

# **ΔΙΑΧΕΙΡΙΣΗ ΔΙΚΤΥΩΝ - NETWORK MANAGEMENT**

## **Αρχιτεκτονική & Δρομολόγηση στο Internet – Internet Architecture & Routing**

**Το Εμπορικό Παγκόσμιο Internet – The Commercial Internet  
Tier 1 & Tier 2 Internet Service Providers, Internet Exchanges**

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**[www.netmode.ntua.gr](http://www.netmode.ntua.gr)**

**21/10/2019**

# ΔΙΚΤΥΑ ΜΕ ΓΝΩΣΤΑ IP & ΑΥΤΟΝΟΜΕΣ ΠΕΡΙΟΧΕΣ (επανάληψη)

**Announced Public IP Networks, Autonomous Domains**

**Autonomous System Numbers - ASN**

**Border Gateway Protocol - BGP**

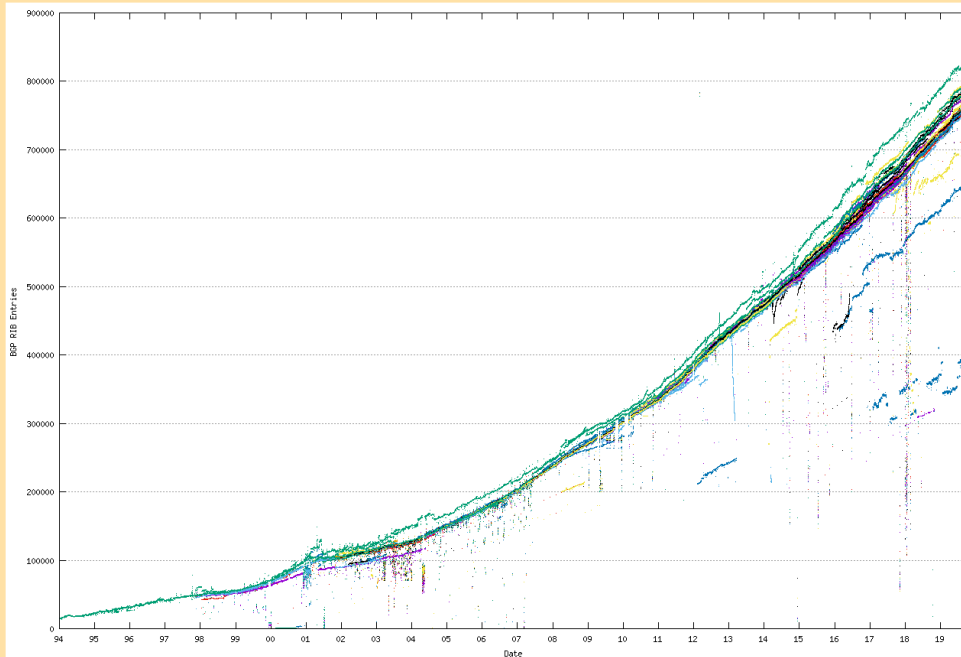
- Το Internet σήμερα (Ιούνιος 2019)
  - Πάνω από **4.536.248.808** τελικοί χρήστες (συνδέσεις) σε συνολικό πληθυσμό 7.717.223.209, διείσδυση **58,8%**
  - Γύρω στα **830.000** ανακοινώσιμα δίκτυα – γνωστοί προορισμοί (announced public IPv4 networks via **BGP announcements**)
  - Ιεραρχικά ταξινομημένα σε Αυτόνομες Διαχειριστικές Περιοχές **AS** (Autonomous Systems) με μοναδικό αριθμό **ASN** (Autonomous System Number, 16 bits ή 32 bits)
  - Αριθμός διαφημιζόμενων (advertised) AS's μέσω BGP announcements: περίπου **65.999** (από 104.446 καταχωρημένα ASN)
  - Διάθεση IP & ASN σε blocks των 1024 AS's με διεθνή συντονισμό από **ICANN** (Internet Corporation for Assigned Names & Numbers) - **IANA** (Internet Assigned Number Authority) μέσω **RIR's** (Regional Internet Registries): **ARIN** (American Registry for Internet Numbers), **RIPE NCC** (Réseaux IP Européens Network Coordination Centre), **APNIC** (Asia Pacific Network Information Centre), **AFRINIC** (African Network Information Center), **LATNIC** (Latin America and Caribbean Network Information Centre)

# BGP TABLES: ΑΡΙΘΜΟΣ ΓΝΩΣΤΩΝ (PUBLIC) ΔΙΚΤΥΩΝ – ΠΡΟΟΡΙΣΜΩΝ

(επανάληψη)

