IP Networking
Introduction

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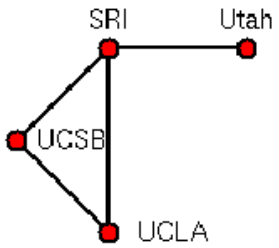
Evolution of the Internet - Origin: Arpanet

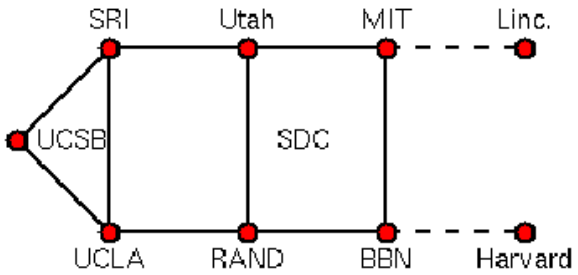
- 1960: first studies on packet switching technology
- December 1969: start of the Arpanet in the USA
  - initiative and funding by (D)ARPA (= (Defense) Advance Research Projects Agency; responsible for funding of research projects of the US military and academic institutions)
  - goal: survivable, fully decentralized, self-organizing network of peer nodes
  - initially only 4 nodes (IMPs = Interface Message Processor): UCLA, UCSB, SRI and Utah
- Integration of wireless links (based on ALOHA) and satellite links
- 1973: first international links
- 1979: now 100 nodes

