ΔΙΑΧΕΙΡΙΣΗ ΔΙΚΤΥΩΝ

Αρχιτεκτονική & Δρομολόγηση στο Internet (Τμήμα 1/2)

Το Εμπορικό Παγκόσμιο Internet
Tier 1, Tier 2 Internet Service Providers
Internet Exchanges

Β. Μάγκλαρης

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www.netmode.ntua.gr

15/10/2018

ΔΙΚΤΥΑ ΜΕ ΓΝΩΣΤΑ IP & ΑΥΤΟΝΟΜΕΣ ΠΕΡΙΟΧΕΣ

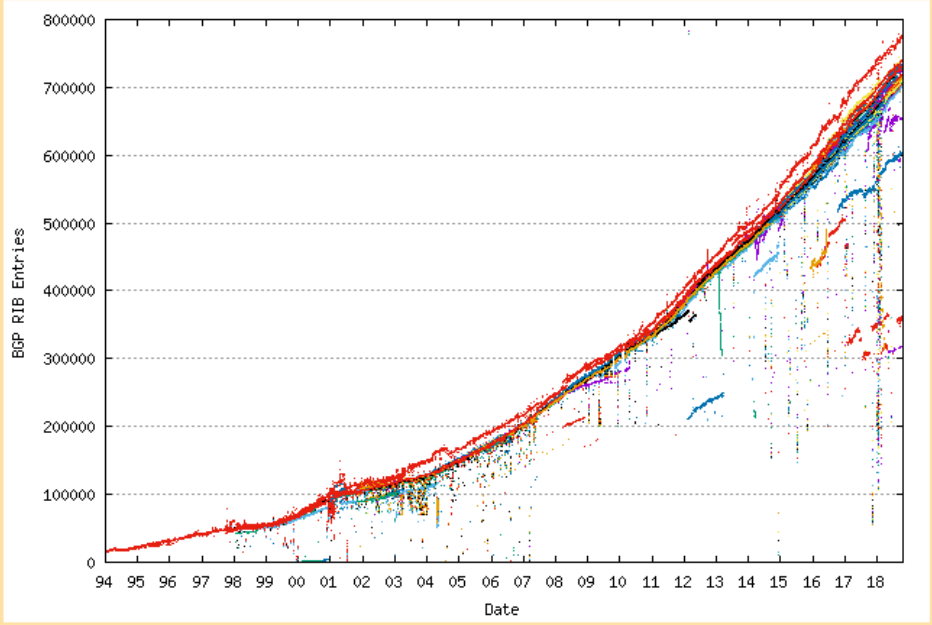
Announced Public IP Networks, Autonomous Domains
Autonomous System Numbers - ASN
Border Gateway Protocol – BGP (επανάληψη)

- Το Internet σήμερα *(Ιούνιος 2018)*
  - Πάνω από **4.208.571.287** τελικοί χρήστες (συνδέσεις) σε συνολικό πληθυσμό 7.634.758.428, διείσδυση **55,1%**
  - Γύρω στα **750.000** 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)
  - Αριθμός διαφημιζόμενων (advertised) AS's μέσω BGP announcements: περίπου **62.000** (από 100.000 καταχωρημένα)
  - Διάθεση IP & ASN σε blocks των 1024 AS's με διεθνή συντονισμό από **ICAAN** (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/



BGP Table Data

Report last updated at Mon, 8 Oct 2018 10:17:28 GMT

IPv4 BGP Reports

AS131072	APNIC R&D	739708
AS6447	Route-Views.Oregon-ix.net	774977

IPv4 Route-Views

IPv6 BGP Reports

AS131072	APNIC R&D	58691
AS6447	Route-Views.Oregon-ix.net	62011

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)

