

Contents

1 Introduction	1
2 Fundamentals of Computer Science	3
2.1 Bit	3
2.2 Representation of Numbers	4
2.2.1 Decimal System	5
2.2.2 Binary System	5
2.2.3 Octal System	6
2.2.4 Hexadecimal System	7
2.3 File and Storage Dimensions	8
2.4 Information Representation	9
2.4.1 ASCII Encoding	10
2.5 Unicode	12
2.6 Representation of Strings	13
3 Fundamentals of Computer Networking	15
3.1 History of Computer Networks	15
3.2 Mandatory Components of Computer Networks	17
3.3 Computer Networks distinguished by their Dimensions	18
3.4 Data Transmission	19
3.4.1 Serial and Parallel Transmission	19
3.4.2 Synchronous and Asynchronous Transmission	20
3.4.3 Directional Dependence of Data Transmission	21
3.5 Devices in Computer Networks	21
3.6 Topologies of Computer Networks	24
3.6.1 Bus Network	24
3.6.2 Ring Network	25
3.6.3 Star Network	26
3.6.4 Mesh Network	26
3.6.5 Tree Network	27
3.6.6 Cellular Network	27
3.7 Frequency and Data Signal	28
3.8 Fourier Series and Bandwidth	28
3.9 Bit Rate and Baud Rate	29
3.10 Bandwidth and Latency	29
3.10.1 Bandwidth-Delay Product	30
3.11 Media Access Control	32
3.11.1 Deterministic Media Access Control	32
3.11.2 Non-deterministic Media Access Control	32
3.12 Collision Domain	33

4 Protocols and Reference Models	35
4.1 TCP/IP Reference Model	36
4.2 Hybrid Reference Model	37
4.2.1 Physical Layer	37
4.2.2 Data Link Layer	38
4.2.3 Network Layer	39
4.2.4 Transport Layer	39
4.2.5 Application Layer	40
4.3 How Communication works	41
4.4 OSI Reference Model	42
4.4.1 Session Layer	42
4.4.2 Presentation Layer	43
4.5 Conclusion on the Reference Models	43
5 Physiscal Layer	45
5.1 Networking Technologies	45
5.1.1 Ethernet	45
5.1.2 Token Ring	47
5.1.3 Wireless Local Area Network (WLAN)	48
5.1.4 Bluetooth	61
5.2 Transmission Media	64
5.2.1 Coaxial Cables	64
5.2.2 Twisted Pair Cables	67
5.2.3 Fiber-optic Cables	77
5.3 Structured Cabling	78
5.4 Devices of the Physical Layer	79
5.4.1 Impact of Repeaters and Hubs on the Collision Domain	81
5.5 Encoding Data with Line Codes	82
5.5.1 Non-Return to Zero (NRZ)	84
5.5.2 Non-Return to Zero Invert (NRZI)	85
5.5.3 Multilevel Transmission Encoding – 3 Levels (MLT-3)	86
5.5.4 Return-to-Zero (RZ)	86
5.5.5 Unipolar RZ	87
5.5.6 Alternate Mark Inversion (AMI)	87
5.5.7 Bipolar with 8 Zeros Substitution (B8ZS)	88
5.5.8 Manchester	89
5.5.9 Manchester II	90
5.5.10 Differential Manchester Encoding	90
5.6 Line Codes which improve the Payload	91
5.6.1 4B5B Encoding	91
5.6.2 5B6B Encoding	92
5.6.3 8B10B Encoding	93
5.7 Further Line Codes	94
5.7.1 8B6T Encoding	95
6 Data Link Layer	97
6.1 Devices of the Data Link Layer	97
6.1.1 Learning Bridges	100
6.1.2 Loops on the Data Link Layer	101
6.1.3 Spanning Tree Protocol (STP)	104
6.1.4 Impact of Bridges on the Collision Domain	108
6.2 Addressing in the Data Link Layer	108

