Effective Industry-Academia Cooperation In Telecom: A Method, A Case Study And Some Initial Results

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EFFECTIVE INDUSTRY-ACADEMIA COOPERATION IN TELECOM: A METHOD, A CASE STUDY AND SOME INITIAL RESULTS

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ABSTRACT

This work suggests a method to achieve successful cooperation between industry and academia in telecommunication in the context of developing countries. To illustrate the method, the authors describe a case study on how to integrate an academic research group and an industrial development team to generate useful research results as well as products. The trade-off that must be done between academic and industrial interests is stressed as the single most important point of an effective cooperation between industry and academia. The authors present the first results obtained in an ongoing cooperation. The paper also presents a set of issues that must be addressed to improve the quality of the method and consequently the satisfaction of both parties involved.

1. INTRODUCTION

The cooperation between industrial and academic sectors plays a significant role in developed countries, especially during the development cycle of products based on high technology. This is particularly true in the telecommunications arena, which requires fast evolving products and employs state of the art technologies that advance very quickly. Quite often, the interaction between industry and academy in these countries is mediated by private or state research centers. Private research centers are often connected to big corporations, while state research centers may interact with these and also provide the necessary infrastructure to allow the interaction between smaller and medium enterprises with academic research groups. The last enterprises are seen as the main vector of innovation in telecommunications. Thus, state-funded research centers are an important asset for technological development. In developing countries, however, neither private nor state research centers abound. Big corporations have very little interest in research centers outside developed countries with their highly skilled technicians, and the state either does not value research centers enough or simply does not have the funds to invest in the long term results of research.

Another way to support industry-academia cooperation in telecom has been proposed in Brazil. The approach involves the creation of laws offering the opportunity of tax reduction for enterprises that invest in research both internally and in cooperation with academic institutions. A first law (no. 8248) ensured 100% IPI tax exemption (IPI is a tax applied to every industrialized product produced or commercialized in the country) to enterprises applying at least 5% of their annual gross income in research being 3% internally and 2% in academic institutions. After that first law expired, another one is being set up (no. 10176) with the same objective, also with limited duration but with diminishing tax exemption percentage [1]. The exact numeric figures are still in discussion, but the duration of tax exemption applicability should be around 10 years, and the tax percentage reduction should start close to 100% and end up in around 60%. The extent of these laws is not limited to telecom enterprises. They address Information Technology enterprises in general, based on a list of 50 product classes enumerated in the law regulation, ranging from vehicle electronic fuel injection systems and electronic gauges to computers and integrated circuits [2].

These laws do represent an excellent opportunity to further industry-academia relationship, since *every* enterprise will have to seek research investments under the auspices of the tax exemption law, even if it is to remain competitive in the internal market. On the other hand, the long-term goal of the law is clearly to add competitiveness to national enterprises, in order for them to stand the effects of market globalization. Indeed, it seems that the next years will witness international free trade alliances such as ALCA and MERCOSUL prosper, menacing the national industry, if it is not prepared for competing globally. National enterprises must be aware of this objective, accept it and use the law benefits to achieve it.

On the other hand, Brazil is thriving in academic research groups. Indeed, the country has several successful state-funded graduate and research programs that are hardly found in developing countries or even in developed countries. Federal and regional agencies such as CAPES, CNPq, FINEP, FAPESP and others FAPs (regional research support foundations) provide great amounts of research funding for many fields of knowledge. However, there is a poor match between what is produced by the Brazilian industry and what the excellent national research groups develop. Again, tax exemption laws like the ones cited above could be an excellent way to improve the applicability of the excellent work developed by the academic research groups. This can be seen as another main objective of the cited laws.

However, the two-way fruitful cooperation is not easy to achieve. It is even possible for both sides to obtain short-term benefits without achieving the main objectives stated above. This happened in some situations during the period covered by the 8248 law. Several enterprises invested large amounts of money in academia, achieving the requirements of tax exemption without creating, in some cases, a single effective research cooperation. On the academia side, some institutions acquired significant resources without really committing to any research applicable to the donating industry. In some cases, government investigations revealed that the donated funds were even used to allocate resources to the institution administrative sectors and not to research laboratories. The 10176 law was enhanced to provide a more tightly coupled industry-academia cooperation, but it would be naive to expect it to completely rule out the misuse of the resources, even when the law is thoroughly respected. Only if both industry and academia decide to commit themselves to the ultimate law objectives it will be possible to achieve the final competitiveness goal.

