

# Introduction

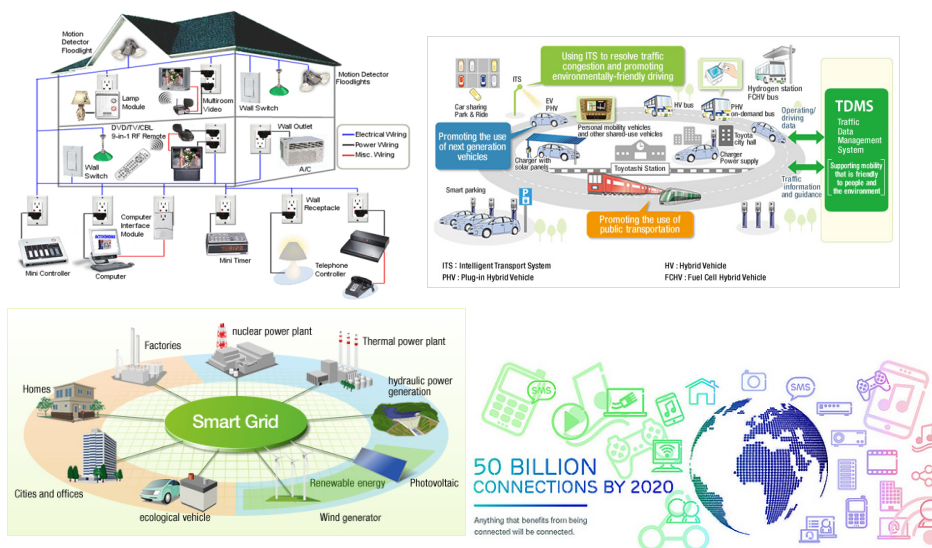
# Lecture 1

György Dán  
KTH/EE/LCN

**Literature:**

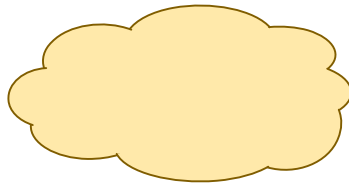
Forouzan, TCP/IP Protocol Suite  
(3<sup>ed</sup> Ch 1,2,3 )(4<sup>ed</sup> Ch 1,2,3)

# Why Internet?



## Introduction

# What is the Internet?

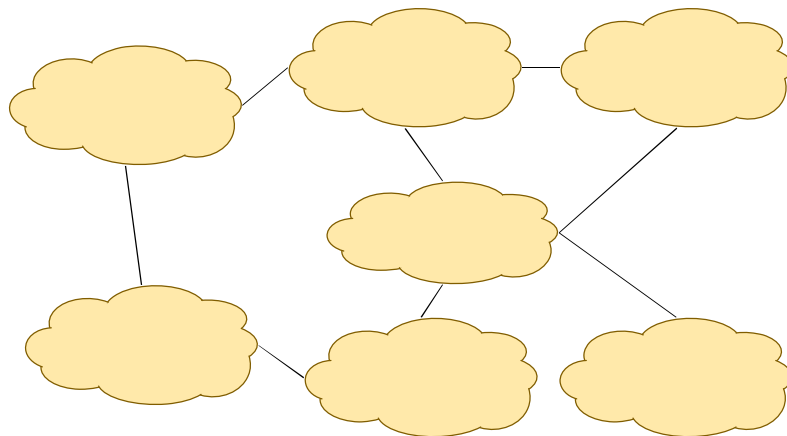


*J.C.R. Licklider, BBN, 1962  
"Galactic Network"*

Global information infrastructure

*Introduction*

# What is the Internet?

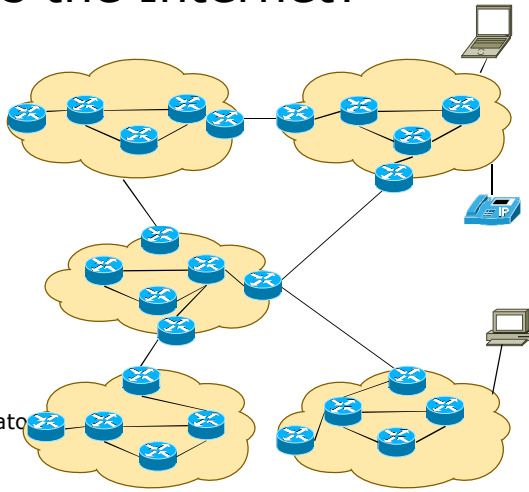


- Network of networks = Internetwork

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# What is the Internet?

