IPv6-Based 5G
The Two-Way Internet

lacnic25
2/6 mayo – la habana, cuba

IPv6-based EVERY-NET

IPv6 FORUM

5G WORLD ALLIANCE

Vision 2020

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5G EMERGING TECHNICAL COMMITTEE

NORMAL

NORMAL

CAFFEINE

NORMAL

MARIJUANA

CAFFEINE

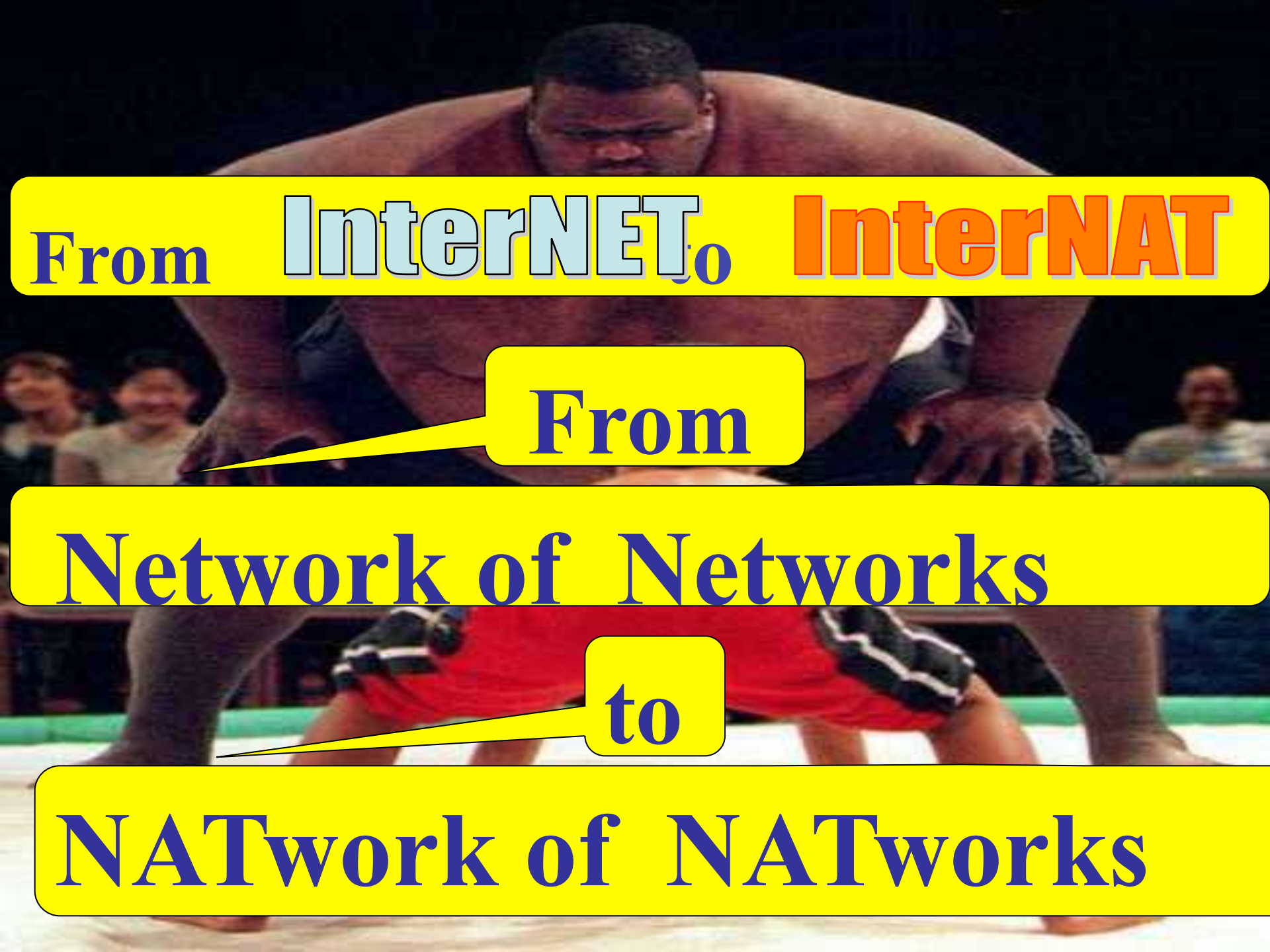
NORMAL

MARIJUANA

CAFFEINE

BENZEDRINE

STUN-ned


From InterNET to InterNAT
From
Network of Networks
to
NATwork of NATworks

Internet Generations

ArpaNET	InterNET InterNAT	New InterNET
NCP 2^8	IPv4/NAT 2^{32}	IPv6 2^{128}
Pioneers	Innovators NAT engineers	EveryOne Everything
Email, FTP	WWW- Client/Server	Wireless, Streaming Media, P2P, GRID
TOURISTS		RESIDENTS
Gov. Internet	Public Internet	Global Internet

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First Losers

ArpaNET

NCP

Pioneers

Email, FTP

TOU

Gov. Internet

Vendor Proprietary

SNA

DecNET

Novell IPX

Netbios

Proprietary Network

nterNET

IPv4

Innovators
AT engineers

WWW- Client/Server

S

lic Internet

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OSI Losers

ArpaNET	Vendor Proprietary	OSI	InterNET
NCP	SNA	CLNP	10 9- Nodes
Pioneers	DecNET	USG GOV NATO	Innovators
Email, FTP	Novell IPX	Minitel (FT)	WWW- Client/Server
TOU	Netbios		
Gov. Internet	Proprietary Network	Government Network	Public Internet

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OSI II - Political Internet

InterNET InterNAT	New InterNET	WSIS IGF ITU
IPv4/NAT	IPv6	
Innovators NAT engineers	EveryOne Everything	Zero Protocol Chasing ICANN USG
WWW- Client/Server	Wireless, Streaming Media, P2P, GRID	
TOURISTS	RESIDENTS	Government Control
Public Internet	Global Internet	

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OSI III - Non-IP Internet

InterNET InterNAT	New InterNET	ITU	Clean Slate Internet
IPv4/NAT	IPv6		
Innovators NAT engineers	EveryOne Everything	Phone Internet Protocol Chasing IETF	Non-IP Protocol
WWW Client/Server	Wireless, Streaming Media, P2P, GRID		GENI/Future Internet
TOURISTS	RESIDE	China Control	Researchers' Internet
Public Internet	Global Internet		

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OSI III - Non-IP Internet

InterNET InterNAT	New InterNET	CCN ICN	New IP
IPv4/NAT	IPv6		
Innovators NAT engineers	EveryOne Everything	Chasing IP	Business
WWW Client/Server	Wireless, Streaming Media, P2P, GRID		SDN-NFV
TOURISTS	RESIDE	Researchers' Internet	Business Internet
Public Internet	Global Internet		

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OSI III - Non-IP Internet

InterNET InterNAT	New InterNET	New IP	NGP
IPv4/NAT	IPv6		
Innovators NAT engineers	EveryOne Everything	Business	ETSI
WWW Client/Server	Wireless, Streamin Media, P2P, GRID	SDN-NFV	IP for 5G
TOURISTS	RESID	Business Internet	Researchers' Internet
Public Internet	Global Internet		

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Wireless Generations

1G	2G	3G	4G	5G
Non-IP	IPv4/NAT			IPv6
Analogue	GSM	WCDMA	OFDM	? MIMO/mmWAVE
Voice	Voice	- WWW- C/Server		Streaming Media, P2P,..
9.6 Kbps	64 Kbps	2 Mbps	10 Mbps	1 Gbps +
		Public Internet		Global W. Internet

IoT Generations

	IoT 1	IoT 2	IoT 3
IP	Non-IP	IPv4/NAT	IPv6
Technology	RFID/KNX BackNet	Gateways	Mix GW 6LowPAN-Roll
Media	-	video	Sensors IoT Devices ..
Speed	K-Mbps	Mbps	Gbps
			Global IoT Internet

DATA Generations

	DATA	BIG DATA	BIG IoT DATA
IP	Non-IP	IPv4/NAT	IPv6
Technology	Telex, Fax Telegraph	Hadoop Gateways	Mix GW 6LowPAN-Roll
Media	-	All	Sensors IoT Devices
Volume		 Global Data	.. HB Global IoT Data