Evolution of the Internet - Development of the Arpanet

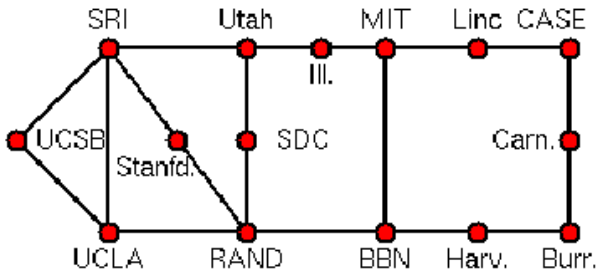
Dec. 1969: 4 IMPs



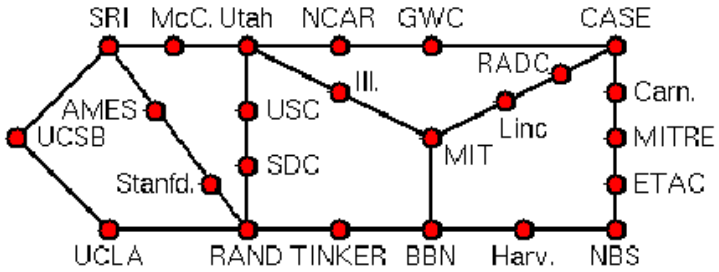
July 1970: 10 IMPs



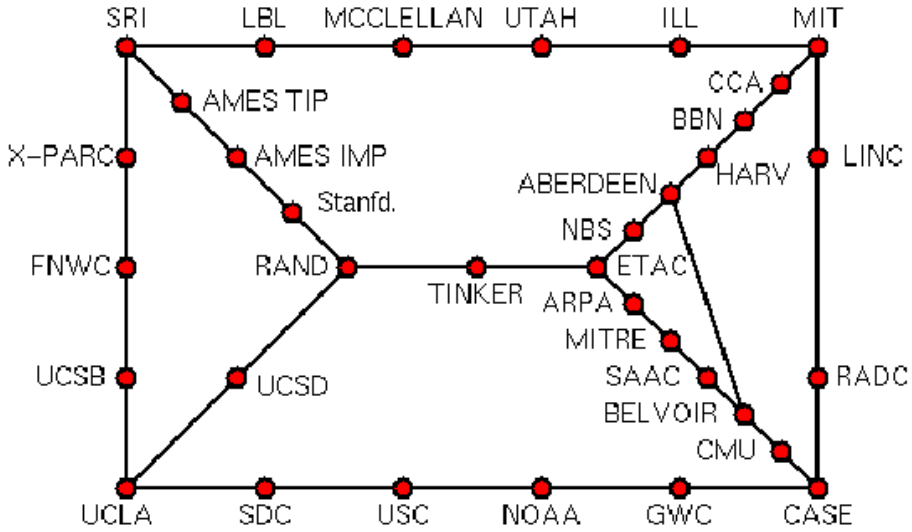
