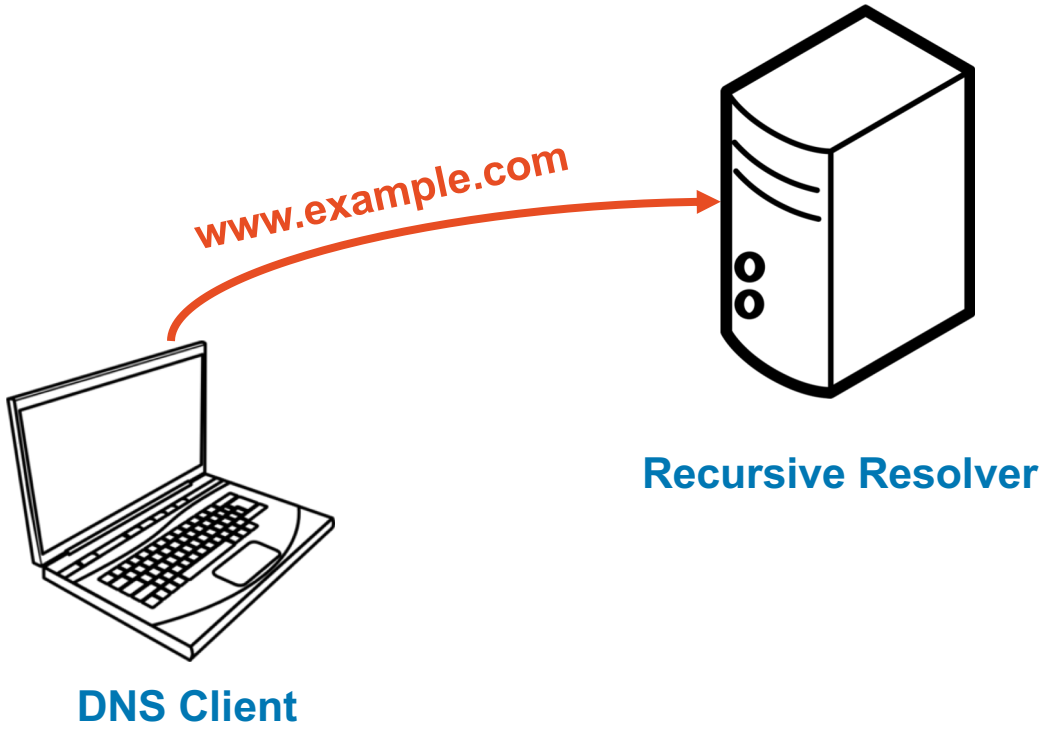
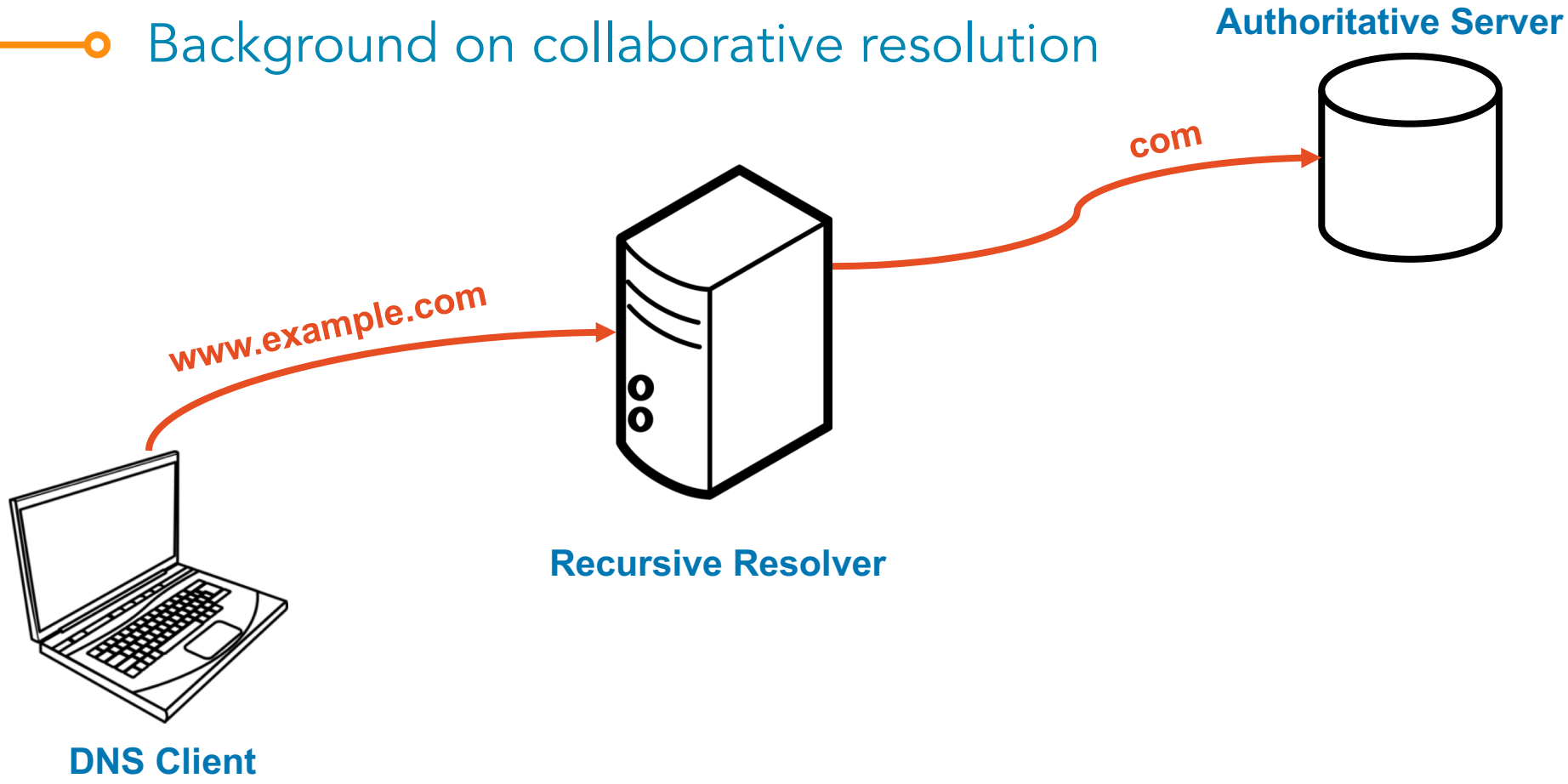
Characterization of Collaborative Resolution in Recursive DNS Resolvers

