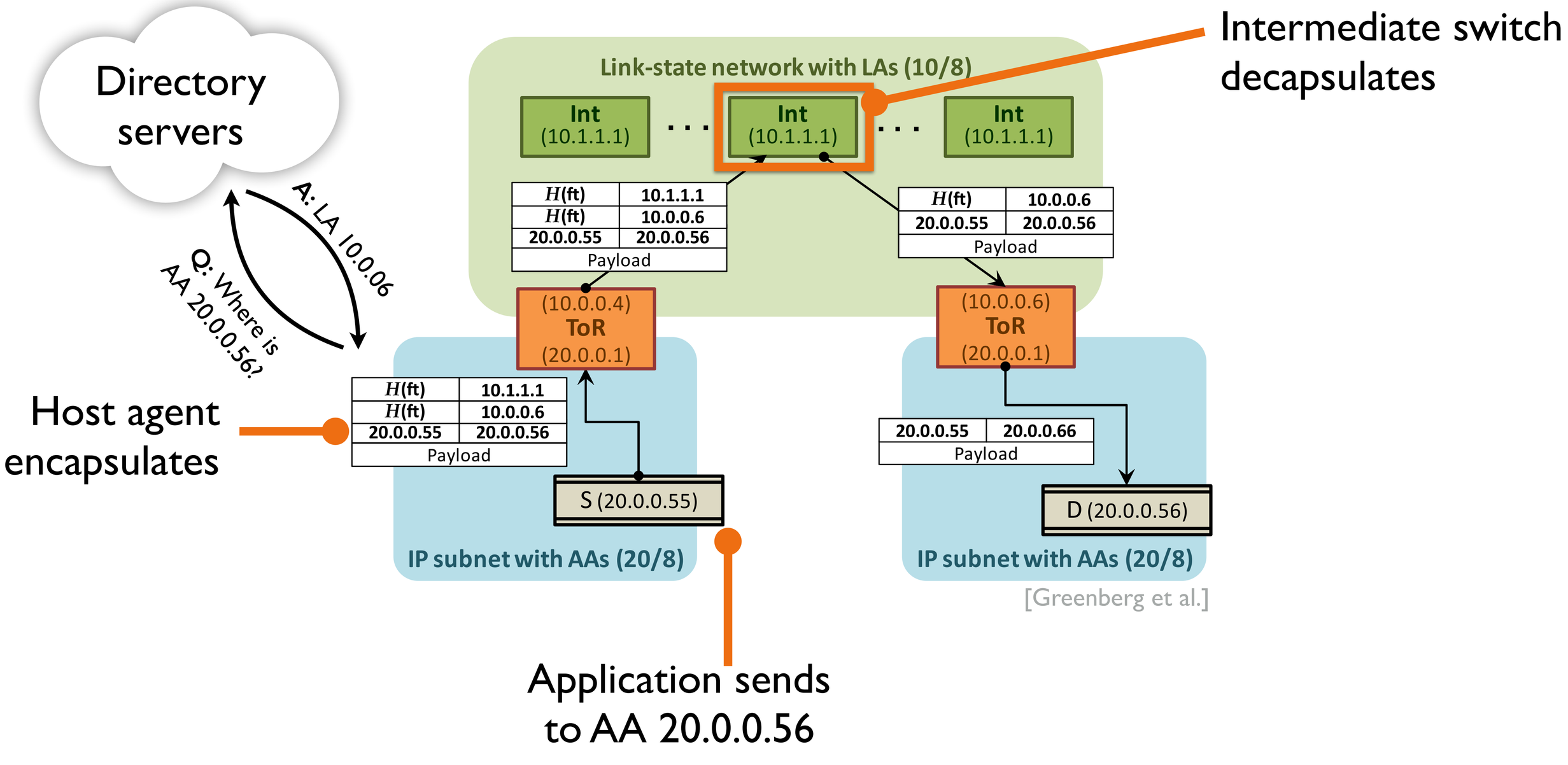