March 1971: 15 IMPs



Apr. 1972: 24 IMPs



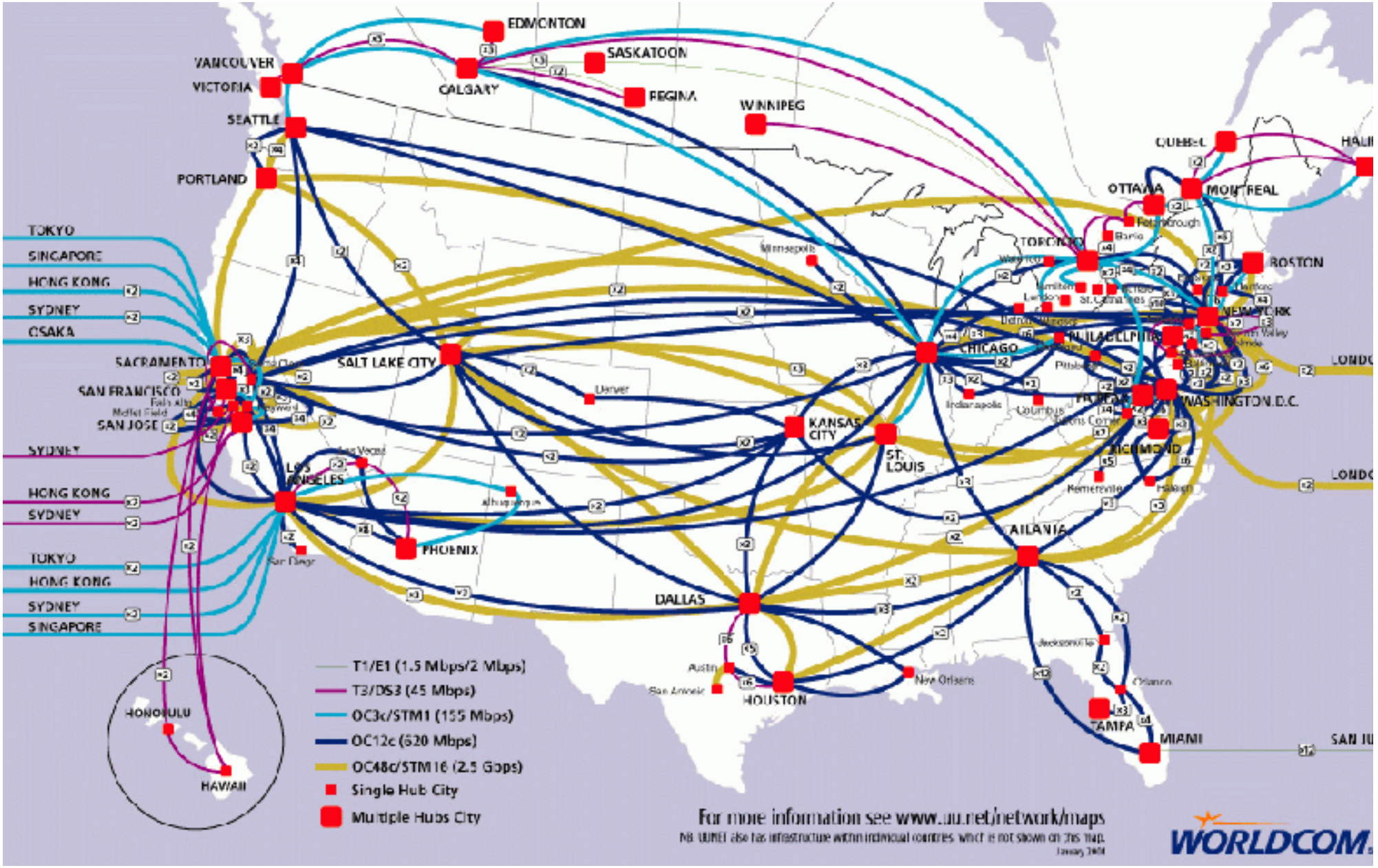
Sep. 1972: 34 IMPs



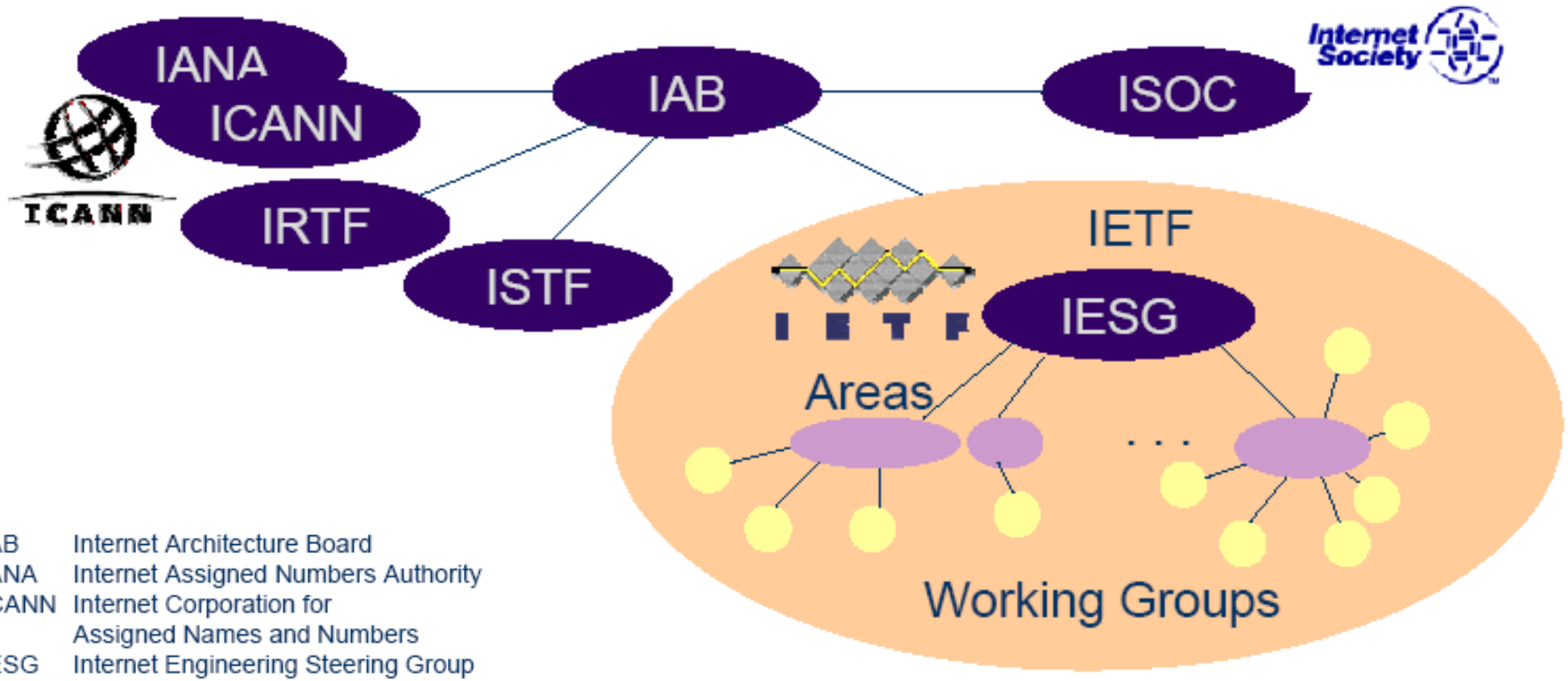
Evolution of the Internet - Further Development

