

Prisoner of IPv4

Lee.Howard@Retevia.net



TCO of CGN

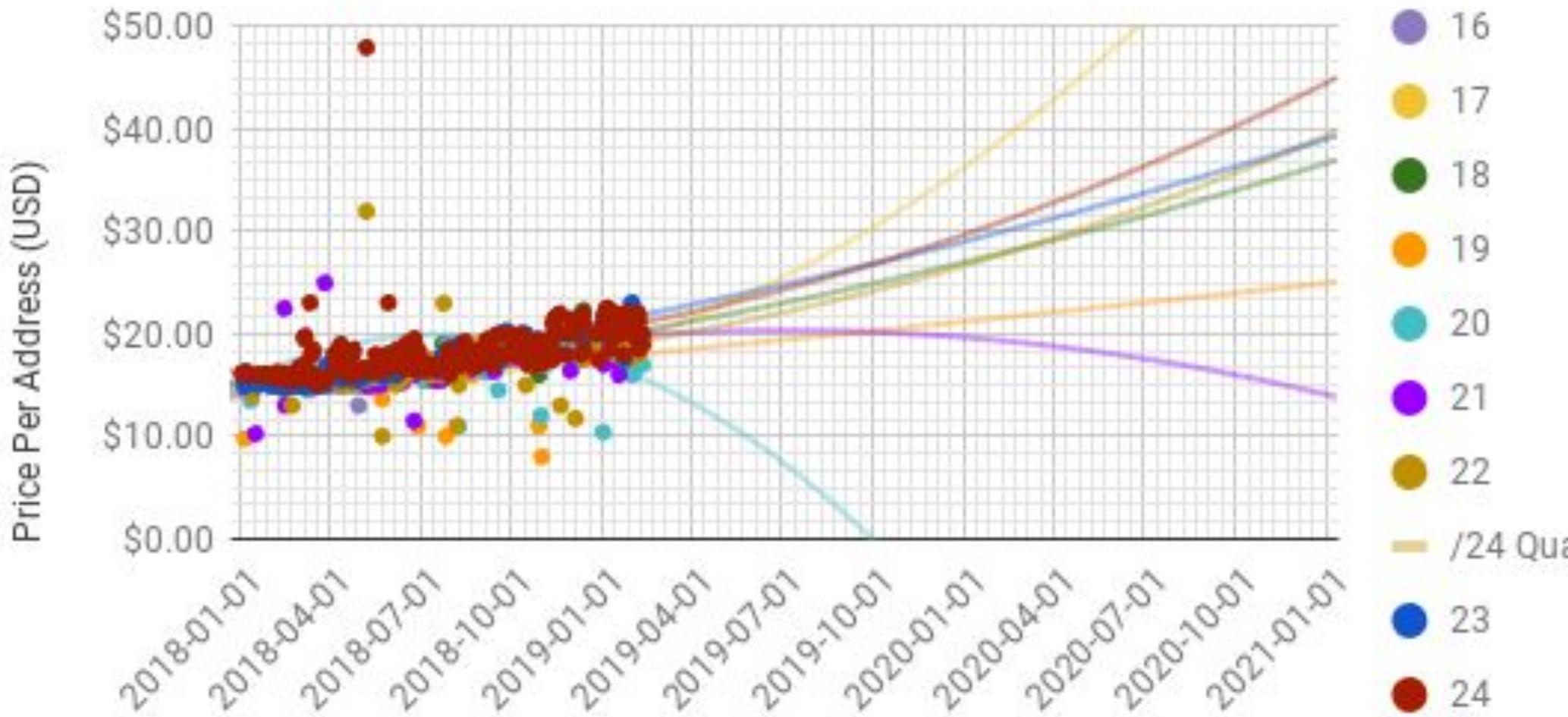
Number of users covered by CGN	10,000						
				Cost per support call		\$50	
Cost of CGN device (per 10,000 users)	\$ 150,000						
Cost of logging systems	\$ 10,000			Average Annual Revenue per User		\$400	
Software development	\$ 10,000			Margin		30%	
CAPEX Total	\$ 170,000			Profit		\$120	
OPEX: Space, power, cooling, personnel	\$ 15,000			Average Customer Lifetime (months)		16	
Use	Number of Potential Users	Percent Affected	Number Affected	Percent Calling	Number of Support Calls	Percent Cancelling	Number of Lost Users
Xbox	2100	20%	420	25%	262	50%	210
PS3	1100	50%	550	25%	137	50%	275
P2P	1500	80%	1200	25%	300	50%	600
Netflix	1200	5%	60	25%	15	50%	30
Misc.	800	100%	800	25%	200	50%	400
	6,700		3,030		914		1515

TCO of CGN

Cost of CGN - 5 year, per user	\$332.07
Profit (5 year)	\$268
Profit (1 year)	\$53.59
Margin	13%
Rules of Thumb:	
Buy IPv4 address if less than (Half of expected lifetime profit under CGN)	\$35.72
Sell IPv4 address if greater than (Expected lifetime profit of customer)	\$71.45

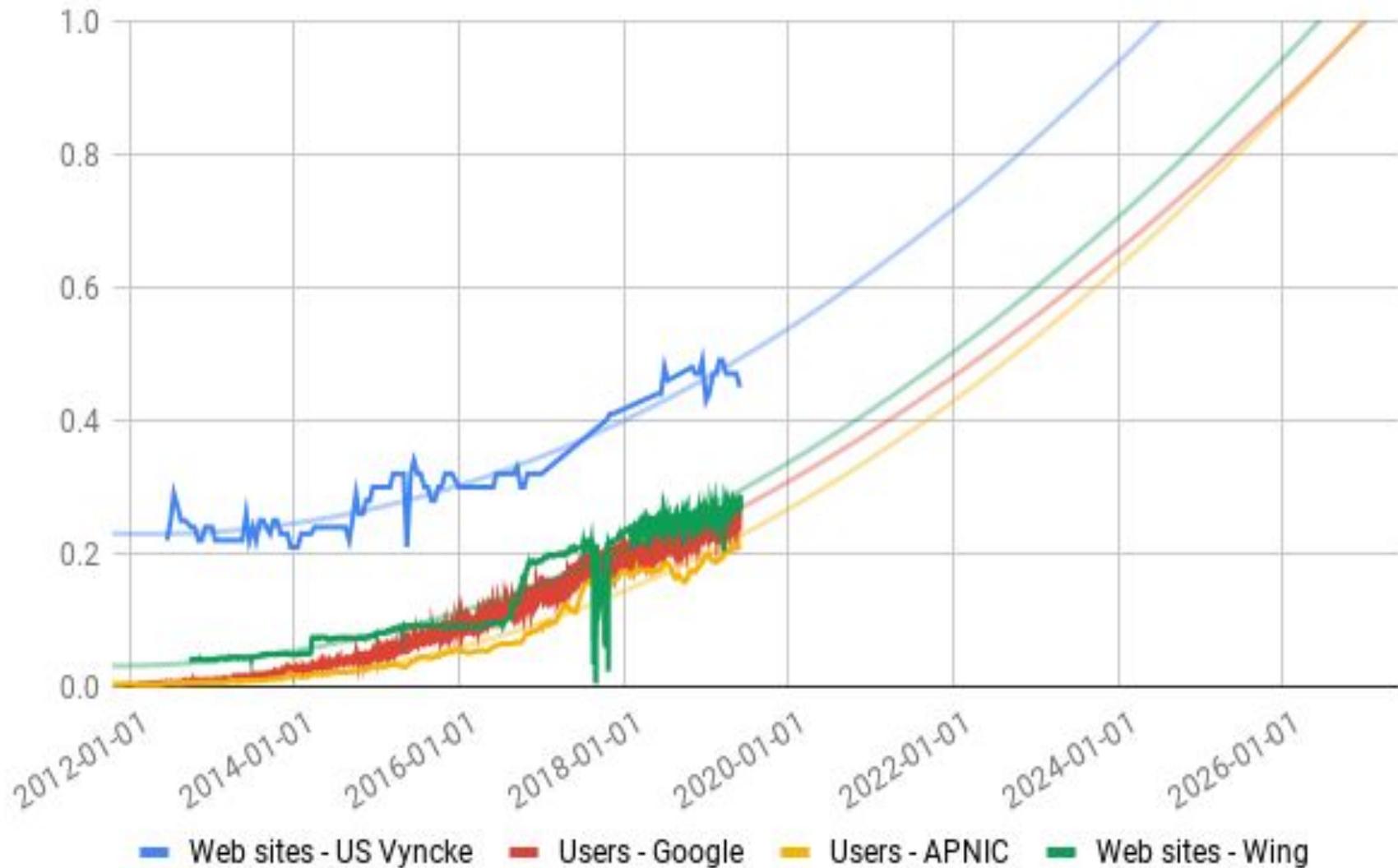
IPv4 Market Prices by Size

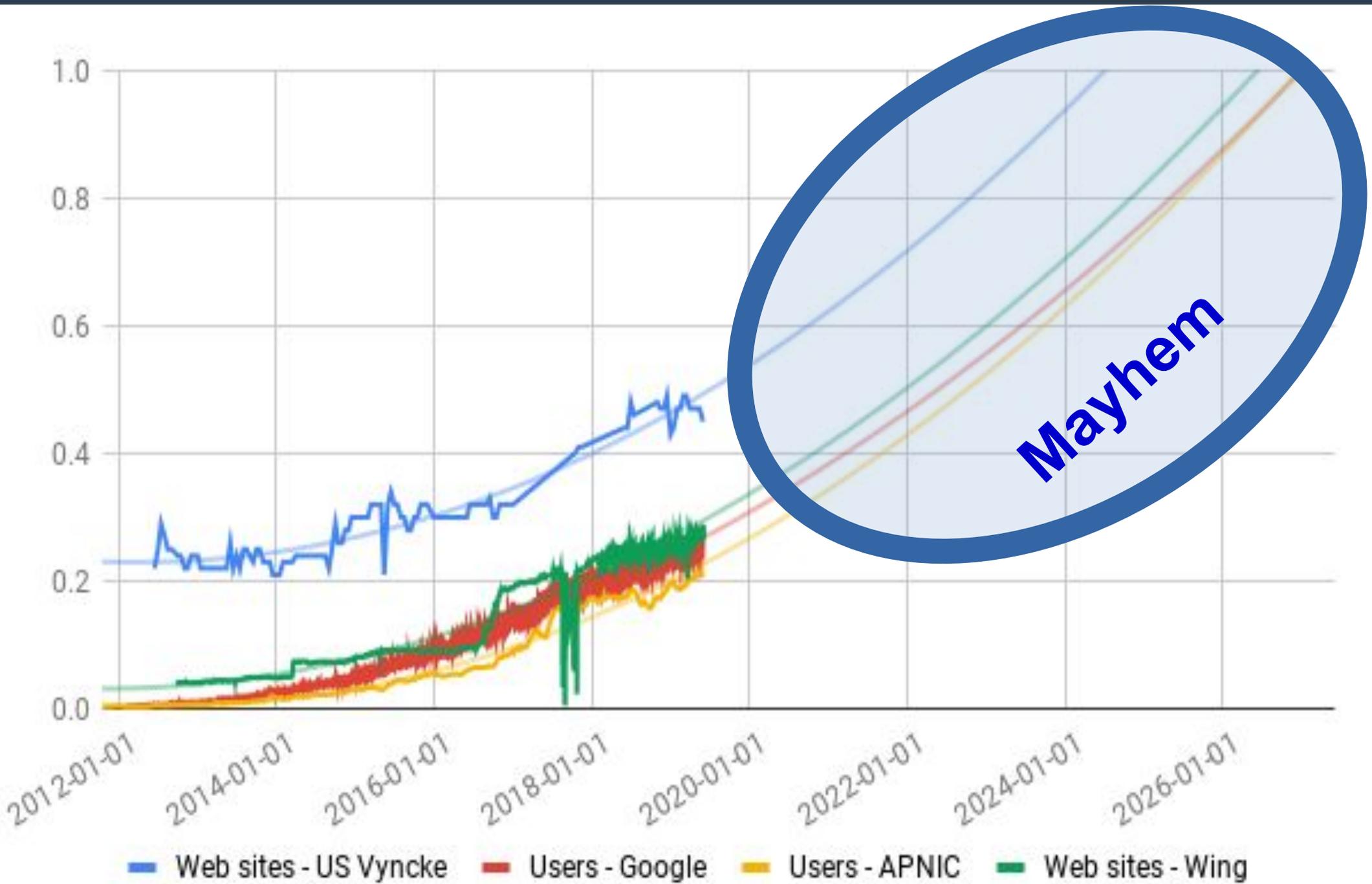
Data from IPTrading and IPv4auctions.com



Lee Howard, Retevia

IPv6 Penetration Extrapolation





Prisoner's Dilemma

When can I stop using IPv4?

A light blue thought bubble with a dark blue outline and three smaller circles at the bottom left.

All I have to do is
outlast the
competition

A light blue thought bubble with a dark blue outline and three smaller circles at the bottom right.

