The editorial board of CSELT TECHNICAL REPORTS feels appropriate, as a goodbye to dr. B. Catania, who is leaving his position of general director of CSELT, to publish his invited paper at IOOC '89.

Optical technologies and telecommunication strategy

B. Catania[1]

Since the inception of optical fiber technology, numerous breakthroughs have occurred, posing severe problems to both Telecommunications Operators and Manufacturers, as for the introduction of innovative products and services, with reasonable return of the investments. The paper reviews the 20-year history of optical fiber technologies and debates strategic issues to cope with their unending proliferation.

Next September, when I will leave my present position of Director of CSELT, which I have held for about thirteen years, it will be almost exactly 37 years that I have worked in Research on Telecommunications. So, I thought that, in concluding this part of my life, I could share with you some considerations on how Research is placed within the varied world of telecommunications, in which researchers have to play a complex game with Operators, Equipment Manufacturers, Service Providers and Service Users, these latter representing the largest part of what is called the market.

Maybe the most delicate relationships are those with Telecom Operators. In fact, public network planners have always been rather cautious in introducing new technologies, which would upset their network architecture, mostly because of the high level of investments already made in the existing public telecommunication network. As these are of the order of, say, 1500 $ per subscriber, a typical network of 20 million subscribers (such as that of large Nations in Europe or of each Bell Operating Company in the USA), represents a whole investment or “book value” of around 30 billion $. Considering, for instance, an annual substitution rate of 5% (corresponding to an average life of network equipments of 20 years) and an annual increase of 5% of the total number of subscribers, an additional investment per annum of 10% would be needed i.e., on the above hypothesis, around 3 billion $/year, but steadily increasing after each year (just an awful lot of money!).

In theory, the entire annual investment could be utilized for the introduction of new technologies, but if, as an extreme example, different, more advanced, technologies were introduced each year, the resulting network would soon become an intricate mosaic of substantially different equipments, transmission lines and control devices, which would render its operation, administration and maintenance rather impracticable.

On the other hand, leading telecommunication manufacturers continuously push Operators and Users to buy new products, as new technologies generally feature increased technical performances and better quality/cost ratio. Even if innovation has a high cost to those manufacturers being first in the market, it generally allows them to conquer a larger market share.

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[1] Dr. Basilio Catania, CSELT, Torino. Invited paper at IOOC ‘89, Kobe, Japan, July 1989. Printed in CSELT Technical Reports, Vol. XVII, No. 5, October 1989, p. 325-328

As a result, we may observe a strong unbalance between the push exercised by the vendors of new technology products and the capability of the buyers to absorb said ever increasing offer. This unbalance seems much weaker in the users' terminal equipment market where the demand appears to be quite high, in many Countries of the world.

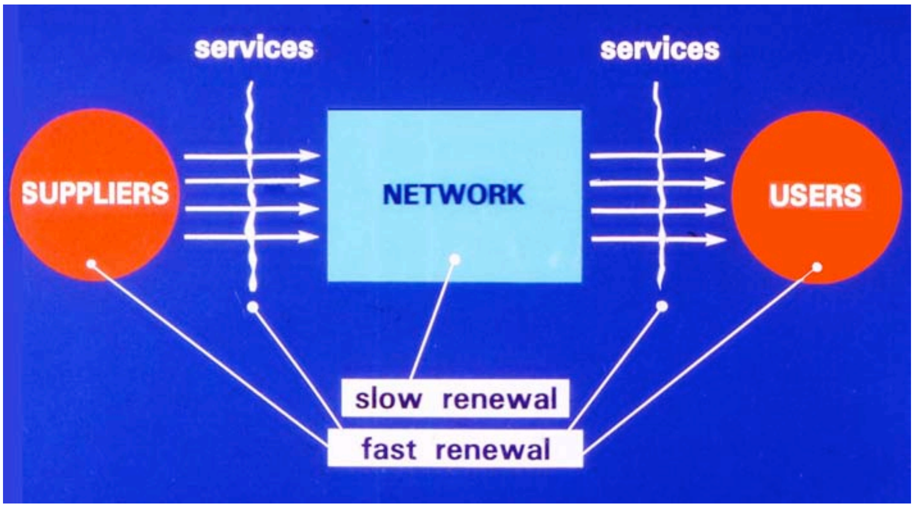

Fig. 1. The IBC changing environment.

