ΕΠΛ425: Τεχνολογίες Διαδικτύου

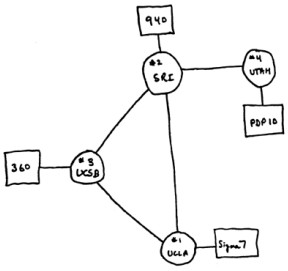
Μάριος Δικαιάκος

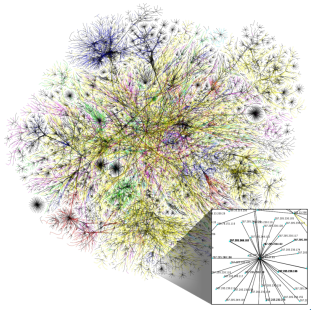
http://www.cs.ucy.ac.cy/mdd

Ενότητα 1η: Ανασκόπηση Διαδικτύου

Δίκτυα Η/Υ και Διαδίκτυο

Δίκτυα = Γράφοι = Κόμβοι + Ακμές





Δίκτυα Πακετομεταγωγής

- **Μεταγωγή Πακέτων** - **Packet switching** - permits multiple pairs of computers to communicate over a shared network
- Messages/files broken into segments of varying size, called packets.
- Each packet is labeled with source and destination address.
- The receiver must re-assemble the packets in the proper order

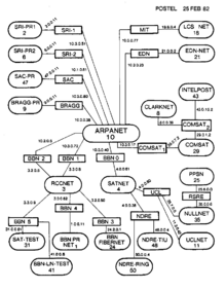
Τι *είναι* το Διαδίκτυο;

Definition (Wikipedia)

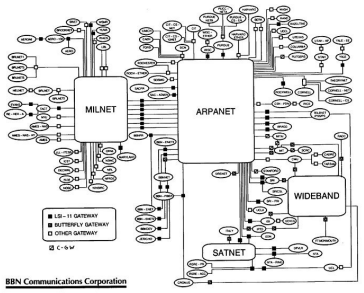
The Internet is the worldwide, publicly accessible network of interconnected computer networks that transmit data by packet switching using the standard Internet Protocol (IP). It is a "network of networks" that consists of millions of smaller domestic, academic, business, and government networks, which together carry various information and services, such as electronic mail, online chat, file transfer, and the interlinked Web pages and other documents of the World Wide Web.

http://en.wikipedia.org/wiki/Internet

Internet Map

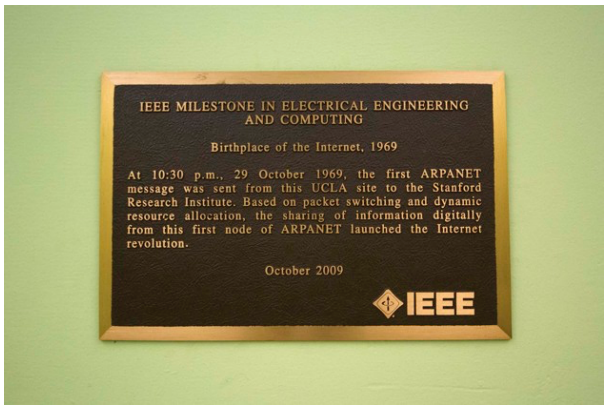


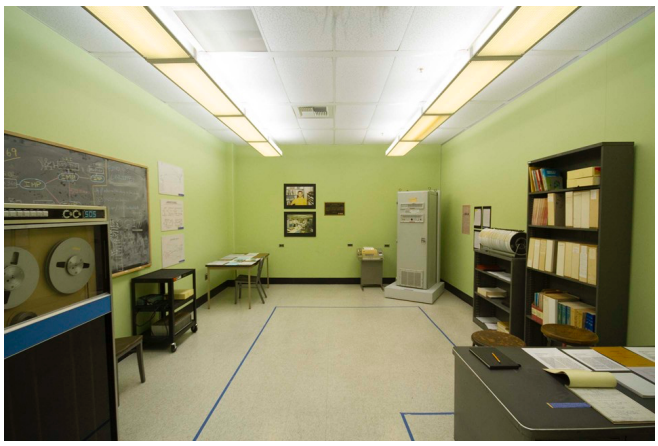
1982



1986

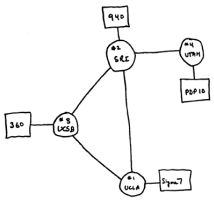
Πώς ξεκίνησε;