- 1980-1983: development of the TCP and IP protocols
  - application: data communication between Unix hosts
- 1984: introduction of the Domain Name System (DNS)
- 1986: Arpanet is split into MILnet and NSFnet (NSF = National Science Foundation)
- 1989: now 100000 network nodes
- 1989: first Web proposal (from Tim Berners-Lee, Robert Cailliau)
- 1991: gopher (first information service)
- 1992: MBONE (Multicast Backbone for audio/video distribution)
- 1993: NCSA Mosaic Browser (first major web browser)
- 1994: the Internet becomes knowns to the general public; multiple Internet Service Providers (ISPs)
- 1995: the NSFnet backbone is handed over to commercial operators
- since 1995: research on Next Generation Internet (e.g. setup of research networks like Internet2, Canarie (1993) etc.)

Evolution of the Internet - Example: Backbone of a big ISP



Standardization - Overview of the relevant Boards



IAB	Internet Architecture Board
IANA	Internet Assigned Numbers Authority
ICANN	Internet Corporation for Assigned Names and Numbers
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
IRTF	Internet Research Task Force
ISOC	Internet Society
ISTF	Internet Societal Task Force

Standardization - Responsibilities of the Boards

- Internet Society, ISOC
  - responsible for Internet strategies, head of IAB and IESG
- Internet Architecture Board, IAB
  - responsible for the architecture, planning and strategic guidelines for the development and the management of the Internet
  - consists of 20 elected experts and scientists from academia and industry
- Internet Engineering Task Force, IETF (central committee)
  - responsible for the technology and protocol development
- Internet Engineering Steering Group, IESG
  - responsible for technical management of the IETF activities and the Internet standardization process
- Internet Corporation for Assigned Names and Numbers, ICANN
  - responsible for all centrally managed parameters of the Internet (assigns domain names and addresses, coordinates protocol parameters and port numbers, coordinates the stable operation of the root server system)
- Internet Network Information Center, InterNic
  - responsible for the management of the Internet domain name data base and the corresponding registration process

Standardization - IRTF Research Groups

- Active IRTF Research Groups
  - Anti-Spam
  - Authentication Authorization Accounting (AAA) Architecture
  - Crypto Forum
  - Delay-tolerant Networking
  - End-to-End
  - Group Security
  - Internet Measurements
  - IP Mobility Optimizations
  - Network Management
  - Peer-to-Peer
  - Routing
  - Services Management

Standardization - IETF Areas and Working Groups

- Applications Area (22)
  - e.g. EDI, FTP, Fax, LDAP, Web
- General Area (5)
- Internet Area (21)
  - e.g. DNS, DHCP, IPnG, IP over x, Mobility
- Operations and Management Area (24)
  - e.g. AAA, SNMP, several MIBs, Policy, MBONE
- Routing Area (14)
- Security Area (21)
- Sub-IP Area (1)
  - IP over x (x = optical, MPLS, VPN) Traffic Engineering
- Transport Area (27)
  - DiffServ, Telephony, SIP, Media Gateways, NAT, SigTran

Standardization - Principles of the IETF Working Groups

- Basic principles
  - limited to narrow, focused topic (instead of big, overlapping topic areas)
  - preference of a limited, moderate amount of options
- Charter
  - foundation of groups with focused topic
  - publishes goals and milestones
  - creates a mailing list and designates the corresponding group leader
- "Rough Consensus (and running Code)"
  - no formal election
  - disputes solved by discussion and demo implementations
  - discussions via mailing list and at scheduled meetings
- Decisions via E-Mail
  - usually no final decisions during meetings

