Yarp'ing the IPv6 Internet

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CMAND

AIMS 2017
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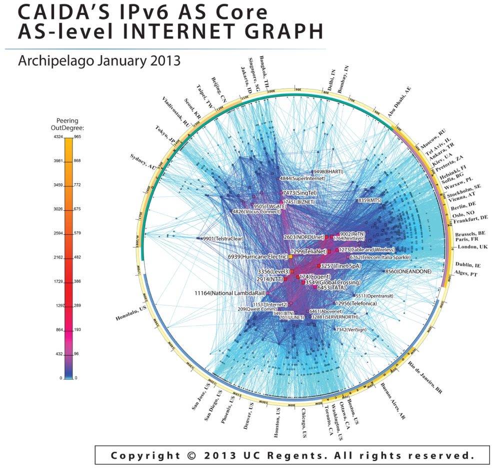
IPv6 Active Topology Discovery


CAIDA'S IPv6 AS Core
AS-level INTERNET GRAPH
Archipelago January 2013

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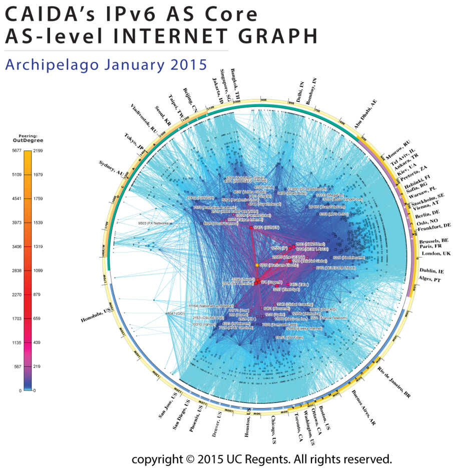
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- Goal: Discover IPv6 Internet's interface-level topology
- But, completeness is a challenge with 2^{128} (~3.4 X $10^{38)}$ unique addresses
- And, rate limiting in IPv6 is more aggressive than in IPv4
- Current state-of-the-art: scan small number of prefixes slowly.

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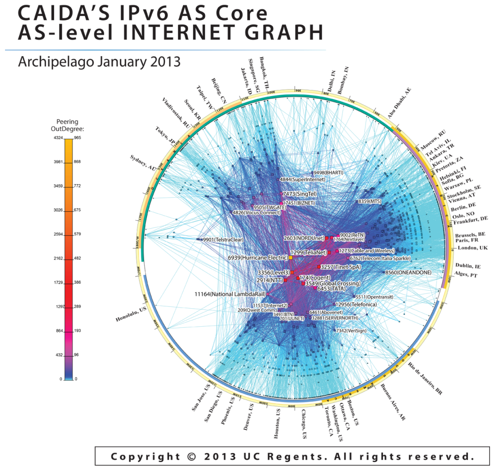
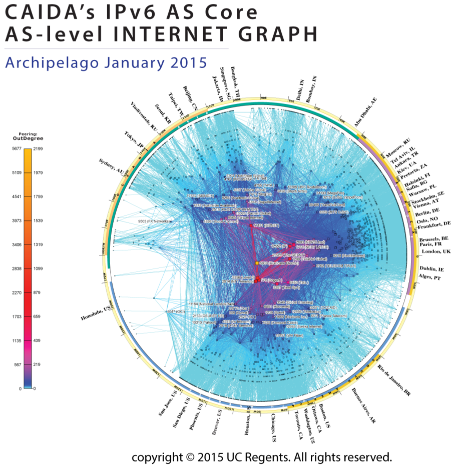
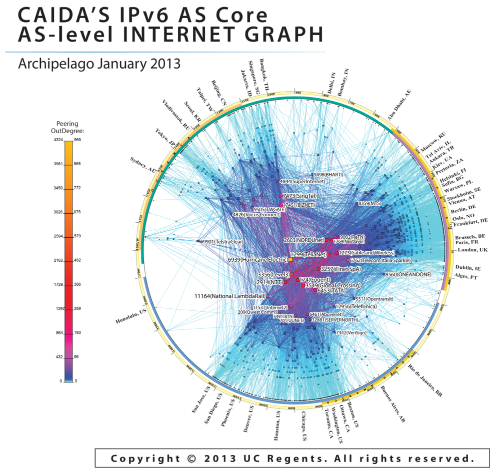
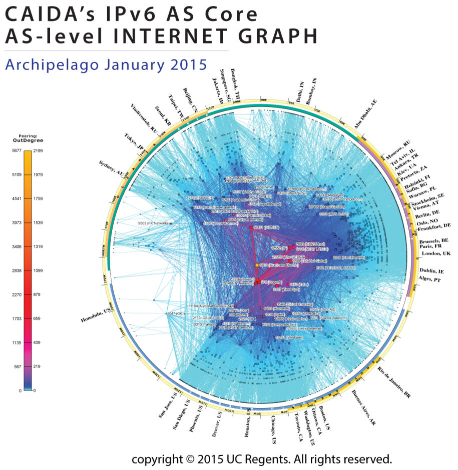




IPv6 Topology Mapping Today



CAIDA IPv6 Topology Probing



- Send probes toward each globally announced /48 or shorter prefix once every 48 hours
- 37,797 prefixes as of February 12, 2017
- From 46 globally distributed Ark VP
- Each VP scamper icmp-paris traceroutes toward ::1 and a random address in each prefixes.