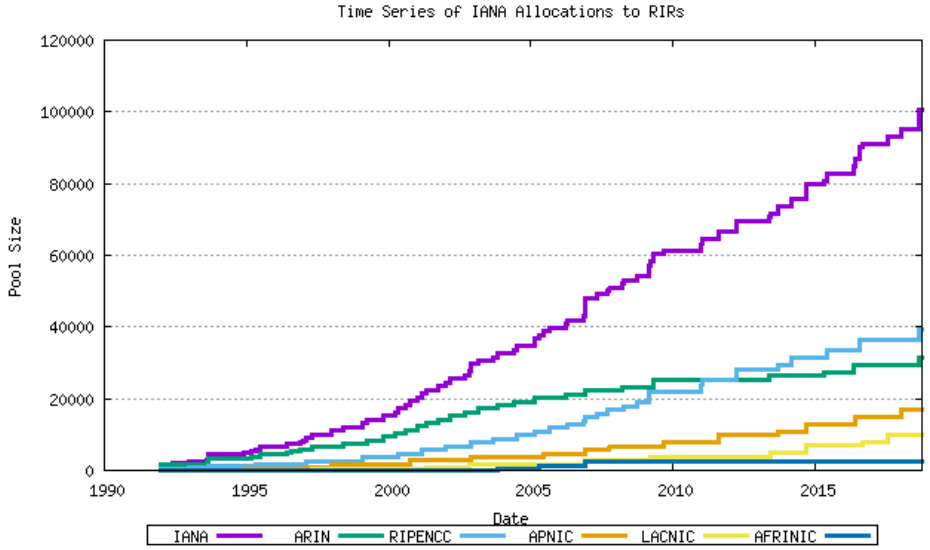


Figure 3 - Cumulative IANA AS block allocations per RIR

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

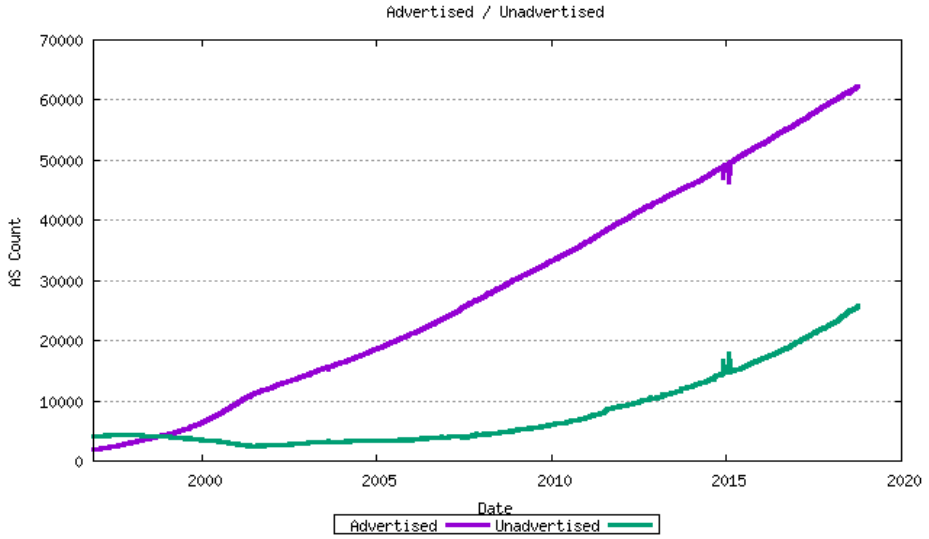
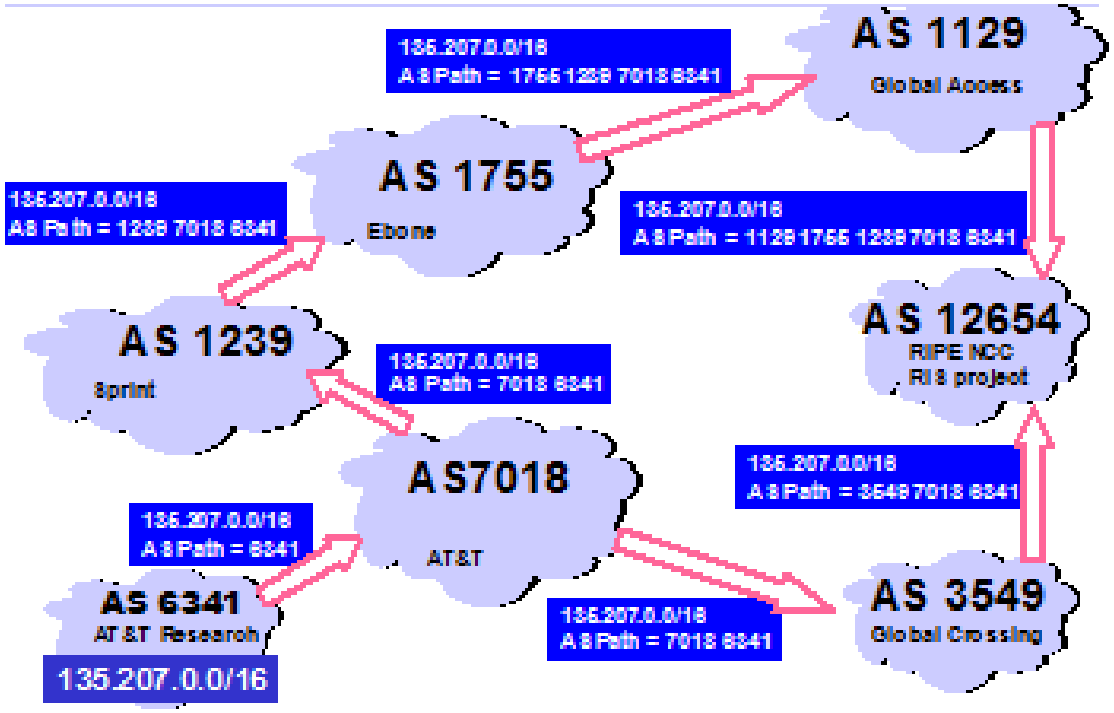