All I have to do is
outlast the
competition

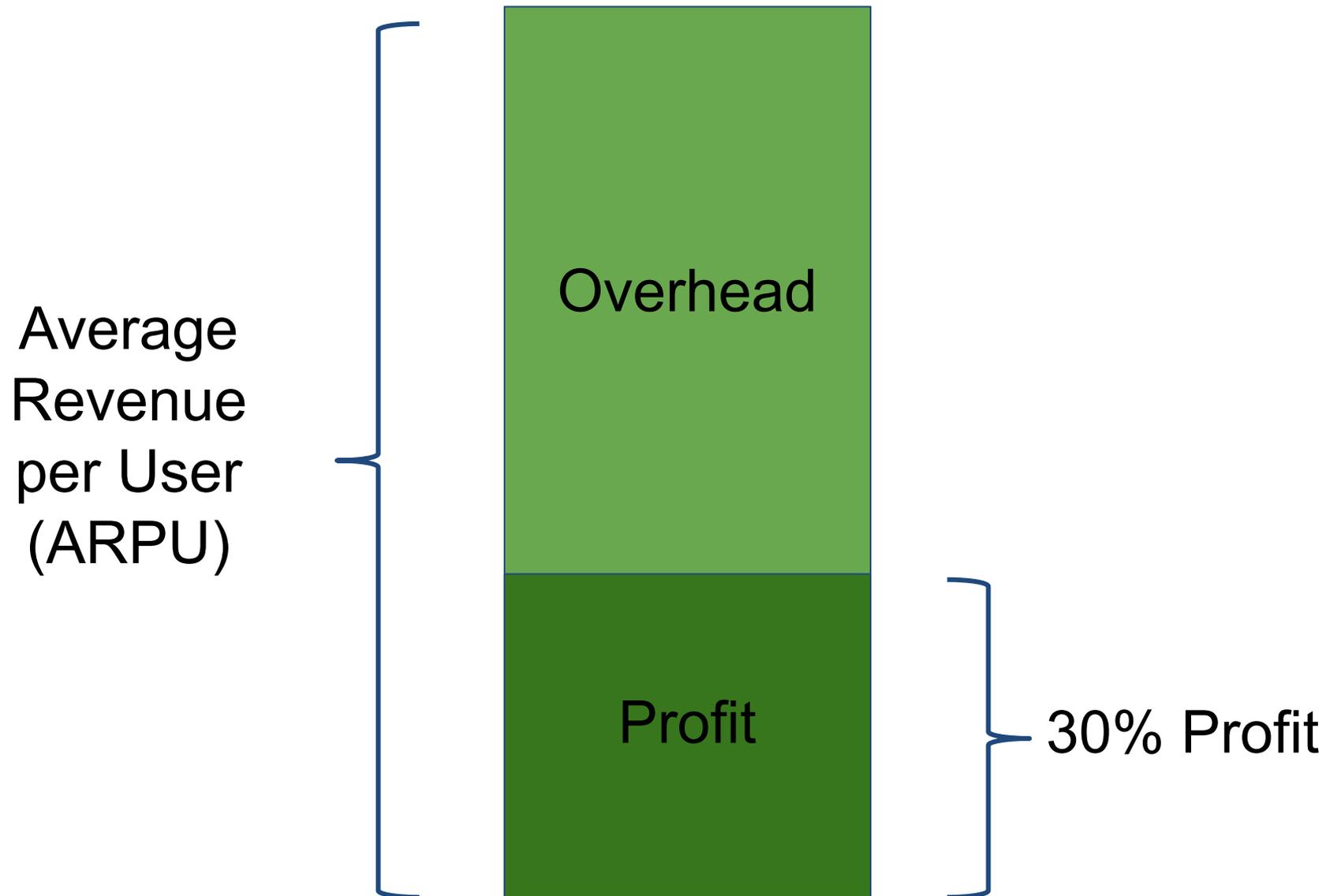
Prisoner's Dilemma

	Content Promotes IPv6	Content Does Nothing
Carriers Promote IPv6	<ul style="list-style-type: none">· Content wins· Carriers win	<ul style="list-style-type: none">· Content no change· Carriers lose
Carriers Do Nothing	<ul style="list-style-type: none">· Content loses· Carriers no change	<ul style="list-style-type: none">· Content loses· Carriers lose

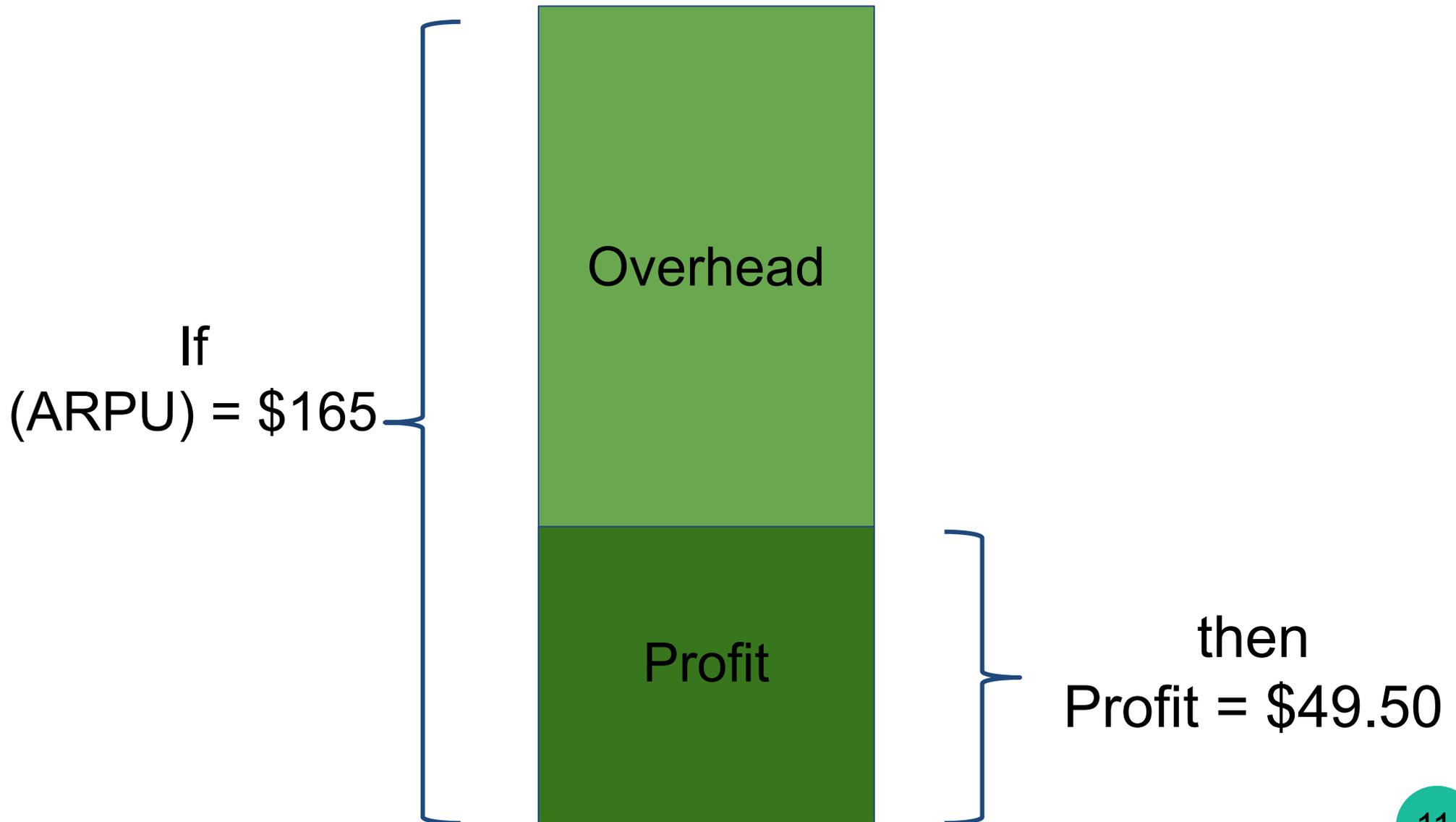
Payoff Matrix

Fixed Broadband ISPs and Mobile Carriers

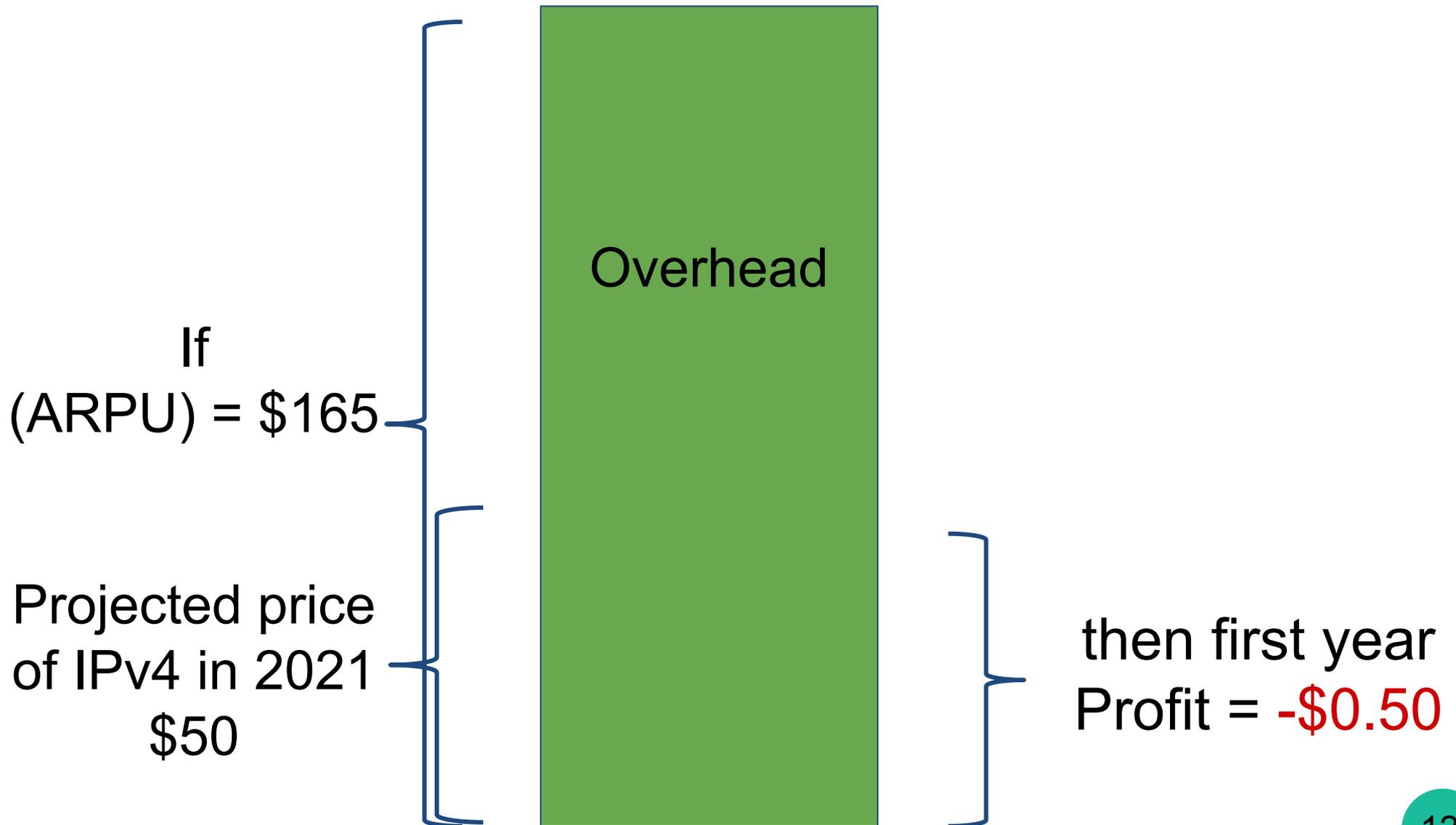
Compare Profitability: Customer Fee vs. Sale of Address



Compare Profitability: Customer Fee vs. Sale of Address



Compare Profitability: Customer Fee vs. Sale of Address



Countries with a Tier <\$50 Profit

Afghanistan	Italy	Romania
Algeria	Japan	Russian Federation
Argentina	Kazakhstan	Serbia
Armenia	Kuwait	Slovakia
Azerbaijan	Kyrgyzstan	Somalia
Bangladesh	Latvia	South Africa
Belarus	Lebanon	Sri Lanka
Bolivia	Lithuania	Sudan
Bosnia and Herzegovina	Macedonia	Swaziland
Brazil	Mexico	Syria
Bulgaria	Moldova	Taiwan
China	Mongolia	Tajikistan
Egypt	Mozambique	Tunisia
France	Myanmar	Turkey
Georgia	Nepal	Ukraine
Germany	New Caledonia	Uruguay
Hungary	Pakistan	Uzbekistan
India	Palestine, State of	Venezuela
Iran	Papua New Guinea	Vietnam
Israel	Poland	Yemen

Within Two Years, Options Are:

- A. Raise prices
- B. Require extended contracts
- C. Address sharing (CGN)
- D. Deploy IPv6
- E. Sell addresses
- F. Combination of the above