<http://bgp.potaroo.net/>

Growth of the BGP Table - 1994 to Present



## BGP Table Data

Report last updated at Mon, 14 Oct 2019 08:19:15 GMT

### IPv4 BGP Reports

AS131072 APNIC R&D 802426

AS6447 Route-Views.Oregon-ix.net 830652

### IPv4 Route-Views

### IPv6 BGP Reports

AS131072 APNIC R&D 76832

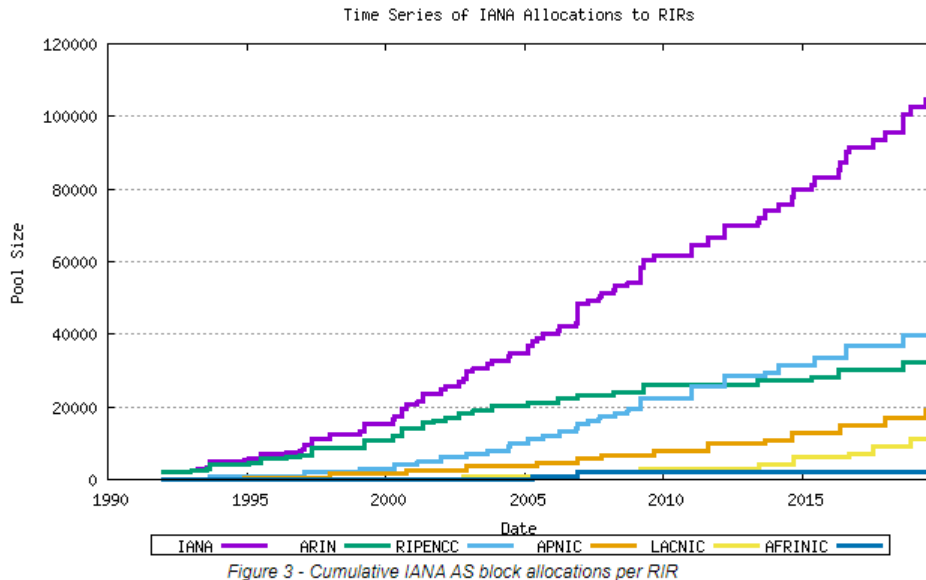
AS6447 Route-Views.Oregon-ix.net 79237

# ΠΛΗΘΟΣ ΑΡΙΘΜΩΝ ΑΥΤΟΝΟΜΩΝ ΣΥΣΤΗΜΑΤΩΝ

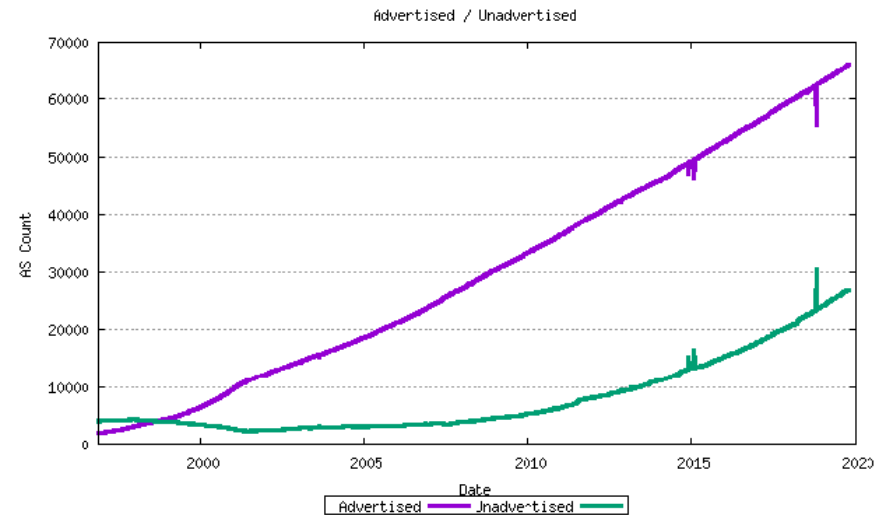
(ASN/RIR: Autonomous System Numbers ανά Regional Internet Registry & Συνολικά από ICAAN - IANA) (επανάληψη)

<http://bgp.potaroo.net/>

Χρονική Εξέλιξη Κατανομής ASN ανά RIR  
(Regional Internet Registry)



Χρονική Εξέλιξη Συνολικού Αριθμού Διαφημιζόμενων AS's μέσω BGP & Συνολικού Αριθμού μη Διαφημιζόμενων AS's

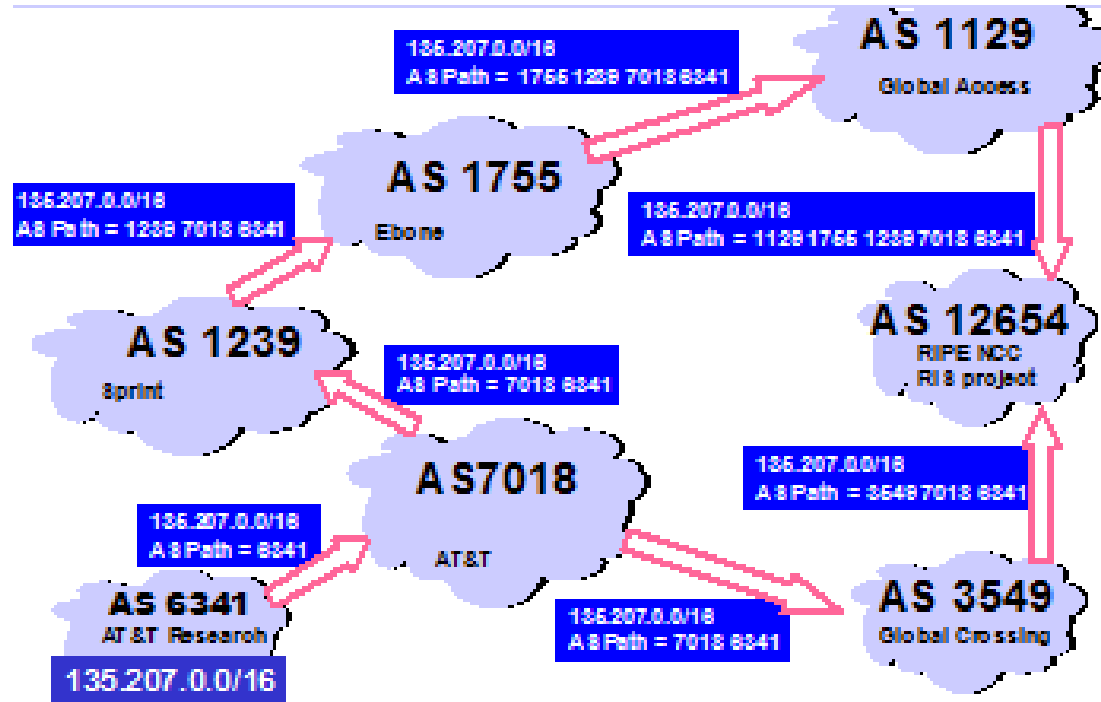


The ratio of unadvertised to advertised AS numbers can be plotted over time.