This paper proposes a method to obtain effective industry-academia cooperation deemed to achieve global competitiveness for the industry side while guaranteeing high quality research results for the academia side. Section 2 describes the general aspects of the method. While it has been developed for cooperation in the field of telecom products, the method should be equally applicable, *mutatis mutandis*, to other fields covered by the cited tax exemption laws. Section 3 provides details of an ongoing cooperation developed by the authors based on the proposed method. The case study illustrates the practical implementation of the method. Next, Section 4 describes the first practical results obtained in the first year of the cooperation, while Section 5 presents some conclusions, together with some issues that must be addressed.

2. THE METHOD

The first aspect to take into account while trying to implement an industry-academia cooperation is to realize that industry and academia are two quite different species. They have distinct goals and widely different characteristics. Both sides must recognize and accept the differences of the other party in order to enable installing a useful cooperation for both sides.

The next two subsections provide a brief discussion of the differing goals and characteristics of each, industry and academia partners. Following these subsections, Subsection 2.3 introduces the essence of the method, through the proposition of a new technological product development flow for telecom industries. The proposed flow includes points where academic research groups may best contribute and considers the goals and characteristics of each party. The same Subsection presents also a proposition of roles to be played by each, industry and academia in the cooperation.

2.1 Partners Goals

The main goal of industries is to produce high quality products in order to achieve maximum profit. Here quality is perceived in its broadest sense, meaning products with the best trade-off between price and performance. However, technological products in general and telecom products in particular are expected today to respect a still more important figure, namely time to market. The first enterprise to insert a new product in the market will most probably acquire the biggest share of profits on this product during the whole product life cycle. This market law dictates that enterprises must be fast in developing new ideas. Academia on the other hand has as main goal to develop good quality research, in order to maximize the number and quality of its main products, i.e. publications and human resources.

Very often, industry and academia goals may seem conflicting, since high quality human resources and high level publications usually take long time to become mature, and industry needs speedy development. However, the human resources formed at the academic environment will ultimately become developers or entrepreneurs of high technology products, and the time spent in their formation will pay back in increased product quality and enhanced time to market. On the other hand mature research results and documents are invaluable to enhance understanding of new, revolutionary technologies.

2.2 Partners Characteristics

Commercial product development is an intrinsically multidisciplinary activity, comprising several distinct technologies. Telecom products typically involve dealing with fields like digital systems, analog systems, and RF circuit design. Additionally, supporting technologies may also need attention, such as integrated circuit design and printed circuit board design. Academic research, on the other hand is a highly specialized activity usually quite restricted in context. This is necessary to enable advances in the state of the art of a field. Research groups capitalize in the constitution of research networks with other groups to complement its abilities. Since both profit and secrecy are often unimportant issues among academics, cooperation with different groups is easier than among enterprises.

Another remarkable difference between industry and academia relies on the way the respective human resources are involved in research and development (R&D) projects. On the one hand, industry R&D teams are usually allotted to work in a single or in a few fronts, most of them related to a single product family, such as copper modems or ATM switches. We may then classify industry R&D teams as *problem-driven*. In other words, they are skilled in the (possibly multidisciplinary) aspects of one or a few problems. Academic teams, on the other hand, may be classified as *subject-driven*, since they are more often skilled in a field of knowledge, such as digital signal processing or computer networks. In this way, academic R&D teams use specific problems as case studies to validate a developed method, and not as a goal in itself. Fruitful cooperation between industry and academia arises only if both sides recognize these distinct profiles as complementary, not antithetic. New technologies, tools or design methods that were never applied to solving specific problems in some industry may provide the cost, performance and/or time to market differential among competing products. Examples for the telecom industry might be the use of reconfigurable hardware and/or hardware-software codesign tools and methods. Another distinction is that industry teams are more permanent, while research teams are mostly volatile. A few researchers and a number of graduate and undergraduate students form the latter. Graduate students are usually the main work force in most projects, but their main goal is not the project in itself, but the achievement of the graduate diploma, typically a master or doctor degree. The cooperation project learning curve for this work force may be quite high, especially if the students were not part of the research group before enrolling in the graduate program. Even if the student is already a previous member of the research group graduate courses are very demanding in the first year, and typically unrelated to the cooperation, contributing to make things worse for the project schedule.