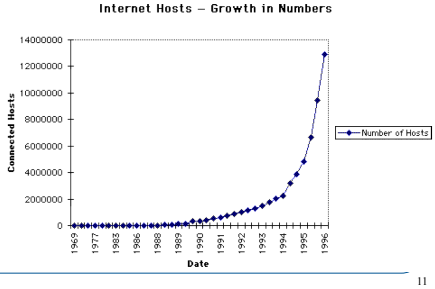


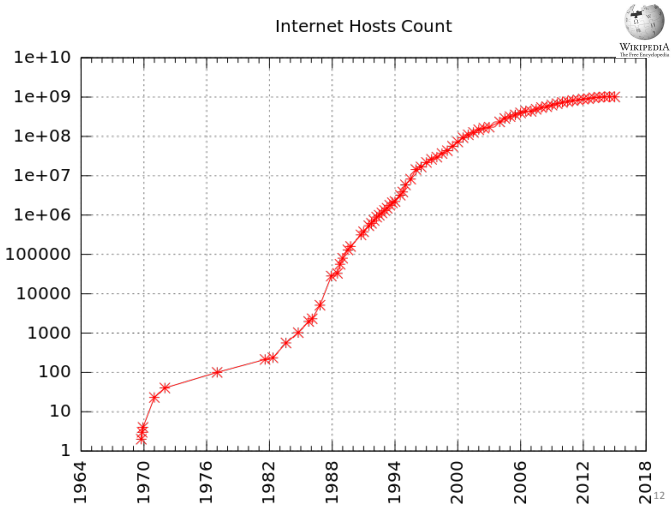


Εκθετική Εξέλιξη Διαδικτύου

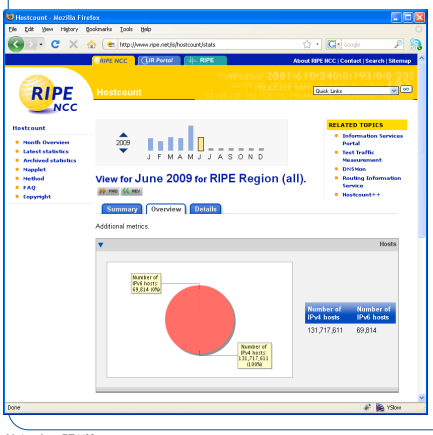
- 1969: Πρώτες δοκιμές του δικτύου ARPANET (προοίμιο του Internet), με τη διασύνδεση 4 Η/Υ στις ΗΠΑ.
- 1969-1978: Εκθετική ανάπτυξη του ARPANET και μετασχηματισμός του στο Internet (διαδίκτυο)







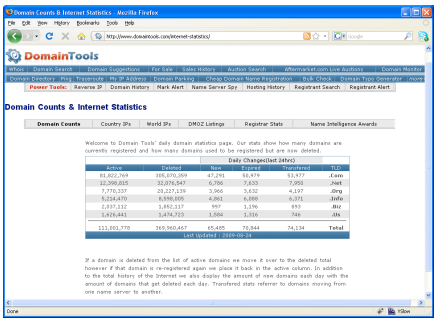
Internet Statistics



RIPE NCC is one of five Regional Internet Registries providing Internet resource allocations, registration services and co-ordination activities that support the operation of the Internet globally.

According to their survey (2014)
132 million hosts running IPv4
70,000 hosts running IPv6

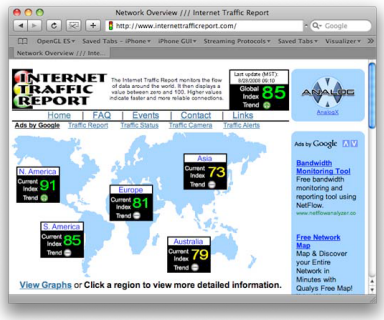
A host is a domain name, such as a-host.a-com.de



Shows how many domains are Registered and how many used to be registered, but are now deleted.

111 million active
369 million deleted
.com has the largest number, by far (2015)

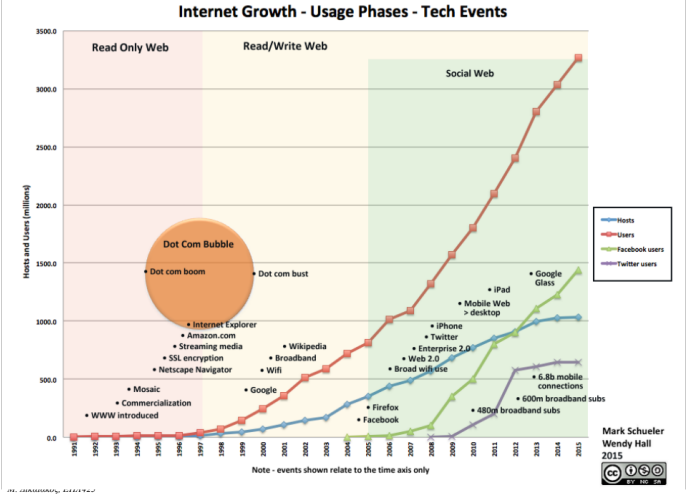
- How efficiently is the Internet working now
  - http://www.internettrafficreport.com/
  - http://netflow.internet2.edu/



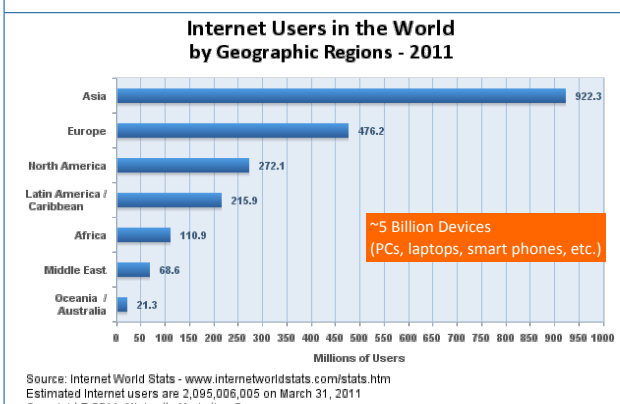
Άλλες πηγές

- Internet hosts Jul-15
  - http://ftp.isc.org/www/survey/reports/current/
- Internet users Jun-15
  - http://www.internetworldstats.com/emarketing.htm
- Facebook users Sep-15
  - http://www.statisticbrain.com/facebook-statistics/
- Twitter users Sep-15
  - http://www.statisticbrain.com/twitter-statistics/

