



E Q U I N I X

Bandwidth and Internet

OK, maybe panic.

SINOG Meeting, Ljubljana

June 2014
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Global Director of Interconnection

Quick Introduction



About me



Bandwidth pricing

Down and to the right (mostly)

The Price of Bandwidth, in bulk, per Mbps

Western Europe, Fall 2013 (based on 10Gbps or 300GB)

A EUR80 fiber cross connect:	\$0.01
Internet Exchange traffic:	\$0.12*
Backbone traffic Western Europe:	\$0.10
Transatlantic traffic, wholesale:	\$0.35
Internet Transit, wholesale:	\$0.30
Internet Transit, retail:	\$10
Broadband Internet, consumer:	\$25
National Ethernet service:	\$120
3G mobile data, data plan:	\$5,063
3G mobile data, outside plan:	\$40,500
3G mobile data, roaming low:	\$12,698
3G mobile data, roaming high:	\$3,685,500
SMS Text Messages, roaming:	\$928,972,800

The Good News

Pricing Evolution:

- **GSM Voice Call, national: \$483,840 → \$1/∞ (for ~0.1Mbps)**
- **SMS Text Messages: \$210,000,000 → \$1/∞ (for ~0.01Mbps)**
- **Internet Exchange Traffic: \$0.25* → \$0.12***
- **Backbone traffic Western Europe: \$0.50 → \$0.10**
- **3G Mobile Data, national: \$11,400 → \$ 5,063**
- **3G Mobile Data, roaming Europe: \$834,000 → \$12,698**

- **But roaming outside Europe has become more expensive??**

The Price of Bandwidth, in bulk, per Mbps

Western Europe, early-mid 2011 (based on 10Gbps or 300GB)

A EUR80 fiber cross connect:	\$0.01
Internet Exchange traffic:	\$0.25*
Backbone traffic Western Europe:	\$0.50
Transatlantic traffic, wholesale:	\$1
Internet Transit, wholesale:	\$2
Internet Transit, retail:	\$15
Broadband Internet, consumer:	\$50
National Ethernet service:	\$180
3G mobile data, national:	\$11,400
GSM voice call, national:	\$483,840
3G mobile data, roaming low:	\$834,000
3G mobile data, roaming high:	\$3,127,500
GSM voice call, roaming:	\$3,338,496
SMS Text Messages:	\$210,000,000
SMS Text Messages, roaming:	\$1,166,400,000

Interconnection markets

How do you create one?

Caveat Emptor

- One man's success is another man's failure
- Local relevance is better than no relevance at all
- Building Interconnection markets is hard,
- takes significant amounts of time and resources
- and inordinate amounts of cooperation

Definition time

A Healthy Interconnection market

- **Has sufficient critical mass to be self-perpetuating**
- **Has at least a regional significance**
- **Minimizes duplication of effort**

3 Basic Motivators

Why does a network expand its footprint?

- 1. Increase Revenue**
- 2. Reduce Cost**
- 3. Improve Quality**
- (4. Legal Requirement)**

These decisions are made

- For different reasons,**
- By different people,**
- In different parts of an organisation.**

Where does it work?

- **Singapore**
- **Silicon Valley**
- **Washington DC**
- **New York**
- **London**
- **Amsterdam**
- **Frankfurt**
- **Moscow**
- **Stockholm**

And on a more limited scale:

