Freie Universität Berlin

Telematics

Chapter 2

The Internet as a Blackbox: Terminology & Concepts

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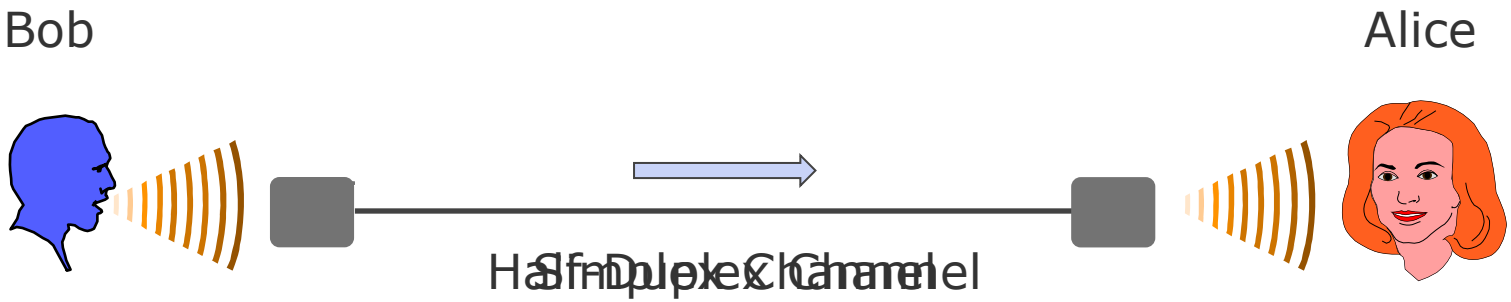
Contents

- The Big Picture: Internet as a Bit Delivery Service
  - Virtual Pipe
- Basic Terminology
  - Data vs. Information vs. Signal
  - Communication Protocol
- Basic Concepts
  - Evaluation Communication Quality
  - Client-Server Architecture
  - Peer-to-Peer Architecture

Back to a String and Tin Cans

Back to a String and Tin Cans



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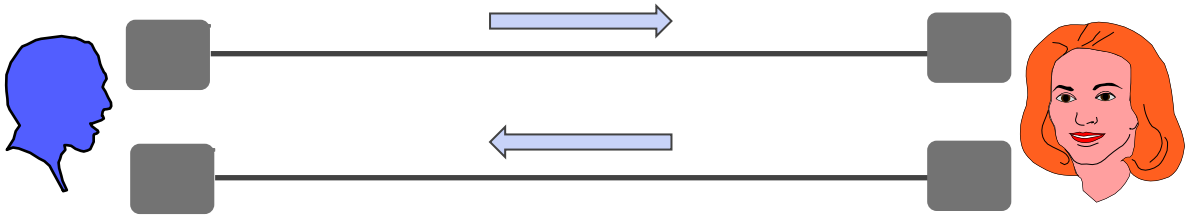
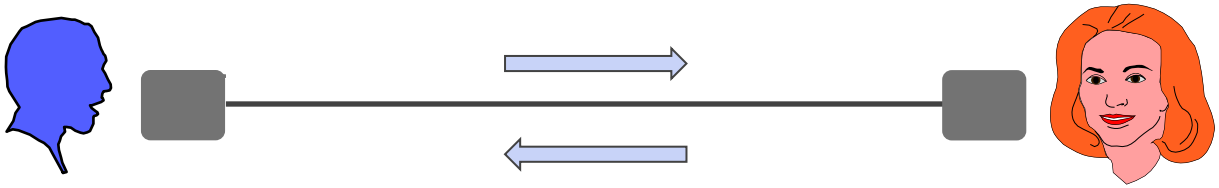


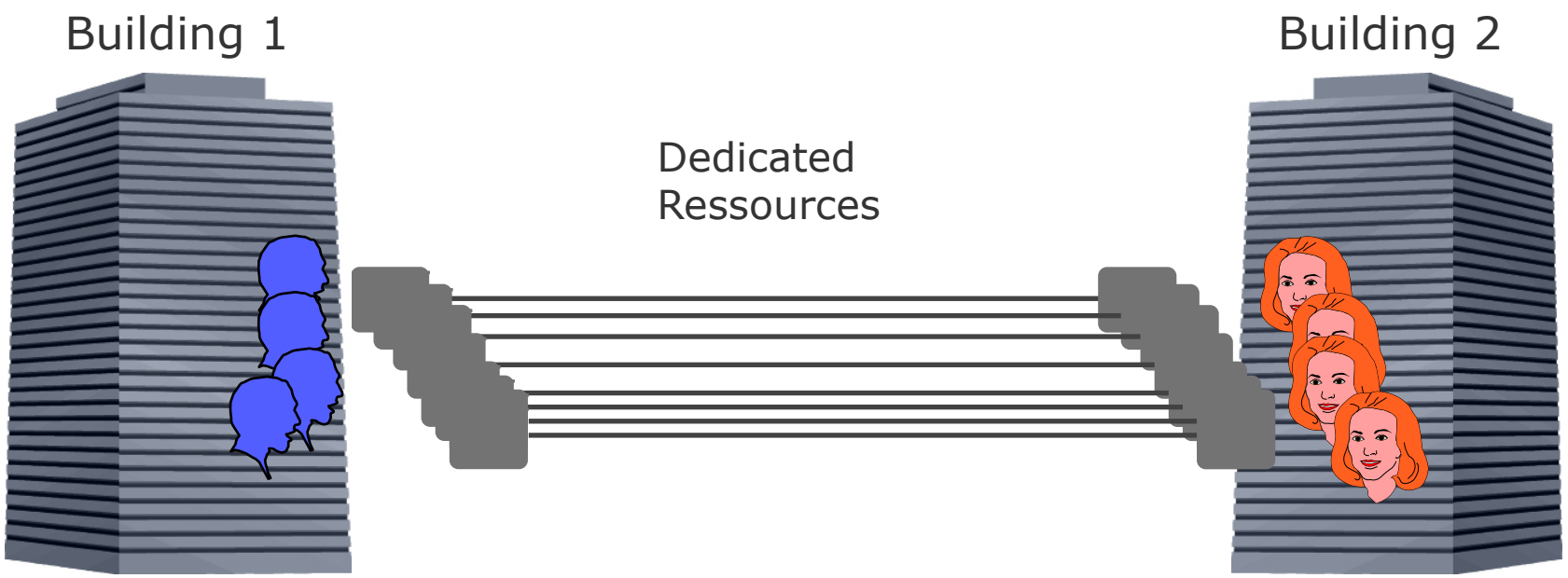
Duplex Channel

Connecting Two Individuals?



