New SDR architecture enables ubiquitous data connectivity

While WiFi in the laptop has enabled unheralded mobility for many, WiFi hotspot coverage is not ubiquitous, limiting where laptops can be connected. Other emerging global standards for high-speed data, like WiMAX, WiBro, HSDPA and EVDO, presently provide islands of coverage. What is required is a laptop wireless modem that can seamlessly interoperate amongst these various standards. Although, software-defined radio (SDR) is the right technology to stitch together these services for ubiquitous global laptop connectivity, the high-power ADCs found in common SDR architectures make it uneconomical. A new approach to SDR is required, which is described in this article.

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Pervasive wireless connectivity has clearly catalyzed change in today’s high technology businesses as well as in personal lives. When the first mobile phones were being developed back in the 1980s, few foresaw the impact that mobile communications would have on our daily lives. The growth in all types of mobile connectivity has exceeded expectations. On March 6, 1983 when Motorola introduced the world’s first commercial portable cellular phone, the DynaTAC 8000X, none of us would have thought that by 2005 more than 80% of the population in Europe and in the United States would subscribe to a cellular service provider; more than 250 billion SMS messages would be sent in 2004; sales of mobile computing devices (laptops) would exceed those of desktops and that almost each laptop sold would have an 802.11 b/g adapter built in.

Although many protocols for wireless data have been proposed and implemented, WiFi (802.11) stands out. It has managed to cross a tipping point similar to the way cellular services became ubiquitous in the 1990s. The nationwide availability of hotspots has reached a point where the network effect has begun to drive WiFi’s acceptance and inclusion in a range of mobile devices. Although hotspots are not yet as ubiquitous as many road warriors would like, it has become accessible enough that most users are confident that they can locate a hot spot quickly and easily.

In spite of its marketing success, the business model for WiFi services—offering speeds up to 54 Mbps within several hundred feet of an access point—has been difficult. Potential users have been turned off by roaming and coverage problems. Prices have also seemed high given the inconsistent coverage.

However, when considering how to best implement mobile data services, it would be incorrect to focus on just WiFi. What users want is seamless mobility. We realize that a single standard is incapable of providing global mobile data services. Engineering trade offs must be made to balance battery life, transmit power, sensitivity and throughput. Thus, in reality, WiFi is only one part of a successful global mobile data solution because of the inevitable need for true mobility provided by multiband multistandard devices.

Multiple data standards

When users consider which mobile data standard to choose, they intuitively trade off cost with range and throughput. Efforts to improve the WiFi standards have focused on just that. However, the wireless world doesn’t only exist within the local area network (LAN), it can be compressed and stretched to match the geographic scale of business and personal lives. Users require laptop data connectivity in wide area networks (WANs) as well as in metropolitan area networks (MANs),
Table 1. A complex array of wireless data standards.

LANS and personal area networks (PANs) as illustrated in Figure 1.

Many new emerging data protocols are on the horizon. WiMAX, which can transfer 70 Mbps over a distance of up to 30 miles to thousands of users from one base station, is undergoing numerous trials around the world, in countries such as the United Kingdom, the Philippines, Indonesia, Malaysia and in the United States.

In today’s mobile world, it has become commonly accepted that mobile communication solutions have been the foundation for the productivity increases of the last decade. An overly simple approach to ubiquitous coverage is to choose one standard as a global standard; the next step in delivering true mobility is the success of a software-defined transceiver suitable for mobile applications.

Current approaches

The practical approach that today’s transceiver vendors have defaulted to is providing multiple analog transceivers. They’ve built multichip modules, multide packages, as well as multiple transceivers on die. Unfortunately, these approaches all come with limitations. They
all require more die area for each additional band. Each additional transceiver draws additional power. Also, each additional transceiver may require an additional antenna and matching network. Designers are thus forced to make trade offs for cost, size, performance and power, yet the resulting designs are still inflexible, large, expensive and power hungry.

On the other extreme, an SDR takes a completely different approach to multiband yet still runs the same problems that the multitransceiver/multidiemultichip module approaches all do. The classical SDR architecture requires a high sampling rate, wide bandwidth and power-hungry analog-to-digital converter (ADC), as well as a high-performance, high-power digital drop receiver (DDR). For mobile applications, this creates unacceptable demands on the battery and so far has precluded its use in mobile devices.

**Considerations in designing a multiband solution**

The trick is to come up with a transceiver architecture that is flexible enough to support a variety of signal bandwidths, modulation formats, signal levels and blocking specifications. As an example, cellular standards have low to medium bandwidths, but have very high dynamic range requirements and challenging blocker environments. WLAN standards, on the other hand, tend to operate in unlicensed spectrum and thus have lower power levels, less dynamic range, fewer blocker considerations, but have high signal bandwidths and high-order modulation (and thus require higher signal-to-noise ratio or SNR).

So one can either design multiple low noise amplifiers (LNAs), multiple baseband filters and several ADCs (which doesn’t seem like an improvement over the multi-chip or multi-die approach), or one can design the circuits to be configurable. The LNAs must be tunable over a wide bandwidth and support high linearity; the bandwidth, dynamic range and order of the baseband filters must be configurable; the ADC must adapt its power consumption to the dynamic range and bandwidth required. Finally, low-power digital processing is necessary to achieve the necessary decimation, downconversion, channel selectivity and gain/phase compensation.

