Computer Networks I

Network Layer: Internet Protocols

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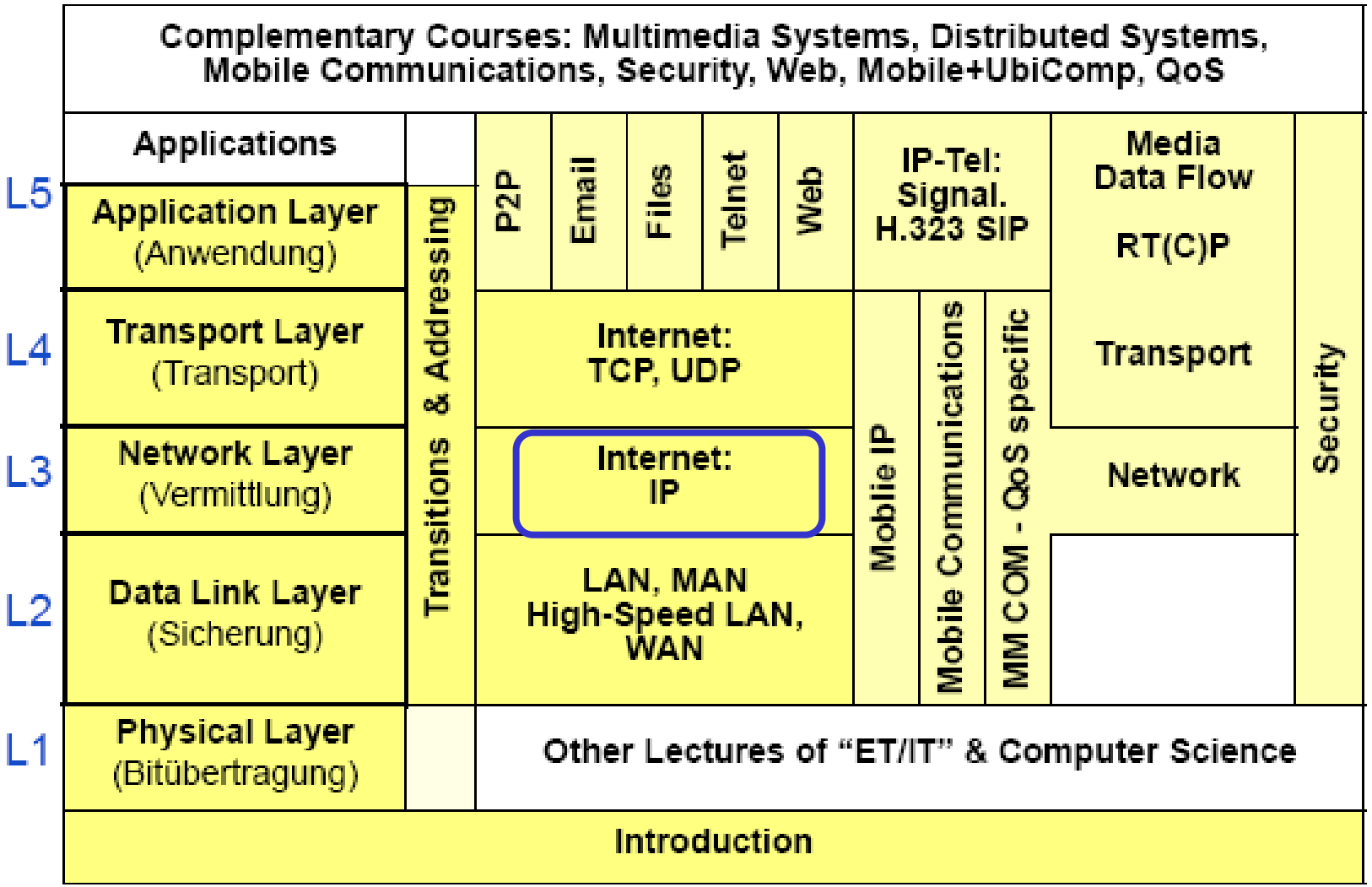
Scope


Complementary Courses: Multimedia Systems, Distributed Systems, Mobile Communications, Security, Web, Mobile+UbiComp, QoS
Applications
L5
Application Layer (Anwendung)
L4
Transport Layer (Transport)
L3
Network Layer (Vermittlung)
L2
Data Link Layer (Sicherung)
L1
Physical Layer (Bitübertragung)
Transitions & Addressing
P2P
Email
Files
Telnet
Web
IP-Tel: Signal. H.323 SIP
Media Data Flow
RT(C)P
Transport
Internet: TCP, UDP
Internet: IP
Network
LAN, MAN High-Speed LAN, WAN
Moblie IP
Mobile Communications
MM COM - QoS specific
Security
Other Lectures of "ET/IT" & Computer Science
Introduction