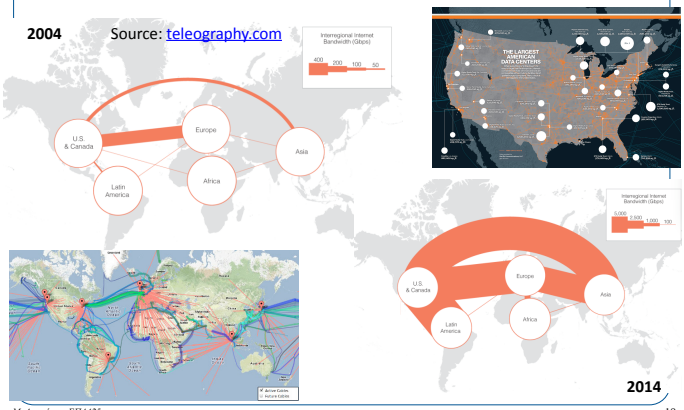
Πηγή: http://growthchart.weebly.com/



Two Billion Internet Users



Internet bandwidth growth

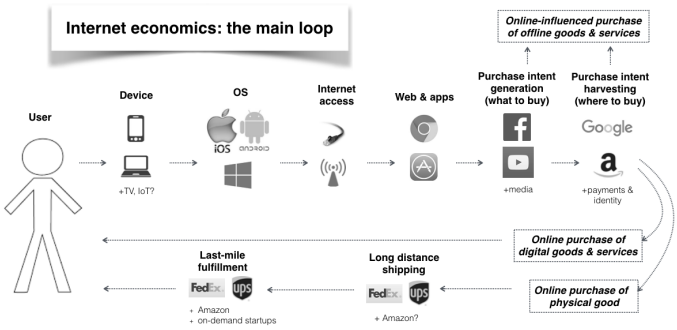


Internet Applications (2010)

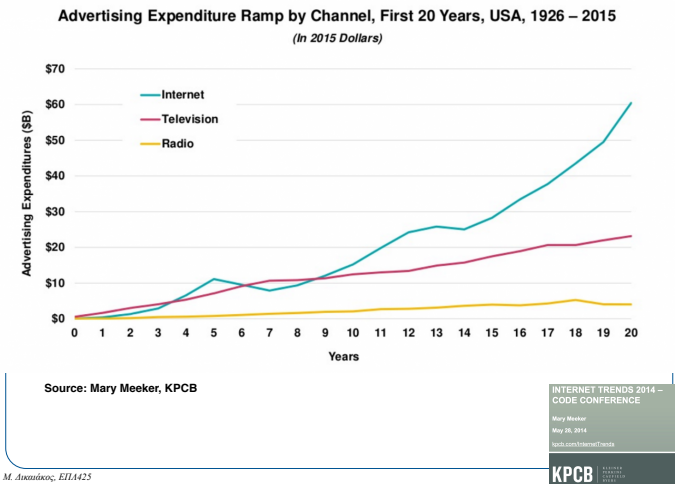
- Email
  - 1.9B people used email
  - 294B emails sent per day
- Web
  - 255M Web sites
  - 21.4M new Web sites
- YouTube
  - 2B videos watched per day
  - 35 hours of video uploaded per minute
- Blogs
  - 152M blogs
- Twitter
  - 100M new Twitter accounts
  - 25B tweets
- Facebook
  - 20M Facebook apps installed per day
  - 36B photos uploaded
  - Estimated 1B users by 2012

http://mashable.com/2011/01/25/internet-size-infographic/

The Internet Economy



Source: Chris Dixon, https://medium.com/@cdixon/the-internet-economy-fc43f3eff58a#.2zo35k1oe



How does the design of the Internet support growth and foster innovation?

Διαδίκτυο: Βασικά Συστατικά

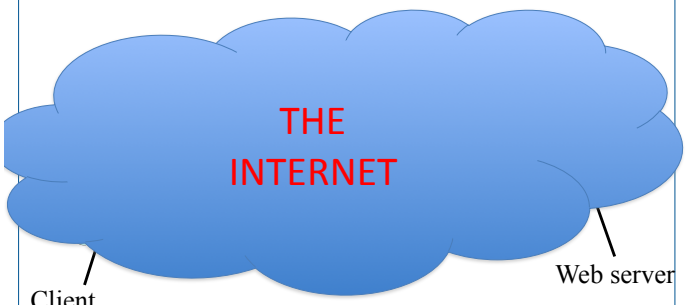
- Πρωτόκολλα Διαδικτύου:
  - TCP/IP
  - Hourglass Architecture (αρχιτεκτονική κλεψύδρας)
- End-to-End Architecture (άκρου-εις-άκρον αρχιτεκτονική)
- IP Addresses (διευθύνσεις διαδικτύου)
- Domain Name System (ονοματοδοσία)

Πρωτόκολλα Διαδικτύου

Τι είναι το πρωτόκολλο;

- A formal description of message formats and a set of rules for message exchange
  - Rules may define sequence of message exchanges
  - Protocol may define state-change in endpoint, e.g., file system state change
- Good protocols designed to do one thing
  - Protocols can be layered
- Examples of protocols
  - IP, TCP, TLS (was SSL), HTTP, Kerberos

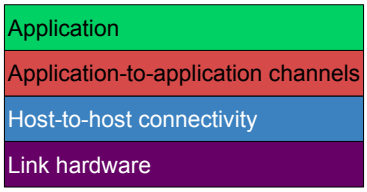
"A Network of Networks"



- How do you name?
- How do you find a name?
- How do you route packets?

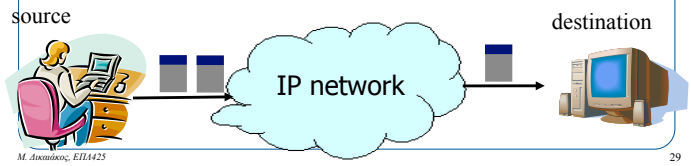
"A Stack of Protocol Layers"

- Modularity
  - Each layer relies on services from layer below
  - Each layer exports services to layer above
- Interfaces
  - Hides implementation details
  - Layers can change without disturbing other layers



IP Service: Best-Effort Packet Delivery

- Packet switching
  - Divide messages into a sequence of packets
  - Headers with source and destination address
- Best-effort delivery
  - Packets may be lost
  - Packets may be corrupted
  - Packets may be delivered out of order



IP Service Model: Why Packets?