On the transmitter side, one requires an architecture that supports narrow and wideband signals, constant and non-constant envelope modulation schemes, various output powers and covers a wide frequency tuning range. While polar modulators have proven efficient for narrowband signals, they have yet to be successful for wideband signals such as WiFi. Direct IQ modulators have significant flexibility as long as the digital-to-analog converter (DAC) sampling rates and filter bandwidth can be configurable. Again, highly configurable digital processing can be used for upsampling, digital upconversion, and even pulse shaping and modulation.

Since some data standards are full duplex while the WiFi and WiMAX protocols are half-duplex, the multiprotocol transceiver faces additional challenges. Whereas half-duplex designs typically share the synthesizer between transmit and receive, the full-duplex architecture requires that two local oscillators (LOs) be generated. To reduce power in the half-duplex mode of operation, a single LO can be used to drive the transmit and the receive mixers. However, this must be done in such a way that avoids leakage (from the transmit mixer LO to the receive mixer) when in full-duplex operation.

Based on the challenges, it’s clear a parallel hardware architecture is not the economical solution. To enable this “Holy Grail” of true mobile multiband multistandard devices, an SDR-like solution is required. Only SDR can offer the adaptability, the low cost (programmability) and future proofing needed to convince operators, laptop designers and customers to accept SDR as a necessary part of the mobile world.

**Traditional SDR**

A traditional SDR solution places the ADC as close to the antenna as possible. For low-cost, low-power consumer devices, this has to be after the downconversion, either at baseband or at an intermediate frequency (IF). Once the entire signal band has been digitized with sufficient dynamic range to capture the maximum blocker levels as well as the minimum desired signals, the signal-processing algorithms can quite easily extract the signal of interest. One example was the Steinbrecher MiniCell base transceiver station, which digitized the 12.5 MHz of cellular bandwidth and extracted 30 kHz AMPS or TDMA channels using DSPs.

A multistandard SDR would require that the ADC dynamic range be variable (or designed for the worst case) and that the signal processing be programmable. This precludes the use of application-specific ICs (ASICs), and requires the use of field-programmable gate arrays (FPGAs) or DSP technology, both of which are expensive for consumer devices. For a 10 MHz band of interest and a 100 dB of dynamic range (-110 dBm to -30 dBm signals with 20 dB allocated for headroom, modulation crest factor and quantization noise), the ADC has to sample at greater than 20 Msamples/s with 17 effective number of bits (ENOB). Alternatively, one could also use an oversampling sigma-delta architecture with a 320 Msamples/s clock rate and reduce the ENOB to a more manageable 10 bits to 12 bits (depending on the order of noise shaping).

Both of these alternatives are about on the edge of current technology. Figure 2.) As an example, an advanced ADC from TelASIC,
the TC1411, claims to support 14 bits, 250 Msamples/s over a 75 MHz bandwidth. While this is sufficient for many SDR applications, it requires 1.9 W, which is too power hungry for mobile applications. As a consequence, the optimum transceiver design must include the channelization and AGC functions before the ADC for the foreseeable future.

A new approach

BitWave’s long experience with SDR has enabled it to develop a new solution to this complex problem. To convince the wireless industry to accept and adopt a new implementation of SDR, one must first step back and consider what the market requires. It’s apparent that a low power solution is required. This led the decision to base all components on existing analog architectures. A software-defined transceiver must also be able to optimize itself for each unique protocol; i.e., be easily controlled with digital technology by the baseband through a simplified interface.

Finally, the dynamic optimization required for each potential operating environment of the device led to innovation for individually controlling each RF, analog and mixed-signal blocks within the transceiver.

Hence, a Softransceiver technology was created with the preceding ideas in mind: it provides a way to increase flexibility while at the same time reducing cost, decreasing power consumption and increasing performance. (Figure 3).

The Softransceiver can effectively move its operating characteristics in real time by software commands. It can shift the center frequency, modify the bandwidth and sampling rate, and change the linearity and noise figure of a transceiver channel in real time. Thus, one programmable transceiver can replace the many fixed transceivers now found in a typical cell phone or data modem. This reconfigurable transceiver technology also dramatically reduces the size and power of the transceiver chip and increases flexibility when compared with a multi-transceiver on die solution. The Softransceiver stands apart from other multiband solutions in that it is competitive in performance even against single standard transceivers.

One of the ways in which the Softransceiver compresses the required area is through a programmable LO. Each standard that the Softransceiver supports has an optimal architecture for implementation. For example, most GSM standards can be more easily implemented in a low IF (LIF) architecture while other standards such as WiFi or WiMAX may be more easily implemented with a zero IF (ZIF) architecture. The Softransceiver allows the selected standard to be demodulated with whichever architecture works best.

In an analog architecture such as that shown in Figure 4, implementing both LIF and ZIF is possible, however, it requires a lot more analog die area since the designer needs to provide a second analog stage. In Figure 5, the combination of a widely programmable LO and the inclusion of a digital downconverter allows for the complete elimination of the second analog stage. In this manner, the Softransceiver achieves the desired combination of low

![Figure 7. Component diagram of a dynamically reconfigurable low-noise amplifier (LNA).](image)

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