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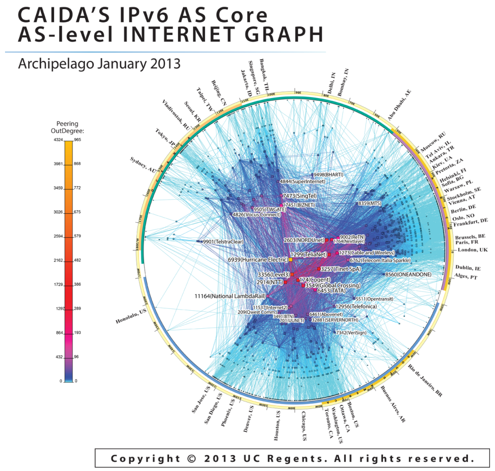
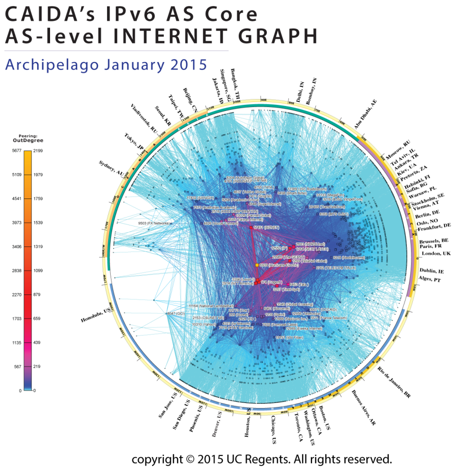


Rohrer et al: IPv6 Scans



- Used Ark
- Largest scan to date probing ~406 million prefixes
- (Data publicly available)
- Traceroute to the ::1 in each /48 in all /32's
- Scan took 4 months to complete (Nov 14 – Mar 15)
- Current routing table contains ~536 million prefixes
- Increase of 32% in 2 years

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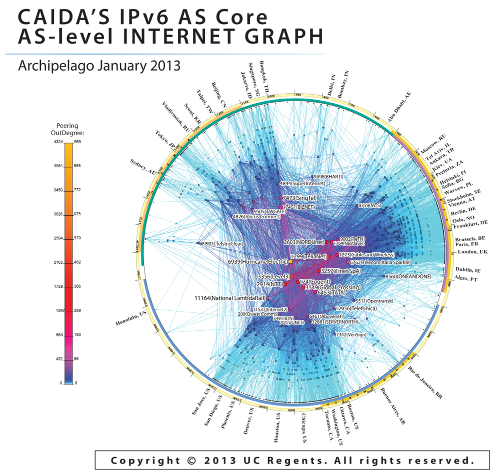
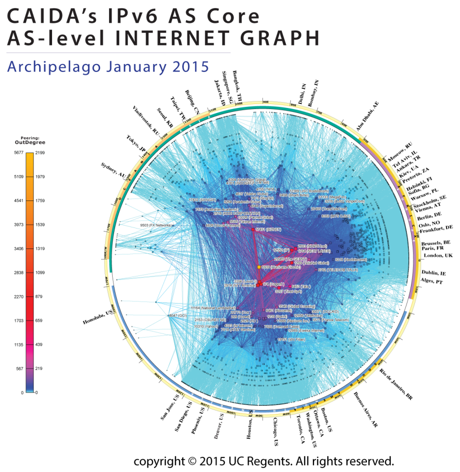


Foremski et al: Entropy/IP



- IMC 2016 study to find active portions of IPv6 Internet
- Combines information theory and machine learning to probabilistically model IPv6 addresses
- Ability to generate candidate address list for active scanning can be used to reduce the target space