Standardization - IETF Internet Documents

- Internet drafts
  - documents in progress
  - status-free if not archived, removed after 6 months
  - announced and published by the IETF secretary
- RFCs (Request for Comment), since1969
  - archived document series of the IAB
  - announced, edited and published by the RFC editor
  - different categories (not all RFCs belong to the "Standards Track"!)
- RFC categories
  - Standards Track
    - Proposed Standard
    - Draft Standard
    - Standard
  - Informational
  - Experimental
  - Historic

- Proposed Standard
  - full specification
  - proven functionality
  - exists for minimum 6 months, maximum 2 years
- Draft Standard
  - multiple, independent, interoperable implementations
  - limited field experience
  - exists minimum 4 months, maximum 2 years
- Standard
  - proven stability in the field
  - may exist infinitely or may be deprecated ("Historic“)

Standardization - Guidelines for IETF Standards

- Openness
  - vendor-independent
  - patents are not desired, see also RFC2026
- Open access
  - via Internet (see: http://www.ietf.org/rfc.html)
  - no fees (contrary to ITU, ISO, ANSI, IEEE)
- Multi-platform format
  - only ASCII Text
- Readability and clearness
  - beneficial if there is a working implementation available ("running code") at the time of the standard development
- Clearly defined requirement levels:

– MUST/REQUIRED	absolutely required
– MUST NOT / SHALL NOT	permitted
– SHOULD / RECOMMENDED	required for full implementation
– SHOULD NOT / NOT RECOMMENDED	only if necessary
– MAY / OPTIONAL	optional

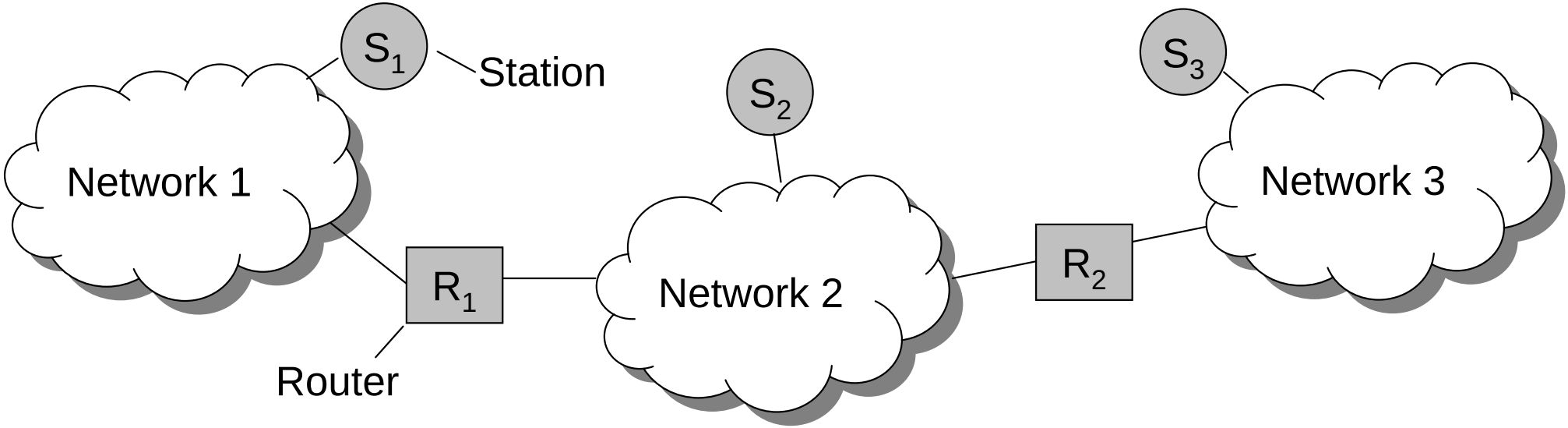
Standardization - Useful Links

- IETF home page http://www.ietf.org/
- RFCs http://www.ietf.org/rfc.html
- Novices' guide http://www.ietf.org/tao.html
- IESG home page http://www.ietf.org/IESG.html
- Working groups http://www.ietf.org/html.charters/wg-dir.html
- Monthly status reports of the IETF http://www.ietf.org/IMR/
- Further information http://www.ietf.org/intro.html