Probable Combination

- If 50% IPv6 and . . . lower users ok with CGN

UNITED STATES

Fit Y-Axis To Data

Export All ▼

- IPv6 Deployment - Weekly Growth - Monthly Growth

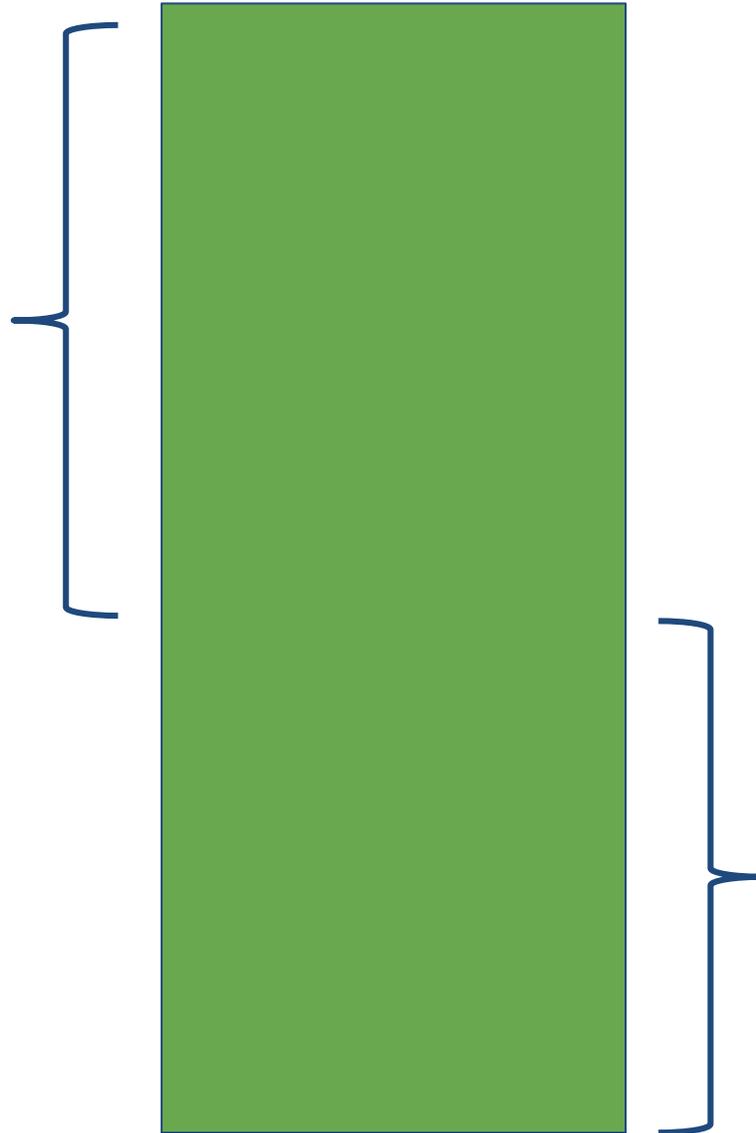


Plan:

1. Deploy IPv6
2. Put lowest tier behind CGN (NAT64, etc.) at 100:1
3. Profit! Sell 99% of addresses

Cost of CGN

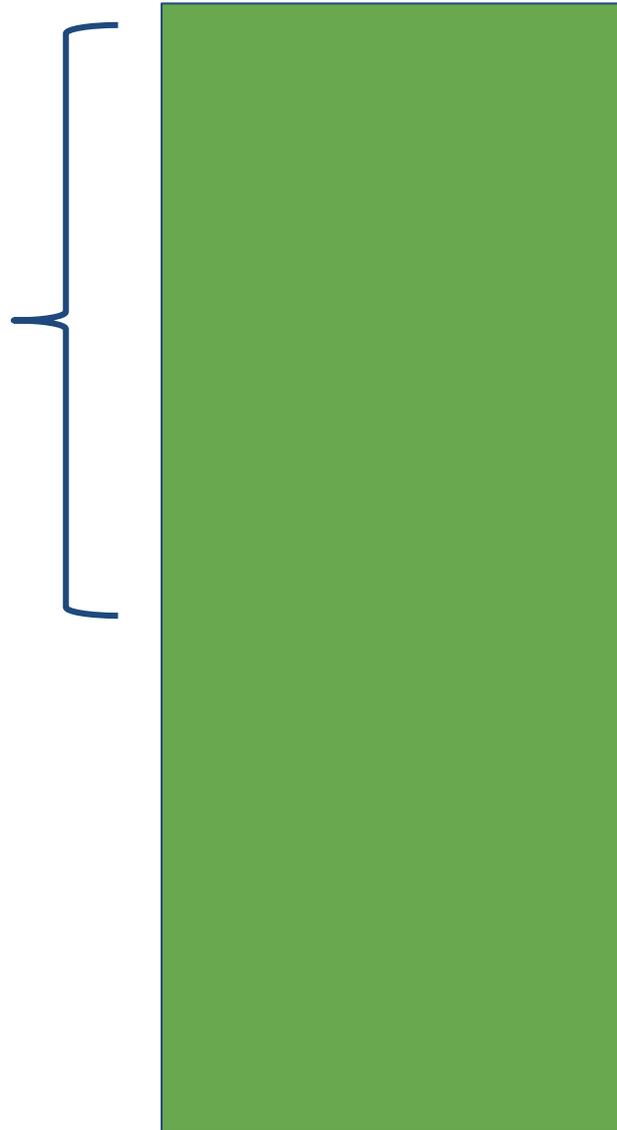
Hardware:
\$1000/Gbps



IPv4 Addresses:
\$50 *
How many?

Cost of CGN

Hardware:
\$1000/Gbps



1 Gbps can serve
200-1000 users at peak.
“Modeling residential
subscriber bandwidth
demand” thread. Thanks,
NANOG!
Lower in a few years, so
let’s say 400.

IPv4 Addresses:
\$50 *
How many?

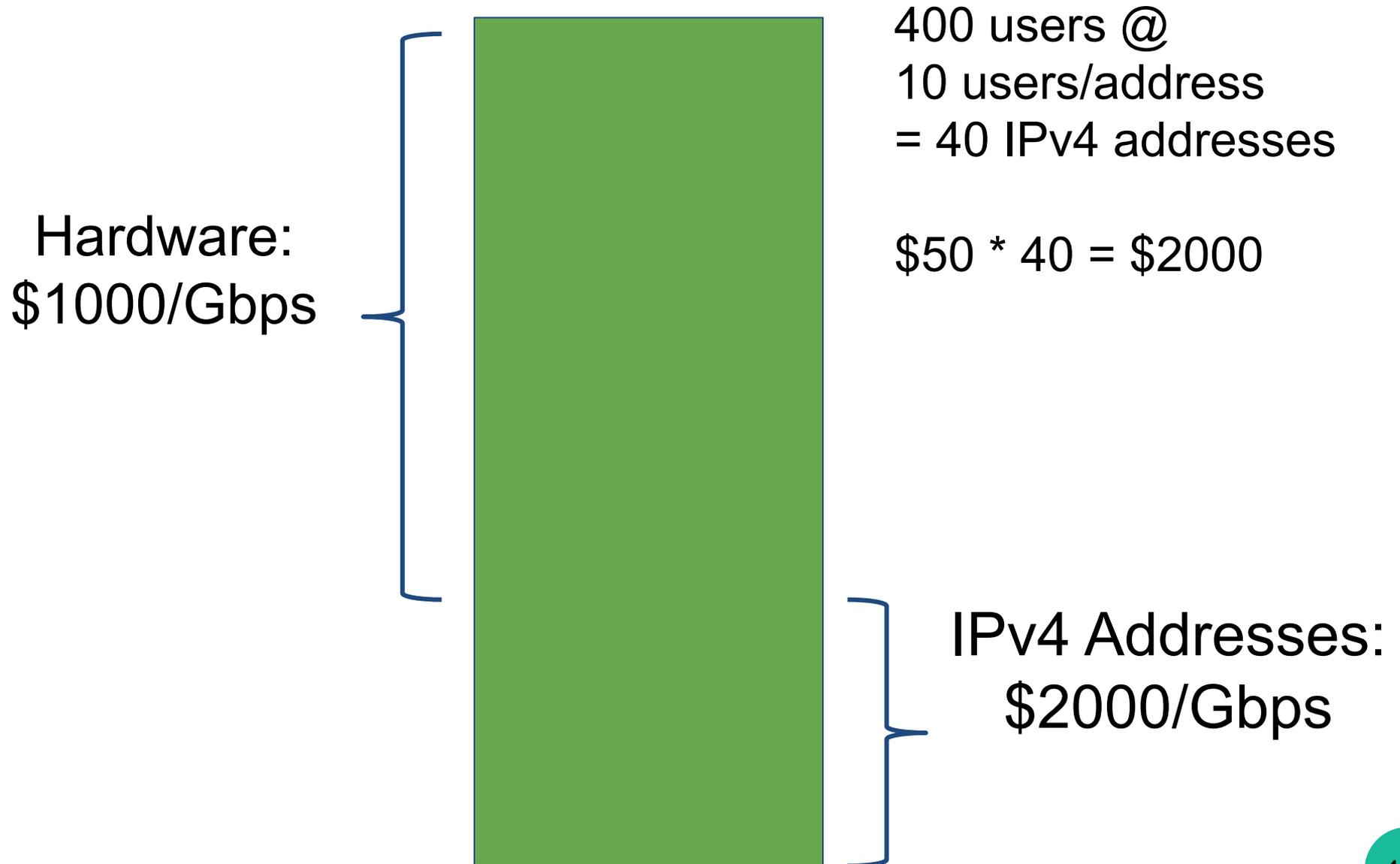
Mobile NAT Ratios

ASN	Company	IPv4 Addresses	<u>Subscribers</u> Q2-2018	Users/ Address
20057	ATT Mobility	5,565,952	147,260,000	26
22394	Verizon Wireless	13,641,728	152,650,000	11
21928	T-Mobile	13,050,368	75,620,000	6
10507	Sprint	2,959,360	53,700,000	18
6085	O2/Telefonica DE	6,828,800	43,048,000	6
3320	Deutsche Telekom	36,300,288	42,730,000	1
3209	Vodafone	8,861,816	29,692,000	3