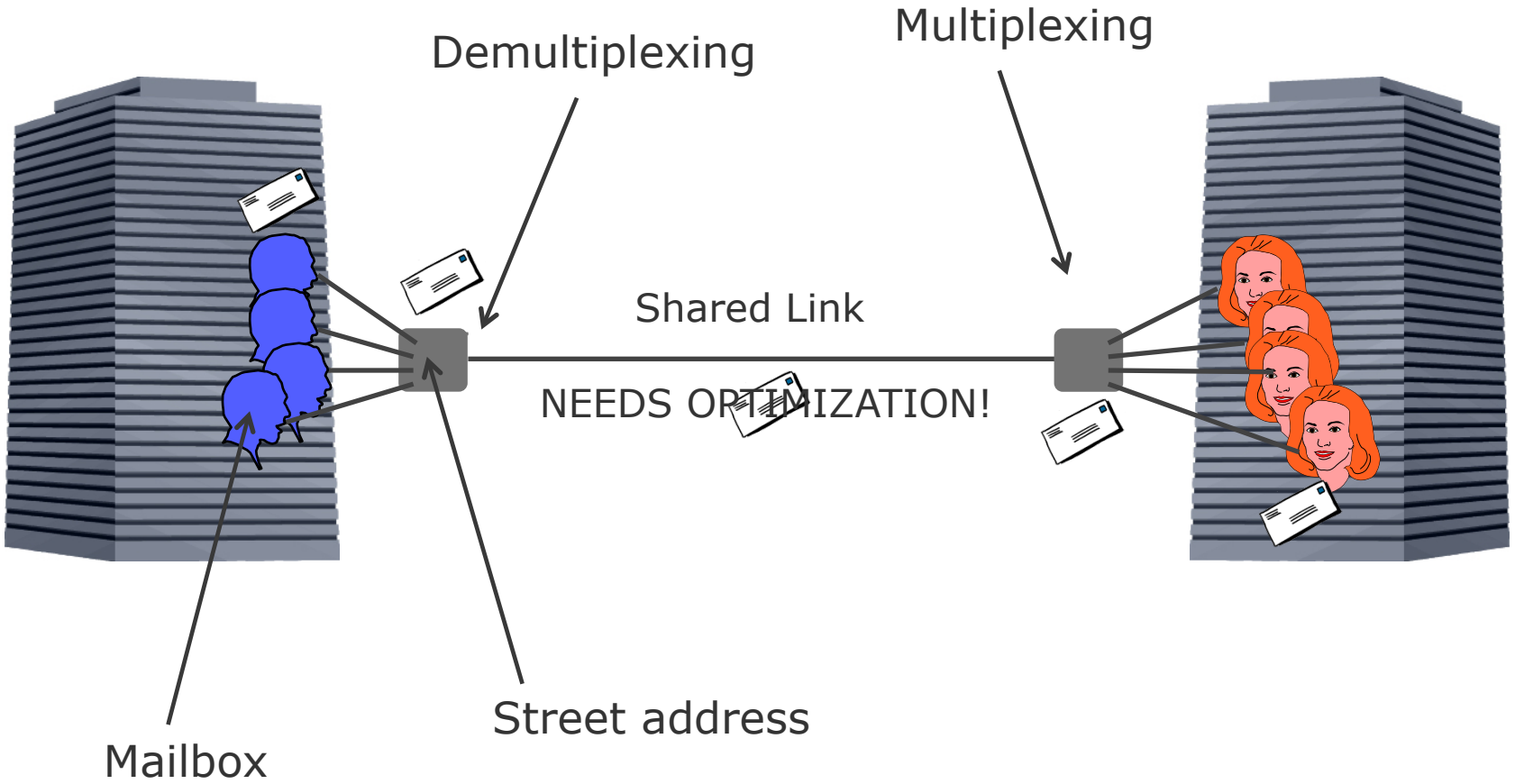
Duplex Channel

Connecting Two Sites?



Problem: Waste of resources! How can we share resources?

Ressource Sharing: Multiplexing, Addressing

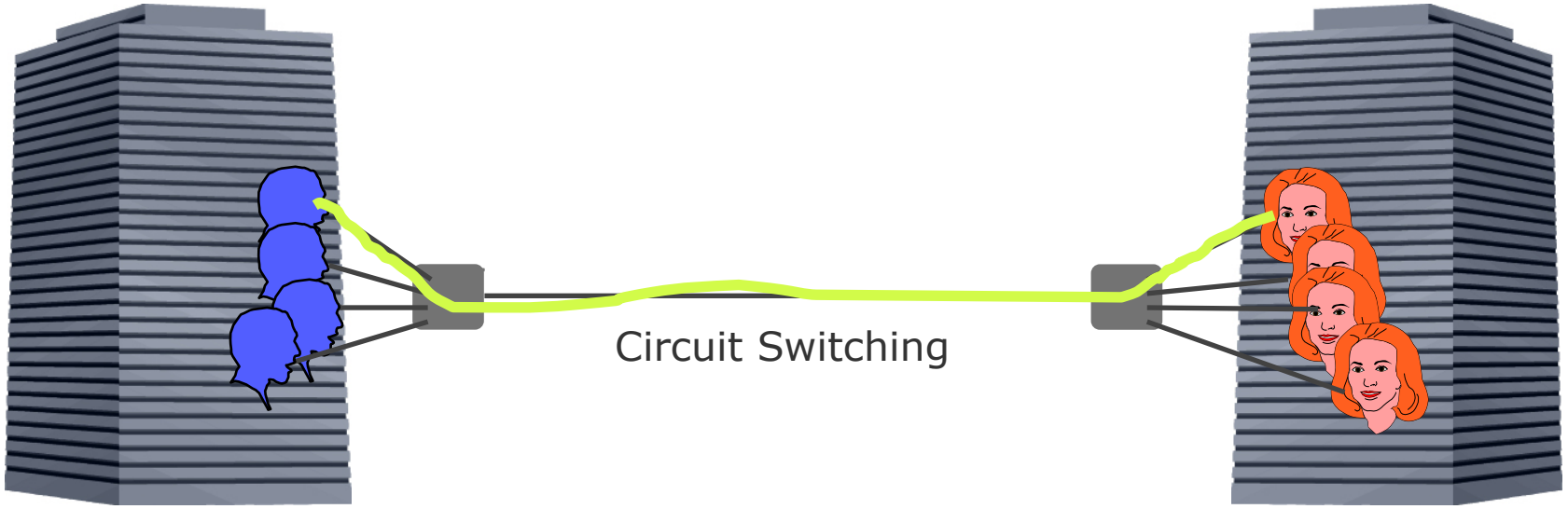


Sharing Communication Resources

- Sharing resources saves costs:
  - By communication, one can access resources of other parties
  - Several institutions can share expensive resources
  - Requirements:
    - Efficient mechanisms for data exchange between components of a distributed system
    - Efficient mechanisms to minimize blocking due to multiplexing

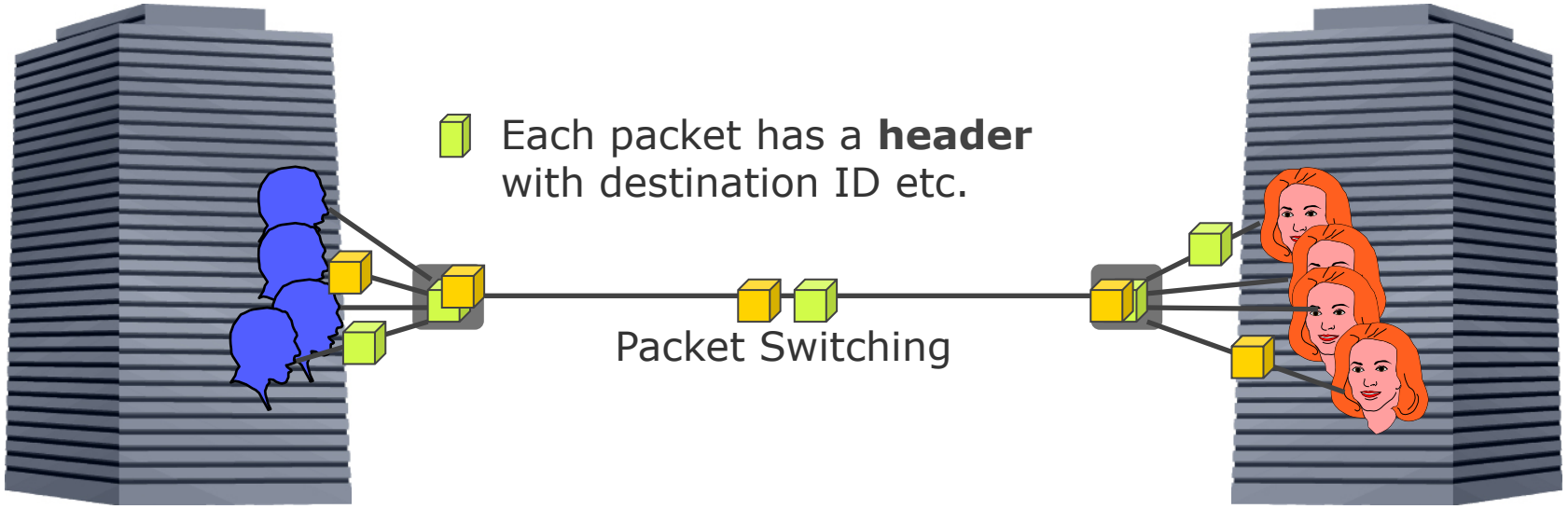
- The "driving power" for the enormous increase of data communication:
  - Decreasing costs for hardware…
    … while the computing power increases.
  - Jevons paradox