The pressure to innovation, exercised at both ends of the public telecommunication network (Fig. 1), will become even more pronounced with the advent of Integrated Broadband Communication (or IBC, as we call it in the European RACE program) because of the increased variety of services, which would be permitted by a prospective broadband users' *infoduct*. Incidentally, with the RACE second phase (which is about to start) a research project called RISE, i.e. Research on Integrated Services Engineering will call for exercising the creativity of researchers in devising new services, which will help - if you wish - to "fill up the hole"(i. e. the users' *infoduct*) and therefore allow a quicker return of the investments.

Data	Europe	USA	
Size	110	100	Million lines
Value/main line	1800	1800	ECU
Book value	200	180	BECU
Yearly revenue	54	130	BECU
Yearly revenue/main line	490 (1)	1300	ECU
Revenue increase/year	6	16	%
Book value/yearly revenue	3.7	1.4	
Yearly investments(2)	20	18	BECU
Investment/revenue	37 (3)	14	%

* *Ref. R. Teesdale (RCO) ''The economic viability of IBC'' Int. Memorandum, August 1986*

Note (1): resulting from averaging: top 1% users (LARGE BUSINESS) ~ 10.000 ECU/year
top 20% users (BUSINESS) ~ 1.500 ECU/year
lower 80% users (RESIDENTIALS) ~ 190 ECU/year

Note (2): estimated @ 10% of BOOK VALUE (5% for replacements, 5% for growth)

Note (3): similar figures apply for Railways, Highways, Power Co.s; Broadcasters ~ 8%; Industry ~ 5%

Fig. 2. Finance: the viewpoint of Operators. Comparing Europe and USA telephone Networks,

In fact, we could not follow, in Europe, the USA's strategy (particularly that of my friend Richard Snelling of Bell South) of bringing fibers to the homes, just based on the Plain Old Telephone Service (POTS), not only because the average sub-scriber loop length in Europe is much shorter than that in the USA, but also (Fig. 2) because the average European user's bill turns out to be about one third of that of the average American user, and, moreover, it increases at one third the USA's rate. That's why we must *fill-up the hole* with something else.

Despite these kinds of differences among various regions of the world, there is no doubt that, since the introduction of optical fiber technology, about 20 years ago, a continuous strategic review has taken place in the whole telecommunication sector, as a result of the intense and effective research activity performed in the more advanced Countries.

Let me briefly survey a few historical breakthroughs that have had strategic relevance, even if much has been said yesterday on this subject.

Let me first recall that, at the very beginning, it was debated whether, e.g. a 7-fiber bundle had to be used instead of a single fiber, given the fact that early available sources and detectors were of the large area type. (Does any one remember some catch words as "packing fraction" and "proliferative breaking"?) A few years later a definite superiority of the single-strand step-index fiber was demonstrated and high radiance emitters and small surface photodetectors were developed. However, a larger cross-section step-index fiber and larger surface optoelectronic components were conceded for short distance applications. At that time, very few Operators and Manufacturers were even aware of the potentialities of optical fibers. A few of them were still giving some thought to millimeter waveguide systems.