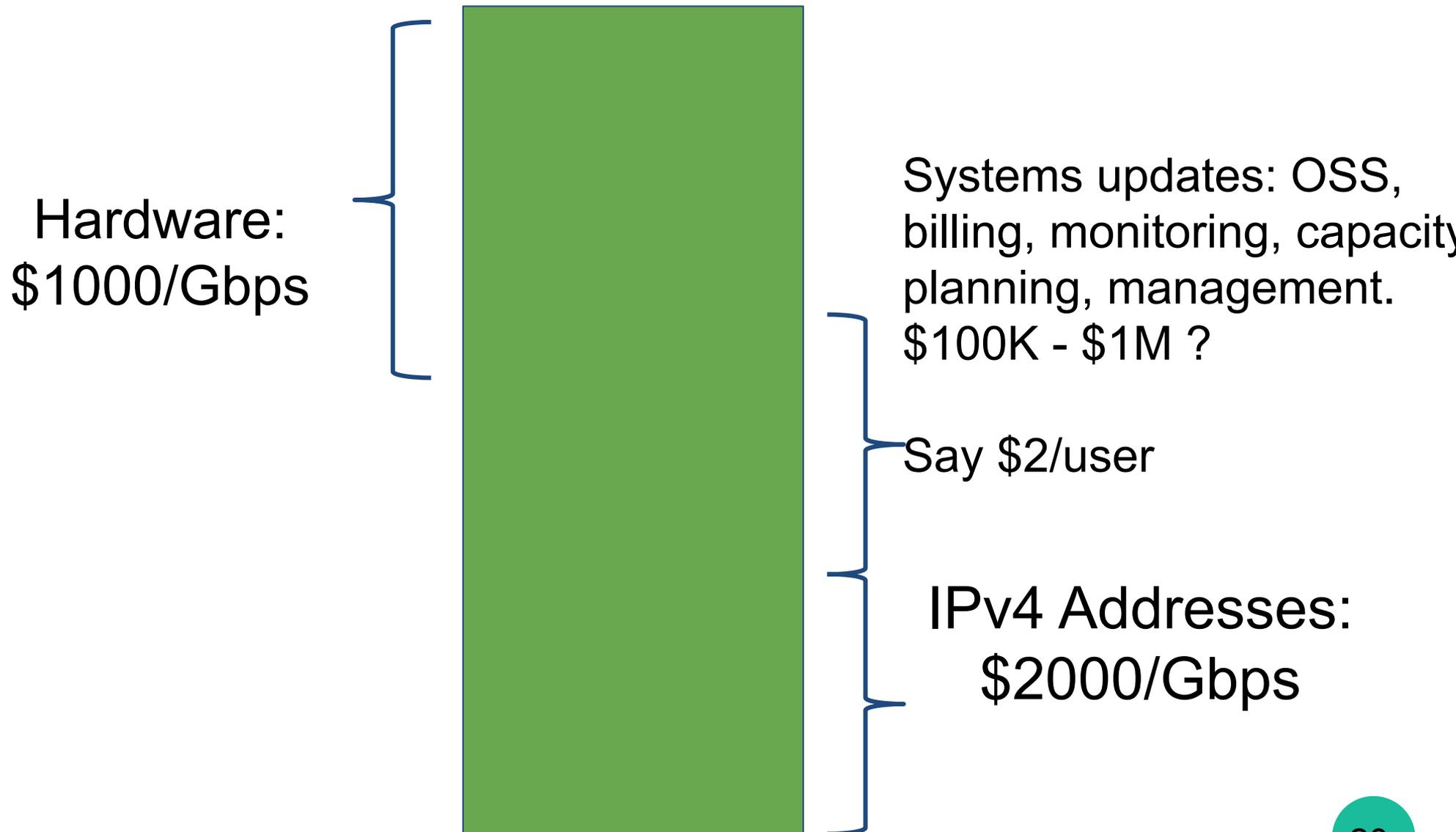
Call it 10 users per address

Mix of Route-view count and <http://as-rank.caida.org/asns/>

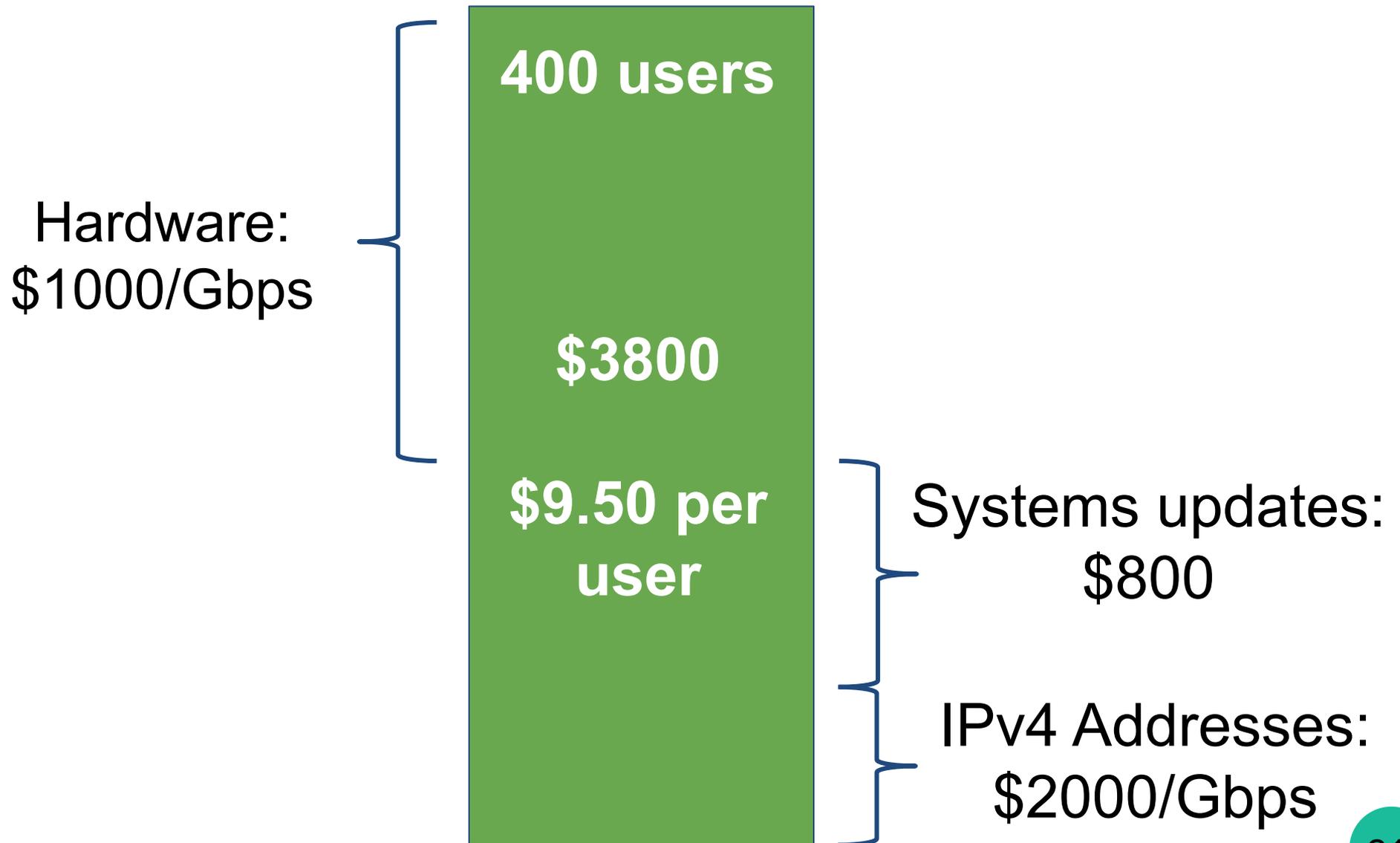
Cost of CGN



Cost of CGN



Cost of CGN



Prisoner's Dilemma

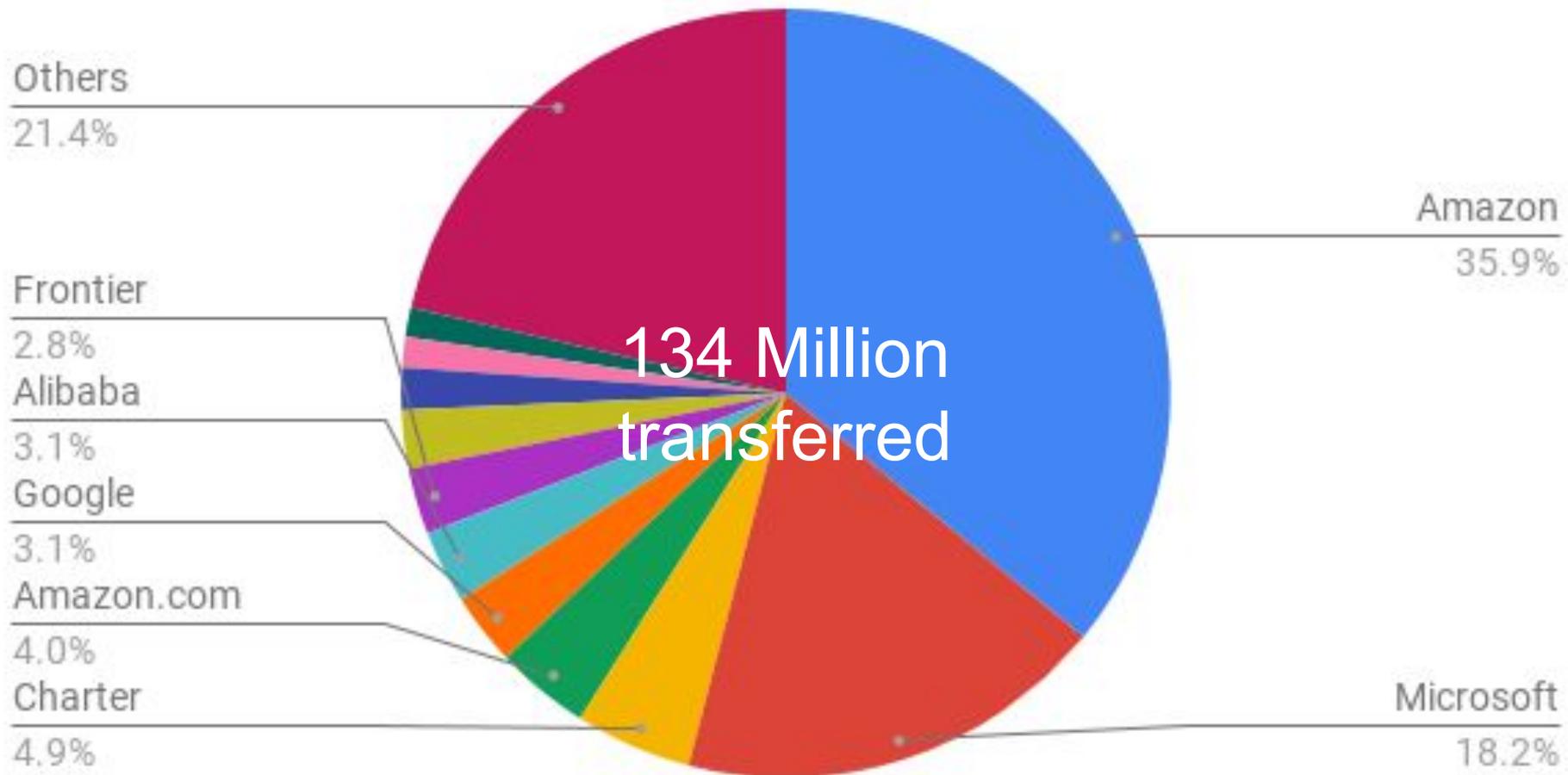
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Carriers Promote IPv6	<ul style="list-style-type: none">· Content wins· Carriers win: avoid \$9.5 + \$2/yr per new user	<ul style="list-style-type: none">· Content no change· Carriers lose \$9.5 + \$2/year per new user + customer losses
Carriers Do Nothing	<ul style="list-style-type: none">· Content loses· Carriers lose -\$50 per new user	<ul style="list-style-type: none">· Content loses· Carriers lose -\$50 per new user

Payoff Matrix Content Providers

Buyers of IPv4 Addresses

Percent of IPv4 Purchases

Kuerbis, Mueller. "The Hidden Standards War: Economic Factors Affecting IPv6"



Value of a Millisecond

“Every 100ms of latency costs 1% in Sales”

Amazon

“100-millisecond delay in website load time can hurt conversion rates by 7%”

Google

Akamai

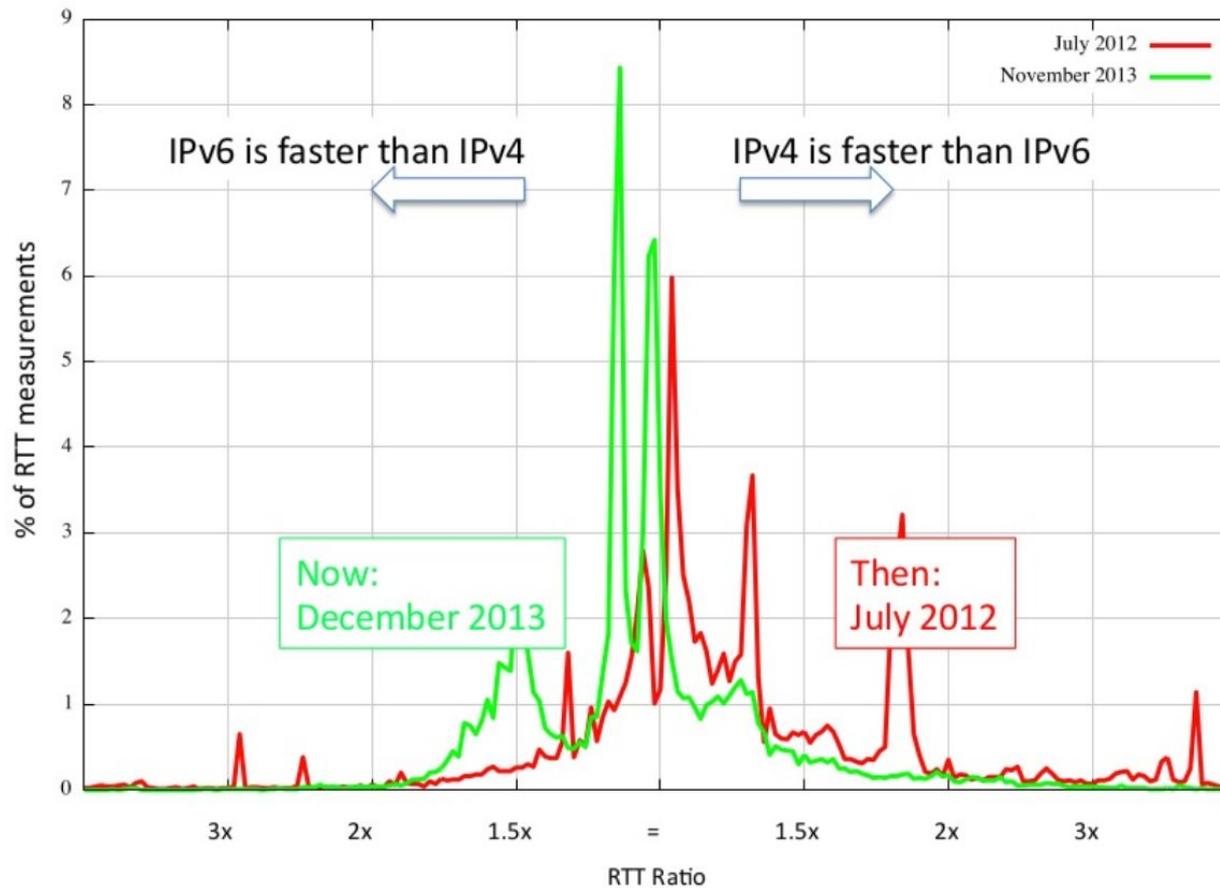
“Traffic and revenue from Google searchers in the experimental group dropped by 20%. . . Half a second delay caused a 20% drop in traffic.”