Circuit Switching vs. Packet Switching



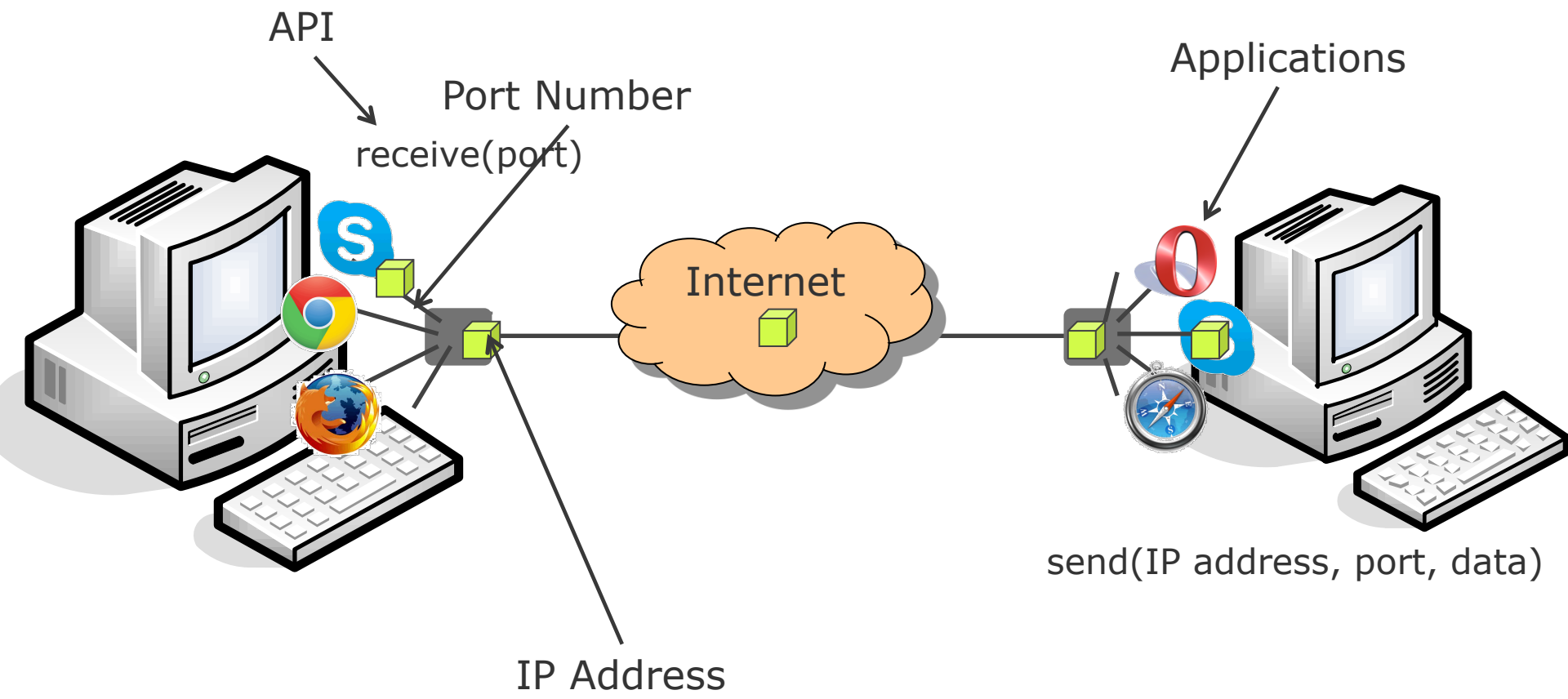
- **Circuit switching** establishes dynamically a dedicated communication channel before communication starts
  - Explicit communication channel => transmitted data don't need to carry addresses
  - Provides full bandwidth of the channel to the parties
  - Disadvantages? What happens with the reserved resources during silence?

Circuit Switching vs. Packet Switching



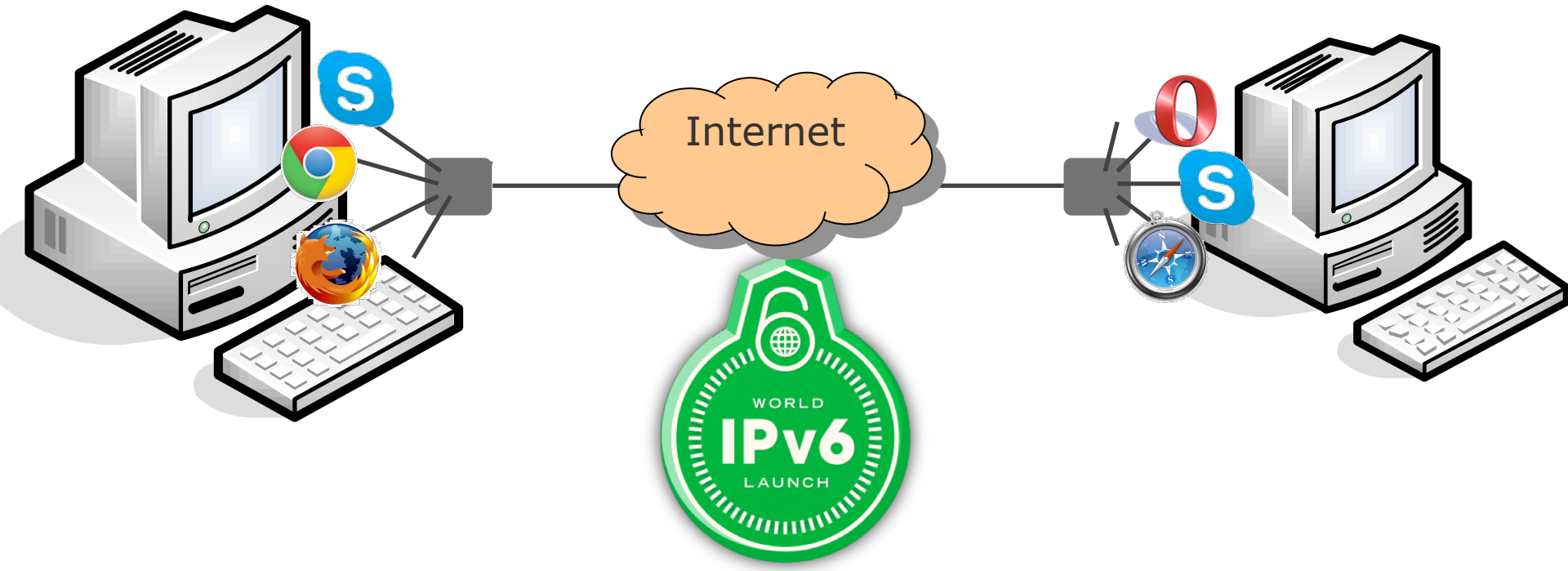
- **Packet switching** allows parallel sharing of the same resource for different communication endpoints
  - Overhead: Transmitted data need to carry address
  - Buffers introduce variable delay but are required. Why?
  - More: L. G. Roberts: "The Evolution of Packet Switching", Proc. of IEEE, 66(11), 1978.