Prague, Budapest, Milan, Zurich, Madrid, Dublin

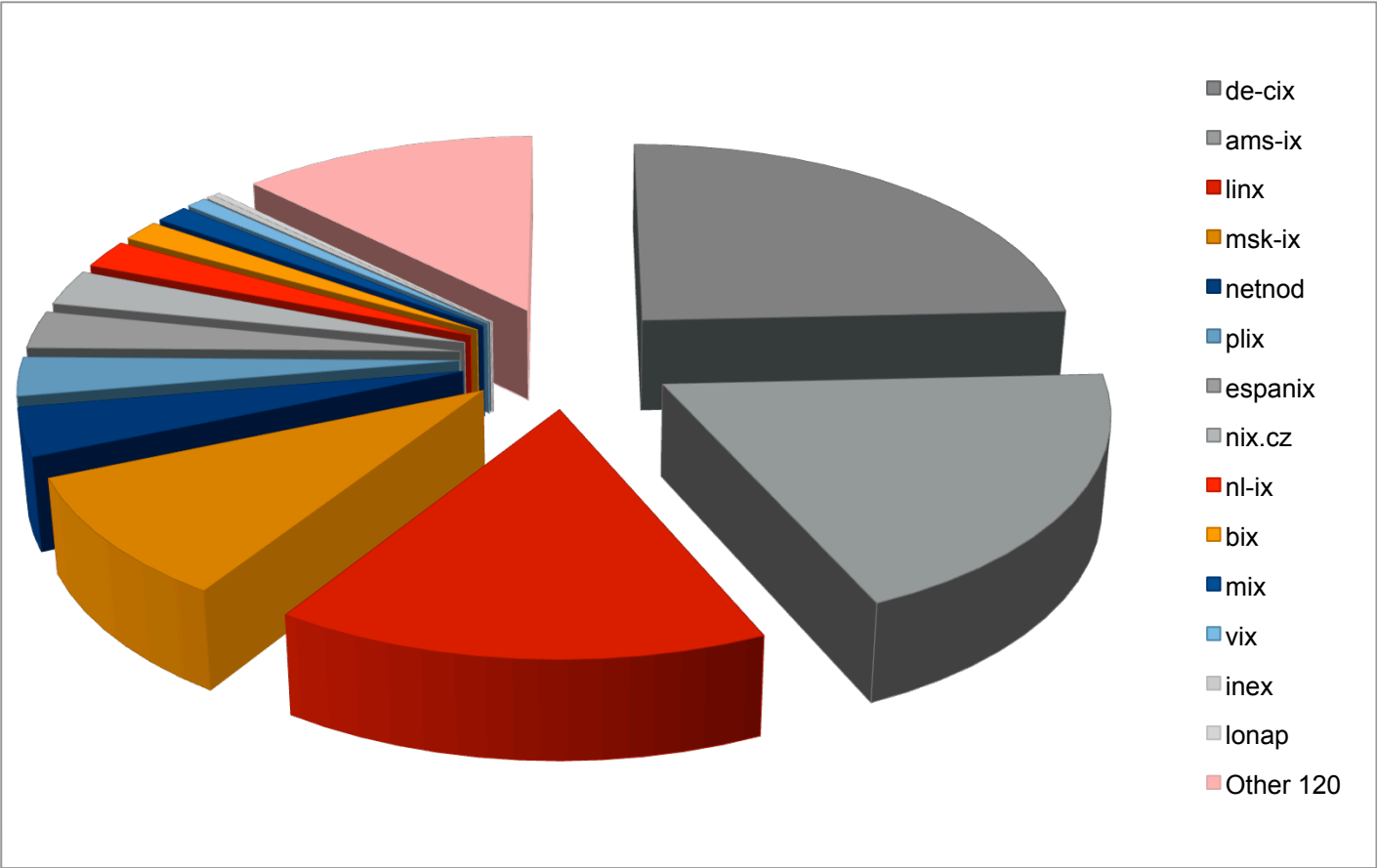
But don't take my word for it...

Here's what Telegeography says

	2013	'09-'13 CAGR
City	Bandwidth	Bandwidth
Frankfurt, Germany	21,143	47%
London, U.K.	19,225	37%
Amsterdam, Netherlands	15,001	42%
Paris, France	14,285	36%
Stockholm, Sweden	5,429	39%
Milan, Italy	3,437	30%
Moscow, Russia	3,661	59%
Madrid, Spain	3,622	34%
Hamburg, Germany	3,222	43%
Brussels, Belgium	3,448	73%
Vienna, Austria	2,981	43%
Prague, Czech Republic	2,266	51%
Copenhagen, Denmark	2,702	41%
Warsaw, Poland	2,400	50%
Budapest, Hungary	1,990	44%
Dusseldorf, Germany	1,937	28%
Marseille, France	1,735	104%
Kiev, Ukraine	1,563	106%
Bratislava, Slovak Republic	1,913	54%
Zurich, Switzerland	1,258	40%