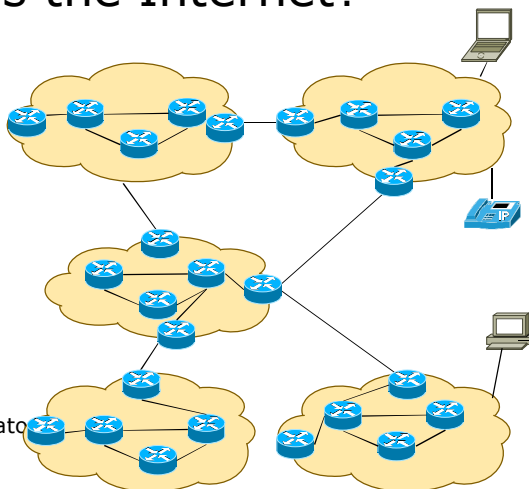
- Physical infrastructure
  - Communication links
  - Connecting devices (switches, routers)
  - Hosts
- Logical infrastructure
  - Protocols
  - Standards
- Organizations
  - Standards bodies, regulatory bodies
  - Operators
- Services



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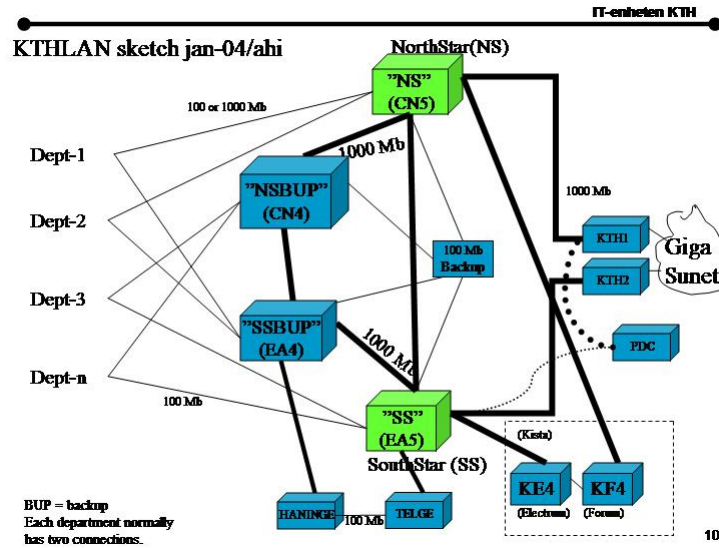
# What is the Internet?

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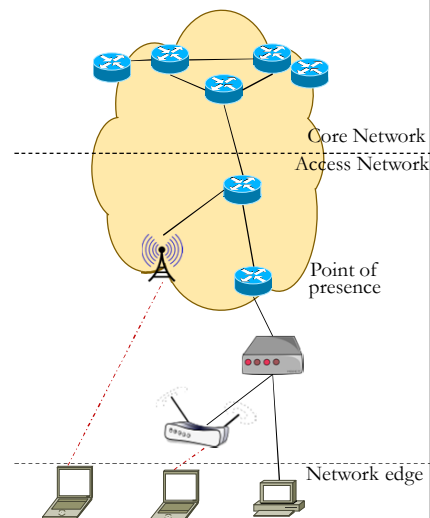
# A (small) real-world network



Introduction

## Edge, Access and Core Network

- Core Network
  - Mesh of routers
- Access network
  - Residential/institutional
  - Wired
    - Optical/cable/copper
    - Ethernet/ATM/Frame relay
  - Wireless
    - Local (802.11)
    - Wide area (WiMax, UMTS)
- Network Edge
  - Hosts
  - Local infrastructure



