Introduction to TCP/IP

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- Introduction
  - Internetworking, Internet
  - TCP/IP
- General Description of TCP/IP
  - TCP/IP protocol architecture
  - Network Access Layer
  - Internet Layer
  - Transport Layer
  - Application Layer
- Where to get more Information

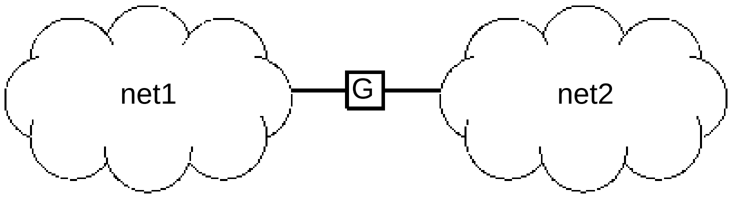
Internetworking, Internets

- No single network can serve all users.
- Users desire universal interconnection.

- The goal is to build a unified, cooperative interconnection of networks that supports a universal communication service.
- Such an interconnection scheme is called an *internetwork* or *internet*.
- 'How are two networks interconnected to form an internetwork?'
- The answer has two parts: Hardware and Software.
  - Hardware: *Router*
  - Software: *TCP/IP*

Router

- Physically, two networks can only be connected by a computer that attaches to both of them.
- This computer must be able to shuffle packets from one network to another.
- Computers that interconnect two networks and pass packets from one to the other are called *internet routers* or *internet gateways*.

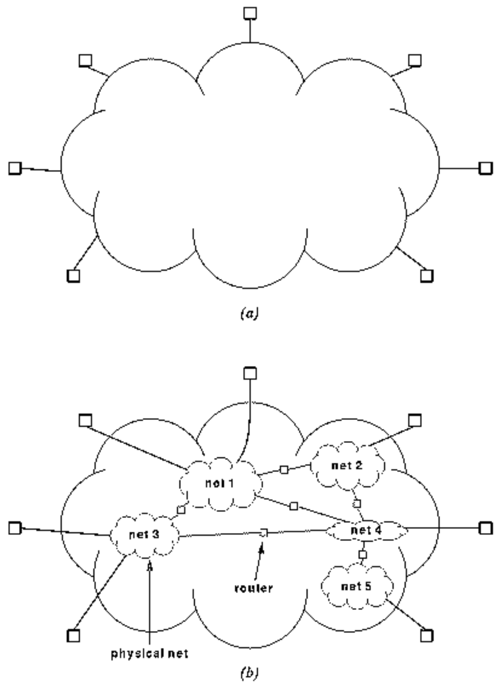


Two networks interconnected by a router
(Comer D.: Computernetzwerke und Internets)

- In a TCP/IP internet, computers called gateways provide all interconnections among physical networks.
- Gateways route packets based on destination network, not on destination host.

The User's View

'The TCP/IP internet protocols treat all networks equally. A local area network like an Ethernet, a wide area network like NSFNET backbone, or a point-to-point link between two machines each count as one network.'
(Comer D.: Internetworking with TCP/IP, Vol. I)

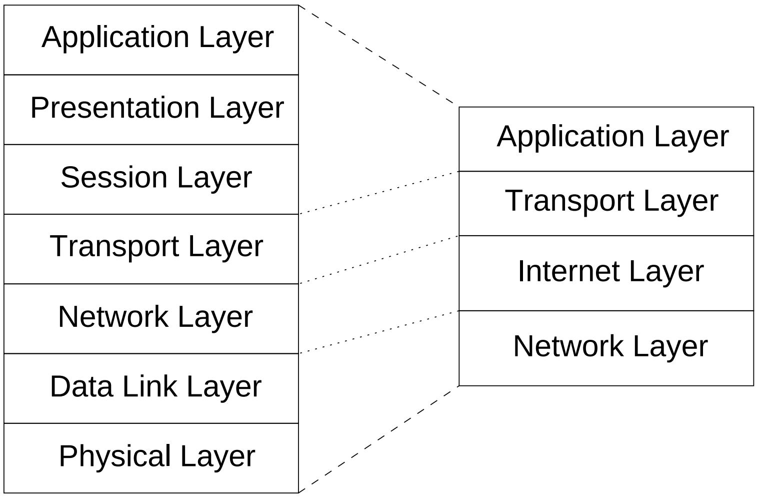


(a) The user's view of a TCP/IP internet in which each computer appears to attach to a single large network, (b) the structure of physical networks and gateways that provide interconnection. (Comer D.: Computernetzwerke und Internets)