Overview

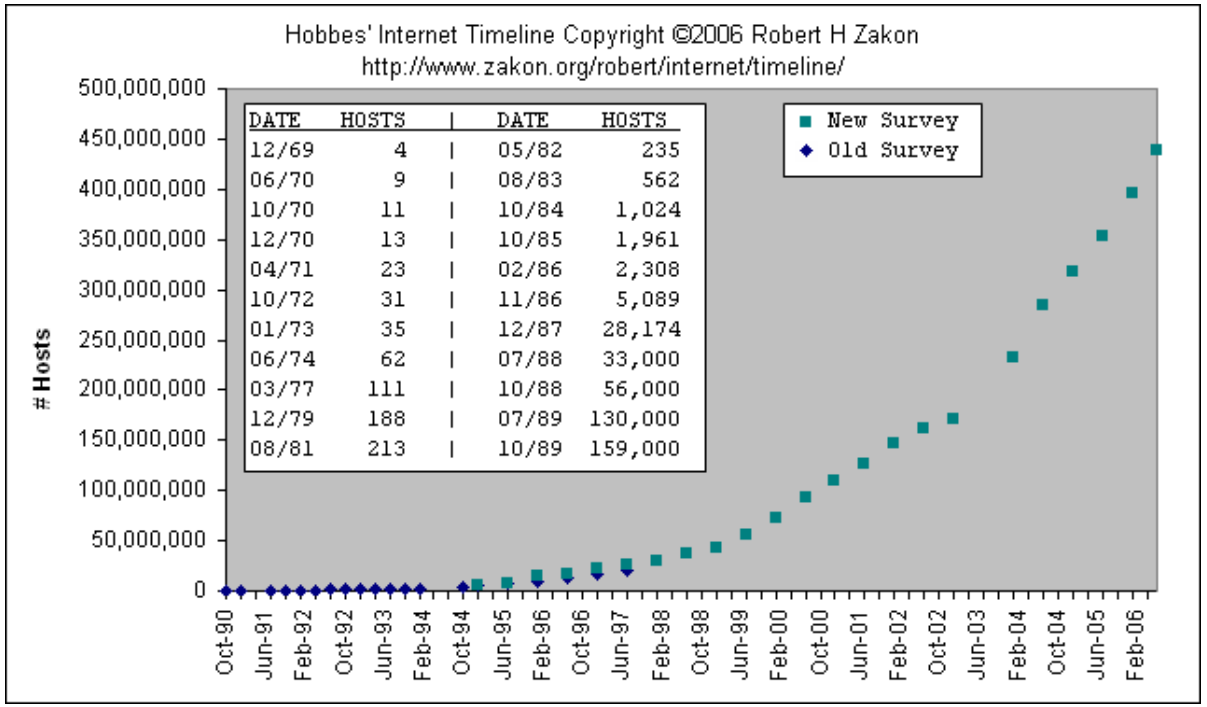
Overview

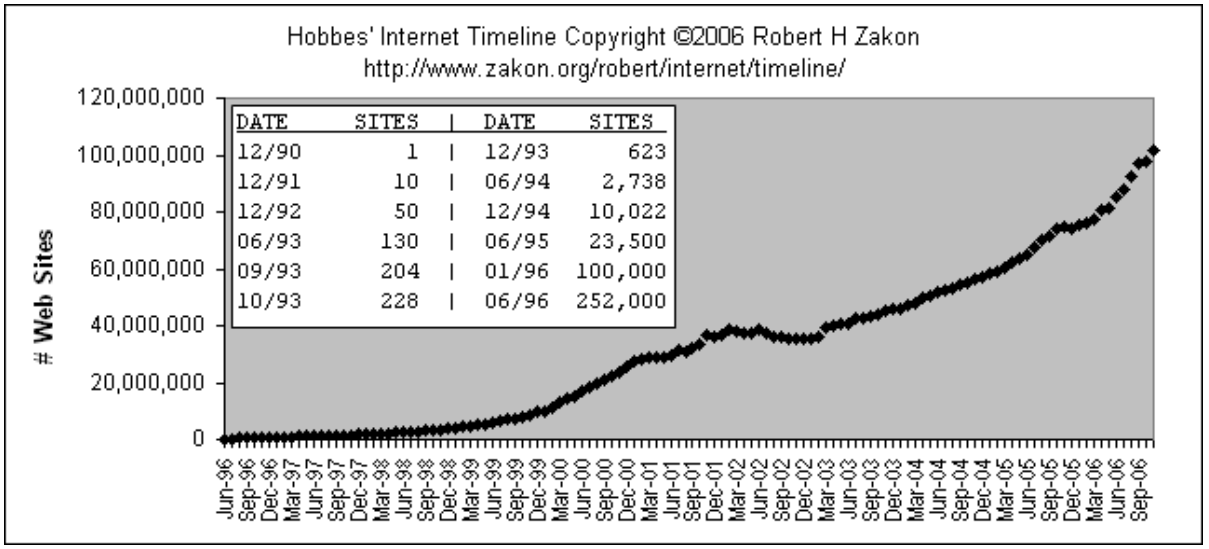
1 History and Architecture

ARPANET

- initiated and financed by ARPA
  - Advanced Research Projects Agency of the U.S. Department of Defense (DoD)
- objective:
  - originally: network to survive nuclear war
  - later: network to connect scientific and military institutions
- 1969:
  - experimental network with 4 nodes,
    followed by rapid growth, BBN first contractor
- development of the INTERNET
  - standardized protocols for comm. between networks: TCP/IP (1983)
  - linking military networks (MILNET, MINET)
  - linking satellite networks (SATNET, WIDEBAND)
  - linking the LANs of the universities
- fast spreading of TCP/IP technology as a part of UNIX
  → ARPANET growing rapidly
  - 1987: 15% per month
  - 1987: 20.000 computers, more than 100.000 users
- 1990: ARPANET replaced, MILNET still exists
  - services: E-mail, file transfer, remote login, later WWW. . .