- Data traffic is bursty (εκρηκτικό)
  - Logging in to remote machines
  - Exchanging e-mail messages
- Don't want to waste reserved bandwidth
  - No traffic exchanged during idle periods
- Better to allow multiplexing
  - Different transfers share access to same links
- Packets can be delivered by almost anything
  - RFC 2549: IP over Avian Carriers (aka birds)
- … still, packet switching can be inefficient
  - Extra header bits on every packet

IP Service Model: Why Best-Effort?

- IP means never having to say you're sorry…
  - Don't need to reserve bandwidth and memory
  - Don't need to do error detection & correction
  - Don't need to remember from one packet to next
- Easier to survive failures
  - Transient disruptions are okay during fail-over
- … but, *applications do want efficient, accurate transfer of data in order, in a timely fashion*

IP Service: Best-Effort is Enough?

- No error detection or correction
  - Higher-level protocol can provide error checking
- Successive packets may not follow the same path
  - Not a problem as long as packets reach the destination
- Packets can be delivered out-of-order
  - Receiver can put packets back in order (if necessary)
- Packets may be lost or arbitrarily delayed
  - Sender can send the packets again (if desired)
- No network congestion control (beyond "drop")
  - Sender can slow down in response to loss or delay

Transport Protocols

- Logical communication between application processes running on end-hosts
  - Sender divides a message into segments and passes them to network layer
  - Receiver reassembles segments into messages and passes them to application layer
- Transport services
  - (De)multiplexing packets
  - Detecting corrupted data
  - Optionally: reliable delivery, flow control, …
- Multiple transport protocol available to applications
  - Internet: TCP and UDP

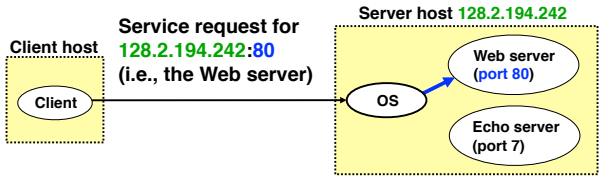
3

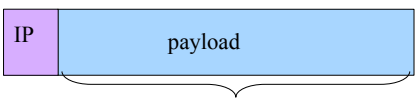
Transmission Control Protocol (TCP)

- Adds multiplexing, guaranteed message delivery on top of IP
- **Multiplexing**: multiple programs using the same IP address
  - **port**: a number given to each program or service
  - port 80: web browser (port 443 for secure browsing)
  - port 25: email
  - port 22: ssh
  - port 5190: AOL Instant Messenger
  - more common ports
- Some programs (games, streaming media programs) use simpler UDP protocol instead of TCP

Two Basic Transport Features

- **Demultiplexing:** port numbers



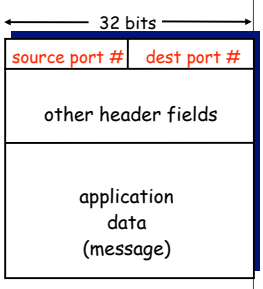


- **Error detection:** checksums

detect corruption

Multiplexing and Demultiplexing

- Host receives IP datagrams
  - Each datagram has source and destination IP address,
  - Each datagram carries one transport-layer segment
  - Each segment has source and destination **port number**
- Host uses IP addresses and port numbers to direct the segment to appropriate socket (υποδοχή)



TCP/UDP segment format

Σχεδιαστικά Χαρακτηριστικά TCP/IP

- Subnetworks can stand on their own
- Computers can dynamically join and leave the network
- Built on open standards; anyone can create a new internet device
  - Οι προδιαγραφές και τα πρωτόκολλα του Διαδικτύου - TCP/IP δημοσιεύονται σαν Requests for Comments (RFCs).
- Lack of centralised control (mostly)
- Everyone can use it with simple, commonly available software

People and organisations

- Internet Engineering Task Force (IETF): internet protocol standards
- Internet Corporation for Assigned Names and Numbers (ICANN):
  decides top-level domain names
- World Wide Web Consortium (W3C): web standards

Σύνοψη: TCP/IP

- Πρωτόκολλο IP, αποτελεί το δικτυακό «υπόστρωμα» - τα datagrams του IP είναι ο μηχανισμός μεταγωγής πακέτων στο Διαδίκτυο.
- 2 πρωτόκολλα μεταφοράς:
  - TCP (Transmission Control Protocol) – αξιόπιστο, προσανατολισμένο σε διατήρηση συνόδων (connection-oriented).
  - UDP (User Datagram Protocol) – πρωτόκολλο πακέτων (datagram protocol) το οποίο δεν εγγυάται αξιόπιστη μετάδοση.

Λόγοι Επιτυχίας TCP/IP

- Ανοικτές προδιαγραφές πρωτοκόλλων (Open protocol standards): freely available and developed independently from any computer hardware or OS.
- Ανεξαρτησία από υλικό δικτύωσης και πρωτόκολλα φυσικής διαστρωμάτωσης.
- Κοινό σχήμα διευθυνσιοδότησης.
- Προδιαγεγραμμένα πρωτόκολλα υψηλότερων διαστρωματώσεων (Standardized high-level protocols).