Rami Al-Dalky
Kyle Schomp

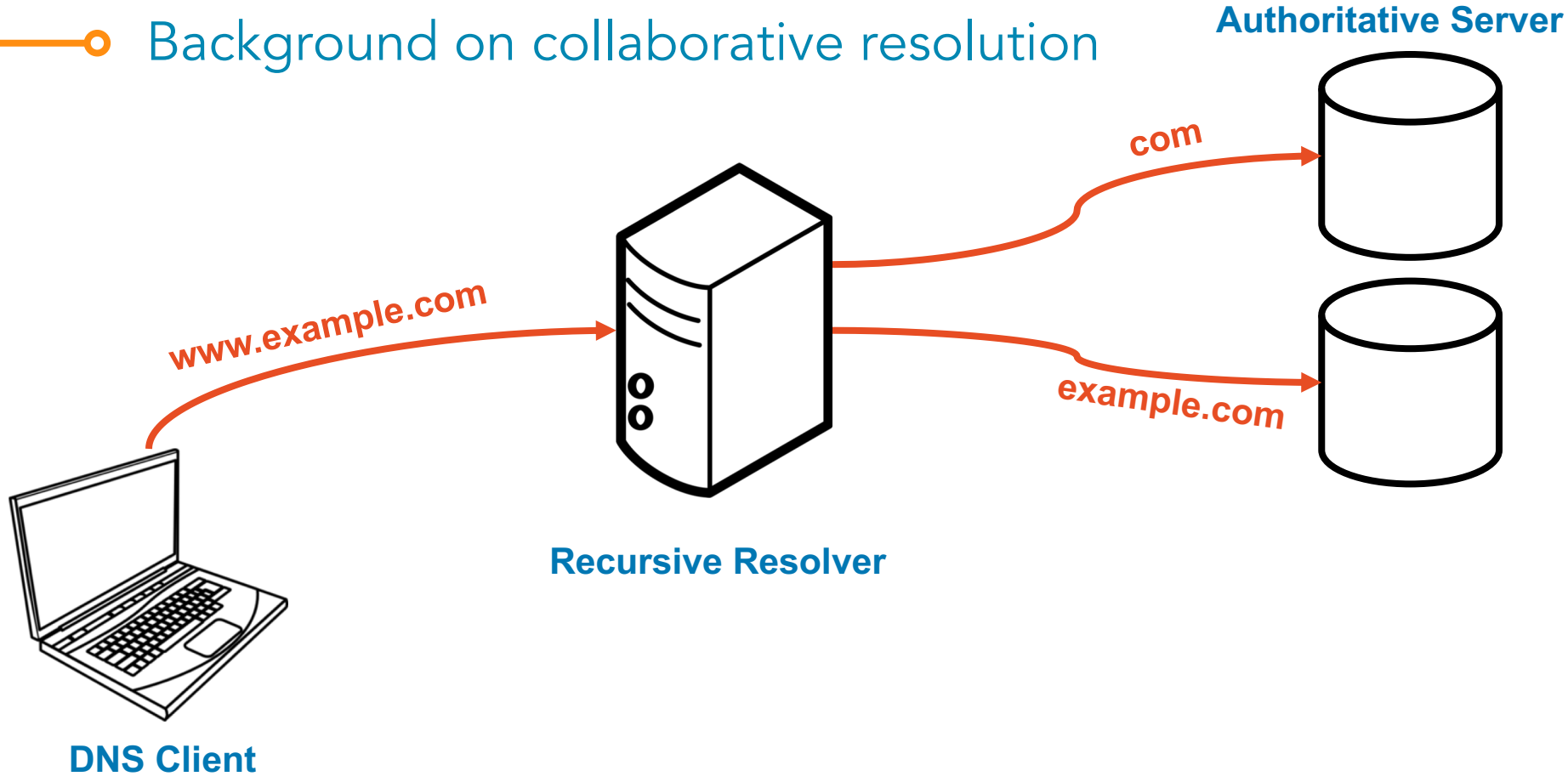
Background on collaborative resolution



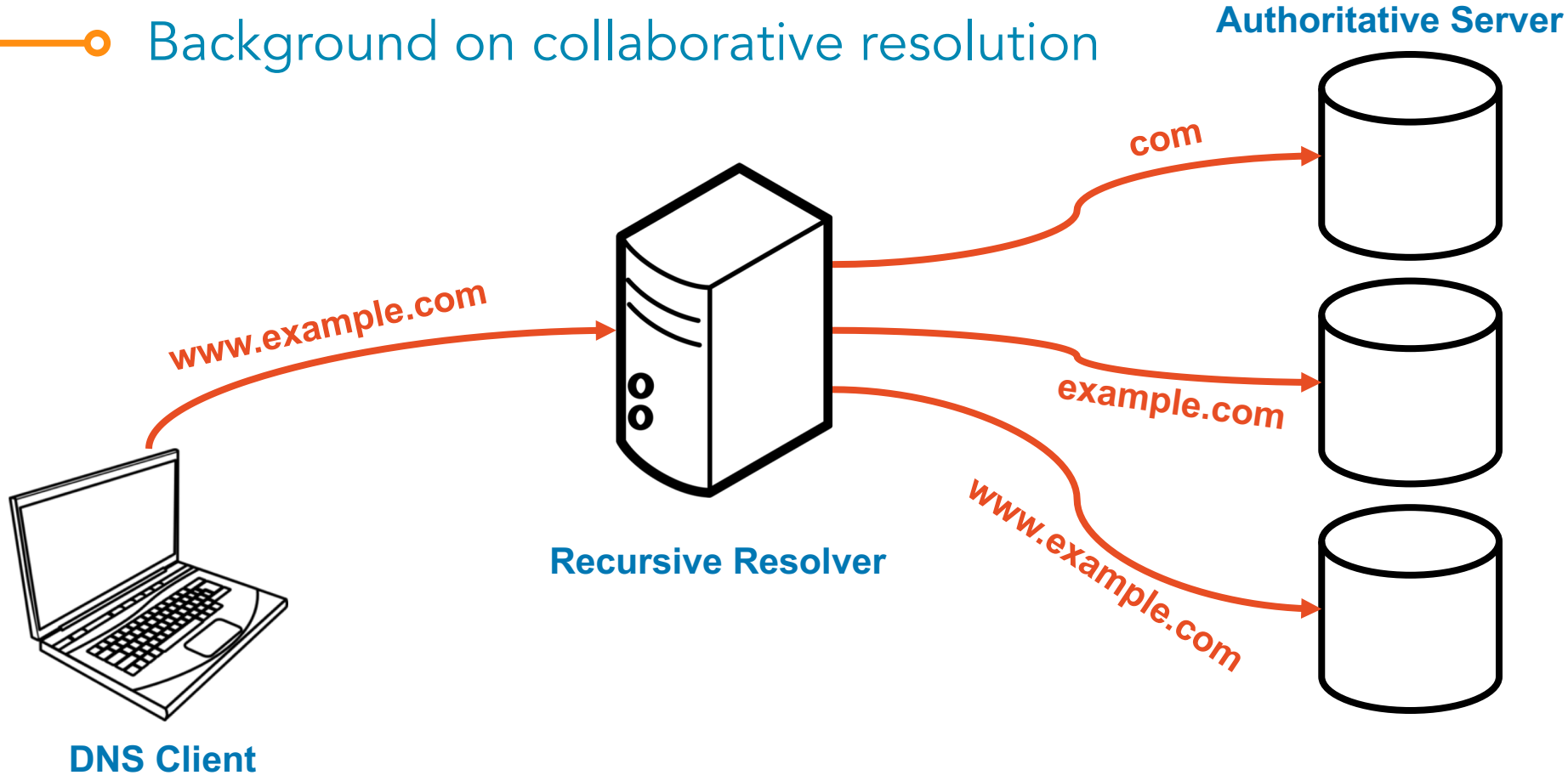
Background on collaborative resolution



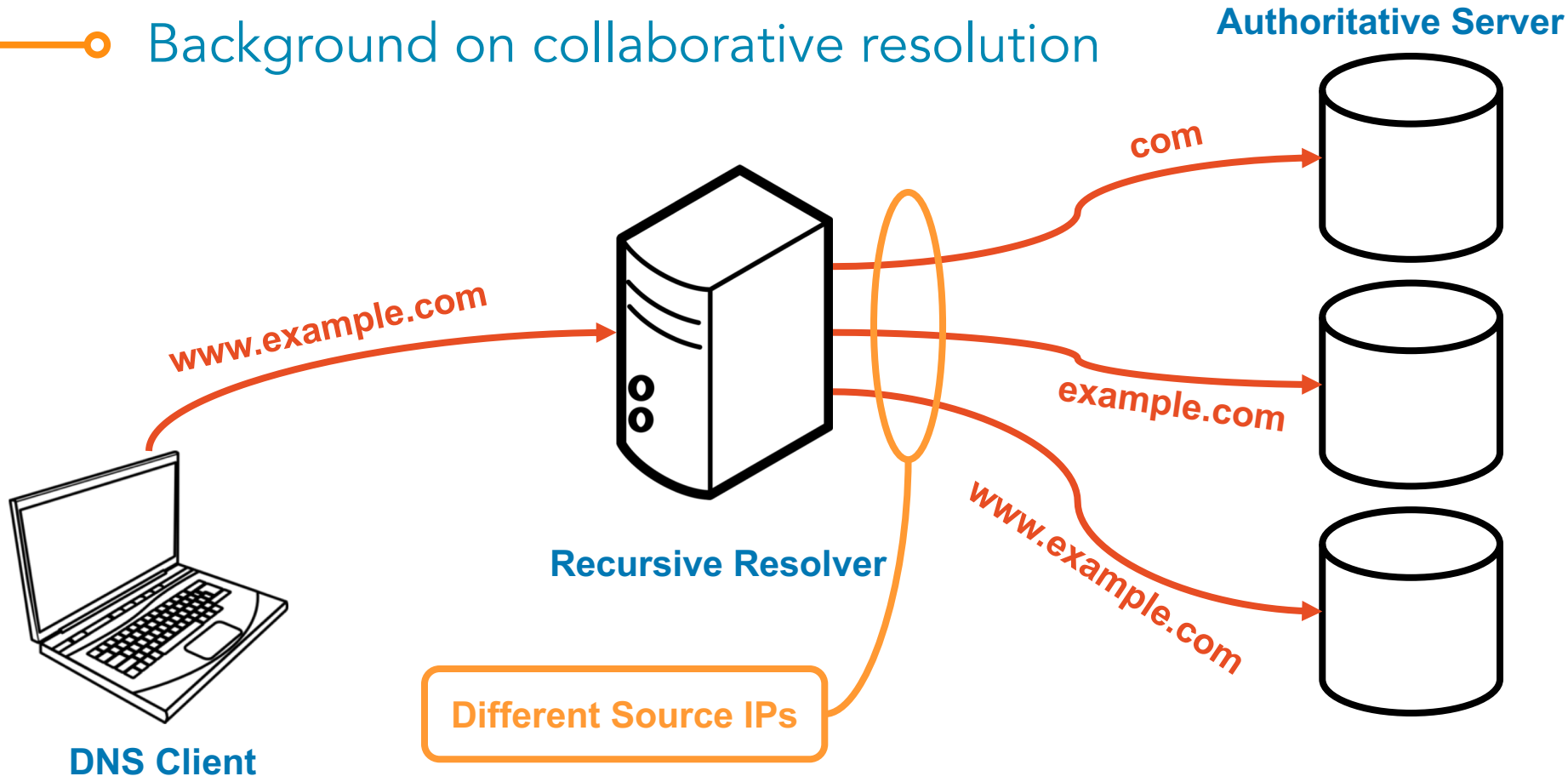
Background on collaborative resolution



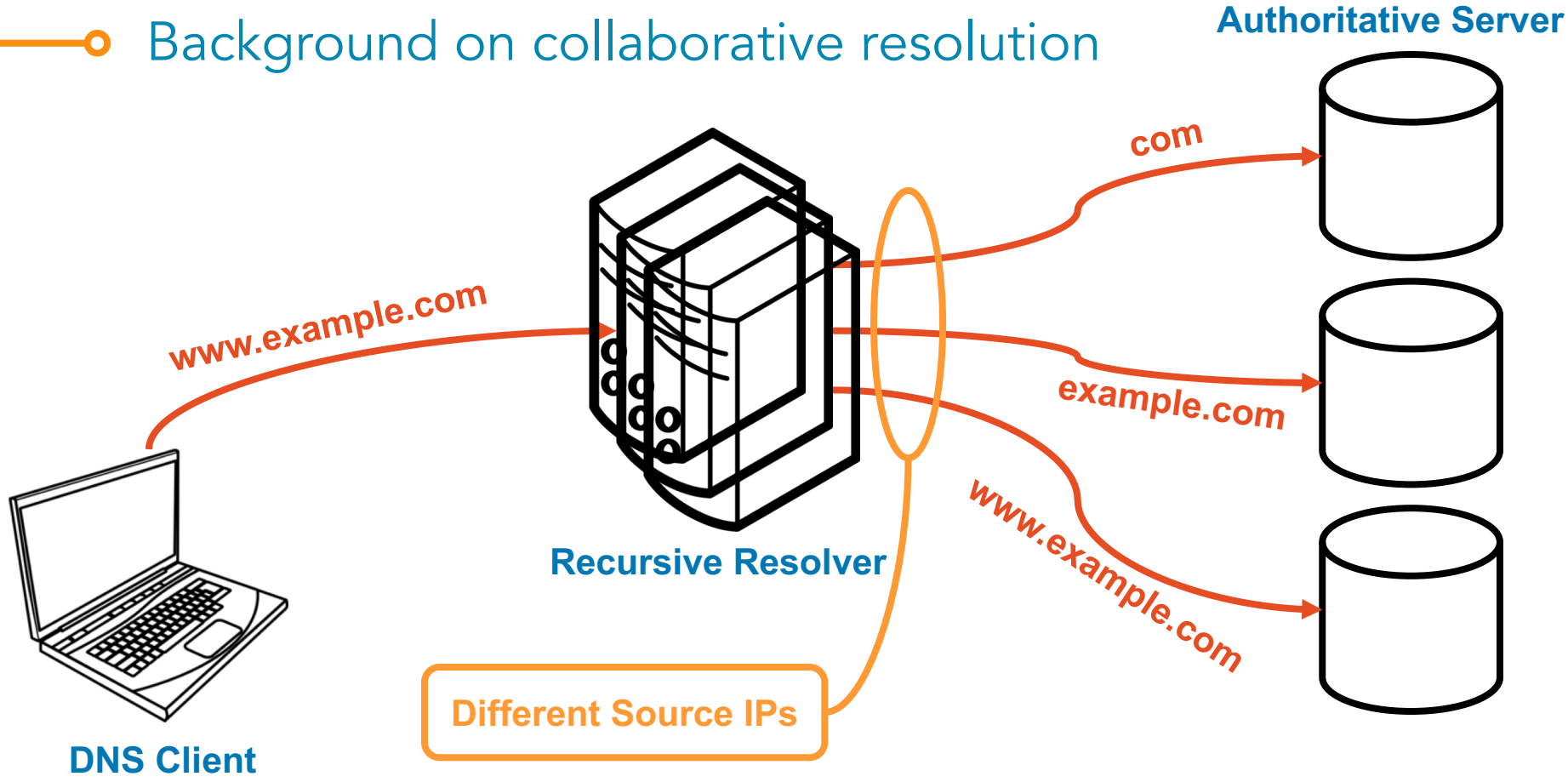
Background on collaborative resolution