Some Data about Internet Growth





The Internet and its Tasks

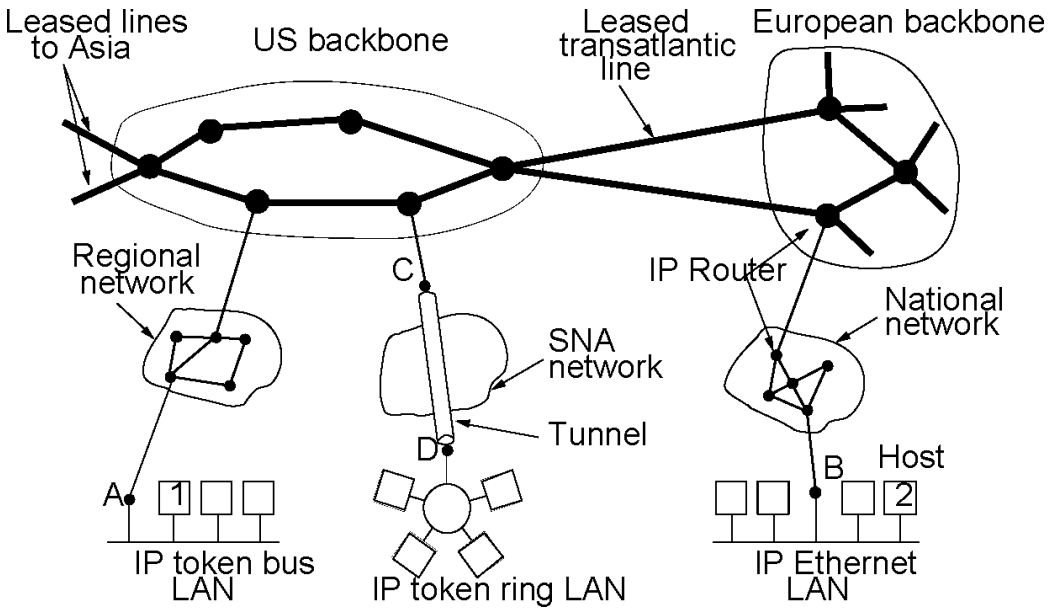
Internet (Internet Society)

- mid-80s
  - a multiple of networks was designated as the "Internet"
- Jan. 1992:
  - founding of the (actual) Internet Society
  - objective: to spread the use of the Internet (protocols and services)
- IAB: Internet Architecture Board
  - founded in 1983 to involve researchers in the ARPANET
  - today it is the supreme Internet board
- IAB oversees/nominates
  - IETF (INTERNET ENGINEERING TASKFORCE)
    - divided into approx. 70 working groups (e. g. RSVP, ST-II)
    - actual governing board
  - IRTF (Internet Research Taskforce)
- RFC (REQUEST FOR COMMENTS)
  - recommendations, e.g. June 2007 approx. 5000

Tasks in the INTERNET

- to connect different networks over gateways
- definition of
  - protocols that work on all subnetworks
  - standardized addressing pattern for a very large network
  - global routing architecture