Internetworking - Motivation

- Why is the layer 3 (network layer = routing layer) or the IP protocol necessary for the Internet?
- Characteristics of a pure layer 2 network (e.g. bridged/switched Ethernet LAN):
  - each station has a unique address (e.g. Ethernet MAC address)
  - each bridge knows the addresses of all stations
  - all stations are reachable via broadcast
- Main problem of pure layer 2 networks:
  - bad scalability for big networks
- Requirement: hierarchy (layer 2 / layer 3) to reduce the overhead of routing in big networks
  - route calculation
  - storage of addresses (in the node's routing tables)
- Solution: separation of bigger networks into multiple layer 2 networks (bridged/switched) that are interconnected by routers (layer 3 coupling)

Internetworking - Basic Scenario

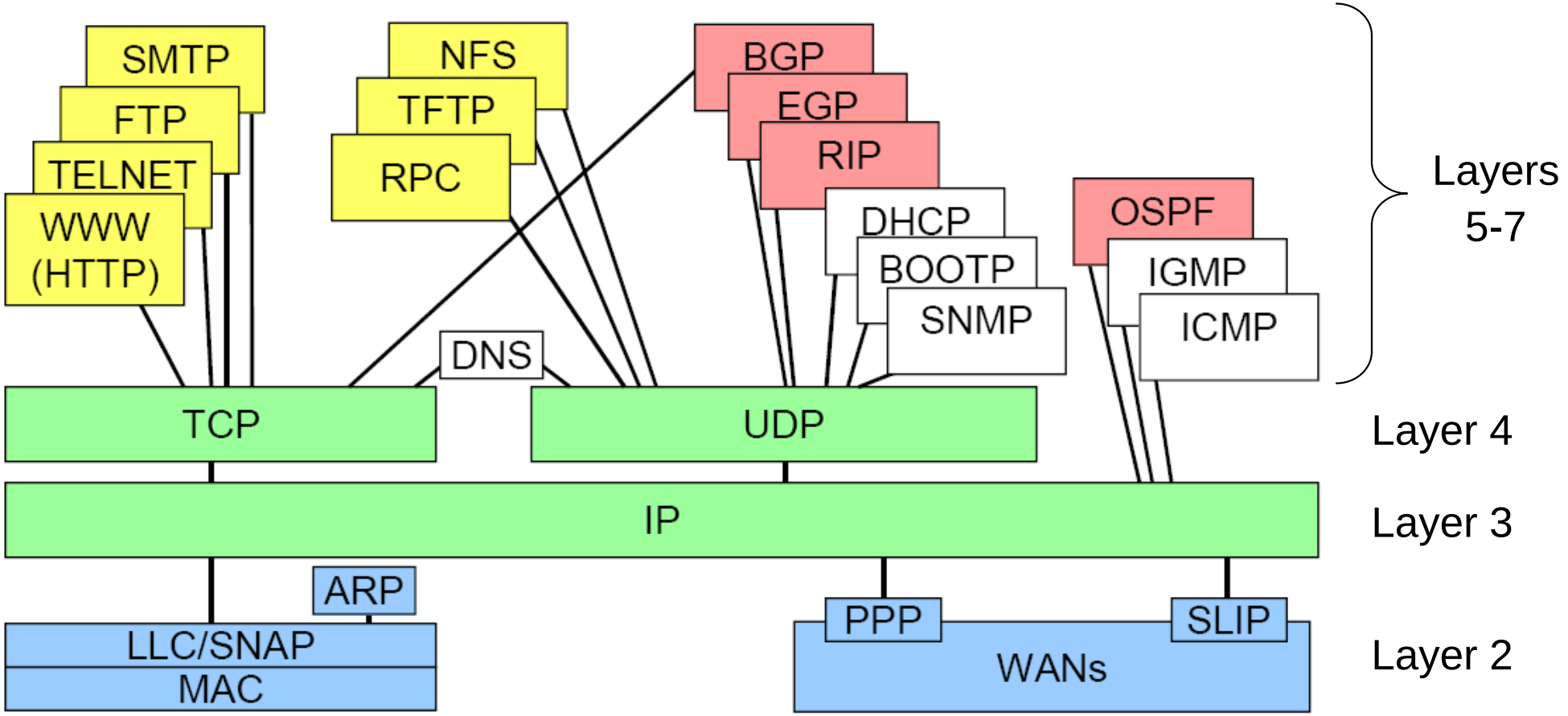


- Stations (End Systems)
  - have a layer 3 address (per network interface)
  - have knowledge of a router (in their network) for forwarding packets to other networks
  - communicate within their network via their layer 2 addresses (e.g. Ethernet MAC addresses)
- Routers (Intermediate Systems)
  - forward packets using the layer 3 destination address: determine the “next hop” from their routing table