Background on collaborative resolution



Background on collaborative resolution



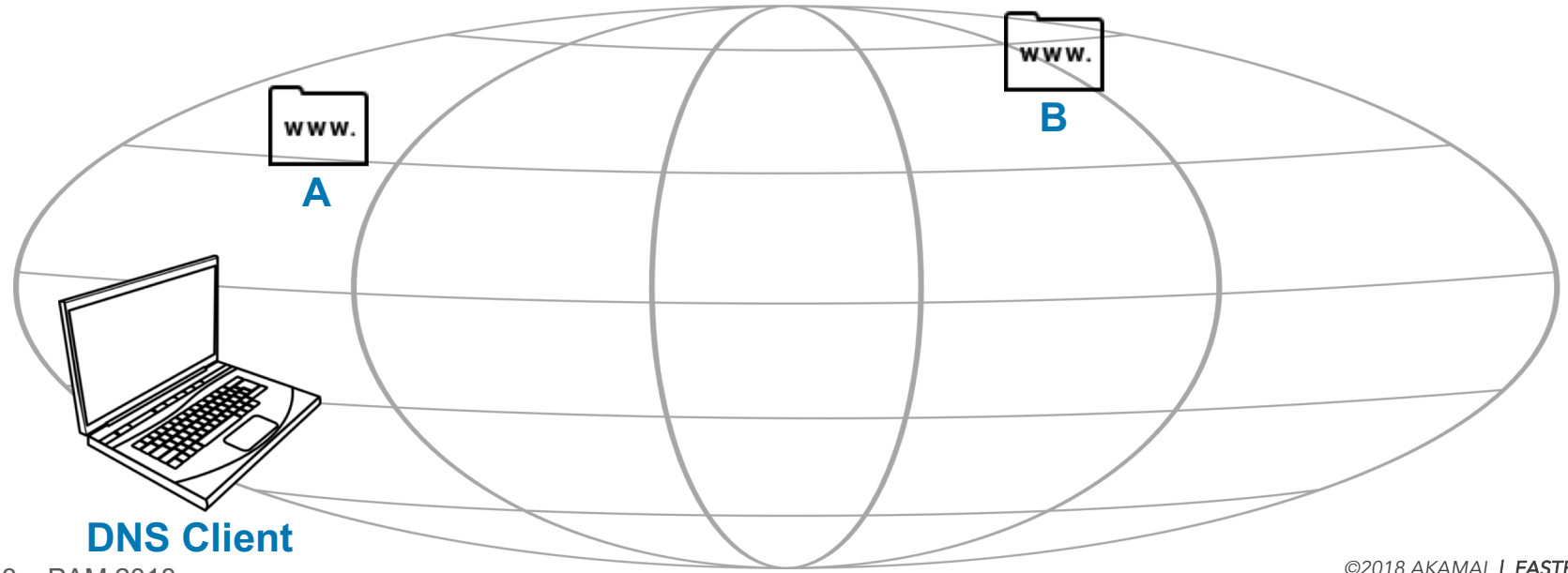
Why study recursive resolvers?

- DNS resolutions prefaces majority of web transactions
- But also, resolvers have an outsized role in performance

DNS-based Replica Selection

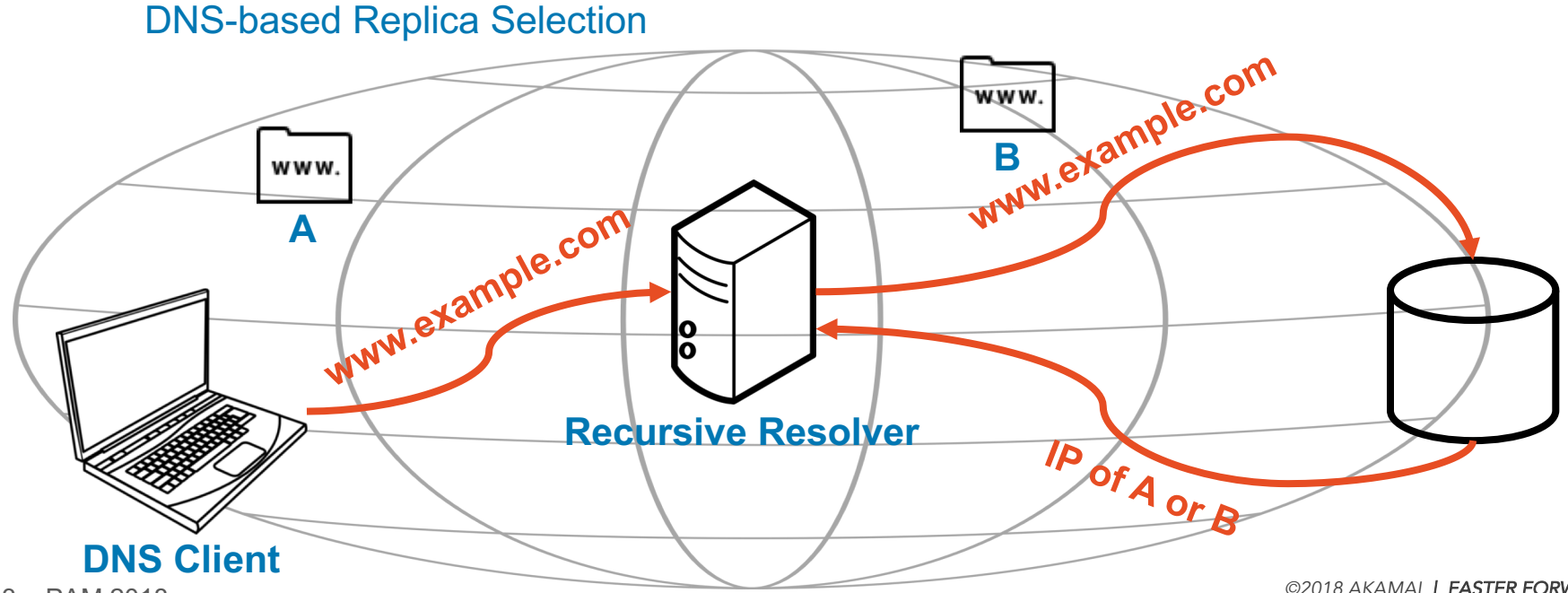
Why study recursive resolvers?