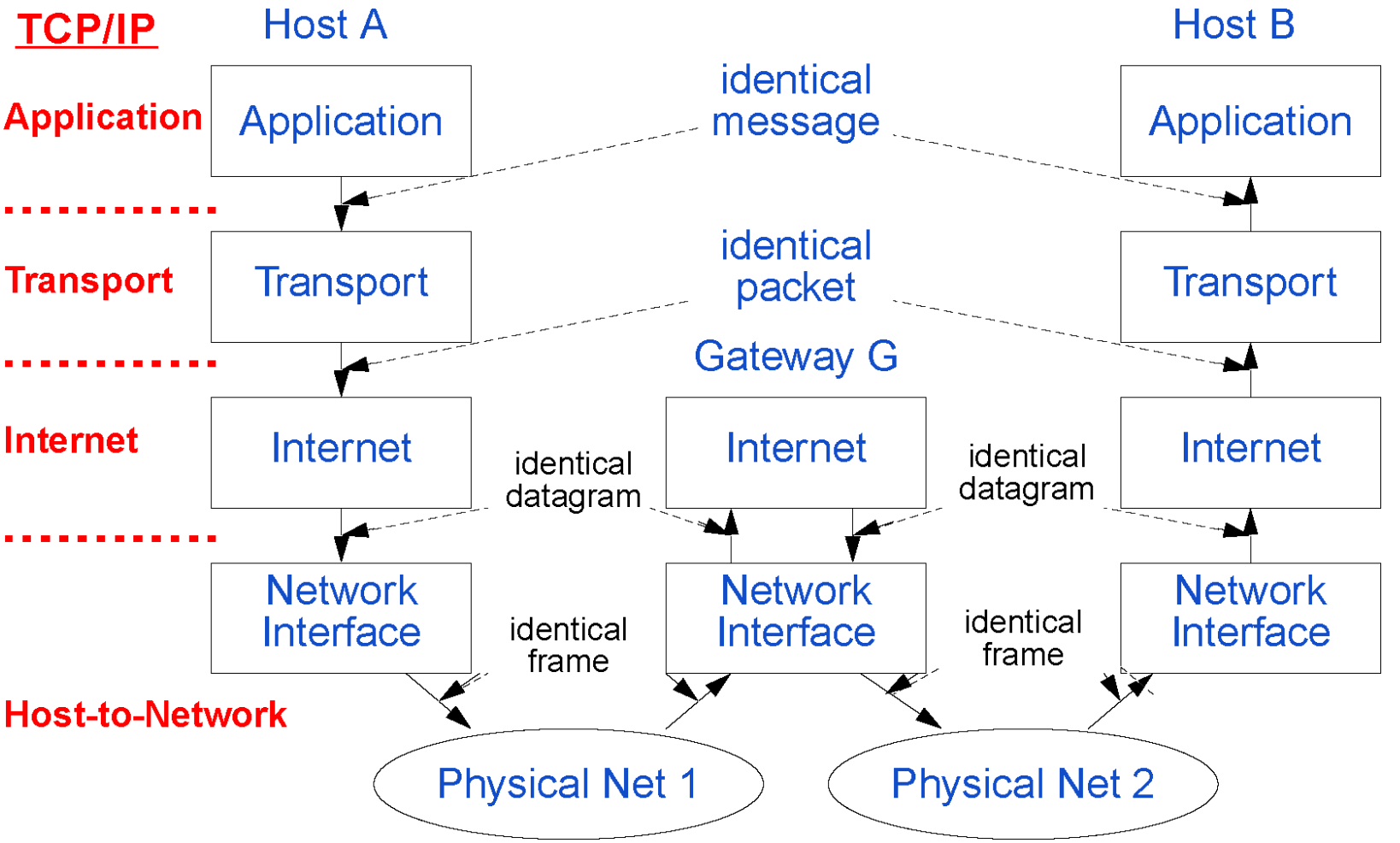
Subnets in the INTERNET



e.g.

- Ethernet LANs
  - mainly large campus networks
- other LANs
  - mainly smaller/experimental networks
- Arpanet
  - network with specific protocols, partially connected over leased lines
- NSF Net (National Science Foundation Network)
  - backbone consisting of leased high-speed lines
  - connecting the NSF supercomputers with each other and to regional networks and campus networks
  - later 1995 AOL, now a multitude of backbones in USA
- CSNET (X.25 NET)
  - public packet relay network by X.25

Internet Architecture



i.e.

- ISO-OSI presentation and session layer not explicitly available
- data link layer and physical layer combined

Internet Architecture

No formal architecture

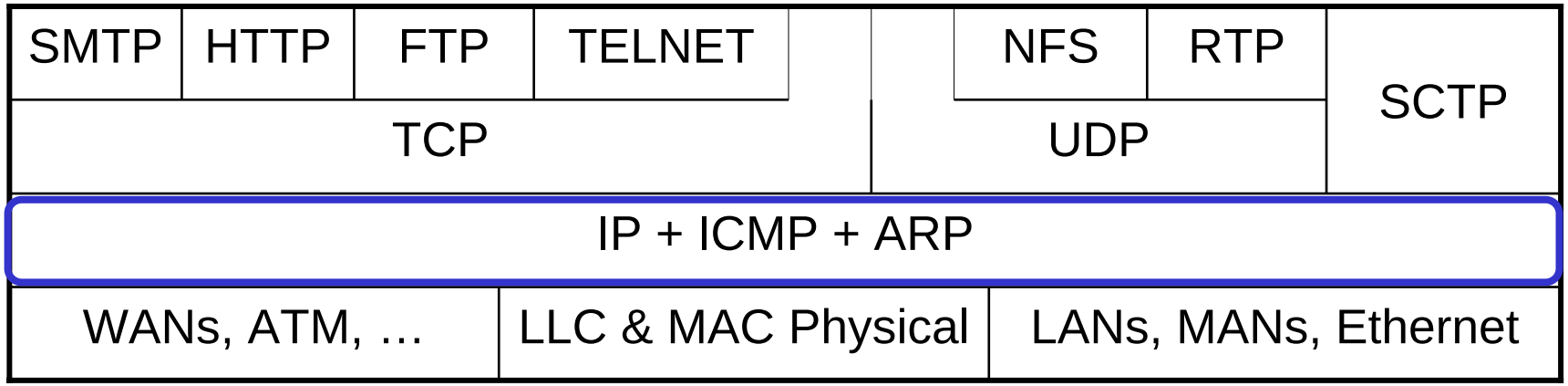
No unchangeable principles:

The principle of constant change is perhaps the only principle of the Internet that should survive indefinitely. [RFC 1958, Architectural Principles of the Internet, June 1996]

The Internet approach in very general terms (from RFC 1958):

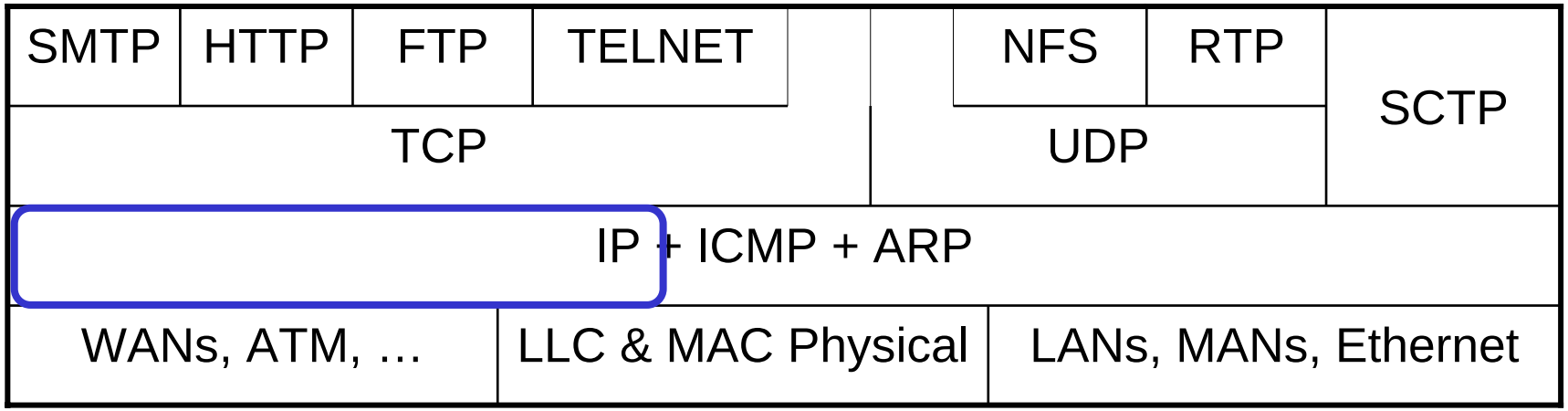
- the goal is connectivity
- the tool is the Internet Protocol
- the intelligence is end-to-end rather than hidden in the network