In another few years time, the graded-index fiber appeared at the horizon and gradually killed any idea of utilizing the step-index fiber, due to its superior bandwidth performance. Just a few years afterwards, network planners in Europe, USA and Japan were eventually convinced of using fibers in the network and took the decision of widely introducing graded-index fibers in their junction and long distance networks: at the same time manufacturers began very substantial productions of such fibers and related equipments; however, this strategy was again upset by the decisive progress made later on monomode fibers, accompanied by substantial techno-economical and reliability improvements of laser diodes, capable of injecting mW powers into the small cross section of the monomode fiber. In addition, fiber manufacturers demonstrated the prospectively lower cost of monomode fibers with respect to graded-index fibers, therefore most network planners had to regret to have already invested in graded-index fiber systems and had to look to modification of their plans, by foreseeing the use of monomode fibers.

In addition, the use of fibers optimized for the 0,85 μm wavelength was abandoned, because of the superiority of fibers optimized at 1.3 μm zero-dispersion wavelength, and featuring drastic reduction of OH impurities, which in turn allowed further reduction in fiber loss. Of course, suitable laser sources and photodetectors with new semiconductor compounds were developed, together with new sophisticated techniques for monomode fiber splicing and for detachable connectors. And thus, network planners launched themselves again into a vast introduction of such systems into their national network, and also into the oceans, as with the first transatlantic optical cable TAT8.

But, as everybody knows, the story was not ended at all. First, the breakthrough of the "third window" systems at 1.55 μm with dispersion shifted fibers, then, the advent of the coherent systems with multichannel capabilities, and so on, up to the ongoing studies with medium infrared fibers, squeezed light and soliton transmission, again holding great promises of further quasi-unbelievable breakthroughs, and related further upset of telecommunication strategies.

The disconcerting aspect of all that exponential proliferation of technologies is that each time after a new discovery, one has the feeling that nothing dramatically better would be achieved in the short-medium term and that one could make plans for new-technology introduction with reasonable confidence on its stability, say, for 5-10 years; but that has regularly been upset, even in much less than the minimum 5 years time.

Thus, as a conclusion from the above analyses, a clear need appears to exist to develop entirely new strategies to govern the evolution of the public telecommunication network with innovative equipments and services. In fact, in addition to the mere development of ever superior types of fibers, sources and detectors, network planners are faced with new system's architectures and with a roster of previously unimaginable narrowband and broadband terminals and services.

As an example, long distance (including transoceanic) transmission systems may get rid of regenerators by using in their place inexpensive and more reliable distributed Raman amplification or lumped optical amplifiers or, in a longer term, even get rid of amplifiers, by using medium infrared fibers, with or without soliton transmission, provided that the splicing losses could be kept as low as not to impair the extremely low attenuation of the fiber alone.

Also in the switching area, important revolutions are taking place. In fact, coherent multichannel and asynchronous mode techniques may be combined in such a way as to completely eliminate centralized switching and let signals be generated and selected everywhere in the network, thus achieving distributed switching and user-controlled routing, thus leaving the network completely transparent and flexible to users.

Thus, after the transition from the analog telephone network to IDN, followed by that from IDN to (2B + D) ISDN and from (2B + D) to (30B + D) ISDN and there from to full broadband ISDN, we may expect another two or three important transitions, in the next 10-15 years, leading to an all-optical network, capable of connecting all users' premises with unsuspected large streams of information of all kinds.

Beyond that, the fantasy of manufacturers and service providers may find an unlimited field of activity in users' terminal equipments, where progress in processing and display technologies may allow to offer powerful terminals, in increasingly lesser space, with decreasing costs and increased reliability and ease of use. In this market segment, very evidently, (Fig. 3) progress in coding technologies may upset any rigidly conceived network architecture, as it may well happen that one order of magnitude in reduction of the operating bit rate of audio and video signals could be achieved in only a 10 years period. This again calls towards devising a vast palimpsest of services, to "fill up the hole", but it also confirms the prospective superiority of ATM (Asynchronous Time Mode) technique (Fig. 4), because it breaks signals into small packets and therefore any reduction in bit-rate simply reflects into a lesser number of packets, though leaving the network architecture unchanged.