- DNS resolutions prefaces majority of web transactions
- But also, resolvers have an outsized role in performance



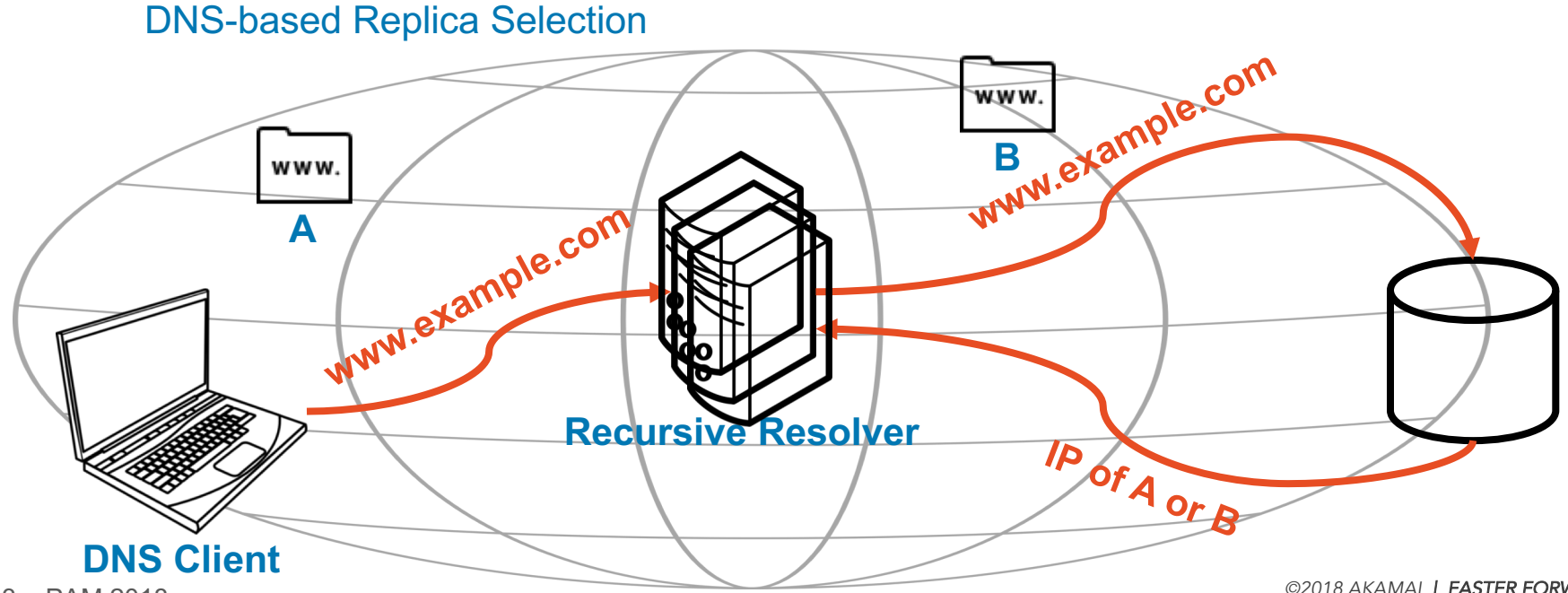
Why study recursive resolvers?

- DNS resolutions prefaces majority of web transactions
- But also, resolvers have an outsized role in performance



Why study recursive resolvers?

- DNS resolutions prefaces majority of web transactions
- But also, resolvers have an outsized role in performance



Data Collection

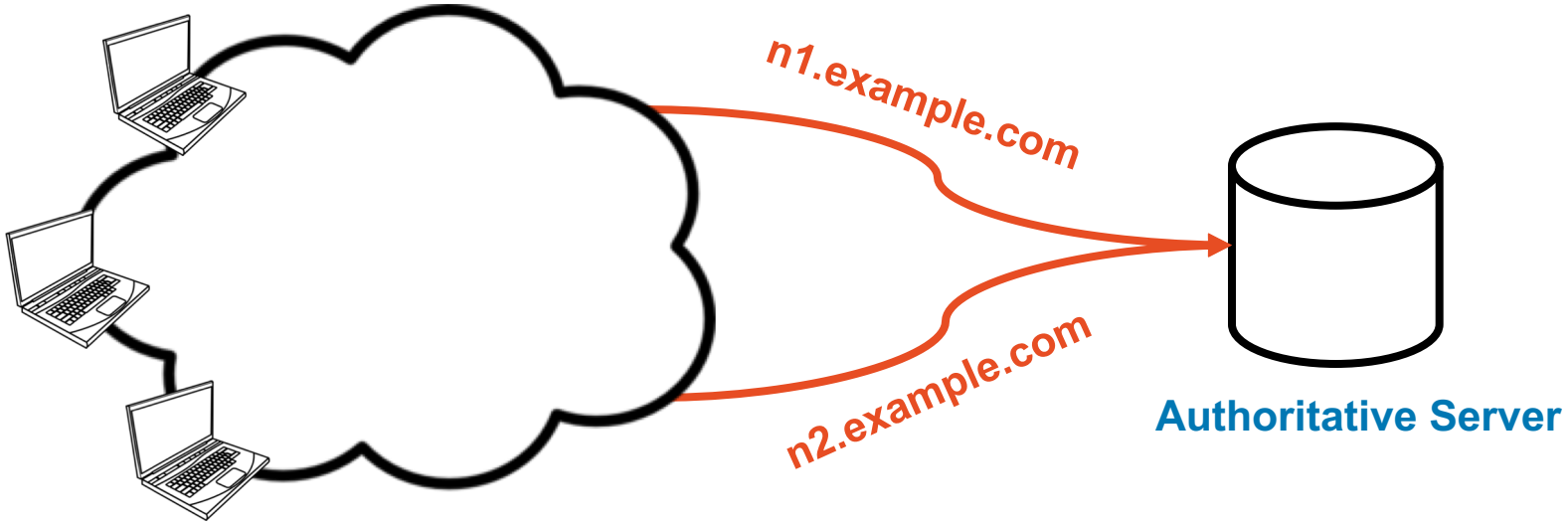
Experimental DNS Records

n1.example.com	300	IN	CNAME	n2.example.com
n2.example.com	300	IN	A / AAAA	1.2.3.4 / 1:2:3:4::

Data Collection

Experimental DNS Records

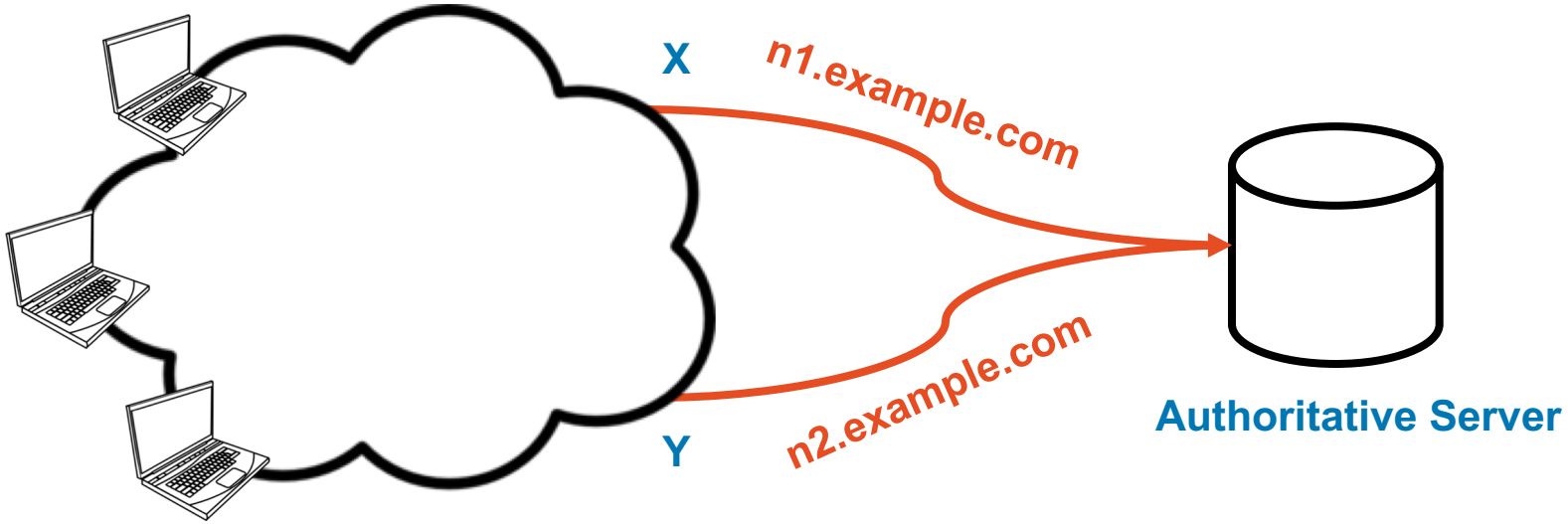
n1.example.com	300	IN	CNAME	n2.example.com
n2.example.com	300	IN	A / AAAA	1.2.3.4 / 1:2:3:4::