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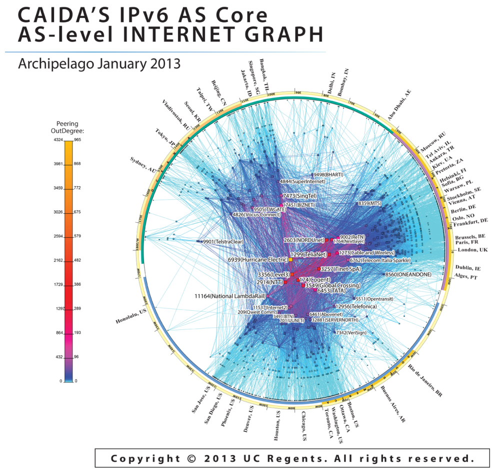
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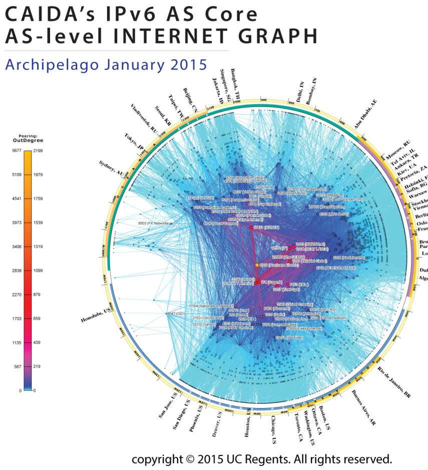
Why is mapping IPv6 Important?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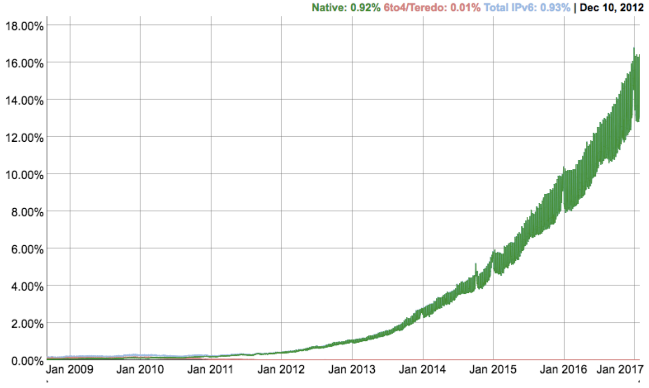
- IPv6 Topology mapping crucial to:
  - Security
  - Policy
  - Research
- IPv6 use has doubled every year since 2012
- Measurement community needs:
  - Better visibility into IPv6 topology
  - Better tools



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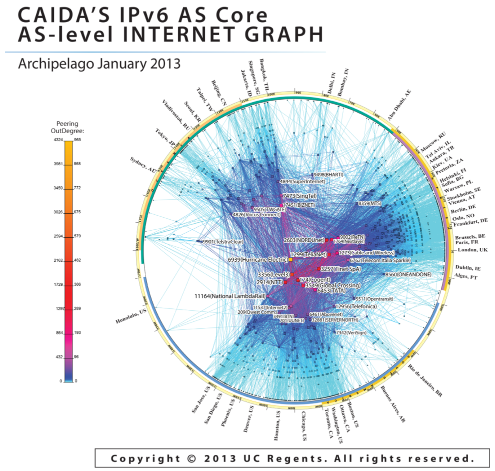

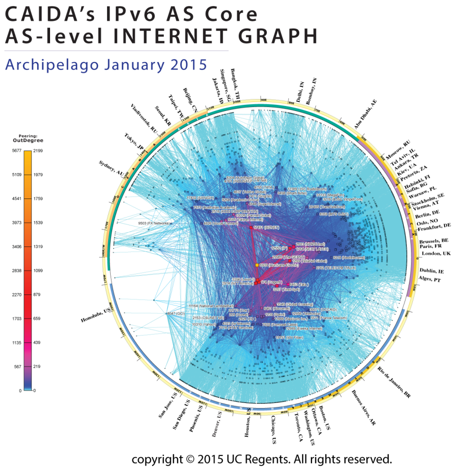

Our approach: Yarrp6

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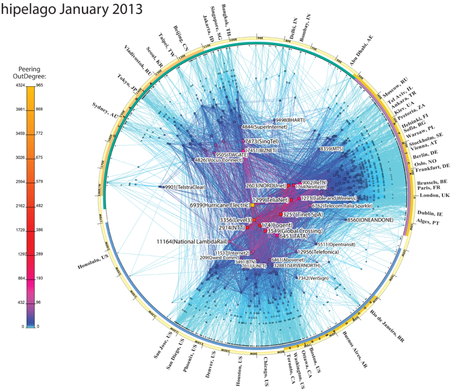

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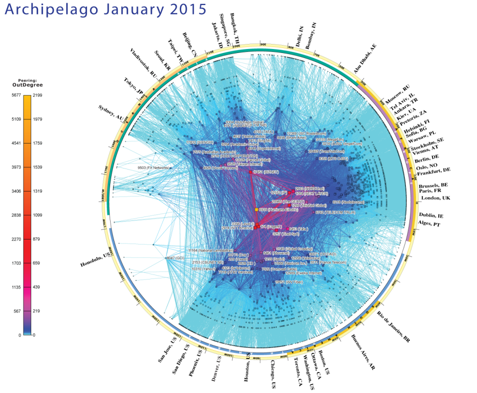

