Network Services

Administrative
Protocols & Services

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Overview

- Administrative Services
  - Internet Standardization Process
  - Basic Internet Protocols
  - DHCP & Stateless Address Configuration
  - Telnet
  - Traceroute + Ping

Main question

- User invokes an operation in a networked enabled application
  - Examples
    - Sends an email
    - Retrieves an email
    - Requests HTML page
    - Invokes a Web service
    - RMI call
- Question
  - Which messages are emitted at network interface?

Request for Comments

- Each distinct version of an Internet standards-related specification
  - Published as part of the "Request for Comments" series
- RFCs are official publication channel
  - Since 1969
  - Publication responsibility of the RFC Editor
    - Under direction of IAB (Internet Architecture Board)
- Standards Process itself is RFC 2026
- Formatting conventions RFC 1543

Internet Standards Process

- First posted as an Internet-Draft
  - Published for informal review and comment
- Proposed Standard
  - Generally stable
  - Significant community review
- Draft Standard
  - At least two independent and interoperable implementations with different code bases
- Internet Standard
  - Significant implementation
  - Successful operational experience
  - STDs in addition to RFCs

Internet Standards

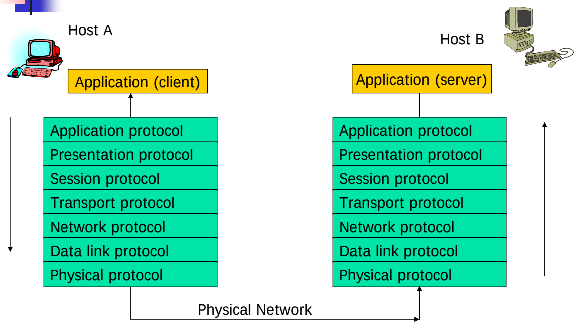
- http://www.rfc-editor.org/rfc.html
- See RFC 3700
- IP+ICMP+IGMP
  - STD 5 (RFC 791+792+919+922+950)
- UDP
  - STD 6 (RFC 768)
- TCP
  - STD 7 (RFC 793)

ISO OSI Model

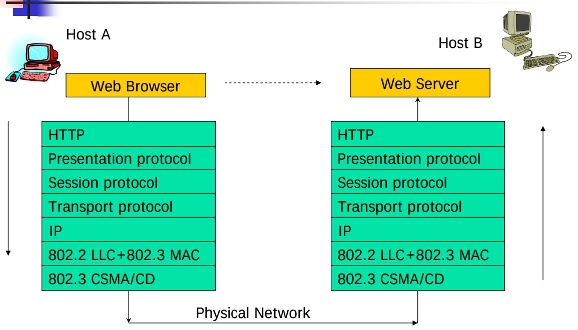
Application protocol
Presentation protocol
Session protocol
Transport protocol
Network protocol
Data link protocol
Physical protocol

- Idealized protocol stack
  - Implementations look different (usually)
- Each upper level protocol builds on the next lower
- ISO = International Standards Organization
- OSI = Open Systems Interconnection

Application Protocols



Sending Email



Message structure

- Message header
  - Message id
  - Message length (header length)
  - Checksum
  - Source and destination address
  - Options
  - ...
- Payload

Headers & Layers

- Encapsulation of messages
  - Message from Layer n+1
  - Forms payload of message in Layer n
  - Header for message Layer n added
- Effect of encapsulation
  - Headers for all messages contained in the final message

802.3 (Ethernet) Frames

- 48 bit addresses
- Max. 1500 Bytes of payload!
- Frames
- All hosts listen on frames for their address
  - Frame is picked when address is found
- Unique address for each node (MAC address)

6 bytes	6 bytes	2 bytes	46 - 1500 bytes	4 bytes
Destination address	***Source address***	***Type***	***Data (Payload)***	***checksum***

Internet Protocol (IP)

- IPv4
  - STD 5 (RFC 791)
- IPv6
  - RFC 2460
  - Draft Standard

IP

- Virtual Network
- Routing
- Connectionless (datagram)
  - Not required to connect to recipient
- Transmission over several networks
- Unreliable
  - Order undetermined
  - Loss of packets

IPv4

- Addressing
  - IP address: 32bits (network id, host id)
- Max packet size 64kB
- Fragmentation and reassembly
  - Data Link Layer Frames usually smaller
- Time to live
  - Number of hops