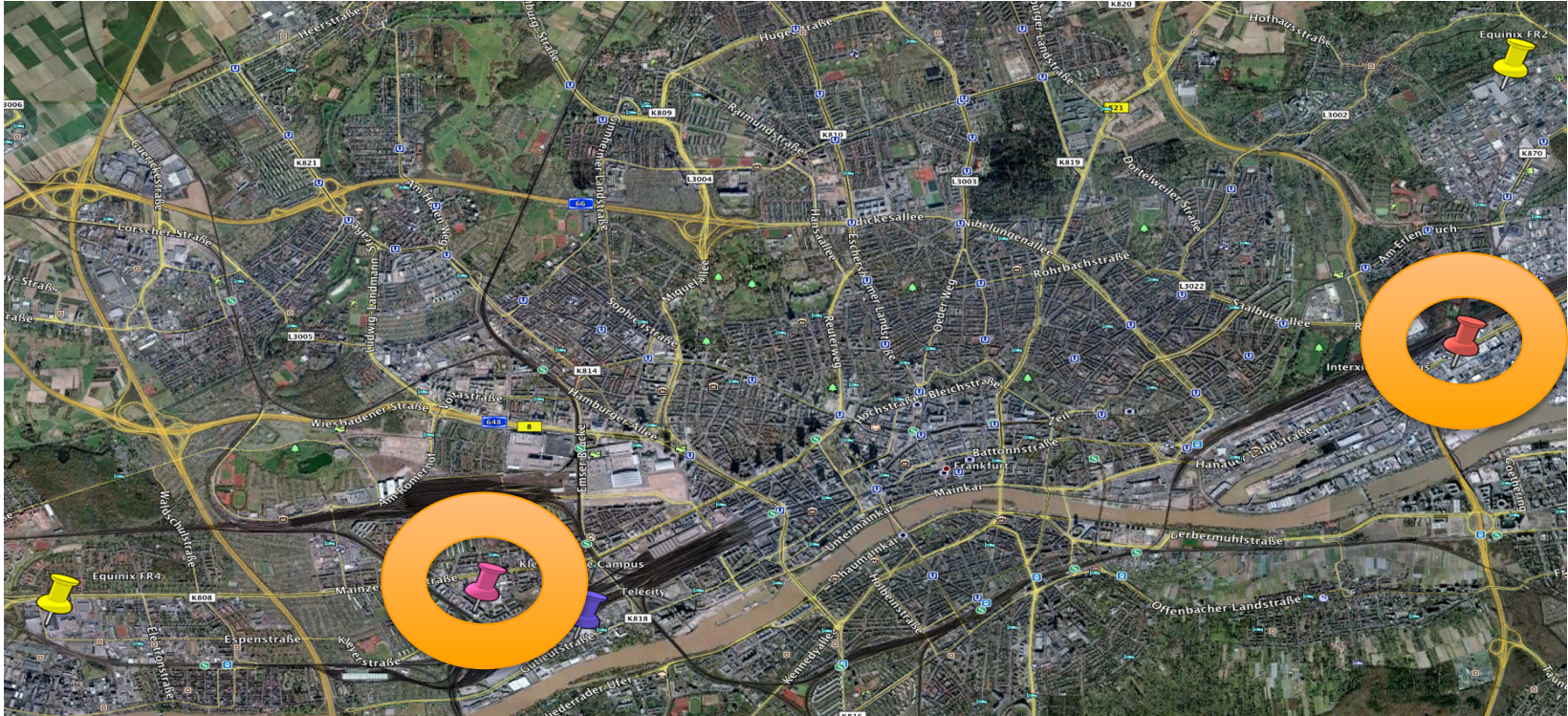


No seriously, where?



No seriously, where?

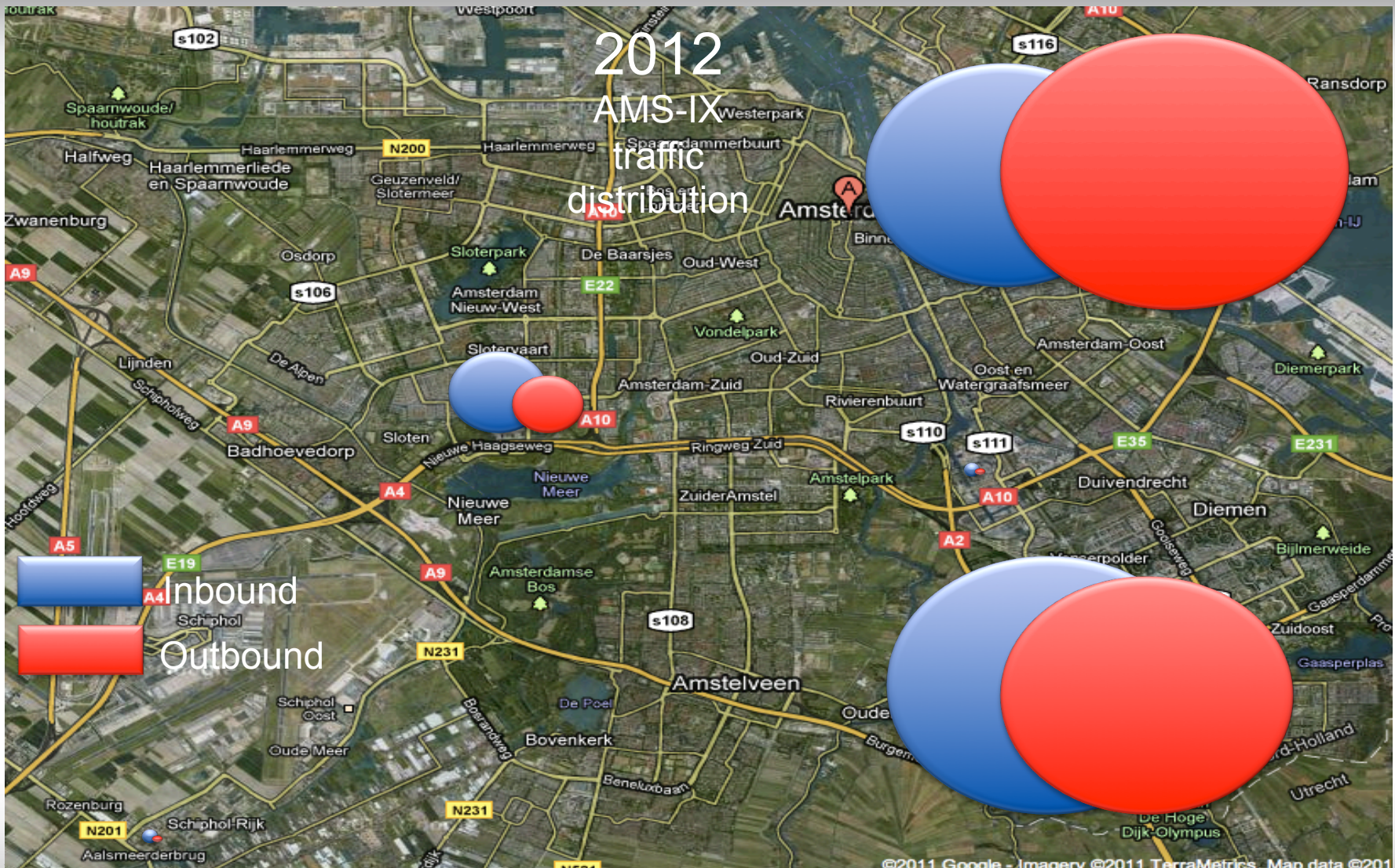
Take Frankfurt, for example:



No seriously, where?