Τι τύπου είναι το Διαδικτύο;

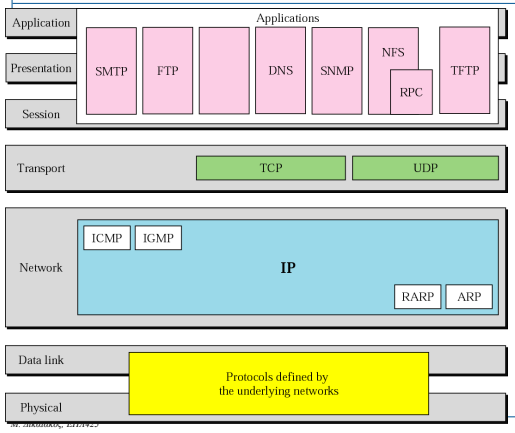
- Δίκτυο μεταγωγής κυκλώματος
- Ομοαξονικό δίκτυο
- Δίκτυο πακετομεταγωγής
- Φρυκτωρία

Τι σημαίνει ότι το IP είναι πρωτόκολλο best effort;

- Αξιοποιεί με τον βέλτιστο τρόπο τους δικτυακούς πόρους
- Αποδέχεται απώλειες πακέτων
- Πετυχαίνει υψηλές ταχύτητες
- Προσαρμόζεται στο φυσικό μέσο μεταφοράς

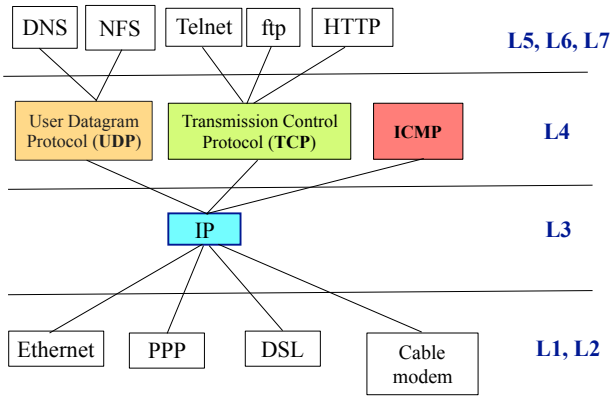
Διαστρωμάτωση Πρωτοκόλλων

OSI και Διαδίκτυο

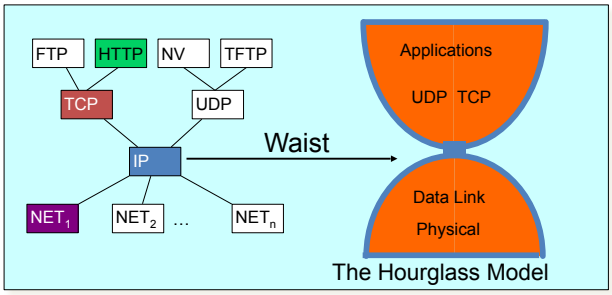


OSI Reference Model

Common protocols in the Internet



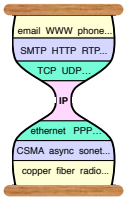
Αρχιτεκτονική Κλεψύδρας



The “narrow waist” facilitates interoperability

Why the Hourglass Architecture?

- Why an internet layer?
  - make a bigger network
  - global addressing
  - virtualise network to isolate end-to-end protocols from network details/changes
- Why a *single* internet protocol?
  - maximise interoperability
  - minimise number of service interfaces
- Why a *narrow* internet protocol?
  - assumes least common network functionality to maximise number of usable networks



Source: Hoffman & Beaumont

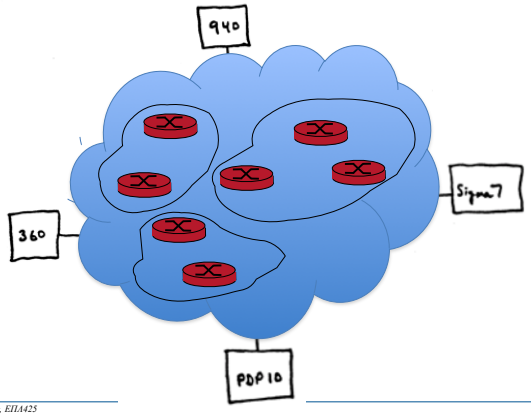
End-to-end principles

Αρχές Σχεδιασμού Άκρου-εις-άκρον

Power at the Edge

- End-to-End Principle
  - Whenever possible, communications protocol operations should be defined to occur at the end-points of a communications system.
- Programmability
  - With programmable end hosts, new network services can be added at any time, by anyone.
- And then end hosts became powerful and ubiquitous….

Πυρήνας και Άκρα



Αρχιτεκτονική άκρου-εις-άκρο

- Η αρχιτεκτονική «άκρου-εις-άκρο» (end-to-end principle) είναι μια αρχή σχεδιασμού στα δικτυοκεντρικά / κατανεμημένα συστήματα που προτάθηκε στο άρθρο "End-to-end arguments in system design" των Jerome H. Saltzer, David P. Reed, and David D. Clark (1981).

End-to-end arguments in system design

Full Text: PDF

Authors: J. H. Saltzer — M.I.T. Laboratory for Computer Science, 545 Technology Square, Cambridge, MA
D. P. Reed — Software Arts, Inc., 27 Mica Lane, Wellesley, MA
D. D. Clark — M.I.T. Laboratory for Computer Science, 545 Technology Square, Cambridge, MA

1984 Article

Bibliometrics
· Downloads (6 Weeks): 96
· Downloads (12 Months): 1,234
· Downloads (cumulative): 13,922
· Citation Count: 350

Published in:
· Journal
ACM Transactions on Computer Systems (TOCS) TOCS Homepage archive
Volume 2 Issue 4, Nov. 1984
Pages 277-288
ACM New York, NY, USA
table of contents doi>10.1145/357401.357402

Αρχιτεκτονική άκρου-εις-άκρο

…σε ένα γενικής χρήσης δίκτυο, εξειδικευμένες λειτουργίες εφαρμογών πρέπει να υλοποιούνται και να εγκαθίστανται στους ακραίους κόμβους του δικτύου (end hosts) και όχι στους ενδιάμεσους κόμβους, αν και εφόσον η υλοποίηση στα άκρα μπορεί να είναι «πλήρης και ορθή».