The Internet as a Bit Delivery Service



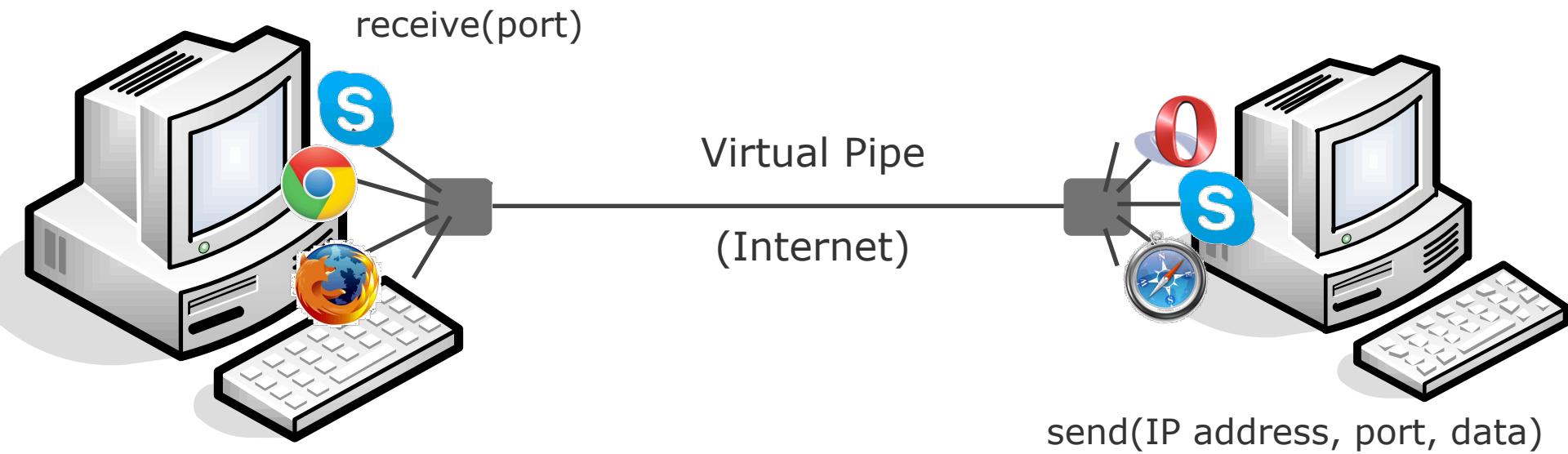
- Port numbers are coded on 16 bits, from 0 to 65535
- IPv4 addresses are coded on 32 bits, represented as four octets A.B.C.D

The Internet as a Bit Delivery Service



- Port numbers are coded on 16 bits, from 0 to 65535
- IPv6 addresses are coded on 128 bits, represented in colon hex notation

The Internet as a Bit Delivery Service



- **Port** allows application multiplexing on a single host
- **Application Programming Interface (API)** allows developers to access other services

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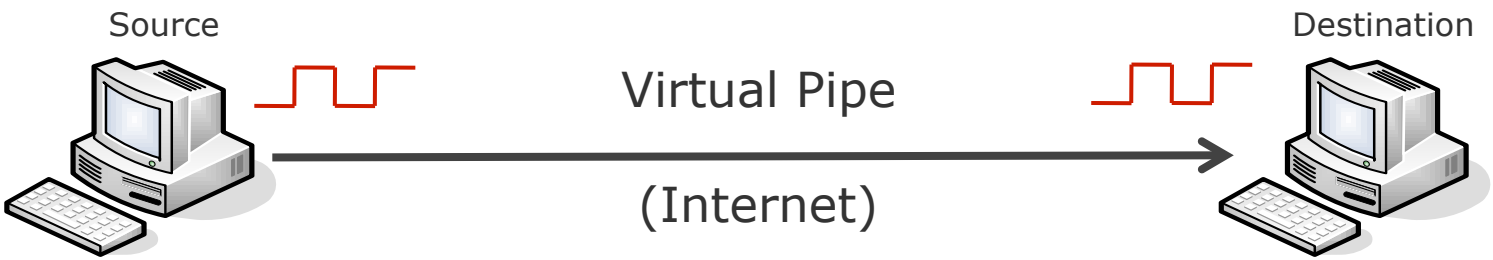
What are we sending/receiving?

Data (File, Stream…)

1010011100
1101011100
1101011100
1101010100
0001110101
1110001...

Digital Data (= Binary Data)



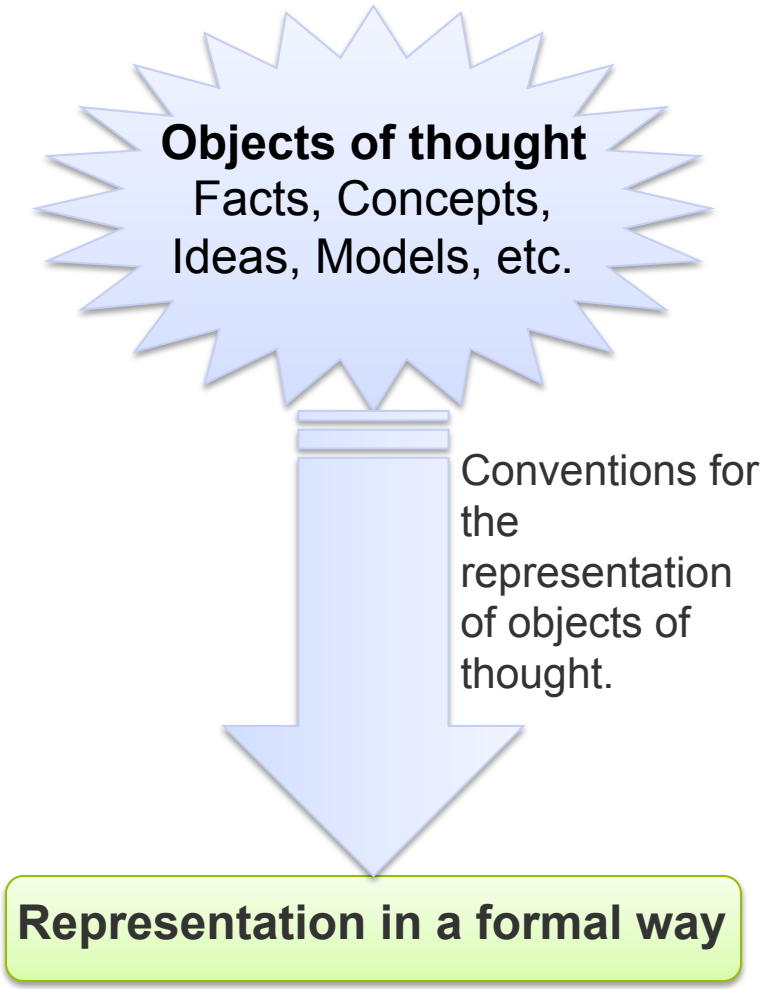
Digital Data Communication = processing and transport of digital data between interconnected computers

The Term of Data

- An apple can be represented by:
  - The word "apple"
  - The drawing of an apple
  - etc.

- A definition for "**data**":
  - **Representation** of facts, concepts, and statements in a formal way which is **suitable for communication, interpretation, and processing** by human beings or technical means.

  - Examples for data representation
    - Spoken language
    - Sign language
    - Written language



Example Data: ASCII Characters

- American Standard Code for Information Interchange (ASCII)
  - Character encoding (English characters only)
  - Printable, non-printable, and control characters

Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char
0	0	0		32	20	40	[space]	64	40	100	@	96	60	140	`
1	1	1		33	21	41	!	65	41	101	A	97	61	141	a
2	2	2		34	22	42	"	66	42	102	B	98	62	142	b
3	3	3		35	23	43	#	67	43	103	C	99	63	143	c
4	4	4		36	24	44	$	68	44	104	D	100	64	144	d
5	5	5		37	25	45	%	69	45	105	E	101	65	145	e
6	6	6		38	26	46	&	70	46	106	F	102	66	146	f
7	7	7		39	27	47	'	71	47	107	G	103	67	147	g
8	8	10		40	28	50	(	72	48	110	H	104	68	150	h
9	9	11		41	29	51	)	73	49	111	I	105	69	151	i
10	A	12		42	2A	52	*	74	4A	112	J	106	6A	152	j
11	B	13		43	2B	53	+	75	4B	113	K	107	6B	153	k
12	C	14		44	2C	54	,	76	4C	114	L	108	6C	154	l
13	D	15		45	2D	55	-	77	4D	115	M	109	6D	155	m
14	E	16		46	2E	56	.	78	4E	116	N	110	6E	156	n
15	F	17		47	2F	57	/	79	4F	117	O	111	6F	157	o
16	10	20		48	30	60	0	80	50	120	P	112	70	160	p
17	11	21		49	31	61	1	81	51	121	Q	113	71	161	q
18	12	22		50	32	62	2	82	52	122	R	114	72	162	r
19	13	23		51	33	63	3	83	53	123	S	115	73	163	s
20	14	24		52	34	64	4	84	54	124	T	116	74	164	t
21	15	25		53	35	65	5	85	55	125	U	117	75	165	u
22	16	26		54	36	66	6	86	56	126	V	118	76	166	v
23	17	27		55	37	67	7	87	57	127	W	119	77	167	w
24	18	30		56	38	70	8	88	58	130	X	120	78	170	x
25	19	31		57	39	71	9	89	59	131	Y	121	79	171	y
26	1A	32		58	3A	72	:	90	5A	132	Z	122	7A	172	z
27	1B	33		59	3B	73	;	91	5B	133	[	123	7B	173	{
28	1C	34		60	3C	74	<	92	5C	134	\	124	7C	174	|
29	1D	35		61	3D	75	=	93	5D	135	]	125	7D	175	}
30	1E	36		62	3E	76	>	94	5E	136	^	126	7E	176	~
31	1F	37		63	3F	77	?	95	5F	137	_	127	7F	177	

The Term of Information

- Generally, **information** is whatever is capable of causing a human mind to change its opinion about the current state of the real world. Formally, and especially in science and engineering, information is whatever **contributes to a reduction in the uncertainty of the state of a system**; in this case, uncertainty is usually expressed in an objectively measurable form.