Or Amsterdam:

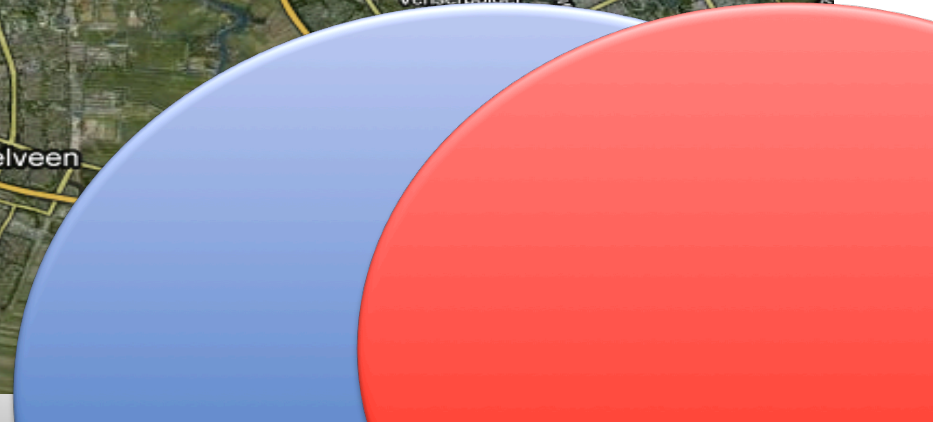




2014 AMS-IX traffic distribution



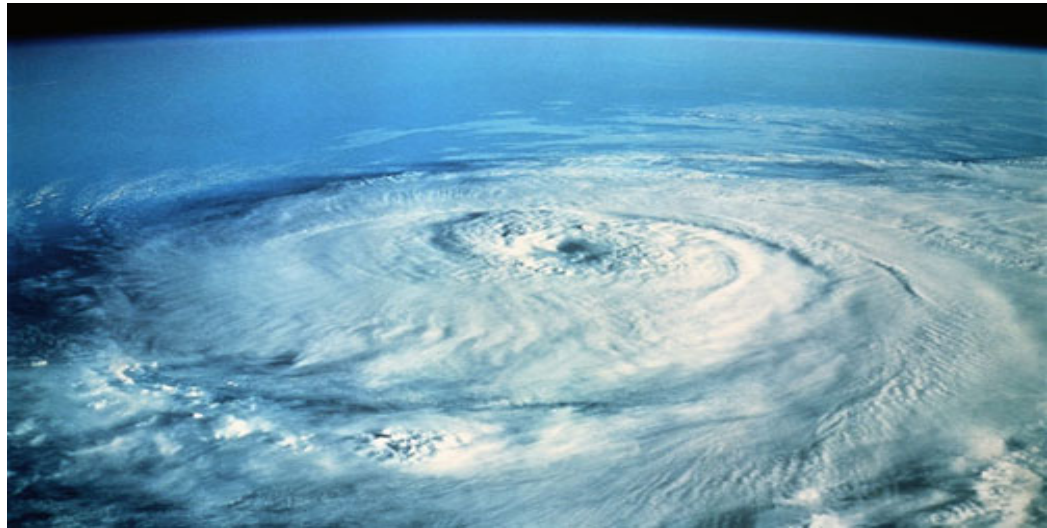
Inbound
Outbound



Why does it work?

A Combination of

- Regulatory framework
- Consolidated effort
- Availability and Scalability
- Cost
- Density