What is Yarrp?

https://www.cmand.org/yarrp/

- A new <u>high-speed</u> <u>stateless</u> traceroute technique (IMC 2016 demonstrates topo discovery @100K pps)
- Reconstructs states from data encoded in IP and TCP headers of ICMP quotation
- Currently only supports IPv4 and TCP probes
- (Presently working w/ CAIDA to deploy in production)

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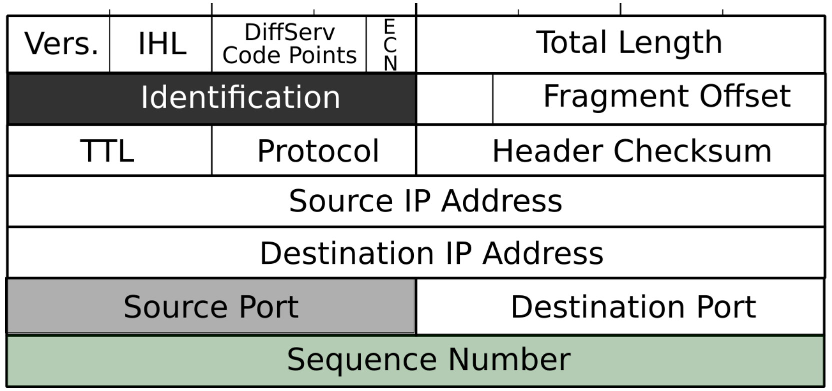
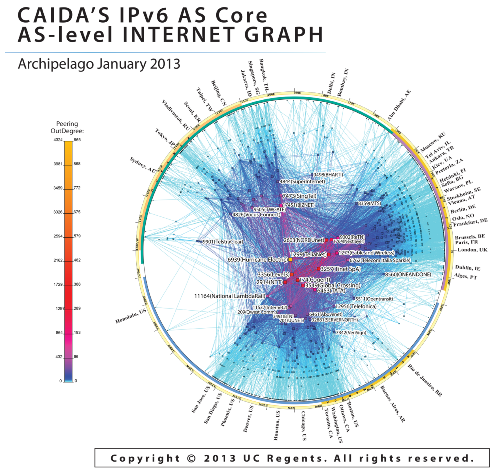


Vers.	IHL	DiffServ Code Points	ECN	Total Length	
Identification					Fragment Offset
TTL	Protocol			Header Checksum	
Source IP Address					
Destination IP Address					
Source Port				Destination Port	
Sequence Number					

■ Send TTL
▨ cksum(IP Dest)
🟩 Send Elapsed Time



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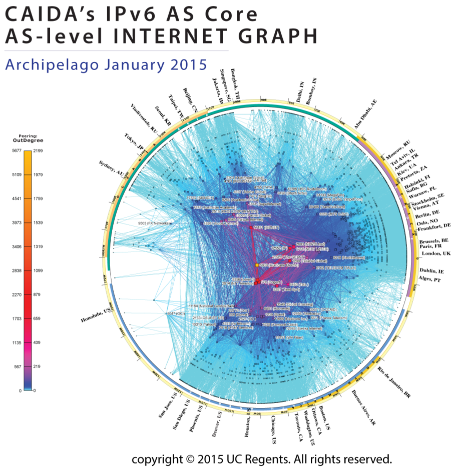
What is Yarrp6?



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- Yarrp6 is a port of Yarrp for IPv6
- Also stateless and randomized
- But encodes state in a different manner
- Maintains Paris traceroute method for all scan
- Adds the capability to do ICMPv6 and UDP scans as well as the TCP SYN and TCP ACK provided by Yarrp

