Course on

Computer networks

Introduction

Henk Corporaal

Leiden University
2000

Ch1 Introduction : Overview

- Computer network usage
- Network hardware
- Network software
- Reference models: OSI, TCP/IP
- Example networks
- Example data communication services
- Standardization

Introduction

The end of the 20th Century: age of information processing and distribution

- worldwide telephone networks
  - GSM
- radio and tv broadcasts
- computer birth and spectacular progress
- communication satellite
  - stationary, or low orbit

Introduction

Old model: centralized computers with lots of dumb terminals

New model: ***computer networks***

= interconnected collection of ***autonomous*** computers

(autonomous: exclude master-slave systems)

Interconnection: copper wire, fiber, electromagnetic wires, wireless

Merger of computing and communication !

Introduction

Distinguish ***distributed system*** from ***computer network***

Distributed system: a computer network which appears to the user as a single processor/computer

- Transparently running jobs and getting files
- No explicit login onto each computer

Distributed system can be built as software layer on top of a computer network

Examples: Amoeba, MACH, and Chorus

Computer network usage

Why computer networks?

- Resource sharing
- Improve reliability through redundancy (CPUs, disks, printers)
- Cheaper; compare mainframe with micro's
- Scalable
  - easy addition of clients and servers
- Easy and fast communication medium

Client-Server approach (fig 1-1)

Computer Network usage

- Access to information
  - www
  - online libraries
  - video
  - music tracks (mp3), midi
- Communication
  - usenet
  - email
  - video conferencing
  - chat
- Entertainment
  - video on demand
  - multi-user games/virtual reality
- E-commerce
  - the dot.com's
- Electronic banking

Social issues

- Access everywhere to everything
- How about copyrights
  - e.g. online audio CD tracks / MP3
- Security
  - who is sending this message?
  - who can read this message?

Network hardware

Two important dimensions

1. Transmission technology
   - *broadcast networks* all-to-all connectivity
   - *point-to-point networks*
2. Scale 10cm - 10.000 km (see fig 1-2)

Broadcast networks

- Single communication channel shared by all computers on the network
- All receivers listen to each message
  - one destination
  - multi-cast: a group of destinations
- Used for smaller networks

Point-to-point networks

- Many connections between pairs of computers
- Multiple routes from source to destination
- Routing required (chapter 5)
- Used for larger networks

Remark

- Note that transmission technology (i.e. having a broadcast or point-to-point network) is orthogonal to the communication pattern:
  - one-to-all (broadcast)
  - all-to-one
  - one-to-many (multi-cast)
  - one-to-one (private)

Local Area Networks : LAN

- Restricted size / delay
  - broadcasting possible
- Transmission
  - 10-1000 Mbps
  - low delay (10 micro seconds)
  - few errors

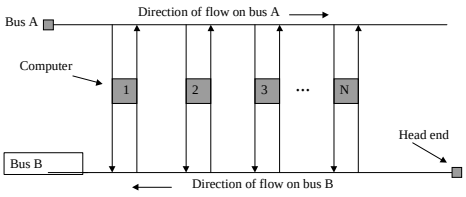
  Examples: ethernet (IEEE 802.3)
  token ring (IEEE 802.5)
- Regular topology (see fig 1-3)
- Channel allocation: static or dynamic
  - arbitration needed

Metropolitan Area Networks: MAN

- Basically a larger LAN
- Broadcasting used
- Interesting only because a special protocol has been proposed
- DQDB: distributed queue dual bus
  - IEEE 802.6

Metropolitan Area Networks: MAN

DQDB: distributed queue dual bus
• unswitched
• cells of 53-bytes (with 44 byte payload)



Wide Area Networks: WAN

WAN spans large geographical area:

- collection of hosts (computers) connected by a communication ***subnet*** (see fig 1-5)

Subnet is:

- transmission lines (circuits, channels, trunks)
- switching elements/computers (also called routers)
- point-to-point / store-and-foreward / packet-switched communication
- cell: fixed size packet (e.g. in ATM)

Wide Area Networks: WAN

Topology

- often irregular (see fig 1-6)
- satellite networks: inherently broadcast

Wireless Networks

- Motivation: computing/connected everywhere
- Distinguish wireless and mobile computing (fig 1-7)
- Wireless LAN (university campus antennas)
- Using wireless phone: Cellular Digital Packet Data (CDPD)
- Combine wired and wireless
  - e.g. airplane (fig 1-8)

Internetworks

Collection of networks connected by gateways

- e.g. collection of LANs connected by a WAN

Distinguish this from:

- Subnet: collection of routers and communication lines (e.g. America online, CompuServe, Telephone system)
- Network: combination of hosts + subnet
- Internet: a specific worldwide internetwork

Network Software

- Most networks are organized as a series of layers (fig 1-9)
- Each layer is implemented by an entity
- Peers: two communicating entities (within the same layer)
- Network architecture: set of layers and protocols
- Protocol stack: list of protocols, one per layer

