Technical Means for Human Communication

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1. Introduction

The process of human communication is very complex and subtle. It has been investigated by psychologists and physiologists. Engineers are also interested in this process, in particular when they have to develop telecommunication systems, i.e. technical systems which replace direct human communication by artificial means for conveying information from one point to another, in many cases over a long distance.

The way how engineers consider the problem of communication, and especially of human communication, may be of some general interest to enlight the process of communication itself.

Engineers like scientists are used to apprehending the complexity of real problems by first elaborating a simplified model, which lends itself to some logical and mathematical considerations. The conclusions drawn out of this model are then confronted with the crude reality by means of an experimental analysis, whose results may lead to a more or less thorough revision of the model.

Thus the general models used by communication engineers to develop the telecommunication systems and networks will be presented without technical details but bearing in mind the much more complicated and imbricated process of human communication.

2. What is information?

This question is just as embarrassing as asking for a definition of energy. Everybody understands roughly what is meant, but even engineers used to working daily with these two concepts will have big difficulties in explaining them in an understandable way.

Rather than try to define information, let us illustrate its meaning:

- information is an abstract notion
- information is conveyed by messages
- a message whose occurrence is predictable and whose content is known in advance with certitude carries no information
- the less predictable a message is, the most information it carries
- the improbability of apparition of a message is a measure of its information content.

This last statement gives a means of evaluating the amount of information. For instance the letter E being much more frequently used (i.e. most probably picked out of a text at random) than an X, it brings less surprise, i.e. less information, when it appears.
3. Analog and digital information

If the source of information produces its messages by using only a limited set of n characters (26 letters, 10 decimal digits, conventional signs, etc.), the source is called digital. The amount of decision it has to take by choosing one of these n characters is defined by the expression:

\[ D = \log_2 n \text{ in bit} \]

(\(\log_2\) stands for binary logarithm)

For instance, the Latin alphabet has a decision content of \(D = \log_2 26 = 4.7\) bit per letter.

But a given language uses these letters with different frequencies, so that the amount of information produced by writing a coherent text, taking into account the probability of occurrence of each sequence of letters and averaging over all of them, is only about 1.5 bit per letter.

Thus, the amount of information of a typed A4 page with about 3000 characters can be evaluated at some 4.5 kbit. That of a printed book of 300 pages at about 2 Mbit.

But most natural sources of information do not use a limited set of characters. They rather produce an infinity of continuous and extremely fine nuances. They are called analog.

In human communication, e.g. by voice, these two types of information are simultaneously present:

- digital information corresponding to the semantic content of the spoken words, as they were spelled out (1.5 bit of information per letter). This represents an average information flow of about 15 bit/s
- analog information representing the personality, the mood and the expression of the speaker. This very important subjective envelope conveys a lot of information which is difficult to evaluate. In commercial telephony, an information flow of about 60 kbit/s has been considered as necessary to offer satisfactory quality.

4. A simple model for an ideal communication channel

Information being an abstract concept, it has to be first expressed in a conventional way by means of a code which translates ideas into symbols or groups of elementary characters and vice versa.

A transmission of information from a source to a sink is only possible if a convention has been preestablished between them about the code to be used. If the addressee of a message does not have the key to decode it, this message is of no value for him.

Examples of such codes in human communication are the spoken and the written language, gestures, symbolic signs, etc.

In technical transmission systems the coded symbols and characters have furthermore to be converted into signals. A signal is a physical represen-
tation of information, according to a convention between the transmitter and the receiver.

Examples of commonly used transducers operating this conversion are the microphones, earphones, loudspeakers, TV-cameras, TV-screens, etc.

The principle of a transmission system can thus be represented in a simple block diagram (fig. 1).

![Block diagram of a transmission system](image)

**Fig. 1. Transmission system with ideal channel**

The transmission channel is only concerned with signals, without considering the meaning of the information they carry. However, the telecommunication system as a whole must take into account the nature of information to be conveyed and adapt the performances of the transmission to the requirements of the source and of the sink.