Στις αντιπαραθέσεις σχετικά με την δικτυακή ουδετερότητα, μια συχνή ερμηνεία της αρχιτεκτονικής άκρου-εις-άκρος ισχυρίζεται ότι η αρχιτεκτονική υπονοεί ένα ουδέτερο ή «χαζό» δίκτυο.

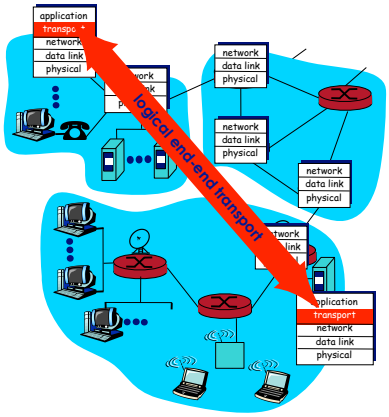
Rethinking the design of the Internet: the end-to-end arguments vs. the brave new world

Authors: Marjory S. Blumenthal — National Academy of Sciences
David D. Clark — Massachusetts Institute of Technology, Cambridge

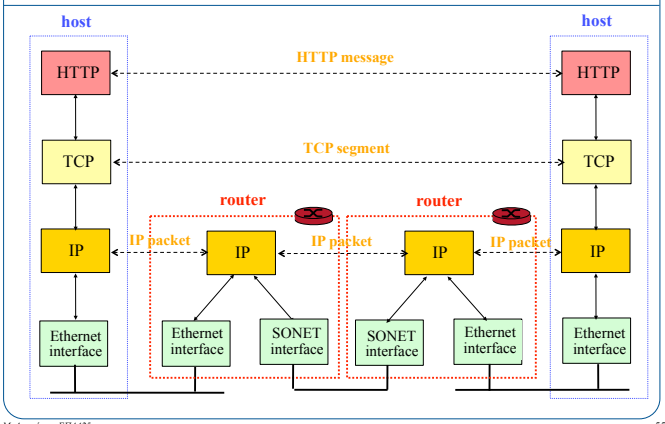
2001 Article

Bibliometrics
· Downloads (6 Weeks): n/a
· Downloads (12 Months): n/a
· Downloads (cumulative): n/a
· Citation Count: 2

Published in:
· Book
Communications Policy in Transition
Pages 91-139
MIT Press Cambridge, MA, USA ©2001
table of contents ISBN:0-262-03292-9



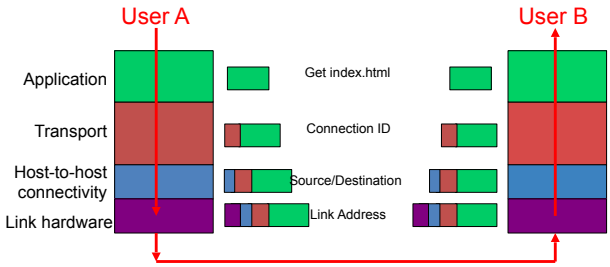
IP Suite: End Hosts vs. Routers



IP Suite: End Hosts vs. Routers

IP Protocol Stack: Key Abstractions

Layer Encapsulation



Τι *είναι* το Διαδίκτυο; ✓

Ποιός ρυθμίζει τη λειτουργία του;

Ποιός το ελέγχει;

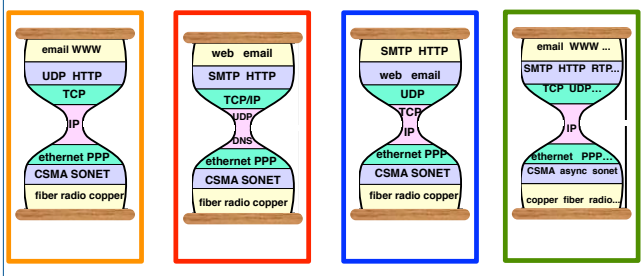
Ποιά είναι η αρχιτεκτονική του Διαδικτύου; ✓

Ποιός αναθέτει τη διεύθυνση ενός διαδικτυακού κόμβου;

Πώς μεγεθύνεται το Διαδίκτυο; ✓

Τι σημαίνει «Δικτυακή Ουδετερότητα»;

Ποιά από τις ακόλουθες κλεψύδρες είναι η σωστή;



Τι κατανομή ακολουθεί η κίνηση στο Διαδίκτυο;

- Κανονική φυσικά (normal)!
- Ομοιόμορφη (uniform)
- Εκρηκτική (bursty)
- Σταθερή

Ποιό από τα παρακάτω στοιχεία ανήκει στον πυρήνα του Διαδικτύου;