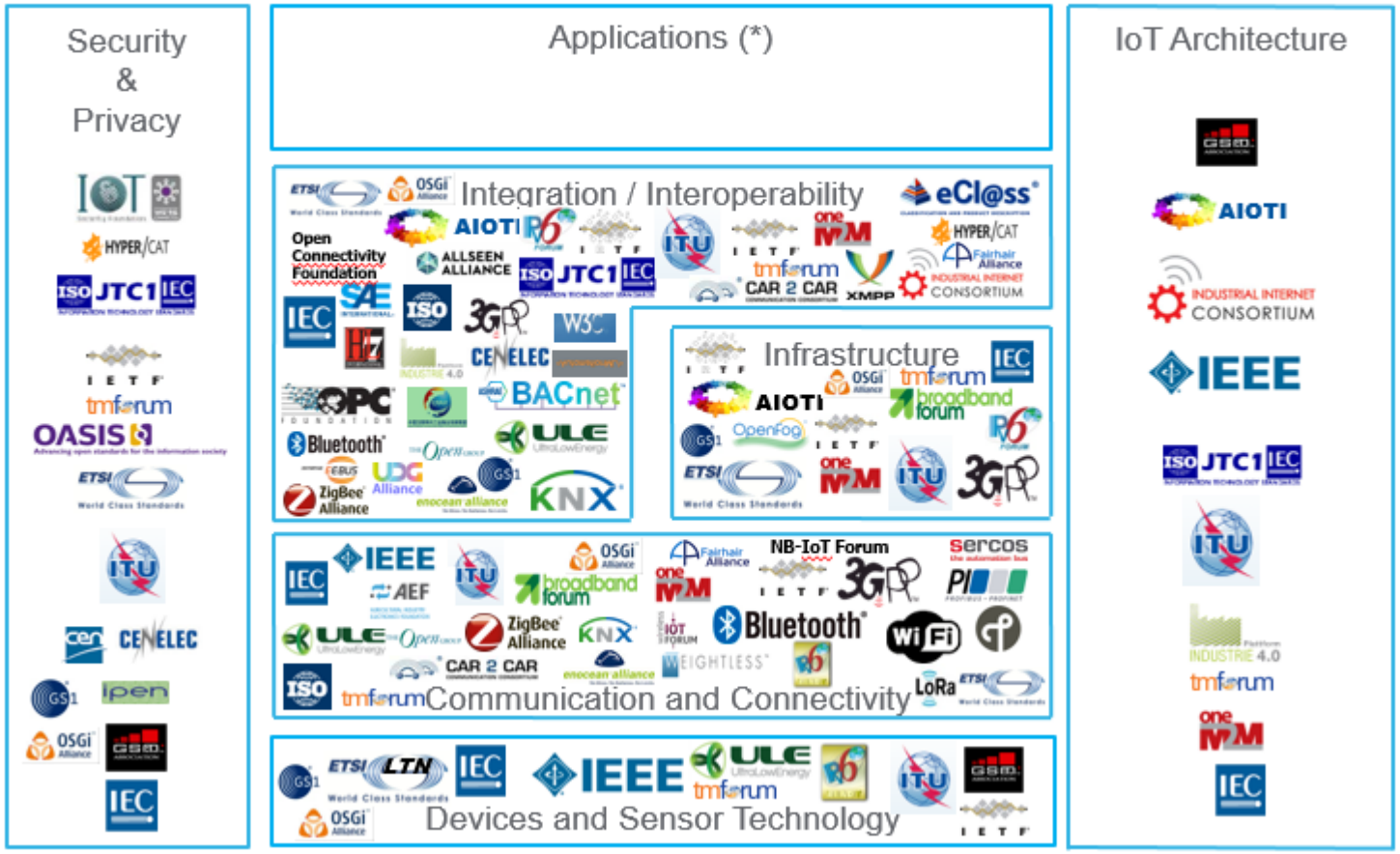
IoT SDOs and Alliances Landscape (Technology and Marketing Dimensions)

Source: AIOTI WG3 (IoT Standardisation) – Release 2.0

IPv6 Forum Logo added on 1/11/2015 (for Release 3.0)

IoT SDOs and Alliances Landscape (Technology and Marketing Dimensions)

Mapping of IoT SDOs/Alliances to Knowledge Areas



So

Source: AIOTI WG3 (IoT Standardisation) – Release 2.4

IPv6 Forum Logo added on 1/11/2015 (for Release 3.0)

IoT SDOs and Alliances Landscape (Vertical and Horizontal Domains)

Home/Building | Manufacturing/ Industry Automation | Vehicular/ Transportation | Healthcare | Energy | Cities | Wearables | Farming/ Agrifood

Horizontal/Telecommunication

Source: AIOTI WG3 (IoT Standardisation) – Release 2.5

The New Internet
The TWO-WAY Internet
End 2 End

Filesharing

Ressource Sharing

Instant Communication

Interactive

Collaborative Computing

Wide Open Again for INNOVATION

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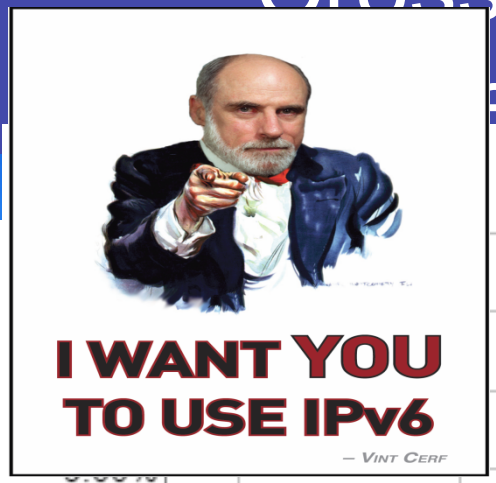
Crossed10.0%
ers over IPv6 (2016



Google™

Native: 11.25% 6to4/Teredo: 0.01% Total IPv6: 11.26% | Apr 24, 2016

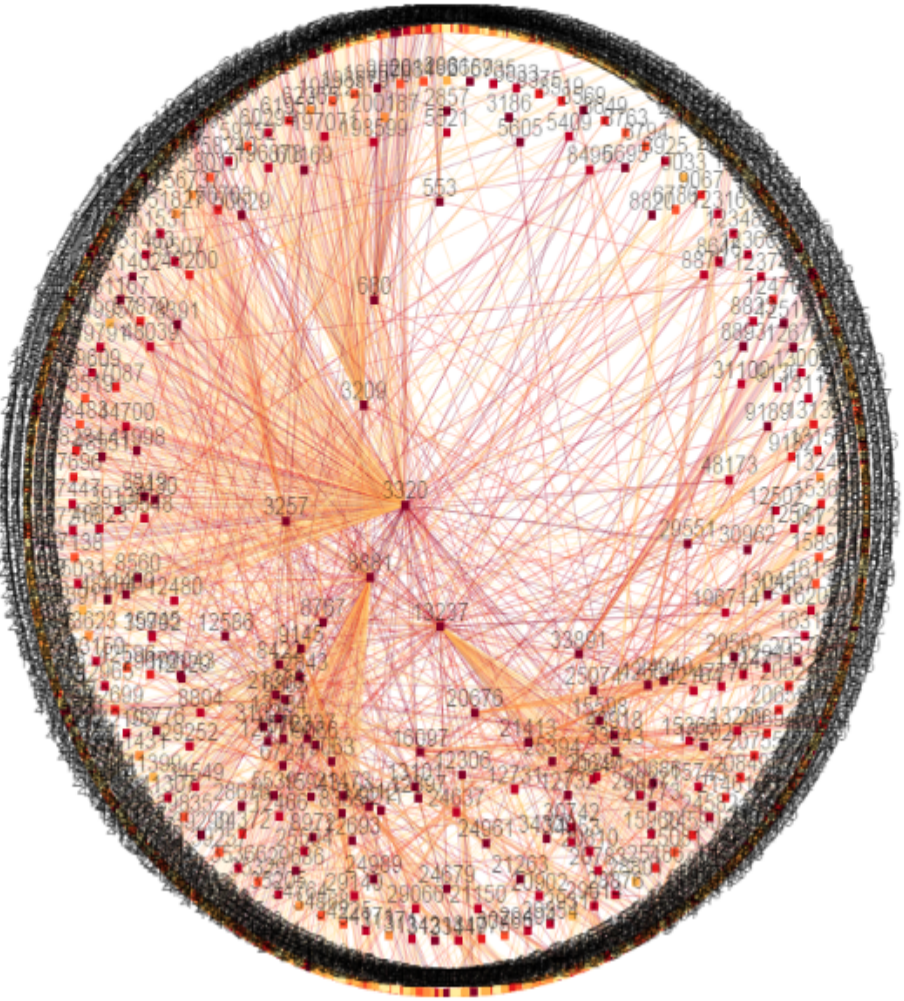
8.00%
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%