Data Collection

Experimental DNS Records

n1.example.com	300	IN	CNAME	n2.example.com
n2.example.com	300	IN	A / AAAA	1.2.3.4 / 1:2:3:4::



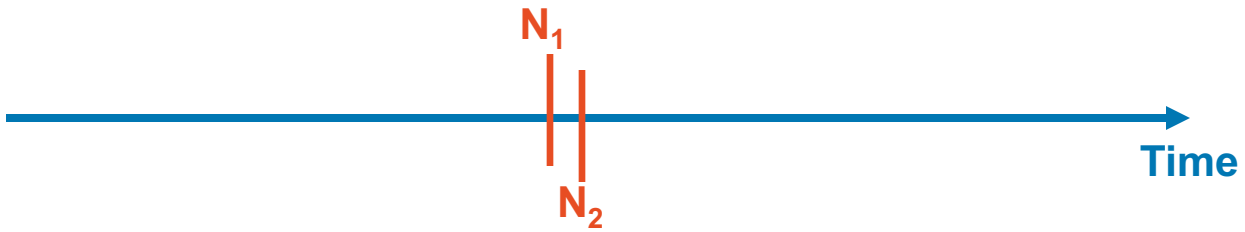
Directed Edge (X → Y) is a Pair

Removing False Positive Edges

1. Happy eyeballs
   - Include query type (A or AAAA) in the tuple when pairing queries
2. Multiple clients resolving the experimental name at the same time
   - Hostnames encode the client subnet
3. "Racing" recursive resolvers for fastest response
4. Re-resolution of one, but not both, hostnames
   - Window-based noise elimination

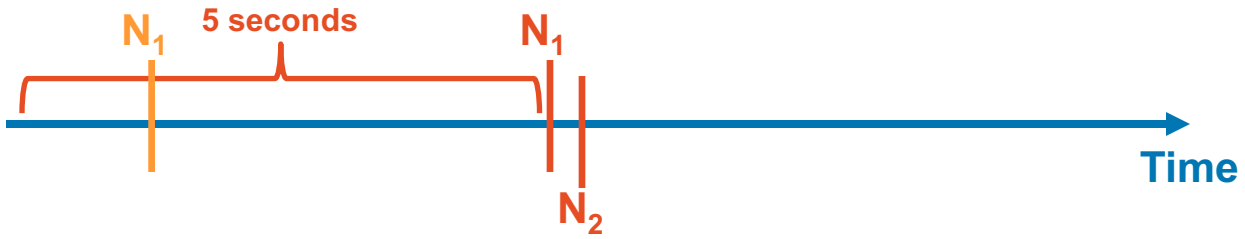
Removing False Positive Edges

1. Happy eyeballs
   - Include query type (A or AAAA) in the tuple when pairing queries
2. Multiple clients resolving the experimental name at the same time
   - Hostnames encode the client subnet
3. "Racing" recursive resolvers for fastest response
4. Re-resolution of one, but not both, hostnames
   - Window-based noise elimination



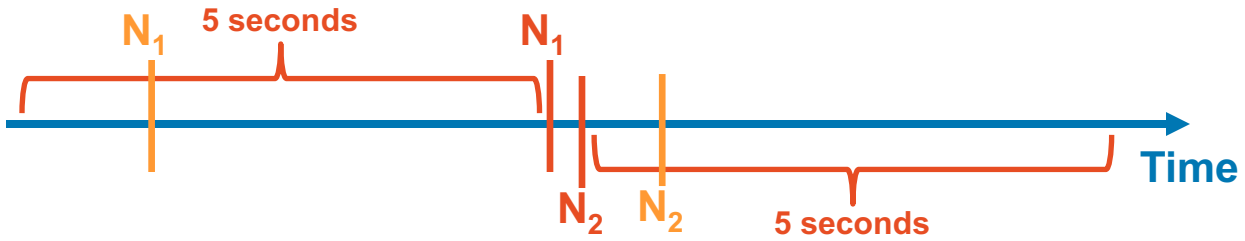
Removing False Positive Edges

1. Happy eyeballs
   - Include query type (A or AAAA) in the tuple when pairing queries
2. Multiple clients resolving the experimental name at the same time
   - Hostnames encode the client subnet
3. "Racing" recursive resolvers for fastest response
4. Re-resolution of one, but not both, hostnames
   - Window-based noise elimination



Removing False Positive Edges

1. Happy eyeballs
   - Include query type (A or AAAA) in the tuple when pairing queries
2. Multiple clients resolving the experimental name at the same time
   - Hostnames encode the client subnet
3. "Racing" recursive resolvers for fastest response
4. Re-resolution of one, but not both, hostnames
   - Window-based noise elimination



Data

- 1 week of authoritative DNS query logs

DNS Queries	820M

Data

- 1 week of authoritative DNS query logs
- Filter down to pairs from the queries

DNS Queries	**820M**
Pairs	**109M**

Data

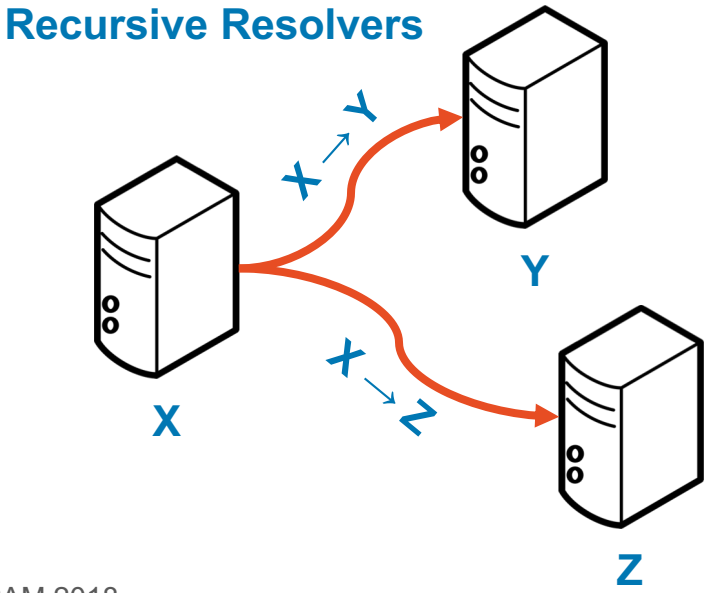
- 1 week of authoritative DNS query logs
- Filter down to pairs from the queries
- Cluster *same* initiator into pools

DNS Queries	**820M**
Pairs	**109M**
Clusters	**421K**

Data

- 1 week of authoritative DNS query logs
- Filter down to pairs from the queries
- Cluster *same* initiator into pools

DNS Queries	**820M**
Pairs	**109M**
Clusters	**421K**

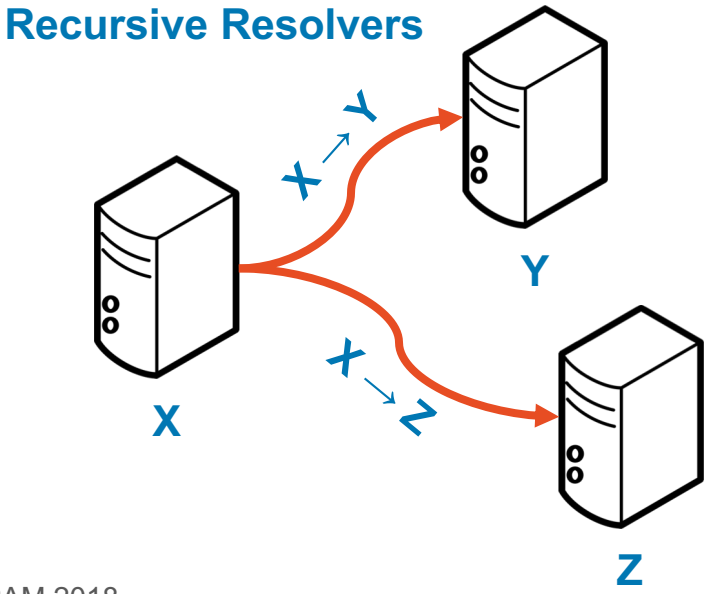


Pool: X → Y , Z

Data

- 1 week of authoritative DNS query logs
- Filter down to pairs from the queries
- Cluster *same* initiator into pools