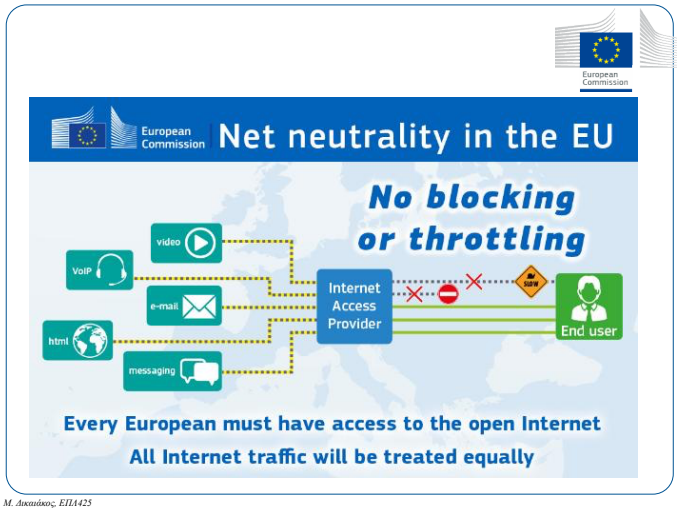
- Δρομολογητές επιπέδου 3 (L3 switches / routers)
- Εξυπηρετητές HTTP (HTTP servers)
- Μεταγωγείς επιπέδου 7 (L7 switch)
- Δρομολογητές επιπέδου 7 και εξυπηρετητές HTTP

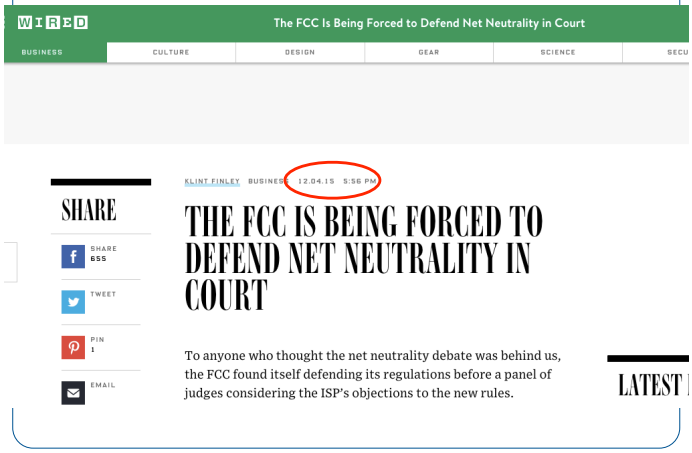
Ποιό από τα παρακάτω πρωτόκολλα δεν είναι end-to-end (από άκρου είς άκρο);

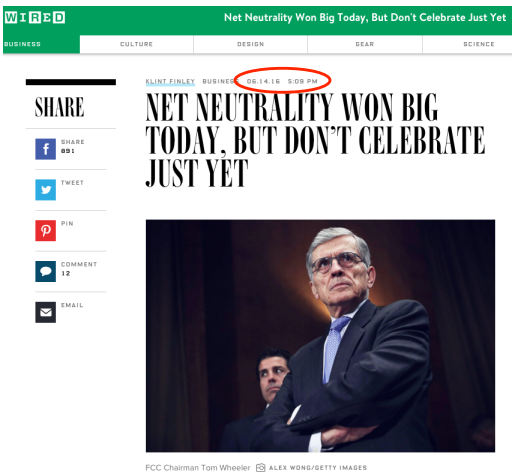
- IP
- TCP
- HTTP
- UDP

Δικτυακή Ουδετερότητα

- **All traffic has to be treated equally**.
- Blocking (φραγή), throttling (στραγγαλισμός) and discrimination (δυσμενής διάκριση) of internet traffic by Internet Service Providers (ISPs) is not allowed in the EU, save for three exhaustive exceptions:
  - compliance with legal obligations;
  - integrity of the network;
  - congestion management in exceptional and temporary situations
- and users are free to use their favourite apps and services no matter the offer they subscribe to






WIRED

Net Neutrality Won Big Today, But Don't Celebrate Just Yet

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NET NEUTRALITY WON BIG TODAY, BUT DON'T CELEBRATE JUST YET

FCC Chairman Tom Wheeler ALEX WONG/GETTY IMAGES

"Today, a federal appeals court ruled that the Federal Communications Commission does indeed have the authority to reclassify Internet service providers as "common carriers," meaning the agency can regulate them in much the same way it regulates telephone service providers.

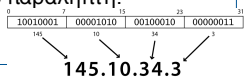
The upshot is that the FCC can now enforce the net neutrality rules it passed last year prohibiting ISPs from blocking or throttling certain sites or types of content, and banning **"paid prioritization"**–aka "Internet fast lanes."

Wired, 14/6/2016

Διευθύνσεις Διαδικτύου

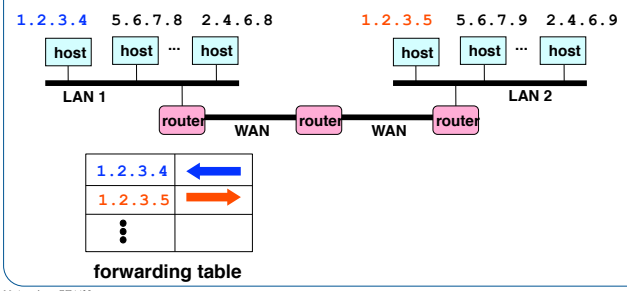
Διευθυνσιοδότηση σε Δίκτυα IP

- Για τη δημιουργία ενός παγκόσμιου δικτύου, είναι αναγκαία η ταυτοποίηση κάθε κόμβου του δικτύου.
- Το IP επιτυγχάνει την ταυτοποίηση με την ανάθεση μιας μοναδικής IP διεύθυνσης σε κάθε κόμβο:
  - Each IPv4 address has *32 bits* divided into *four* 8-bit segments, separated by dots.
  - Each segment is number between 0 and 255
  - Identifies an interface (on a host, on a router, …)
- Η IP διεύθυνση του παραλήπτη ενος μηνύματος τοποθετείται στην επικεφαλίδα του κάθε IP πακέτου και περιλαμβάνει όλη την πληροφορία που χρειάζονται οι δρομολογητές για να παραδώσουν το πακέτο στον κατάλληλο παραλήπτη.



