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
Back to a String and Tin Cans

Duplex Channel
Connecting Two Individuals?

Duplex Channel
Connecting Two Sites?

Problem: Waste of resources! How can we share resources?
Ressource Sharing: Multiplexing, Addressing

NEEDS OPTIMIZATION!
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?
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?
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...)

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

**Objects of thought**
- Facts, Concepts, Ideas, Models, etc.

**Representation in a formal way**

**Conventions for the representation of objects of thought.**
Example Data: ASCII Characters

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

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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

- Network protocols:
  - Machines rather than humans
  - All communication activities in the Internet is governed by protocols

- In General
  - … specific messages sent
  - … specific actions taken when messages received or other events happen

- 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?

Hi

Hi

Time?

11:00

connection request

connection response

get page X

page X
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 negligible 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)
  - \[ T = \sum \frac{data_i}{\Delta t} \]

- **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

\[ \text{Delay-Throughput-Product} = \text{Storing capacity of the line} \]

**Example: Store capacity of the transmission line**
- With a connection of 1 Mbps, 200 ms delay: \(1 \text{ Mbps} \times 0.2 \text{ s} = 200 \text{ kbit} \)
- With a connection of 100 Mbps, 100 ms: \(100 \text{ Mbps} \times 0.1 \text{ s} = 10 \text{ Mbit} \)
QoS: Security & Privacy Aspects

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

Normal Data Flow

Data Source → Data Destination

Passive:
- Eavesdropping

Active:
- Modifying
- Masquerade
- Interruption
QoS: More Basic Aspects

- Packet loss rate

- Bit error rate
  - ‘Finer-grained’ characteristic 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

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<td>E-Mail Program</td>
<td>Domain Name System (DNS)</td>
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<td>FTP Client</td>
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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 resources
  ● 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...