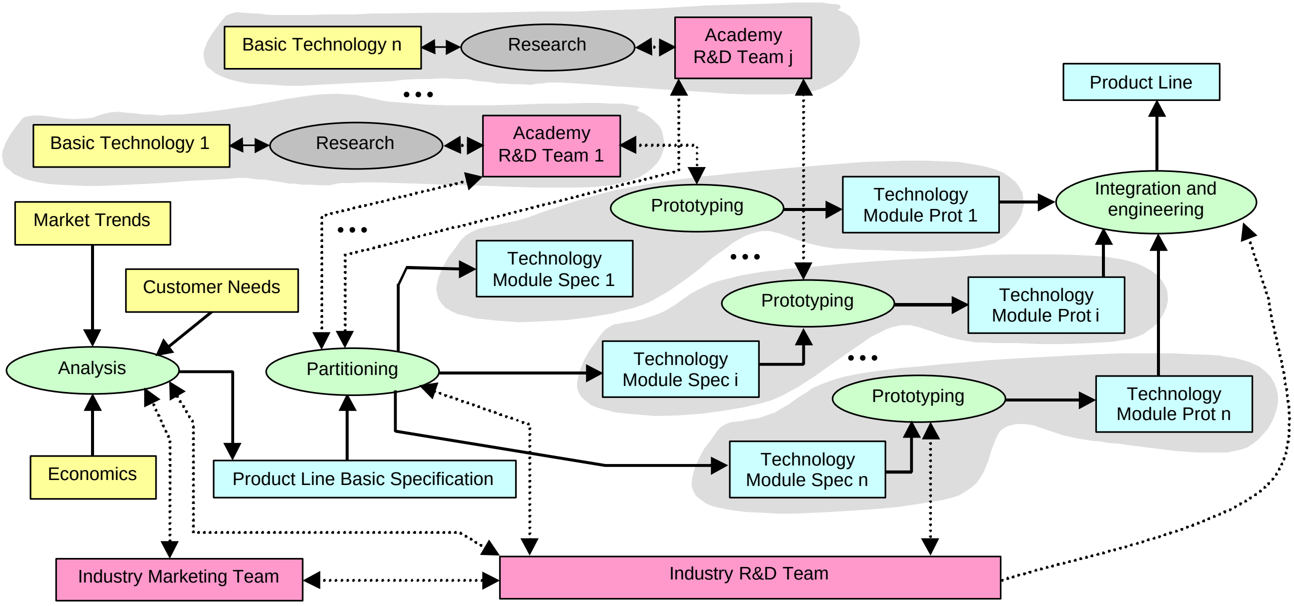

Figure 1 - Proposed technological product development flow for telecom industries cooperating with academic research groups. Solid lines represent information flow, while dotted lines convey information of team action and/or team interactions.

2.3 Technological Products Development Flow

Figure 1 depicts a proposition for the development flow of telecom technological products within the scope of an industry-academia cooperation. Given the multidisciplinary nature of the product development and the specialization of research groups, the proposition involves several research groups and one enterprise. A generalization might add more than one enterprise and other levels of interaction, such as at the marketing level, but the proposition is expected to model the more common case found in practical situations.

The product line development starts within the industry marketing team that, based on the analysis of market trends, aspects of economics and customer needs devise a window for the insertion of a new kind of product in the market. The interaction between the marketing team and the industry R&D team leads to the elaboration of a product line basic specification. This is the point where industry-academia cooperation should start. The basic specification determines the necessary technologies to employ during the product development. A partitioning step, which might already involve the **j** academy research partners, will ultimately produce **n** technology module specifications. It should be clear from Figure 1 that the most important criterion in the partitioning step is the implementation technology, modulated by the specialization of all R&D teams involved. A second criterion to employ is the individual module complexity that may determine migration of functionality between modules. For example, optical or CMOS silicon devices can be used at several steps of high-speed data transmission. The decision where to employ each technology can be based on the balance between the relative dimensions of the optical and CMOS modules. Of course, the cost criterion cannot be overlooked, and will determine the final choice, since an optical implementation might be a simple, serial and small, but cost much more than an equivalent complex and bulky parallel implementation.

