

Introduction to the Use of Computers

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Networking

Overview

Communication of information between computer systems or devices.

- ▶ Physical layer: bits from node to node;

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Networking

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- ▶ Transport layer: data from process to process;
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Networking

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- ▶ Application layer: data translation and interpretation.
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Networking

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(One) TCP/IP 5-layer reference model

Networking

Physical Layer

Transmission of bits from node to node.

- ▶ responds to service requests of the Data Link layer

Examples:

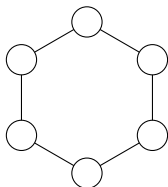
- ▶ Ethernet (e.g. 10BASE-T, 100BASE-T, 1000BASE-X, 10GBASE-SR)
- ▶ xDSL (e.g. ADSL, SDSL)
- ▶ 802.11x (e.g. 802.11b, 802.11g)

Networking

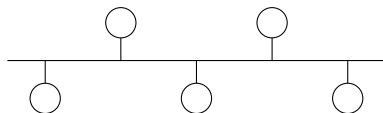
Physical Layer: topology

Physical layout of nodes:

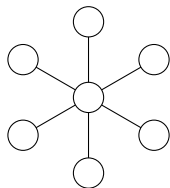
ring



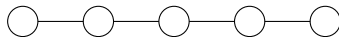
bus



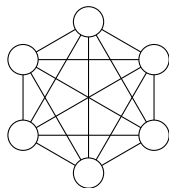
star



line



fully-connected



Networking

Data Link layer

Transmission of frames from hop to hop. (Not necessary to reach everywhere in one hop).

- ▶ responds to service requests of the Network layer;
- ▶ issues service requests to the Physical layer.

Frame:

- ▶ `header|payload|trailer`

Examples:

- ▶ Token ring
- ▶ Ethernet protocol (CSMA/CD)
 - ▶ Carrier Sense Multiple Access with Collision Detection
- ▶ 802.11 (CSMA/CA)
 - ▶ Carrier Sense Multiple Access with Collision Avoidance

Networking

Network layer

Transmission of variable-length data from source to destination.

- ▶ responds to service requests of the Transport layer;
- ▶ issues service requests to the Data Link layer.

Examples:

- ▶ Internet Protocol (IPv4, IPv6)
- ▶ Address Resolution Protocol (ARP)
- ▶ Internet Control Message Protocol (ICMP)

Networking

Transport layer

Transmission of variable-length data from process to process.

- ▶ responds to service requests of the Application layer;
- ▶ issues service requests to the Networking layer.

Examples:

- ▶ Transmission Control Protocol (TCP)
- ▶ User Datagram Protocol (UDP)

Networking

Application Layer

Transmission of meaningful information from process to process.

- ▶ issues service requests to the Transport layer.

Examples:

- ▶ HyperText Transfer Protocol (HTTP)
- ▶ Simple Mail Transfer Protocol (SMTP)
- ▶ Secure Shell (SSH)

The Internet

IPv4 addresses

'A records' in DNS: four bytes or 'dotted quad'. e.g. 192.0.2.1

There are $2^{32} \sim 4.3 \times 10^9$ possible addresses – fewer than one per person. (Not all of those addresses are valid on the Internet).

Possible solutions:

- ▶ Pervasive Network Address Translation (NAT)
- ▶ Classless Inter-Domain Routing (CIDR)
- ▶ New Protocol (IPv6)

The Internet

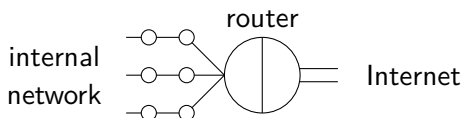
Network Address Translation

Some IPv4 addresses are specified for 'private use'

- ▶ 10.0.0.0 – 10.255.255.255;
- ▶ 172.16.0.0 – 172.31.255.255;
- ▶ 192.168.0.0 – 192.168.255.255.

Provides for sharing one public IPv4 address between multiple devices (but lose 'end-to-end' nature of Internet):

- ▶ 'router' with public IPv4 address;
- ▶ private network with private use IPv4 addresses;
- ▶ router provides translation.



The Internet

IPv6 Addresses

New (1996) protocol – not yet commonly deployed.

- ▶ 'AAAA records' in DNS;
- ▶ 16 bytes (2^{128} addresses);
- ▶ sparsely populated;
- ▶ hierarchical routing.

Example address:

2001:0db8:0000:0000:1319:8a2e:0370:7334

(also written as 2001:db8::1319:8a2e:370:7334)

The Internet

Address Resolution Protocol

We know: the network address (e.g. IPv4 address) that we want to send to; need to find: the hardware address (e.g. Ethernet MAC address) to send to.

- ▶ broadcast request;
- ▶ listen for reply.