Jan 2009 Jan 2010 Jan 2011 Jan 2012 Jan 2013 Jan 2014 Jan 2015 Jan 2016

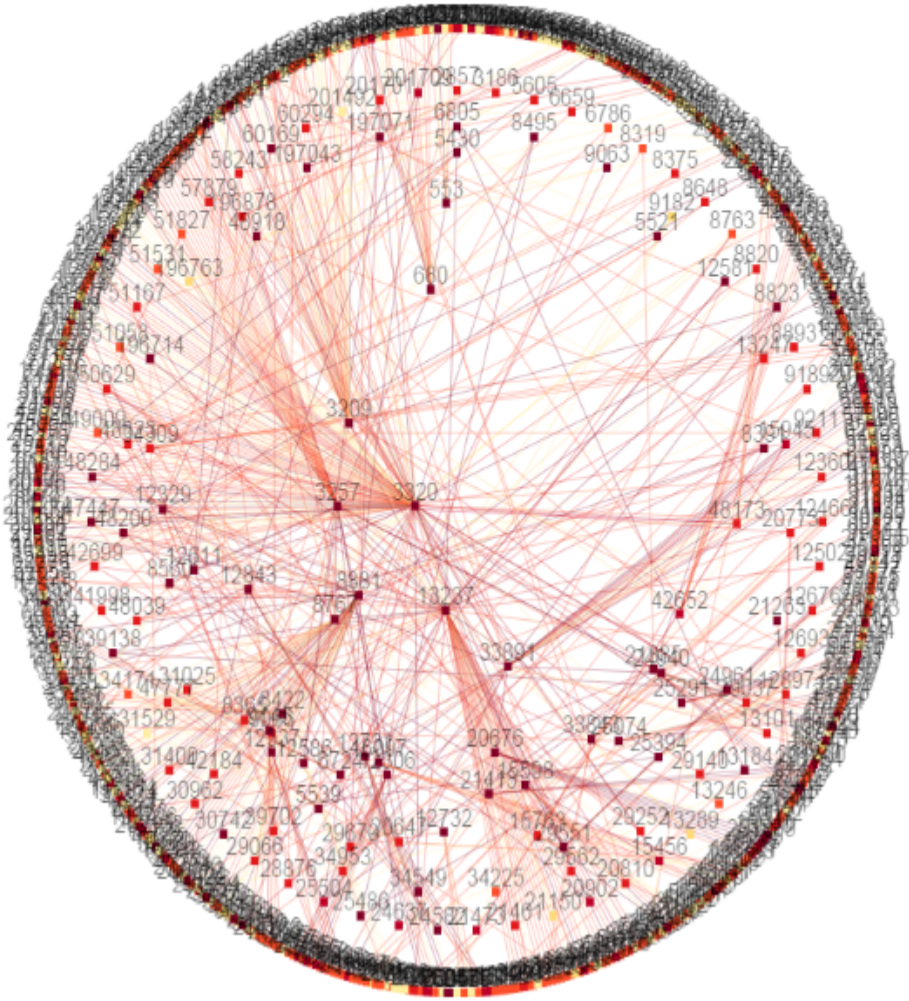
vizAS explores the interconnections between ASes within an economy, and compares the state of interconnections between the IPv4 and IPv6 address families.

DE Germany

IPv4



IPv6

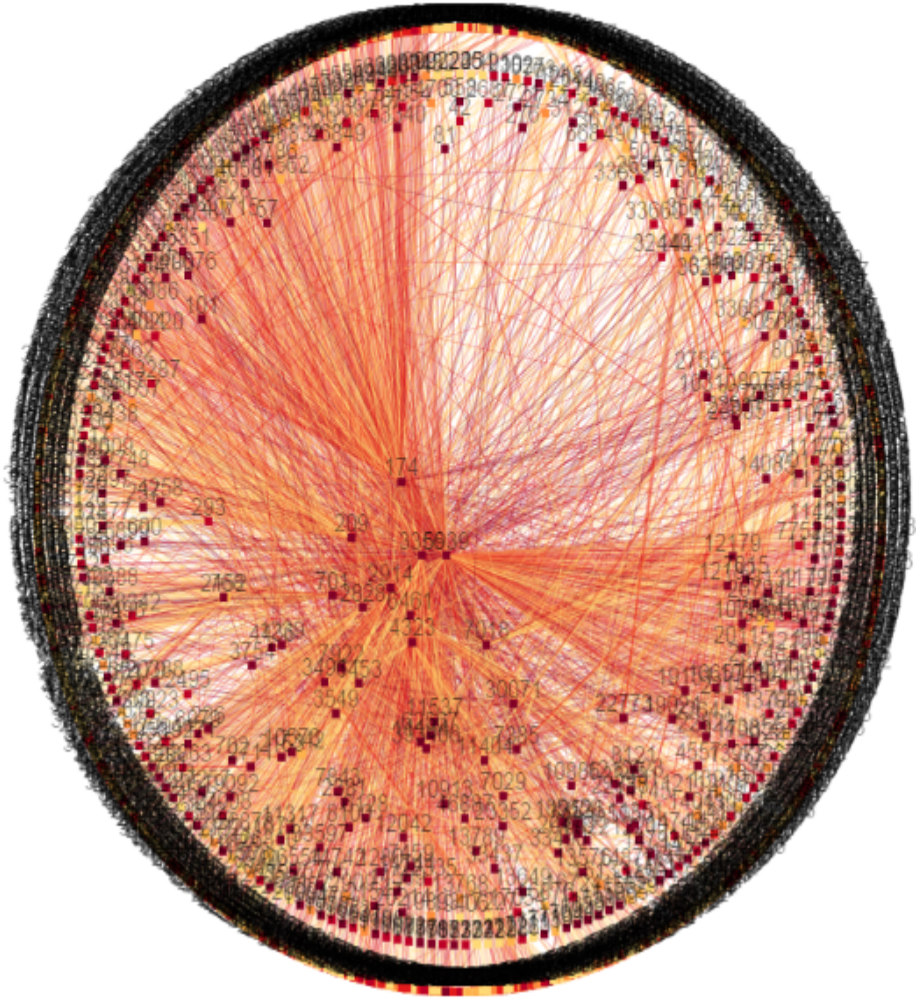


vizAS explores the interconnections between ASes within an economy, and compares the state of interconnections between the IPv4 and IPv6 address families.