# ΠΑΡΑΔΕΙΓΜΑ ΑΝΑΚΟΙΝΩΣΗΣ

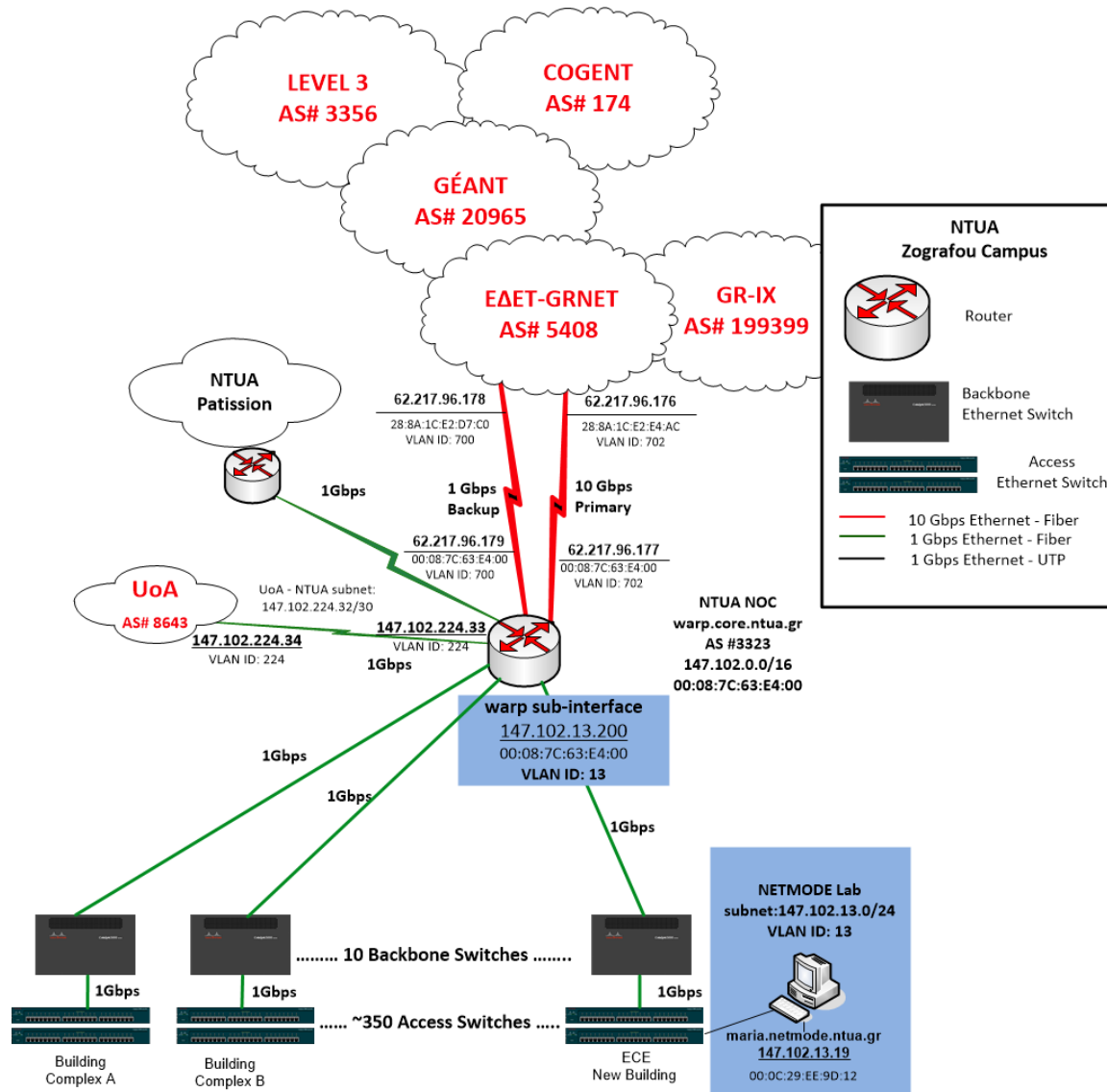
## ΔΙΚΤΥΟΥ 135.207.0.0/16 ΜΕΣΩ BGP (επανάληψη)

(από παρουσίαση του Timothy G. Griffin, AT&T Research, Paris 2002)



# ΤΟ ΔΙΚΤΥΟ ΤΟΥ Ε.Μ.Π. (2016) (επανάληψη)

ntua.gr (147.102.0.0/16, 2001:648:2000::/48, AS# 3323)



# ΤΟ ΔΙΚΤΥΟ ΚΟΡΜΟΥ ΤΟΥ ΕΔΕΤ - GRNET (2018) (επανάληψη)

Εθνικό Δίκτυο Έρευνας & Τεχνολογίας – Greek Research & Technology Network

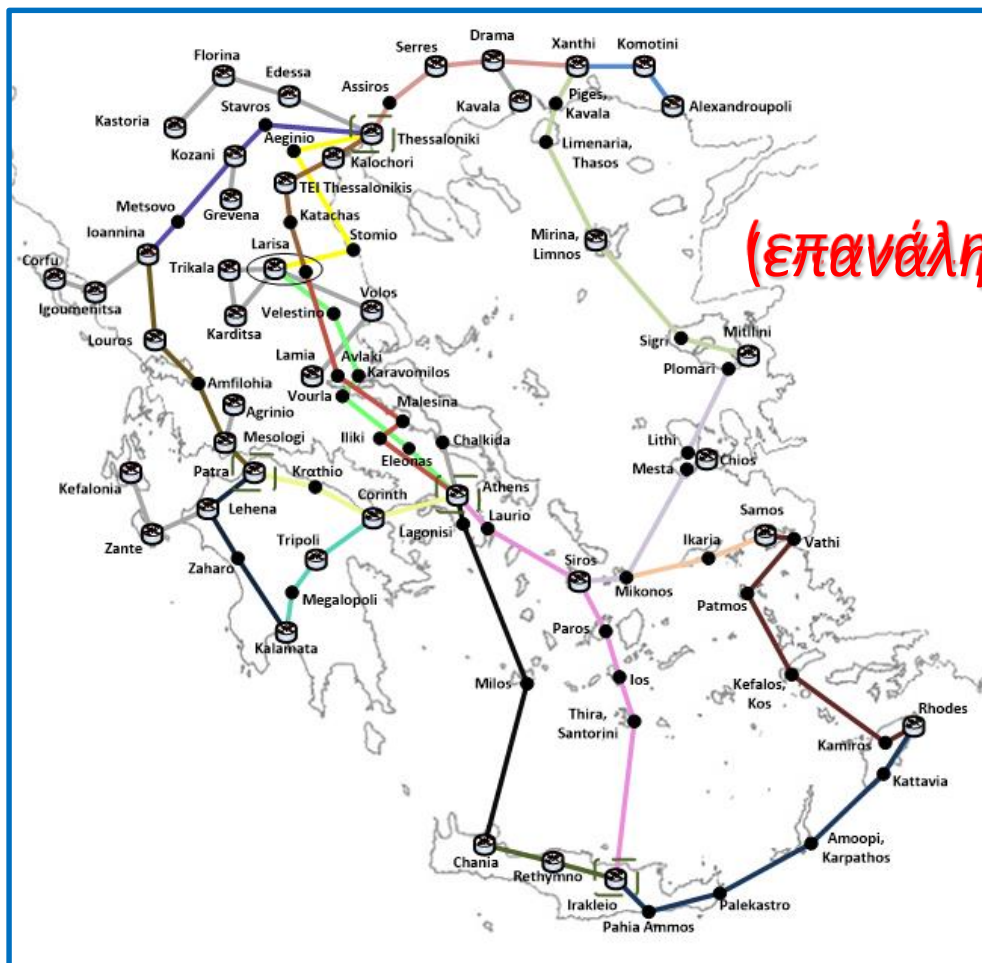
[www.grnet.gr](http://www.grnet.gr)

Το Οπτικό Δίκτυο (Layer1 Topology)