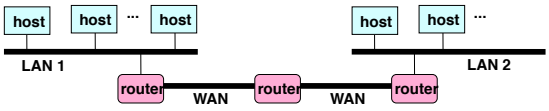
Scalability Challenge

- Suppose hosts had arbitrary addresses
  - Then every router would need a lot of information
  - …to know how to direct packets toward the host



Grouping Related Hosts

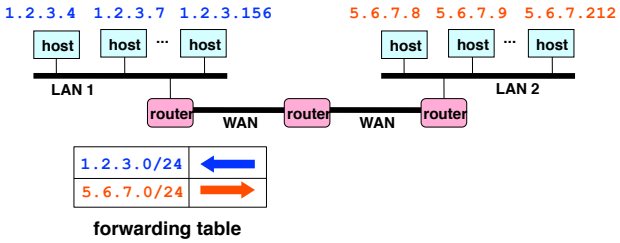
- The Internet is an "inter-network"
  - Used to connect *networks* together, not *hosts*
  - Needs a way to address a network (i.e., group of hosts)



LAN = Local Area Network
WAN = Wide Area Network

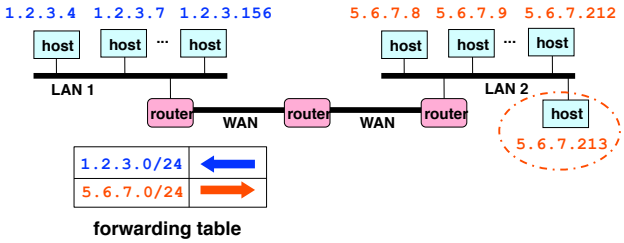
Scalability improved

- Number related hosts from a common subnet
  - 1.2.3.0/24 on the left LAN
  - 5.6.7.0/24 on the right LAN



Easy to add new hosts

- No need to update the routers
  - E.g., adding a new host 5.6.7.213 on the right
  - Doesn't require adding a new forwarding entry



Διευθύνσεις IPv6

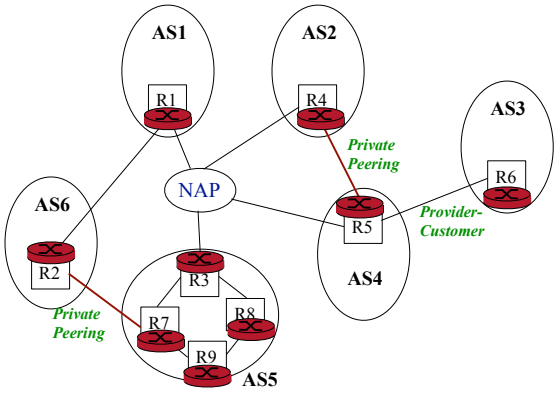
- Γιατί το IPv6;
- **IPv6** is *128 bits* divided into *eight 16-bit segments*, separated by colons.
  - Each segment is a number between 0 and 2^{16}-1.
  - The number is written as 4 hexadecimal digits, separated by colons, e.g. 3ffe:1900:4545:3:200:f8ff:fe21:67cf
- IPv6 has the potential of about 3.4 x 10^{38} hosts

Αυτόνομα Συστήματα

Αυτόνομα Συστήματα

- The Internet is divided into regions under a single administrative control, each of which is called an Autonomous System and contains a group of network IDs.
- Routing inside an AS is completely hidden from the rest of the Internet.
- Routes between ASs are computed in terms of AS hops: lists of intermediary ASs from the source AS to the destination AS.

Autonomous Systems



Δρομολόγηση εντός των ΑΣ

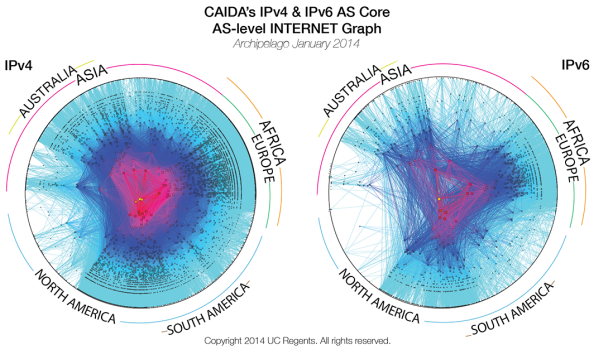
- Under complete control of AS owner
- Small ASs have only one router, which does the internal and external routing (e.g., AS1, AS2, AS3, AS4, AS6)
- Larger ASs may have more than one routers:
  - some of them are *border routers* and deal with outgoing or incoming traffic to the AS (e.g., AS5)
  - others used for internal routing only - Open Shortest Path First (OSPF) protocol is used

Διασύνδεση ΑΣ

- Network Access Point (NAP): a physical network that connects routers from different ASs
- Private Peering Links (ιδιωτική διασύνδεση): private physical networks connecting only the routers from two ASs
  - Peering agreements usually limit traffic over peering link to non-transit traffic
- Provider-customer relationship: similar to peering linkage but usually complies to different business model:
  - the provider delivers transit traffic to the customer

Δρομολόγηση μεταξή ΑΣ

- Done according to the Border Gateway Protocol (BGP):
  - Each router advertises reachability information (προσβασιμότητα) to neighbour routers for:
    - all networks within its AS and
    - for outside networks reachable via its AS (for transit ASs)
  - Reachability information includes a list of reachable networks and performance cost expressed as the number of hops to the destination
  - An AS can set routing policies that determines which reachability information is advertised to which routers



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