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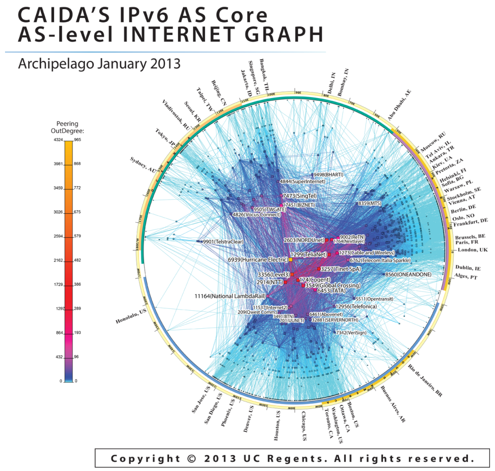
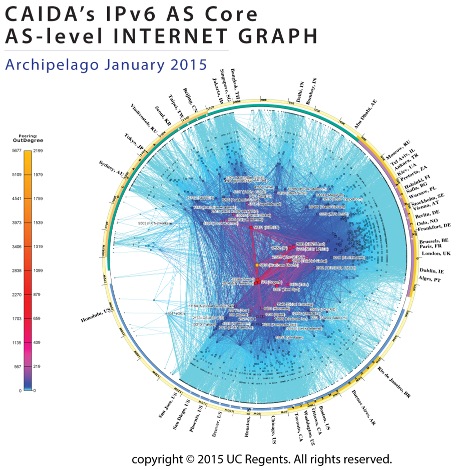


Porting Yarrp to IPv6



- Extending Yarrp to IPv6 is not a trivial task
- Issues:
  - How to encode state
  - Yarrp permutation library's 32-bit block size too small for IPv6
  - Raw sockets in IPv6 do not allow for full control of packet headers
  - Rate-Limiting of ICMPv6 error messages
  - Unable to detect responses to TCP probes from targets

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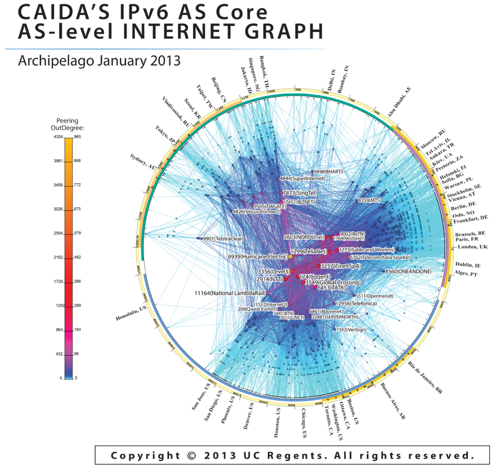
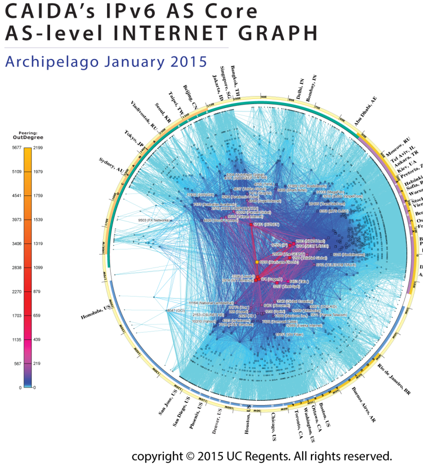
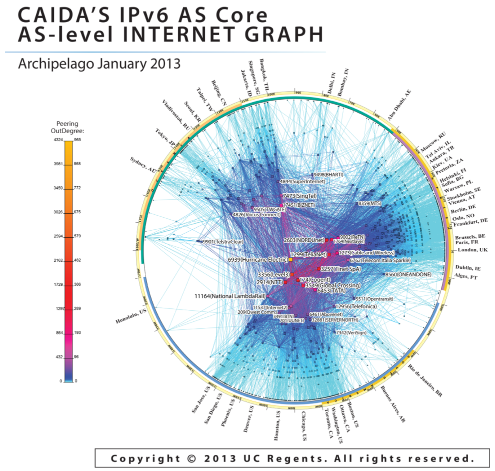