The roles of industry and academia sides in the technology modules specification are capital in the partitioning step. In the previous step, basic product line analysis and specification, the academy teams could contribute e. g. by bringing new enabling technologies providing added product performance or functionality. However, in the prototyping step, the academy contribution is being defined. The academy team must then moderate the prototype specification to ensure its research contents and the possibility of timely implement the prototype. The first guarantees that research is indeed being addressed, enabling good quality publications about it. The second can only be determined by the academy group that knows the academic context where the prototype will be developed, balancing students academic activities with the cooperation project activities. On the other hand, the industry team must ensure that the academy prototype schedule does not impair the product schedule, and also that secrecy is not compromised by the publication of results.

In the next phase of the cooperation, prototyping, each team proceeds alone, except when need arises to clarify the module specification, in which case interaction with the industry R&D team takes place. It is necessary to note that the industry team will certainly reserve the prototyping of some modules to itself, based on criteria like secrecy, team abilities and time to market.

After the prototyping phase, comes the step where the several modules are integrated and engineered. This step should be clearly assigned to the industry R&D team alone, cooperating with other sectors, such as the production and product engineering teams.

Finally, it is important to note in Figure 1 that the arrows connecting the academy R&D teams to the research process and the state of the art of the basic technology it addresses are bi-directional. This is so to indicate that the cooperation between industry and academy is expected to produce new methods and techniques, which advance the state of the art in that technology.

3. METHOD APPLICATION CASE STUDY

The authors of this paper have established an industry-academia cooperation based on the method presented in the last Section. Indeed, the cooperation helped to determine the main characteristics of the method, and it has, in the opinion of the authors been quite successful. The involved industry has cooperation with several R&D teams, as in the proposed model. However, for space reasons and simplicity of the presentation, only the interaction between one academy team and the industry team is described here.

The next subsection discusses the industry and academy R&D teams profile. Subsection 3.2 provides the main characteristics of the cooperation, in view of the teams' profile.

3.1 Industry and Academy R&D Teams Profile

The industry is specialized in telecom products, and has its R&D department divided into two mains technological branches, optical and copper devices. Specifically, its product lines comprise analog, digital and optical modems, ADSL modems and routers and management software. The industry R&D teams are used to design products containing technologies such as general purpose and digital signal processing microprocessors, analog, digital and optical transmission devices and digital systems in general. Some of the industry products contain programmable devices with application specific circuits in them, but most of it have been specified internally and designed externally to the enterprise. This occurred because device design was not, prior to the cooperation with academia being established, one of the abilities of the industry R&D teams.

The academy research group, on the other hand, is part of a graduate program at a Computer Science department in a private university. It is specialized in the support of integrated digital systems design activities, including fast prototyping, (re) configurable devices and systems, computer aided design (CAD) tools and integrated circuit design. The research group has invested since the mid-90´s, when it was created, in acquiring expertise in digital device design and implementation. More specifically, it has a deep knowledge of the state of the art in VLSI configurable devices design and architecture, including complex FPGAs and CPLDs.

The industry needed dominate the device implementation technology, and the research group desired to dominate telecom applications, due to its increasing importance in VLSI device design. As a motivation to this, it is known today that approximately 80% of the FPGA devices sold in the world are used in telecom applications, while 3 years ago this figure was in less than 40% [3]. The profile and needs of the industry and academia teams were clearly complementary.

3.2 Characteristics of the Cooperation

The first phase of the cooperation took the form of a course on modern device design techniques using configurable hardware, taught by the academics of the research group to the whole R&D sector of the industry. The course was mostly about VHDL device design targeted to FPGAs. During this course the students suggested a class exercise. The instructors designed the circuit arising from this exercise using the basic techniques in the course. This prototype was later refined in the industry, and become part of a commercial product. The seed for the cooperation was thus planted.