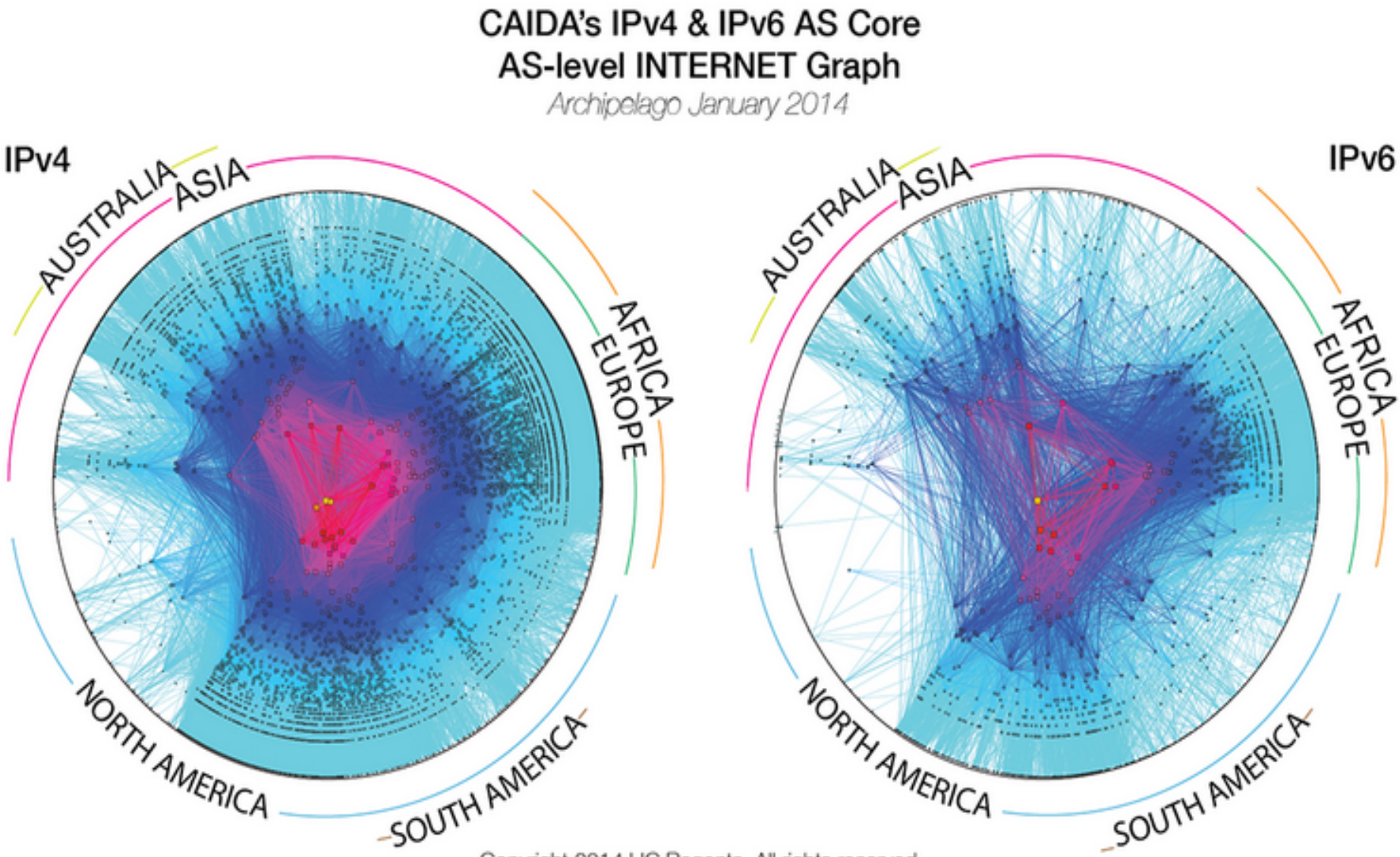
US United States of America

IPv4

IPv6



Visualizing IPv4 and IPv6 Internet Topology



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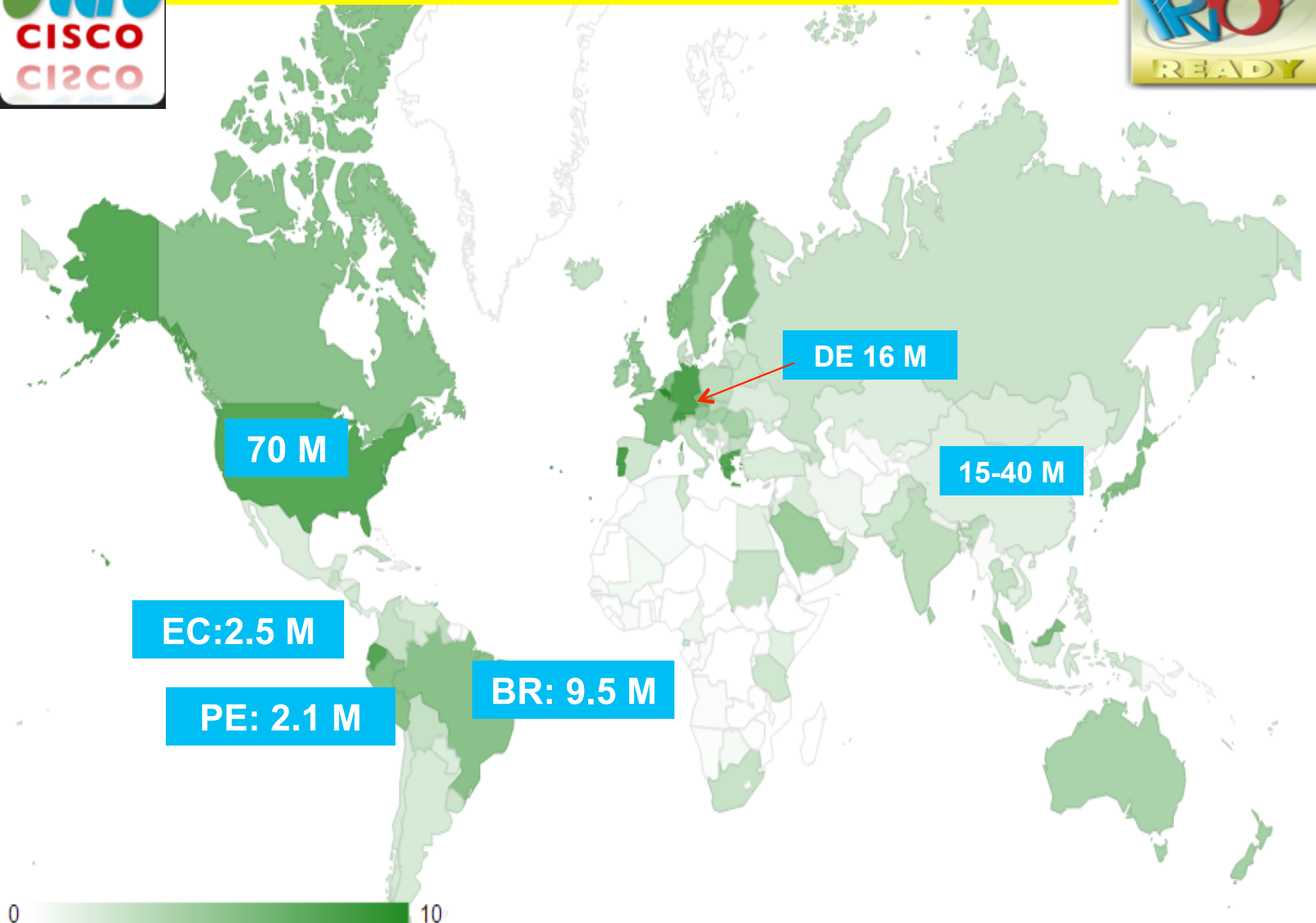
IPv6 Deployment Worldwide



IPv6 Deployment Worldwide

APNIC

IPv6 Users by Country

Labs.APNIC.NET -

Date: 26 Apr 2016

Index	ISO-3166 Code	Internet Users	V6 Use ratio	V6 Users (Est)	Population	Country
1	BL	1915	100.0000%	1915	9035	Saint Barthelemy
2	BE	9337077	52.2597%	4879525	11358975	Belgium
3	PT	6404070	29.0686%	1861574	10312513	Portugal
4	CH	7252528	26.6260%	1931055	8365085	Switzerland
5	US	281296304	26.4796%	74486069	323701156	United States of America
6	GR	6544506	25.6374%	1677843	10925720	Greece
7	DE	69549137	23.3545%	16242854	80683454	Germany
8	AP	0	19.9065%	0	0	Asia Pacific code
9	EC	12649108	19.8010%	2504652	16342517	Ecuador
10	PE	13220329	18.5257%	2449159	31703428	Peru
11	EE	1047775	18.1541%	190213	1309719	Estonia
12	LU	538990	17.1653%	92519	574617	Luxembourg
13	FI	5051040	16.7613%	846620	5520263	Finland
14	JP	114489583	15.2816%	17495798	126368194	Japan
15	EU	0	14.3930%	0	0	European Union
16	MY	20706773	14.0975%	2919136	30676702	Malaysia
17	FR	53828085	14.0364%	7555521	64619551	France
18	BR	113419759	11.2954%	12811221	209261549	Brazil
19	CA	34304772	10.7835%	3699256	36224681	Canada
20	NO	4998042	10.2788%	513739	5261097	Norway
21	AT	6903529	10.0269%	692210	8565173	Austria
22	SG	4657588	8.2584%	384644	5679986	Singapore
23	NL	15951771	8.2294%	1312735	16969970	Netherlands
24	GB	58406585	8.0968%	4729088	65040741	United Kingdom of Great Britain and Northern Ireland

Key Performance Indicators: 500 Sites Tested

Global IPv6 Deployment

28.0%

500 sites tested
0 DNS errors
140 with IPv6

China

7.0%

500 sites tested
0 DNS errors
35 with IPv6

Germany

14.4%

500 sites tested
0 DNS errors
72 with IPv6

Finland

15.8%

500 sites tested
0 DNS errors
79 with IPv6

India

16.4%

500 sites tested
0 DNS errors
82 with IPv6

IETF

18.3%

3038 sites tested
0 DNS errors
556 with IPv6

Japan

9.4%

500 sites tested
0 DNS errors
47 with IPv6

South Korea

10.6%

500 sites tested
0 DNS errors
53 with IPv6

United Kingdom

12.0%

500 sites tested
0 DNS errors
60 with IPv6

United States

14.2%

500 sites tested
0 DNS errors
71 with IPv6

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Key Performance Indicators: DNSSEC & SIP