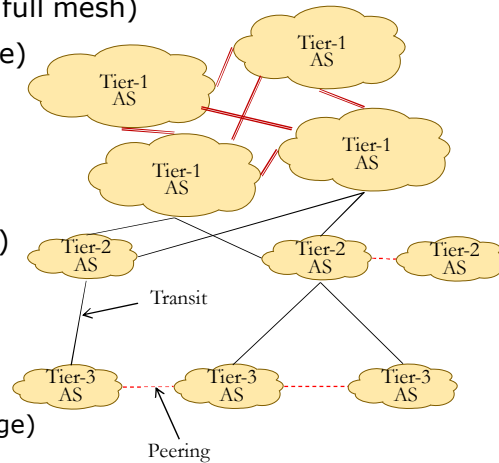
Introduction

# Structure of the Internet

- Hierarchical structure
  - Tier-1 (Global coverage, full mesh)
  - Tier-2 (Regional coverage)
  - Tier-3 (Local coverage)

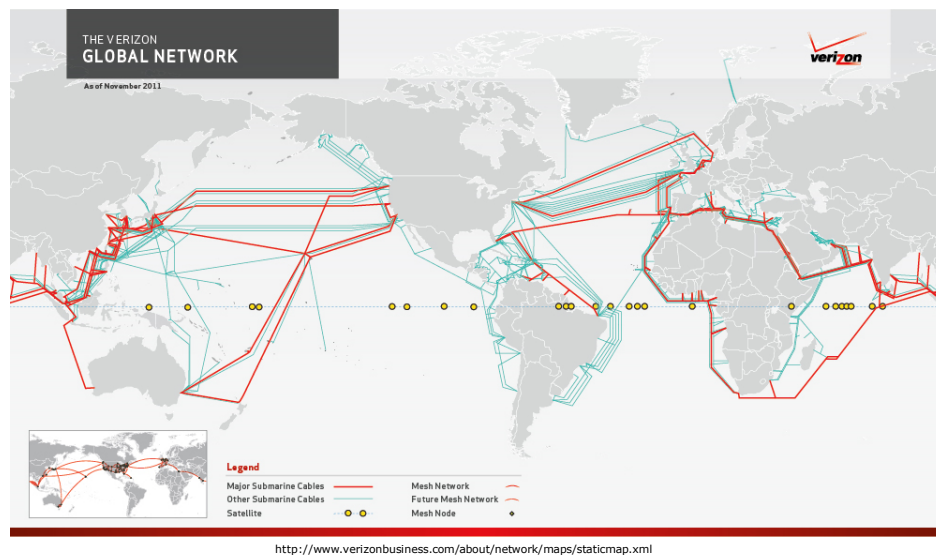
- Connection types
  - Transit/customer (\$)
  - **Peering** (settlement-free)

- Location
  - Exchange points
    - Private
    - Public (Internet eXchange)



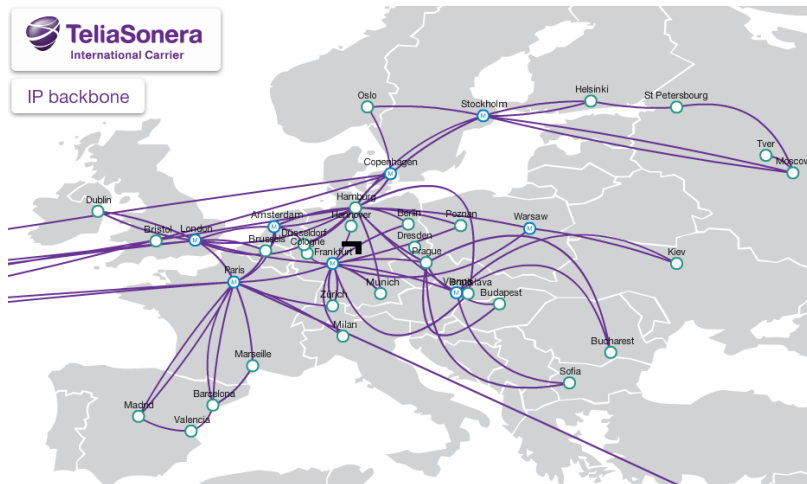
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## Example Tier-1 ISP: Verizon Business