A classification of implementation options for technological products appears in Figure 2. Telecom industries in developing countries like the one described here do not often use the options at the extremes of this classification. The leftmost option usually does not provide enough performance for telecom products, and the rightmost option is too expensive for the product sales volume of these industries. The industry in question here already dominated the DSP, microcontroller and chip sets implementation options, but not the remaining option, i. e. the one based on the design of specific devices over configurable devices. This was exactly the main competence of the academic research group.

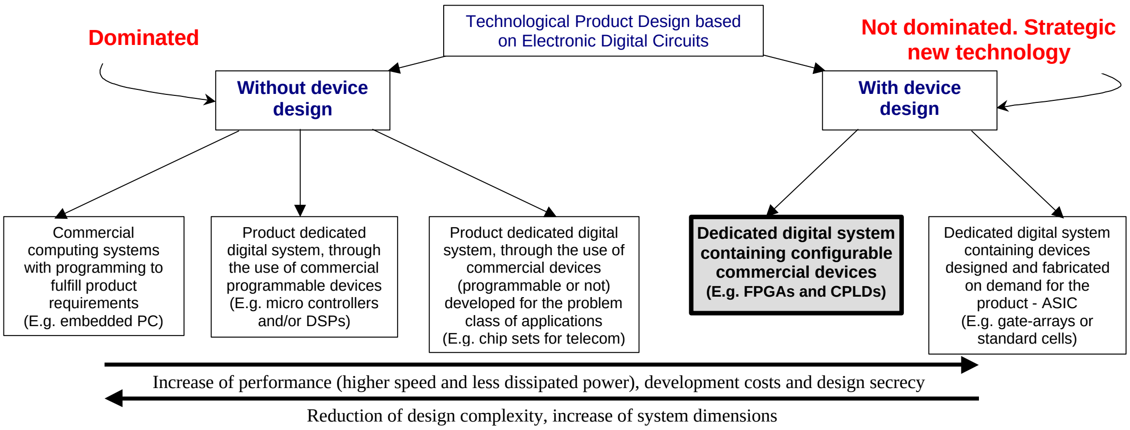

Figure 2 - Implementation options classification for technological products based on electronic digital circuits. The classification criterion is the type of the main electronic device employed in the system.

The cooperation involved in the whole seven technically skilled people, two on the industry side, three graduate students (2 MSc and 1 PhD) and two academics. The industry personnel propose the basic specification of modules to implement. A discussion follows to moderate the design, adapting the size and complexity of the module to the capacity of the academy team. Modules are designed as Intellectual Property soft cores (or IP cores), validated by simulation and prototyped in hardware platforms available at the research group academic laboratory. After initial validation the design is sent for the industry team that independently tests the design on their hardware platforms. Refinement and minor bugs are then detected and fixed by the academy team. The final IP core is released with documentation by the research team for both sides to use it, in products and/or research.

4. CASE STUDY FIRST RESULTS

Within the context of the industry-academia cooperation reported in the previous Section the first year was dedicated to establishing a common ground between industry and academy. A design project was then specified and conducted by the academy team. Graduate students training in the basic technology occurred in this period, involving FPGA architecture and design, digital system design, validation implementation and testing starting from VHDL descriptions and other issues. The design is described in this Section.

The goal of the design project was the development of two real time telecom IP core modules, which use the E1 protocol. The main IP core, named Drop, operates inserting and dropping information to/from an E1 frame. The Drop core respects the ITU-T Recommendations G.703, G.704 and G.706 [4][5][6].

To obtain better control over the validation phase, the Padder core was developed, which in essence creates an “empty” E1 frame. Figure 3 shows an example of the typical concatenation of Padder and Drop core modules in a cascade, with a transceiver that adequates the digital signal to the E1 line.

