Network Security
Introduction to networks

Radboud University, The Netherlands

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What is a (computer) network

Definition
A *computer network* is two or more computers that are connected, so that information can be transmitted between them.

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- The phone network? Yes
  (phones and backbone infrastructure are (special) computers)

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- Session initialization and termination
- Synchronization of communication

A simple example: `netcat`

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- What information (sequence of bits) goes through the cable?

The lowest level: Ethernet

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- MAC stands for "media access control"
- Specified in IEEE 802, not only used by Ethernet
- Ethernet ensures that bits are correctly transmitted
  - Transmit data in *frames*
  - Detect and recover from collisions
  - Ethernet uses a 32-bit checksum

The Ethernet frame

Preamble	Start of Delimiter	Destination MAC address	Source MAC address	802.1Q tag (optional)	Ethertype or Length	Payload	Frame check sequence (32-bit CRC)	Interpacket gap
7 Bytes	1 Byte	6 Bytes	6 Bytes	(4 Bytes)	2 Bytes	46–1500 Bytes (42–1500 Bytes)	4 Bytes	12 Bytes

- ▶ Most interesting for us: MAC addresses (and payload)
- ▶ Minimal payload size is 46 bytes (without 802.1Q tag) or 42 bytes (with 802.1Q tag)
- ▶ Gigabit Ethernet defines *Jumbo Frames* with payload >1500 bytes

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- ▶ Multiple versions of IP, most important: IPv4 and IPv6
- ▶ For the moment, only consider IPv4:
  - ▶ 32-bit addresses (typically written in *dotted decimal*)
  - ▶ *Hostnames*, such as `tyrion` or `arya` are aliases for such an IP address
  - ▶ Multiple mechanisms to map hostnames to IP addresses, easiest one: `/etc/hosts`

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- ▶ Entry in /etc/hosts on arya:

        192.168.42.1   tyrion

IP networks and addresses

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  - ▶ Specify network together with mask, e.g:
  - ▶ Example: 192.168.42.0/24

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- 127.0.0.0/8: Loopback, important host: 127.0.0.1 (localhost)

Picture source: http://ars.userfriendly.org/cartoons/?id=20010523

The IP header

0 1 2 3	4 5 6 7	8 9 10 11 12 13	14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Version	IHL	DSCP	ECN	Total Length
Identification			Flags	Fragment Offset
Time to Live		Protocol		Header Checksum
Source IP Address				
Destination IP Address				
Options . . .				

Address mapping from IP to MAC: ARP

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- ▶ arya remembers this information in the *ARP cache*

Getting to the right process: TCP

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- Solution: Transport Control Protocol (TCP)
- TCP introduces *port* numbers
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- ▶ Examples: 22 (SSH), 25 (SMTP), 80 (HTTP), 443 (HTTPS)
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- ▶ Low ports can typically only be opened (used by an application) with root rights
- ▶ TCP does *much* more than offering ports; e.g:
  - ▶ Creates a *reliable* connection
  - ▶ Takes care of retransmissions
  - ▶ Congestion control

The TCP header

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Source Port	Destination Port
Sequence Number	
Acknowledgement Number (if ACK set)	

Data Offset	Re-served 0 0 0	N S	C W R	E C E	U R G	A C K	P S H	R S T	S Y N	F I N	Window Size
Checksum											Urgent pointer (if URG set)

Options
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TCP sessions

- Before sending data, create TCP connection with three-way handshake:
  - Client sends SYN, SEQ=X
  - Server answers with SYN, ACK, SEQ=Y, ACK=$X+1$
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- Termination of a connection uses a 4-way handshake:
    - Each side terminates independently (through a FIN)
    - Each side acknowledges the FIN of the other side

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- ► `arya` sends "Hi tyrion" through the established TCP connection
  - ► TCP segment with destination port 51966
  - ► IP packet with source IP addr: 192.168.42.2 and dest. IP addr: 192.168.42.1
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- ▶ `tyrion` receives frame, opens it up, hands payload of TCP segment to the application listening on port 51966 (netcat)

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- `tyrion`'s netcat "listens" on TCP port 51966
- `arya` looks up the IP address of `tyrion`: 192.168.42.1
- `arya` sends an ARP request (ARP who has 192.168.42.1) to the broadcast MAC address ff:ff:ff:ff:ff:ff
- `tyrion` answers with ARP reply 192.168.42.1 is at 28:d2:44:54:88:02
- `arya` establishes a TCP/IP connection to `tyrion` (TCP port 51966)
- `arya` sends "Hi tyrion" through the established TCP connection
  - TCP segment with destination port 51966
  - IP packet with source IP addr: 192.168.42.2 and dest. IP addr: 192.168.42.1
  - Ethernet frame with source MAC addr: 00:1e:68:b8:c7:eb, and dest. MAC addr: 28:d2:44:54:88:02
- `arya` sends all the bits of the Ethernet frame through the cable
- `tyrion` receives frame, opens it up, hands payload of TCP segment to the application listening on port 51966 (netcat)
- `tyrion` confirms receipt of the TCP segment (ACK)

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- `arya` closes the session, `tyrion` closes the session

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  - **send():** Send data through connected socket
  - **recv():** Receive data from connected socket
  - **close():** Close the connection, release resources allocated to socket

"netcat" client in Python

```
#!/usr/bin/env python

import socket

host = 'tyrion'
port = 51966
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect((host,port))
s.send('Hi tyrion\n')
s.close()
```

"netcat -l" in Python

```python
#!/usr/bin/env python

import socket

host = ''
port = 51966
backlog = 5
bufsize = 1024

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.bind((host,port))
s.listen(backlog)

client, address = s.accept()
data = client.recv(bufsize)
if data:
    print data
    client.close()
```

The Internet protocol suite

- ▶ The "Internet protocol suite" knows four layers:
- ▶ The *link layer*:
  - ▶ Communication of directly connected nodes
  - ▶ Physical channel, media access control
  - ▶ Examples: Ethernet (IEEE 802.3), WiFi (IEEE 802.11)

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- The application layer:
  - Process-to-Process communication
  - Examples: HTTP, SSH, SMTP

# Lightweight communication: UDP

- For some messages you do not have to ensure that they arrive
- A TCP session for sending "Hi tyrion" is like cracking nuts with a sledgehammer
- Solution: User Datagram Protocol (UDP):
  - No session initialization
  - No session termination
  - No acknowledgements
  - No guaranteed transmission
- "Send your data and hope for the best"

The UDP header

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Source Port																Destination Port															
Length																Checksum															

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0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Source Port	Destination Port
Length	Checksum
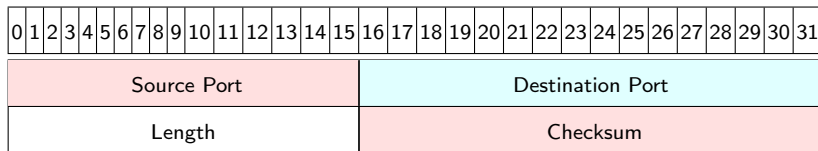
▶ The Source Port and the Checksum are even optional

Control messages: ICMP

- ICMP stands for Internet Control Message Protocol
- Provides diagnostics and control on the internet layer
- ICMP messages are in the IP payload (protocol number 1)
- Most important ICMP messages:
  - Echo request and Echo reply ("ping")
  - Destination unreachable
  - Redirect message
  - Source quench