WHICH SIGNAL PROCESSING TECHNOLOGIES SHOULD I USE IN MY WIRELESS APPLICATION? WELL, IT DEPENDS...

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Technology providers, including companies that create commercial off-the-shelf signal processing devices, are constantly trying to drive new features and innovative technologies into the marketplace. The underlying reason for this is fairly simple: these elements help to differentiate the technology provider's products in the market and thus drive revenue. Conversely, technology consumers, including both military and commercial wireless original equipment manufactures (OEMs), are constantly pulling the market toward the commoditization of technology, with a goal of fostering competition, driving economies of scale, and ultimately lowering overall costs. For the communications systems engineer, this friction between "technology push" and "market pull" means that the technologies most appropriate for use in intermediate frequency (IF) and modem processing are constantly evolving. So the question is: at any given point in time, how does one choose which signal processing technologies to apply in creating a wireless circuit or system?

Prior to the tech bubble burst in 2001, the technology strategy for many OEMs was to rely heavily on the use of custom application-specific integrated circuits (ASICs) for wireless signal processing applications [1, 2]. ASIC-centric signal processing solutions were generally perceived as offering the maximum degrees of freedom in optimizing for cost and performance when supporting a fixed feature set. Circuits and systems utilizing ASICs may also have incorporated an off-the-shelf application-specific standard processor (ASSP), such as a digital downconverter chip, or an off-the-shelf digital signal processor (DSP) if an appropriate technology was available, but these devices were generally relegated to a supporting role in the overall architecture.

Creating a custom ASIC for use in a wireless signal processing application requires a fairly high investment in nonrecurring engineering (NRE). In a resource-constrained environment — and let's face it, since the tech bubble burst we are all a bit resource constrained — many OEMs have taken a hard look at their technology strategy to redefine how they maximize their investments to differentiate their products and services in the market and ultimately grow revenue. Component technology such as a custom ASIC is pretty far down on the wireless value chain, and as such the NRE cost associated with ASIC development can only be justified if it helps an OEM make money by providing some truly innovative feature or capability that will drive overall product sales [3].

More and more, this reassessment of technology strategy is compelling OEMs to outsource the development of technologies such as custom ASICs that are lower on the overall value chain. Industry efforts such as the Open Base Station Architecture Initiative (OBSAI) are a clear indication of this trend [4]. OBSAI is consortium of over 120 companies, led by Hyundai Syscomm, LG Electronics, Nokia, Samsung, and ZTE, that is defining a standards-based modular architecture for base stations supporting a wide range of commercial communications standards. Through the OBSAI initiative, vendors will be able to enter the market with modular products and technologies supporting the defined standards. As more and more vendors enter the market, the technologies will become commoditized, allowing OEMs to choose from a range of vendor products and consequently driving down the overall cost due to competitive pressure.

This trend in outsourcing technologies that are lower down on the value chain has opened the door for commercial signal processing device manufacturers to enter the wireless market with specialized products targeted at technology areas that have historically been dominated by in-house development. In doing so, vendors must define how they differentiate their signal processing devices in a manner that OEMs perceive as truly impacting their bottom line. Often this differentiation lies in the level of flexibility offered by the off-the-shelf technology in addressing the OEM's target application. The custom ASICs traditionally utilized by OEMs were generally limited in the number of functions they could support. As such, the addition of any new revenue generating feature or capability beyond the fixed functions of a custom ASIC required another NRE investment and a forklift upgrade to the signal processing subsystem for each radio in service. "Software"-based signal processing solutions (and when I say software I am generically including both firmware and HDL code in what is traditionally thought of as software) offer the maximum flexibility in adding new features and capabilities to a radio platform while in service, through software upgrades. Software-defined radio (SDR) technology therefore saves a company money by allowing a common "radio platform" to be reused for multiple applications, and makes a company money by enabling the OEM to offer new revenue generating features and capabilities in existing products. Programs like the U.S. JTRS program recognized the economic advantages of this model for tactical military communications and have been actively driving standards supporting the proliferations (and thus commoditization) of SDR technology [5].