DNS Queries	**820M**
Pairs	**109M**
Clusters	**421K**



Pool: X → Y , Z

$N_{X \to Y}$, $M_{X \to Z}$

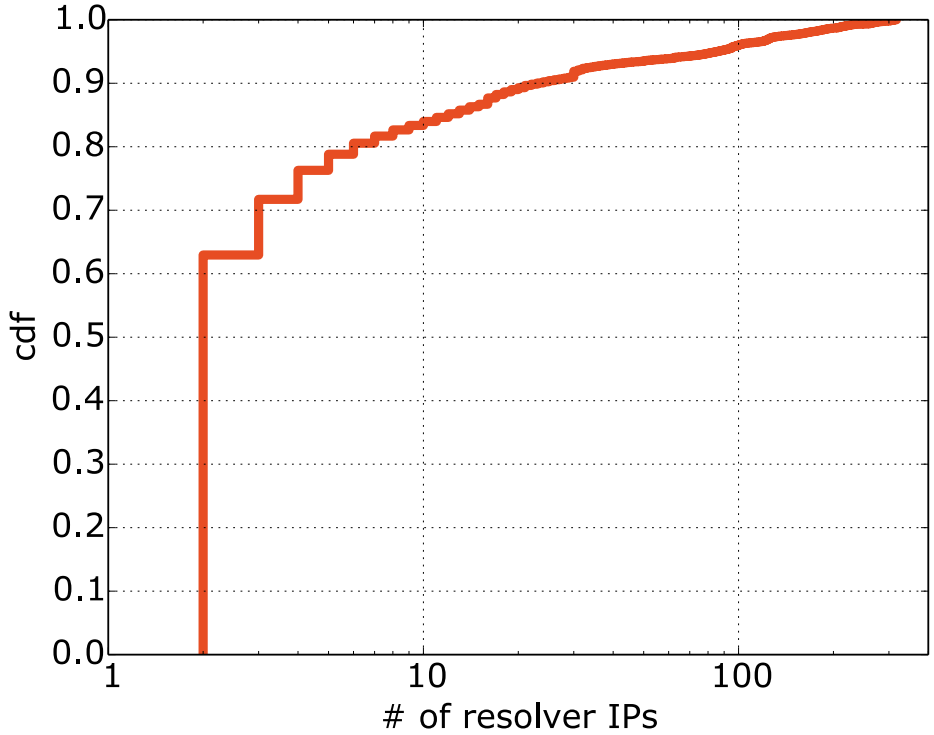
Data

- 1 week of authoritative DNS query logs
- Filter down to pairs from the queries
- Cluster *same* initiator into pools
- 14% of clusters contain more than 1 IP

DNS Queries	**820M**
Pairs	**109M**
Clusters	**421K**
→ Singletons	**360K**
→ Pools	**61K**

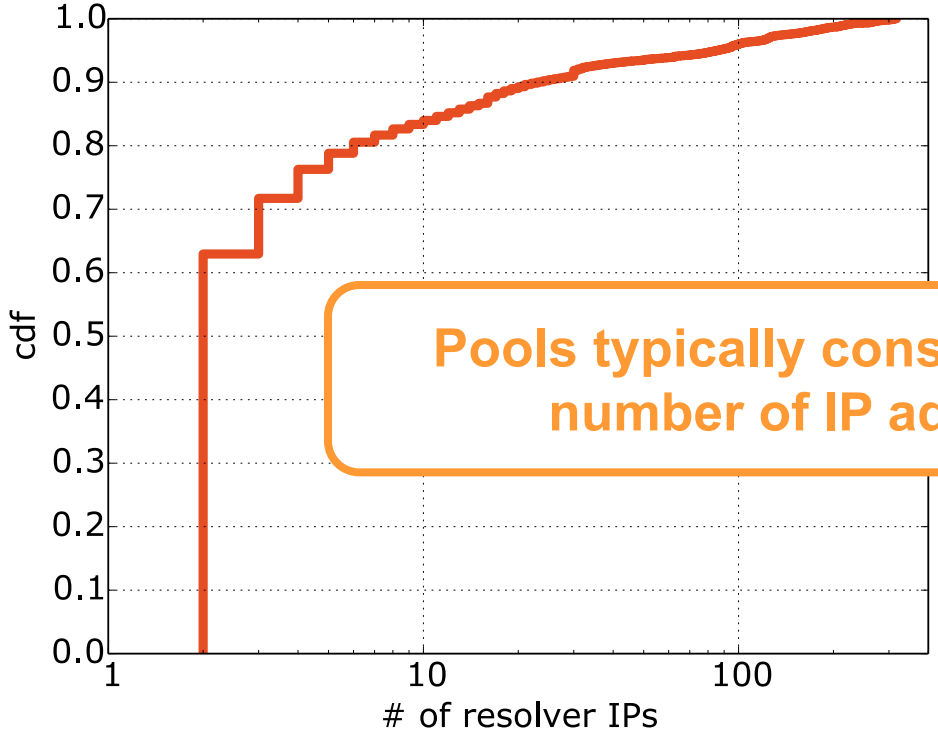
What do the pools look like?

Number of recursive IPs per pool



What do the pools look like?

Number of recursive IPs per pool



Pools typically consist of a small number of IP addresses

What do the pools look like?

Distribution in IP-Space

IPv4 representation	Binary representation
1.2.3.1	0000 0001 0000 0010 0000 0011 0000 0001
1.2.3.128	0000 0001 0000 0010 0000 0011 1000 0000
1.2.4.1	0000 0001 0000 0010 0000 0100 0000 0001

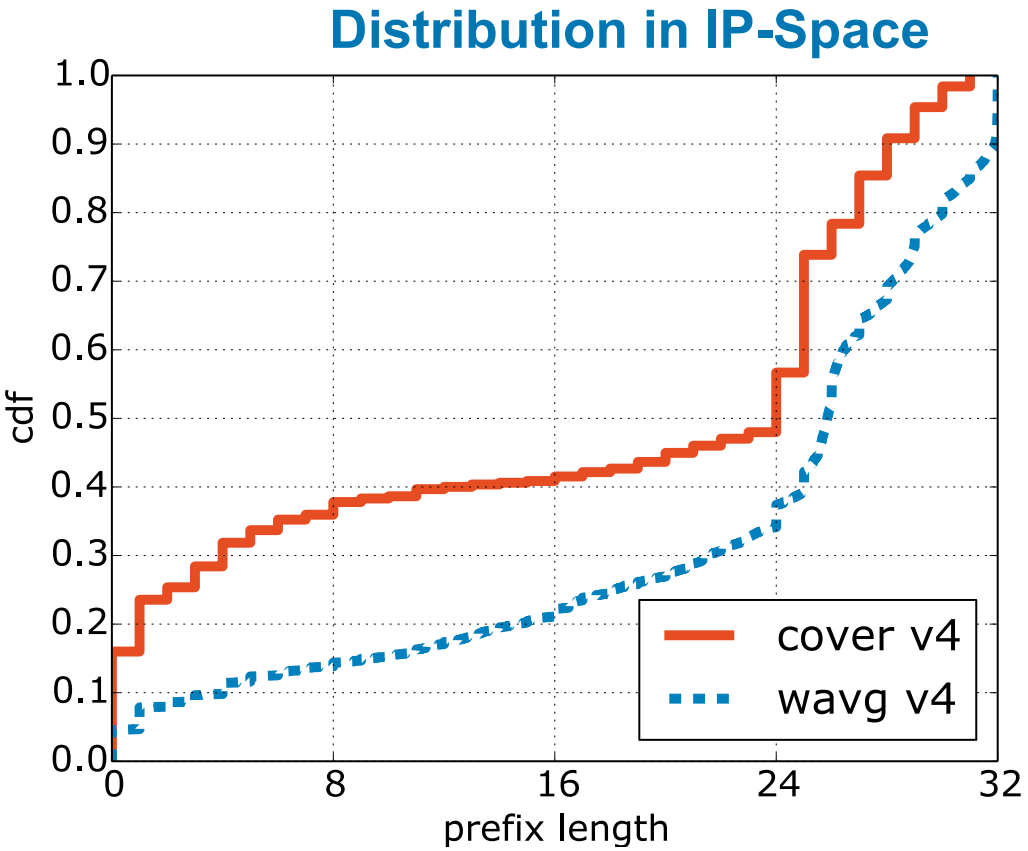
What do the pools look like?

Distribution in IP-Space

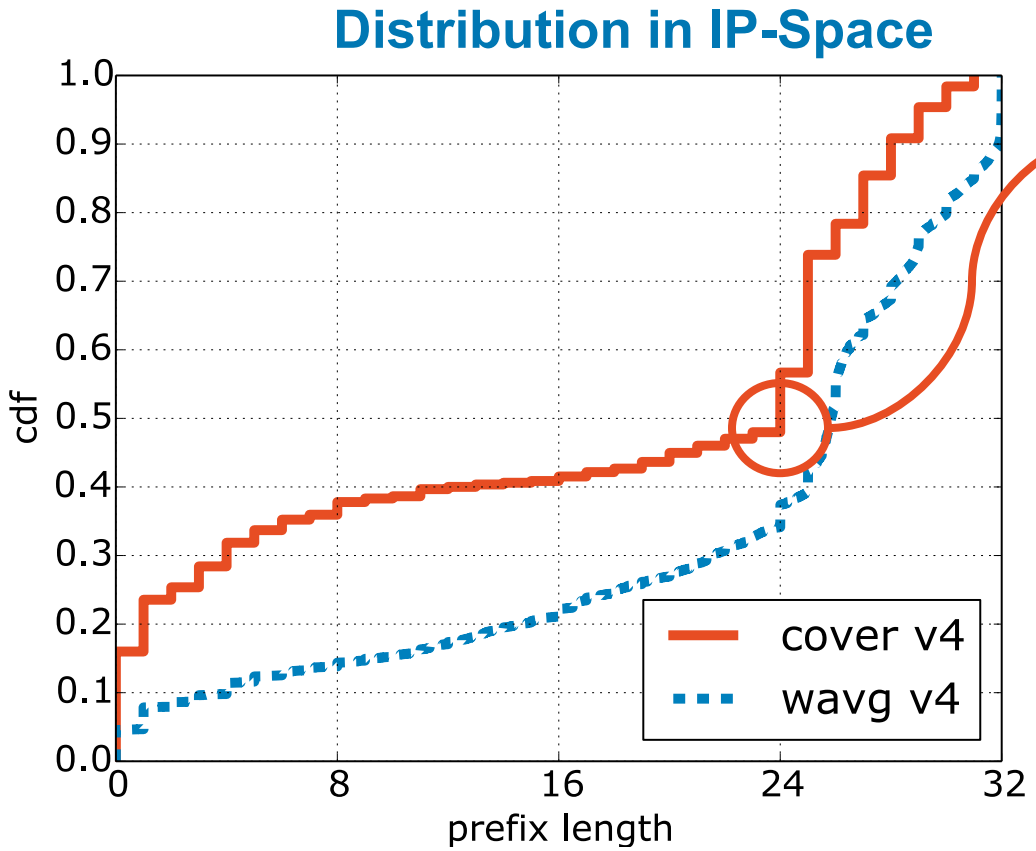
IPv4 representation	Binary representation
1.2.3.1	0000 0001 0000 0010 0000 0011 0000 0001
1.2.3.128	0000 0001 0000 0010 0000 0011 1000 0000
1.2.4.1	0000 0001 0000 0010 0000 0100 0000 0001

Length of covering prefix is 21

What do the pools look like?