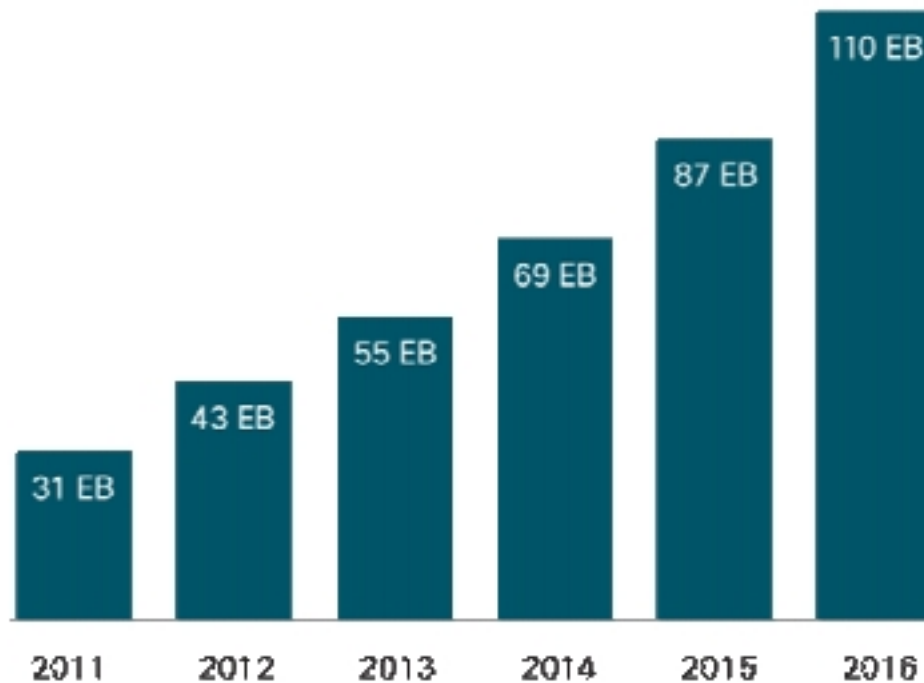


“The Exaflood”

or “The Zettabyte Era”, or “The Death of the Internet”
or: the consequences of vertical scaling

Cisco's VNI – All IP Traffic

Exabytes per Month



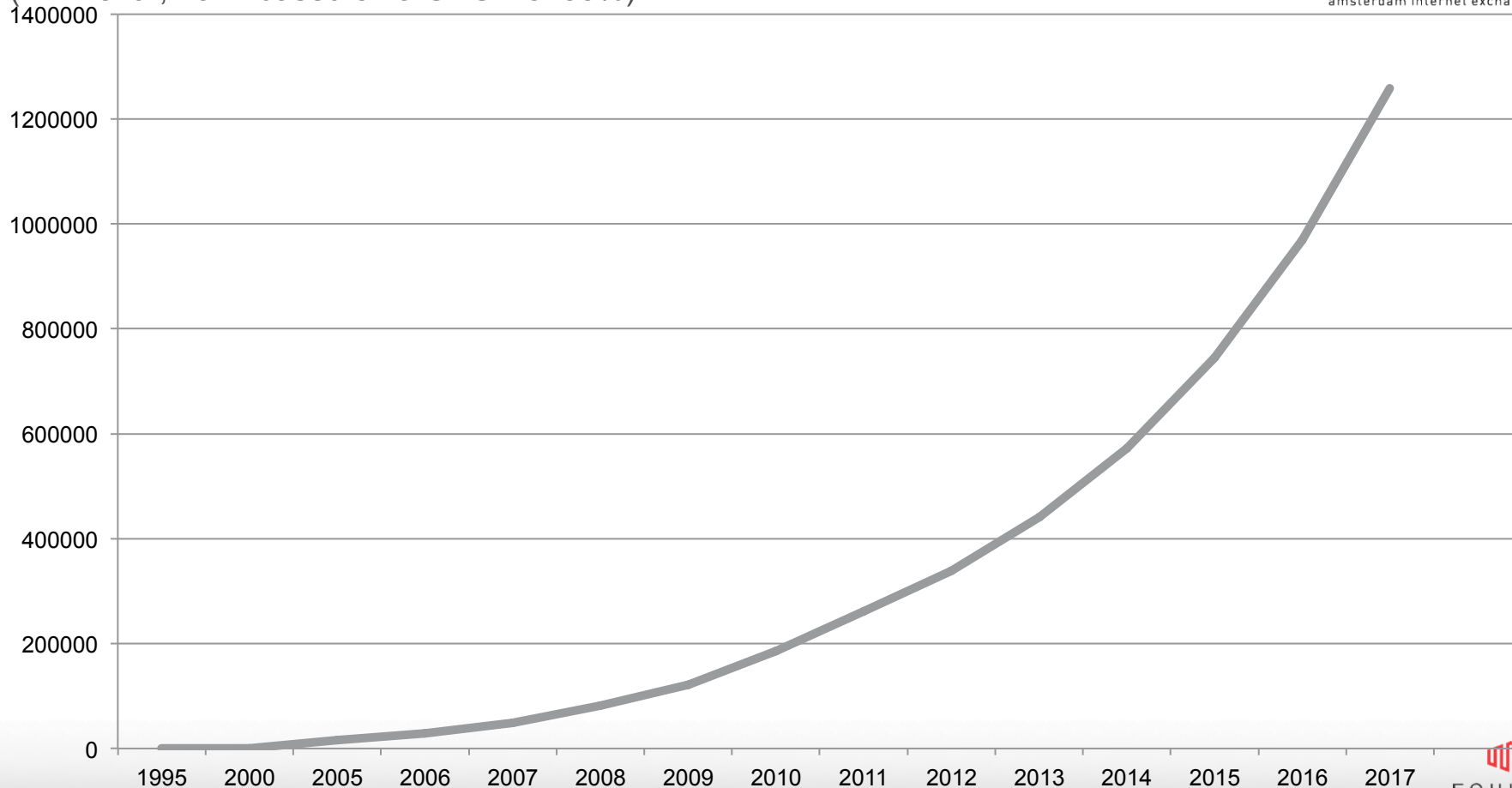
Source: Cisco VNI Global Forecast, 2011-2016