IPv4 Header

4-bit version	4-bit header length	8-bit type of service (TOS)	16-bit total length (in bytes)	
16-bit packet id			3-bit flags	13-bit fragment offset
8-bit time to live (TTL)		8-bit higher level protocol (TCP,UDP,...)	16-bit header checksum	
32 bit - source IP address				
32 bit - destination IP address				
0 - 40 bytes Options (if any)				

20 bytes

0-40 bytes

IPv4 Addresses

- Numeric: 128.131.172.25
- network id and host id
- 3 unicast classes A-C, 1 multicast D

Class A	0	7 bit netid	24 bits - hostid				
Class B	1	0	14 bits - netid	16 bits - hostid			
Class C	1	1	0	21 bits - netid	8 bit hostid		
Class D	1	1	1	0	28 bits - Multicast group ID		
Class E	1	1	1	1	0	27 bits – reserved for future use	

Subnet Addressing

- Only small number of networks possible
  - ~2.000.000
- Interpret IP address considered as 3 parts
  - Host-ID split in Subnet-ID and Host-ID

Class B	1	0	14 bits - netid	8 bits - subnetid	8 bits - hostid

- Subnet Mask
  - Hosts need to know how many bits for subnet
  - 32-bit value with bits set in Network id & Subnet id field
  - Example
    - Explicit: 128.131.172.25 255.255.255.0
    - Prefixlength:128.131.172.25 **/24** (number how many bits are set) (11111111.11111111.11111111.00000000 = 255.255.255.0)

IPv6

- Large addressing scheme
  - 128 bit addresses
- Next header field
  - Realizes linked list of headers
  - Last field refers to protocol type (TCP, UDP, ...)
- Extension headers
  - Hop-by-Hop Options
  - Routing
    - lists Intermediate nodes to be visited
  - Fragment
    - For sending a packet larger than the path MTU
  - Destination Options
  - Authentication
  - Encapsulating Security Payload
- Support for Jumbograms (RFC 2675)
  - Payload larger than 64kB

IPv6 Header

4-bit version	8-bit traffic class	20-bit flow label	
16-bit payload length + extension headers (in bytes)		8-bit next header (next protocol)	8-bit hop limit (TTL)
128 bit - source IP address			
128 bit - destination IP address			
Extension Headers			

40 bytes

IPv6 Addresses

- 128bit
- Written as 8 hex-numbers
  - Ex: 2001:0db8:0000:1347:0000:0000:0000:0001
  - Leading zeros may be omitted
    - 2001:db8:0:1347:0:0:0:1
  - One sequence of 0s replaced by ::
    - 2001:db8:0:1347::1
  - ::1 is loopback
- Last 64 bits are Interface ID
- First 64 bits Global Routing Prefix and Subnet ID
  - Global Routing Prefix provided by Internet Service Provider

Transmission Control Protocol TCP

- Multiple TCP endpoints – Ports
  - 1-65535
  - Like Post Office Boxes
- Connection-oriented
  - Virtual Circuit
  - Special Flags
- Flow control
  - Transmission speed reduction if one side is too slow

TCP Header

16 bit - Source port	16 bit - Destination port	
32 bit - Sequence number		
32 bit – Acknowledgement number		
4 bit – Header length	6 bit - reserved	6 bit - Flags
16 bit – Window (size of receive buffer)		
16 bit – Checksum		
16 bit – Urgent pointer		
Options (optional)		

20 bytes

TCP Communication

- Client connects to server
  - Sends TCP (command) segment with
    - SYN flag on, ACK flag off
    - SequenceNr = x
- Server responds
  - Sends TCP (command) segment with
    - SYN flag on, ACK flag on
    - SequenceNr = y, AckNr = x+1
- Client sends data to server
  - Sends TCP segment with
    - SYN flag off, ACK flag on
    - SequenceNr = x+1, AckNr = y+1
- ...

User Datagram Protocol

- Transmitted within IP protocols
- Multiple UDP endpoints – Ports
  - 1-65535
- Connection-less

UDP Header

16 bit - Source port	16 bit - Destination port
16 bit - Length	16 bit - checksum

8 bytes

Internet Control Message Protocol - ICMP

- Transmitted within IP protocols
- IP's Response & Error mechanism
- ICMP error message
  - Types
    - Network unreachable
    - Host unreachable
    - Port unreachable
    - ...
- ICMP query messages
    - Eg. Echo request, Echo reply
    - ...