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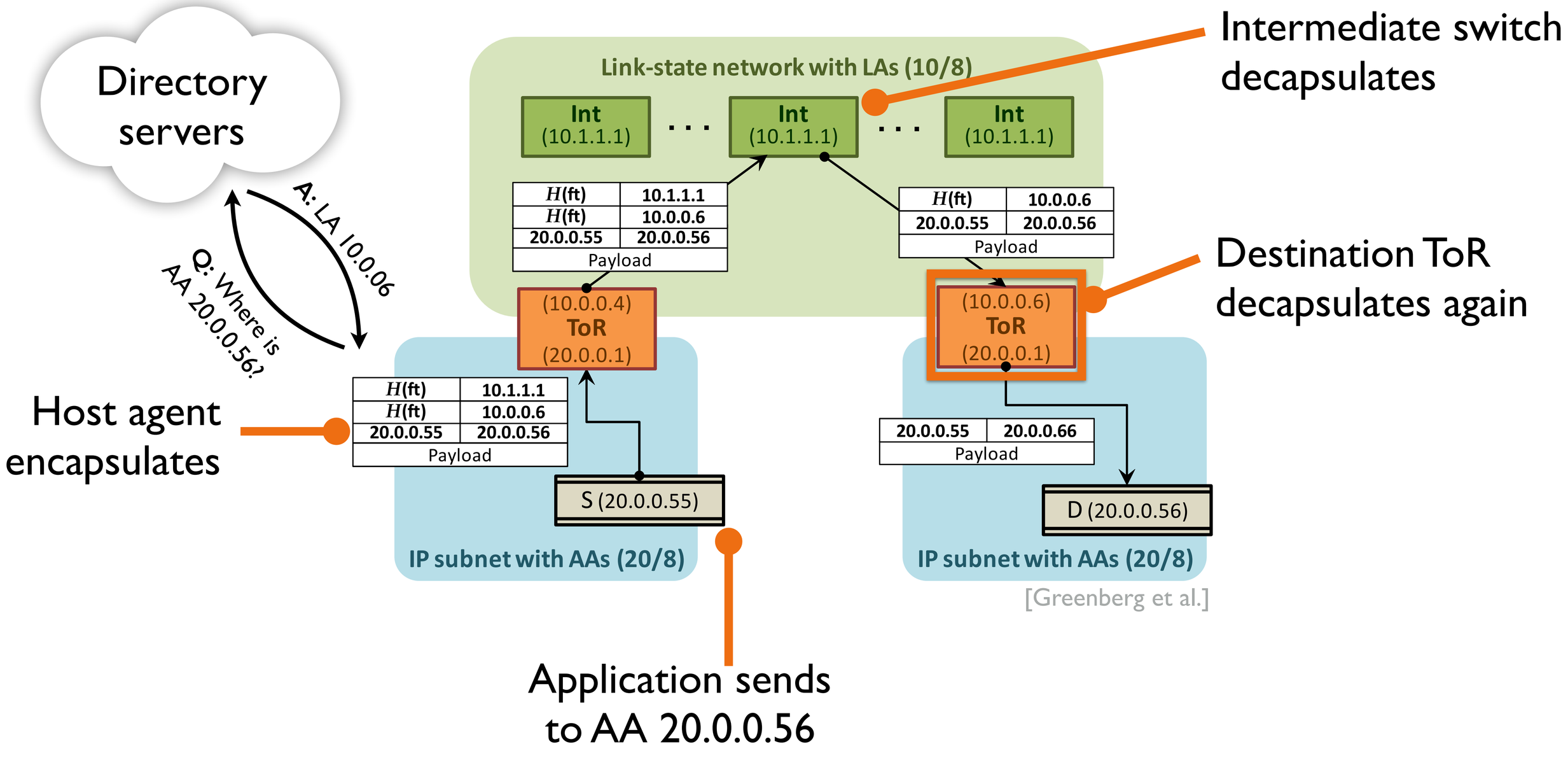