6.2.1 Format of MAC Addresses	109
6.2.2 Uniqueness of MAC Addresses	110
6.2.3 Security Aspects of MAC Addresses	110
6.3 Framing	111
6.3.1 Character Count in the Frame Header	111
6.3.2 Byte/Character Stuffing	112
6.3.3 Bit Stuffing	113
6.3.4 Line Code Violations	113
6.4 Framing in current Computer Networks	114
6.4.1 Ethernet Frames	114
6.4.2 WLAN Frames	116
6.4.3 WLAN Control Frames	119
6.5 Maximum Transmission Unit (MTU)	120
6.6 Error-detection Codes	121
6.6.1 Two-dimensional Parity-check Code	121
6.6.2 Cyclic Redundancy Check	122
6.7 Error-correction Codes	124
6.8 Media Access Control Methods	125
6.8.1 Media Access Control Method of Ethernet	125
6.8.2 Media Access Control Method of WLAN	129
6.9 Flow Control	135
6.10 Address resolution with ARP	136
7 Network Layer	139
7.1 Devices of the Network Layer	139
7.1.1 Impact of Routers on the Collision Domain	140
7.1.2 Broadcast Domain	141
7.2 Addressing in the Network Layer	141
7.2.1 Format of IPv4 Addresses	143
7.2.2 Subnets in the IPv4 Address Space	145
7.2.3 Private IPv4 Address Spaces	147
7.2.4 Structure of IPv4 Packets	148
7.2.5 Fragmentation of IPv4 Packets	150
7.2.6 Representation and Structure of IPv6 Addresses	151
7.2.7 Representation of Networks in the IPv6 Address Space	153
7.2.8 Selected IPv6 Address Spaces	154
7.2.9 Embed IPv4 Addresses into the IPv6 Address Space	154
7.2.10 Structure of IPv6 Packets	155
7.3 Forwarding and Path Determination	157
7.4 Routing Information Protocol (RIP)	158
7.4.1 Count-to-Infinity	159
7.4.2 Split Horizon	161
7.4.3 Conclusion on RIP	162
7.5 Open Shortest Path First (OSPF)	164
7.5.1 Routing Hierarchy with OSPF	165
7.5.2 Functioning of OSPF	166
7.5.3 Structure of OSPF Messages	167
7.5.4 Conclusion on OSPF	169
7.6 Internetworking	170
7.7 Network Address Translation	172
7.8 Diagnostic and Error Messages via ICMP	175

8 Transport Layer	179
8.1 Characteristics of Transport Layer Protocols	179
8.2 Addressing in the Transport Layer	180
8.3 User Datagram Protocol (UDP)	182
8.3.1 Format of UDP Segments	183
8.4 Transmission Control Protocol (TCP)	183
8.4.1 Format of TCP Segments	185
8.4.2 Functioning of TCP	187
8.4.3 Flow Control	192
8.4.4 Congestion Control	194
9 Application Layer	203
9.1 Domain Name System (DNS)	203
9.1.1 Functioning of TCP	204
9.1.2 Example of a Domain Name Resolution	206
9.2 Dynamic Host Configuration Protocol (DHCP)	207
9.2.1 Functioning of DHCP	208
9.2.2 Structure of DHCP Messages	209
9.2.3 DHCP Relay	211
9.3 Telecommunication Network (Telnet)	212
9.4 Hypertext Transfer Protocol (HTTP)	213
9.5 Simple Mail Transfer Protocol (SMTP)	218
9.6 Post Office Protocol Version 3 (POP3)	219
9.7 File Transfer Protocol (FTP)	220
10 Network Virtualization	223
10.1 Virtual Private Networks (VPN)	223
10.1.1 Technical types of VPNs	224
10.2 Virtual Local Area Networks (VLAN)	225
11 Command Line Tools	229
11.1 ethtool	232
11.2 mii-tool	233
11.3 iwconfig	233
11.4 iwlist	234
11.5 arp	234
11.6 ifconfig	235
11.7 ip	235
11.8 iftop	237
11.9 tcpdump	237
11.10 termshark	238
11.11 route	238
11.12 ping	239
11.13 traceroute	239
11.14 netstat	240
11.15 nmap	241
11.16 dhclient	241
11.17 dig	242
11.18 ftp	242
11.19 nc	242
11.20 netperf	243
11.21 nslookup	244

11.22 ssh	244
11.23 telnet	245
Technical Terms	247
Glossary	255
References	265
Index	267