Global DNSSEC Deployment

1.2%
500 sites tested
0 DNS errors
6 with DNSSEC

China 0.2%
500 sites tested
1 DNS error
1 with DNSSEC

Germany 0.8%
500 sites tested
0 DNS errors
4 with DNSSEC

Finland 1.0%
500 sites tested
0 DNS errors
5 with DNSSEC

India 0.6%
500 sites tested
1 DNS error
3 with DNSSEC

IETF 5.2%
3038 sites tested
295 DNS errors
143 with DNSSEC

Japan 1.2%
500 sites tested
1 DNS error
6 with DNSSEC

South Korea 0.8%
500 sites tested
0 DNS errors
4 with DNSSEC

United Kingdom 1.0%
500 sites tested
0 DNS errors
5 with DNSSEC

United States 2.2%
500 sites tested
0 DNS errors
11 with DNSSEC

Global SIP Deployment

4.6%
500 sites tested
0 DNS errors
23 with SIP

China 1.0%
500 sites tested
1 DNS error
5 with SIP

Germany 4.4%
500 sites tested
0 DNS errors
22 with SIP

Finland 5.0%
500 sites tested
0 DNS errors
25 with SIP

India 3.0%
500 sites tested
0 DNS errors
15 with SIP

IETF 11.2%
3038 sites tested
238 DNS errors
314 with SIP

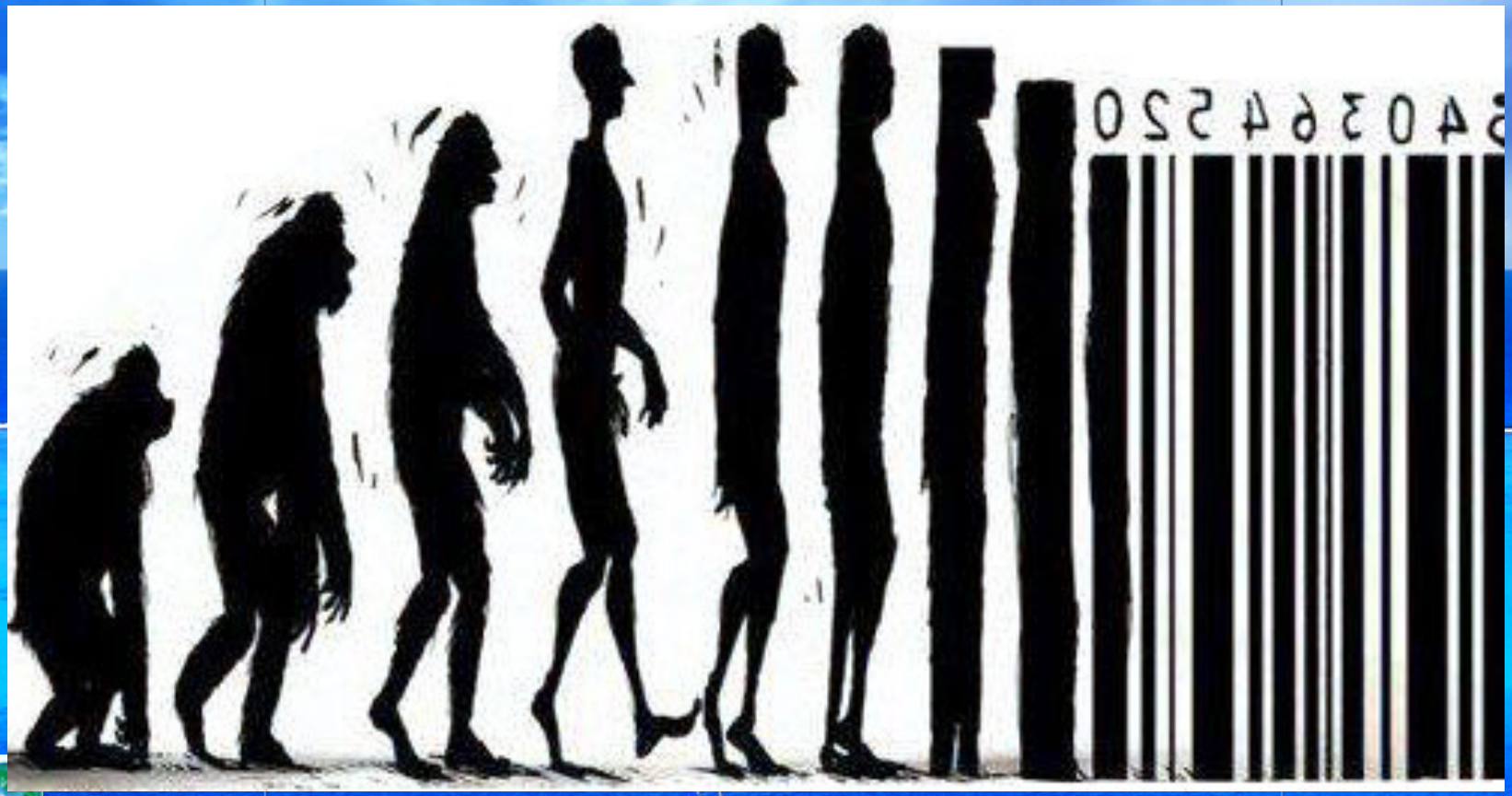
Japan 1.0%
500 sites tested
1 DNS error
5 with SIP

South Korea 3.8%
500 sites tested
0 DNS errors
19 with SIP

United Kingdom 2.6%
500 sites tested
0 DNS errors
13 with SIP

United States 8.8%
500 sites tested
0 DNS errors
44 with SIP

Evolution from ...
to RFID .....to IoT



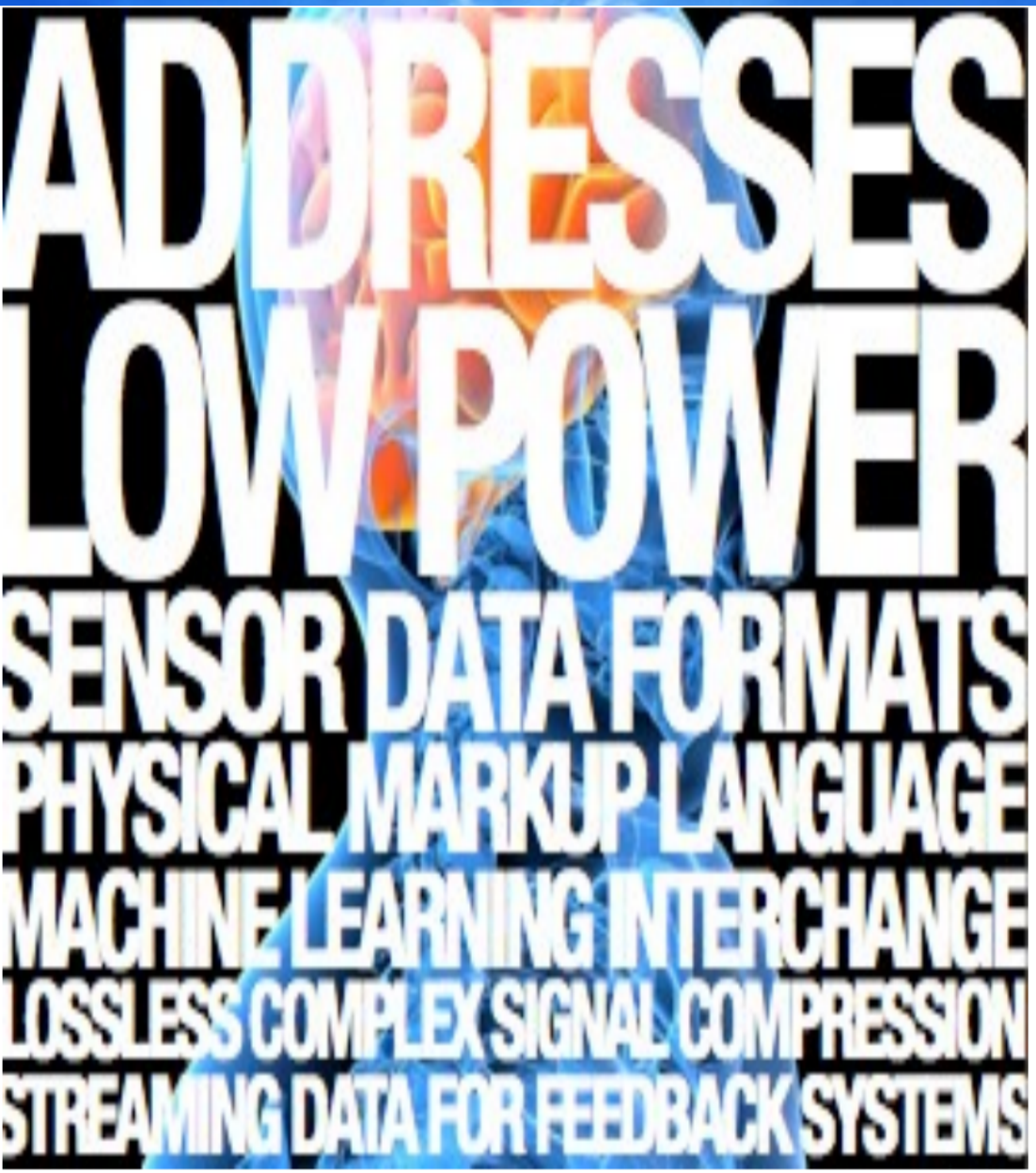
IEEE COMSOC Emerging Technologies Committees

IEEE COMSOC
INTERNET OF THINGS

IEEE COMSOC
SDN-NFV

IEEE COMSOC 5G

Success Challenges: Kevin Ashton



Use IPv6

Harvesting Power
Wireless Power

Open data formats

CoAP

Autonomicity

standardisation

Sensor QoS

What's needed for IoT:

IPv6 for the IOT is a must (same as radio technologies)

→ ETSI ISG IP6 best practices documents

IPv6 up to the end device

→ Close but not yet there

→ IETF 6lowPan, 6lo

Gateways → will be your (our) next nightmare:

Manageability (maintenance, configuration, deployment…)

Energy consumption

Security: Breaking end to end security, Network entry point.

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Multi-protocol integration

Cloud Computing Inventors

Christopher C Pinkham

Willem van Biljon

2 South Africans

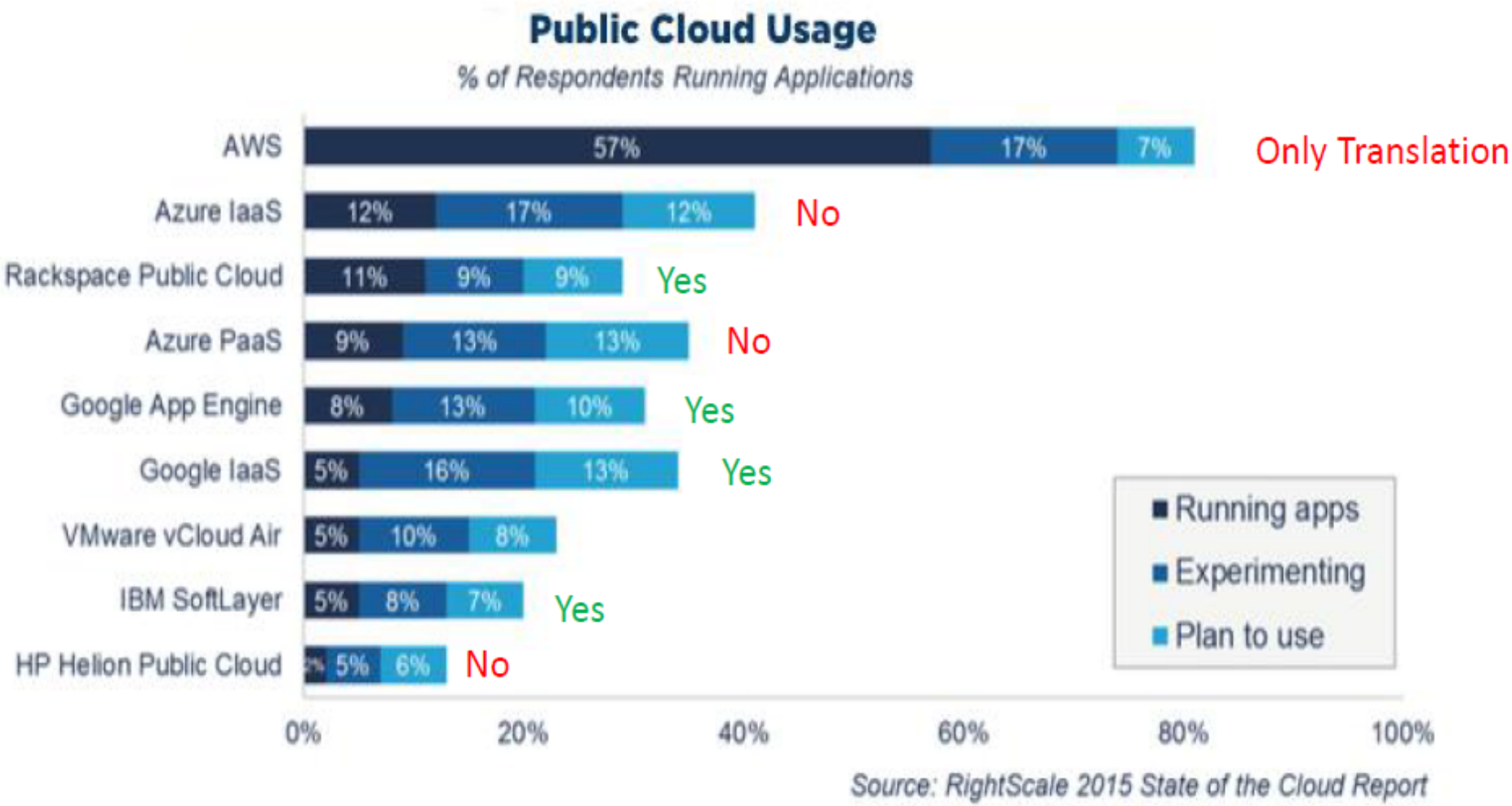
Amazon's Elastic Compute Cloud (EC2)