APNIC

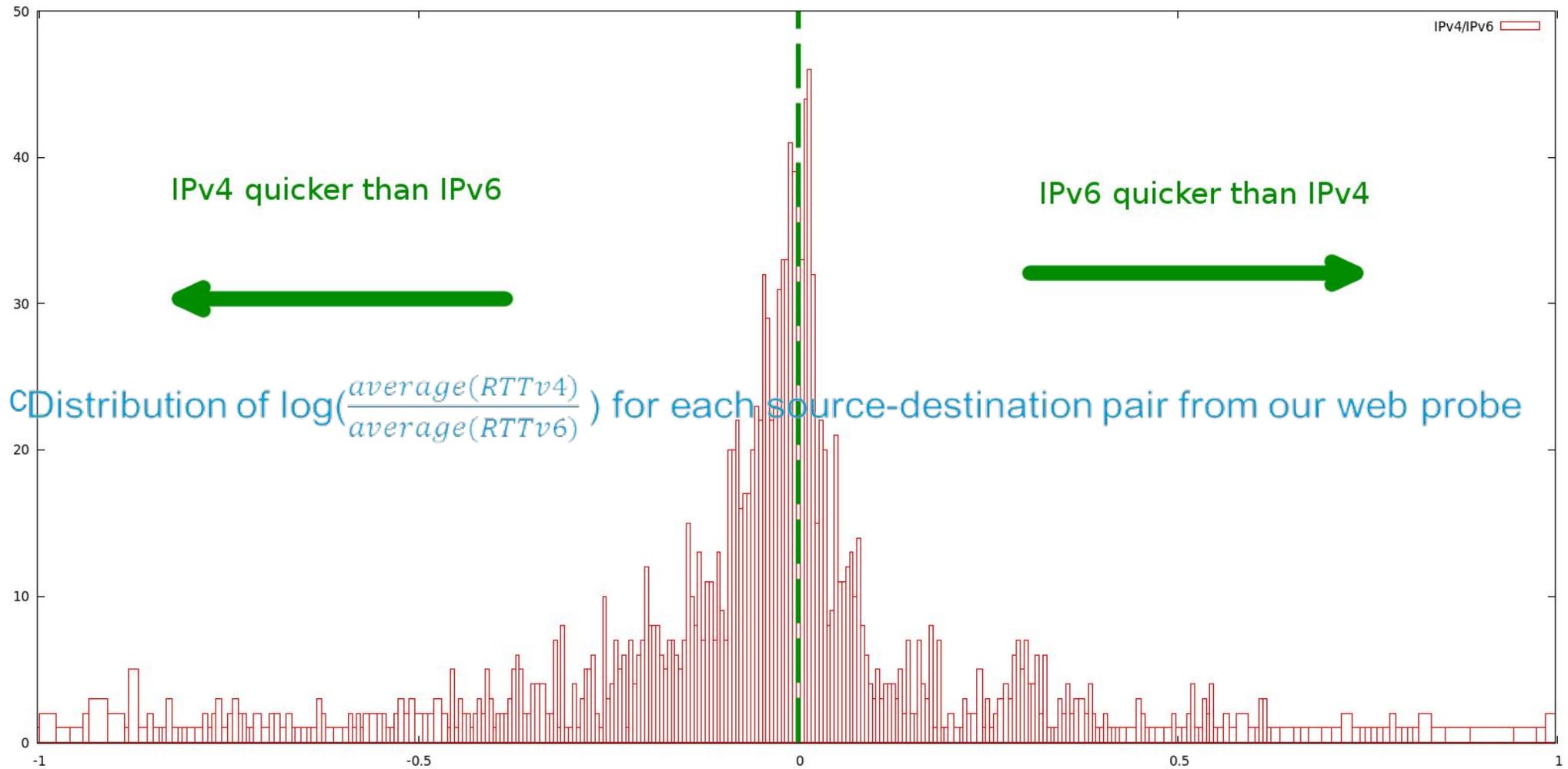
2013

IPv4 / IPv6 Performance, by Geoff Huston [APNIC 38 / IPv6 Plenary]

Paired RTT Distribution



Cisco 2014



Time Warner Cable

2014

IPv6 Performance Bonus

Performance Dashboard: Hop Count

	atl20-tbp1	chi10-tbp1	chi30-tbp1	clt01-tbp1	dca10-tbp1	dca20-tbp1	dfw10-tbp1	hou30-tbp1	lax00-tbp1	lax30-tbp1	nyc20-tbp1	nyc30-tbp1	sea20-tbp1	sjc10-tbp1	sjc30-tbp1
A	4.8 5	6.8 4.3	5 4.5	3.6 5	3.6 4	4 4	3.7 4	3.6 4	2.6 4.3	3.3 3.2	3.9 2.6	3.9 4	5.4 6.4	4.4 5.5	4.4 5.5
B	8 8	10 8	10 8.9	10 5.8	8 9.8	10 4.9	10 8	10 9.1	9.4 9.8	9 9.8	9 9	9 10.9	10 8	9 13.6	10 14.4
C	8 8	10 8	10 8.9	10 6.2	8 9.8	10 4.5	10 8	10 9.2	9.4 9.8	9 9.8	9 9	9 10.9	10 8.1	9 13.6	10 14.4
D	9.3 8.6	9 6.9	8 6.9	12.9 10.4	12.8 8.7	11 8.5	6 6	7 6.9	6 6	7.6 6.9	11.3 5.6	9.4 7.5	11 9	10 7	11 7.9
E	9 9.9	7.1 6.1	7.1 7	7.1 5.6	5 7.9	7 3.5	8.6 7.1	8.7 8	8.2 9.2	6.5 9.2	9.4 9	9.4 10.9	9.7 10.6	6.7 13.6	7.7 14.5
F	9 10	7.3 6.2	7.3 7	7.1 5.3	5 7.9	7 3.6	7 6	7 6.9	7.6 7.9	6 7.9	10 9	10 10.9	11 11	8 13.6	9 14.4
G	11 7.9	10 7.9	10 7.9	11.9 8.9	10 6.9	12 6.9	13 12	13 13	12.6 11	11 9.1	10 6	10 7.9	8 7	13.6 10	13.6 11
H	4 6	5 6.4	6 7.3	5 6	5 4	3 3.3	5 8.9	6 9.7	8.6 9.3	7 10.7	4 4.4	4 6.4	7 8.4	5 6.4	6 7.4
J	11 6.1	9.8 7.3	10.8 8.1	12 7.8	12 6.1	10 4.6	12.8 8.3	13.8 9.2	12.8 10.6	11.2 10	8 4	11 6	8.3 8	10.2 10	11.2 10.8
K	9 8	7 8	7 8.8	7.1 5.6	5 9.8	7 4.2	7 8	7 9.1	7.6 9.8	6 9.8	10 9	10 10.9	11 8	8 13.6	9 14.4
Average	8.3 7.8	8.2 6.9	8.1 7.5	8.7 6.7	7.4 7.5	8.1 4.8	8.3 7.6	8.6 8.5	8.5 8.8	7.7 8.6	8.5 6.8	8.6 8.6	9.1 8.5	8.4 10.7	9.2 11.5
95th percentile:	11.0 9.9	10.0 8.0	10.1 8.9	12.1 9.1	12.1 9.8	11.1 7.1	12.8 9.2	13.1 10.0	12.6 10.6	11.0 10.1	10.1 9.0	10.1 10.9	11.0 10.6	10.5 13.6	11.4 14.4

IPv4 Average 8.38

IPv6 Average 7.54

Difference 10%

Akamai

2016

We performed such an experiment looking at one specific site (URL) on one specific device (**iPhone**) on one network (**Verizon**), and we saw that the selected sites load **5% faster in median** and **15% faster for the 95% percentile** on IPv6 compared to IPv4.

<https://blogs.akamai.com/2016/06/preparing-for-ipv6-only-mobile-networks-why-and-how.html>

Measurements using Akamai's RUM system have also shown measurable performance improvements for US mobile users from dual stacking content.

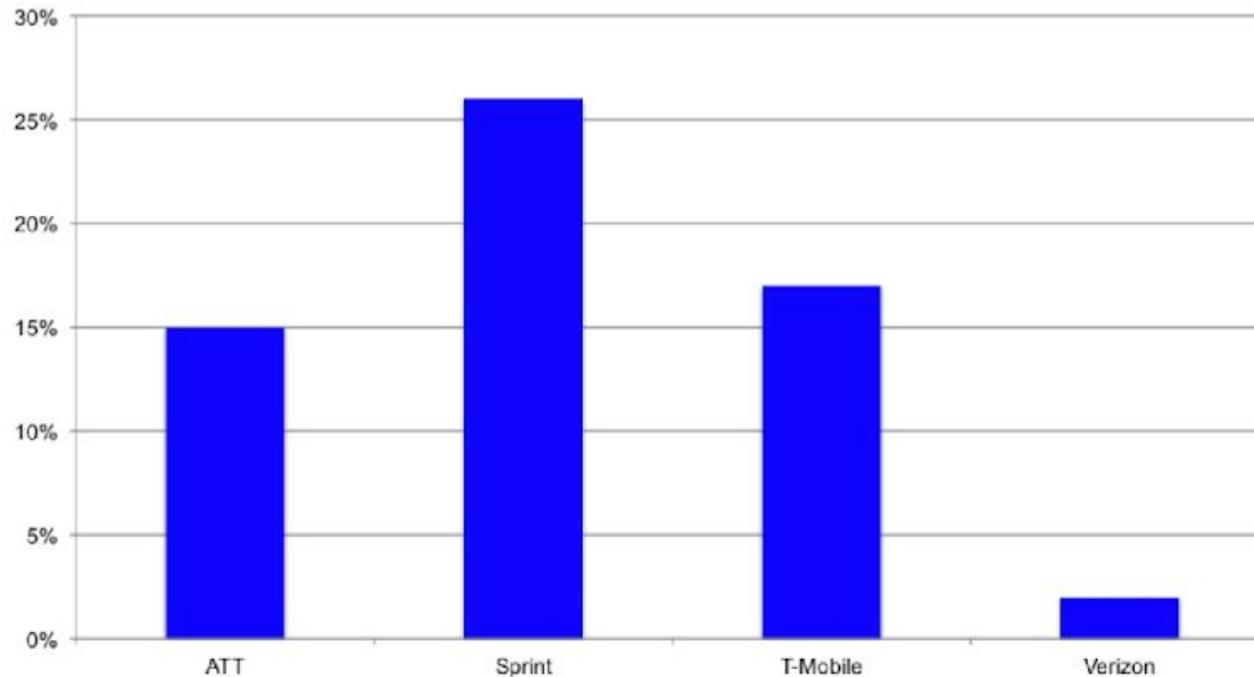
<https://blogs.akamai.com/2016/10/ipv6-at-akamai-edge-2016.html>

LinkedIn

2016

United States mobile performance (US)

Page download improvement IPv6

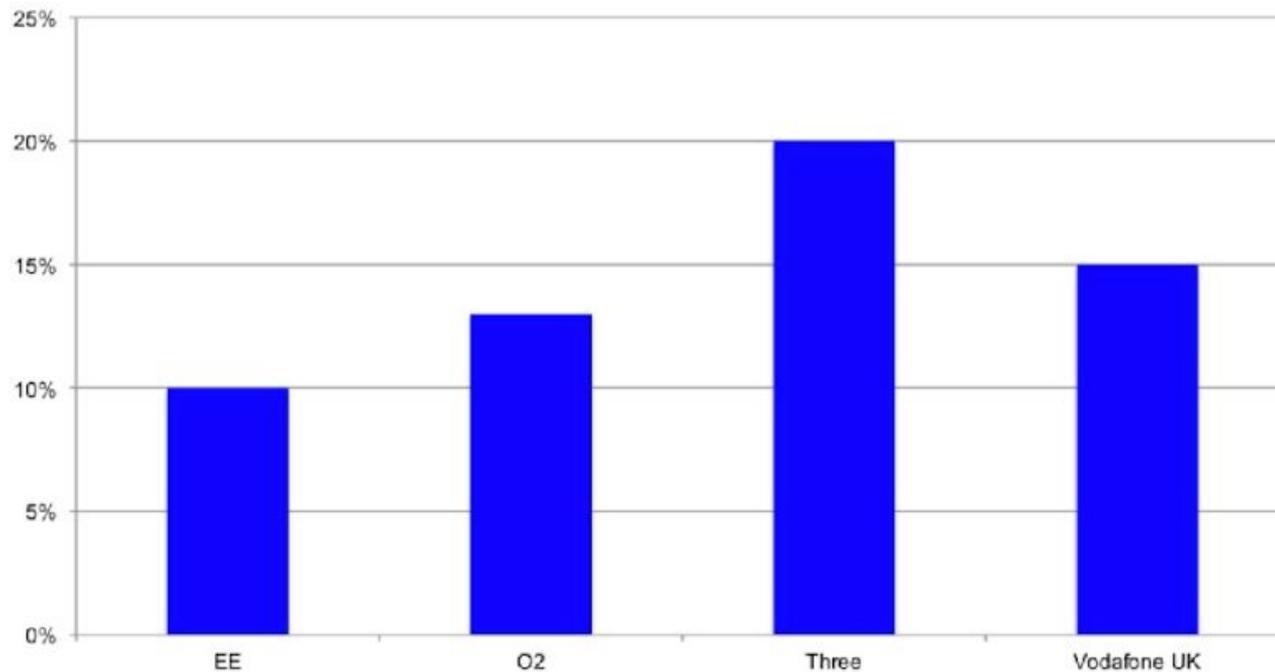


LinkedIn

2016

Europe mobile performance (UK)