Well-Known Internet Protocols



ARP = ADDRESS RESOLUTION PROTOCOL
FTP = File Transfer Protocol
HTTP = Hypertext Transfer Protocol
IP = INTERNET PROTOCOL
ICMP = INTERNET CONTROL MESSAGE PROTOCOL
LLC = Logical Link Control
MAC = Media Access Control
NFS = Network File System
SMTP = Simple Mail Transfer Protocol
TELNET = Remote Login Protocol
TCP = Transmission Control Protocol
UDP = User Datagram Protocol
RTP = Real-Time Transport Protocol

2 Internet Protocol (IP)



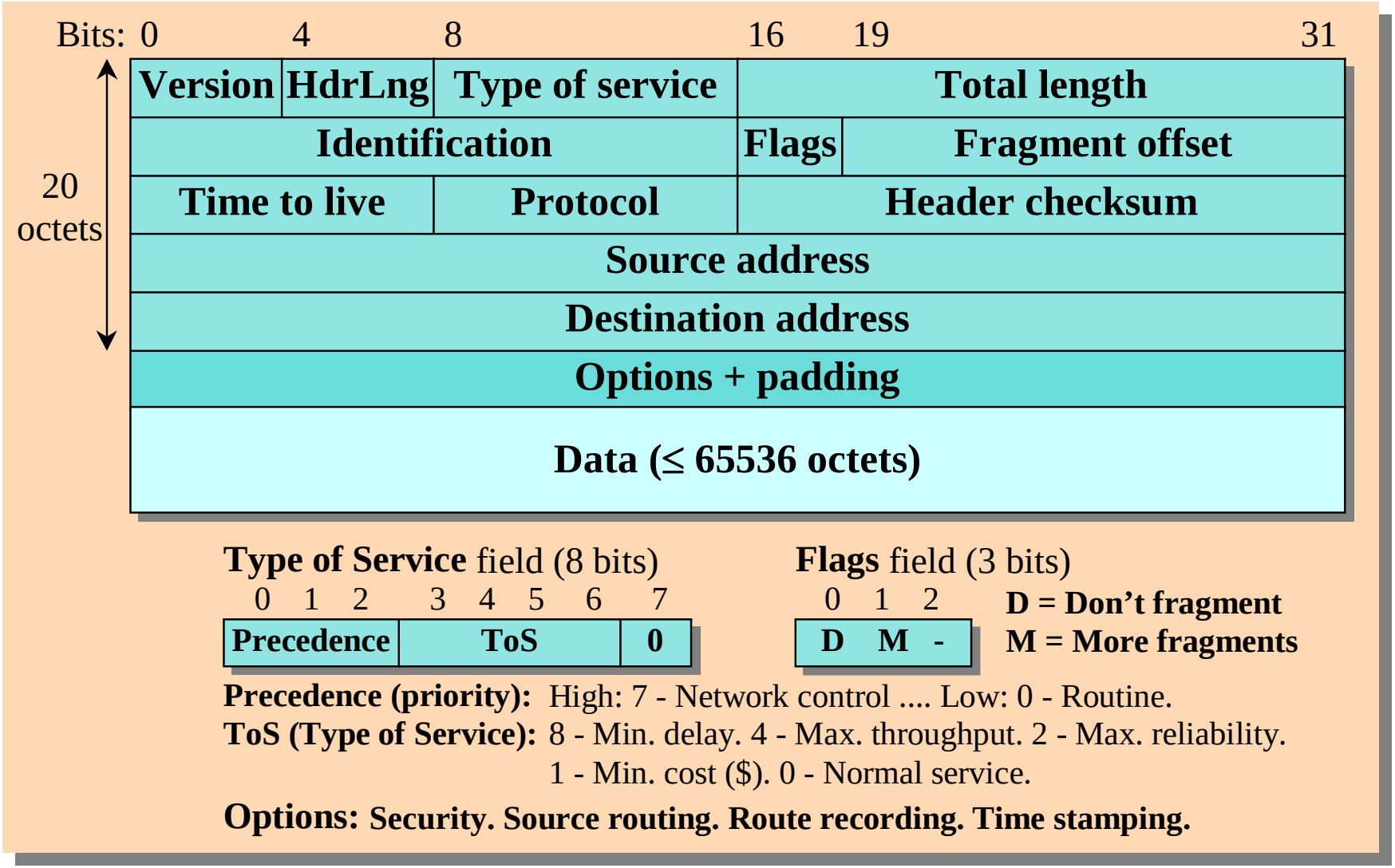
IINTERNET PROTOCOL IP basics

- defined for the first time in 1981
  - J. Postel
  - RFC 791, September 1981
- packet length
  - in theory: up to 64 kBytes
  - in real life: approx. 1500 Bytes

connectionless service (datagram)

- provide best-efforts (not guaranteed) way to transport datagrams
  - from source to destination
  - without regard whether
    - these machines are on the same network
    - there are other networks in between

