Application layer, services and protocols

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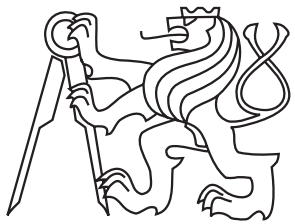

Content

- FTP, SFTP
- telnet/SSH
- e-mail (SMTP/POP/IMAP)
- web (HTTP/HTTPS)
- NTP
- BOOTP, DHCP
- streaming
- VoIP
- peer-to-peer

Application layer

- implementation of protocols and services
  - use the transport layer (TCP/IP model)
  - or the presentation layer (OSI model)
    - OSI strictly distinguishes between application and functions of session and presentation layers
- client-server architecture
  - server offers a service
  - client connects to server and uses services
- peer-to-peer architecture
  - communicating parties are not distinguished

FTP I

File Transfer Protocol

- file transfer between client and server
- command channel TCP, port 21
- TCP data channel
  - active mode: data channel – port 20
    - the client determines the port number for data channel on its side, informs the server and expects a connection on it
    - server starts transfer from port 20
    - firewall issues on the client side – the data channel opened by the server
  - passive mode: data channel – dynamically assigned port
    - the server determines the port number for the data channel and informs client about it
    - client starts connection on the data channel from generated source port
    - solves the problem of firewalls filtering the incoming data port connection to the client from the server – connection is initiated by the client

FTP II, SFTP

- clients: command-line utilities, browsers, third-party applications
- user/password authentication (anonymous account: password guest or e-mail)
- FTP is not secure (no encryption)
- Secure File Transfer Protocol, or SFTP provides secure file transfer, extension of SSH

Telnet

- old interactive text-oriented communication utility
- for a remote access via a virtual terminal connection
- TCP port 23
- user/password authentication
- without encryption
- no support for mouse
- still used for configuration of network devices

SSH

Secure Shell

- TCP port 22
- replaces telnet
- encrypted channel (asymmetric encryption: public and private keys)
- encrypted authentication user/password
  - alternatively: public key authentication
- support for file transfer (scp)

E-mail

- electronic mailing system
- the first service with great popularity
- software:
  - MTA (Mail Transfer Agent) – sendmail, postfix, gmail, Microsoft Exchange
  - MUA (Mail User Agent) – Thunderbird, MS Outlook, Mailbird, Opera
  - MDA (Mail Delivery Agent) – procmail
- POP3/IMAP4 protocol
- MUA $---$smtp$--->$ MTA $---$smtp$--->$ MTA $---$smtp$--->$ ... $--->$ MDA $---$pop3/imap4$--->$ MUA

E-mail: protocols

SMTP

- TCP port 25
- for sending a messsage from MUA to MTA
- for communication between MTAs

POP3

- TCP port 110
- for reading of the received message (from MDA by MUA)

IMAP4

- TCP port 143, replaces POP3

Web

- the most used internet service
- HTML, Cascading Style Sheets (CSS) and JavaScript
- HTTP protocol
  - TCP port 80
  - no encryption
- HTTPS is HTTP over SSL/TSL encryption layer
  - TCP port 443
- server does not store information about states
- cookies is state information saved at the client side
- scripts

NTP

Network Time Protocol

- clock synchronization between computers over variable-latency data networks
- UDP port 123
- practically achievable accuracy of 1-10 ms
- hierarchical system of NTP servers
  - the number "Stratum" indicates the distance from the primary source
  - Stratum-0 - server with external time source (atomic clock, GPS, DCF)

BOOTP, DHCP

- general purpose: assigning network configuration for computers
- Bootstrap protocol allowed the station to get IP address, mask, gateway, DNS server address and image of operating system
- Dynamic Host Configuration Protocol
  - uses the same ports as BOOTP (UDP 67/68)
  - support for dynamic IP adresses
  - support for time-limited IP addresses
  - more options – NTP, DNS, etc.
  - IPv6 support

Streaming

- transmission of audiovisual content
  - in real time: TV, radio
  - on demand: based on client request (eg. YouTube)
- protocols:
  - RTSP (Real-time Streaming Protocol)
  - RTP (Real-time Transport Protocol)
  - RTCP (Real-time Transport Control Protocol)
- unicast x multicast

VOIP I

Voice over IP

- internet telephony
- codecs
  - ITU patented standards: G.711, G.722, ... , G.729.1
  - Google: internet Speech Audio Codec (iSAC)
  - SPEEX (BSD license)
- protocols
  - H.323, standard ITU-T for packet networks: signaling/control
  - SIP (Session Initiation Protocol)

VOIP II

- equipment
  - MCU (Multipoint Control Unit): support for video conference
  - VoIP gateway (between telephone network and VoIP)
  - VoIP gatekeeper: client registration
- end devices
  - IP telephone
  - videoconferencing equipment
  - software on the computer

Peer-to-Peer Networks

Clients are communicating directly

- BitTorrent
  - structured network
  - indexes content in a distributed table (hash)
  - effective direction of the request
- Bitcoin
- Tor
- Delivery Optimization by Microsoft
  - Windows 10