ICMP Error Message

8 bit - Type	8 bit - Code	16 bit - Checksum
32 bit – Message Data		
20-60 bytes – Original Header		
8 byte – Original Data		

Request Example / 1

- Via HTTP (HyperText Transfer Protocol)
  - more details in some weeks
- In Pseudocode (Java-like):

```
Socket s =
  new Socket("www.tuwien.ac.at", 80);
s.send("GET / HTTP/1.0");
```

Request Example / 2

- TCP socket
  - Server listens on particular port
    - 80 in our example, standard port for HTTP
  - Client connects to the server host with its own client port
    - Free port is choosen
- Socket Pair
  - Server IP address + Port
  - Client IP address + Port

Request Example / 3

- Problem
  - IP needs IP destination address
- What is the IP address of "www.tuwien.ac.at"
- Solution
  1. Already cached by client
  2. Domain Name System
     - Sends other messages!
  3. HOSTS / HOSTS.TXT

Request Example / 4

- How is IP packet delivered?
  - IP makes only sense to IP layers
  - Data link layer protocols own addressing
- In same subnet
  - Requires MAC address in destination field
- Other subnet via Routers

Request Example / 5

- How is MAC address of another host found?
  - Address Resolution Protocol (ARP)
  - ARP cache
    - Hosts may fill cache when they see frames

Address Resolution Protocol

- ARP
  - Provides a mapping between two different forms of addresses
  - Ethernet
    - RFC 826
    - 32-bit IP and 48-bit ethernet
    - Ethernet specific protocol
  - Exists in every TCP/IP implementation
    - Automatically without intervention of Administrator

Reverse Address Resolution Protocol

- RARP
  - Maps Hardware Addresses to IP
  - RFC 903
- Original task
  - Optain IP address on booting
    - Only IP address
  - Today replaced by DHCP

Dynamic Host Configuration Protcol (DHCP)

- RFC 2131
- Passing configuration information to hosts
  - On TCP networks
- Based on BOOTP (Bootstrap) (RFC 951)
  - DHCP allows transmission of larger options
- UDP as transport protocol
  - DHCP server port 67,DHCP client port 68

DHCP Goals

- Delivery of host-specific configuration parameters
  - from a DHCP server to a host
  - key-value pairs stored at server
- Allocation of network addresses to host
  - Eg. Client requests use of an IP address

DHCP Address assignment

- Automatic assignment
  - Permanent IP address to a client
- Dynamic allocation
  - Assignment of IP address for a limited time
  - Reassigning free IP addresses

DHCP Client-Server Protocol

- Assumption
  - client does not know its IP address!

1. Client broadcasts message "DHCPDISOVER" on local physical subnet
   - Client's hardware address (eg. MAC address)
2. (Multiple) Server respond DHCPOFFER messages
   - Includes client's IP address
   - Client's Lease (expiration time)
3. Client chooses one Server that sent DHCPOFFER
   - Verification of server parameter
   - Sends DHCPREQUEST message
4. Server sends DHCPACK
   - Contains configuration parameters

DHCP

- Information valid as long as lease
  - No guarantee IP address is valid any longer
- Client may send RENEW messages
  - Timer watches lease expiration
  - Gets a new lease from DHCP server
- DHCP for IPv6 (RFC 3315)
  - Different messages than DHCP for IPv6
  - More configuration options than DHCP for IPv4
    - Eg. NIS+, NTP
  - Authorization

Stateless Address Configuration

- Stateless means
  - No DHCP server required
  - No specific configuration required
- IPv6 only
- RFC 2462
- IPv6 Interface ID (64 bit)
  - Created based on 48-bit MAC address
  - Verified with routers that it is unique
- 64 bit Prefixes determined from routers
  - Global Routing Prefix & Subnet ID

Routing / 1

- Any host has a routing table
  - Which physical interface to use for outgoing IP datagrams

Destination IP	Next Hop Router	Flags	Interface
127.0.0.1	127.0.0.1	UH (H=Host)	Lo0
128.131.172.25	128.131.172.72		

Routing / 2

- Target host is determined via
  1. Routing table has entry that matches complete destination IP
     - Send packet to this router / interface
  2. Routing table has entry that matches destination network ID
     - Send packet to this router / interface
  3. Search routing table for default entry
     1. Send packet to this router / interface

Remote Login Agenda

- RLogin
- Telnet
- SSH
- X-Window

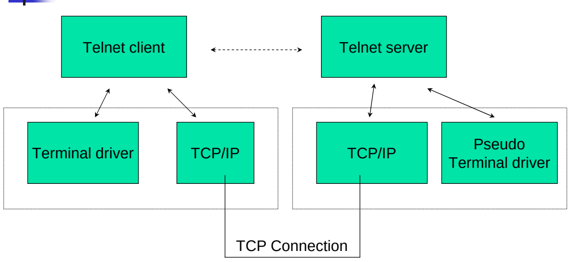
Remote Login

- RLogin
  - one of the first remote login tools
  - Clear-text passwords
  - Allows bypassing of passwords
    - Security Problem

