Communication = the process of sending data between sender and receiver
Depending on the number of participants

- broadcast
- unicast
- multicast
Depending on the connection model

- client-server
- peer-to-peer
Depending on the channel capabilities

- simplex
- half duplex
- full duplex
Is connection established?

- connectionless (e.g., post office)
- connection-oriented (e.g., phone)

Acknowledgements?

- With (letter with advice of delivery, dictating over a phone)
- Without (normal unregistered letter, video conference)
Is connection established?
- connectionless (e.g., post office)
- connection-oriented (e.g., phone)

Acknowledgements?
- With (letter with advice of delivery, dictating over a phone)
- Without (normal unregistered letter, video conference)
Successful communication requires:

- communication channel (medium: e.g., cable)
- communication protocol:
  - fixed (or negotiated for a single session) scheme
  - defines data format and transition function
  - necessity of open protocols (widespread protocols)
Successful communication requires:

- communication channel (medium: e.g., cable)
- communication protocol:

Protocol

- fixed (or negotiated for a single session) scheme
- defines data format and transition function
- necessity of open protocols (widespread protocols)
Protocols

- RFC documents: http://www.rfc-editor.org/
- Produced mainly by IETF workgroups (Internet Engineering Task Force)
- Undergo formal process of standardization (Normal RFC document → Proposed Standard → Draft Standard → Internet Standard)
Layered approach

Each protocol is based on something and enables something else (otherwise the protocol would have to encompass everything starting from description of single bit transmission).

Layer 1

Layer 2

Layer 3

Layer 1 protocol

Layer 2 protocol

Layer 3 protocol

physical medium

L3 ↔ L2 interface

L2 ↔ L1 interface
Example of layer communication
## Internet reference model

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. application</td>
<td>user-space protocols (<em>FTP, HTTP, SMTP, ...</em>) accepting data from layer 5, dividing it into smaller segments, assuring that these segments arrive, combining them back (<em>TCP, ...</em>)</td>
</tr>
<tr>
<td>4. transport</td>
<td>routing (<em>IP, ...</em>) sending frames of data, access to shared media (<em>Ethernet, ...</em>)</td>
</tr>
<tr>
<td>3. network</td>
<td></td>
</tr>
<tr>
<td>2. data link</td>
<td>can send and receive a bit</td>
</tr>
<tr>
<td>1. physical</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: this model with layers 1 and 2 glued is called TCP/IP model  
Note 2: OSI model has two additional layers: session and presentation (between 4th and 5th)
## Internet reference model

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. application</td>
<td>user-space protocols (FTP, HTTP, SMTP, ...)</td>
</tr>
<tr>
<td>4. transport</td>
<td>accepting data from layer 5, dividing it into smaller segments, assuring that these segments arrive, combining them back (TCP, ...)</td>
</tr>
<tr>
<td>3. network</td>
<td>routing (IP, ...)</td>
</tr>
<tr>
<td>2. data link</td>
<td>sending frames of data, access to shared media (Ethernet, ...)</td>
</tr>
<tr>
<td>1. physical</td>
<td>can send and receive a bit</td>
</tr>
</tbody>
</table>

Note 1: this model with layers 1 and 2 glued is called TCP/IP model

Note 2: OSI model has two additional layers: session and presentation (between 4th and 5th)
Logical connections: point-to-point or chained

Diagram showing the logical connections between FTP client, FTP server, TCP, IP, Ethernet driver, router, Ethernet, and token ring driver.
Physical layer
Network card vs. network interface

Figure from http://en.wikipedia.org/wiki/Network_card
Send bits as electric signals, e.g., 1 as 5V, 0 as -5V.

Fixed frequency of transmission → bandwidth (in kbit/s, Mbit/s or Gbit/s). Note: 1 kbit = 1000 bits, 1 Mbit = 1000 kbits.

Signal propagates on the medium (cable) and is received by another card.
Cables: coaxial cable

- Cable up to 200m
- half duplex transmission

Figure from http://www.phy.davidson.edu/StuHome/phstewart/IL/speed/Cableinfo.html
Cables: optical fibre

- Rather used at higher bandwidths
- Invulnerable to electric and electromagnetic signals
- Could be very long
- Hard to tamper with $\rightarrow$ security
- Usually simplex transmission: sending and receiving diodes
Cables: unshielded twisted pair (UTP) (1)

- Cheapest and most popular solution
- Different categories
  - cat. 3 - 16 Mhz
  - cat. 5 - 100 Mhz
  - cat. 6 - 250 Mhz
- Works up to 100m, afterwards repeaters needed.
Physical layer

Cables: unshielded twisted pair (UTP) (2)

- 8 wires inside
- Point-to-point: computer with computer or computer with network device
- In both cases, cables are the same but the permutation of wires in the connectors is different.
  - straight-through cable
  - crossover cable
- Full duplex possible