*Managed Dark Fibers*

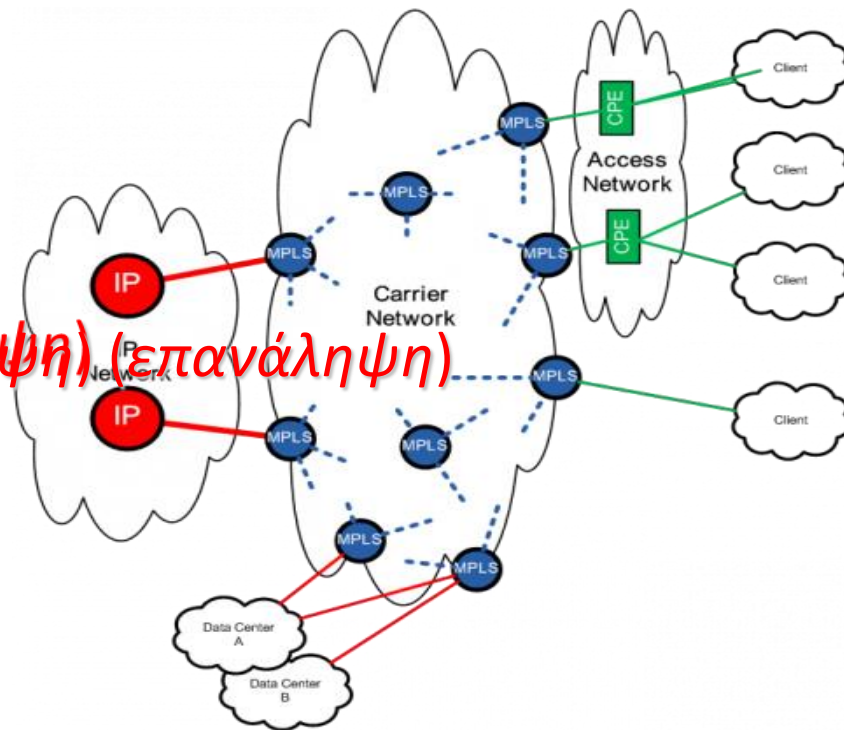
*DWDM - Dense Wavelength Division Multiplexing*

*Ευέλικτοι Πολυπλέκτες - ROADM)*



Το Υπερκείμενο Δίκτυο IP/MPLS

(Layer 2.5, Layer 3 Overlay Topology)



(επανάληψη) (επανάληψη)

**151** Φορείς (ΑΕΙ, ΤΕΙ, Ερευνητικά Κέντρα, Σχολικό Δίκτυο)

**400.000** Τελικοί Χρήστες

**50** Πόλεις, **340** Σημεία Παρουσίας (PoP's)

**1, 10 (100)** Gbps/λ (DWDM 1-10 λ/fiber)

Διασύνδεση με GÉANT & Εμπορικό Internet

(επανάληψη)

**ΓÉΑΝΤ**  the pan-European research and education network

**ΔΙΑΣΥΝΔΕΕΙ ΜΕ ΟΠΤΙΚΕΣ ΣΥΝΔΕΣΕΙΣ ΠΟΛΛΑΠΛΩΝ 10-100 Gbps:**

42 Εθνικά Δίκτυα Έρευνας & Εκπαίδευσης (National Research & Education Networks – NRENs)

**ΤΕΛΙΚΟΙ ΧΡΗΣΤΕΣ:**

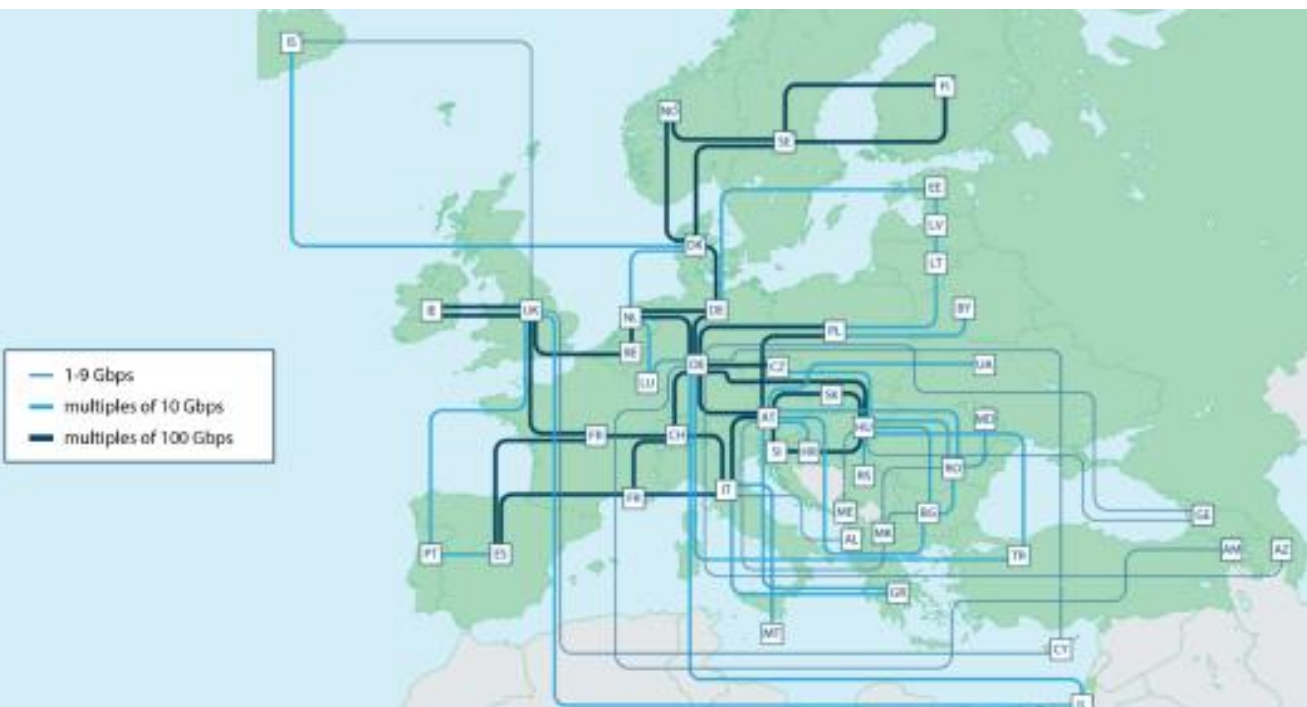
10.000 ++ Ιδρύματα

Ερευνητικές υποδομές παγκόσμιας εμβέλειας (CERN/HEP, ITER, ESFRI...)