IPv4 Datagram Format



Type of Service field (8 bits)

0	1	2	3	4	5	6	7
Precedence			**ToS**				**0**

Flags field (3 bits)

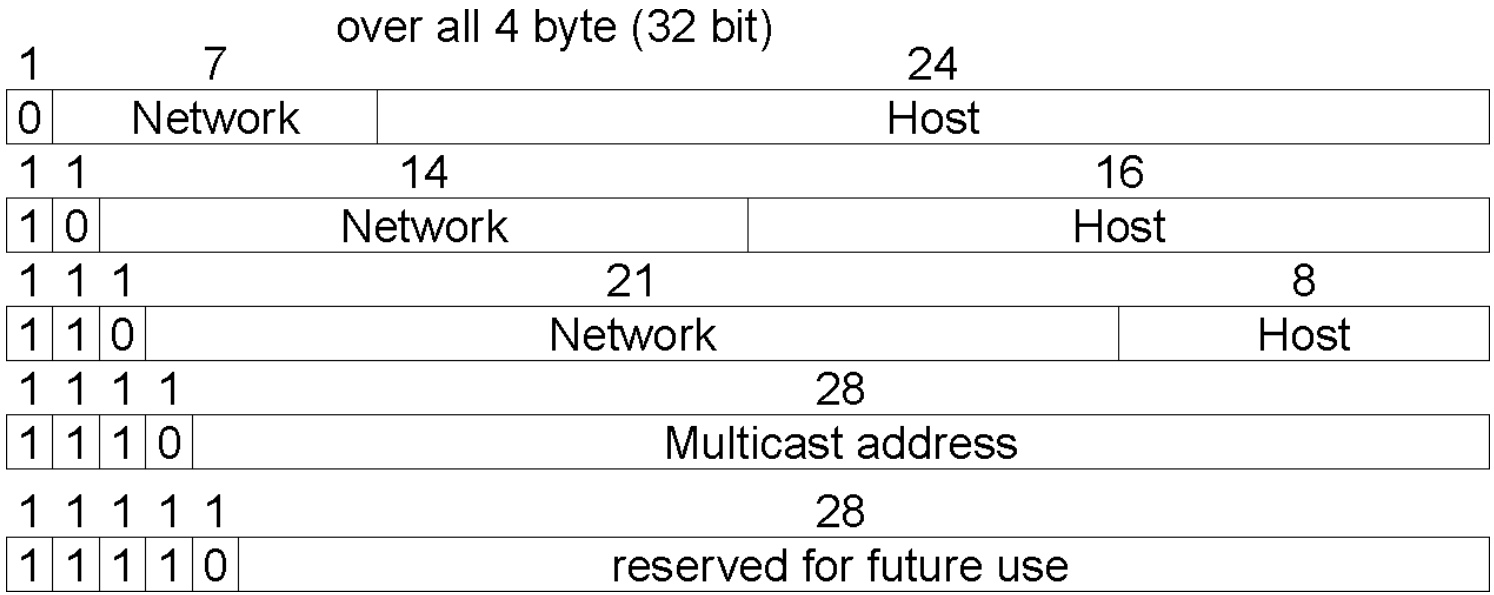
0	1	2
D	**M**	**-**

D = Don't fragment
M = More fragments

Precedence (priority): High: 7 - Network control .... Low: 0 - Routine.
ToS (Type of Service): 8 - Min. delay. 4 - Max. throughput. 2 - Max. reliability. 1 - Min. cost ($). 0 - Normal service.

Options: Security. Source routing. Route recording. Time stamping.

4 Internet Addresses and Internet Subnetworks



Global addressing concept for ES (and IS) in the Internet
- unique 32 bit address with net-ID (subnetwork-Id), ES-Id
- i.e., each network interface (not ES) has its own unique address
- 5 classes

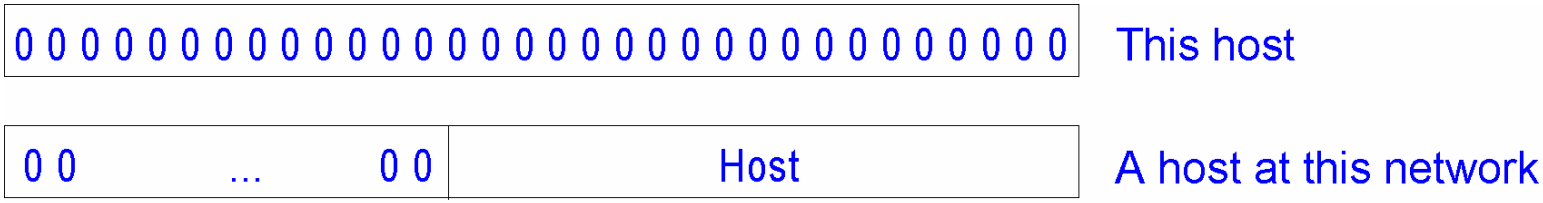
ICANN (Internet Corporation for Assigned Numbers and Names)
- manages network numbers
- delegates parts of the address space to regional authorities
  - NIC Network Information Center www.denic.de/

Network addresses typically written in dotted decimal notation
- e.g., 134.169.34.18 or at TUD e.g. 130.83.139.88
- lowest 0.0.0.0 (0 means this host or network)
- highest 255.255.255.255 (broadcast on local network)

