The Benefits of Standardizing the Interface Between the RF Front End and Digital Sections of SDR Mobile Devices

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ABSTRACT

As SDR (Software Defined Radio) technology matures and comes to market, it arrives at a time of increasing cost pressures, coupled with the emergence of a growing number of AIS's (Air Interface Standards). These technical, development, and market pressures are highlighting the interface between the RF Front End and the digital section of mobile SDR devices. This paper shows how the development of industry standards in this area will serve the interests of a broad cross section of the industry including established and emerging chip, device, service and carrier companies in the commercial, civil and military sectors. It then considers the various technical approaches and concludes by describing the most promising.

1. INTRODUCTION

The cellular / wireless industry is going through a period of rapid change. The changes include technology and business models and have profound implications for standards. We will first look at changing technology and the resulting changing business model environment, then how that environment is affecting standards. Then we will consider implications for and alternatives in standards for mobile devices.

2. CHANGING BUSINESS MODELS

As cellular systems began to proliferate and the WLAN industry laid the foundations for its eventual lift off, the prevailing technical environment was dominated by a digital computer centric perspective. High speed signal processing used in radios was considered arcane and analog RF was close to black magic. In this environment, a relatively small number of companies developed dominant positions. These dominating companies considered the arcane /black magic status of the key enabling technologies as a competitive differentiator providing sustainable competitive advantage. To this end, they organized as vertically integrated companies selling a complete solution seeking to lock their customers in.

In order to obtain spectrum, regulatory bodies required the definition of AIS's, sufficiently detailed to eliminate interference and other issues of primary concern to the regulators.

Network operators found that customers wanted a range of choice in handsets, at the same time the operators desired second sources and that, as well as other drivers, led to a requirement for interoperability between base stations of one manufacturer and handsets of another. This led to more detailed AIS's to allow interoperability; however, handset internal interfaces remained proprietary.

The situation for base stations was different. Base stations are one system component of a larger system often referred to as the wireless or cellular infrastructure. Other infrastructure system components can include base station controllers, billing systems, address servers (such as Home Location Registers), switches, routers, etc. Although, network operators desired to have second sources for infrastructure equipment, the dominant suppliers were able to successfully argue that vendor proprietary solutions with closed interfaces were best.

As cellular systems grew and the Internet model entered the wireless industry through WLAN's, pressure grew. New entrants sought to enter the infrastructure business. What emerged was a situation similar to that in the mainframe industry commonly referred to as "the plug compatible wars". The dominant entrenched infrastructure suppliers worked strenuously to prevent, or at least delay, the development of open interface standards, while the less dominant suppliers, network operators, new entrants and enabling technology suppliers worked just as strenuously for open standards. The result was deadlock.

What resulted was what can be called the classic era of cellular / wireless systems with:

- AIS's that allow for handset cross vendor interoperability,
- Proprietary handset internal interfaces,
- Proprietary infrastructure interfaces.

3. PERIOD OF TRANSITION

A series of usage, technical, business and regulatory changes forced the industry out of the "classic period" into a period of transition. These forces include:

- Penetration explosion,
- AIS proliferation creating demand for multimode multiband systems,
- Emergence of SDR,
- Spectrum auctions,
- Telecommunications bubble burst,
- Appearance of venture funded enabling technology companies,
- Transition from desktop to personal portable information tools.

The industry moved from a period of industrial usage models where less than 1% of the world's population was connected to wireless systems less than 1% of the time to a situation where in some developed countries where close to 100% of the population was connected close to 100% of the time.

New AIS's began to appear rapidly, driven by technical innovation, a need to serve the larger user base, and a recognition that a single AIS could not support all the users' varied requirements: 2G, 2.5G, 3G, 3.5G, 4G, WLAN, WPAN, GPS…

A corollary of AIS proliferation is the growing demand for multimode multiband systems so that users can meet their varied requirements regardless of where and when.