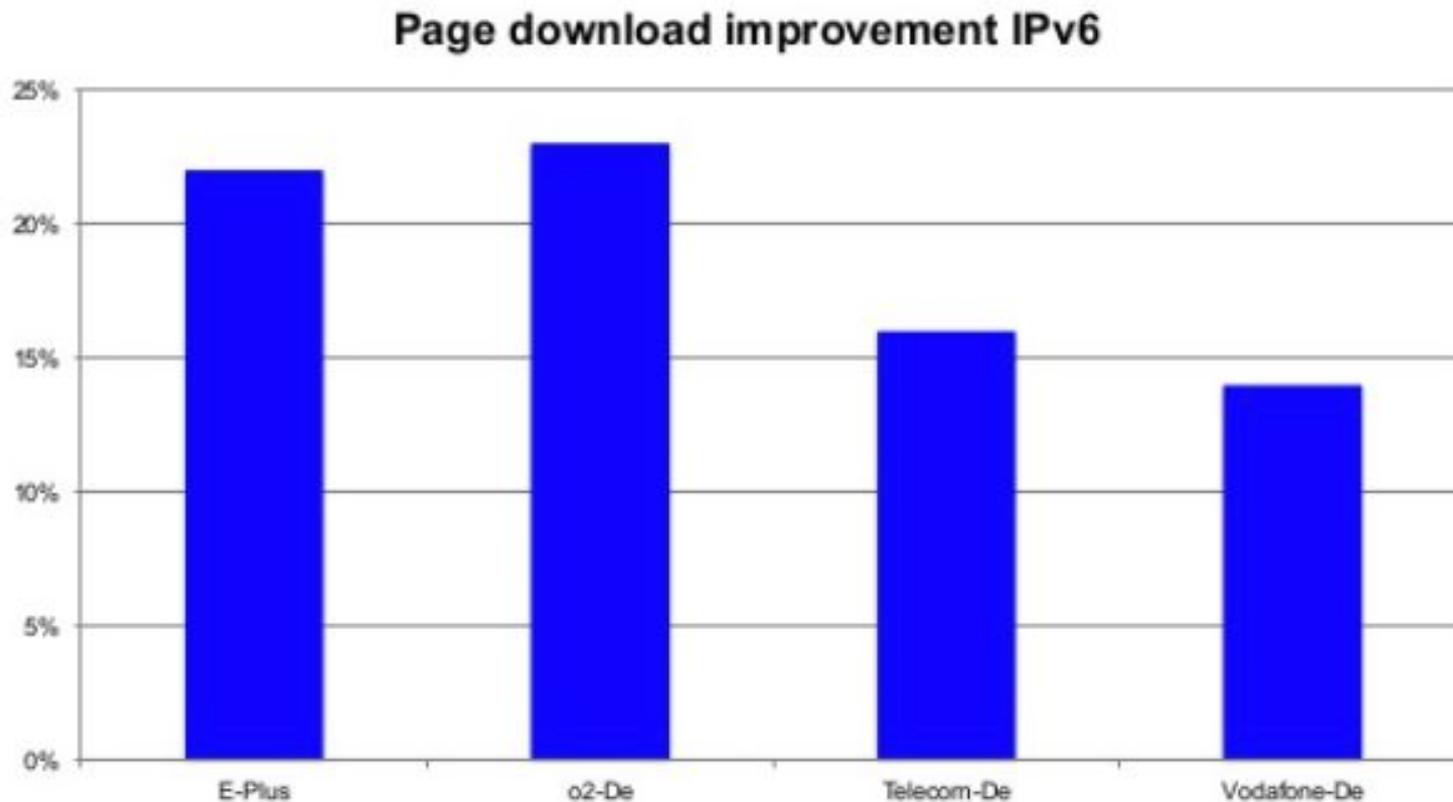
Page download improvement IPv6



LinkedIn

2016

Europe mobile performance (Germany)

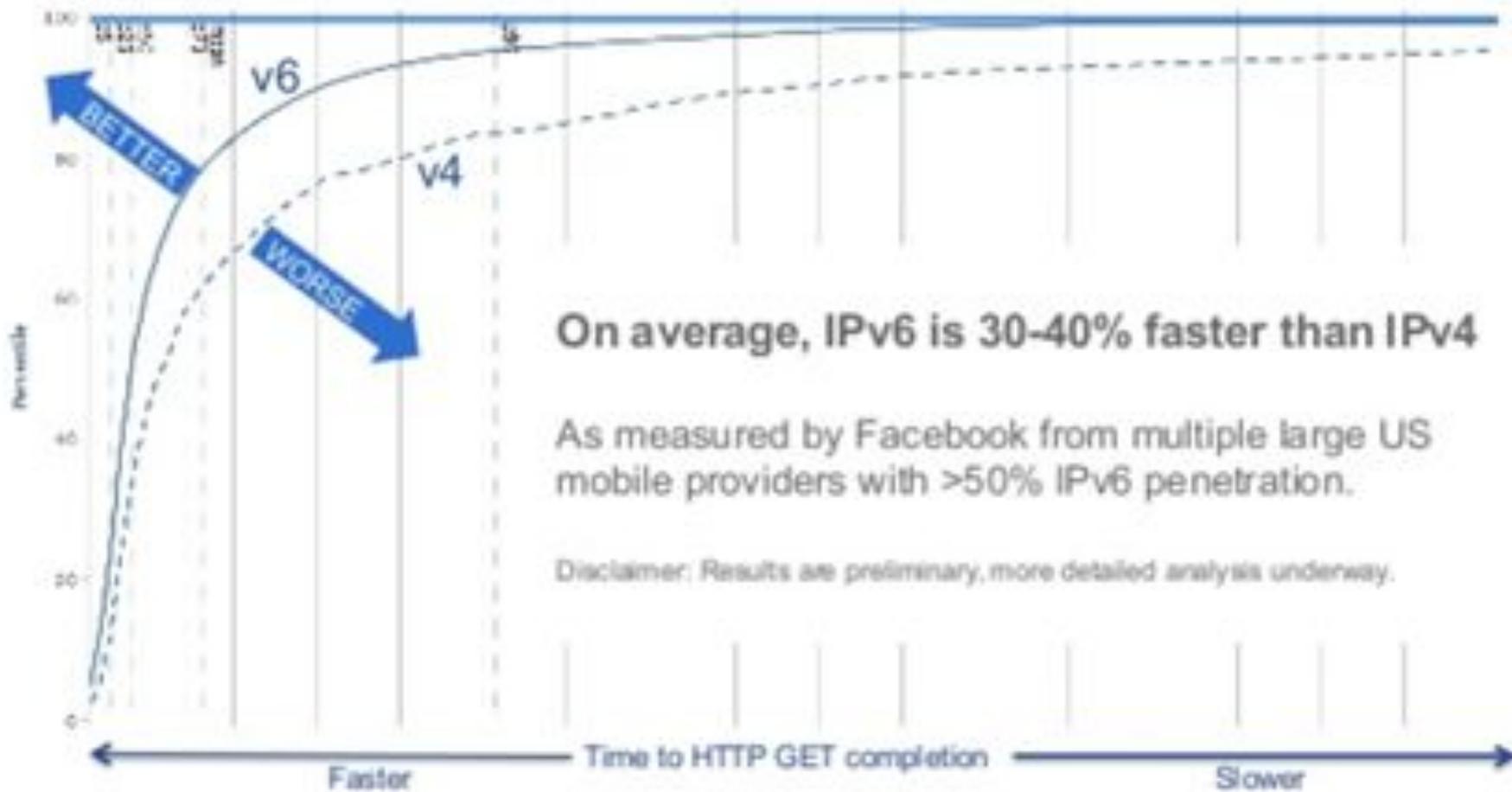


Facebook

2016

IPv6 vs. IPv4 - Performance

facebook.



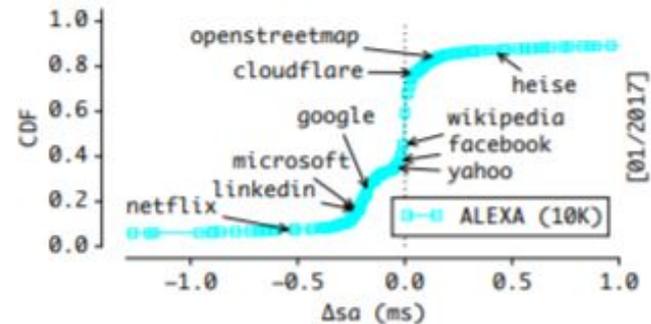
Source: Paul Saab, Facebook

Academia

2017

ALEXA top 10K websites (as of Jan 2017):

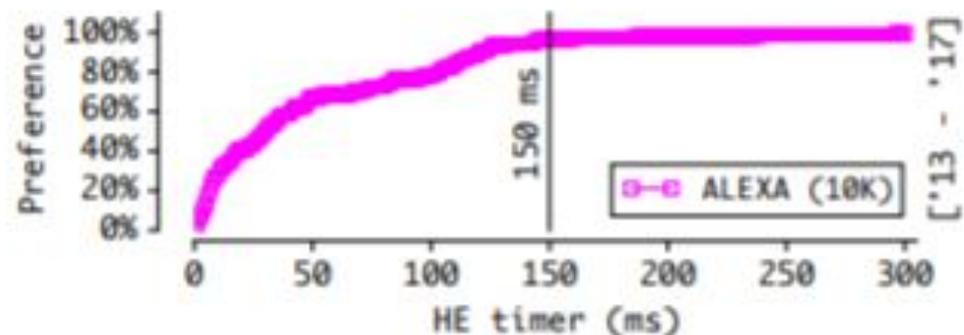
- ▶ 40% are *faster* over IPv6.
- ▶ 94% of the rest are at most 1 ms slower.
- ▶ 3% are at least 10 ms slower.
- ▶ 1% are at least 100 ms slower.



$$\Delta s_u(u) = t_4(u) - t_6(u)$$

- ▶ Relevant for content providers to get insights on how their service delivery compares over IPv6.

- ▶ HE timer of 150 ms maintains same IPv6 preference levels.
- ▶ We get margin benefit of 10% because timer cuts early.



- ▶ RFC 6555 should have used 150 ms timer. Measurements should inform protocol engineering.
- ▶ Drive an RFC 6555 update with operational experience within the IETF.

APNIC

2019

Region	Avg RTT Diff (V6-V4)
<u>Asia</u>	23.12 ms
<u>Oceania</u>	-1.25 ms
<u>Europe</u>	-15.32 ms
<u>Americas</u>	-23.05 ms
<u>Africa</u>	-23.35 ms
<u>Africa</u>	-24.30 ms

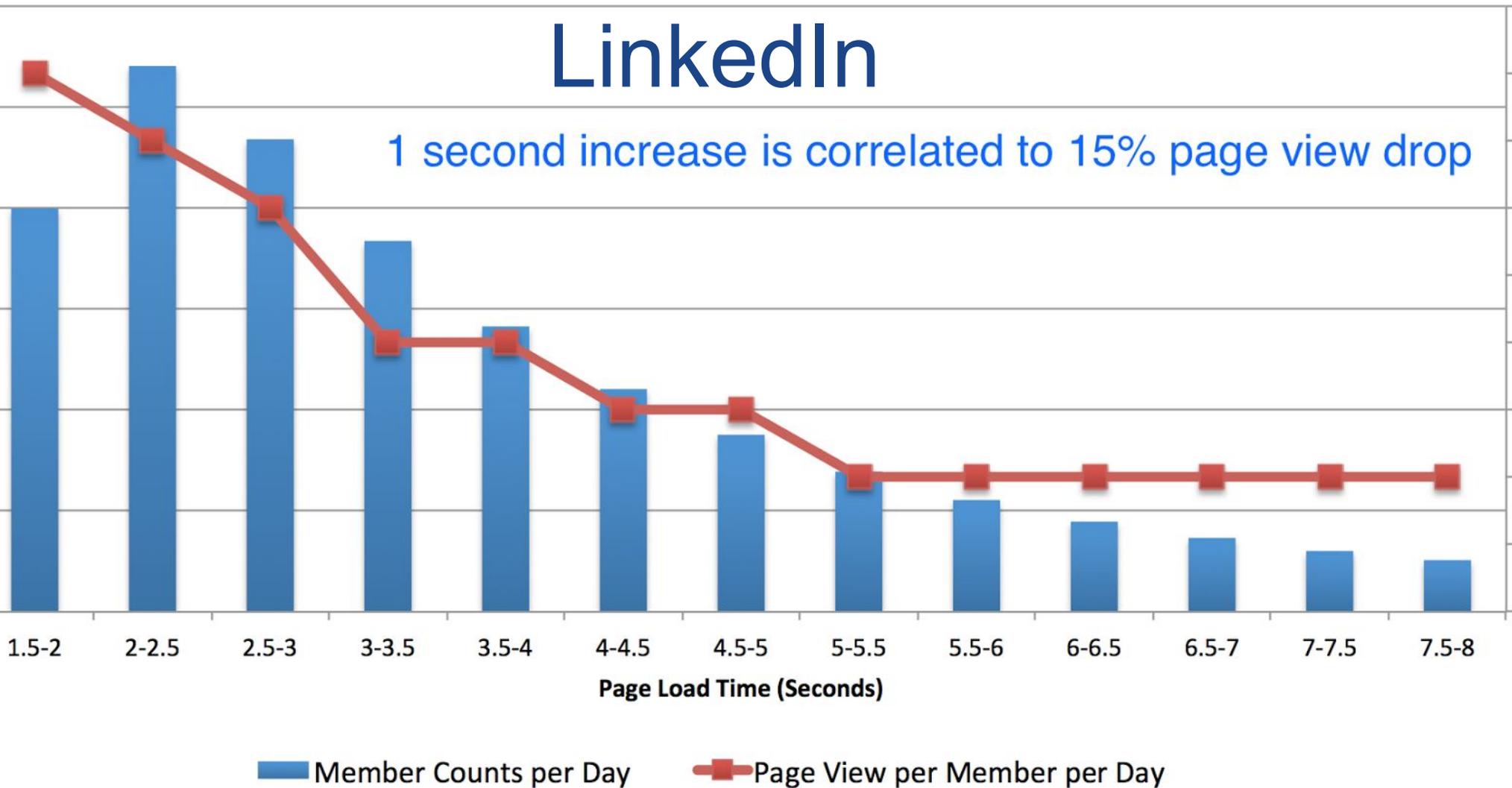
Speed Summary

APNIC 2013	IPv6 is faster more often than IPv4 is.
Cisco 2014	IPv6 is faster more often than IPv4 is.
TWC 2014	IPv6 is 10% faster on average.
Akamai 2016	(One case) 95% sites are 15% faster.
LinkedIn 2016	IPv6 is often 15-25% faster.
Facebook 2017	IPv6 is 30-40% (or less) faster.
Bajpai, Schönwälder 2017	95% of sites are same or faster.
APNIC yesterday	In most regions, IPv6 is 20ms faster.