  (Oxford Reference Online)

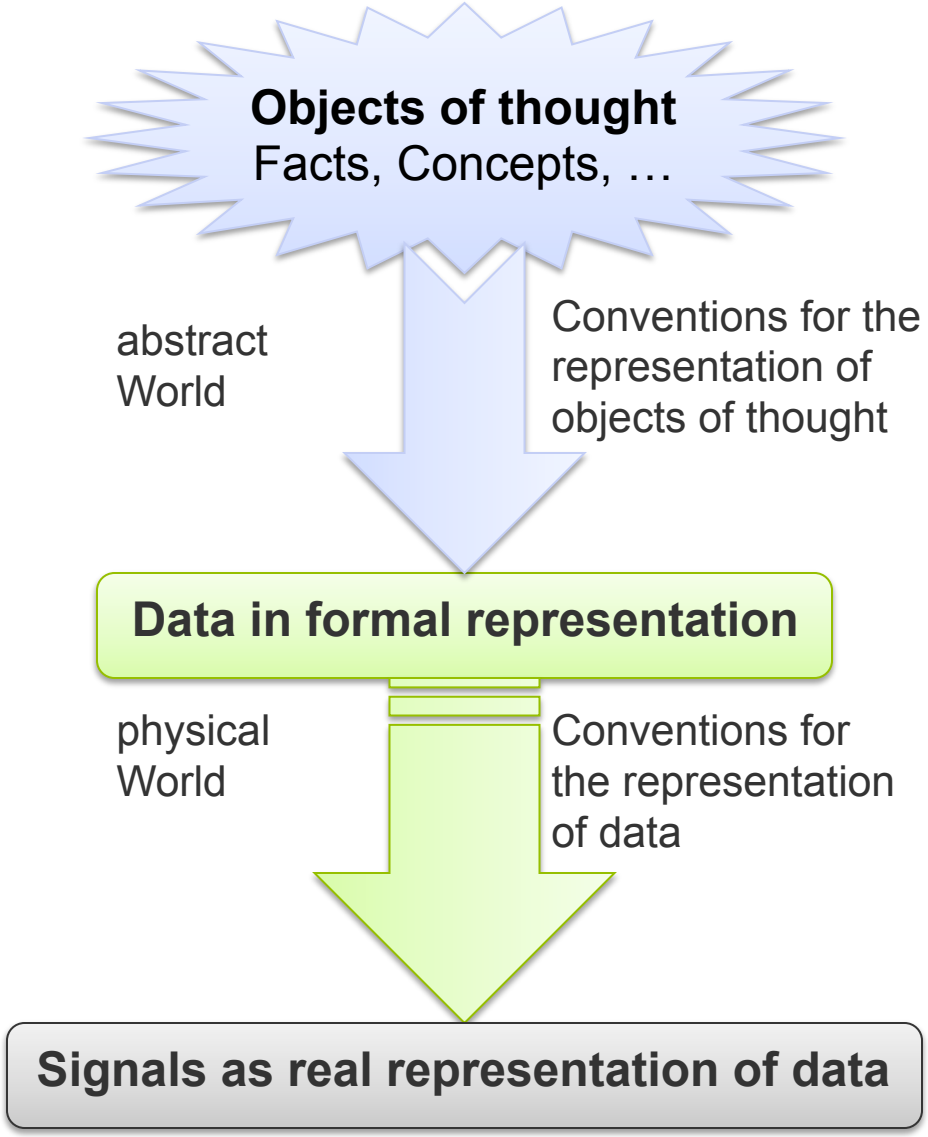
- The communication or reception of knowledge or intelligence

- Information has to be distinguished from any **medium** that is capable of **carrying** it

- Humans and machines can handle **data**, however only humans can handle **information**

The Term of Signal

- A signal is the physical representation of data by **spatial** or **timely variation** of physical characteristics
  - The variable parameter that contains information and by which information is transmitted in an electronic system or circuit.
  - The signal is often a **voltage source** in which the **amplitude**, **frequency**, and **waveform** can be varied.
- Signal is the real physical representation of an abstract representation



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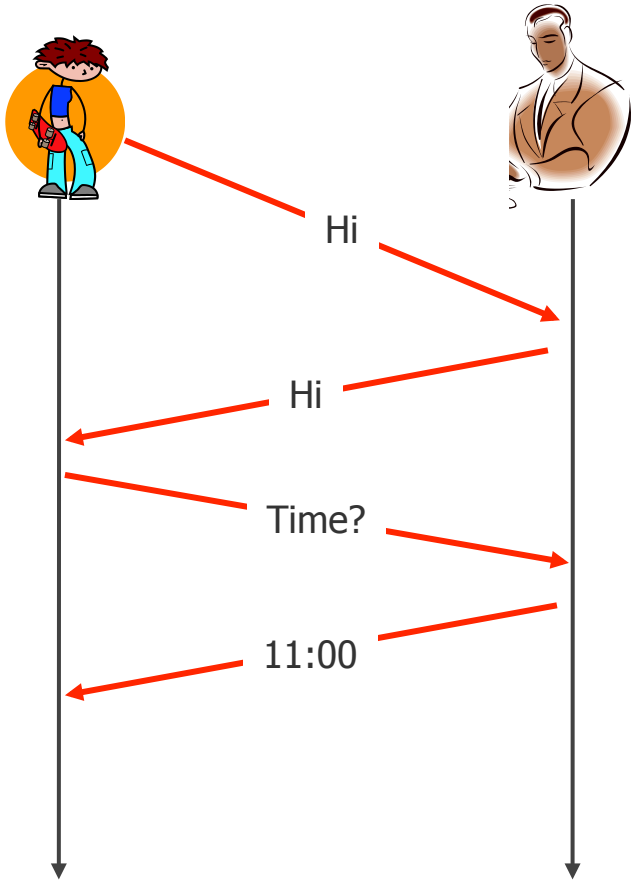
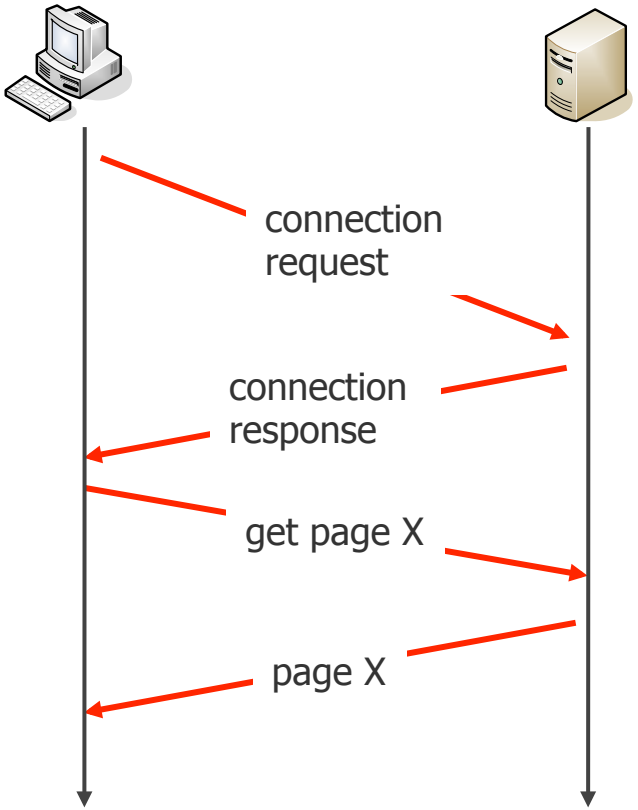
What is a Protocol?