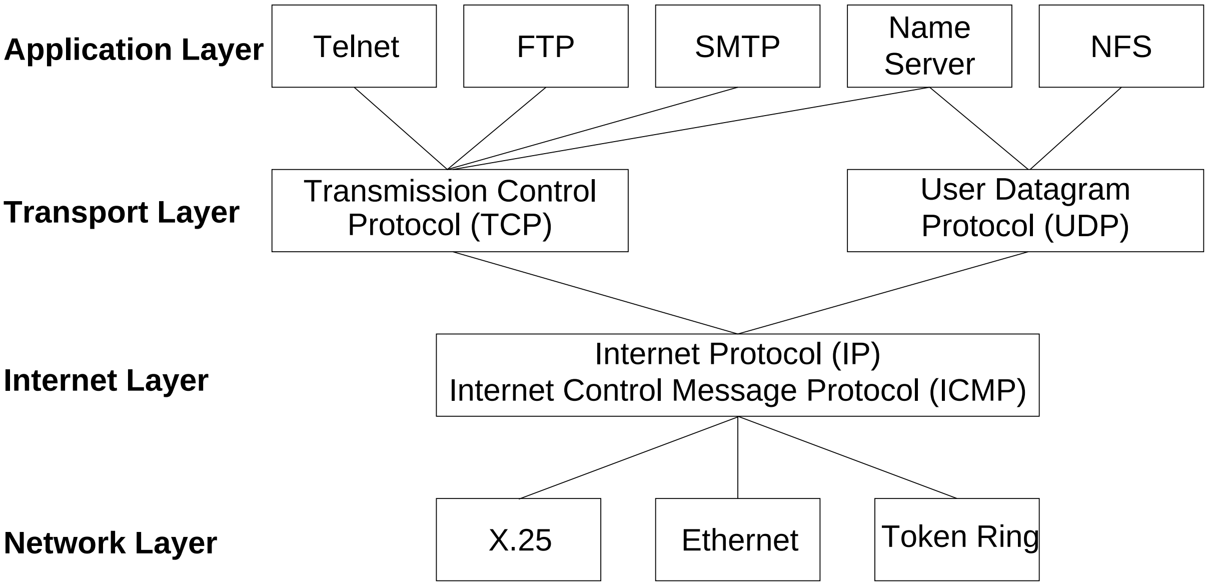
What is TCP/IP?

- TCP/IP is a set of protocols developed to allow cooperating computers to share resources across a network.
- The most accurate name for the set of protocols we are describing is the 'Internet Protocol Suite'.
- TCP (*Transmission Control Protocol*) and IP (*Internet Protocol*) are two of the protocols in this suite.
- Because TCP and IP are the best known of the protocols, it has become common to use the term TCP/IP to refer to the whole family.
- TCP/IP was developed by a community of researchers centered around the ARPAnet.