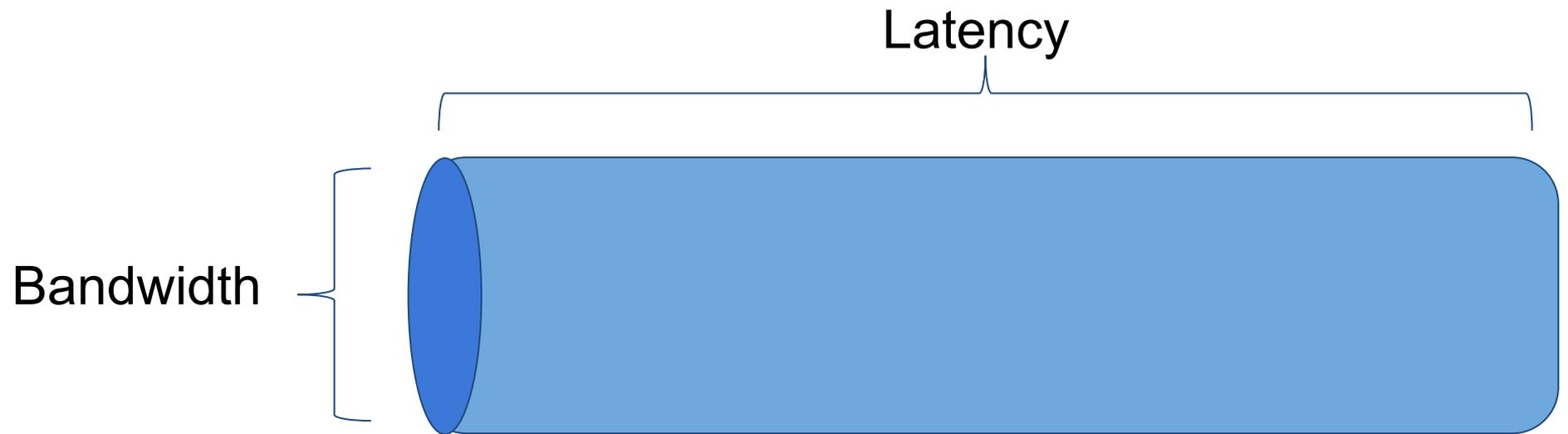
Value of a Millisecond

LinkedIn

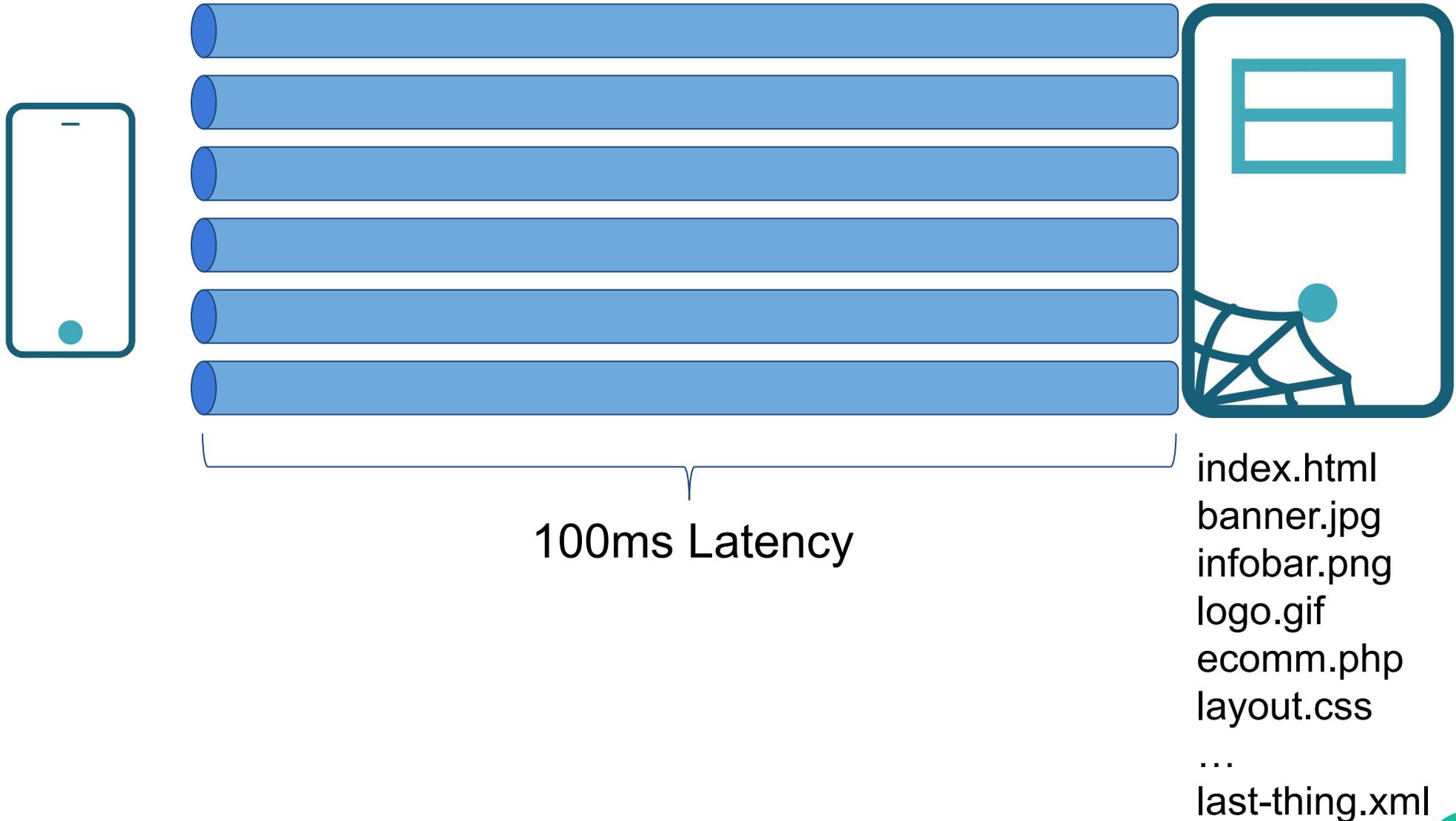
1 second increase is correlated to 15% page view drop



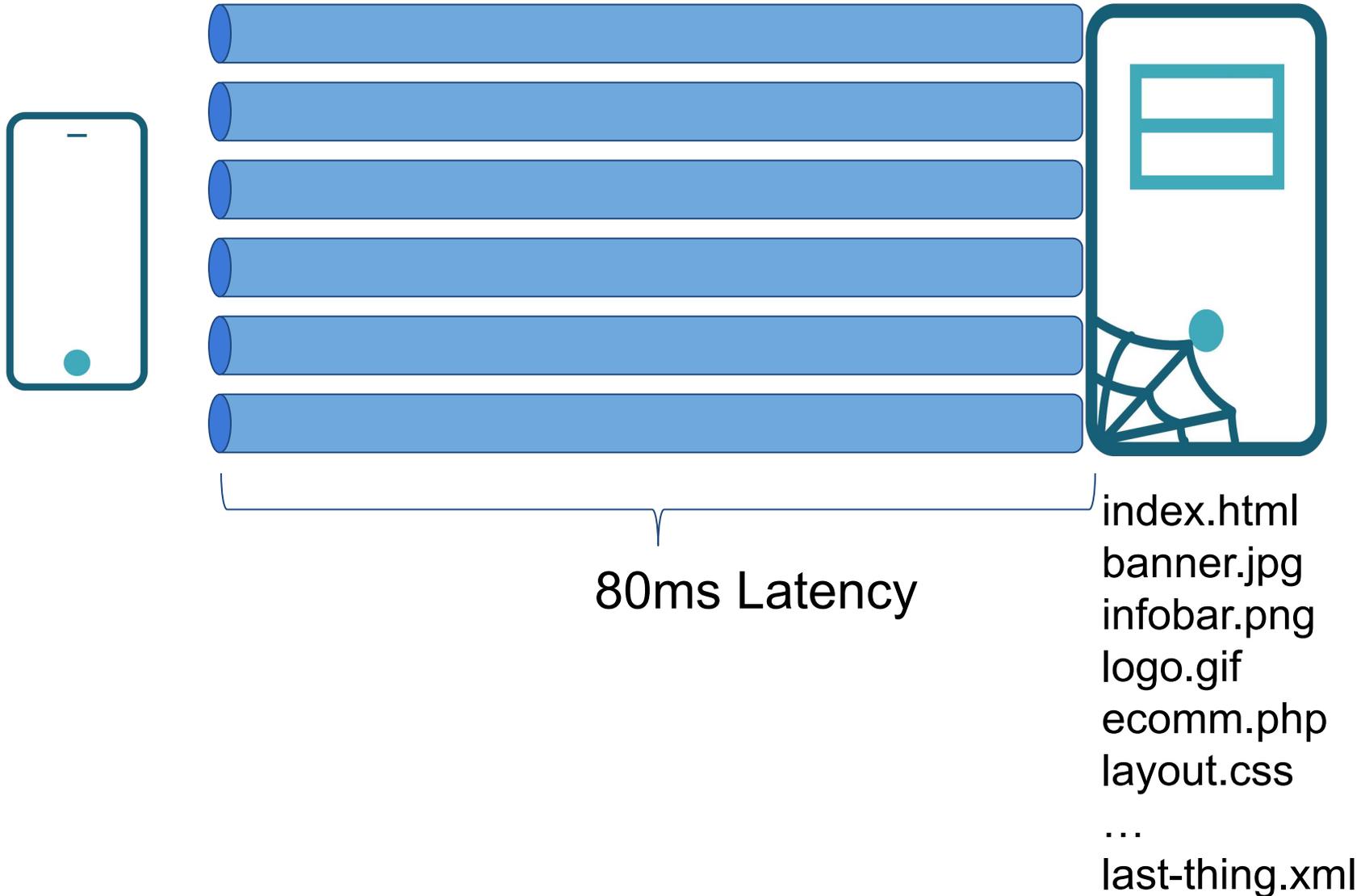
Value of a Millisecond



Value of a Millisecond



Value of a Millisecond



Value of a Millisecond

$$PageLoadTime = \frac{ObjectsInPage}{Concurrency} * Latency$$

(150 HTTP GET / 6 simultaneous connections) * -20ms latency
= -500ms
= 1/2 second improvement

20ms = 1/2 second page load time

Value of a Millisecond

“Every 100ms of latency costs 1% in Sales”

Amazon

“100-millisecond delay in website load time can hurt conversion rates by 7%”

Google

Akamai

“Traffic and revenue from Google searchers in the experimental group dropped by 20%. . . Half a second delay caused a 20% drop in traffic.”

Value of a Millisecond

20ms =
+ 0.2% in sales

Amazon

Google

20ms =
+ 1.4% in sales

Akamai

$\frac{1}{2}$ sec = 20% in revenue

Value of a Millisecond

- 2018 [BBC lost 10% of users](#) for every 1s page load time.
- 2017 [Pinterest increased sign-ups 15%](#) with 40% lower wait.
- 2016 [COOK conversions up 7%](#) when PLT down 850ms.
- 2016 [DoubleClick 53% of mobile site visits bailed](#) if PLT > 3s.
- 2016 Mobify: [100ms PLT = +1.11% conversion= \\$380,000](#).

Value of a Millisecond

20ms =
+ 0.2% in sales
= \$400 million

Amazon

Google

20ms =
+ 1.4% in sales =
\$38 million

Akamai

$\frac{1}{2}$ sec = 20% in revenue
= \$1.1 billion

Prisoner's Dilemma

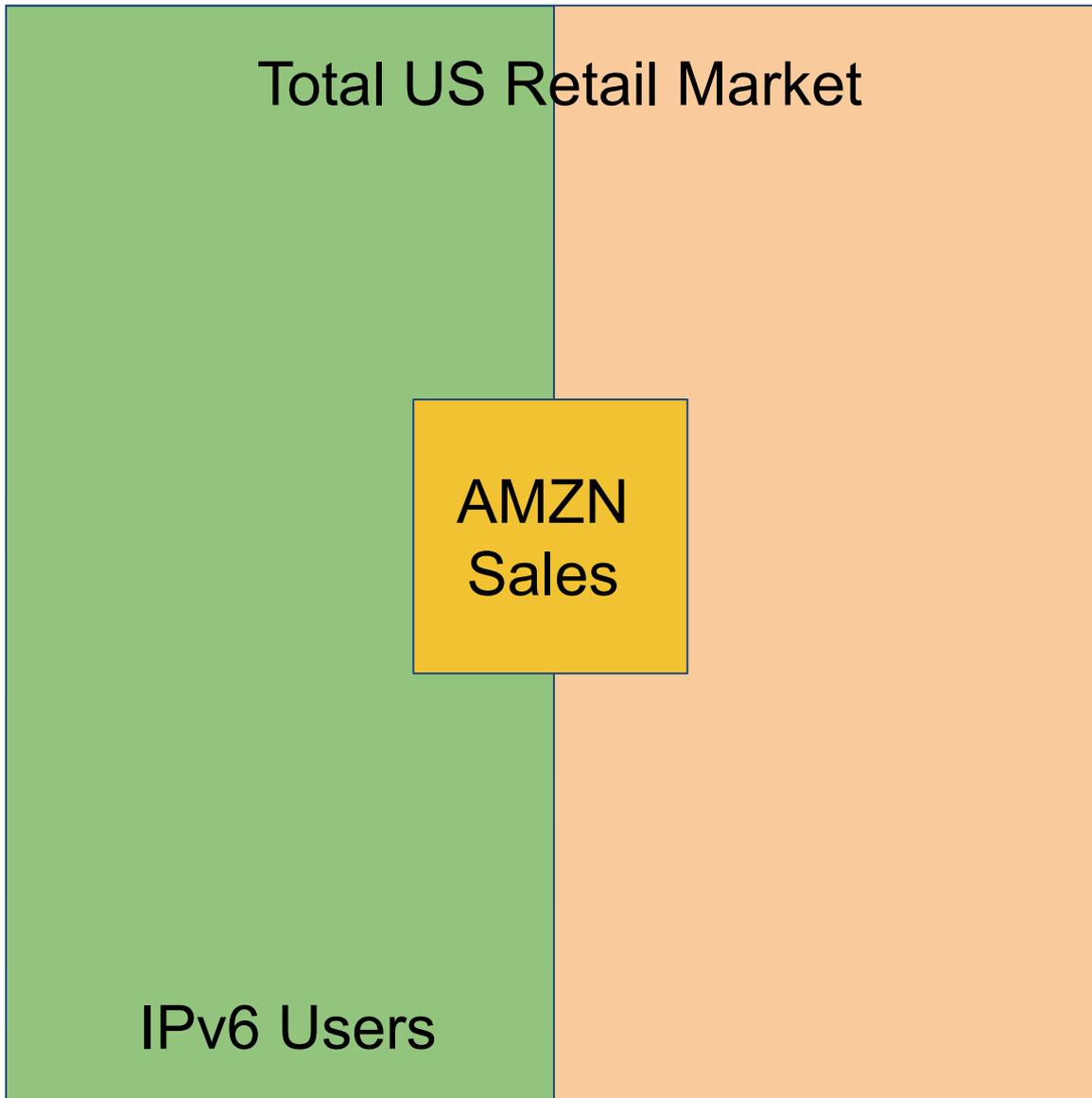
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Carriers Do Nothing	<ul style="list-style-type: none"> • AMZN: Keep buying IPv4 • GOOG: Keep buying IPv4 • Carriers: \$50 per new user 	<ul style="list-style-type: none"> • AMZN: miss \$400M/yr • GOOG: miss \$1.1B/yr • Carriers: \$50/new user

