From ATP to ISDN
Three Billion Years of Communication Technology*

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Life is communication. St. John's gospel starts with the very penetrating sentence: At the beginning was the word. *ευ αρκε ευ ο λογοσ*. *Am Anfang war das Wort* has Faustian resonances. And also its mirror image: *Am Anfang war die Tat.*

Living objects are quintessentially communicating systems, both in terms of keeping their parts operating together, or sending signals into the external world, sensing and decoding the ones coming from it.

The driving force of living objects is to multiply in number and expand in space, organizing into themselves material and energy resources laying in the external world. Their success is linked to their capacity to manipulate complexity.

Manfred Eigen has done a magnificent job in quantifying the evolutionary processes that selected more and more complex organisms, up to the most complex of all: Man.

The process took about four billion years and it is clear that many of the problems that now attract the labor of communication engineers were invented already in the course of evolution. When I was first able to decode the acronym ISDN, I giggled. *Deja vu*. Invented three billion years ago like the movable types of DNA.

In biological systems in fact most messages are sent through informational molecules with an address. The common carrier can be the plasma of a cell, or the blood of a higher animal, or the open space.

The cell can be in fact seen as an evolutionary device to increase the efficiency of signaling by keeping signals to a restricted space, with a wall on which they rebound. The wall, however, is a signaling interface with the external world.

These signal molecules were obviously of very great importance and a sign of this can be seen in their longevity. They last for million or even billions of years preserving their messenger character, although sometimes with different objectives. ATP was there since the beginning swapping around negentropy. We produce and destroy our weight of it every day.

We can find insulin in spinach, or the central element in our defenses against viruses, interferon, in tobacco leaves. But more often the function is similar, and I will retell a very curious case.

The beer yeast, *Saccaromices Cerevisiae*, as many other micro-organisms, is sexuated and has *a* and *alpha* cells which are aploid, i.e., with half the dowry of chromosomes like the gametes of higher animals.

α cells, in order to attract *a* cells emit a pheromone, G_nRH a gonadotropic releasing hormone, which is basically identical to arousal hormones in mammals. So much that female rats can be activated using the stuff produced by α cells.

Now when an α cell and an *a* cell approach and meet, their skins fuse so that their plasms become the same common carrier, fulfilling literally what is written in Mathew 19-5: *For the twain shall be one flesh.*

Another curious observation is that the common carrier for the love message from α to *a*: "I am here ready to mate, dear", is plain beer. Really very little is new under the sun. Sex included.

The story of sex is actually a great unsolved problem for biological theory. Formally sex provides "transversal" information inside biological species, a kind of *language*, but then the advantages are difficult to model and quantify.

I have just read cover to cover a recent anthology on the subject by the great buffs in the area. Their only point of agreement is that sex is expensive for the individual. True. Consequently, it must be important. It seems in fact that all the circus about sex is finally a complex *error correcting strategy.*

Information engineers, with machines becoming more and more complex and with components approaching molecular size and facing thermal noise, may have a lot to learn from biological systems, where molecules were there since the beginning and where the system works in spite of appalling levels of noise. We should wait for the sexy chip.

Another area where biological systems have found every possible solution, as they reached the physical limits, is in detection and processing of weak signals. The eye can see a couple of photons and the nose can feel a few molecules. But the most astonishing result is in the ear, where a flux of 10^{-18} W can be detected. A feat corresponding to a receiver noise temperature near zero Kelvin. But the ear operates at about 300°K!

Man is the final product of the evolution of these informational systems and he might be constrained into their rules. He is! As we have shown, in thousand of cases at IIASA, cultural packets carried by syntactic language produce actions in a way quantitatively analogous to what happens with DNA. In a sense, syntactic language is the last level in DNA evolution with higher potential for control of complexity . In the immense library of solutions of biological systems, there are no nuclear reactors or flights to the moon.

But apart from the degree, the mechanisms are the same and this permits sharp insights into the dynamics of social systems of direct interest to communication engineers.

To give a small example, man is a territorial animal and devotes about one hour per day and 15% of his disposable income to expand, patrol and exploit his territory. Actually, he allocates time and money between different transport means in such a way as to maximize distance traveled.

If we observe France during the last two centuries, distance traveled by mechanical means (passenger-km) has increased about 3000 times or a mean 4% per year. Messages exchanged by mechanical means, letters, telegrams and telephone calls, have increased also about 3000 times. This reveals the basic nature of personal communication demand: the expansion of the territory generates contact points not reachable by shouting and creates a demand for long distance mechanical communication. In this frame the idea that communication is a substitute for travel appears quite whimsical, as every practical operator well knows.

New ideas, like mutations, diffuse into the system substituting progressively old ones. The mathematics of substitution is identical in both cases. The time constant of diffusion depends on the object diffusing. It is 1000 years for religion and ten for social fashions. However, for basic innovations of industrial nature it is systematically around 50 years, and this is the most probable origin of the pulsation of our economies and of societal behavior with about this periodicity - the famous Kondratiev cycles.

We are at the end (1995) of one of these cycles, in a period of intense creativity at the engineering and entrepreneurial levels. The EuroComm 88 Conference is a good mirror of this situation. Who can emerge from the deadly selection will have fresh markets to fill for fifty years. Also the parallel here with the biological case is striking. Of hundred mutations that survive the error correcting systems, basically only one will find place in the evolutionary line. A study I did, on the launching of new companies to make cars in the USA during the first decades of this century, shows a similar survival rate. The same for mainframe computer manufacturers nowadays. *Many are called but few are chosen.* The biblical say holds perfectly for this pitiless butchery.

Coming back to expansion in mechanical communication, an analysis of the French, Belgian and Swiss case did show a very precise delimitation of three growth pulses by the Kondratiev time boxes. This refers to interpersonal communication. It did grow by a factor of ten at each pulse. I did not study yet the problem of intermachine communication, and I have yet no idea if the next pulse will bring another factor of ten.

The mainlines of this future are accessible, however, using the conceptual framework delineated. In the parallel case of transport development, a selfconsistent and quantita-

tive picture for the next 30 years has been drawn, with Maglevs and hypersonic planes finding their niches.

The word was at the beginning. It will be central at the end. The power of a man is expressed by uttering words – for other people to execute. If magic dreams are templates for technological development, one of them is left unrealized, the "Open Sesame!" The capacity to give orders to inanimate things.

This is a quintessential power dream. Jesus orders fish and bread to multiply and saints occasionally stop falling bodies mid-air. After having invented mechanical flying carpets, machines for hearing and seeing at a distance and bulldozers with the force of thousand oxen, it is really due.

A first shy attempt is represented by a machine interfacing a typewriter. A voice addressed computer may come next. But this is only the beginning. As said, the voice identifies the man and carries its command. This function should be extended to inanimate objects.

The smart card can be the seed. With more and more electronics packed into it, it can become a cellular telephone, linking the man to the world. It can also identify the voice of the owner and become its identity card. In this configuration it can talk to computers, open doors and safes, guarantee to them the identity of the owner and execute his orders.

At the beginning was the word. The word will be at the end. The word – action realizing the Faustian dream. Thanks to the new technologies of communication, man will approach his dream of becoming a quasi god. It is perfectly said in Isaiah 55,11: *So shall my word be that goeth forth out of my mouth: it shall not return unto me void, but it shall accomplish that which I please, and it shall prosper in the thing whereto I sent it.*