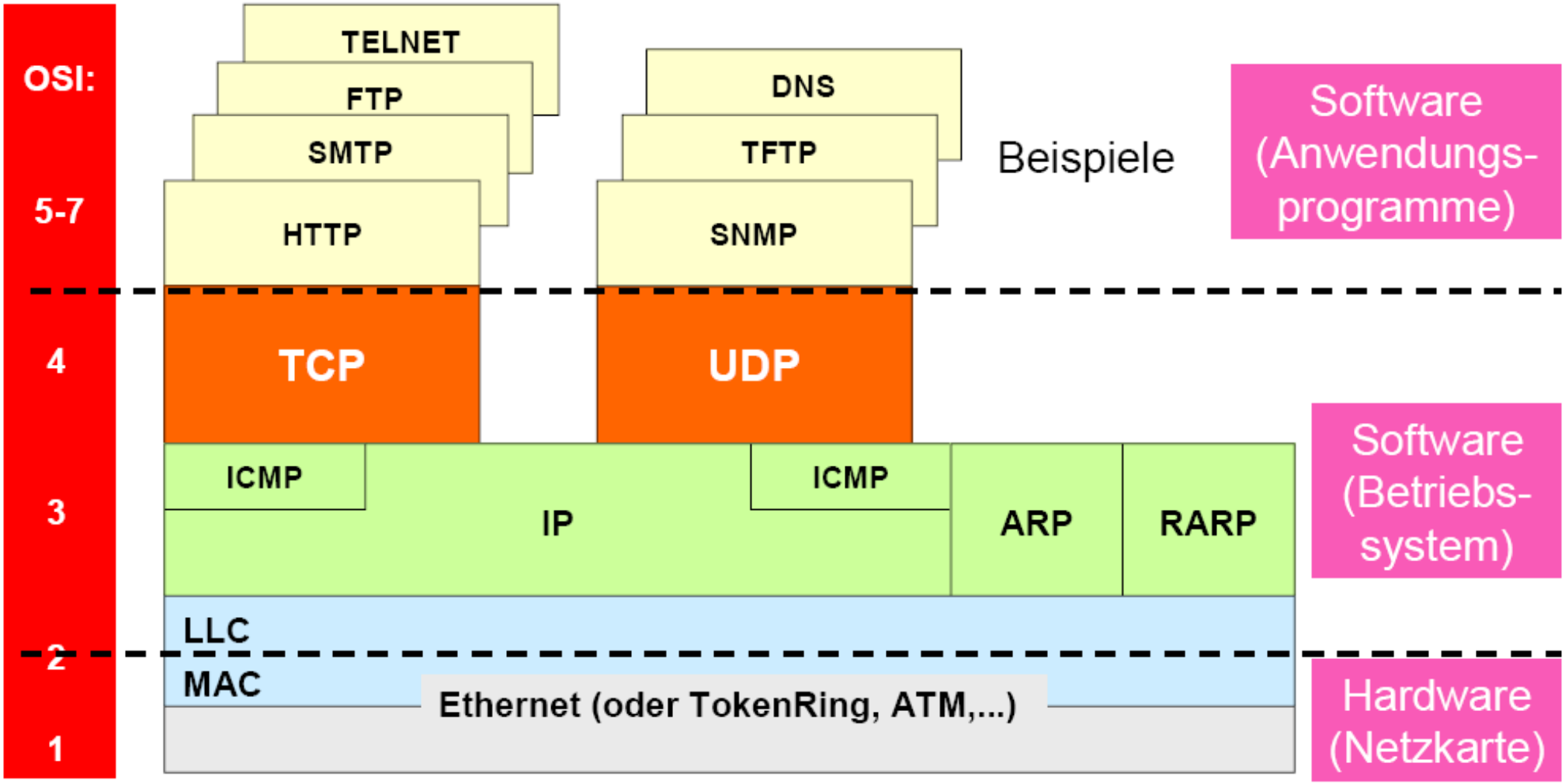
Internetworking - Characteristics

- Connection-less packet switching
  - every packet is forwarded individually
- No guaranteed Quality of Service ("best effort")
  - packet losses are possible
  - packet order is not guaranteed
- Packets with variable length
  - optimized for data traffic
  - possible packet fragmentation to adapt the packet length to different maximum frame lengths of the respective layer 2 network
- Routing