Introduction

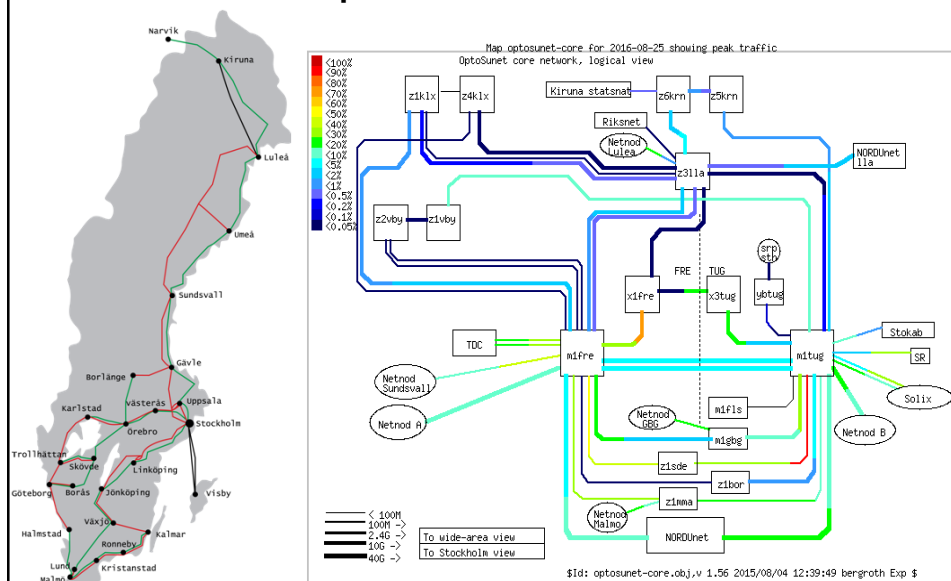
## Example Tier-1 ISP: TeliaSonera IC



<http://www.teliaasoneraic.com/Our-network/Network-map.html>

Introduction

## Example Tier-2: SUNET

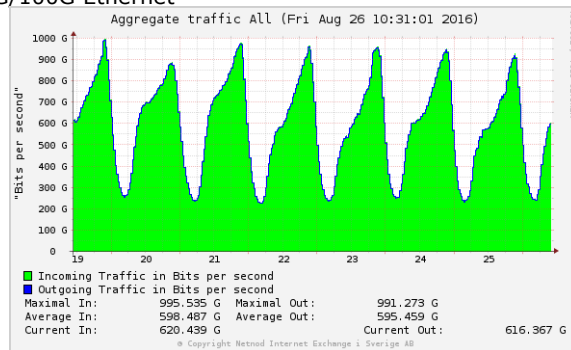


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## Example IXP: NetNod

- Netnod: Swedish IXP

- Locations: Stockholm, Göteborg, Malmö, Sundsvall, Luleå
- 272 ASs: Tele2, Breadband2, TeliaSonera, Comhem, Telenor, Riksnät, Bahnhof, Akamai, ...
- Technology: 1G/10G/100G Ethernet
- Price (2x10G)
  - 22KEUR/y