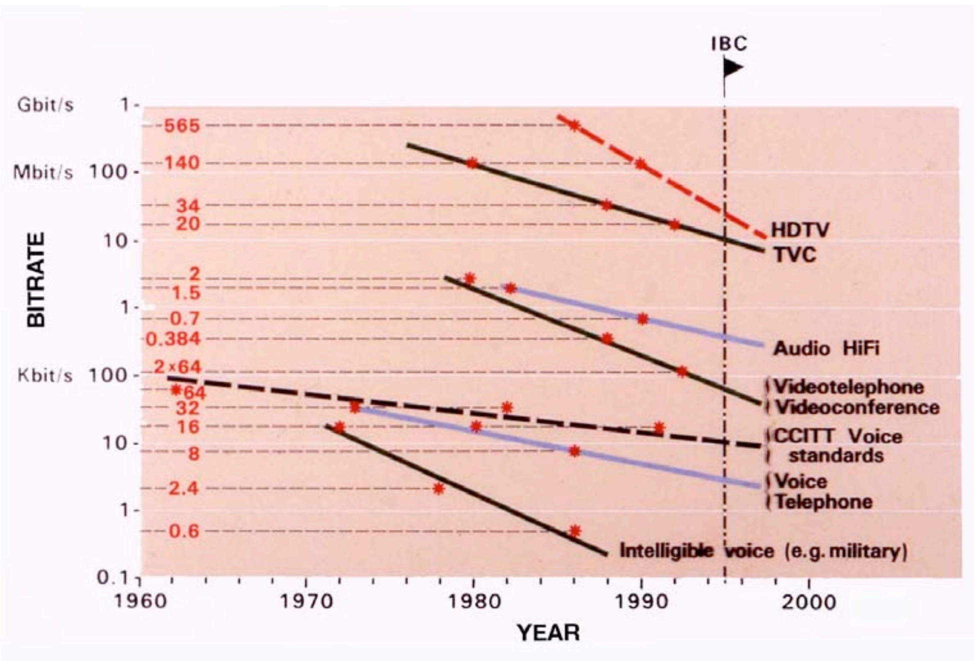

Fig. 3. Progress in coding technologies.

But there is more to come: superconductivity, photonics and organic computers (how about "Bionics" for a name of this new technology?), neural networks and self-learning techniques, as well as personal communication techniques are just showing up at the horizon, and nobody is underestimating their capability of upsetting plans, again and again.

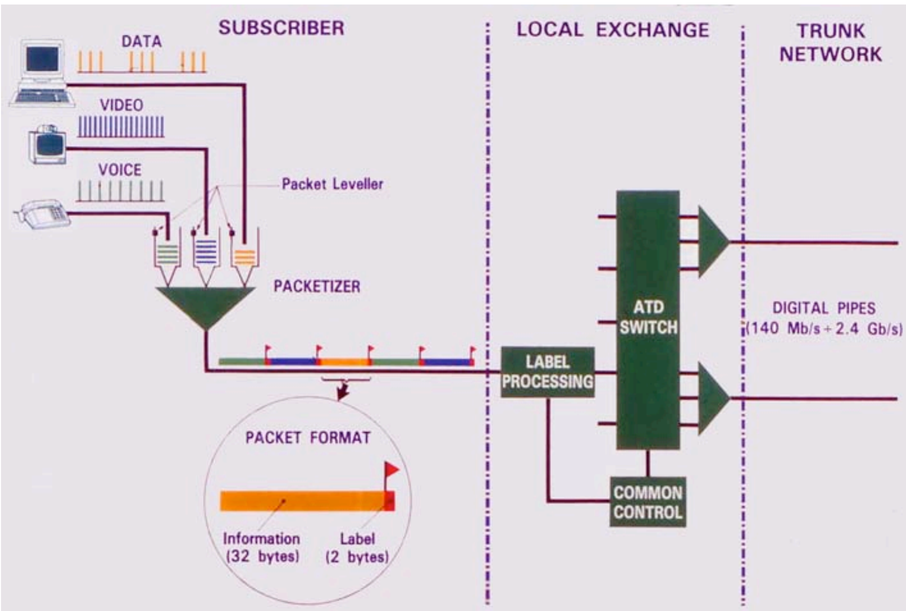

Fig. 4. Asynchronous Time Division concept.