- Human protocols:
  - "What's the time?"
  - "I have a question"
  - Introductions
- In General
  - … specific messages sent
  - … specific actions taken when messages received or other events happen
- Network protocols:
  - Machines rather than humans
  - All communication activities in the Internet is governed by protocols
- In General
  - Protocols define format, order of messages sent and received among network entities, and actions taken on message transmission and receipt

What is a Protocol?





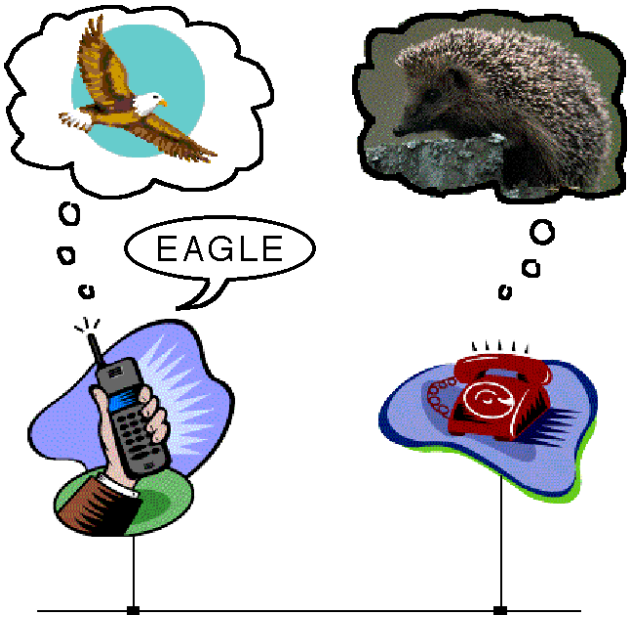
Why Protocols?

To enable understanding in communication, all communication partners have to speak the same "language".

Protocol

A protocol is **a set of unambiguous specifications** defining how processes communicate with one another through a connection (wire, radio etc.).

- Types of message
- Syntax of messages
- Semantics of messages
- When/how to send a message
- When/how to respond to a message
- Control/multiplexing over media access
- Priorities
- Handling of transmission errors
- Sequence control / Fragmentation
- …



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Communication Quality

- Characteristics of the bit delivery service?
- Need for quantitative, measurable parameters, such as:
  - Technical Performance
    - Required transmission performance, delay, jitter, throughput, data rate, etc.
  - Costs
    - Investment costs, cost of operation, etc.
  - Reliability
    - Fault tolerance, system stability, immunity, availability, 99999
  - Security and Protection
    - Eavesdropping, authentication, denial of service, etc.
- Dedicated term in the tech lingo: QoS (Quality of Service)
  - ITU standard Recommendation ITU-T E.800: definition of terms related to QoS

QoS: Latency Aspect

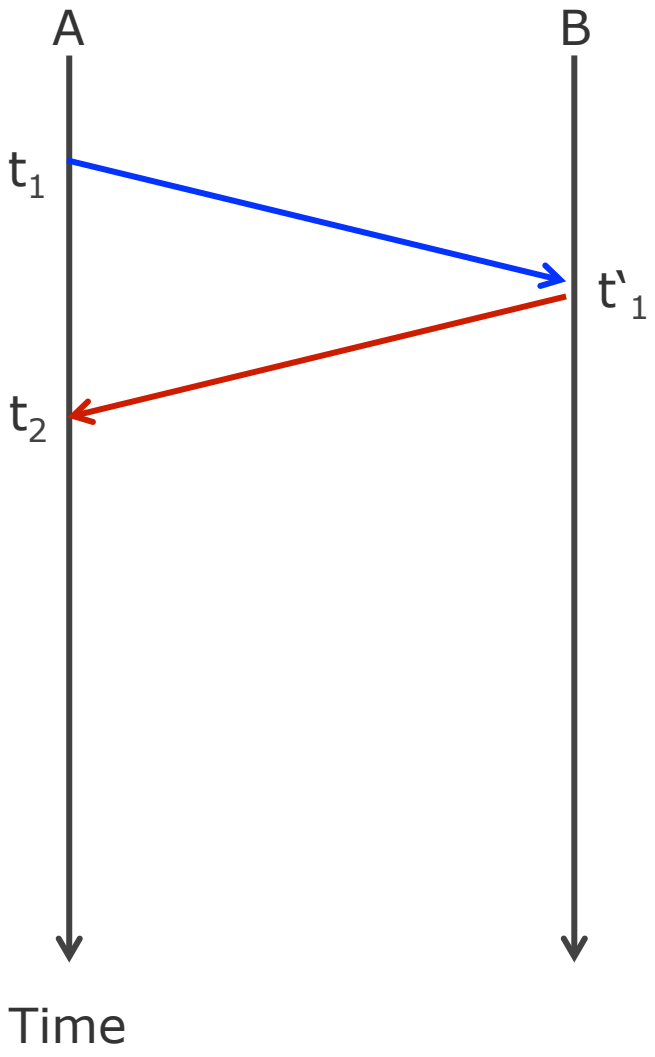
- (One-way) Delay
  - Measured in seconds [s]

  $d_1 = t'_1 - t_1$

- Round-trip-time (RTT)
  - Measured in seconds [s]

  $r_1 = t_2 - t_1$

- RTT *should* also integrate the processing time in B
  - Usually negligeable compared to delay



QoS: Stability Aspect

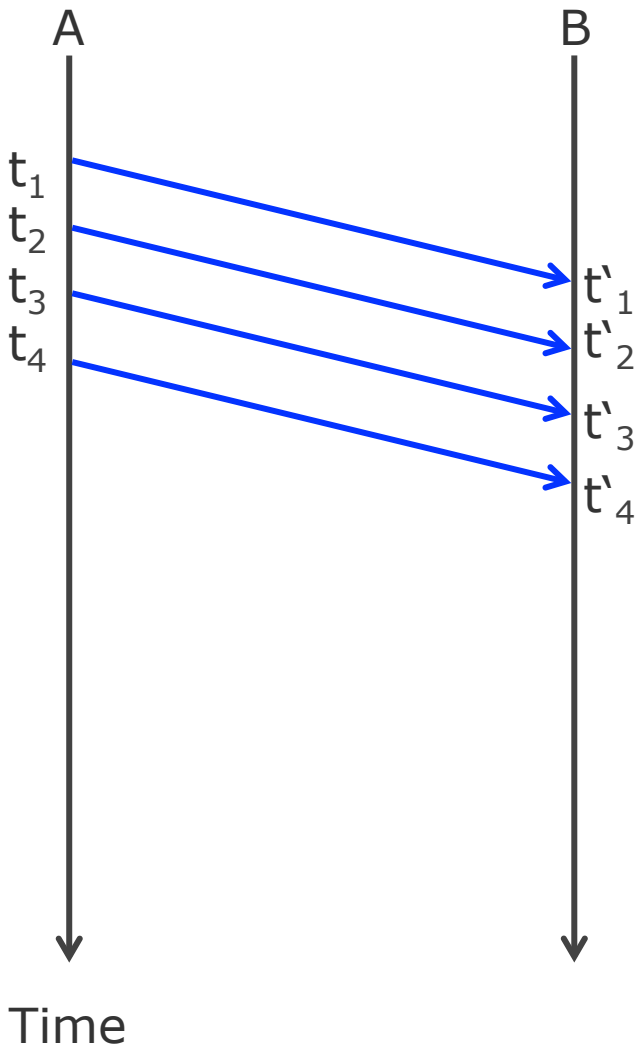
- Jitter: fluctuation between successive arrivals
  - Measured in seconds [s]
  - First calculate delay as

$$d_1 = t'_1 - t_1$$
$$d_2 = t'_2 - t_2$$
$$d_i = t'_i - t_i$$

  - Afterwards derive the jitter

$$j_1 = d_2 - d_1$$
$$j_2 = d_3 - d_2$$
$$j_i = d_{i+1} - d_i$$

- Irregular arrivals are difficult to deal with.
  - e.g. need to buffer before start of video stream, to playback at constant speed. Optimal buffer size?