Strategy

Amazon: \$400M per year

- Drop any device without an IPv6 certification by June 2020
 - Warn manufacturers
 - Start with home gateways
- Enable IPv6 on Amazon.com

Amazon Impact



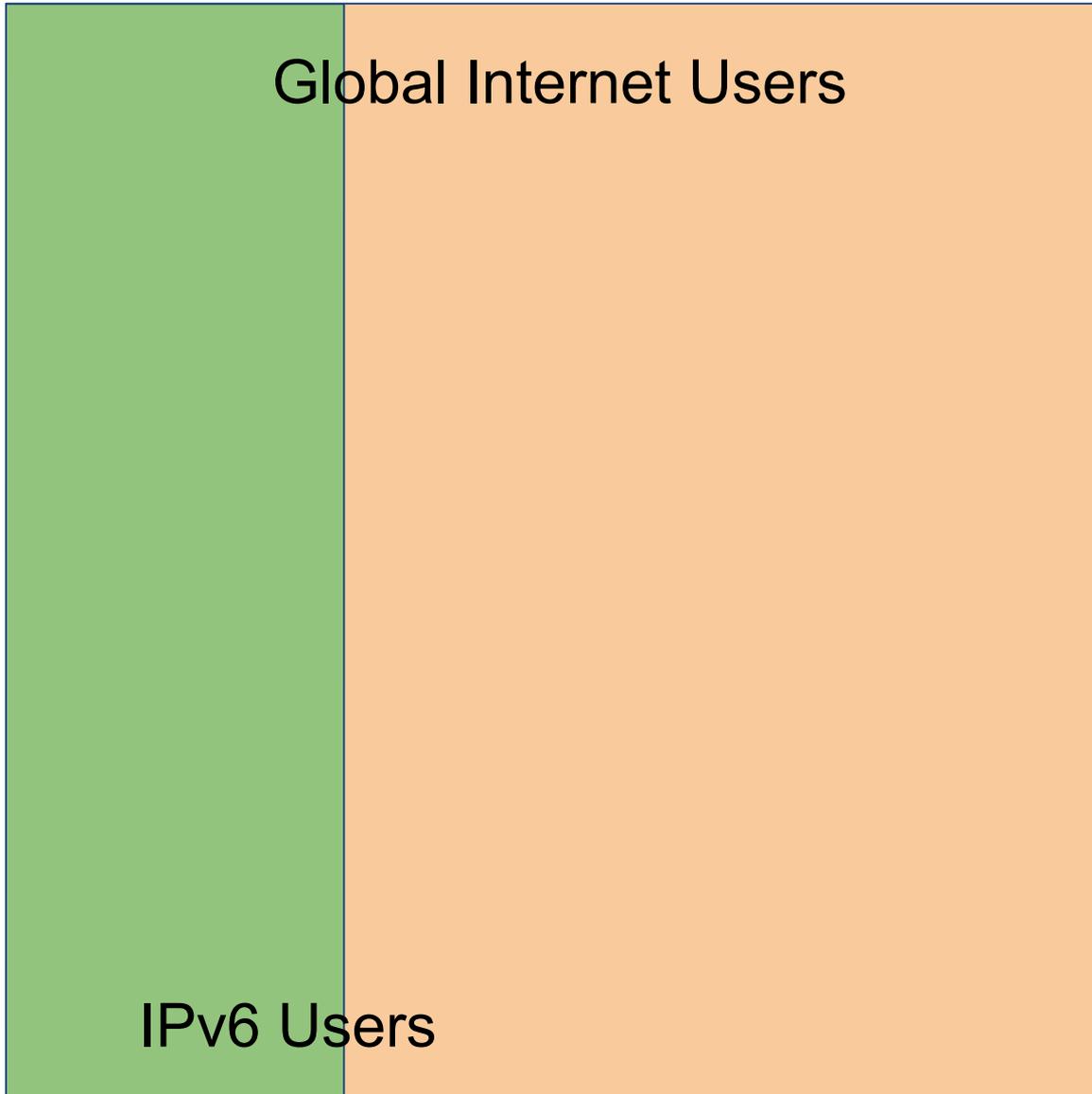
Amazon is 5% of all US retail sales.

50% of US consumers have IPv6.

... 2.5% more US people would get IPv6 if Amazon sold IPv6-only

AMZN N.Am. sales \$141B
 $+2.5\% * +.2\% =$
 $+ \$70M$ US
compounding annually

Amazon Impact



AMZN 207B global
revenue
x 28% with IPv6
x 0.2% sales boost

Simply dual-stacking
Amazon.com
would increase sales
by \$116 million the
first year.

Google: \$1.1B per year

- Blog that IPv6=speed=higher search rankings.
- IPv6 in GCP by default.
- Google Shopping: promote devices with IPv6 certification
- Require all Android apps to support IPv6 by June 2020.
- Block Android apps in the Google Play Store that require IPv4

Alibaba, are you listening?

Other e-Commerce Sites

Site	2018 online sales	Value of Dual-stack*
Walmart.com	\$16.67B	\$47M
Macys.com	\$13.56B	\$38M
Staples.com	\$7.77B	\$22M
Homedepot.com	\$7.72B	\$22M
Bestbuy.com	\$6.69	\$18M
Dell.com	\$5.35	\$15M
eBay	\$10.7B	\$30M

* Assuming 20ms = +1% sales, sales are evenly distributed globally, 28% of the world has IPv6.

Note that the U.S. is over 50%: if all sales are US, double the above value

Other Ad Revenue Sites

Site	2018 ad revenue	Value of Dual-stack*
Twitter.com	\$3B	\$60M
Reddit.com	\$100M	\$2M
Twitch.tv	\$500M?	\$10M
Zillow.com	\$1B	\$25M
CBS	\$1B?	\$25M
Yelp.com	\$240M	\$5M
Buzzfeed.com	\$300M	\$6M

* Assuming 20ms = +7% sales, sales are evenly distributed globally, 28% of the world has IPv6.

Note that the U.S. is over 50%: if all views are US, double the above value

Value of IPv6 to Your Web Site

%increase in revenue from 20ms	1.00%
Total online sales	\$10,000,000
%Sales in North America	90%
%Sales in Europe	8%
%Sales in Asia	1%
%Sales in Oceania	0%
%Sales in Latin America	0%
Dual-stack on your web site would increase your sales by:	\$46,280

Try it yourself!

<https://tools.retevia.net/web-value.html>

ISPs: \$9.50 per new user + \$2/year

- Fund Home Gateways testing
 - Amazon, help us by listing CPE by sales
 - Include MAP-T, MAP-E, and 464xlat because to hell with stateful NAT
 - Use IPv6 CPE Ready or USG IPv6 Ready
- Fund testing of all consumer electronics
 - CE Ready or CEA IPv6 Profile

ISPs: \$9.50 per new user + \$2/year

Also enable IPv6 for all business customers.

- DSL/FTTH/DOCSIS: respond to DHCPv6.
- Static address customers: assign a /48 and route it, then email the customer.
- BGP customers: assign a /48 (and maybe a /64 with /127 for link), route it, email the customer.

Worried about Support calls? Those calls were going to happen someday; at least here you can control when.

Value of IPv6 Partnering to Your ISP

Current Subscriber count		1,000,000			
Average growth rate		5.00%			
Current IPv6 deployment level		60.00%			
Value of CGN avoidance (CapEx)		\$9.50			
Value of CGN avoidance (annual OpEx)		\$2.00			
Expect increase in IPv6 with e-commerce help		5.00%			
	2020	2021	2022	2023	2024
IPv6 subscribers without help	630,000	661,500	694,575	729,304	765,769
IPv6 percent without help	63%	63%	63%	63%	63%
IPv6 subscribers with help	660,000	726,575	798,600	878,460	966,305
IPv6 percent with help	66%	66%	66%	66%	66%
Incremental value of help	\$234,150	\$741,750	\$1.2M9	\$2.3M	\$2.9M

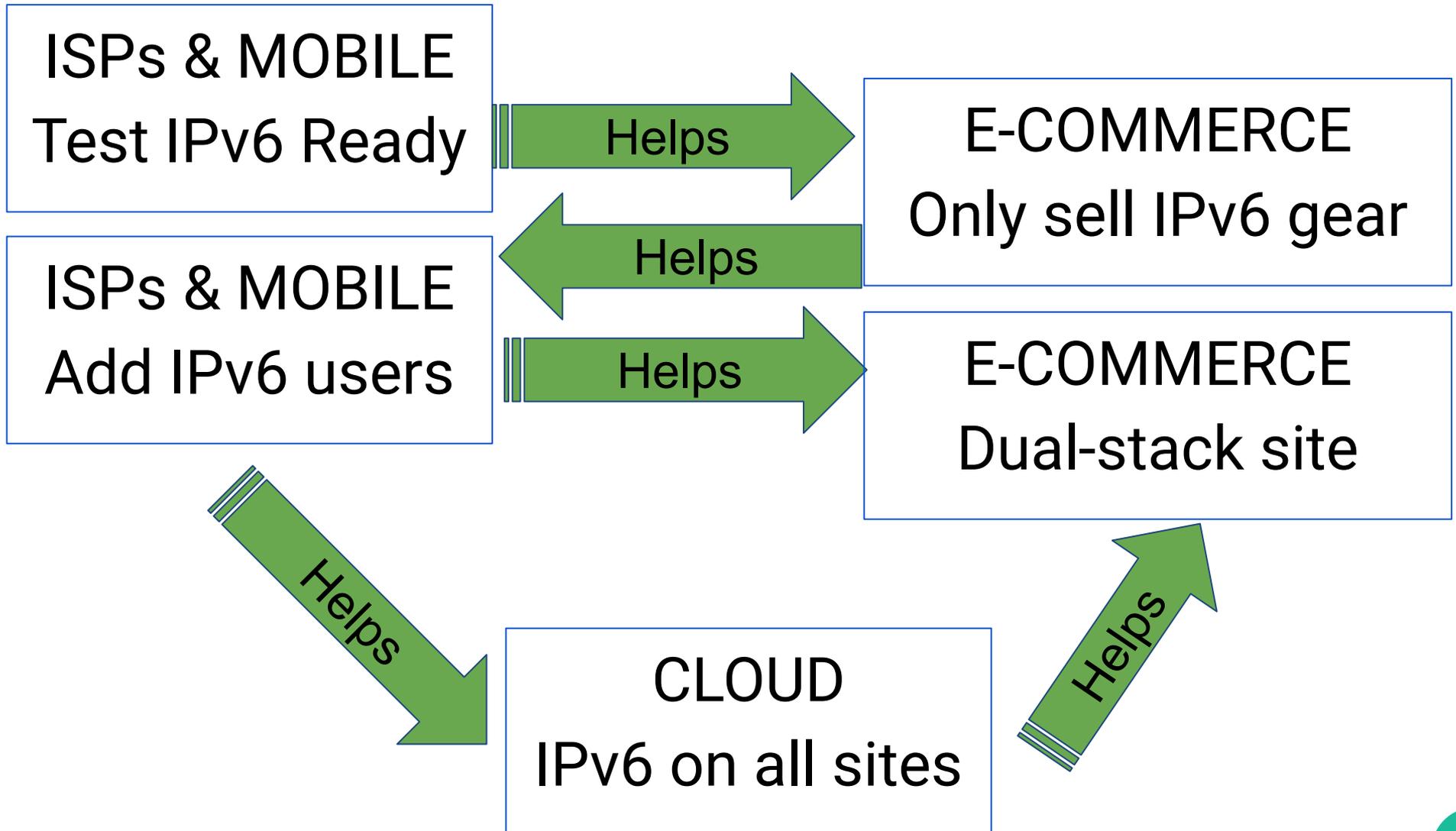
<https://tools.retevia.net/carrier-value.html>

Mobile Carriers:\$5.75 per user + \$2/year. . .

Suggestion:

- Help identify apps needing IPv6 updates
- Don't allow handsets from vendors who have any IPv4-only products
- IPv6-only in 5G

The Prisoner's Resolution



Prisoner of IPv4



Summary and Links: <https://retevia.net/prisoner>