TCP/IP Protocol Architecture

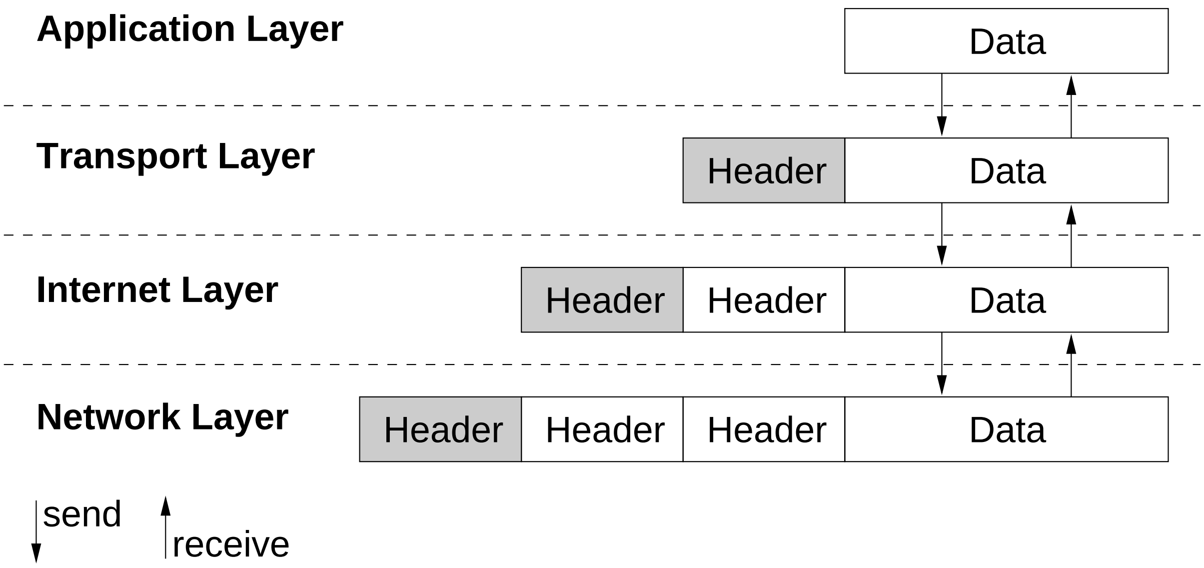


Comparison of OSI and TCP/IP architecture



TCP/IP architecture model

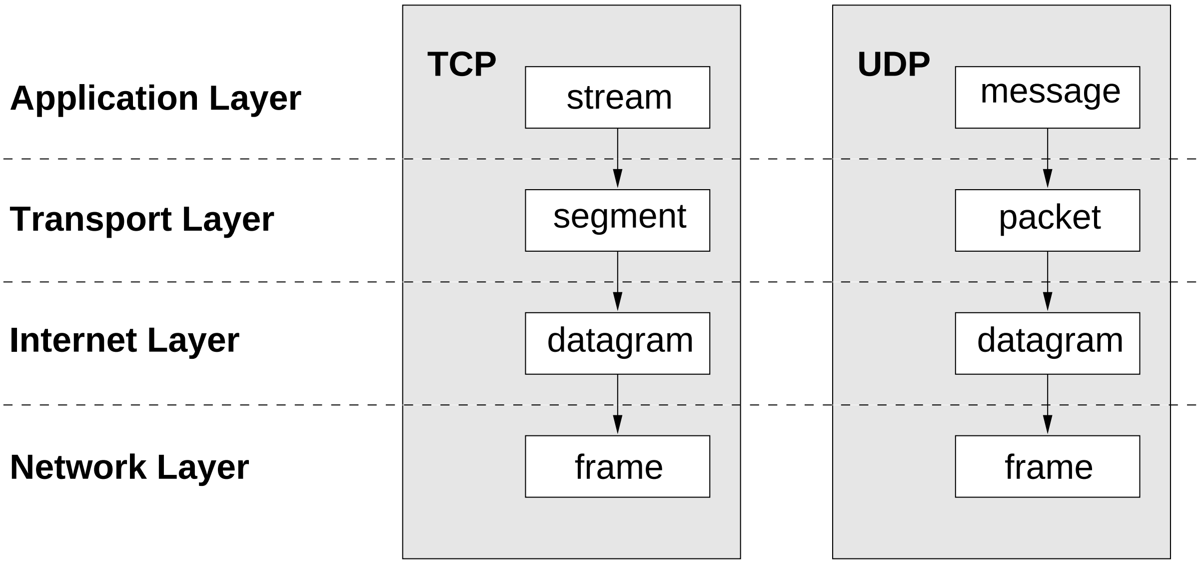
TCP/IP Protocol Architecture



Data Encapsulation

- Each layer in the stack adds control information to ensure proper delivery.
- This control information is called a *header*.
- Each layer treats all of the information it receives from the layer above as data and places its own header in front of that information.
- The addition of delivery information at every layer is called *encapsulation*.