For instance, the statistical properties of the human voice such as spectral frequency distribution, amplitude distribution, and time structure have a deep and direct influence on the design of a telephone system. In the same way, characteristics of the human ear, which by the way is remarkably well matched to the voice, can be exploited to specify the required quality. A classical example is the relative insensitivity of the human ear to phase distortions which allows the wide use of an economic and simple modulation technique (single sideband modulation SSB) quite unsuitable for other transmissions such as television, for instance.

Engineers are, and must be, cost conscious. Therefore, they try to make the best possible use of available channels by reducing as much as possible the redundancy of the source, that means by transmitting only the minimum amount of information compatible with the required quality. Concretely, the original frequency range of the human voice is usually reduced from about 12 kHz to about 3 kHz; efforts are made to take profit out of the usually slow and restricted variations from one TV-picture to the next one, etc.

5. Model of a system with a realistic, imperfect channel

Available transmission channels such as metallic lines, optical fibres or
Radio waves have 4 unavoidable drawbacks:

- they attenuate the signals
- they introduce distortions which affect the form of the signals
- they delay the signals according to the velocity of the electromagnetic waves
- they include noise sources which superimpose unwanted random signals to the originally transmitted signals

As a consequence, the received signals are not identical to those sent by the transmitted. Here a very important difference appears between digital and analog transmission:

In the case of digital transmission, the receiver knows, by means of the preliminary convention, that the source can use only a limited number of different characters. Even though the received signals are distorted, attenuated and spoiled by noise, the receiver will interpret them by comparison with the known set of possible characters and decide which has been most probably sent by the source. This decision may of course be wrong and lead to an irreversible transmission error, but in most cases within certain limits the effect of channel imperfections can be eliminated and the carried digital information can be completely regenerated.

On the contrary in an analog transmission each detail of the signal is supposed to carry information, so that the slightest deformation or degradation of signals during transmission deteriorate the transmitted analog information.

So is it also by human communication: a handwritten message may be intelligible even if the letters are not well formed or partly obliterated. The eye and the brain are able to recognize them because it is agreed that there should be letters of a known alphabet. On the other hand the every day experience shows that the expression of feelings by gestures, attitudes or intonation can be slightly or even seriously misunderstood especially when disturbing factors like bad lighting or hoarseness interfere into this analog communication.

A technical communication system must take the imperfection of the channel into account by adapting the transmission mode to the behaviour of the channel. This is done by means of an appropriate modulation which makes the signals less sensitive to the distortions and noise. By digital transmission adequate coding methods allow the detection and even the correction of at least some transmission errors.

This leads to a more realistic model of a transmission system given in fig. 2.
6. Forms of communication

The fig. 3 summarizes 3 forms of communication classified according to the kind of information flow between different points.

unilateral (monologue)

bilateral (dialogue)

multilateral (conference)

A communication is said to be in "real time" when no noticeable delay occurs between the production of information by the source and its arrival at destination. Technically speaking, there is in this case no other delay than the unavoidable propagation time through the transmission channels.

The unilateral communication is not sensitive to delays, since the receiver has no way of reacting on the source. There is in fact no real communication but a simple transmission in which the receiver plays a purely passive role.
On the contrary, bilateral or multilateral communications allows an interaction between partners and a true exchange of information. The alternate sending of questions and answers or actions and reactions gives rise to a requirement for real time communication. Psychological conditions have to be take into account: for instance a telephone conversation becomes troublesome when the one-way delay time exceeds about 200 ms and extremely difficult for values over 400 ms. This is a serious problem for satellite links in which delay times of about 250 ms are quite usual due to the high altitude of geostationary satellites.

In multilateral communication another problem arises: a very strict discipline is necessary to avoid conflict between messages coming from different sources. This is particularly critical by videoconferences where the receiver’s screen can obviously not superpose several pictures. A voice controlled switch has then to be designed in order to distribute only the picture of the speaking partner (active source). What then if somebody else is just coughing at this moment?

As soon as several sources and/or sinks are involved in the process of communication the concept of network appears. Depending again on the kind of information flow, 3 functional types of networks can be identified:

- a diffusion network including only one source but several, even many, receivers to which the same information is broadcasted. The communication is unilateral. Typical examples are books and newspapers, radio and TV
- a collecting network with several sources sending their information unilaterally to a common receiver, i.e. for telemetering or supervision purposes
- a switched network in which connections between sources and sinks are not permanent, but must be set up according to the expressed needs, prior to each information transmission. The communication may then be unilateral, bilateral or even multilateral. The switching operation consumes some information.