Software Defined Radio technology had been developing slowly as part of the evolution of enabling radio technologies. Multimode multiband requirements and the desire to "future proof" systems in the environment of rapidly evolving AIS's, vaulted SDR to the forefront. Related to SDR development, was the evolution of radio technology away from very large numbers of discrete components in complex and very sensitive board designs to a relatively small number of integrated circuits on simpler board designs with the critical functionality implemented in software. This movement to integrated circuit hardware and software took the "black magic" out of radio development and allowed firms with reasonable technical competence to enter the industry.

Regulators driven in part by the explosive growth of cellular, the windfall profits some had achieved by trading in early cellular licenses, and changes in political philosophy initiated the process of selling spectrum licenses at auction rather than granting licenses in the "public interest, convenience and necessity". This drained very large amounts of capital from the industry that would other wise have been available for other purposes.

The internet dream took hold of the larger telecommunications industry and prompted traditional telecommunications network operators and suppliers to greatly over invest in capacity and inventory. When it became unavoidably clear that the realization of the dream would be many years (not days) in the future and the bubble burst, the large telecommunications companies that were the parents of most of the wireless network operators, found themselves dangerously overextended. This resulted in a further drain of capital away from the wireless industry.

When the cellular industry started to grow, the venture industry was focused on the microcomputer revolution and the enabling technology was developed by what became the dominant equipment vendors. By the time the transition period began, the dynamic growth of the wireless industry had attracted the attention of the venture industry. Venture capitalists began to look for start-up opportunities to provide enabling technology to the dominant equipment vendors. What resulted was a period of competition in enabling technology development between internal groups (in the dominant equipment vendors and the large consumer electronic companies) and venture backed start-ups.

All of the above happened in the context of a larger process of moving information off of desktops into personal portable devices. Such devices as Game Boys, MP3 Players, Digital Cameras, portable DVD players, PDA's, etc. characterize this larger process. One of the consequences was the movement away from industrial business models to consumer electronic business models.

During this transition period, standards development in the commercial cellular industry proceeded, but not at the same pace across all segments. AIS development made steady progress. Infrastructure standards development was started, but proceeded very slowly. The SDR Forum published an architectural standard (SDR Forum "TR 2.1" and "Terminal and Network Architecture", available from the Forum at www.sdrforum.org). Several organizations started standards efforts aimed at developing open interfaces between various components of cellular infrastructure but made little or no progress. Resistance from the dominant equipment vendors slowed or prevented further progress. The SDR Forum found strong support across a broad cross section of the wireless industry for work with regulators on subjects such as "soft" labeling, secondary use, security, and over the air download.

4. CURRENT SITUATION

With the publication of the OBSAI and CPRI press releases, it is clear that the forces that were at work in the transition period have now come to a head and the industry is entering a new era.

Because of the economic forces that appeared in the transition period, there is no longer sufficient capital for the dominant equipment vendors to internally develop all the required enabling technology. (The consumer electronic vendors are in a similar position and the new entrants from China are seeking to catch up to the established vendors.) Each of the large vendors finds themselves with strong enabling in some but not all of the required enabling technologies.

The business model that is emerging is then similar to that of the Chrysler automobile company in the late 1980's:

- Focus on understanding what the market requires,
- Develop or acquire the necessary enabling technology,
- Deliver the product to market before the competition,
- Sell any internally developed enabling technology to any other vendor as long as it is at a profit.

Now the dominant vendors, instead of resisting standards development, are seeking to control their development. Each is trying to force the standards process to develop standards which are based on implementations of their strongest enabling technologies.

At the same time, enabling technology vendors are seeking to force the standards process in a direction where their technology (hardware, software, design, IP, etc.) retains the largest possible portion of the available margin.

To make this emerging business model fully efficient, subsystem interfaces that will allow system vendors to integrate subsystem components from a variety of sources are necessary while at the same time allowing the maximum possible technology innovation.

5. THE IMPORTANCE OF THE RF / DIGITAL INTERFACE

Because of the way that architectures and semiconductor processes are evolving, it appears that there will be different technology bases for high performance wireless systems, one for the RF Front End and the other for the Base Band / Controller portion of the system.

The RF Front End is the portion of the system that provides amplification, filtering and down conversion. The Base Band / Controller is the portion of the system that provides modulation/demodulation, user data encoding, protocol stack, human interface and local control.