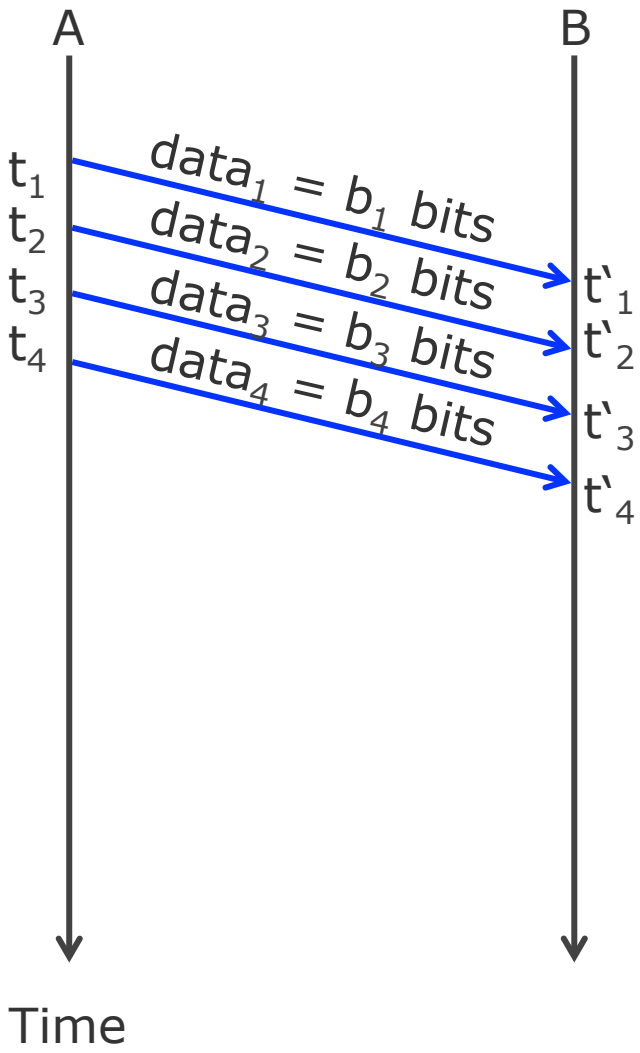
QoS: Capacity Aspect

- Throughput
  - Measured in bits per second (bit/s)

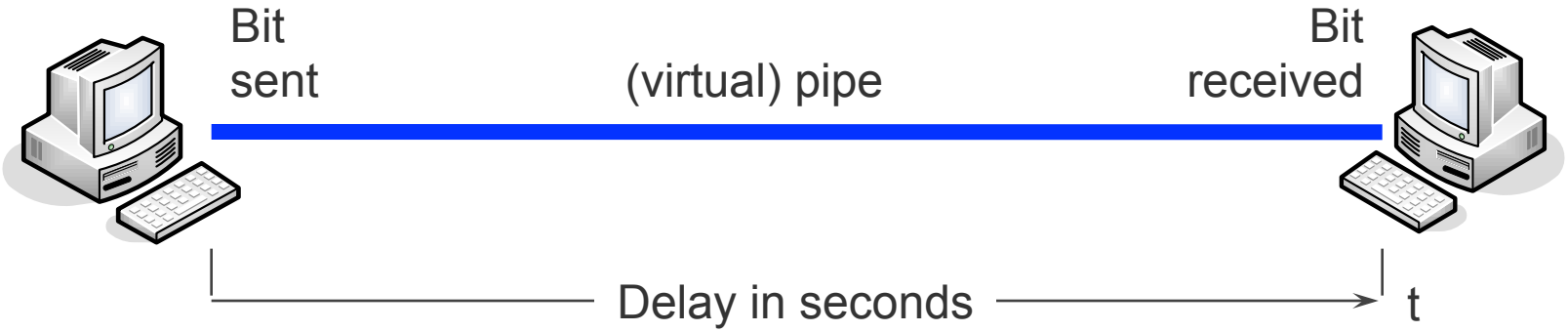
$$T = \frac{\sum data_i}{\Delta t}$$

- Goodput
  - useful throughput from the user perspective (i.e. throughput minus control traffic overhead).

- Do not use „bandwidth" as a synonym for throughput!!



QoS: More Complex Aspects



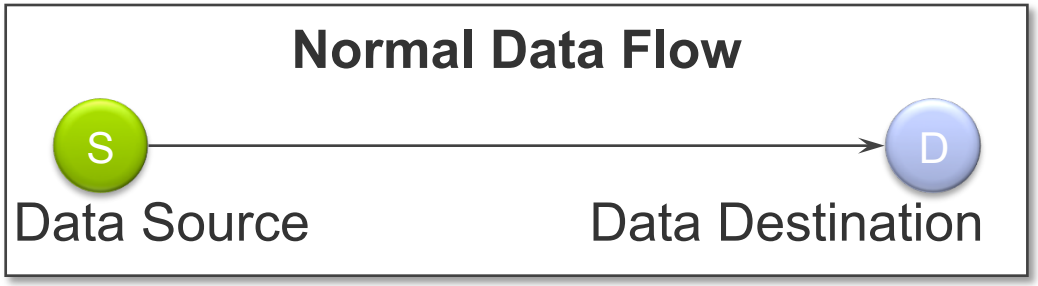
Delay-Throughput-Product =
Storing capacity of the line

Example: Store capacity of the transmission line

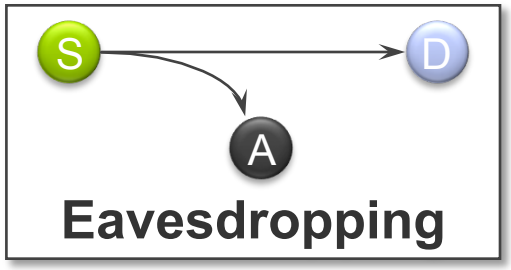
- With a connection of 1 Mbps, 200 ms delay: 1 Mbps × 0.2 s = 200 kbit
- With a connection of 100 Mbps, 100 ms: 100 Mbps × 0.1 s = 10 Mbit

QoS: Security & Privacy Aspects

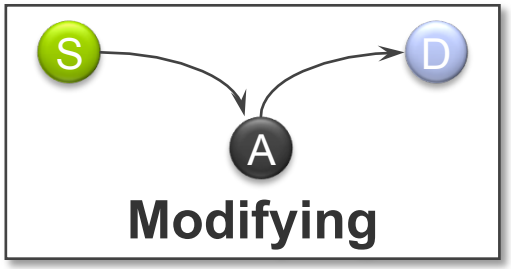
- Safety measures
  - Encryption (cryptographic codes)
  - Trustworthy systems (Authentication, Authorization)

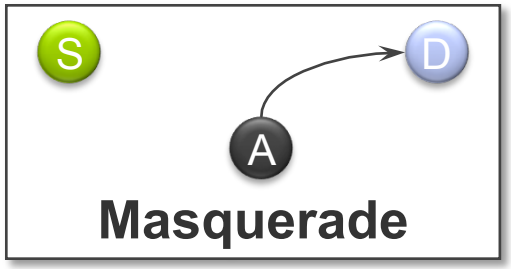


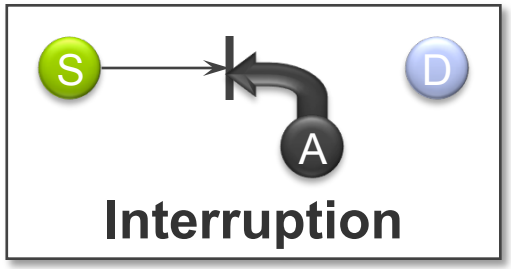
Passive:



Active:







QoS: More Basic Aspects

- Packet loss rate
  - What guarantees for the bit delivery service? Best-effort? More?

- Bit error rate
  - 'Finer-grained' caracteristic for the bit delivery service

Implications of QoS Requirements

- QoS requirements may impact the choice of communication architecture

Example 1

- You want to increase the availability of a service.
- Which architecture will be the cheapest to achieve that?