TCP/IP Protocol Architecture



Data Structures

- Each layer has its own independent data structure and its own terminology to describe the structure.
- Each of this terms refers to the same thing - data to be transmitted.
- The terms vary as the view of the data varies from layer to layer.

Network Layer

The *Network Layer* is the lowest layer of the TCP/IP protocol hierarchy.

- Protocols in this layer define how to use a specific network to transmit an IP datagram.
- Protocols in the Network Layer must know the details of the underlying network (packet structure, packet length, addressing, . . .) to correctly format the data being transmitted over the network.
- For new hardware technologies, new Network Layer protocols must be developed.
- Because of this there are many protocols, one for each physical network standard.
- Functions performed at this level include encapsulation of IP datagrams into *frames* for transmission over the network and mapping of IP addresses to physical network addresses.
- Example RFCs that define protocols in the Network Layer are:
  - RFC826, *Address Resolution Protocol (ARP)*
  - RFC894, *A Transmission of IP Datagrams over Ethernet Networks*
  - RFC903, *Reverse Address Resolution Protocol (RARP)*
  - RFC877, *Transmission of IP datagrams over X.25*
  - . . .

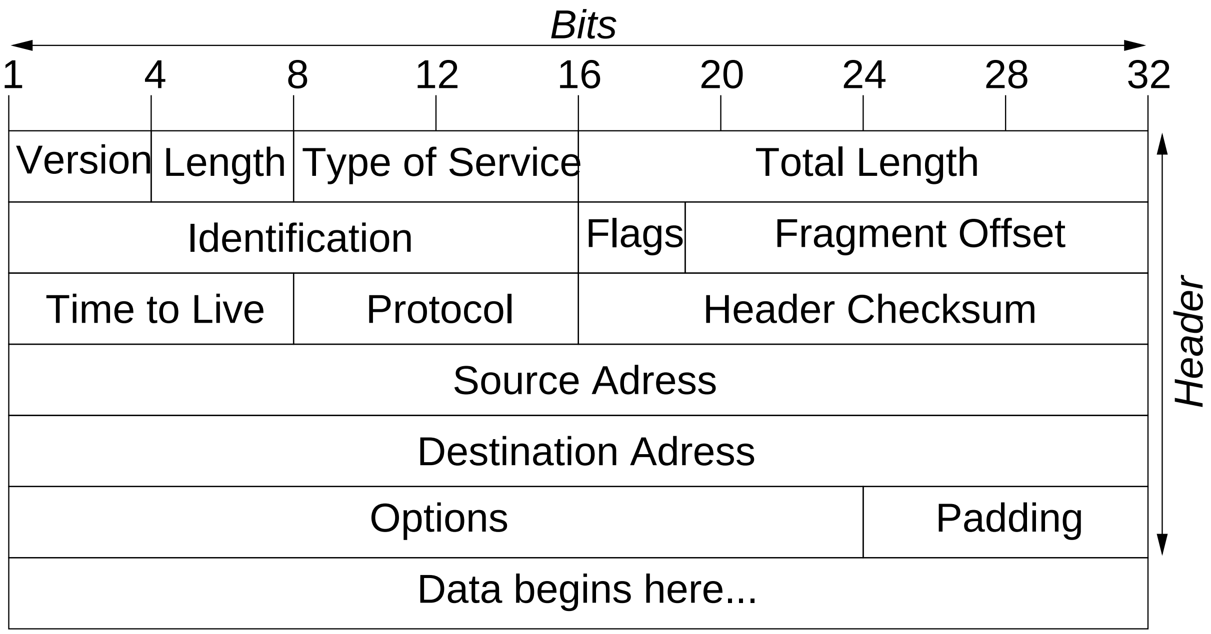
Internet Layer

The *Internet Protocol (IP)* provides the basic packet delivery service on which TCP/IP networks are built.

