Exercise 4

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IP as Narrow Waist

- „IP over anything, anything over IP“
- Single common tie between multiple upper and lower layer protocols
- Innovation in upper/lower layers
- Makes changes to IP difficult (IPv6 …)

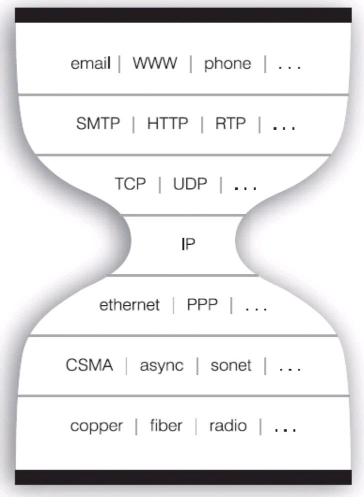
email | WWW | phone | . . .
SMTP | HTTP | RTP | . . .
TCP | UDP | . . .
IP
ethernet | PPP | . . .
CSMA | async | sonet | . . .
copper | fiber | radio | . . .

Figure 4.1 Hourglass architecture of the Internet

Key Functionalities of a Router

- Forwarding: move packets from router's input to appropriate router output
- Routing: determine route taken by packets from source to dest.
- A routing protocol determines the forwarding table

Switching Fabrics

- Responsible for redirecting data from imput port to output port (i.e., implement forwarding)
- Different types:
  - Shared Memory used by all ports (limited by memory bandwidth)
  - Shared Bus used by all ports (limited by bus bandwidth)
  - Crossbar: Fabric can connect any input port to any output port directly

Buffering

- Required when arrival/departure speed of data exceeds fabric speed/transmission rate
- Datagrams that can't be handled directly are stored in a queue
- Consequence: Buffer overflow if input/output queue are overutilized
- Scheduling (much alike OS job scheduling) determines order of packets processed from queue
  - Will get to scheduling later in the lecture...

IP Datagram Fragmentation

- 3000 byte datagram, 1400byte MTU.
- One datagram is fragmented into multiple smaller datagrams...

Datagram No.	Length	Frag. Flag	Offset = (MTU-Header / 8)
1	1400 (1380+20)	1	0
2	1400 (1380+20)	1	172
3	240 (220+20)	0	344
4			

IP Address Conversion (Decimal to Binary)

- TIP: Make yourself a table:

Power	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1
Rest								
Bit								

- For each octet:
  - Put octet number into first „rest“ cell
  - Bit = (value >= rest ? 1 : 0)
  - Restnext = Restprev – Bitprev x Valueprev
  - Rinse and Repeat

IP Address Conversion (Example)

- First octet of 134.76.249.227:

Power	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1
Rest	6	0	0	0	0	2	0	0
Bit	1	0	0	0	0	1	1	0

Converting IP Addresses

- 134.76.249.227
    - 10000110 01001100 11111001 11100011
- 192.168.0.1
    - 11000000 10101000 00000000 00000001

IP Address Conversion (Binary to Decimal)

- Make yourself a table:

Power	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1
Bit								
Sum								

- For each octet:
  - Fill the „Bit“ row with the bits of the octet
  - Fill the sum row:
    Sumnext = Sumprev + Bitprev x Valueprev

IP Address Conversion (Binary to Decimal)

- Octet 11100011:

Power	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1
Bit	1	1	1	0	0	0	1	1
Sum	128	192	224	224	224	224	226	227

- 11100011100001100000111110101010
  - 227.134.15.170

Subnet calculations

- Subnet calculations are used to break a given network into smaller pieces
- A (sub-) network mask shows how many bits of an IP address denote the network
  - Decimal: /17
  - Binary: 11111111.11111111.10000000.00000000
  - Hexadecimal: 255.255.128.0

Subnet calculations (Example)

- Given network: 128.30.0.0/17
- Wanted: Four sub networks
- First step: Find new subnet mask
  - To address four networks we need at least two bits (2^2 = 4).
  - The new subnet mask is 17+2 = 19
- Second step: Find new network addresses (see next slide)
- Third step: Calculate data for new networks (see homework)

Subnet calculations (example)

New netmask: 19 (= 255.255.224.0)
11111111.11111111.11100000.00000000

=> New network 1: 128.30.0.0/19
10000000.00011110.00000000.00000000

=> New network 2: 128.30.32.0/19
10000000.00011110.00100000.00000000

=> New network 3: 128.30.64.0/19
10000000.00011110.01000000.00000000

=> New network 4: 128.30.96.0/19
10000000.00011110.01100000.00000000

Number of hosts: 213 – 2 = 8,190

Subnet calculation (homework)

A provider has been assigned the network 128.30.0.0/23 and wants to divide it among three customers. Customer A needs to accommodate up to 220 hosts, customer B needs to accommodate up to 110 hosts and customer C needs to accommodate up to 80 hosts. Please fill the following table with the details of the subnetworks that the provider can create to fit its customers' needs.

Subnet No.	Network Address	Netmask	Host Range	No. of Hosts
1 Cust. A	128.30.0.0/24	255.255.255.0	128.30.0.1 – 128.30.0.254	254
2 Cust B	128.30.1.0/25	255.255.255.128	128.30.1.1 – 128.30.1.126	126
3 Cust C	128.30.1.128/25	255.255.255.128	128.30.1.129 – 128.30.1.254	126

IP Address Allocation - Host

- DHCP
  - Dynamically gets an IP address on joining the network
  - Allows reuse of addresses (address only reserved while online)
- Protocol: DHCP discover → offer → request → ack
  - More details: see lecture slides

IP Address Allocation - Network

- Allocation of a portion of the providers ISP address space
  - e.g., provider net 200.23.16.0/20
  - Possible allocated subnet: 200.23.30.0/23

IP Address Allocation - Provider

- ICANN (Internet Corporation for Assigned Names and Numbers)
  - Global allocation of addresses to ISPs
  - ISPs then reallocate their addresses to subnets/customers (see previous slides)
  - However: Shortage of IPv4 addresses → Most blocks occupied

Network Address Translation (NAT)

- IPv4: Address shortage
- NAT: One network (of an arbitrary number of hosts) has only one IP address (NAT enabled router) that is accessible from the internet
- The remaining hosts are addressed internally
- Use port numbers to decide which host the datagram is destined to, mapping inside NAT table
- NAT is often considered a „dirty fix“ to the address shortage issue (→ IPv6)

IPv4 vs IPv6 - Differences

- Address space: IPv4 2^32, IPv6 2^128
- IPv6: Fixed header length, additional information needs to be stored in additional headers
- IPv6: No packet fragmentation supported, fragmentation is moved to the sending host
- IPv6: No header checksum, error detection on layer 4/2
- ...

IPv4 to IPv6 - Migration

- There is no „flag day“ on which IPv4 routers are replaced by IPv6 routers.
    - Not all routers can be upgraded simultaneously
    - Rather a slow process of transition
    - How to achieve this transition, i.e., a mixed, concurrent operation of IPv4 and IPv6 routers?

IPv4 and IPv6 together

- Two different possibilities
  - Tunneling: IPv6 datagram is carried as payload in IPv4 datagram between IPv4 routers; IPv6 routers then decapsulate IPv6 datagram.
  - Dual Stack: Routers can do both, IPv4 and IPv6; direct connection between same protocol clients (IPv4 → IPv4, IPv6 → IPv6); can be used together with tunneling