4.1 Special Internet Addresses

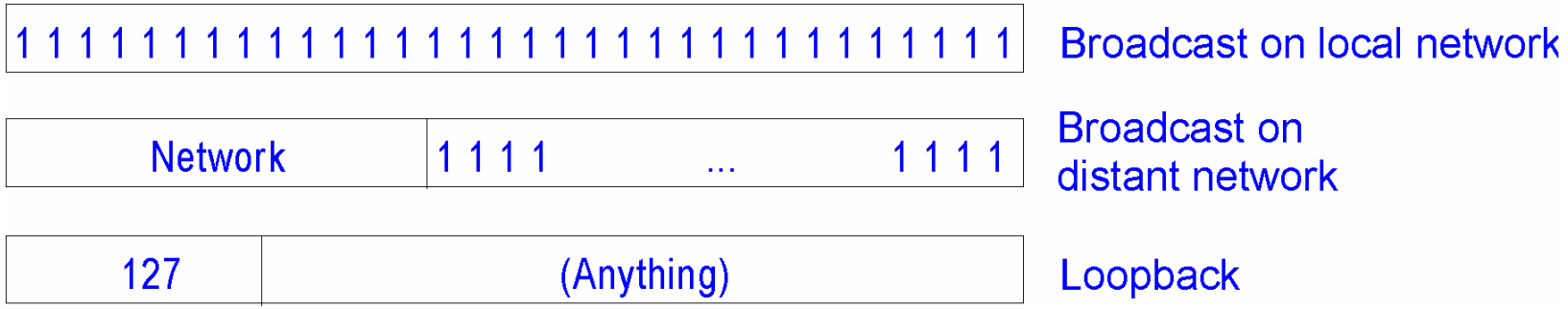
Special IP addresses:

- Source Addresses



Special IP addresses:

- Destination Addresses



4.2 Internet Subnetworks

Structured networks growth

- several networks instead of one preferable
- but getting several address areas is hard
  - since address space is limited
  - e.g.,
    - university may have started with class B address
    - but, doesn't get second one

Problem:

- class A, B, C refer to \
  - one network
  - not collection of LANs

Need

➔ to allow a network to be split into several parts

- for internal use
- still look like single network to outside world

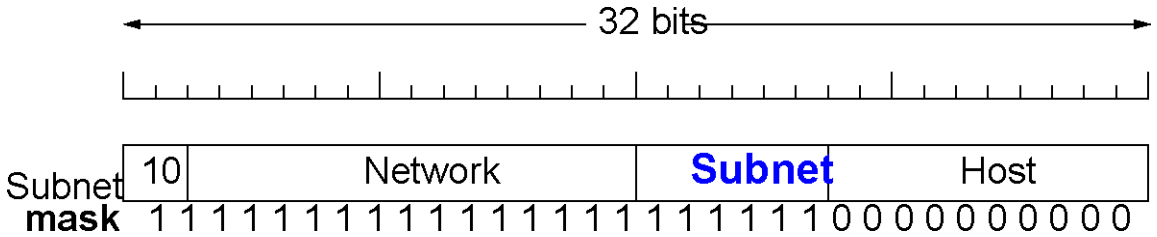
➔ to provide for subnetworks

Internet Subnetworks

Subnets: e.g., Ethernet-based LAN

Idea:

- local decision for subdividing host share into subnetwork portion and end system portion
- example: class B address: max. 63 subnetworks



Use subnet mask to indicate split between network + subnet and host part

routing with 3 levels of hierarchy

- algorithm in router (by masking bits: i.e. AND between address and subnet mask):
  - packet to another network (yes, then to this router)
  - packet to local ES (yes, then deliver packet)
  - packet to other subnetwork (yes, then reroute to appropriate router)

4.3 CIDR: Classless InterDomain Routing

Given constraints with classes

- IPs growth leads to lack of addresses
  - in principle many addresses due to 32-bit address space
  - but inefficient allocation due to class-based organization
    - class A network with 16 million addresses too big for most cases
    - class C network with 256 addresses is too small
    - most organizations are interested in class B network,
      - but there are only 16384
      - (in reality, class B too large for many organizations)
- large number of networks leads to large routing tables

➔ Introduction of CIDR (Classless InterDomain Routing) (RFC1519)

CIDR Principle

- allocate IP ADDRESSES in VARIABLE-SIZED blocks
  - without regard to classes
- e.g., request for 2000 addresses would lead to
  - assignment of 2048 address block starting on 2048 byte boundary

but, dropping classes makes forwarding more complicated

CIDR: Classless InterDomain Routing

CIDR basics

- replacement for the old process of assigning Class A, B and C addresses
- with a generalized network "prefix"
  - Instead of being limited to network identifiers (or "prefixes") of 8, 16 or 24 bits
- uses prefixes anywhere from 13 to 27 bits

➔ blocks of addresses can be assigned to networks

  - as small as 32 hosts
  - until over 500.000 hosts

CIDR address

- includes
  - the standard 32-bit IP address
  - information on how many bits are used for the network prefix
- e.g. CIDR address 194.24.8.0 / 22,
  - the "/22" indicates
    - first 22 bits used to identify unique network
    - remaining bits to identify specific host