Figure 8 - Advertised / Unadvertised AS Count

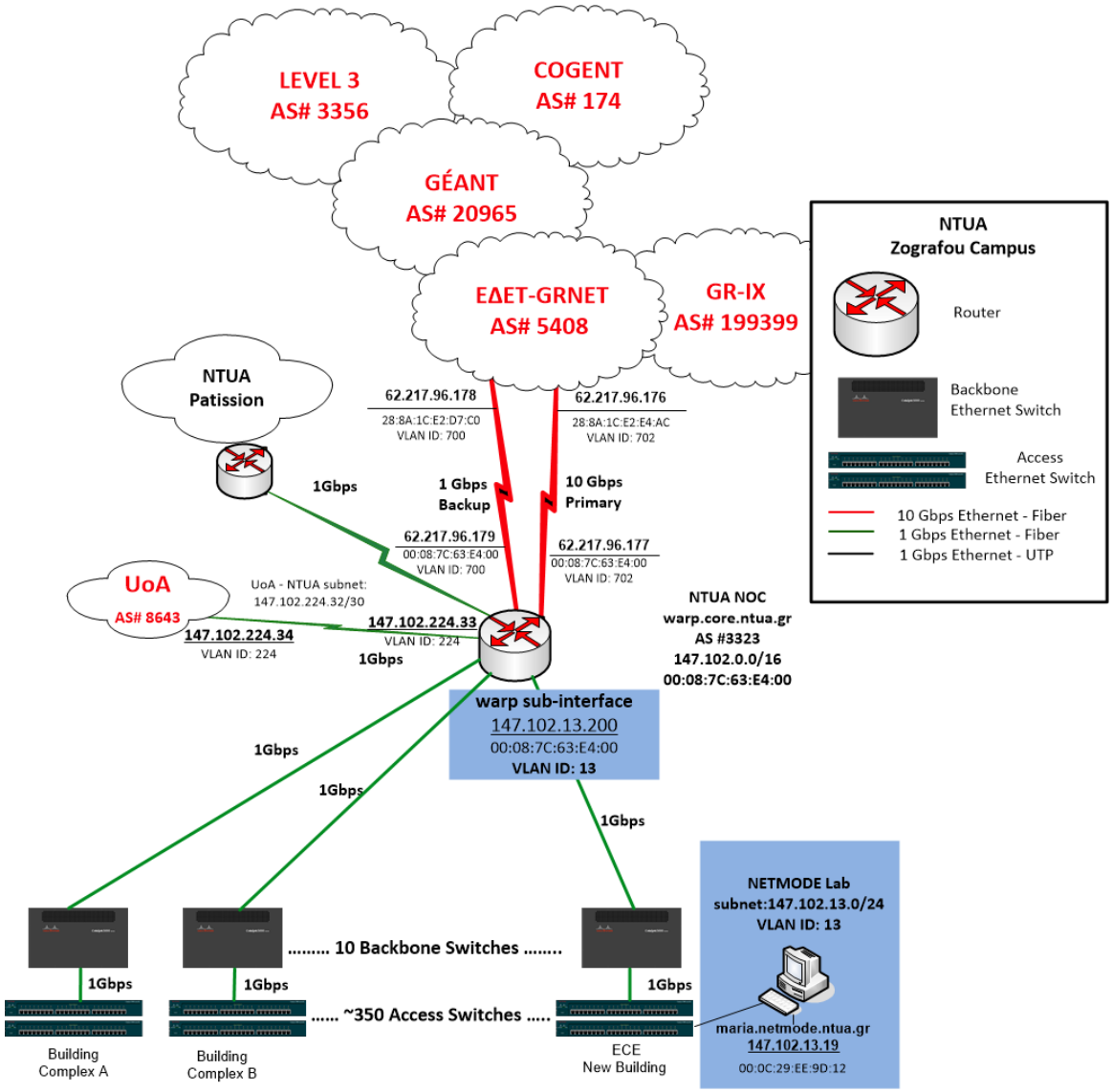
ΠΑΡΑΔΕΙΓΜΑ ΑΝΑΚΟΙΝΩΣΗΣ ΔΙΚΤΥΟΥ 135.207.0.0/16 ΜΕΣΩ BGP (επανάληψη)

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



ΤΟ ΔΙΚΤΥΟ ΤΟΥ Ε.Μ.Π. (επανάληψη)

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



ΤΟ ΔΙΚΤΥΟ ΚΟΡΜΟΥ ΤΟΥ ΕΔΕΤ (GRNET)