  - the forwarding in the nodes is performed per hop (Hop-by-Hop Routing); no knowledge of the whole route necessary
  - the routers only use the destination information for the routing decision; the originator does not influence the route
  - routing target is the destination network address (not the host address)

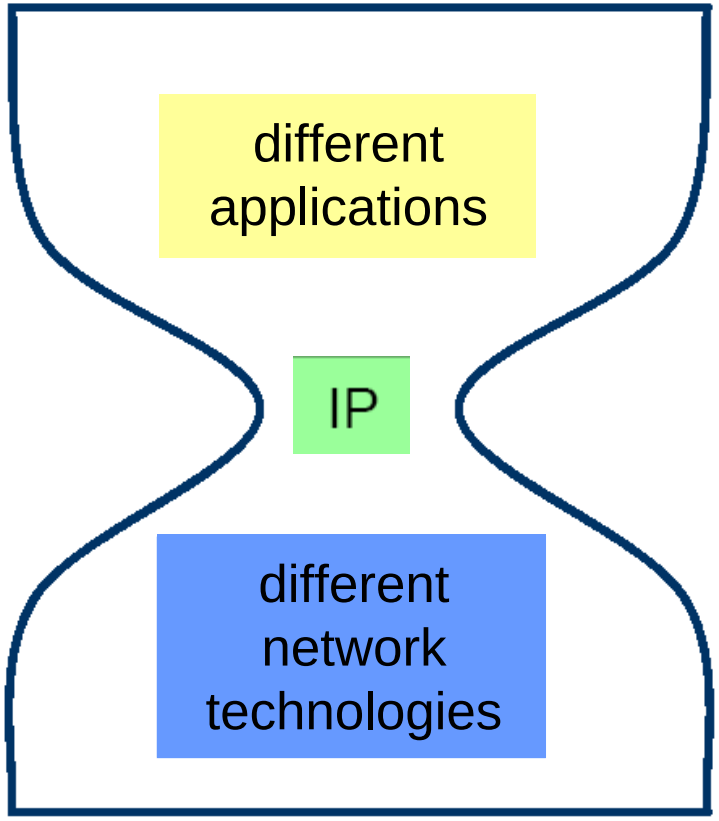
Internetworking - Internet Protocols (TCP/IP Protocol Suite)



Internetworking - Typical Protocol Implementation



Internetworking - “Hourglass Model"



all applications run over IP

IP runs on all networks