Four Major Inflection Points

v6 Openstack

Driver		Business Results
Apps		Business
IOT		Instrumentation
Cloud		Agility
SDN/NFV		Flexibility
IPv6		Scalability

Adoption and Trends



5G Standardisation Entities Interested

Title	Source
IMT-2020/5G	ARIB
IMT-2020 (5G FOCUS GROUP)	ITU
3GPP and The Road to 5G	3GPP
5G in the Americas	4G Americas
IMT2020	5G Forum, Korea
5G IMT 202 Promotion Group: Program 863	China
5G Mobile Network R&D In Japan	5GMF
The 5G Infrastructure Public-Private Partnership	5GPPP
5G Approach in the EU	European Commission
Update on 5G Work Programme	NGMN

5G Requirements

- User Experience
  - Consistent User Experience
  - User Experienced Data Rate
  - Latency
  - Mobility
  - User Experience KPI's

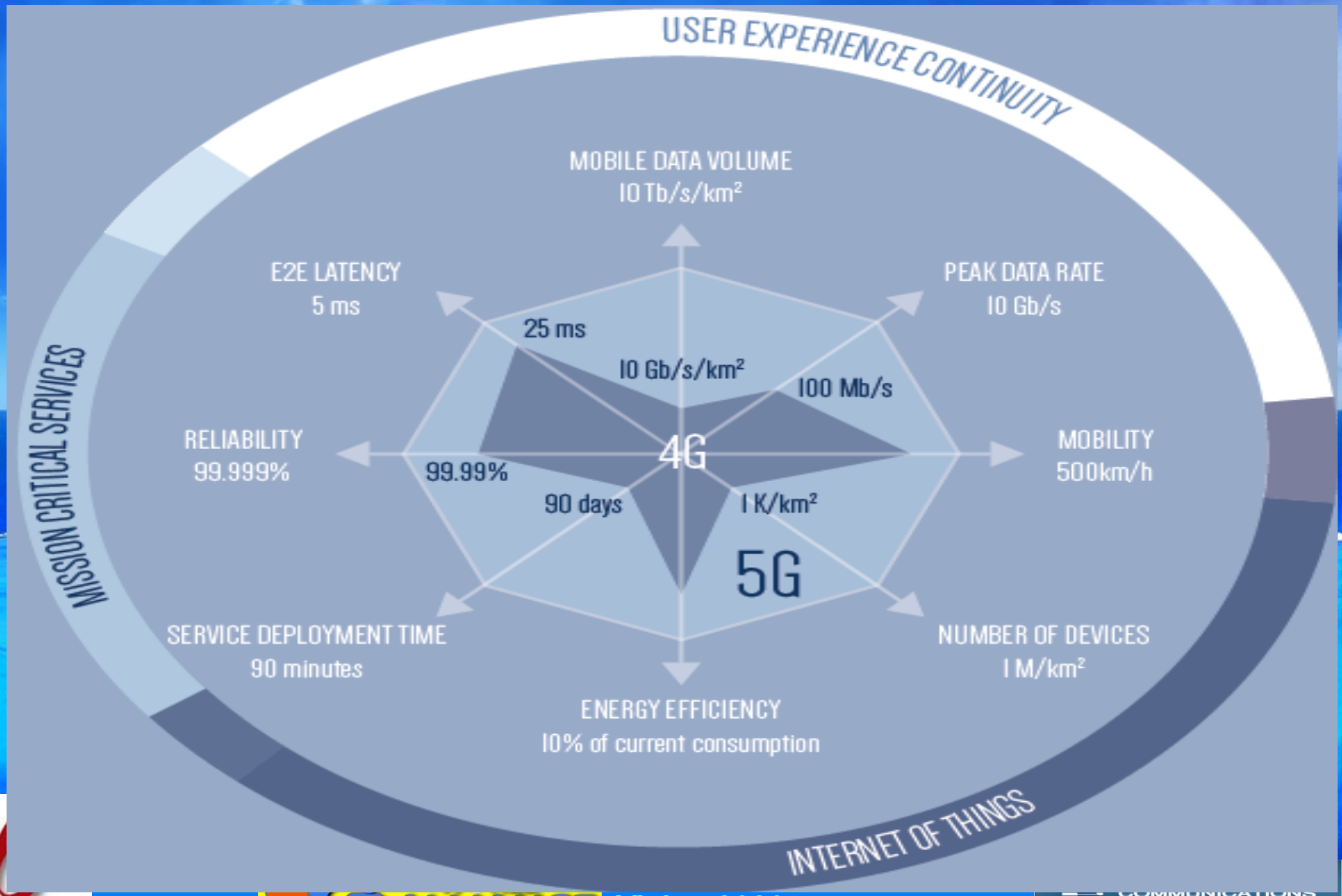
- System Performance
  - Connection Density
  - Traffic Density
  - Spectrum Efficiency
  - Coverage
  - Resource and Signalling Efficiency
  - System Performance KPI's

- Device Requirements
  - Operator Control Capabilities on Devices
  - Multi-Band-Multi-Mode Support in Devices
  - Device Power Efficiency
  - Resource and Signalling Efficiency

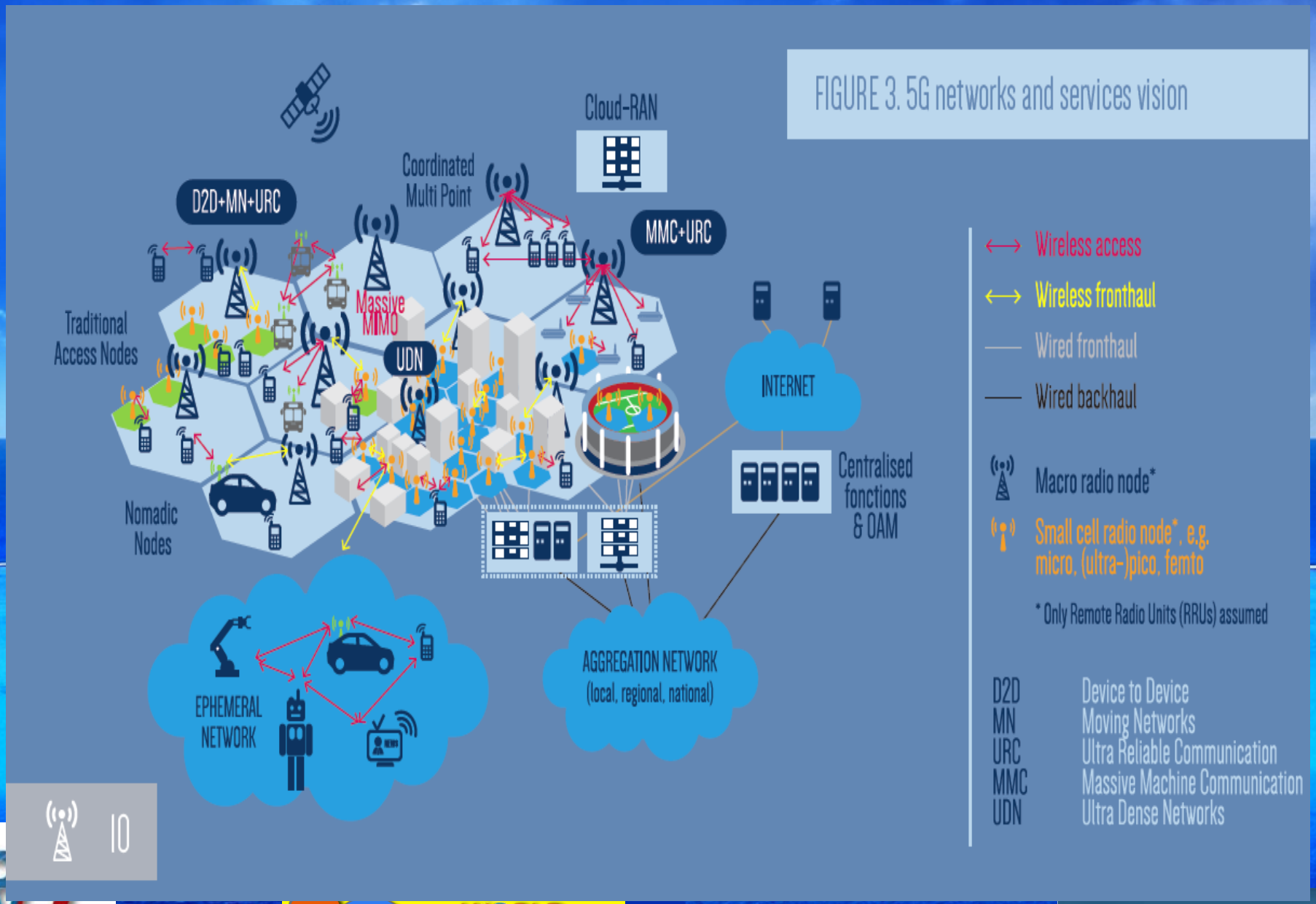
- Enhanced Services
  - Connectivity Transparency
  - Location
  - Security
  - Resilience and High Availability
  - Reliability
- New Business Models
  - Connectivity Providers
  - Partner Service Provider and XaaS Asset Provider
  - Network Sharing Model