Telnet / 1

- Communication between
  - Any host
  - Any terminal
- RFC 854
- Network Virtual Terminal (NVT)
  - Lowest common denominator terminal
  - All Telnet terminals shall conform to NVT
- NVT Printer
- NVT Keyboard

Telnet process model



Telnet / 2

- NVT Ascii
  - 7-bit US variant used in most Internet protocols
    - SMTP, HTTP, FTP, ...
  - Defines allowed symbols for these protocols
- 7-bit character sent as 8-bit (high-order bit = 0)
- Allows specific symbols
  - Those with high-order bit = 1

Telnet / 3

- End-of-line symbol
  - 2-character sequence
    - CR (carriage Return)
    - LF (Linefeed)
    - \r\n
  - Carriage Return symbol itself
    - Sent as \r\0 (CR NUL)

Telnet / 3

- Commands
  - 0xFF (255) (= Interprete as Command)
  - Command-byte follows

Telnet Command

- Exists on most systems
  - telnet <host> [<port>] (default port:23)
  - "Internet terminal"
  - Telnet server: telnetd
  - Windows Telnet server: start via Control Panel
- Data sent in the clear
- Passwords in the clear
  - Not widely used extensions/options for encryption
- Importance of Telnet
  - Debugging Tool
  - NVT Ascii used by most Application layer protocols

Telnet Example / 1 Remote Login

telnet compaq1.infosys.tuwien.ac.at

Suse Linux release 8.1

Kernel 2.4.2

login: joe

Password:

Last login: Tue Mar 22 ... from dellpc05.
...

-bash-3.00$

Telnet Example / 2 Debug HTTP

```
telnet www.tuwien.ac.at 80
Trying 128.131.172.239...
Connected to pent21.infosys.tuwien.ac.at.
Escape character is '^]'.
GET /  HTTP/1.0

HTTP/1.1 200 OK
Date: Fri, 18 Mar 2005 15:51:59 GMT
Server: Apache/1.3.26 Ben-SSL/1.48 (Unix) PHP/4.1.0
Last-Modified: Tue, 15 Mar 2005 08:21:32 GMT
ETag: "109eb-1ae2-42369b0c"
Accept-Ranges: bytes
Content-Length: 6882
Connection: close
Content-Type: text/html

<!doctype html public "-//w3c//dtd html 3.2//en">
   <html lang="de">
<head>
<title>TU Wien</title>
<LINK rel="stylesheet" type
="text/css" href="styles/homepage.css">
...
Connection to host lost.
```

X-Window / 1

- Graphical windows on remote hosts
- X-Client
  - End-user application run on (remote) hosts
    - Terminal
    - Editor
    - ...
  - Sends messages to client
- X-Server
  - Renders the messages at the end-users host
  - Gets input from keyboard/mouse and sends it to X-client
- Be aware: Server vs. Client
  - X Server provides rendering services to the clients

X – Window Protocol

- Origin at MIT
- Currently at X.ORG
  - X11
- Usually on TCP (ports 6000-6063)
- Initial negotiation phase
- RPC like messages
  - CreateWindow, DestroyWindow
  - SetInputFocus
  - ClearArea
  - FillPoly
  - Bell
- X-client initiates the connection

Other graphical remoting tools

- VNC
  - Remote Frame Buffer protocol
    - One primitive operation
      - "put a rectangle of pixel data at a given x,y position"
    - stateless
  - Remote access to graphical user interfaces
    - X11, Windows, Mac
- RDP – Microsoft Remote Desktop Protocol
  - Remote administration of Windows Systems
  - Protocol not published
  - Performs bettern than X

Secure Shell (SSH)

- Protocol for secure
  - Remote Login
  - Other secure network services
- Strong encryption
- Server Authentication
- Integrity protection
- May provide compression (zlib, RFC1950/1951)
- Type of service negotiated
  - Public key algorithm
  - Symmetric algorithm
  - Message authentication algorithm
- RFC 4250-4256
  - Recently "Internet Proposed Standard"

Secure Shell (SSH)

- Standard methods
  - Interactive shell sessions
  - Remote execution of commands
  - Forwarding (tunneling) arbitrary TCP/IP ports
  - X11 connections
- More details
  - Later in this lecture about security protocols