Εθνικό Δίκτυο Έρευνας & Τεχνολογίας – Greek Research & Technology Network

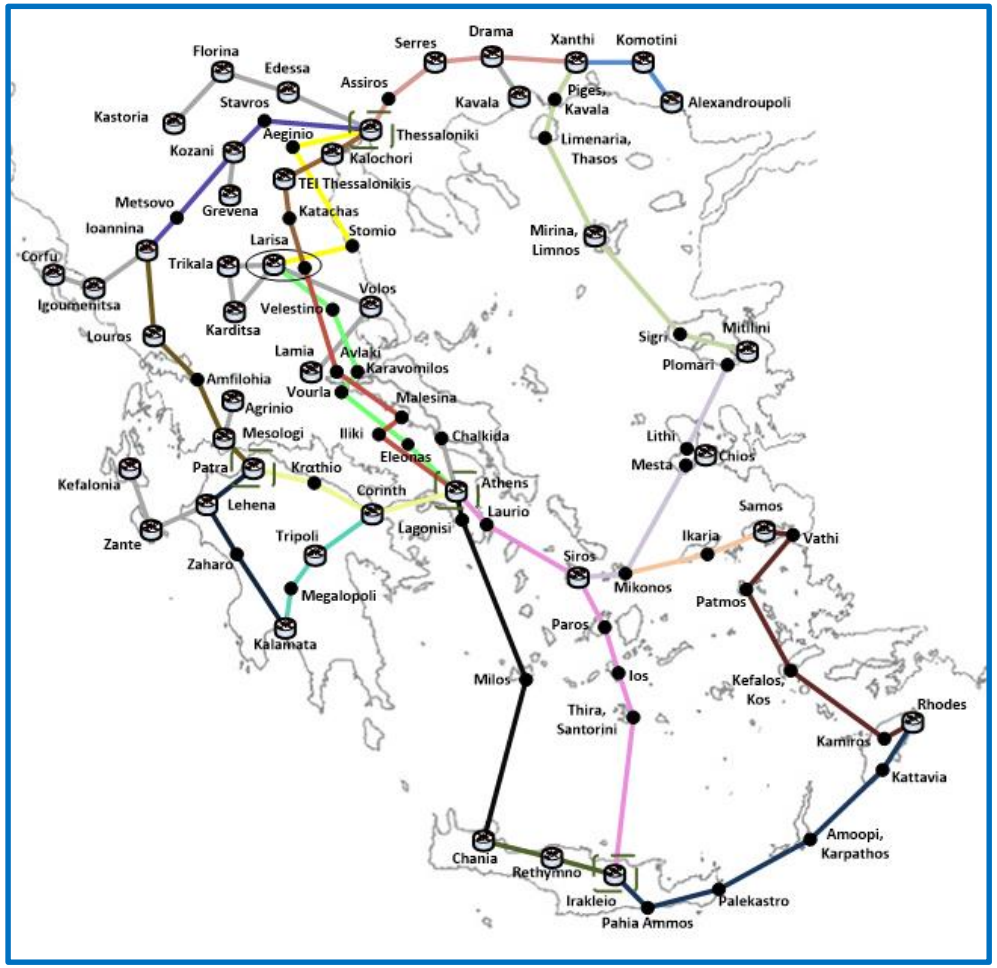
www.grnet.gr

Το Οπτικό Δίκτυο (*Layer1 Topology)*

Managed Dark Fibers

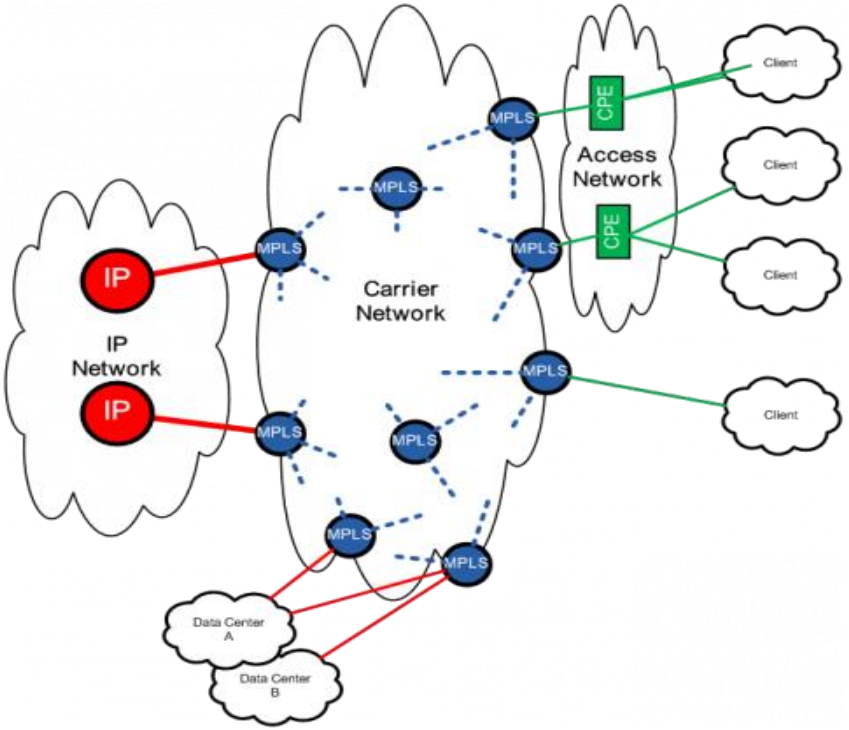
DWDM - Dense Wavelength Division Multiplexing

Ευέλικτοι Πολυπλέκτες - ROADM)



Το Υπερκείμενο Δίκτυο IP/MPLS

(*Layer 2.5, Layer 3 Overlay Topology*)



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

400.000 Τελικοί Χρήστες

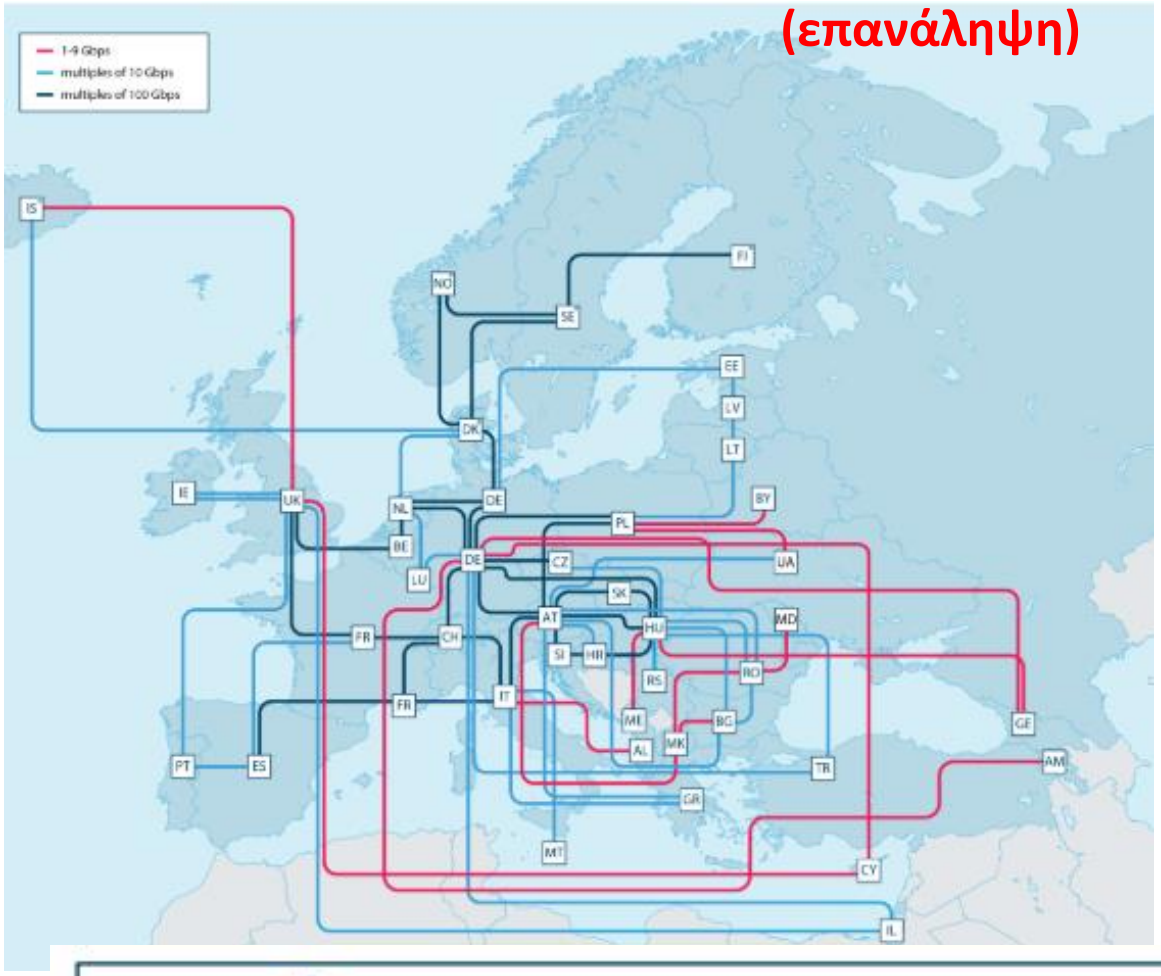
50 Πόλεις, **340** Σημεία Παρουσίας (PoP's)