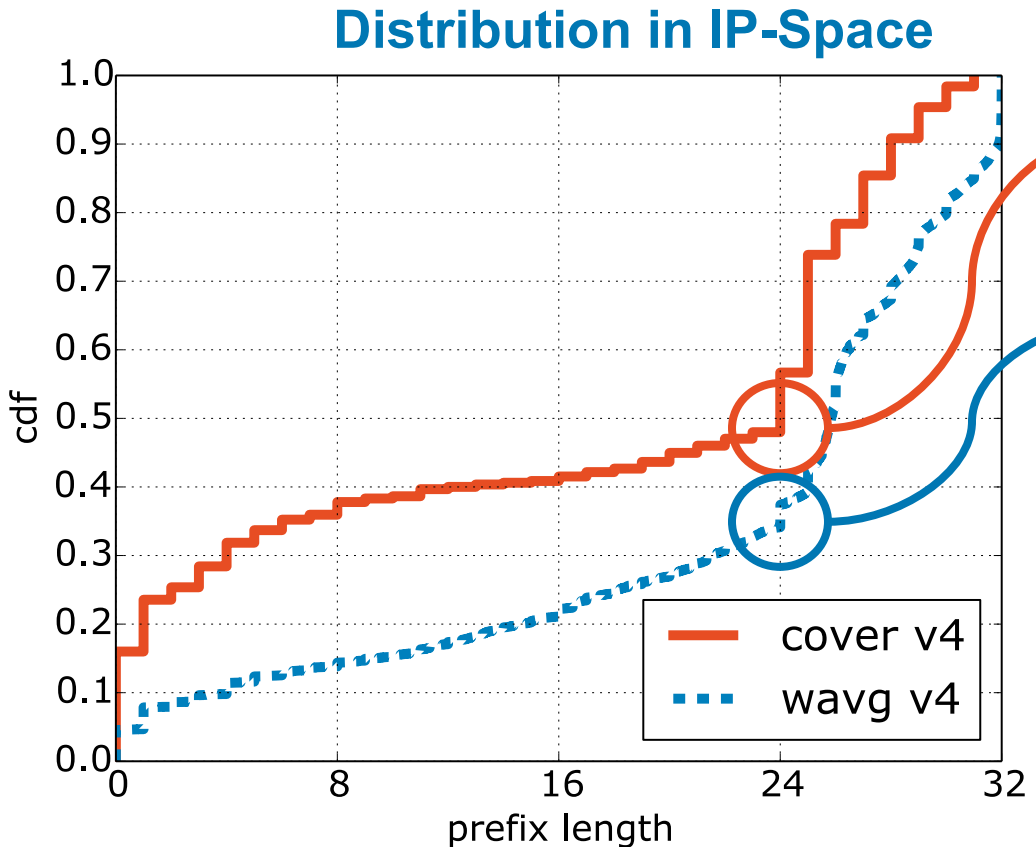


What do the pools look like?



Only 50% of pools are in a single /24

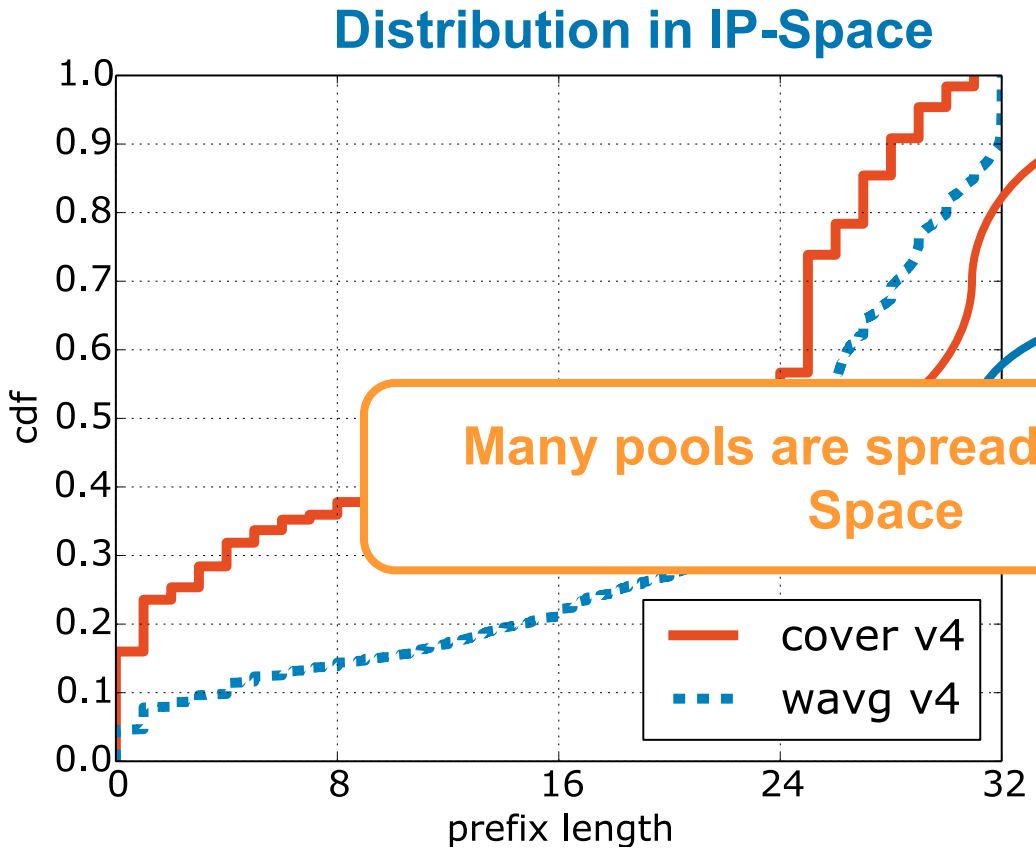
What do the pools look like?



Only 50% of pools are in a single /24

65% of pools are mostly within a single /24

What do the pools look like?



Only 50% of pools are in a single /24

65% of pools are mostly within a single /24

Many pools are spread across IP-Space

What do the pools look like?

Autonomous Systems per Pool

- 85% of pools are within a single AS
- 14% of pools are in 2 ASs
- Comparing WHOIS entries of most frequently occurring AS pairs shows same organization

What do the pools look like?

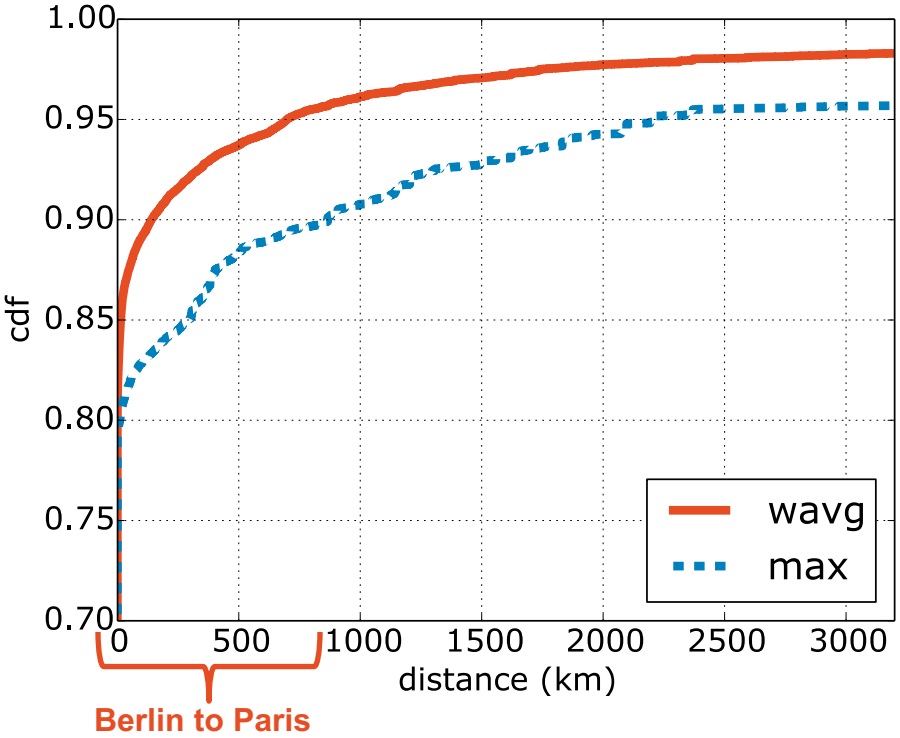
Autonomous Systems per Pool

- 85% of pools are within a single AS
- 14% of pools are in 2 ASs
- Comparing WHOIS entries of most frequently occurring AS pairs shows same organization