As there is no way to resist to technologies' explosion, earliest and deepest understanding of their potentials and implications becomes of paramount importance to both Manufacturers and Operators. This should allow, in turn, to mobilize financial resources for the necessary investments in advanced telecommunications, as they would produce a wider spectrum of social and economic advancements.

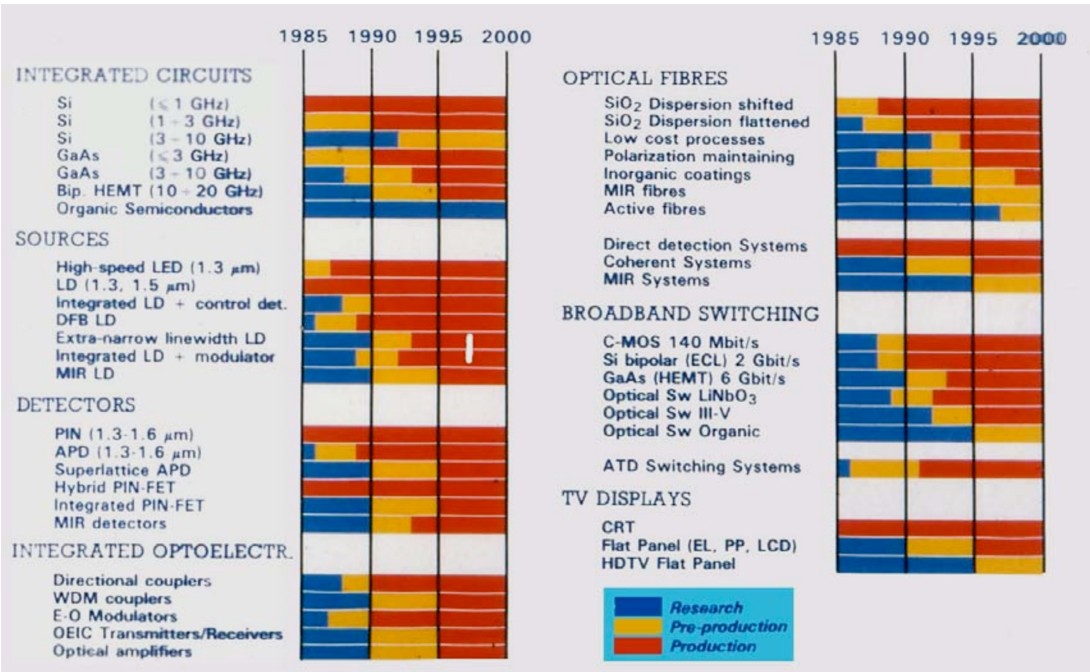

Fig. 5. Availability of enabling technologies.

As an example of how we did set-up a strategy for advanced communication in Europe, trying to take into account what was going on in the field of enabling technologies, I may show this somewhat old slide (Fig. 5) where you may see that we did estimate which technologies were expected to be still in the "blue-sky" research stage, which ones in pre-production stage and which ones in the mass production stage, at the time set for the first introduction of IBC, i.e. in 1995. Of course, forecasts may be wrong and must be readjusted from time to time (in fact, we do have a review each year), but this is a necessary exercise to be done, to identify a strategic trend. From all the above, it appears that we have, at least, three pillars (Fig. 6) upon which a suitable strategy for the development of telecommunications could be constructed: finance, market and, last but not least, technology. However, given the socio-economic impact of telecommunications in any Country, the three pillars, in turn, must be supported by an intelligent policy of public authorities, which we, engineers, sometimes disregard or even despise as being extraneous to science, because that's politics, and politics . . . is dirty.