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

Διασύνδεση με GÉANT & Εμπορικό Internet

ΤΟ ΠΑΝΕΥΡΩΠΑΪΚΟ ΑΚΑΔΗΜΑΪΚΟ ΔΙΚΤΥΟ GÉANT http://www.geant.org/

(επανάληψη)



GÉANT the pan-European research and education network

ΔΙΑΣΥΝΔΕΕΙ ΜΕ ΟΠΤΙΚΕΣ ΣΥΝΔΕΣΕΙΣ 10-100 Gbps:

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

ΤΕΛΙΚΟΙ ΧΡΗΣΤΕΣ:

10.000 ++ Ιδρύματα

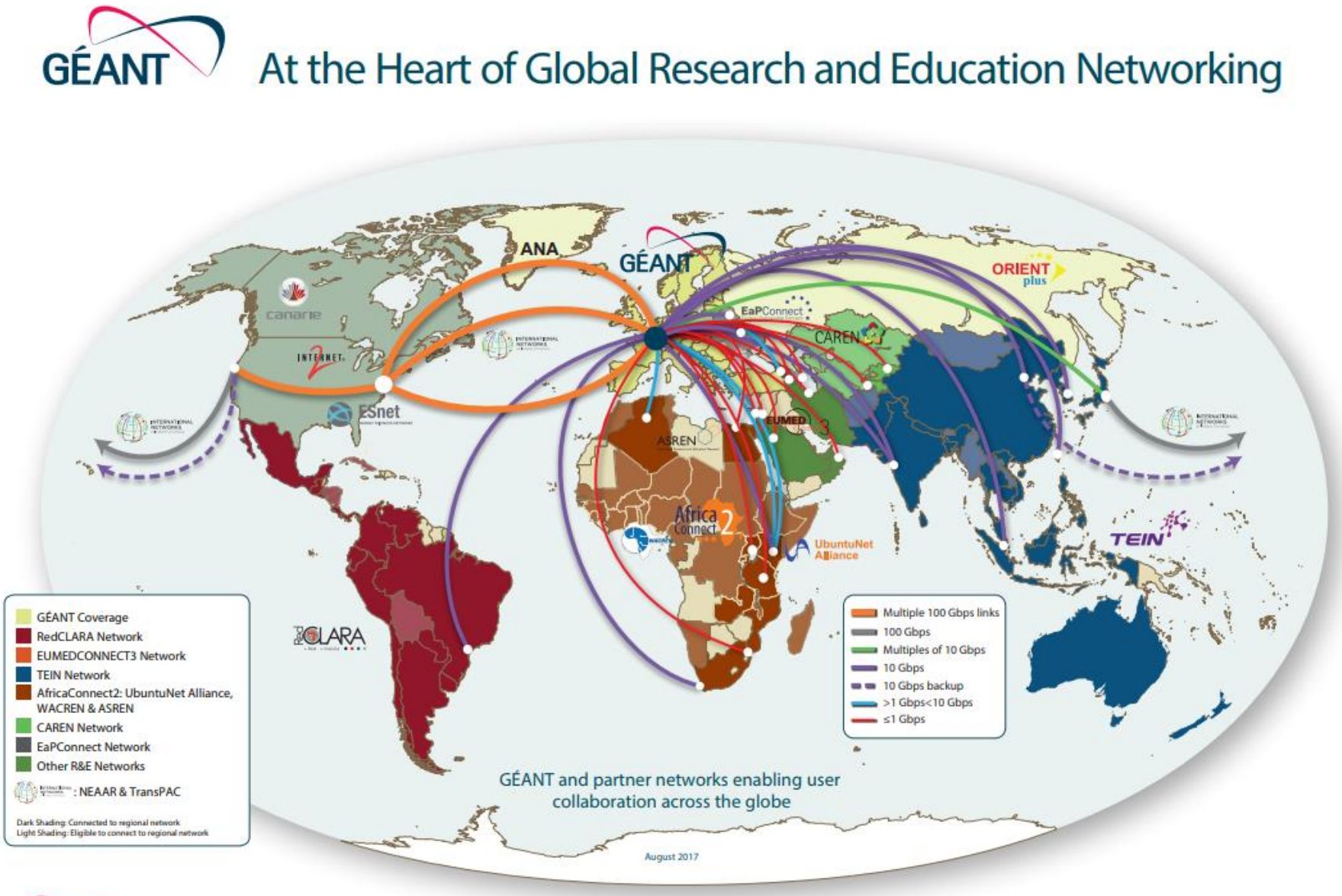
Ερευνητικές υποδομές παγκόσμιας εμβέλειας (CERN/HEP, ITER, ESFRI…)