- Network Deployment, Operation and Management
  - Cost Efficiency
  - Energy Efficiency
  - Ease of Innovation and Upgrade
  - Ease of Deployment
  - Flexibility and Scalability
  - Fixed-Mobile Convergence
  - Operations Awareness
  - Operation Efficiency
  - Ultra Low-cost Networks for Very Lo ARPU Areas
  - Ultra Low-Cost Networks for Very Lo ARPU MTC Services

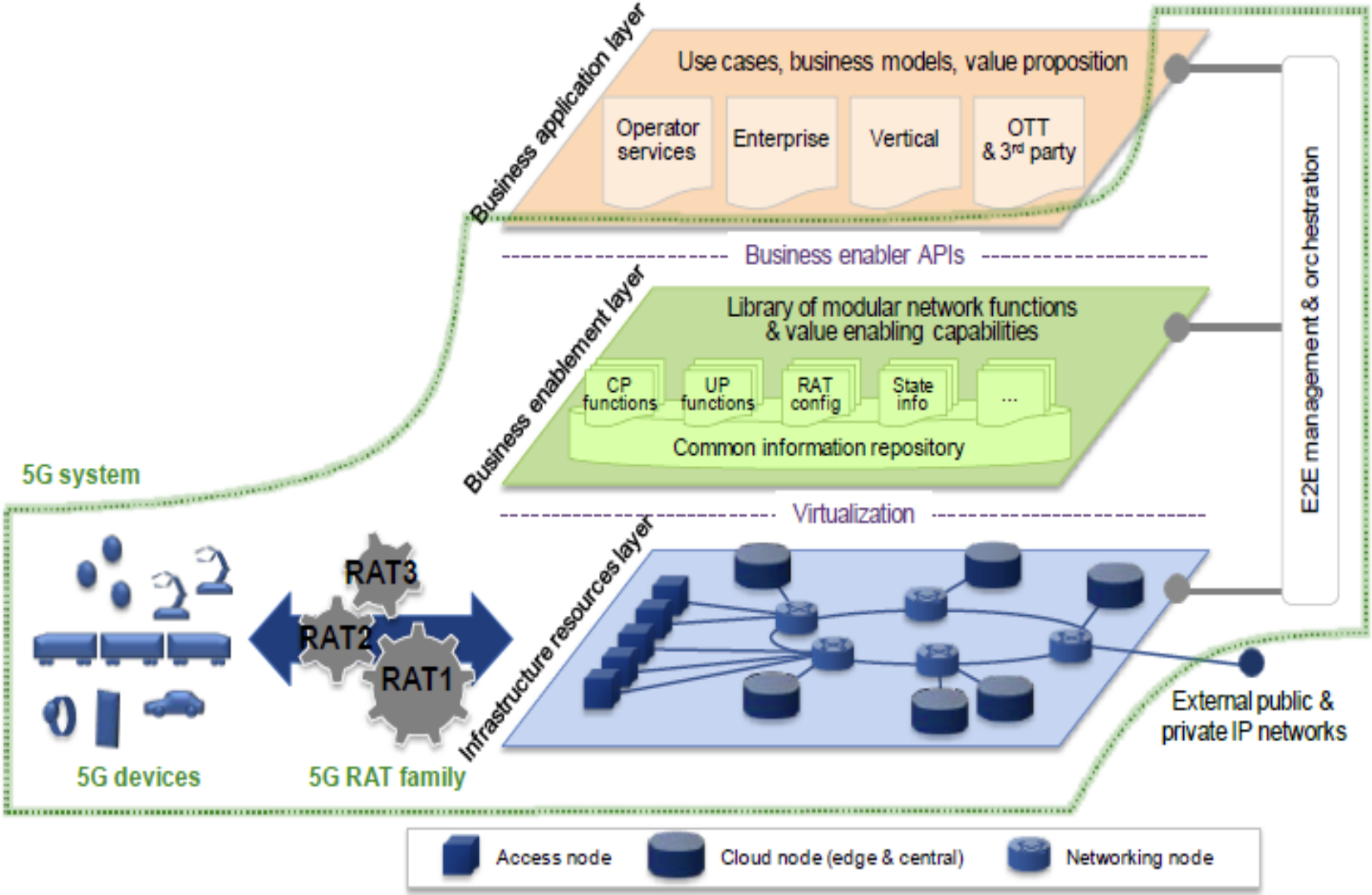
5G PPP : KPIs (drivers) and disruptive capabilities



5G PPP : 5G Architecture

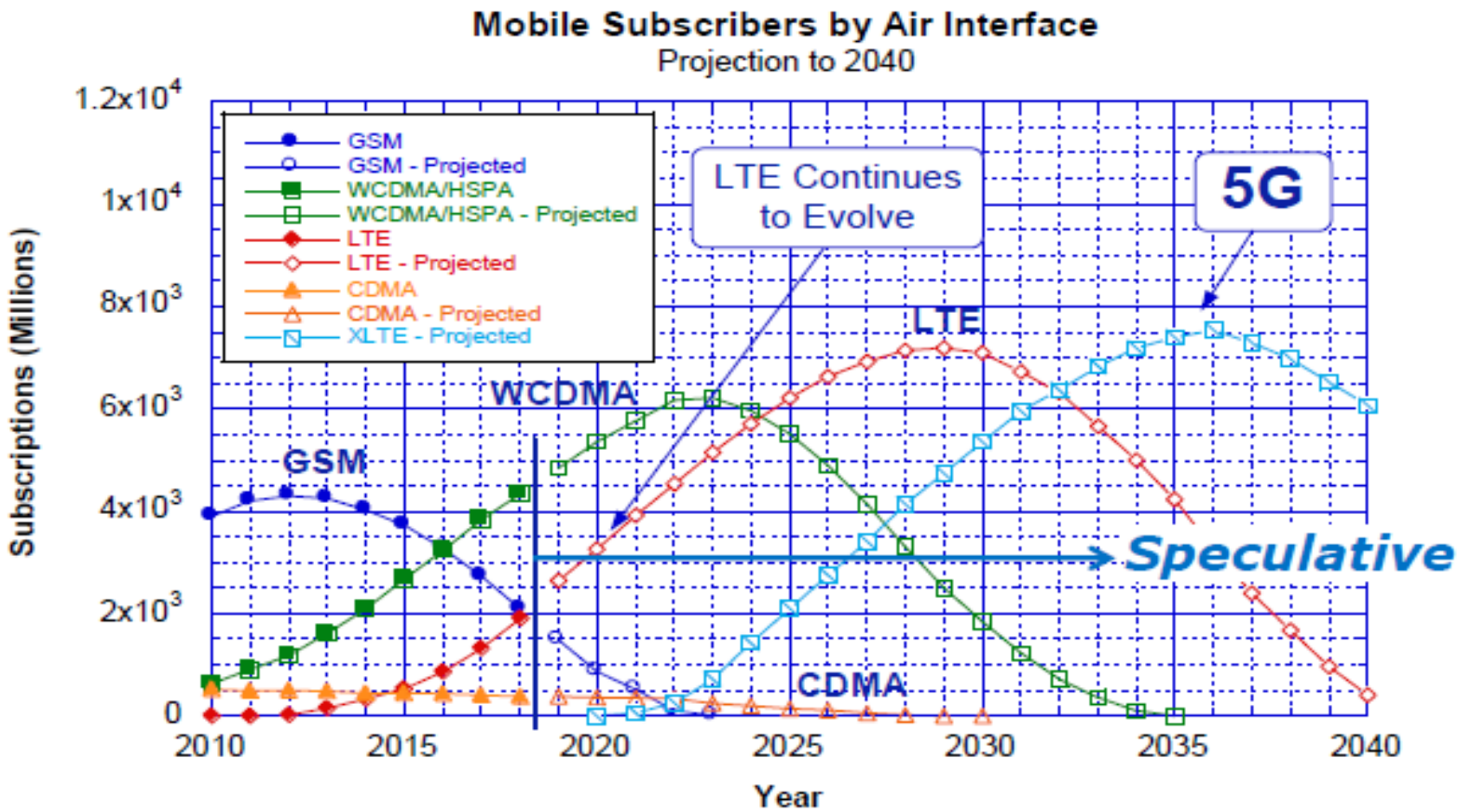


NGMN: 5G Architecture



4G Systems Remain Significant in a 5G World

Low Cost Markets and Legacy Infrastructure



[1] "*Self-Organizing Networks (SON): Self-Planning, Self-Optimization and Self-Healing for GSM, UMTS and LTE*", Hamied et. Al, 2012; [2] Strategy Analytics; [3] Ericsson and Cisco