Packet contents:

- ▶ Hardware (Ethernet = 1); Protocol (IPv4 = 0x800);
- ▶ Operation (Request = 1, Reply = 2);
- ▶ Sender Hardware Address;
- ▶ Sender Protocol Address;
- ▶ Target Hardware Address (zero in requests);
- ▶ Target Protocol Address;

```
'arp who-has 158.223.80.218 tell router.gold.ac.uk'
```

The Internet

Domain Name System

We know: the name of something we want to communicate with in some way; need to find: the network address.

- ▶ send request to 'name server' responsible for the domain (usually using UDP to a server on port 53);
- ▶ receive records requested back.

Types of record:

- ▶ A (IPv4 addresses)
- ▶ AAAA (IPv6 addresses)
- ▶ CNAME (host aliases)
- ▶ MX (mail handler names and 'priorities')
- ▶ NS (name server names)
- ▶ PTR (reverse DNS: numbers to names)

The Internet

HyperText Transfer Protocol

HTTP is for transmitting information over the World Wide Web ('WWW').

- ▶ HTTP/0.9 (obsolete)
- ▶ HTTP/1.0 (still in use)
- ▶ HTTP/1.1 (current)

Stateless protocol: each request/response between client and server is independent of all others.

Request format	Response Format
Request line	Status Code line
Headers	Headers
Empty Line	Empty Line
Optional Message Body	Optional Message Body

The Internet

HyperText Transfer Protocol: Requests

HTTP 'methods' (or 'verbs'):

- ▶ GET (gets a resource)
- ▶ HEAD (like GET but meta-information only)
- ▶ PUT (uploads a resource), DELETE (deletes a resource)
- ▶ POST (submits data)
- ▶ TRACE (echoes request)
- ▶ OPTIONS (displays options), CONNECT (tunnels)

Example request:

```
GET /~mas01cr/teaching/fy04/ HTTP/1.0
```

```
Host: doc.gold.ac.uk
```

The Internet

HyperText Transfer Protocol: Replies

Status Codes:

- ▶ 1xx (Informational)
- ▶ 2xx (Success)
 - ▶ 200 OK
- ▶ 3xx (Redirection)
 - ▶ 301 Moved Permanently
 - ▶ 302 Found
 - ▶ 304 Not Modified
- ▶ 4xx (Client Error)
 - ▶ 401 Unauthorized
 - ▶ 403 Forbidden
 - ▶ 404 Not Found
- ▶ 5xx (Server Error)

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HyperText Transfer Protocol: Replies

Headers:

- ▶ Content-Type
 - ▶ text/html
 - ▶ text/plain
 - ▶ image/gif
 - ▶ image/png
 - ▶ application/pdf
- ▶ Location (used in redirection)
- ▶ Date (date and time of reply)
- ▶ Server (server name)

The Internet

The Apache HTTP Server

- ▶ Widely-deployed Web Server (running on `igor.gold.ac.uk`), developed since 1994;
- ▶ Available for a wide variety of Operating Systems;
- ▶ Supports many features;
- ▶ Free software.

Mechanism for user-level configuration: `.htaccess` files

- ▶ Password-protection;
- ▶ Customized error documents;
- ▶ URL rewriting.

The Internet

Apache: .htaccess files

Text files used for controlling the behaviour of the Web Server.

Example file:

```
AuthType Basic
```

```
AuthName "Foundation Year"
```

```
AuthUserFile /home/mas01cr/public_html/teaching/is50004a/2012-13/lab07/u
```

```
Require valid-user
```

```
Options +Indexes
```

```
ErrorDocument 403 /~mas01cr/teaching/is50004a/2012-13/forbidden.txt
```

```
ErrorDocument 404 /~mas01cr/teaching/is50004a/2012-13/not-found.txt
```

```
AddType 'text/plain; charset=utf-8' text
```

```
AddType 'text/plain; charset=iso-8859-1' txt
```


The Internet

Apache: Basic authentication

Username and password dialog, protecting resources from unauthorized access:

- ▶ 'name' of authentication realm after `AuthName`;
- ▶ password information kept in a file;
- ▶ passwords maintained using `htpasswd` utility.

Problems:

- ▶ weak encryption;
- ▶ password transmitted in the clear over the network.

The Internet

Apache: Other customizations

- ▶ Options
 - ▶ +Indexes: allows the server to send directory indexes;
 - ▶ +ExecCGI: allows the server to execute scripts
- ▶ ErrorDocument *code url*: if the HTTP status is *code*, send *url* to the browser;
- ▶ AddType: associates a 'MIME type' with an extension.

The Internet

Simple Mail Transfer Protocol

SMTP is for sending e-mail. Handled for a domain by servers listed in MX records.

- ▶ gold.ac.uk. 900 IN MX 7 mailhub.gold.ac.uk.
- ▶ the '7' is the server priority (used when there is more than one MX record)

Protocol:

- ▶ Greeting, handshake (banner and HELO)
- ▶ Envelope (MAIL FROM and RCPT TO)
- ▶ Data (DATA)
 - ▶ Message Headers (Subject, Message-Id, References)
 - ▶ Message Body

Extensions to basic protocol: use EHLO rather than HELO.