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

ΔΙΑΧΕΙΡΙΣΗ:

DANTE + TERENA → GÉANT Association

ΠΑΓΚΟΣΜΙΟΣ ΡΟΛΟΣ ΤΟΥ GÉANT (8/2017) (επανάληψη)



GÉANT
Networks · Services · People
www.geant.org

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The content of this document is the sole responsibility of GÉANT and can under no circumstances be regarded as reflecting the position of the European Union.

Funded by the European Union

CAIDA's AS Core 2017 Internet Graph

http://www.caida.org/research/topology/as_core_network/

INTRODUCTION

The CAIDA AS Core visualization depicts the Internet's Autonomous Systems' (ASes) geographic locations, number of customers, 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 121 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 148,455 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.

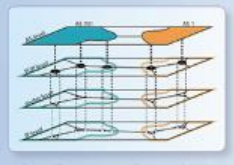
$$\text{radius} = 1 - \log\left(\frac{\text{transit degree(AS)} + 1}{\text{maximum transit degree} + 1}\right)$$

$$\text{angle} = \left(\text{longitude of the AS's BGP prefixes in Netacuity}\right)$$

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

INTERNET LAYERS

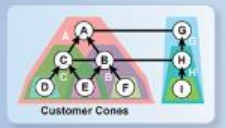
The Internet's network topology is often divided into four layers: AS, PoP, Router, and IP. The IP address uniquely identifies an attachment point (interface) of a device on the Internet. The router layer refers to the set of routers that transfer and route traffic. To support geophysically-aware topology 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

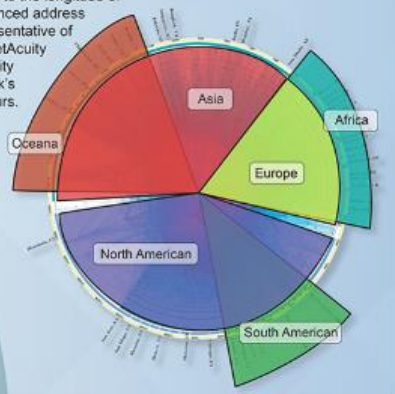
The AS's customer cone is the set of ASes that directly or indirectly pay the AS to connect to the Internet. On the left, A has the largest cone with 6 ASes; H has two. An AS's customer cone contains the set of ASes we observe the AS announce to its peers or providers. This definition is more constrained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

AS	Size
A	6
B	3
I	1



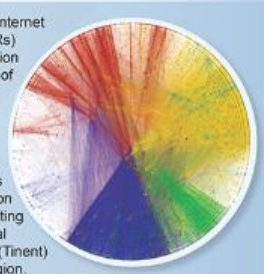
GEOGRAPHIC REGIONS

Each AS is placed according to the longitude of the centroid of its announced address space. This is representative of the area where NetAcuity inters 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 (Tinent) geolocate outside their region.



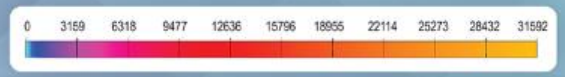
American Registry for Internet Numbers (**ARIN**) for the United States, Canada, several part of the Caribbean region, and Antarctica.

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

African Network Information Center (**AFRINIC**) 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