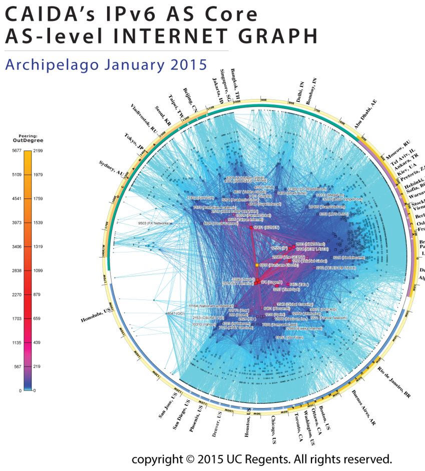
Initial Experiments

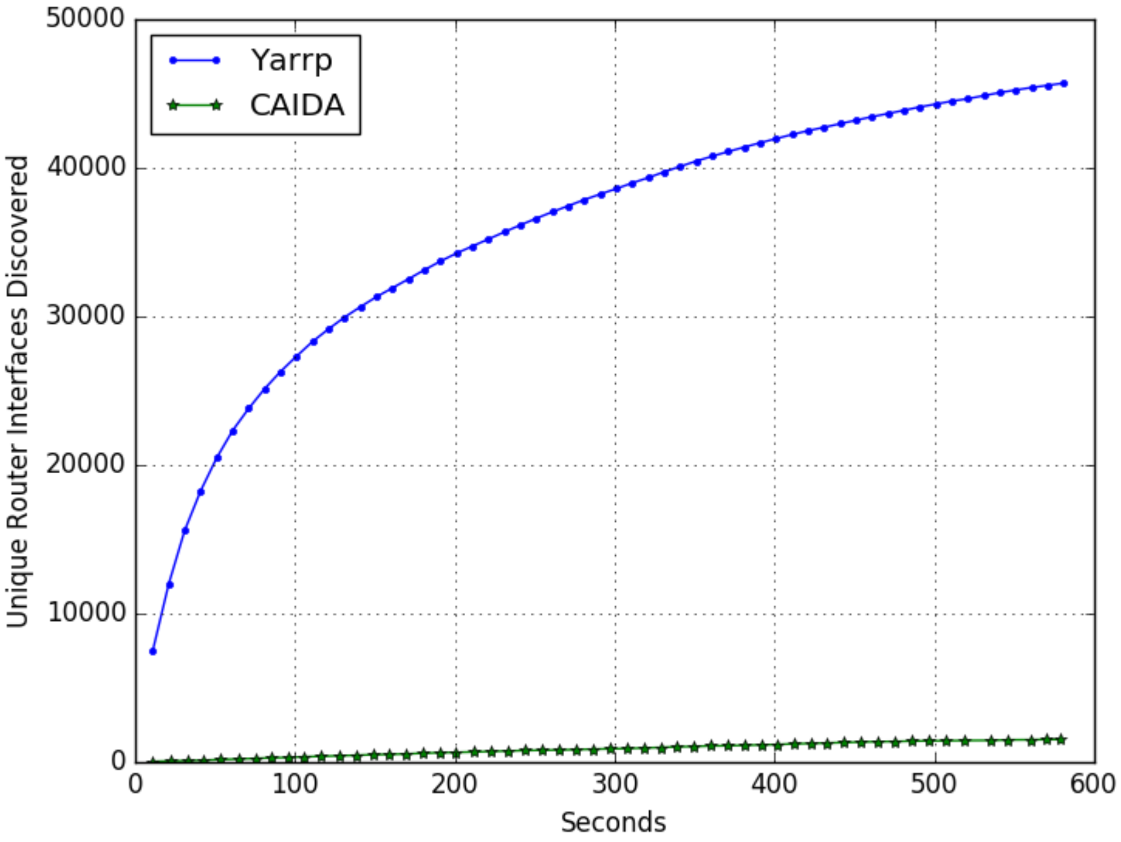


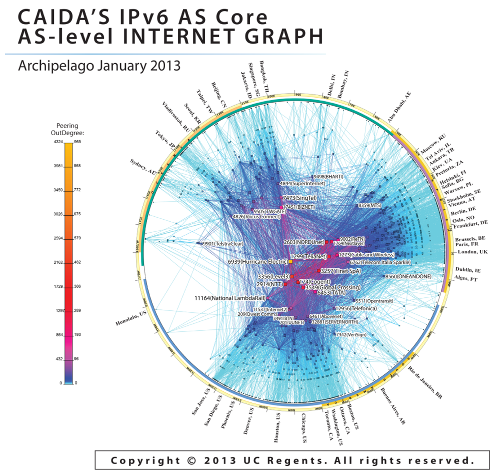
- Sought to validate and compare Yarrp to current state-of-the-art:
  - Recall of Yarrp6 vs. CAIDA v6 probe cycle
  - Speed of Yarrp6 vs. CAIDA v6 probe cycle
- Compared using CAIDA's IPv6 data from san-us VP scans done on February 12, 2017
- Same target list containing 75,594 addresses



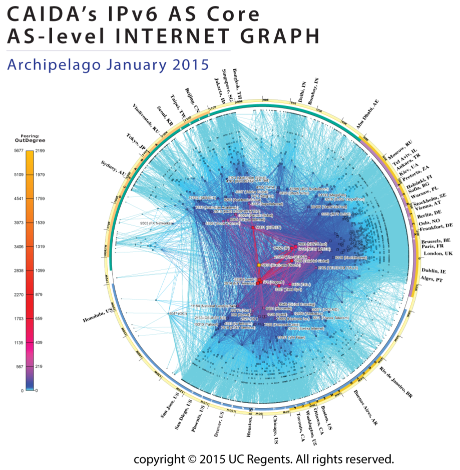
Yarrp6 vs. CAIDA (cont.)