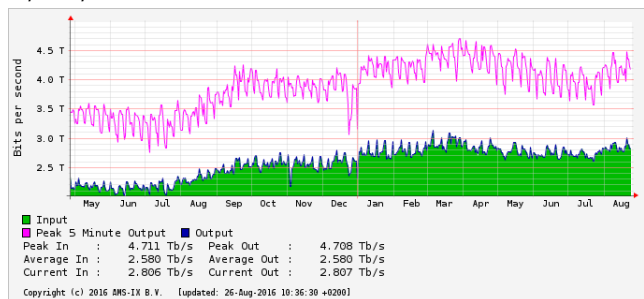
<http://www.netnod.se>

Introduction

## Example IXP: AMS-IX

- Amsterdam Internet Exchange

- Location: multiple in Amsterdam
- 801 ASs: Tele2, TeliaSoneraIC, Telenor, Bahnhof, Akamai, Deutsche Telekom, Orange, AT&T, Verizon, NTT, Google, Amazon, Yahoo, ...
- Technology: 1G/10G/100G Ethernet
- Price (10G):
  - 15KEUR/y



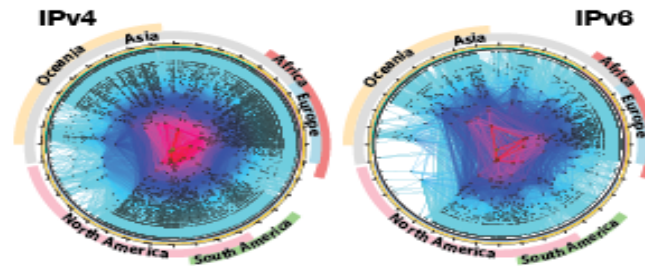
<http://www.ams-ix.net/statistics>

Introduction

# The Big Picture: AS-level Structure

CAIDA's IPv4 & IPv6 AS Core  
AS-level Internet Graph

Archipelago  
July 2015



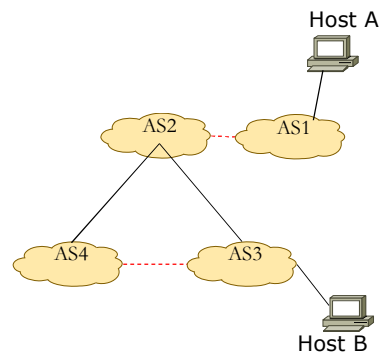
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[http://www.caida.org/research/topology/as\\_core\\_network/](http://www.caida.org/research/topology/as_core_network/)

Introduction

## Quiz

- You transfer 1GB of data from Host A to Host B.  
Because of this data transfer:
  - 1) AS1 will have to pay to AS2
  - 2) AS2 will have to pay to AS1
  - 3) AS1 will have to pay to AS3
  - 4) AS3 will have to pay to AS4
  - 5) AS3 will have to pay to AS2
  - 6) None of the above

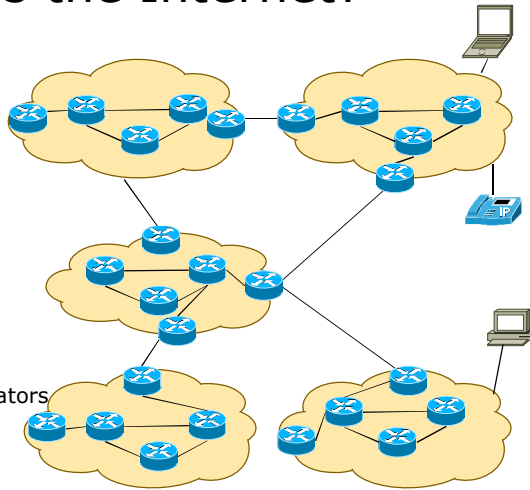


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# What is the Internet?

- Physical infrastructure
  - Communication links
  - Switches, routers
  - Hosts
- Logical infrastructure
  - **Protocols**
  - Standards
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## Communication Protocols

- All Internet communications follow some protocol
- Defines
  - Syntax - format
  - Synchronization - order of messages sent and received among entities
  - Semantics - actions taken upon sending and receiving
- Level of openness
  - Proprietary
  - De-facto standard
  - Standard