Examples: fig 1-10 (analogy)
fig 1-11

Layer Design Issues

- Adressing: specifying source and destination
- Data transfer rules
  - simplex / half-duplex / duplex
  - # logical channels per connection
  - priorities, e.g. one normal and one urgent channel
- Error control
  - detection / correction / retransmission
- Packet order and sequencing

Layer Design Issues

- Flow control
  - regulate traffic; avoid overflow
- Message length: cannot be arbitrary long
  - (re)assembly needed !
- Multiplexing
- Routing
  - multiple paths

Interfaces and Services

Terminology: see fig 1-12

Two categories of services:

1. *Connection oriented*
   e.g. : phone conversation
   telnet / remote login / FTP
2. *Connectionless*
   e.g. postal system
   email
   video film transmission

Service Reliability

Quality of Service (QoS)

- Reliable: never loose data
  - acknowledgements / retransmission
- Unreliable: data may be lost
  - no acknowledgements
  - datagram service

Service overview: fig 1-13

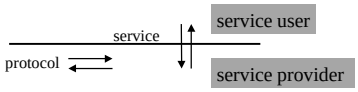
Services versus Protocols

Service = set of primitives (operations) that a layer provides to the above layer

Protocol = set of rules implementing a service

Protocol concerns format, meaning of frames / packets / messages

A protocol may be changed without changing the service



Service primitives

1. CONNECT. request
2. CONNECT. indication
3. CONNECT. response
4. CONNECT. confirm
5. DATA. request
6. DATA. indication
7. DISCONNECT. request
8. DISCONNECT. indication

CONNECT: confirmed service; response required

DISCONNECT: unconfirmed service

- Example: fig 1-15

OSI Reference Model

OSI (Open System Interconnection) Reference Model has 7 layers (fig 1-16)

- a model which tells what each layer should do
- not how it should be done !

OSI Reference Model

- Physical layer
  - transmission of raw ***bits*** (0/1 encoding)
  - relevant aspects are: voltage, µsec / bit, #pins, etc.
  - channel characteristics (mechanical, electric)
- Data link layer
  - transport of ***frames*** (of bits)
  - reliable transmission
  - flow control
  - broadcast networks: channel sharing (medium access sublayer)

OSI Reference Model

- Network layer
  - transport of ***packets***
  - controlling the subnet
  - routing : static or dynamic
  - congestion control
  - accounting (billing information)
  - connect heterogeneous networks (see fig 1-16)
    - gateway meeded

Note : in broadcast networks the network layer may be skipped

OSI Reference Model

- Transport layer
  - Connection management
  - End-to-end layer, from source to destination
  - Split data stream in packets
  - In-order delivery of packets (if network does not guarantee this)

Usually a unique connection is created for each required transport connection.

However it may use 1-n en n-1 mappings !

OSI Reference Model

- Session layer
  - Session management : dialogue control, synchronization after crash
- Presentation layer
  - Concerned with syntax and semantics of transmitted information
- Application layer
  - Commonly needed application protocols
  - Examples:
    File transfer
    Network virtual terminal

OSI model in action: fig 1-17

TCP / IP Reference Model

Originated from ARPA NET (a research network of DoD)

Connecting many USA Universities and government institutes using leased telephone lines

Later satellite and radio networks were added

TCP / IP (fig 1-18, 1-19)

Internet layer is the most important layer

- IP : internet protocol
- connectionless
- packet-switching (out-of-order delivery)

TCP / IP Transport layer

End-to-end communication

TCP transmission control protocol

- reliable
- connection-oriented
- flow control
- sequencing
- fragments byte stream into IP messages

UDP : user datagram protocol

- unreliable
- connectionless
- no sequencing and flow control
- often used for 'one shot' communication: e.g. booting

TCP / IP Application layer

Higher level protocols:

TELNET: virtual terminal
FTP: file transfer protocol
SMTP: simple mail transfer protocol
DNS: domain name service
NNTP: network news transfer protocol
HTTP: hypertext transfer protocol
SNMP: simple network management protocol

Comparing OSI and TCP / IP

Both based on protocol stack

OSI:

- Top-down design methodology
- The concepts clearly distinguishes (compare OOP)
  - Services (specification)
  - Interfaces
  - Protocols (implementation)
- Network layer supports both connectionless and connection-oriented communication
- Transport layer supports only connection-oriented service !!