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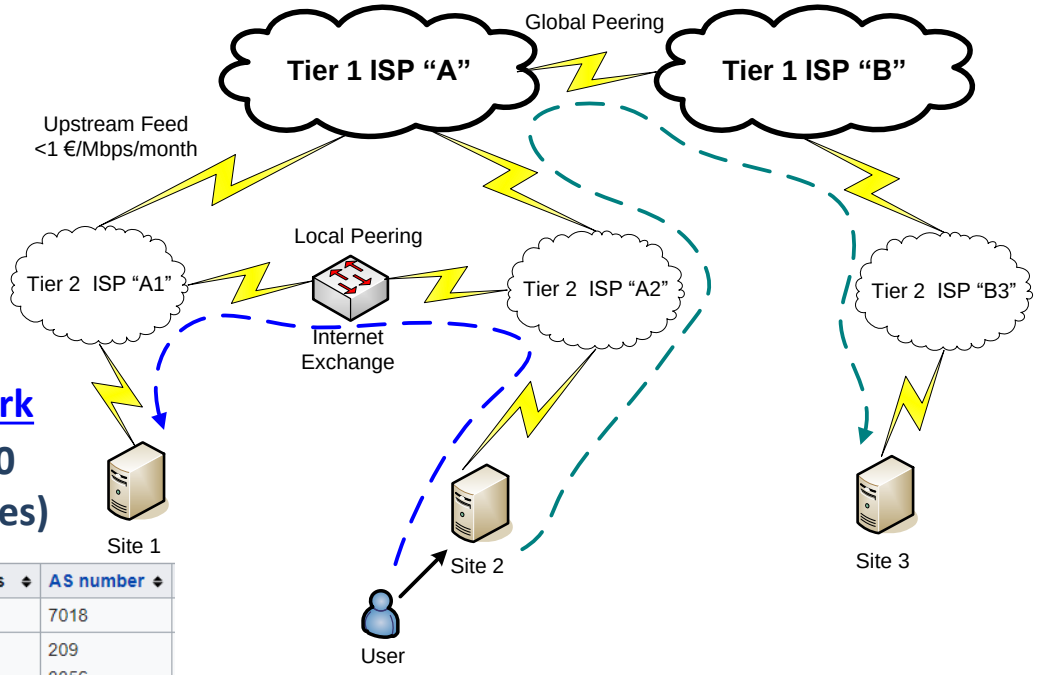
ARK Hosts: AARNet, AFRINIC, AMS-IX, APAN, ARIN, ASTI, Acreo, BDCOM Online Limited at BD-IX, CENIC, CNNIC, CNRST, Cablenet Communication Systems, Canarie, Carnegie Mellon University in Rwanda, Colorado State University, DCS1 Pte Ltd, DePaul University, Eötvös Loránd University (ELTE), Eurocom, Foundation for Research and Technology - Hellas (FORTH), FunkFeuer, GCI, Georgian College, HB Networks, HEANet, Hong Kong Polytechnic University, Hurricane Electric, IP-Max SA, Indonesian IPv6 Task Force, International Computer Science Institute (ICSI), Internet Systems Consortium, Iowa State University, Jacobs University Bremen, Jaguar Network, KREONet2, Kantonsschule Zug, Level 3 Communications, Liberty Global, NCAR, [illegible], Northeastern University, Openmirrors.asia - at Equinix SG1, Ottawa Internet Exchange, Public University of Navarra, QCell, RIPE NCC, RNP, Rede ANSP / Projeto NARA, Registro.br, SURFnet, Simula Research Laboratory, Solido Networks ApS, Southern Methodist University, TKK, TWAREN, Technical University of Munich, Tinet, TorIX, UCAD, US Army Research Lab, Univ. Twente, Universitat Leipzig, Universitat Politecnica de Catalunya, University of Cambridge, University of Hawaii, University of Limerick, 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

Οι 16 *Tier 1* ISP’s με πρόσβαση στα 750,000 δίκτυα - γνωστούς προορισμούς (IPv4 prefixes)

Name	Headquarters	AS number
AT&T[12]	United States	7018
CenturyLink (formerly Level 3, Qwest, Savvis, Global Crossing, TW Telecom and Exodus) [14] [15]	United States	209 3356 3549 4323
Deutsche Telekom AG (ICSS)[18]	Germany	3320
GTT Communications, Inc. (formerly Tinet & nLayer)[19]	United States	3257 (4436)
KPN International[21]	Netherlands	286
Liberty Global[23][24]	United Kingdom[25]	6830
NTT Communications (America) (formerly Verio)[27]	Japan	2914
Orange (OpenTransit)[28]	France	5511
PCCW Global	Hong Kong	3491
Sprint (SoftBank Group)[29]	Japan	1239
Tata Communications India Limited (Acquired Teleglobe)[31]	India	6453
Telecom Italia Sparkle (Seabone)[33]	Italy	6762
Telxius (Subsidiary of Telefónica)[34]	Spain	12956
Telia Carrier[36]	Sweden	1299
Verizon Enterprise Solutions (formerly UUNET and XO Communications)[42]	United States	701 702 703 2828
Zayo Group (formerly AboveNet)[44]	United States	6461

2 *Tier 2* ISP’s με ελαφρά μειωμένη πρόσβαση (συχνά θεωρούμενοι *Tier 1*)

Name	Headquarters	AS Number
Cogent Communications[47]	United States	174
Hurricane Electric[50]	United States	6939

ΤΑ 20 ΜΕΓΑΛΥΤΕΡΑ ΑΥΤΟΝΟΜΑ ΣΥΣΤΗΜΑΤΑ

AS Ranking σύμφωνα με την CAIDA (6/2018)