Historically the level of flexibility associated with SDR comes at a higher cost per unit than an equivalent ASIC solution. To be successful, device companies must therefore offer products that approach the performance and cost benefits of an ASIC while supporting an increase in overall flexibility. One way many companies are addressing this issue for the narrowband applications associated with second-generation (2G)/2.5G cellular and tactical military communications is to marry the capabilities of an ASSP, DSP, and/or general-purpose processor (GPP) in a "system on a chip" solution targeted at specific segments within the wireless market. Examples of this abound. Texas Instruments C64x Digital Signal Processor Family includes integrated Viterbi and Turbo co-processors that can act as "hardware accelerators" to provide ASIC-like performance for wireless applications [6]. Field programmable gate arrays (FPGAs) from companies such as Xilinx® and Altera® are supporting the benefits of GPPs through hard and soft processor "cores," and include banks of multiply-and-accumulate engines to allow more efficient signal

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processing [7, 8]. These integrated signal processing solutions are generic enough to support a broad number of market segments, driving some economies of scale and thus reducing the overall cost of an OEM's SDR solution.

Of course, utilization of innovative technologies such as these has a tendency to tie an OEM to the technology provider for the long term, which ultimately limits the cost savings the OEM can realize. From a business perspective, the OEM's needs can best be met through the use of commodity signal processing technologies that offer sufficient performance to address the application requirements while minimizing overall costs. Does such a technology exist? Well, for many narrowband applications the answer is yes. Last year, Vanu® in partnership with ADC earned Federal Communications Commission certification for a software defined GSM base station utilizing off-the-shelf Hewlett Packard ProLiant Servers for the signal processing subsystem [9]. While this type of solution may not be appropriate for many size, weight, and power limited systems, such as a mobile handset, or have sufficient performance for many broadband applications, the Vanu solution does illustrate how the economies of scale inherent in the use of commodity processing can provide a significant reduction in the overall cost of a wireless system.

A different type of solution is generally required for broadband applications. Systems supporting applications such as military satellite communications or WiMAX are generally driven by performance, and the serial processing model inherent in most GPPs and DSPs is often insufficient for many of the types of processing required. FPGAs, on the other hand, naturally support a concurrent/parallel processing model that supports these types of processing, and as such, over the past several years the migration away from ASICs in broadband markets, especially in satellite communications, has been dominated by FPGAs.

An alternative approach taken by many signal processing device companies in supporting a parallel processing model for broadband wireless communications is to create a reconfigurable computing device supporting a large array of interconnected parallel processors. These types of devices are ostensibly based on the parallel processing architectures targeted at embedded applications that were developed in the 1980s and '90s, beginning with the transputer introduced by Inmos in 1985 [10]. This device incorporated a RISC processor, memory, and four "high-speed" communications links within a single chip. The links allowed multiple transputers to be interconnected in a high-performance parallel processing array capable of supporting a number of embedded applications. This link-port technology was replicated in DSP devices such as the Texas Instruments TMS320C40 processor to allow large parallel processing arrays to be created for use in embedded applications focused specifically on signal processing [11]. Concurrent with these developments in the embedded space was the creation of massively parallel computer technology, such as MASPAR, that used a distributed memory architecture to interconnect a large array of processors together in a single system [12].

The logical evolution of these technologies is to embed an array of processors into a single device. A number of companies are developing various flavors of this type solution that are specifically targeting broadband wireless applications, including the PicoArray® from PicoChip, the Ivy Cluster™ from Cogent ChipWare, and the Adaptive Computing Machine from QuickSilver Technologies [13–15]. The real test of success for these specialized parallel processing technologies will be whether they "cross the chasm," as defined by Geoffrey Moore, from use by innovators and early adopters into mainstream acceptance [16]. The biggest threat to the emergence of these specialized parallel processing devices may lie in the general-purpose parallel processing solutions that are already finding their way into the mainstream market. AMD has already begun shipping multicore Opteron processors, and Intel has announced plans for upgrades to its Itanium processor line supporting up to 16 independent cores [17, 18]. Similarly, IBM has teamed with Sony and Toshiba to develop the Cell Processor, with each device hosting multiple processing elements operating in parallel, and each processing element incorporating a PowerPC-based processing unit and eight additional processing units acting as an array of DSP engines [19, 20].

So, what is the best signal processing technology to utilize in wireless applications? The answer, of course, is: it depends. Over the next several years, for many size-, weight-, and power-limited systems, and systems requiring high levels of performance, the use of specialized signal processing devices targeted at specific wireless market segments will continue to eat away at the market traditionally held by custom ASICs. Over time, the market will inevitably move toward addressing these applications with more commoditized signal processing solutions, allowing greater economies of scale and significantly lowering overall cost. Ultimately, this cycle will repeat: technology push will drive new wireless applications into the market for which commodity solutions are not appropriate, requiring new technologies and whole new lines of specialized processing devices to meet the demands of the wireless industry.

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