Comparing OSI and TCP / IP

TCP / IP

- Bottom-up approach; grew out of practice
- Not a general protocol stack
- Host-to-network layer is actually an interface description

Critics on OSI model

- too many layers
- reflects proprietary IBM SNA network (also 7 layers)
- too difficult (1 m. handbooks)
- initially ignored connectionless protocols (many LANs use this)
- slow implementations
- not grown out of practice

Book will follow a hybrid, 5-layer model
see fig 1-21

Example Networks

- Novell NetWare : PC environment
- ARPANET : DoD/ARPA (advanced research projects agency) started early 1960s
- NSFNET : U.S. National Science Foundation
  - First TCP/IP WAN early 1980s.
- Internet : Connection of ARPANET and NSFNET in 1983.
  - 1995 : millions of hosts
  - size doubling every year
  - O (40 Mbit/s) backbone
- Gigabit testbeds

Novell NetWare

- LAN usage
- client-server model
- See fig 1-22 for protocol stack
- Resembles TCP/IP with IPX functionally similar to IP
- IPX
  - unreliable
  - connectionless
- Transport layer
  - NCP ; network core protocol
  - SPX and TCP are other options
- Each minute, servers broadcast their address and services to routers. When client boots, it broadcasts a request asking for nearest server

Gigabit Networks

Bandwidth improvement

Gigabit traffic does hardly reduce long distance delay!

Gigabit applications

- Telemedicine
  One image = 0,4 Gigabit
- Virtual meetings: combining multiple video streams
- US goal : 3 Gbit/s in the year 2000

Communication Services

Network services offered (mainly) by (public) telephone companies

- DQDB - distributed queue double bus
- SMDS - switched multimegabit data service (1990)
- X.25 Networks - developed during 1970s
- Frame relay (1993)
- Broadband I-SDN (Integrated Service Digital Network)
- ATM (Asynchronous Transfer Mode)

SMDS

Switched Multi-megabit Data Services

(fig. 1-27)

- 45 Mbps
- Connectionless
- Packet routing (see fig 1-28)
- Unreliable
- Support broadcasting to member list
- Address screening - private network can be build
- Support busy traffic

SMDS

How to control burst traffic:

- A counter C is incremented at a constant rate ; say once every 10 µsec
- When packet with L byte arrives:

```
If C>L then
   send packet; C := C-L
Else discard packet
```


X.25 Networks

Developed during 1970s

Used by many older public networks

Characteristics :

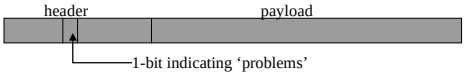
- Establish virtual circuits
  - either switched, or
  - permanent (i.e. no setup needed)
- Up to 128 bytes packets
- 64 kbps
- reliable delivery
- flow control
- connection oriented
- in-order delivery

Frame relay (1993)

Absolute bare bones / low cost connection / simple protocol

Characteristics :

- 1.5 Mbps
- virtual leased line
- predetermined long term average bandwidth
- frames (packets) of up to 1600 bytes
- unreliable : errors should be detected by higher layers



B-ISDN and ATM

Problem of telephone companies : many networks have to be supported

New services rely on packet switching, while telephone uses circuit-switched network

Compete with cable-TV networks

Solution:

- Single, new network, replacing telephone network and all specialized networks
- Huge bandwidth (supporting video on demand)
- Broadband-ISDN based on ATM technology
  - *ATM: asynchronous transfer mode*
  - *ISDN: integrated service digital network*

ATM: Asynchronous transfer mode

Cell based (i.e. fixed packet size)

Cell contains 5 byte header + 48 bytes data

Why cell-switching?

- Flexible, can handle all kinds of traffic
- Allows high speed switching (easier than with multiplexing)
- Supports broadcasting

ATM networks are like WANs with lines & switches

- Speed: 155 Mbps (HDTV) and 622 Mbps
- In-order, unreliable delivery
- Connection-oriented: virtual circuits

B-ISDN ATM Reference Model

3-layer model:

1. Physical layer
   - deals with physical medium
   - converting cells into bit stream
2. ATM layer
   - handling virtual circuits
   - congestion control
   - cell layout handling
3. AAL: ATM adaptation layer
   - packet (re)assembly

See fig. 1-30, 1-31 and for comparison fig 1-32

Standardization: Who's Who

1. Telecommunication world
   - ITU: International Telecommunication Union
3. International standards
   - ISO: Int. Organization for Standardization (1946)
   - ANSI: American National Standards Institute
   - IEEE: Inst. of Electrical and Electronic Engineers
3. Internet
   - IAB: Internet Activities Board (DoD)
   - Internet Society

Book Outline

Book is structured according to the hybrid 5-layer model

- Ch2: physical layer
  - SONET
  - cellular radio
- Ch3: data link layer protocols
  - SLIP and PPP
  - ATM
- Ch4: Medium access sublayer: who may use the network next (single shared channel)
  - LANs
  - fiber optic networks
  - satellite netwoks
  - Bridges, connecting LANs

Book Outline

- Ch5: network layer
  - routing
  - congestion control
  - internetworking
  - connecting heterogeneous networks
  - IP and ATM have extensive coverage
- Ch6: transport layer
  - connection-oriented protocols
  - TCP, UDP, and ATM AAL 1-5
- Ch7: application layer
  - security
  - naming
  - electronic mail and news
  - network management
  - WWW and multi-media

Exercises

Prepare exercises from chapter one:

- 1, 3, 4, 9, 22, 28