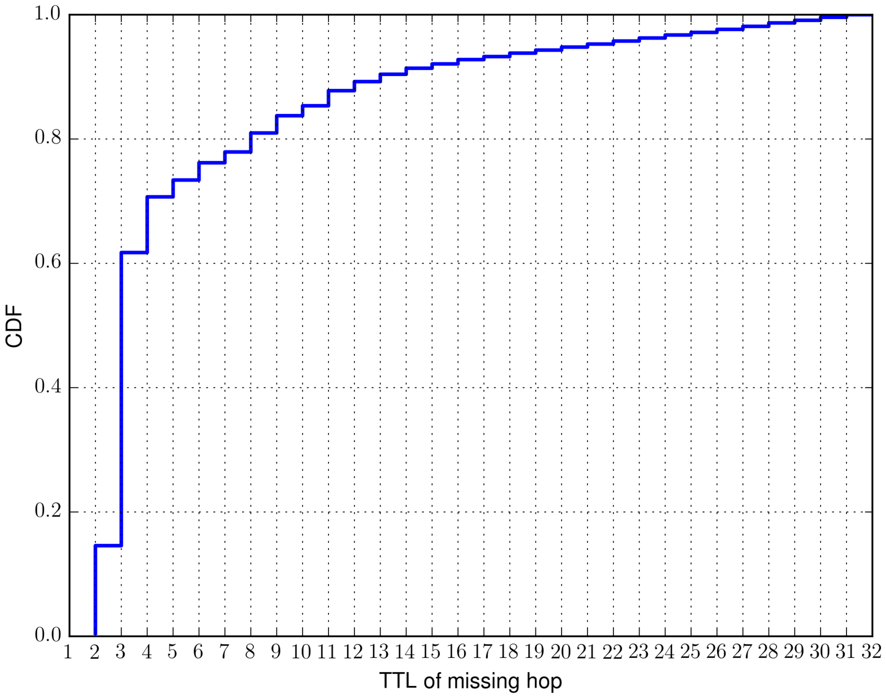




Rate Limiting of IPv6



- "an IPv6 node MUST limit the rate of ICMPv6 error messages it originates." – RFC 4443
- We did observe rate-limiting on IPv6
- Hops 1-4 accounted for ~75% of all missing hops
- Only 57 unique addresses missing from these hop



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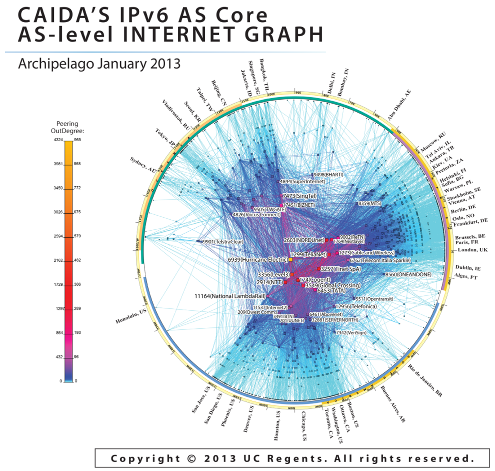
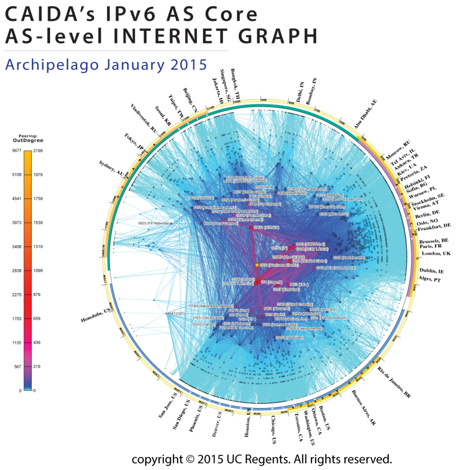
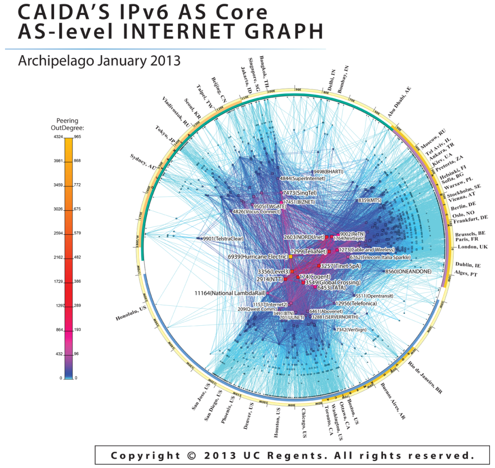