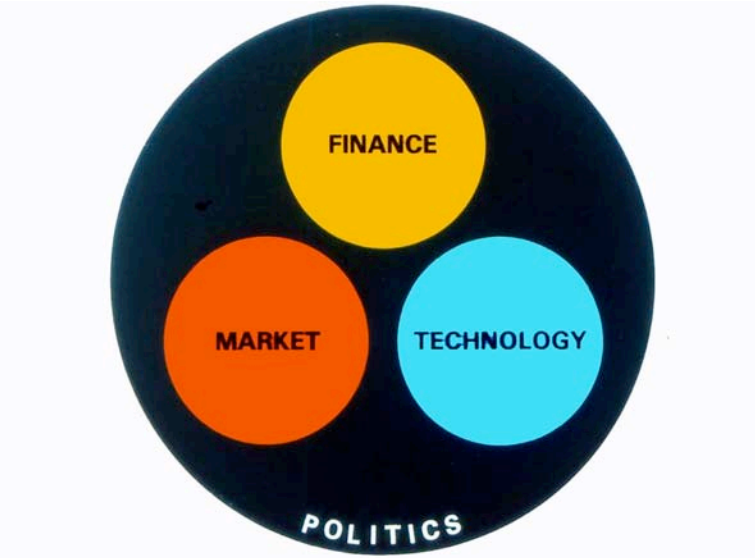

Fig. 6. The three pillars of IBC construction.

There is no doubt that (Fig. 7), apart from rare exceptions, the push towards innovation is exercised by us, the researchers, and that the control of that pressure is exercised by the market (i.e. by the customers) on one side and by the Finance (i.e. by the investors) on the other side. But we keep pushing and keep the pot boiling, by steadily challenging the impossible.

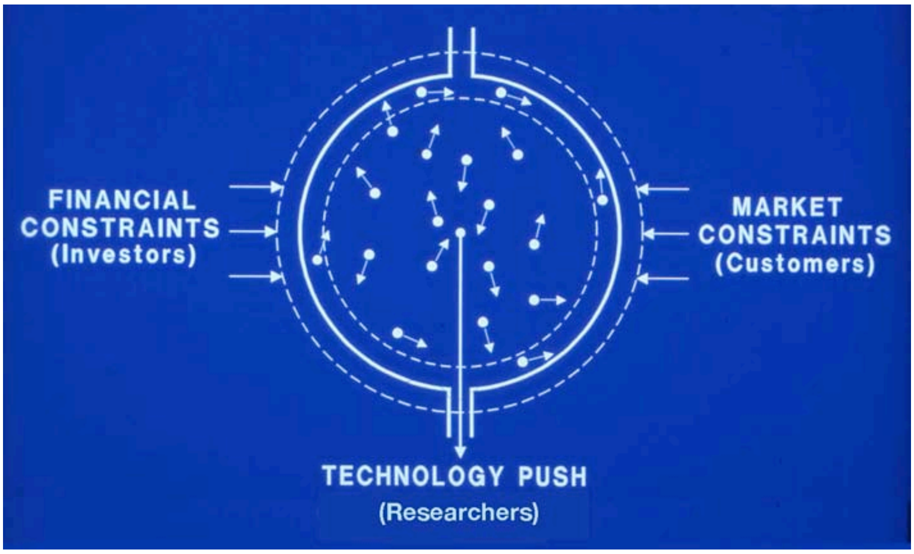

Fig. 7 Control of technology push.

Because research is like a mountain without summit, where researchers climb, pause, and climb again, each time discovering wider, but never ultimate, horizons, only rewarded by the pure joy of feeling, each time, a tiny step nearer to the Artificer of all that which is conceded to be comprehended by human mind.

Dear readers of CSELT TECHNICAL REPORTS,
In leaving my present position as a Director of CSELT, I should like to send my best wishes to all of you, together with my hope that you continue to concede your appreciation to CSELT TECHNICAL REPORTS.