Example 2

- You want to offer online storage service.
- What are the alternatives in terms of architecture?

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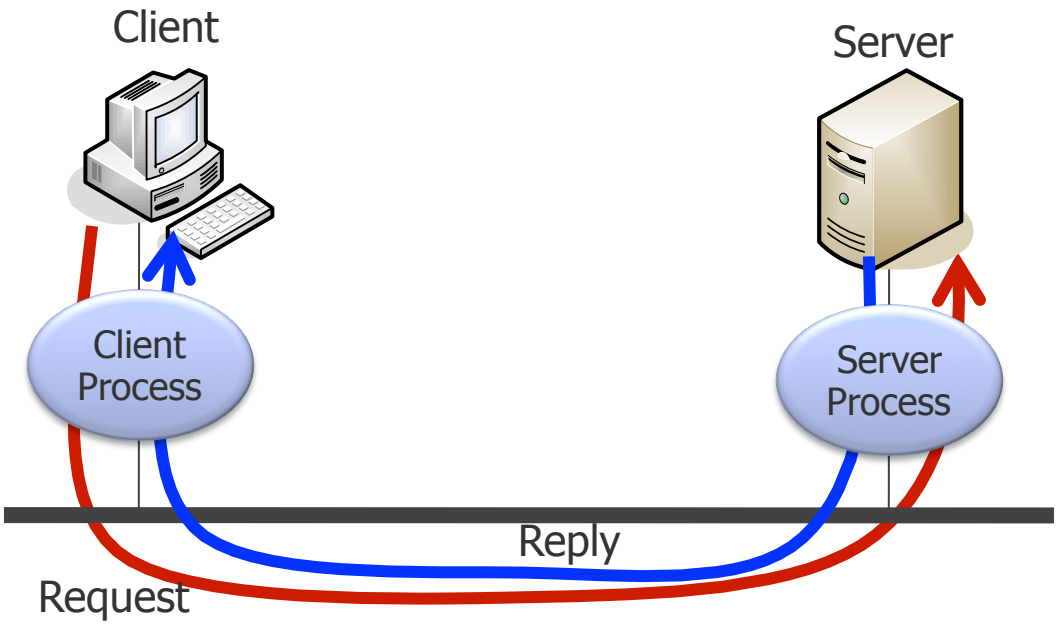
Resource Sharing: Client/Server Architecture



Advantages of the Client/Server Principle

- Cost reduction
- Better usage of resources
- Modular extensions
- Reliability by redundancy

Resource Sharing: Client/Server Architecture

- **Server**
  - Program (process) which offers a service over a network.
    Servers receive requests and return a result to the inquiring party. The services offered include simple operations (e.g. name server) or a complex set of operations (e.g. web server).
- **Client**
  - Program (process) which uses a service offered by a server.

Examples for Client/Server Systems

Client	Server
Web Browser	Web Server
E-Mail Program	Domain Name System (DNS)
FTP Client	FTP Server

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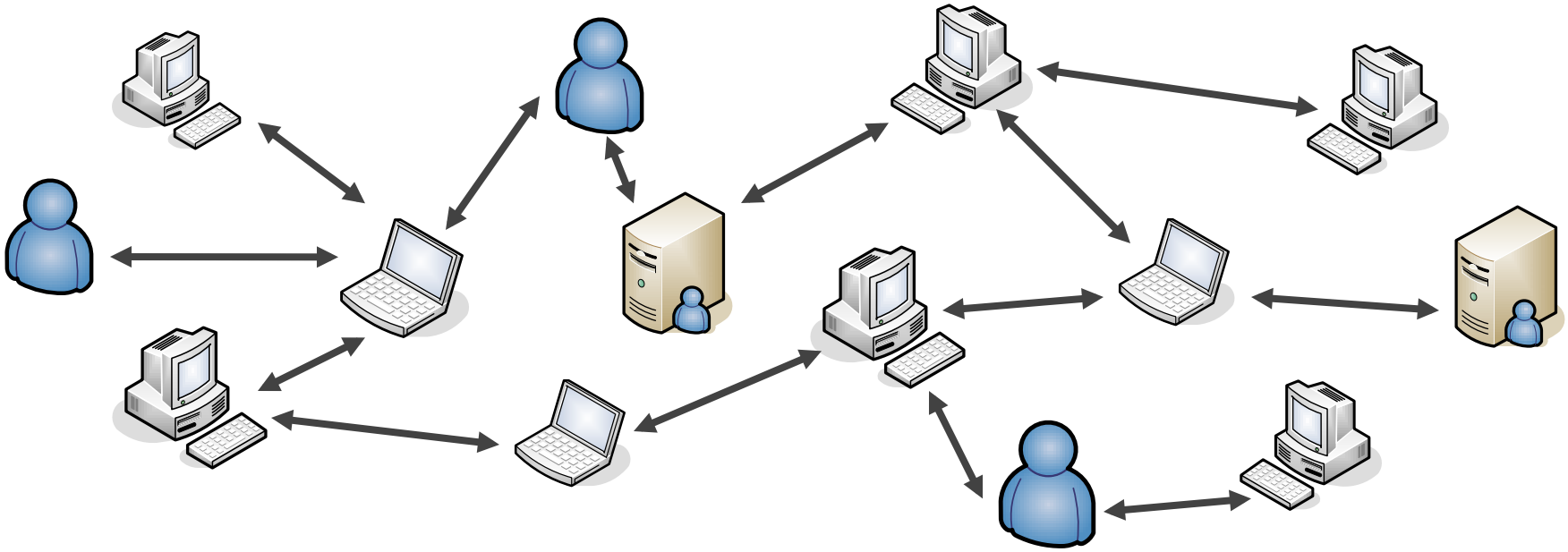
Serverless Resource Sharing: Peer-to-Peer

- The Peer-to-Peer (P2P) concept:
  - No fixed client and server roles
  - Direct connections between any pair of computers



P2P

- Advantages
  - No expensive servers
  - No central point of failure
  - No central point of control

- Drawbacks
  - Everyone needs to dedicate ressources
  - Somewhat more complex

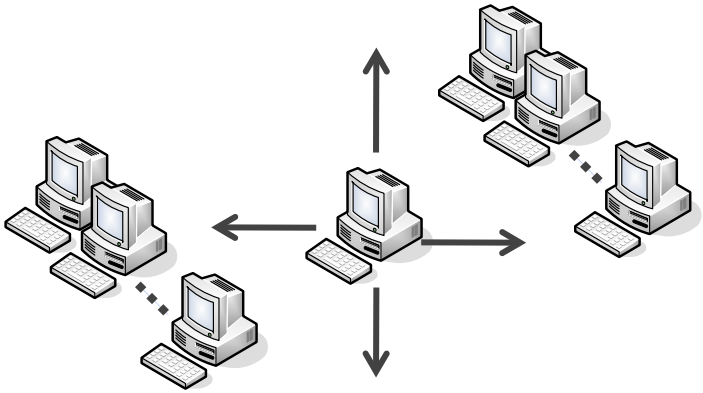
Examples Using the P2P Paradigm

- BitTorrent (filesharing)
- Skype, SIP
- Ad-Hoc Networks, Spontaneous Wireless Networks
- Some botnets

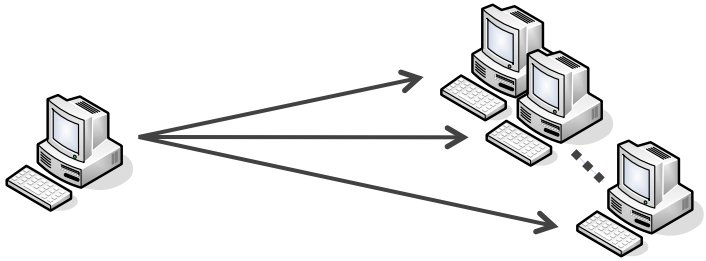
Communication with More than One Peer

- **Unicast**: Two peers communicate.

- **Broadcast**: One sender transmits to *all other peers* in the network.



- **Multicast**: One sender transmits to *a set of peers*, which are known. Similar to **Publish-Subscribe**



- Other concepts: Anycast, Convergecast, Geocast…