Cisco's VNI –All IP Traffic



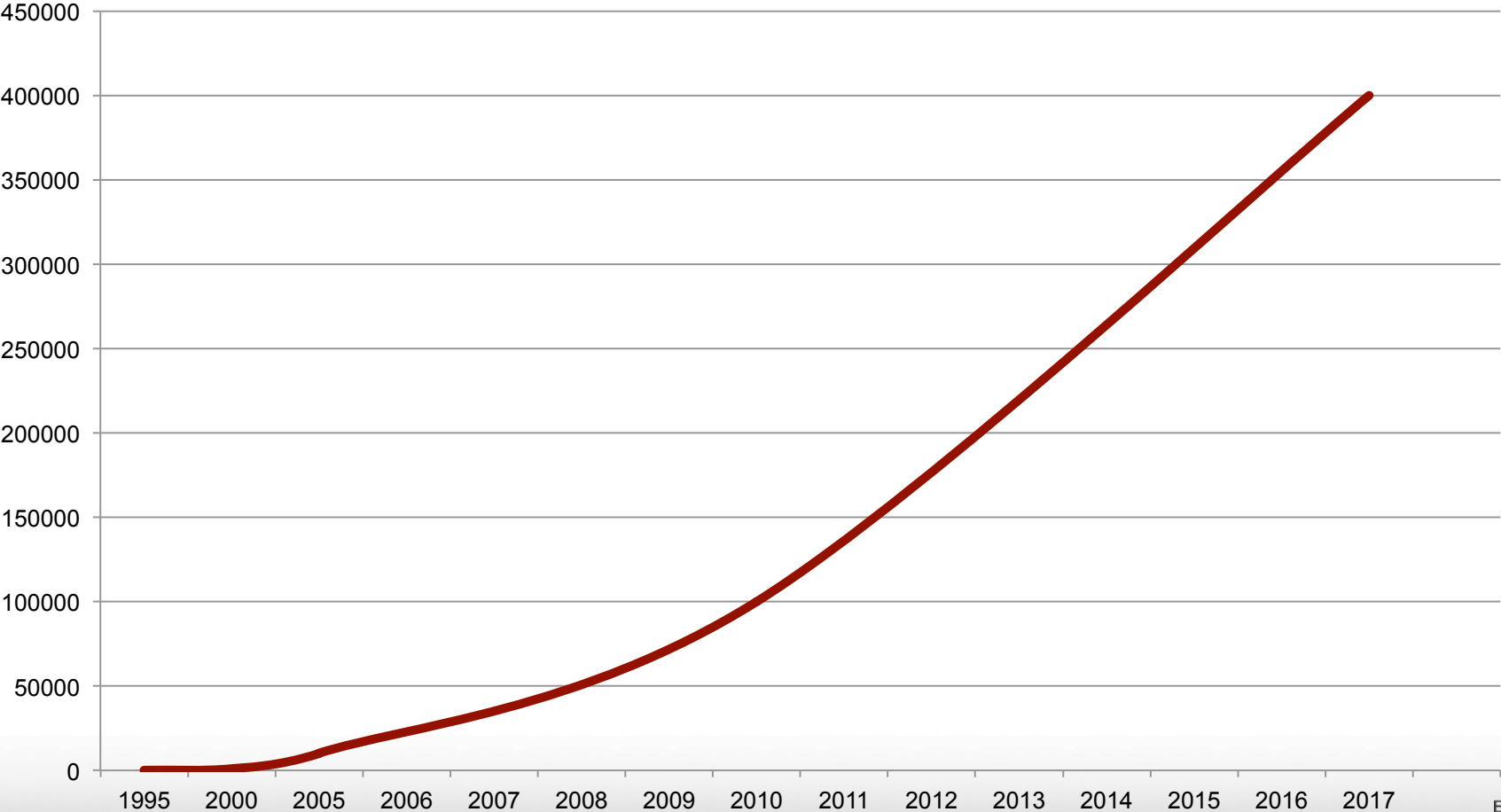
AMS-IX Traffic over a 22 year period

(TB/month, 2017 based on a CAGR of 30%)