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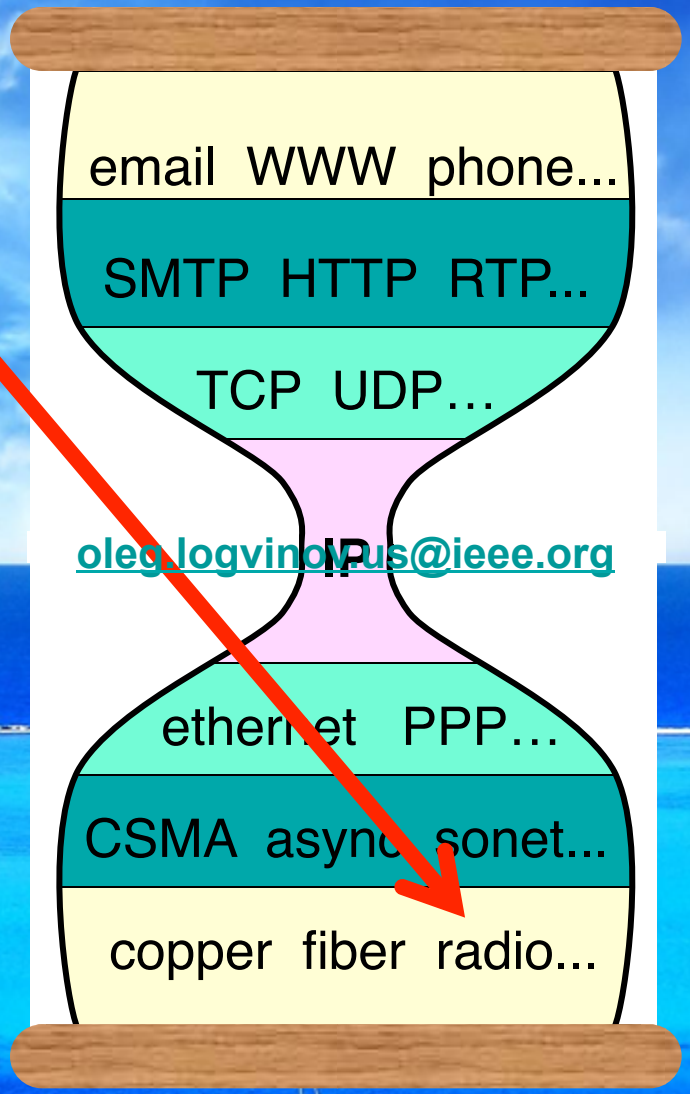
Radio is just Access next to Fibre & old Copper



oleg.logvinov@us@ieee.org

5G as Full SDN to Watch!

- **In all SDN/NFV talks, the infrastructure (i.e.: boxes and links your packet will have to traverse for the most part of its lifetime) is completely ignored. It is assumed:**

  - ❖"always-On"
  - ❖"always secure"
  - ❖"always scalable"

  - ❖ Obviously, it is not the case

- ❑ What most of the network operators (in the very large sense of the words) are doing these days is to prepare the introduction of SDN-like technology on top of their infra.

5G NETWORK EVOLUTION

MANAGEMENT & ORCHSTRATION

APPLICATIONS

CLOUD INFRASTRUCTURE

IP INFRASTRUCTURE

RADIO ACCESS

OPEN NETWORKING FOUNDATION

openstack

IPv6 READY

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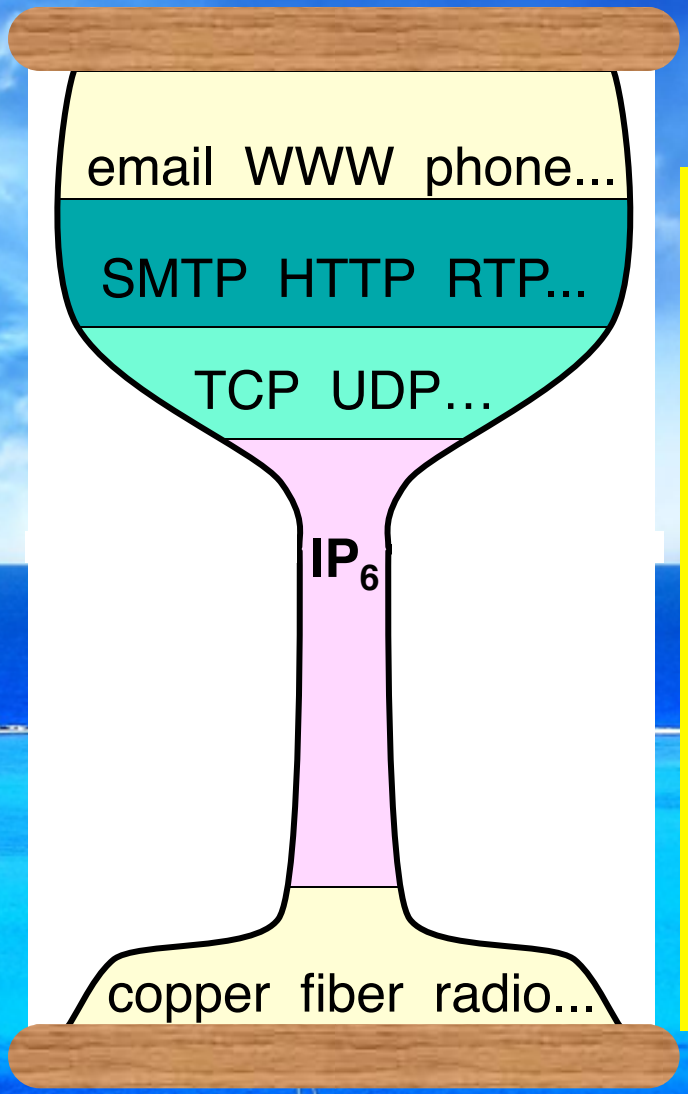
A Fitness Goal



- **perhaps we can trim down from an hourglass to a *wineglass***
- **promising signs: IP-over-WDM, IP-over-5G**
- **IPv6 to restore simplicity *and* functionality**

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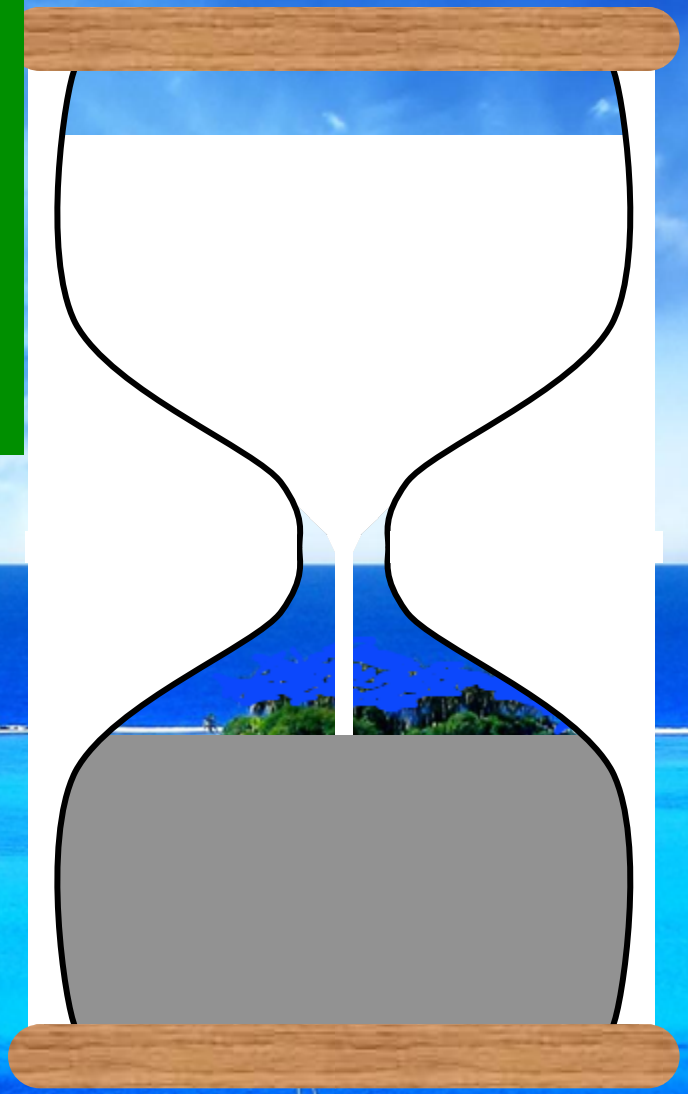
Only Time Will Tell…