50 εκ. ++ φοιτητές, μαθητές, εκπαιδευτικό προσωπικό, ερευνητές

**ΔΙΑΧΕΙΡΙΣΗ:**

DANTE + TERENA → ΓÉΑΝΤ Association



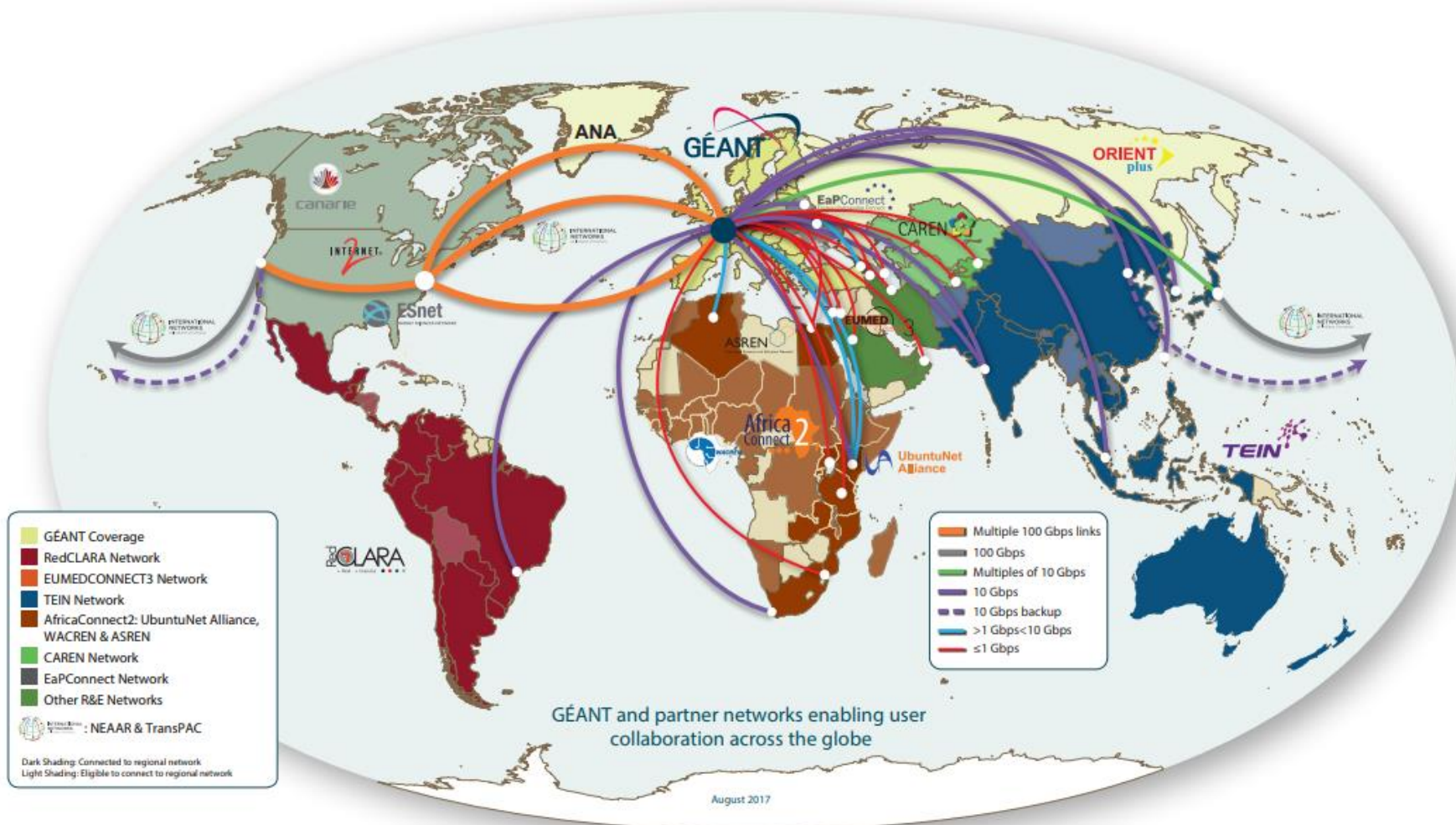
 <b>RASH</b>		 <b>DFN</b>	 <b>NORDUnet</b>	 <b>CARNET</b>	 <b>NORDUnet</b>		 <b>Netherlands</b>			 <b>Jisc</b>
AL Albania	BG Bulgaria	DE Germany	FI Finland*	HR Croatia	IS Iceland*	LV Latvia	NL Netherlands	RO Romania	SI Slovenia	UK United Kingdom
 <b>Armenia</b>	 <b>SWITCH</b>	 <b>NORDUnet</b>	 <b>RENATER</b>		 <b>GARR</b>	 <b>OMREN</b>	 <b>NORDUnet</b>			 <b>Ukraine</b>
 <b>oconet</b>		 <b>EENet</b>	 <b>GÉANT</b>	 <b>HEAnet</b>	 <b>LITNET</b>	 <b>MARnet</b>	 <b>PSRC</b>	 <b>BASNET</b>		
 <b>Belnet</b>	 <b>GÉANT</b>						 <b>FCT</b>	 <b>NORDUnet</b>		
BE Belgium	CZ Czech Republic	ES Spain	GR Greece	IL Israel	LU Luxembourg	MT Malta	PT Portugal	SE Sweden	TR Turkey	



# ΠΑΓΚΟΣΜΙΟΣ ΡΟΛΟΣ ΤΟΥ ΓÉΑΝΤ (8/2017) (επανάληψη)



At the Heart of Global Research and Education Networking



# CAIDA's AS Core 2017 Internet Graph

[http://www.caida.org/research/topology/as\\_core\\_network/](http://www.caida.org/research/topology/as_core_network/)



## INTRODUCTION

The CAIDA AS Core visualization depicts the Internet's Autonomous Systems' (ASes) geographic locations, numbers, and interconnections. Each AS approximately corresponds to an Internet Service Provider (ISP). The geographic location of the individual AS is inferred from the weighted centroid of its address space according to NetAcuity, a commercial geolocation service. The number of direct or indirect customers of an ASA is inferred using its customer cone (described below).

For this visualization we used the Feb 2017 Internet Topology Data Kit (ITDK). We obtained the raw IPv4 topology data for the ITDK by performing traceroutes to randomly-chosen destinations in each routed /24 BGP prefix using 12k Ark monitors located in 42 countries, on Jan 22 to Feb 7, 2017. The resulting IP topology contained almost 50 million IP addresses, 49 million inferred routers, and 36 million inferred links. We inferred the IP address to AS mappings using bordermapit, a tool for inferring router ownership (a collaboration between CAIDA and UPenn). The resulting AS topology contained 47,610 ASes and 148,456 links.