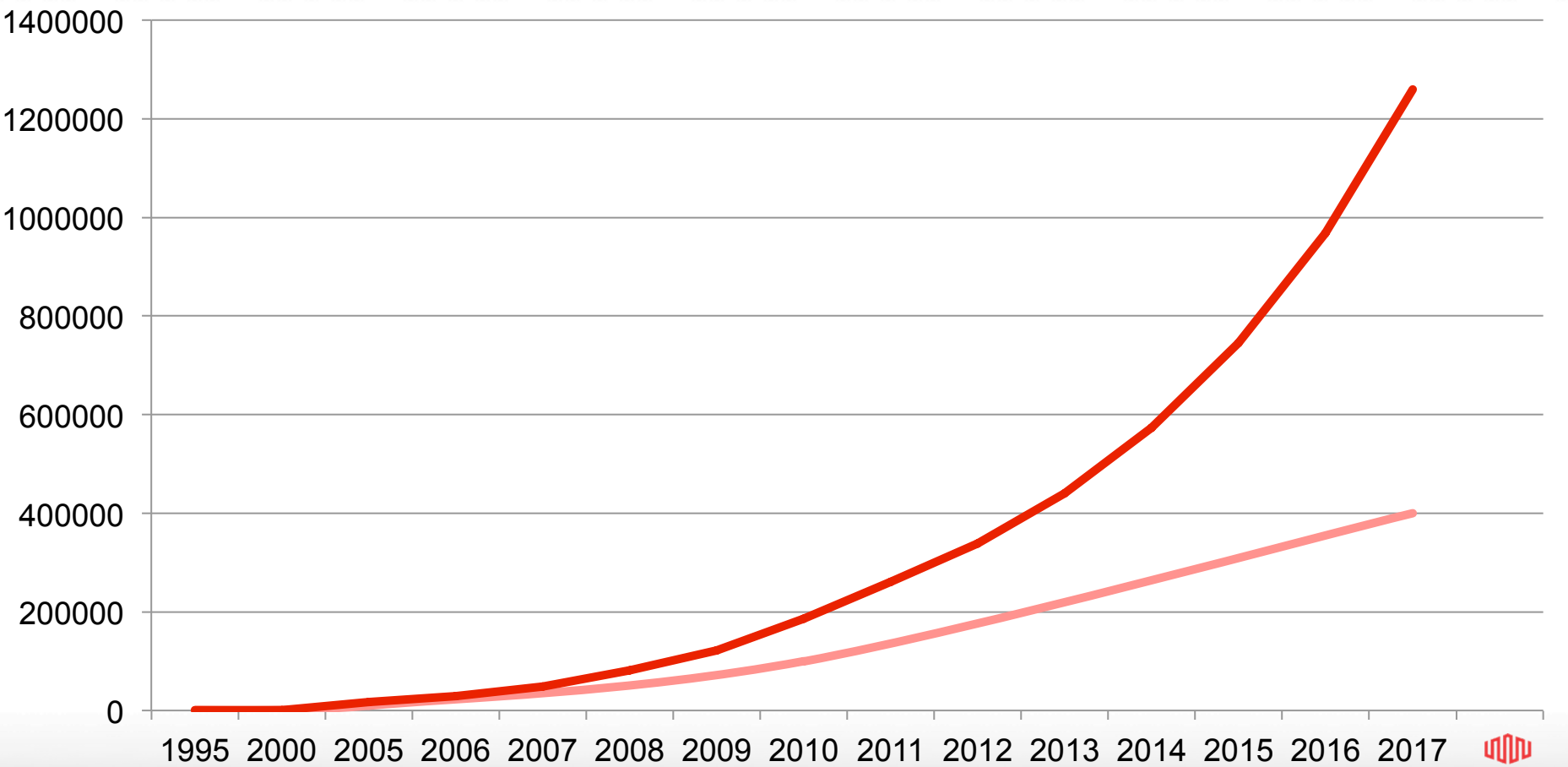


Ethernet interfaces by the IEEE

Speed in Mbps



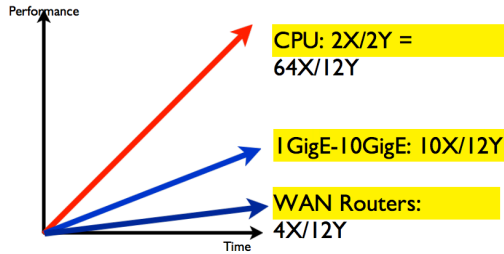
But if we overlay them...



As long as equipment keeps scaling..

We now move to Andy Bechtolsheim, presenting at NANOG 55

Moore's Law and Networking

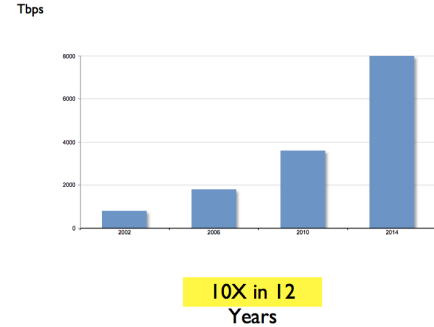


What happened???

Three Major Problems

- **Moore's Law applies to Transistors, not Speed**
 - Transistor count is doubling every 2 years
 - Transistor speed is only increasing slowly
- **Number of IO pins per package basically fixed**
 - Limited by die area and package technology
 - Only improvement is increased I/O speed
- **Bandwidth ultimately limited by I/O Capability**
 - Throughput per chip = # IO Pins * Speed/IO
 - No matter how many transistors are on-chip

Maximum Throughput per Chip



- **ASIC capacity grows at a linear scale**
- **So this could get painful**
- **See the NANOG 55 presentation archive on nanog.org**

Conclusions

Network technology is not really keeping pace

**In the next 5 years or so there's
an order of magnitude missing**

Instead, should we rethink interconnection architecture?