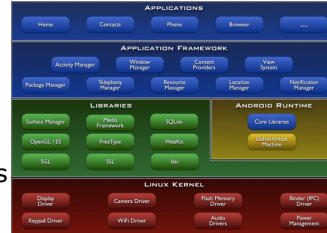
} Interoperability  
Market competition



Introduction

# Layered Protocol Stack

- Modular design for complex system
  - Modules implement functionality
  - Interfaces define services towards other modules
  - Explicit structure to express relationships
- Easier maintenance and change management
  - Can change the implementation of a module
- Layering
  - One dimensional hierarchy of modules
  - Functions with related uses constitute a layer



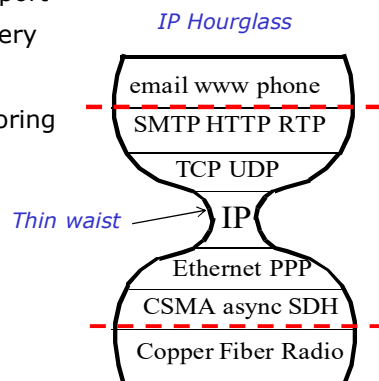
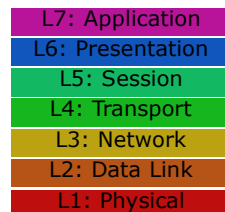
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# Internet Protocol Stack

- TCP/IP protocol stack layers
  - Application : application specific support
  - Transport : process-to-process delivery
  - Network : host-to-host delivery
  - Link : data transfer between neighboring nodes
  - Physical: bits on the wire

- ISO-OSI reference model

- 7 layers

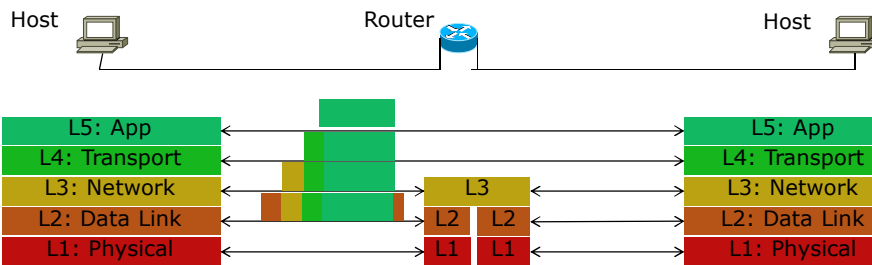


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# Layering and Encapsulation

- Encapsulation

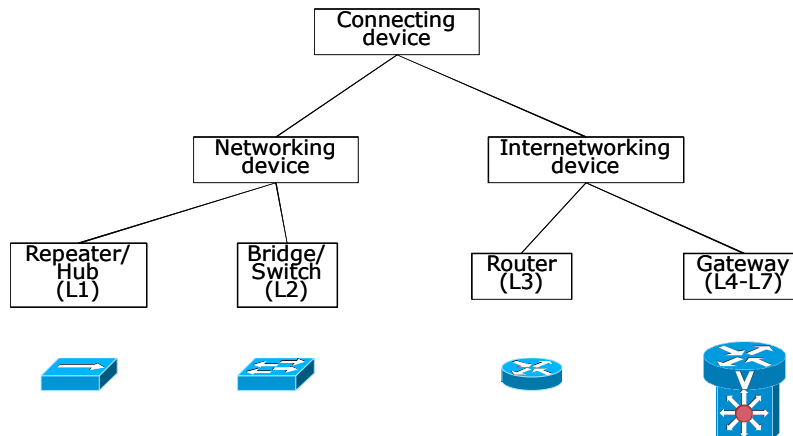
- Use headers to identify higher layer protocol and payload
- Enables multiplexing/demultiplexing



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## Connecting devices

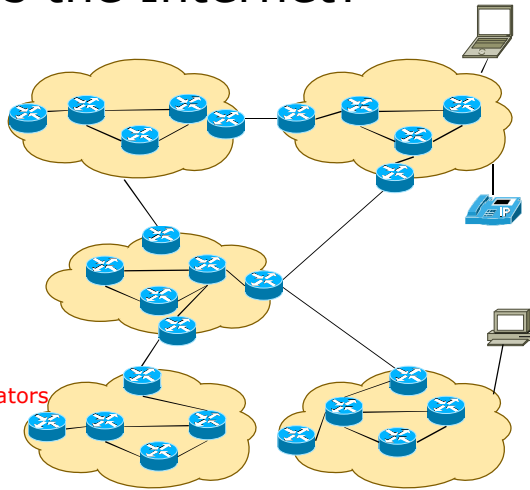
- Connecting device operates up to a specific layer