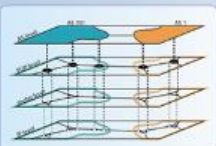
Each AS node is plotted in polar coordinates (radius, angle) on the circle, as formally defined in the equations below. The distance of each AS node from the center of the circle (the radial coordinate) is the inverse of each AS's customer cone size, (roughly) the number of the AS's direct or indirect customers. ASes at the outer edge of the circle have no customers and ASes at the center have the largest number of customers. The angular coordinate indicates the AS's geographic longitude.

$$\text{radius} = 1 - \log \left( \frac{\text{transit degree}(\text{AS}) + 1}{\text{maximum transit degree} + 1} \right)$$
$$\text{angle} = \left( \frac{\text{longitude of the AS's BGP prefixes in NetAcuity}}{360} \right) \times 2\pi$$

The core of this topology, the set of ASes with the largest customer cones, is still dominated by U.S.-centric ASes.

## INTERNET LAYERS

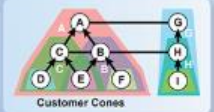
The Internet's network topology is often divided into four layers: AS, PoP, Router, and IP. The IP address uniquely identifies an attachment point (interface) of a device on the Internet. The router layer refers to the set of routers that transfer and route traffic. To support geophysically-aware topology analysis, we aggregate routers into Points of Presence (PoPs). To support interdomain (between networks) topology analysis, we aggregate routers by ownership into Autonomous Systems (ASes).



## CUSTOMER CONE

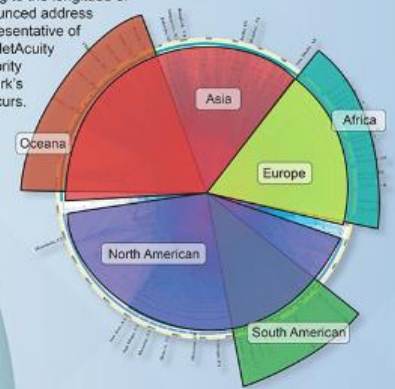
The AS's customer cone is the set of ASes that directly or indirectly pay the AS to connect to the Internet. On the left, A has the largest cone with 6 ASes; H has two. An AS's customer cone contains the set of ASes we observe the AS announce to its peers or providers. This definition is more constrained than, but similar to, the set of ASes reachable through its customers.

AS	Size
A	6
B	3
D	1



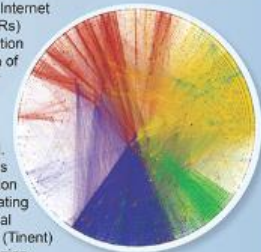
## GEOGRAPHIC REGIONS

Each AS is placed according to the longitude of the centroid of its announced address space. This is representative of the area where NetAcuity enters the majority of this network's activity occurs.



## REGIONAL INTERNET REGISTRIES

The Regional Internet Registries (RIRs) manage allocation and registration of Internet number resources, such as AS numbers, within a particular region of the world. Although most ASes geolocate to the region of the originally allocating RIR, some multinational networks, e.g., AS3257 (Tinet) geolocate outside their region.



American Registry for Internet Numbers (ARIN) for the United States, Canada, several part of the Caribbean region, and Antarctica.



African Network Information Center (AFRICNIC) for Africa

Reseaux IP Europeens Network Coordination Centre (RIPE NCC) for Europe, Russia, the Middle East, and Central Asia

Asia-Pacific Network Information Centre (APNIC) for Asia, Australia, New Zealand, and neighboring countries

Latin America and Caribbean Network Information Centre (LACNIC) for Latin America and parts of the Caribbean region

**Analysis Team:** Bradley Huffaker, kc.daffy  
**Software Development:** Young Hyun, Matthew Luckie, Alex Marder, Bradley Huffaker, Amogh Dnandhore  
**Poster Designer:** Anh D. Nguyen  
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**Center for Applied Internet Data Analysis**  
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**ARK Hosts:** AARNET, AFRINIC, AMSIX, APAN, ARIN, ASTI, Aereo, BDCOM Online Limited at BD-IX, CENIC, CNNIC, CNRST, Cabinet Communication Systems, Canarie, Carnegie Mellon University in Rwanda, Colorado State University, DCSI Pta Ltd, DePaul University, Edovos Lorand University (ELTE), Eurocom, Foundation for Research and Technology - Hellas (FORTH), FunkPreuer, GCL, Georgian College, HB Networks, HEAnet, Hong Kong Polytechnic University, Humana Electric, IP-Max SA, Indonesian IP@ Task Force, International Computer Science Institute (ICSI), Internet Systems Consortium, Iowa State University, Jacobs University Bremen, Jaquer Network, KREONet2, Kantonschule Zug, Level 3 Communications, Liberty Global, NCAR, NCC, NICTD, NIX, NLANL, NORDUNIC, NORSUNET, NPL, NRI, NRI-2, NRI-3, NRI-4, NRI-5, NRI-6, NRI-7, NRI-8, NRI-9, NRI-10, NRI-11, NRI-12, NRI-13, NRI-14, NRI-15, NRI-16, NRI-17, NRI-18, NRI-19, NRI-20, NRI-21, NRI-22, NRI-23, NRI-24, NRI-25, NRI-26, NRI-27, NRI-28, NRI-29, NRI-30, NRI-31, NRI-32, NRI-33, NRI-34, NRI-35, NRI-36, NRI-37, NRI-38, NRI-39, NRI-40, NRI-41, NRI-42, NRI-43, NRI-44, NRI-45, NRI-46, NRI-47, NRI-48, NRI-49, NRI-50, NRI-51, NRI-52, NRI-53, NRI-54, NRI-55, NRI-56, NRI-57, NRI-58, NRI-59, NRI-60, NRI-61, NRI-62, NRI-63, NRI-64, NRI-65, NRI-66, NRI-67, NRI-68, NRI-69, NRI-70, NRI-71, NRI-72, NRI-73, NRI-74, NRI-75, NRI-76, NRI-77, NRI-78, NRI-79, NRI-80, NRI-81, NRI-82, NRI-83, NRI-84, NRI-85, NRI-86, NRI-87, NRI-88, NRI-89, NRI-90, NRI-91, NRI-92, NRI-93, NRI-94, NRI-95, NRI-96, NRI-97, NRI-98, NRI-99, NRI-100.