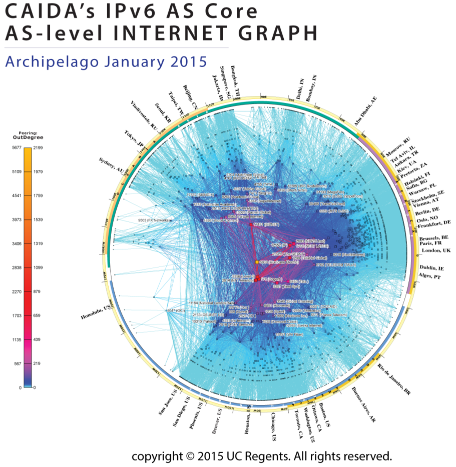
Comparison of Transport Protocols



- Used yarrp6 to compare probe protocol
- Comparison of Transport Protocol on forward IP path inference.
- Used ICMPv6, UDP, TCP SYN, and TCP ACK Paris traceroute probes
- 3 metrics used for comparison:
  - Destination Reached
  - Complete Paths
  - Unique IP Links



Comparison of Transport Protocols (cont.)



Probe Method	Unique Interface	Destinations Reached	Complete IP Paths	Unique IP Links
ICMPv6	45,706	9,535	3,562*	57,667
UDP	34,567	4,455	1,776*	37,514
TCP SYN	34,879	N/A#	N/A#	37,655
TCP ACK	35,178	N/A#	N/A#	38,262

* Hop 3 skipped in determination of complete path
# Unable to retrieve encoded information from TCP responses

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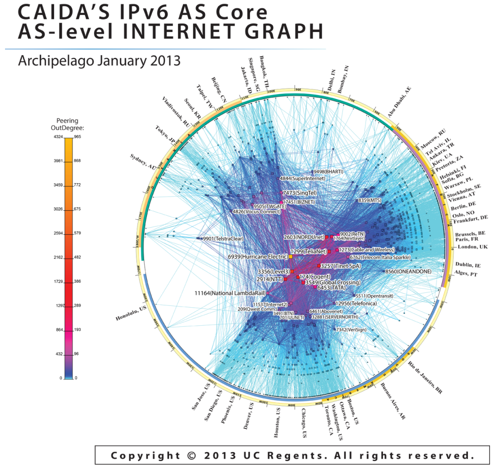

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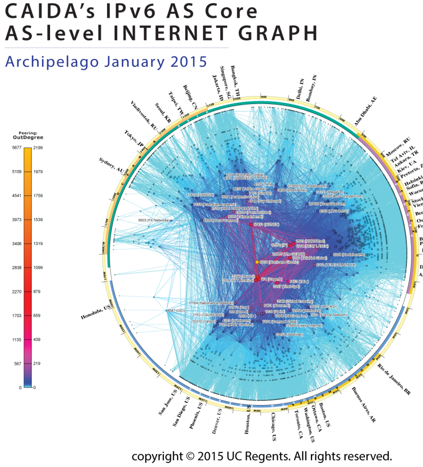
Future Work



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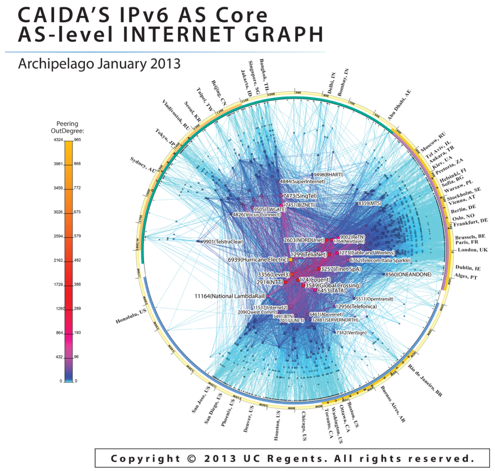
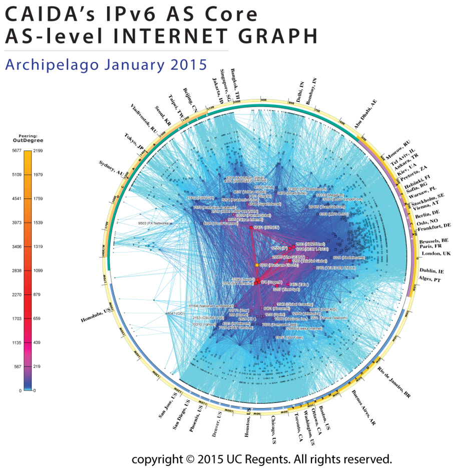
- Working w/ Dave Plonka: Use Entropy/IP to generate target list for Yarrp6 to scan.
- Comparison of Yarrp6 to larger dataset such as Rohrer et al. dataset
- Running scans in rapid succession to allow for study into dynamics of IPv6 Internet.
- Yarrp available now; Yarrp6 real soon now. Contact us to beta!

https://www.cmand.org/yarrp/





Questions?

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https://www.cmand.org/yarrp/