- Functions of IP
  - defines the *datagram*, which is the basic unit of transmission in the Internet.
  - defines the Internet *addressing scheme*
  - routing datagrams to remote hosts
  - performing *fragmentation* and re-assembly of datagrams
- Characteristics of IP:
  - connectionless protocol
  - unreliable protocol
  - correct
  - packet switching

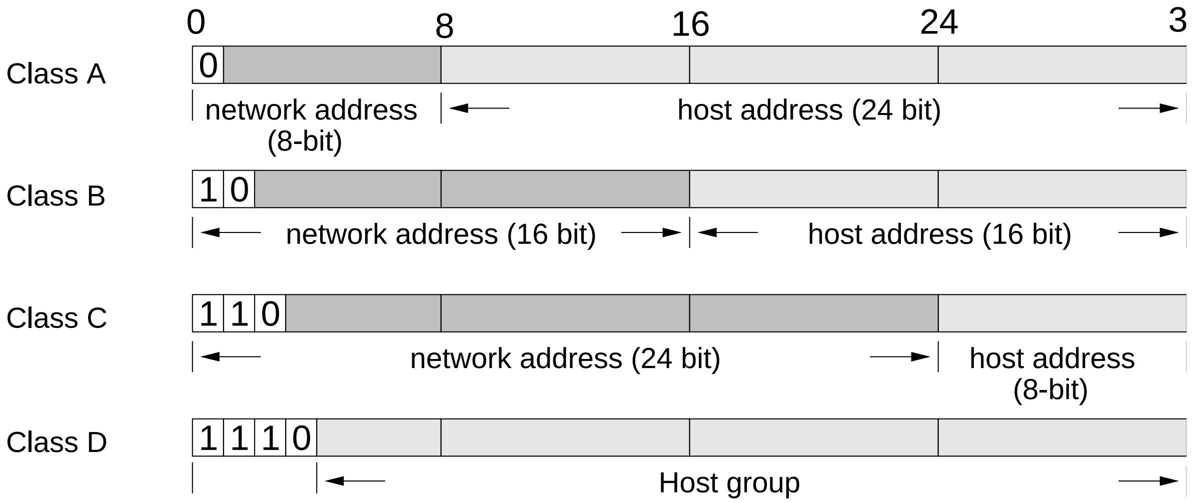
Internet Layer

- A *packet* is a block of data that carries with it the information necessary to deliver it.
- A *packet-switching network* uses the addressing information in the packets to switch packets from one physical network to another, moving them towards their final destination.
- The *datagram* is the packet format defined by the Internet Protocol.
- The first words before data begins are control information called the *header*. The header contains all the information necessary to deliver the packet.



Internet Layer

- IP delivers the datagram by checking the destination address in word 5 of the header.
- The destination address (also the source address) is a standard 32-bit *IP address* that defines a specific network and a specific host on that network. IP addresses are usually written as four decimal numbers (bytes) separated by dots (e.g. 128.34.35.12).



- If the destination address is not on the local network, the datagram is passed to a *gateway (router)* for delivery.
- Deciding which gateway to use is called *routing*. IP makes routing decisions for each individual datagram.

Internet Layer

- Every host and every *gateway (router)* has its own unique IP address.
- An IP address contains a *network part* and a *host part*.
- A host which is connected to more than one network, has a different IP address for every network (e.g. a gateway).
- As mentioned before IP addresses are divided into classes:

  class A: a first byte value less than 128; the first byte identifies the network number, the next three bytes the host address.

  class B: a first byte value between 128 and 191; the first two bytes identify the network number, the next two bytes the host number.

  class C: a first byte value between 192 and 223; the first three bytes identify the network, the last byte is the host number.

  class D: a first byte value greater than 223; 'reserved address'
- The network numbers are assigned by the *Network Information Center (NIC)* to avoid conflicts.
- Often IP addresses are called *host addresses* - but this is misleading: IP addresses are assigned to network interfaces, not to computers.