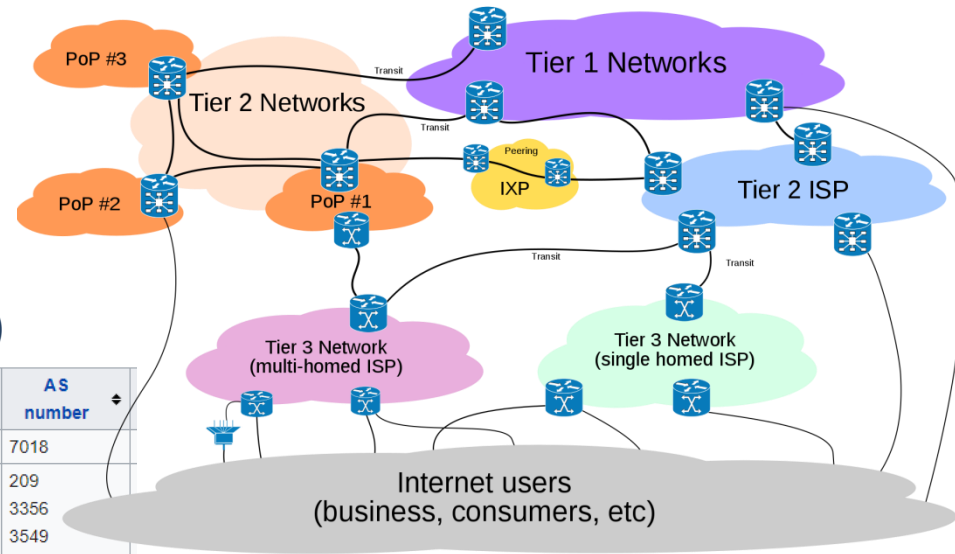
**Northeastern University,** Openmirrors.asia - at Equinix SG1, Ottawa Internet Exchange, Public University of Navarra, QCEI, RIPE NCC, RNP, Rede ANSP / Projeto NARA, Register, SURFnet, Simula Research Laboratory, Soldo Networks ApS, Southern Methodist University, TKK, TWAREN, Technical University of Munich, Tinet, TorIX, UCAD, US Army Research Lab, Univ. Twente, Universitat Llorenz, Universitat Politècnica de Catalunya, University of Cambridge, University of Hawaii, University of Limburg, University of Melbourne, University of Napoli, University of Nevada at Reno, University of Oregon, University of Waikato, University of Washington, University of Zurich, VTR

# ΤΟ «ΕΜΠΟΡΙΚΟ» INTERNET: **There is no Free Lunch**

[http://en.wikipedia.org/wiki/Tier\\_1\\_network](http://en.wikipedia.org/wiki/Tier_1_network)

Οι 15 **Tier 1** ISP's με πρόσβαση στα 830,000 δίκτυα - γνωστούς προορισμούς (IPv4 prefixes)

Name	Headquarters	AS number
AT&T <sup>[12]</sup>	United States	7018
CenturyLink (formerly Level 3, Qwest, Savvis, Global Crossing, TW Telecom and Exodus) <sup>[14][15]</sup>	United States	209 3356 3549 4323
Deutsche Telekom Global Carrier <sup>[18]</sup>	Germany	3320
GTT Communications, Inc. (formerly Tinet, nLayer, Hibernia Atlantic and Interoute <sup>[20][21]</sup> )	United States	3257 4436 5580 8928
KPN International <sup>[23]</sup>	Netherlands	286
Liberty Global <sup>[25][26]</sup>	United Kingdom <sup>[27]</sup>	6830
NTT Communications (America) (formerly Verio) <sup>[29]</sup>	Japan	2914
Orange (OpenTransit) <sup>[30]</sup>	France	5511
PCCW Global	Hong Kong	3491
Sprint (SoftBank Group) <sup>[31]</sup>	Japan	1239
Tata Communications (formerly Teleglobe) <sup>[33]</sup>	India	6453
Telecom Italia Sparkle (Seabone) <sup>[35]</sup>	Italy	6762
Telxius (Subsidiary of Telefónica) <sup>[36]</sup>	Spain	12956
Telia Carrier <sup>[38]</sup>	Sweden	1299
Verizon Enterprise Solutions (formerly UUNET and XO Communications) <sup>[44]</sup>	United States	701 702 703 2828
Zayo Group (formerly AboveNet) <sup>[46]</sup>	United States	6461



3 **Tier 2** ISP's με ελαφρά μειωμένη πρόσβαση (συντά θεωρούμενοι **Tier 1**)

Name	Headquarters	AS Number
Cogent Communications <sup>[50]</sup>	United States	174
Hurricane Electric <sup>[53]</sup>	United States	6939
Vodafone (formerly Cable and Wireless)	United Kingdom	1273

# ΤΑ 20 ΜΕΓΑΛΥΤΕΡΑ ΑΥΤΟΝΟΜΑ ΣΥΣΤΗΜΑΤΑ

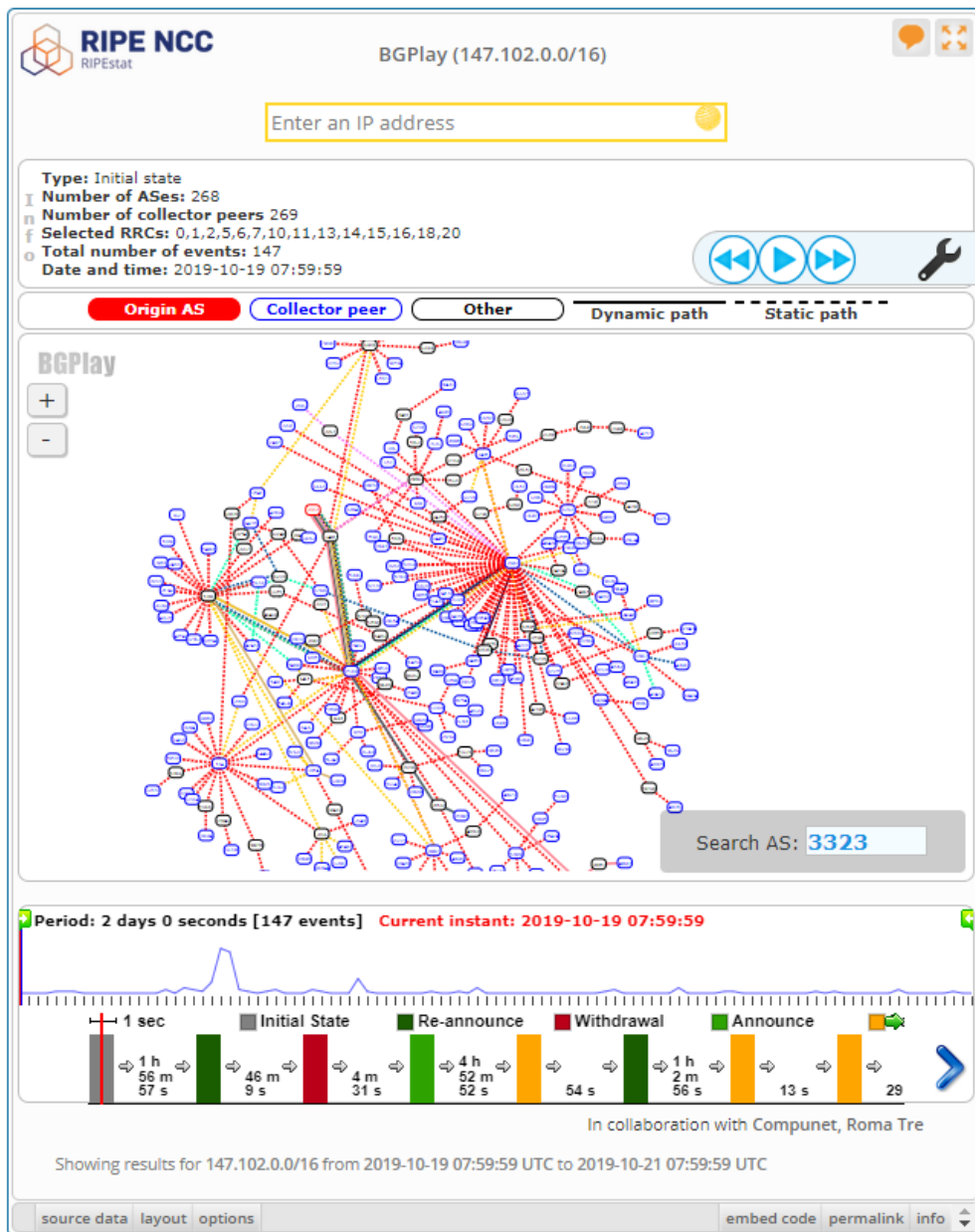
AS Ranking σύμφωνα με την CAIDA (6/2019)