Pools very rarely cross organizational boundaries

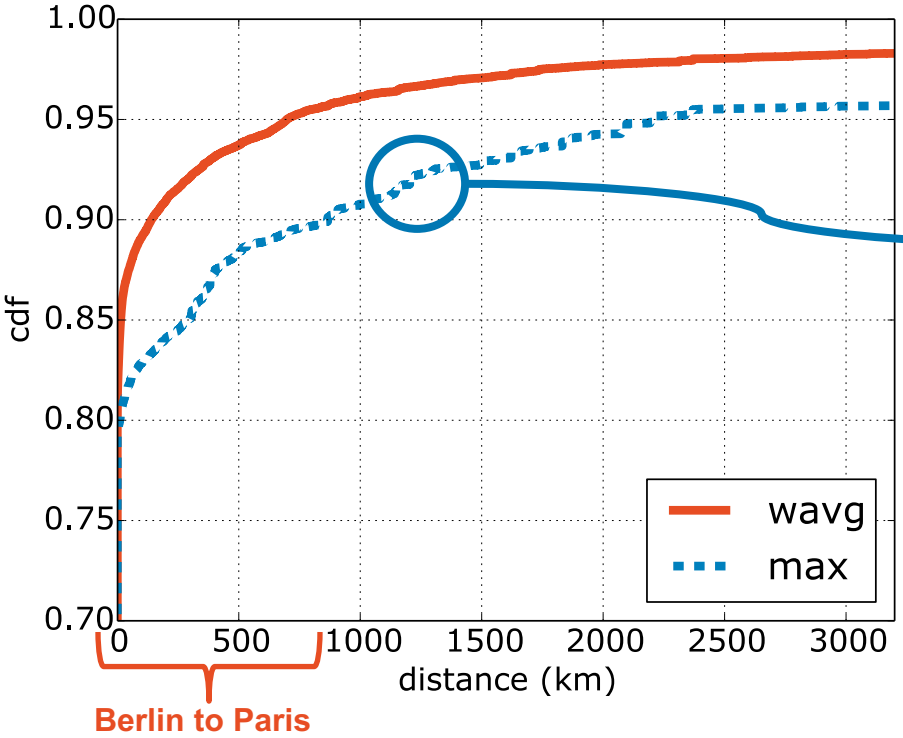
What do the pools look like?

Geographic Distance within Pools



What do the pools look like?

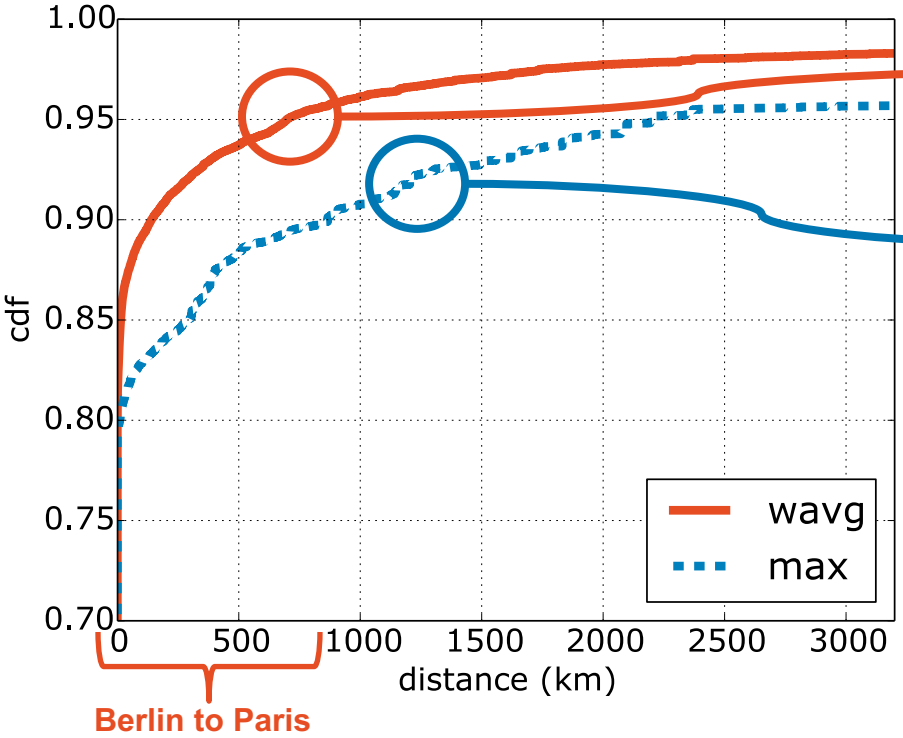
Geographic Distance within Pools



Maximum distance between any 2 IPs in pool

What do the pools look like?

Geographic Distance within Pools

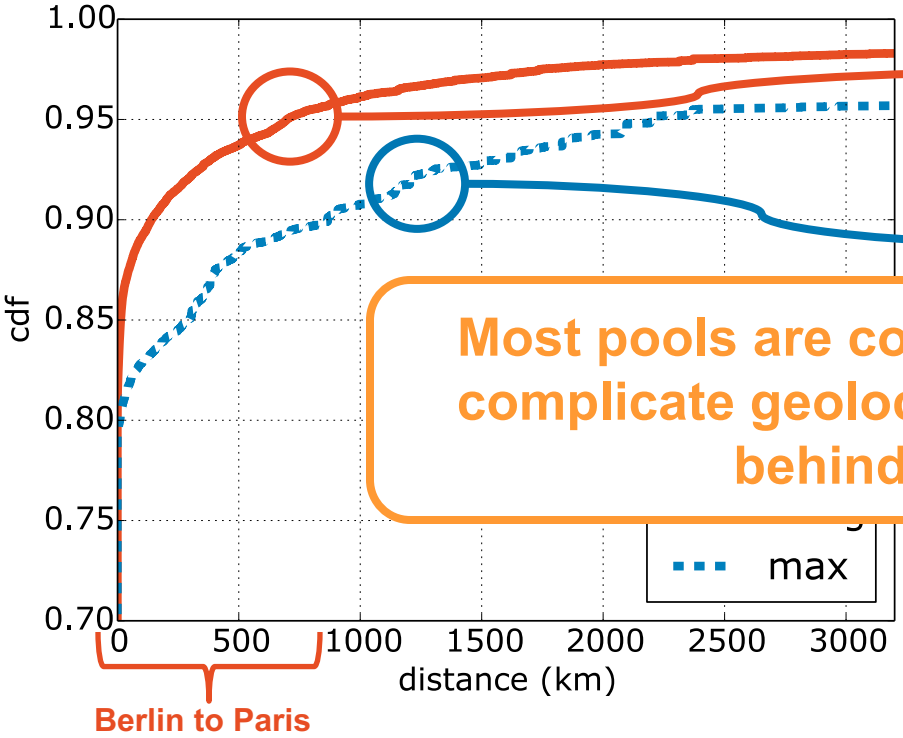


Weighted by number of occurrences

Maximum distance between any 2 IPs in pool

What do the pools look like?

Geographic Distance within Pools



Weighted by number of occurrences

Maximum distance between any 2 IPs in pool

Most pools are compact, but a few complicate geolocating the clients behind them

How are queries distributed within the pool?

Category	
Pools	**100%**

How are queries distributed within the pool?

Pools	100%
→ Dual-Stacks	36%

Category

- Pools with 1 IPv4 / 1 IPv6 address likely dual-stack resolvers

  29% have identifiable patterns:

1.2.3.4 and 89ab::1:2:3:4	10%
1.2.3.4 and 89ab::4	19%

How are queries distributed within the pool?

Category

- Pools with 1 IPv4 / 1 IPv6 address likely dual-stack resolvers
- Use χ^2 to test for uniformly distributing queries within pool

Pools	100%
→ Dual-Stacks	36%
→ Uniform Load Bal	14%

How are queries distributed within the pool?

Category

- Pools with 1 IPv4 / 1 IPv6 address likely dual-stack resolvers
- Use χ^2 to test for uniformly distributing queries within pool
- Pools where the initiator rarely offloads queries to other resolvers

Pools	100%
→ Dual-Stacks	36%
→ Uniform Load Bal	14%
→ Rare Offloading	27%

How are queries distributed within the pool?

Category

- Pools with 1 IPv4 / 1 IPv6 address likely dual-stack resolvers
- Use χ^2 to test for uniformly distributing queries within pool
- Pools where the initiator rarely offloads queries to other resolvers
- Other / unknown

Pools	100%
→ Dual-Stacks	36%
→ Uniform Load Bal	14%
→ Rare Offloading	27%
→ Other/Unknown	23%

How are queries distributed within the pool?

Category

- Pools with 1 IPv4 / 1 IPv6 address likely dual-stack resolvers
- Use χ^2 to test for uniformly distributing queries within pool
- Pools where
  queries to ot
- Other / unkn

Pools	100%
→ Dual-Stacks	36%
→ Uniform Load Bal	14%
→ Rare Offloading	27%
→ Other/Unknown	23%

Wide range of behaviors suggest that recursive resolver pools are used for a variety of purposes

Questions?

Kyle Schomp
kschomp@akamai.com