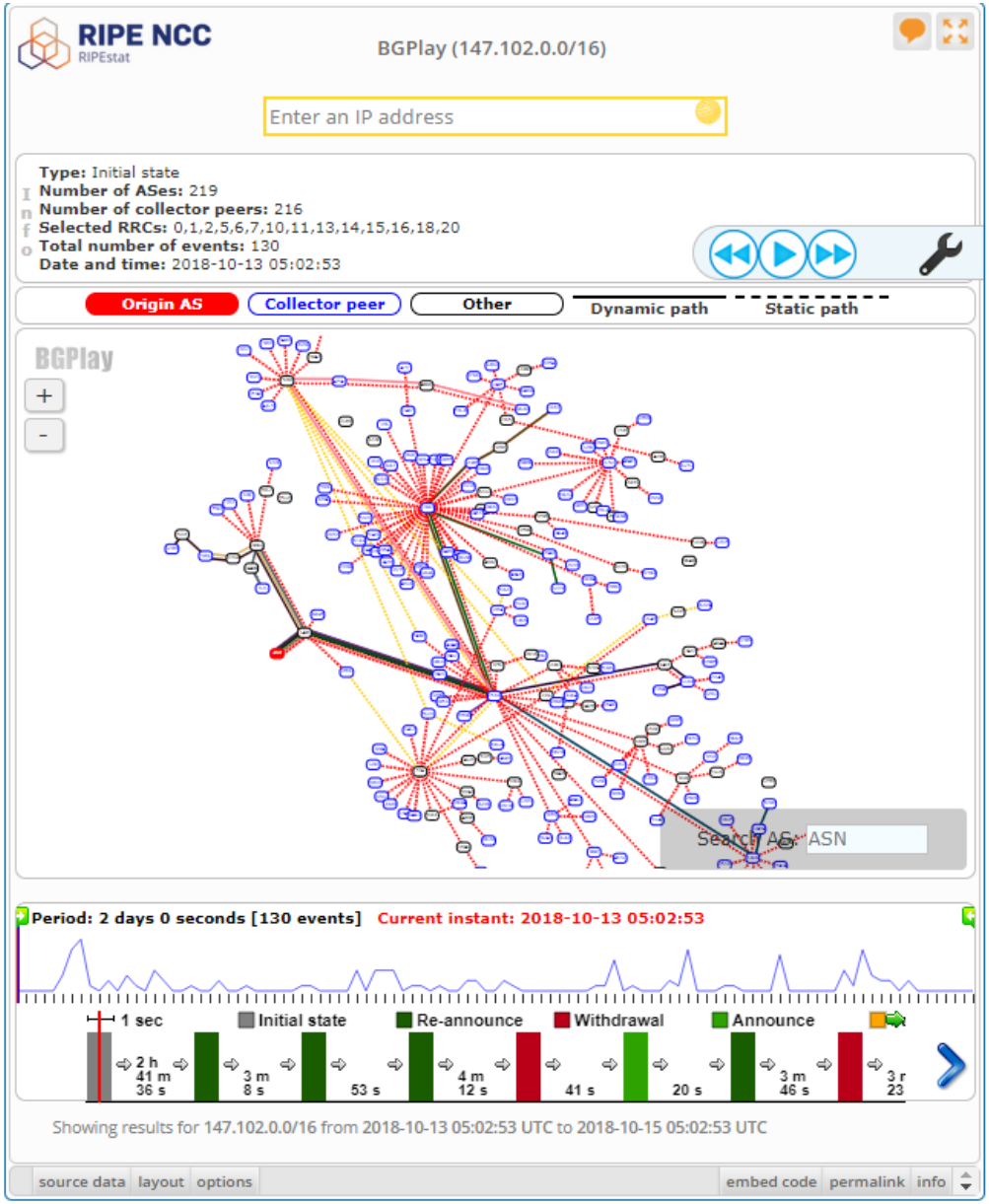
http://as-rank.caida.org/

AS Rank ▲	AS Number	Organization		cone size ▽
1	3356	Level 3 Parent, LLC		32759
2	1299	Telia Company AB		28902
3	174	Cogent Communications		26664
4	2914	NTT America, Inc.		24578
5	3257	GTT Communications Inc.		22113
6	6762	TELECOM ITALIA SPARKLE S.p.A.		15131
7	6453	TATA COMMUNICATIONS (AMERICA) INC		14688
8	6939	Hurricane Electric LLC		14527
9	3491	PCCW Global, Inc.		7961
10	3549	Level 3 Parent, LLC		6680
11	1273	Vodafone Group PLC		6406
12	6461	Zayo Bandwidth		6145
13	9002	RETN Limited		5703
14	209	Qwest Communications Company, LLC		4588
15	12956	Telefonica International Wholesale Services, SL		4253
16	3320	Deutsche Telekom AG		3853
17	7473	Singapore Telecommunications Ltd		3693
18	12389	PJSC Rostelecom		3551
19	7018	AT&T Services, Inc.		3059
20	20485	Closed Joint Stock Company TransTeleCom		3006

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

GRNET (5408), GÉANT (20965), Cogent (174), TELIA (1299)

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



GÉANT Tier 1/2 Providers (Internet feeds)

- Cogent (174)
- TELIA (1299)

ΤΟ ATHENS 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)

ΑΝΑΒΑΘΜΙΣΗ ΤΟΥ ΑΙΧ, 2009

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

Εναλλακτικά ουδέτερα σημεία στέγασης: **Εθνικό Ίδρυμα Ερευνών**, **Lamda Hellix**, **MedNautilus**

ΦΟΡΕΑΣ	ASN	EIE	Lamda Hellix	MedNautilus
Cloudflare	13335		✓	
Connecticore	197580			✓
CYNET	3268			✓
Cyta (Cyprus)	6866			✓
Cyta Hellas	6866			✓
dataways	15544		✓	
ERT	50148	✓		
forthnet	1241		✓	✓
Greek Internet Exchange (GR-IX)	199399	✓		
Greek Research & Technology Network (GRNET)	5408	✓		✓
HCN	57794			✓
Hellenic Telecommunications and Post Commission	203348	✓		
HostMeIn	50520		✓	
Lamda Hellix	56910		✓	
inalan	200736			✓
Metadosis	206529			✓
Microbase	196945			✓
Microsoft	8075		✓	
modulus	201494		✓	
NetIX	57463			✓
O3bNetworks	60725			✓
OTE	6799		✓	✓
TI Sparkle Greece	198477			✓
Riot Games Ltd.	6507			✓
Top.Host	199246		✓	
skroutz	202042			✓
Synapsecom	8280			✓
verizon	702	✓		
Vodafone	3329		✓	✓
WIND	25472		✓	✓