<http://as-rank.caida.org/>

AS Rank ▲	AS Number ▼	Organization		cone size (ASes) ▼
1	3356	Level 3 Parent, LLC		35292
2	1299	Telia Company AB		29756
3	3257	GTT Communications Inc.		28528
4	174	Cogent Communications		27102
5	2914	NTT America, Inc.		21167
6	6453	TATA COMMUNICATIONS (AMERICA) INC		16075
7	6939	Hurricane Electric LLC		15362
8	6762	TELECOM ITALIA SPARKLE S.p.A.		15121
9	3491	PCCW Global, Inc.		9544
10	6461	Zayo Bandwidth		8077
11	1273	Vodafone Group PLC		7444
12	3549	Level 3 Parent, LLC		6274
13	9002	RETN Limited		5913
14	12956	Telefonica International Wholesale Services ...		4912
15	209	CenturyLink Communications, LLC		4257
16	3216	RJSC "Vimpelcom"		4163
17	20485	Closed Joint Stock Company TransTeleCom		4154
18	5511	Orange S.A.		4148
19	7473	Singapore Telecommunications (SINGTEL In...		3943
20	3320	Deutsche Telekom AG		3484

# ΠΑΡΟΧΗ INTERNET ΣΤΟ Ε.Μ.Π. (ΝΤΥΑ - ASN 3323)

<https://stat.ripe.net/special/bgplay>



**NTUA (3323)**  
**GRNET (5408)**  
**GÉANT (20965)**

**GÉANT Tier 1/2 Providers  
(Internet feeds)**

- **COGENT-174 (174)**
- **TELIANET (1299)**

# ΤΟ ΑΘΗΝΣ INTERNET EXCHANGE (AIX)

## Πρωτοβουλία του Ε.Μ.Π. & του GRNET/ΕΔΕΤ, 1996

ΜΕΛΗ: **Tier 2** ISP's της Ελλάδας & ΕΔΕΤ για Εθνικό Peering

- GRNET (ΕΔΕΤ)
- Forthnet
- Hellas On Line
- Altec Telecoms
- NetOne
- Vivodi
- Verizon Hellas
- ON Telecoms
- OTENET
- AT&T Global Network Services Hellas
- ORANGE BUSINESS SERVICES
- Vodafone NET
- WIND
- Tellas
- Lannet

**Το BGP δεν ανακοινώνει Εθνικούς Προορισμούς συνδρομητών εκτός Ελλάδος μέσω AIX, μόνο από Tier 1 – Tier 2 feeds των παρόχων τους (πιθανή συνεργασία μόνο σε καταστάσεις εκτάκτου ανάγκης)**

# GREEK INTERNET EXCHANGE (GR-IX)

2009: ΑΝΑΒΑΘΜΙΣΗ

AIX → GR-IX 2009

<https://www.gr-ix.gr/>

GR-IX::Athens

3 Σημεία Στέγασης

- Εθνικό Ίδρυμα Ερευνών
- Lamda Hellix
- MedNautilus

GR-IX::Thessaloniki

1 Σημείο Στέγασης

## GR-IX::Athens

Member	AS	ATH01	ATH02	ATH03
City of Athens	209608	✓		
Cloudflare	13335		✓	
Connecticore	197580			✓
CYNET	3268			✓
Cyta (Cyprus)	6866			✓
Dataways	15544		✓	
ERT	50148	✓		
Forthnet	1241		✓	✓
Greece telecom	206652			✓
Greek Internet Exchange (GR-IX)	199399	✓		
National Infrastructures for Research and Technology (GRNET)	5408	✓		✓
HCN	57794			✓
Hellenic Telecommunications and Post Commission	203348	✓		
HostMeln	50520		✓	
Hurricane Electric	6939		✓	
Internet Hellas	209162			✓
Lancom	199081			✓
Lamda Hellix	56910		✓	
Inalan	200736			✓
Inter Telecom	48172			✓
Metadosis	206529			✓
Microbase	196945			✓
Microsoft	8075		✓	
modulus	201494		✓	
NetIX	57463			✓
O3bNetworks	60725			✓
OTE	6799		✓	✓
Pointer	209150			✓
Riot Games Ltd.	6507			✓

## GR-IX::Thessaloniki

Member	AS	THESS01
Cloudflare	13335	✓
Dataways	15544	✓
Forthnet	1241	✓
Greece telecom	206652	✓
National Infrastructures for Research and Technology (GRNET)	5408	✓
HCN	57794	✓
Inter Telecom	48172	✓
Metadosis	206529	✓
OTE	6799	✓
Synapsecom	8280	✓
Vestitel	39505	✓
WIND	25472	✓

### DNS services (anycast name servers)

AS112 (reverse DNS lookup for RFC 1918 addresses)	112	✓
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