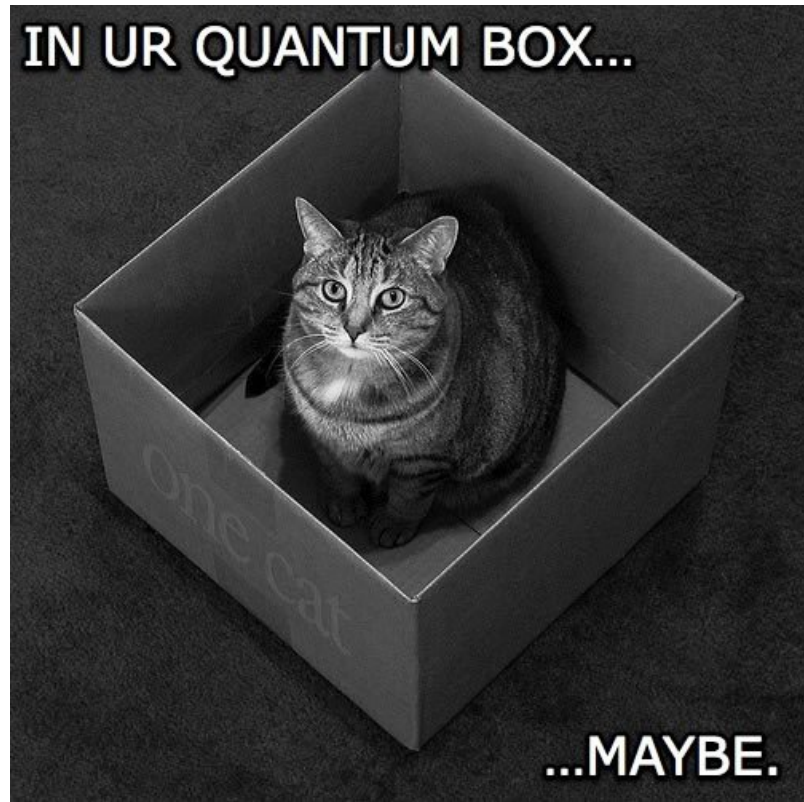
**Stop aggregating traffic and
start distributing interconnection?**

Rethinking Architecture

Aggregation and Distribution
or: the challenges of horizontal scaling

Abridged history of Internet interconnection

1980s	Hey, it works!
Early 1990s	Buy my pipes!
Late 1990s	Wanna Peer?
Mid 2000s	Mine's bigger than yours, go away.
Late 2000s	I'll build my own, then.
Mid 2010s	Why am I building this network again?



“Why am I building this network again?”

Eyeball Version

Those damn users keep eating more bandwidth

I'm not getting paid enough

Forget about peering, I'll just buy transit

~~Let's create a walled garden~~ charge a premium for guaranteed access!

“Why am I building this network again?”

Content Version

Off-net is the new hotness

For some content providers, over half of their traffic is served from inside eyeball networks, trending upwards

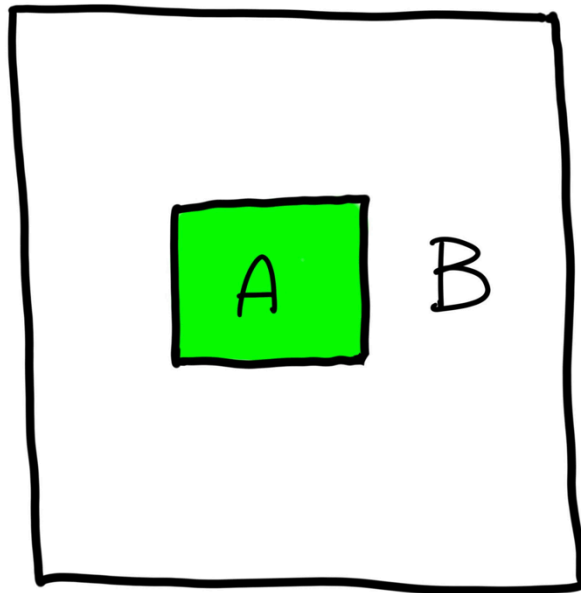
It helps to create walled gardens!

This does not scale!

A short explanation of a “Walled Garden”

(Adult language version)

Walled Gardens Explained:



A: Everyone here
makes money.

@hugh

It doesn't work for a lot of things

- **It only works for data that can be duplicated and cached**
- **This excludes databases, public cloud, multiplayer online games**
- **Good luck if you're competing with a service the eyeball network is offering**

Barrier to Entry

- **It gets 10 times as expensive to keep up with performance**
- **Need to negotiate hundreds of housing deals**
- **Still requires central 'overflow' capacity**
- **There's no space!**

Interconnection markets

How do you create *many*?

This does not scale!

- **Instead of ~20 locations to interconnect worldwide, we're looking at over 200 deployments close to eyeball networks**
- **It doesn't even work for a lot of things (interactive content, cloud)**
- **This sets a huge barrier to entry**
- **There is no physical infrastructure to support this**

No Physical Infrastructure

- **Small datacenters are inefficient, multi-tenant small datacenters even more so**
- **Building carrier-neutral multi-tenant small datacenters in 200 locations will cost between 2bn and 5bn USD**
- **It will take the best part of a decade**
- **Whatever you build needs to scale**

Final Thoughts

- **Building new places to interconnect is hard**
- **Exponential traffic growth is and has been a fact of life**
- **Network technology is falling behind**
- **There several options to evolve the Internet architecture**
- **Most of those options will make the Internet more expensive and/or less open to innovation**

Thank You

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