Internet Layer

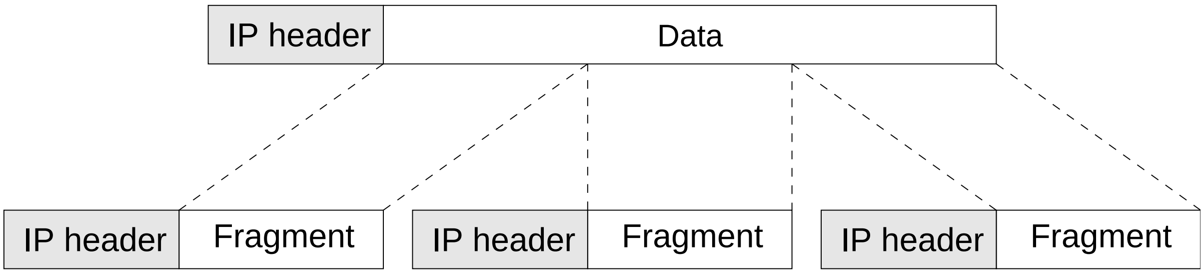
- The standard structure of an IP address can be locally modified by using host-address bits as additional network-address bits.
- These 'new' network bits define a network within the larger network, called a *subnet*.
- The subnet is only known locally. To the rest of the Internet, the address is still interpreted as a standard IP address.
- A subnet is defined by applying a bit mask, the *subnet mask*, to the IP address:
  - If a bit is on (1) in the mask, that equivalent bit in the address is interpreted as a network bit.
  - If a bit is off (0) in the mask, the bit belongs to the host part of the address.

10	Network	Subnet	Host
1 1	1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0

In this mask, the 16-bit host-number is divided into a 6-bit subnet-number and a 10-bit host-number (62 LANs, 1.022 hosts).

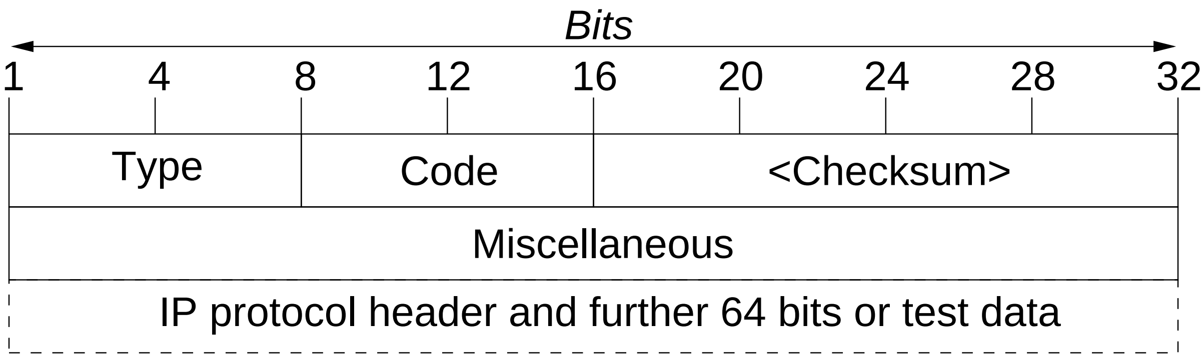
Internet Layer

- As a datagram is routed through different networks, it may be necessary that a gateway divides the datagram into smaller pieces.
- This process is called *fragmentation*.
- The format of each fragment is the same as the format of any 'normal' fragment.
- Word 2 in the header contains information that identifies each fragment and provides information how to re-assemble the fragments back into the original datagram.



Internet Layer

- The *Internet Control Message Protocol (ICMP)* is an integral part of IP and must be implemented by every IP module.
- The only task of ICMP is to transport error and diagnostic data for IP.
- Because ICMP has to transport various information, only the basic structure of the ICMP protocol header is fixed; the meanings of the individual fields are variable.



- ICMP sends messages that perform the following control, error reporting and informational functions:
  - Flow control
  - Detection of unreachable destinations
  - Redirecting routes
  - Checking remote hosts

Where to get more information

- Holtkamp, H.: Einführung in TCP/IP (http://www.rvs.uni-bielefeld.de/~heiko/tcpip)
- 'Request for Comments – RFCs' (http://www.internic.net/rfc)
- Comer D.E.: Computernetzwerke und Internets. Prentice Hall, München, 1998

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