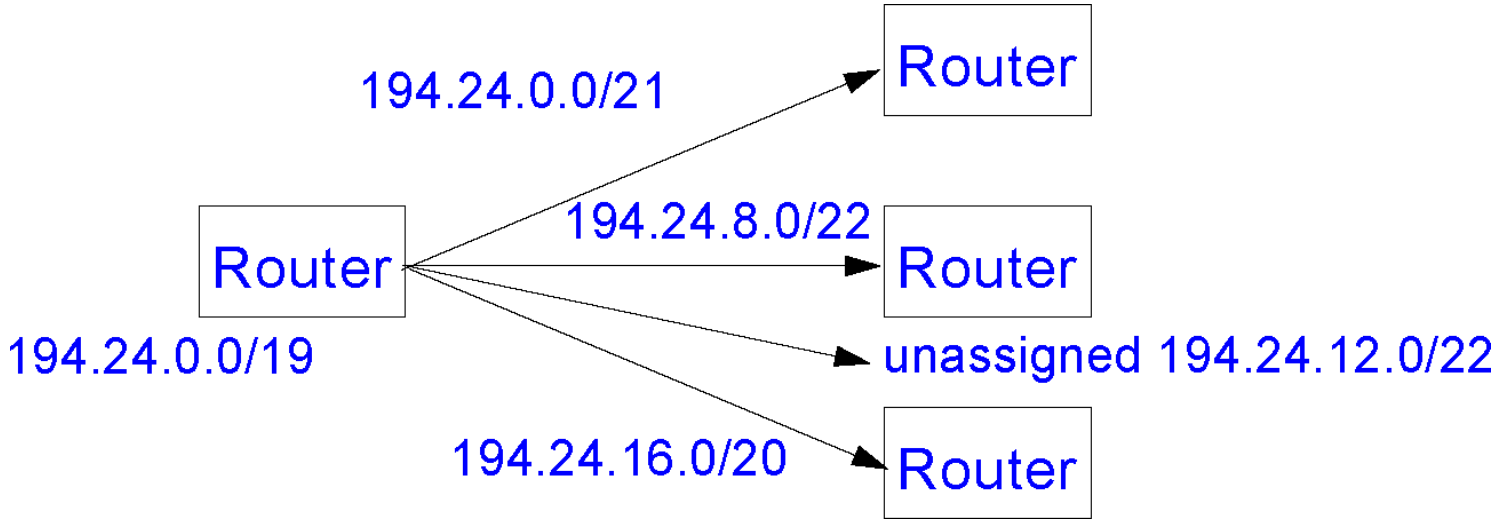
CIDR: Classless InterDomain Routing

Search for longest matching prefix

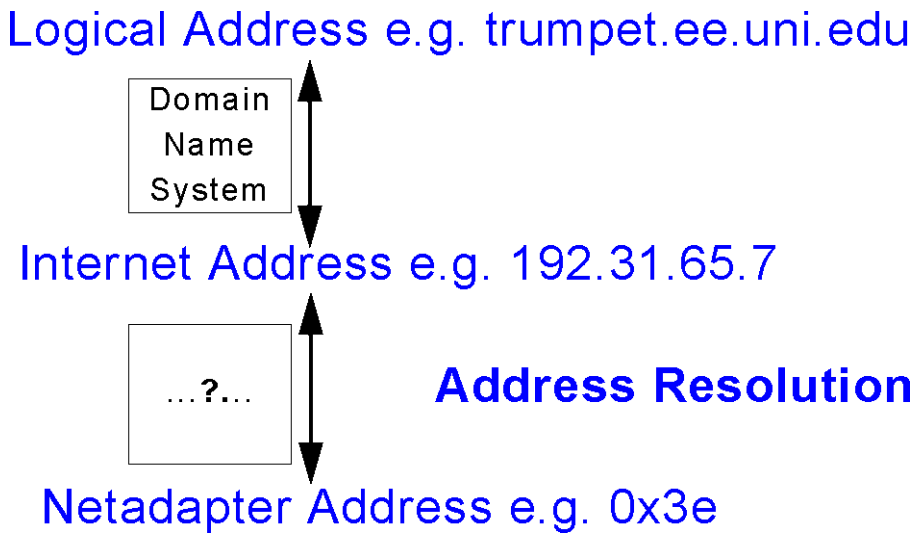
- if several entries with different subnet mask length may match
  - then use the one with the longest mask
- i.e., AND operation for address & mask
  - To be performed for each table entry

E.g., potentially several 'class C' networks can be characterized by one prefix

Entries may be aggregated to reduce routing tables



5 Address Resolution



Addressing levels

Host identification and routing specification within a subnetwork

- based on the (local) physical network addresses of ES
  - e.g. station address of the adapter card

Problem:

- INTERNET address (32 bit)
  must be mapped onto the physical network address,
  - usually 48 bit (ADDRESS RESOLUTION)

Address Resolution: Methods

Address resolution in

- source ES, if destination ES is local (direct routing)
- Gateway, if destination ES is not local

Solutions:

1. Direct HOMOGENEOUS ADDRESSING
   - if the physical address can be dialed by the user, then the dial-up is:
     - physical address = Hostid of the INTERNET address

2. If
   the physical address is pre-defined or if
   it has to have a different format, use one of the following>
   - a mapping table from configuration data base (IPaddr → HWaddr),
     - e.g. in the Gateway,
     - may become maintenance nightmare
   - the Address Resolution Protocol (ARP)
     - mainly applied in LANs with broadcasting facility

8 IP Version 6 (IPv6)

Motivation: Main issues

- addressing (presently 32 bit) and
- many other shortcomings in IP (QoS, mobility, ..)

Status

- started early 1990s, today integrated in OS like Windows and Linux, but still not as much used as expected

Characteristics

- extended addresses (128-bit) and new addressing schemes
- new flexible and efficient packet formats
- autoconfiguration („plug-and-play“)
- some ‚IPv4 add-ons‘ integrated (address resolution, group mgmt)
- security and mobility mechanisms integrated
- QoS support