Ping, Traceroute

Ping / 1

- Based on ICMP
  - Sends an ICMP echo query request to a particular host
  - Receives ICMP echo reply
  - Identifier transmitted
    - Often sender process number (=ping process)
  - Sequence number
    - Identification of the packet
    - Incremented at each send
- Exists on most operating systems
- Ping often blocked by firewalls

Ping / 2

```
joe@mail:~$ ping localhost
PING mail (127.0.0.1): 56 data bytes
64 bytes from 127.0.0.1: icmp_seq=0 ttl=64 time=0.0 ms
64 bytes from 127.0.0.1: icmp_seq=1 ttl=64 time=0.0 ms
64 bytes from 127.0.0.1: icmp_seq=2 ttl=64 time=0.0 ms
64 bytes from 127.0.0.1: icmp_seq=3 ttl=64 time=0.0 ms

--- mail ping statistics ---
4 packets transmitted, 4 packets received, 0% packet loss
round-trip min/avg/max = 0.0/0.0/0.0 ms
```

Traceroute / 1

- Determines the route to a specified target host (via hosts and routers)
- IP header has 8-bit TTL (Time-to-live) field
  - Sender initializes this field to some value
  - Usually 64
  - To avoid endless loops
- Router detects IP datagram with TTL 0 or 1
  - Router throws away the datagram
  - Sends an ICMP message "time exceeded" to originating host
  - TTL > 1 datagram forwarded and TTL decremented by 1
- Today firewalls often block ICMP messages

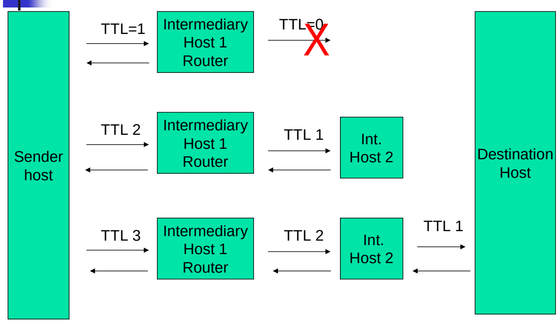
Traceroute / 2

- Traceroute functionality (Pseudocode)

```
boolean hostFound = false;
int port = 30000; // no host shall have a service running this port
int ttl = 0;

while(!hostFound) {
  try {
      ttl = ttl + 1;
      sendUPD(targetHost, port, ttl)
  } catch (ICMP_TTLExceeded ttlExcptl) {
       System.out.println("Host:"+ttlExcpt.host);
  } catch (ICM_PortUnreachable pue) {
       System.out.println("Final port reached!");
       hostFound = true;
  }
}
```

Traceroute / 3



Traceroute example

```
/users/home6/e9425196 36% traceroute www.apache.org

traceroute: Warning: Multiple interfaces found; using 193.170.75.14 @ lan2
traceroute to www.apache.org (192.87.106.226), 30 hops max, 40 byte packets
1  193.170.75.254 (193.170.75.254)  1.357 ms  1.247 ms  1.251 ms
2  192.35.243.25 (192.35.243.25)  0.774 ms  0.782 ms  0.852 ms
3  defcon-in.kom.tuwien.ac.at (192.35.241.35)  0.751 ms  0.454 ms  0.451 ms
4  192.35.241.116 (192.35.241.116)  0.637 ms  0.732 ms  0.750 ms
5  193.171.13.9 (193.171.13.9)  1.440 ms  1.440 ms  1.233 ms
6  193.171.23.33 (193.171.23.33)  1.411 ms  1.748 ms  1.618 ms
7  aconet.at1.at.geant.net (62.40.103.1)  1.955 ms  1.712 ms  2.148 ms
8  at.de2.de.geant.net (62.40.96.58)  13.938 ms  14.032 ms  14.421 ms
9  de2-2.de1.de.geant.net (62.40.96.54)  13.668 ms  24.610 ms  14.290 ms
10  de.nl1.nl.geant.net (62.40.96.102)  20.278 ms  24.153 ms  20.409 ms
11  surfnet-gw.nl1.nl.geant.net (62.40.103.98)  20.475 ms  20.693 ms  20.463 ms
12  PO11-0.CR1.Amsterdam1.surf.net (145.145.166.33)  20.519 ms  20.312 ms  30.719 ms
13  PO0-0.AR5.Amsterdam1.surf.net (145.145.162.2)  20.465 ms  22.724 ms  20.615 ms
14  Te1-1.SW14.Amsterdam1.surf.net (145.145.140.158)  20.362 ms  20.828 ms  20.284 ms
15  * * * *
```