There are a variety of architectures employed for the Base Band / Controller portion. However, they share some similarities. They employ fundamentally digital logic and are implemented in the semiconductor processes developed for PC micro processors. The RF Front End's also have a variety of architectures while sharing some similarities. They employ analog or analog / mixed signal devices and are implemented in higher performance semiconductor processes. What results in high performance (such as commercial cellular) wireless systems is at least two subsystems with an interface between them. The two subsystems are the RF Front End and the Base Band / Controller. Because the Base Band and Controller are both implemented in digital logic and sometimes on a single piece of silicon, they are often referred to as the digital section and this interface then becomes called the RF / Digital Interface.

System designers must then implement an interface between these two resulting subsystems. However, the significance of this interface extends beyond the system developer. Examples include:

- Network operator – software management and over the air download for both infrastructure and mobile terminals
- Regulator security to guarantee field software changes cannot cause devices to operate in an unauthorized fashion,
- User ability to upgrade other portions of the system while reusing the RF portion.

To avoid confusion, we note that in some system implementations there is a finer granularity of interface definition including such interfaces as the Base Band / Controller Interface, Controller / Application Processor Interface, and the Controller / Network Interface Processor Interface. These interfaces can be of interest as potential targets of standardization activity. However, the RF / Digital interface is so much more critical that decisions about whether and if so, how to standardize these other interfaces can be postponed until after the RF / Digital Interface.

6. POSSIBLE STANDARDS APPROACHES

This part of the discussion focuses on the RF / Digital Interface in the handset. A discussion of RF / Digital Interfaces for other types of devices including Base Stations can be found in the soon to be published Chapter 2 of Volume 3 of the Wiley SDR Series.

A mobile device RF/Digital Interface standard should support all currently deployed and foreseeable AIS's as well as real time switching between them. It needs to provide software developers, network operators and regulators a basis for an assured, secure over the air download capability. Because there are likely to be more than one subspecies contained in this standard, there must be a meta language which describes the particular standard implementation and a protocol that allows systems to identify which one(s) it has implemented.

There are two classes of signals that must pass over this interface; control and data. Because of a desire to minimize pin counts and thereby minimizing cost, power consumption and size, the industry is moving to a high speed digital serial interface. The high speed requirement is critical because of the low latency required for some control functions in some AIS's (such as power control). A standard protocol and message formats that accommodate all currently deployed and foreseeable AIS's and which is extensible, plus a physical interface, constitutes this portion of the standard.

Because of the rapid rate of technical innovation it is likely that at least two species of interface will be required on the data side. In the near term an analog point to point I & Q interface will be the most useful for a very large segment of the industry. Over time, the industry is likely to move to a digital bus interface which can support multiple simultaneous RF Front Ends and multiple simultaneous Base Bands. Information could be encoded as digitized I & Q (with standardized word size, etc.) or digitally represented symbol values. Here again, it seems prudent to provide for both to allow for current implementation architectures to easily migrate to the standard while providing a path within the standard for likely industry technical evolution.

7. FUTURE DIRECTIONS

As this paper is written, the SDR Forum is in the process of completing and publishing "Commercial Handset Guidelines" which combines, updates and extends the material previously in "SDR Forum TR 2.1" and the "Terminal and Network Architecture" . This material and the OBSAI and CPRI, material provide a good foundation for the development of open industry standards fro the RF / Digital interface.

The next step is for the industry to decide how the various organizations working in this area; both consensual and treaty standards organizations, regulatory groups, and regional government funded R&D organizations can best work together to produce the best possible set of standards at the earliest possible opportunity.

8. ACKNOWLEDGEMENTS

The author wishes to thank the many people both inside and outside of the SDR Forum, from the commercial, military and public safety sectors of the wireless industry, from dominant equipment suppliers, consumer electronic companies, enabling technology vendors, network operators, service providers, venture capitalists, regulators and academics who have worked to help the author develop an understanding of the area covered in this paper. Just to list these people would take more space than the paper itself and to list some and not all seems unfair.

At the same time, the views expressed in this paper represent only the views of the author and not those of any particular organization he is affiliated with.