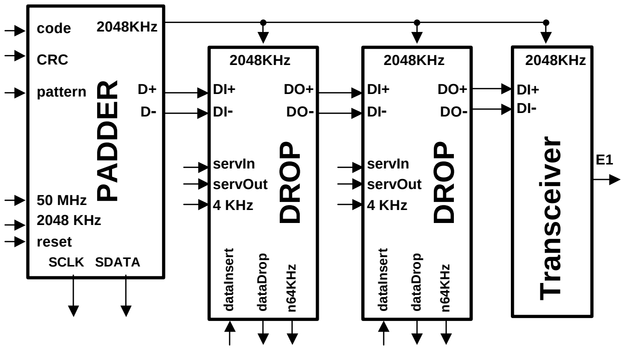

Figure 3 - Typical example of Padder/Drop core modules.

4.1 Basic E1 frame structure

E1 is a multiframe (MF) structure made up of two sub-multiframes (SMF). An SMF contains 8 frames; each frame has 32 slots and each slot has 8 bits, for a total of 256 bits per frame. The basic structure of an E1 Multiframe is depicted in Figure 4.

		Frame no.	time slot 0 (ts 0)								ts 1			···	ts 31		
		↓	1	2	3	4	5	6	7	8	9	···	16	···	249	···	256
MULTIFRAME	Sub-multiframe I	0	C1	0	0	1	1	0	1	1							
		1	0	1	A	S4	S5	S6	S7	S8							
		2	C2	0	0	1	1	0	1	1							
		3	0	1	A	S4	S5	S6	S7	S8							
		4	C3	0	0	1	1	0	1	1							
		5	1	1	A	S4	S5	S6	S7	S8							
		6	C4	0	0	1	1	0	1	1							
		7	0	1	A	S4	S5	S6	S7	S8							
	Sub-multiframe II	8	C1	0	0	1	1	0	1	1							
		9	1	1	A	S4	S5	S6	S7	S8							
		10	C2	0	0	1	1	0	1	1							
		11	1	1	A	S4	S5	S6	S7	S8							
		12	C3	0	0	1	1	0	1	1							
		13	E	1	A	S4	S5	S6	S7	S8							
		14	C4	0	0	1	1	0	1	1							
		15	E	1	A	S4	S5	S6	S7	S8							

Figure 4 - Basic E1 Multiframe structure.

The first slot of each frame contains MF basic control information as follows:

- **Frame alignment**: every even frame contains a “0011011” pattern from bit 2 to bit 8; all odd frames have a ‘1’ in bit 2.
- **Multiframe alignment**: every odd frame, from frame 1 to 11, have in bit 1 a value that generates a “001011” pattern.
- **Cyclic Redundancy Check (CRC)**: each SMF has its own CRC code (C0, C1, C2, C3) sent in the SMF that follows it.
- **CRC error**: there are 2 CRC error bits (E) to indicate if CRC was properly calculated or not.
- **Remote alarm indication**: the bit 3 (A) of all odd frames indicates the event of a remote alarm.
- **Synchronization status**: all odd frames have from bits 4 to 8 five bits used to different purposes, like signaling.

The rest of the slots (1 to 31) are responsible for carrying information (voice and data). As the frame repetition rate is 8KHz, the basic frequency of an E1 frame is 2048KHz.

4.2 Drop Architecture

The Drop IP core architecture can be abstracted by 3 signal sets, as shown in Figure 5:

- **E1 frame**: implemented by DI+ and DI- input signals, and DO+ and DO- output signals. These signals carry E1 information with differential encoding.
- **Insert/Drop Information**: implemented by n64KHz, SS, dataInsert, dataDrop and n64 signals. The insert and drop operation allows Drop to add information in one or more slots of the E1 frame.
- **Information Service**: implemented by 4KHz, inServ, and outServ signals. With these signals the Drop core can receive and transmit information between operators.

4.3 Drop Organization

The Drop organization comprises 6 modules, shown in Figure 5:

- **Decoder**: converts an electrical signal (HDB3 or AMI [4]) into a logical signal (bits of the E1 frame).
- **Encoder**: has functionality opposite to that of the Decoder.
- **CRC4**: calculates and inserts the CRC into the next SMF.
- **Divider**: based on an external frequency of 2048KHz generates all other frequencies (n64KHz, **n** from 1 to 31).
- **Synchronization Circuit**: responsible for frame and MF synchronism, and for operation with or without CRC. When synchronism is found, generates the MF address.
- **FIFO**: 2 FIFO structures allowing inserting and dropping information to and from an E1 frame. The FIFO operation algorithm receives bits in rates smaller than 2048Kbits/s (controlled by n64KHz), and inserts them in the frame at 2048KHz. For example, suppose there is a need to insert 2 bytes of information (n64=2) starting at the third slot (SS=3). In this case n64KHz is 128KHz and Drop reads the external information from the dataInsert signal in the time of one frame, and insert the same information in two time slots (see **Figure 6**). To properly synchronize the reading (endn64) and writing (end2048) addresses, end2048 is reset at each new frame and incremented during the insert phase. The end64 address is reset at the end of the information insertion in the frame and incremented with the n64KHz frequency clock.

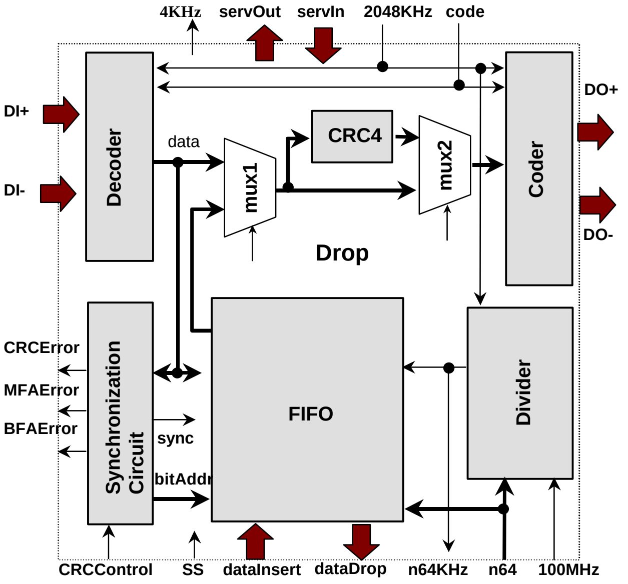

Figure 5 - Block Diagram of the Drop IP core.

4.4 Results

All circuits were described in VHDL [7] and prototyped in Xilinx FPGAs of families Virtex (at the academia) and SpartanII (at the industry). The VHDL description was designed to be reusable and mostly device independent. To get better performance and smaller area, FIFOs were the only block to present a physical dependency on the use of Virtex or SpartanII FPGAs (technology dependent memory modules). However, fully technology independent modules are readily available.

The system is fully operational, attending all design constraints of the original specification. Just 10% of a 150Kgates SpartanII FPGA are necessary to implement the Drop IP core. It thus allows cascading several Drop IP cores in the same FPGA.

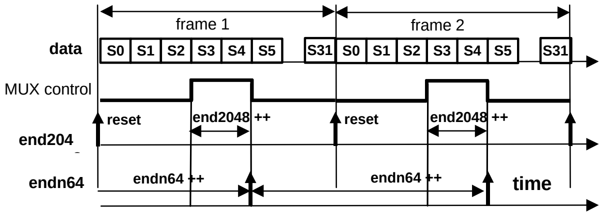

Figure 6 - Insert and drop control operation. In the example, SS=3, n64=2, n64KHz=128KHz.

5. CONCLUSIONS AND FUTURE WORK

Tax exemption laws may offer a real opportunity window for realizing the industry-academia cooperation in developing countries. This work has described a method to implement an effective cooperation under such a set of laws in Brazil. The cooperation has started but so far there is no sign of stopping. In fact, the idea of creating the cooperation is to end up with real interdependence between industrial and academic environments. To achieve success, the single main point in the relationship is *cooperation*. Industry has to value research work, and academy must value the conversion of ideas into real products. An important point to discuss *after* confidence is installed in both sides is the delicate question of intellectual property and patents.

After the results of the first year in the case study cooperation the same team is continuing with another project, a much more ambitious and complex IP core module for application in high speed SDH [8] equipment. The team is already trained in the basic enabling technologies as well as in the product characteristics. Besides, a new team was formed, with the same academics and two new graduate students, to address ATM network IP cores.

The academic team has improved laboratories with the funds furnished by the industry. Also, there are now five graduate students financed with the same funds (scholarship plus fees).

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