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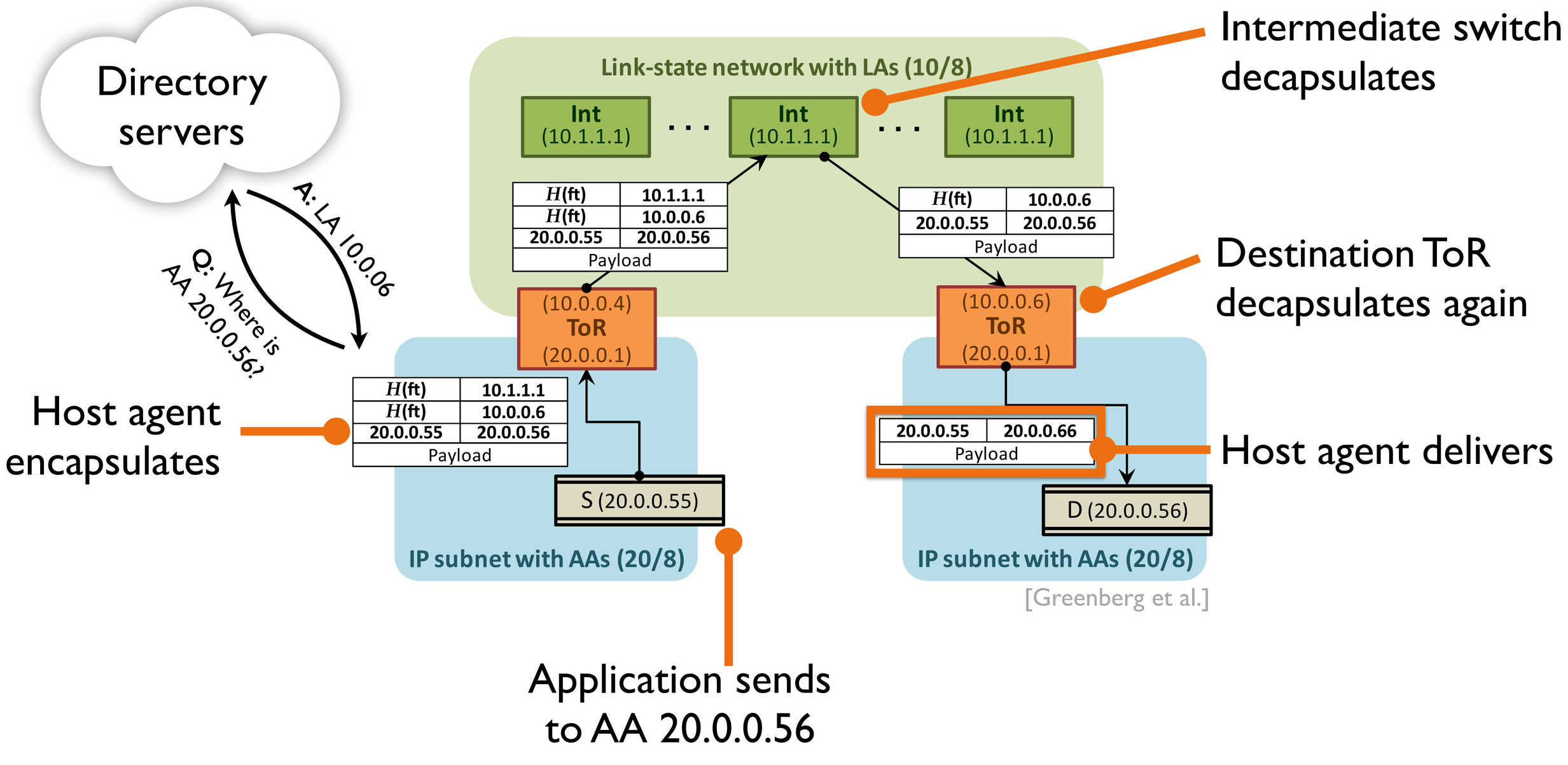

[Greenberg et al.]

Did we achieve agility?

Location independent addressing

- AAs are location independent

L2 network semantics

- Agent intercepts and handles L2 broadcast, multicast

- Both of the above require "layer 2.5" shim agent running on host; but, concept transfers to hypervisor-based virtual switch

Did we achieve agility?

Performance uniformity

- Clos network is nonblocking (non-oversubscribed)
- Uniform capacity everywhere
- ECMP provides good (though not perfect) load balancing
- But, performance isolation among tenants depends on TCP backing off to rate destination can receive
- Leaves open the possibility of fast load balancing

Security

- Directory system can allow/deny connections by choosing whether to resolve an AA to a LA
- But, segmentation not explicitly enforced at hosts

Where's the SDN?

Directory servers: Logically centralized control

- Orchestrate application locations
- Control communication policy

Host agents: dynamic "programming" of data path