Fig. 4 gives an overview of different typical telecommunication services classified according to the above mentioned criteria.

7. Man as a communication partner

The need for communication, i.e. for relationship, contact and exchange of information belongs to the very essence of life. All living beings communicate among each other and with their environment.

The main transmitter used by man is the voice, which translates ideas into acoustical signals by means of a spoken language used as a code. But other physical means such as handwriting, drawing, gestures are also used to express information.

As a receiver the eyes are by far the most powerful means of catching information. The information flow entering the eyes is enormous, at least 100 Mbit/s, compared with that received over the ears (about 40 kbit/s).
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<thead>
<tr>
<th>SWITCHED</th>
<th>NOT SWITCHED</th>
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<tbody>
<tr>
<td><strong>UNILATERAL</strong> (MONOLOGUE)</td>
<td></td>
</tr>
<tr>
<td>Remote control</td>
<td>Radio broadcasting</td>
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<tr>
<td>Telemeasuring</td>
<td>TV broadcasting</td>
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<td></td>
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<tr>
<td>Remote control</td>
<td>Closed circuit</td>
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<td></td>
<td>Television</td>
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<td>Telemeasuring</td>
<td>Automatic</td>
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<td></td>
<td>wake-up system</td>
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<tr>
<td><strong>BILATERAL MULTILATERAL</strong> (CONVERSATION)</td>
<td></td>
</tr>
<tr>
<td>Telex</td>
<td>Interphone</td>
</tr>
<tr>
<td>Data network</td>
<td>Telephony</td>
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<td></td>
<td>Videophony</td>
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<td>Telecopy</td>
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<td>Audio conference</td>
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<td></td>
<td>Video conference</td>
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<tr>
<td><strong>DIGITAL</strong></td>
<td><strong>ANALOG</strong></td>
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Fig. 4: Typical telecommunication services
It is worth mentioning that the information carrying capacity of a technical TV channel (90 Mbit/s) or of the standardized telephone channel (64 kbit/s) are well matched to these natural figures. However the most astonishing and until now completely unexplained fact is that the human brain is able to process only at most about 50 bit/s. It must therefore considerably reduce the input information flow and concentrate itself on the relevant information but without ignoring totally the rest of received information. How the brain achieves this is a still unsolved question. The great amount of research work invested in the development of machines able to recognize spoken sentences or to read handwritten words gave rather poor results in spite of incredible complexity. It shows clearly that the communication and the working processes in the human brain are in fact very badly known and therefore very difficult to imitate.

Another interesting, although rather alarming, property of man is his behaviour in presence of a superabundance of information. According to information theory, providing information to a system decreases its entropy. That means, roughly speaking, that the own disorder of the system will go down. It seems that man is a remarkable exception to this rule: the plethora of information lets him perplex and tends to increase his mental disorder ...

The telecommunication systems, above all the information broadcasting systems, have largely contributed to the present information flood. They have considerably reduced, even deleted, the sometimes useful delay between an event and its announcement, between a thought and its expression.

However the same technical means also give a glimpse of hope. The growing combination of informatics and telecommunication provides new means of increasing what could be called the quality of information. Information is said to be of good quality if it meets the requirements of the user. Of course we are interested in unexpected information found in newspapers or broadcasted by radio and TV. But we also need a lot of specific information in our everyday life at home or in our profession. This information exists somewhere. It is stored in books, in periodicals, in data banks. The problem consists in setting up a communication path from this information to the user.

You know this problem, because it is yours. You know what "information retrieval" means. A difficult problem indeed! But technical means are now available which may open the doors of the traditional libraries to a bilateral flow of information, to a real communication, to an interactive exchange of questions and answers. Telecommunication engineers will provide the communication channel, computer engineers the software, but the central problem remains the organization of the stored information in such a way that it can be made available within a short time. That is certainly an important field of collaboration between engineers and librarians.