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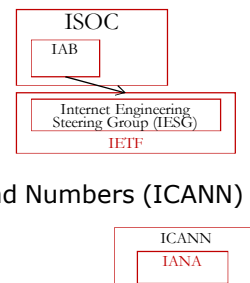
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## Standards and Policy Organizations

- Internet specific
  - Internet Society (ISOC)
    - IAB- Internet Architecture Board
    - IETF - Internet Engineering Task Force
  - Internet Corporation for Assigned Names and Numbers (ICANN)
    - Internet Assigned Numbers Authority (IANA)
- Not Internet specific
  - ISO - International Standards Organization
  - IEEE - Institute of Electrical and Electronics Engineers
  - ITU-T - International Telecommunications Union - Telecom Standards
  - W3C - World Wide Web Consortium



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## Internet Engineering Task Force

- Primary standardization body of Internet protocols
  - Layers 3 to 5
- Work structure
  - Working groups in thematic areas
  - Mailing lists and periodic meetings
  - Open to anyone
  - Requirement specification to standards
- Standards called Request for Comments (RFC)
  - ~7000 RFCs defining Internet protocols (some obsolete)

Read: <https://www.ietf.org/about/>

Introduction

## Internet Design Goals

- Primary
  - “effective technique for multiplexed utilization of existing interconnected networks”
- Secondary
  - “Internet communication must continue despite loss of networks or gateways.”
  - “The Internet must support multiple types of communications service.”
  - ...

D. Clark, “The Design Philosophy of the DARPA Internet Protocols,” in *Proc. of SIGCOMM, 1988*

Introduction

## Goal 1: Inter-networking

"effective technique for multiplexed utilization of existing interconnected networks"

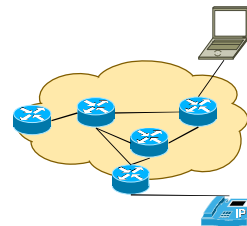
- Interconnection - existing networks
  - ARPANET and ARPA packet radio program, others to come
  - Enable providing larger service
  - Networks administered independently
  - Serves as a glue between networks – interoperability
- Multiplexing – based on packet switching
  - ARPANET and ARPA used packet switching
  - Primary application remote login
- Effective – "store and forward"
  - Gateways (routers) deliver packets between networks

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## Goal 2: Survivability

"Internet communication must continue despite loss of networks or gateways."

- Communication should continue in case of a network failure once the network is restored
  - State should not be lost
- **Fate sharing**
  - State in end hosts (not in the network)
- Consequence
  - Internet gateways (routers) stateless – in principle
  - Hosts more complex, can fail/misbehave



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## Goal 3: Versatility

"The Internet must support multiple types of communications service."

- **End-to-end Argument**

- "functions placed at low levels of a system may be redundant or of little value when compared with the cost of providing them at that low level"

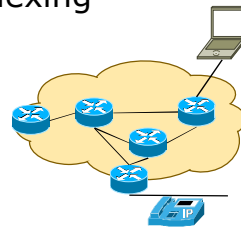
Saltzer, Reed, Clark, "End-to-end Arguments in System Design" ACM Transactions on Computer Systems 2 (4), Nov, 1984, pp. 277-288.

- In the Internet: Functions should be simple and general
  - Low complexity
  - Increases the chances of new applications
- In end-hosts: Application-specific functions
  - Can be optimized for application requirements

Introduction

## Summary

- Internet – Network of networks
- Edge/Access/Core
- Hierarchical structure – 3 Tiers
  - Transit/peering, exchange points
- Protocols, standards, organizations
- Layering, encapsulation, multiplexing
- Design goals of the Internet



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