Introduction

Since its inception, the wireless market has grown rapidly. At first, growth was measured as subscriber growth with a focus on voice, but now, it is measured by data rate and throughput improvements. Arguably wireless spectrum is the wireless operators’ most precious resource. As such, an operator’s ultimate measuring stick is the number of bits transmitted per Hertz of spectrum. The migration to LTE promises the highest spectral efficiency along with higher capacities at optimal costs. Despite the promise of LTE, operators must continue to support current customers on existing deployed technologies as well as optimize the use of the spectrum they currently own, while planning and implementing their ultimate 4G migration.

For wireless base station manufacturers to be competitive, they need to support the different modes and technologies deployed throughout the world, covering many regional differences across the globe. TI is uniquely positioned as the only wireless base station SoC vendor to provide a common platform to manufacturers to economically deliver the multistandard solutions required in this diverse space. This white paper explores the challenges OEMs face in meeting the demands of today’s wireless operator, and how Texas Instruments’ KeyStone multicore architecture is providing the platform that is driving manufacturers’ success.

Enabling multistandard wireless base stations with TI’s KeyStone SoCs

The wireless communications market has always been fascinating and dynamic, although probably never more complex and challenging than it is now. With increasing consumer demands for smartphones and the emerging popularity of tablets, the mobile Internet needs to serve more and more connected users, demanding substantial increases in mobile network capacity. At the same time, 2G technology usage such as GSM is still quite prevalent, and operators must support backward compatibility even as they push forward with new, high-speed networks. Operators must be able to deal with this market and technology picture while living in an economic environment that limits capex spending and forces opex tradeoffs.

Each operator’s spectrum ownership is unique, as is its subscriber base. For OEMs, deploying a “one size fits all” base station solution is a real challenge as each deployment is different. In addition, the adoption of smartphones and skyrocketing data usage is taxing the limited availability of spectrum as well as the limits of the laws of physics for current network deployment strategies. This is spawning the implementation of small cells in and around macro cells adding to the mix of base station configurations, and may fundamentally change the shape of future networks. This makes for a murky landscape for wireless operators and wireless base station manufacturers to navigate through.

The operator dream

A common platform that allows operators to support the ever changing demands of their subscriber base, as well as meeting their own capital and operational goals is the ideal answer.

Multistandard support – Operators have the simultaneous challenge of managing existing customers committed to a variety of technologies, along with the subscriber migration to new technologies at varying paces. In addition, operators need to strategically move to 4G to stay competitive. This requires the tedious task of balancing the satisfaction and revenue of current customers with the investment costs of technology evolution.

Take for example an operator with GSM/EDGE customers who is in the process of migrating aggressively to 3G. The 2G users represent a majority of the subscriber base, yet over time, these subscribers will buy new 3G phones, smart phones and tablets. This means the ratio of 2G to 3G devices will continually change. Many 3G users will buy 4G devices when available, and the operator then has to simultaneously support 2G, 3G, and 4G from the same base station towers.
If the network or parts of the network do not have 4G coverage, the 4G phones will be able to “fall back” to 3G. If certain regions of the network only have 2G coverage, both the 4G and 3G phones will be able to “fall back” to 2G. So the operator must have 2G everywhere as it is the lowest common denominator across the customer base. This multistandard configuration will exist for numerous operators for quite some time.

To help manage this transition, operators continually gather statistics about the demand in various cells in their network for 2G, 3G, and 4G traffic. The operator wants to gracefully – by remote control – change the mix of capacity in the base station to match the demand and to minimize the need for 3G users to fall back to 2G, or similarly for the 4G users to fall back to 3G. Since the spectral efficiency of 4G should be better than 3G and 3G is better than 2G, operators have high motivation to migrate as many of their subscribers to the more advanced standards as possible. This allows them to maximize the traffic on its valuable investment in spectrum.

Another aspect important to many operators centers on the repurposing of the spectrum, as the regulators allow them to do so. By understanding their customer base usage and trends, operators are finding that they can maintain support for existing 2G services while allocating portions of the current spectrum to advanced 3G or 4G. For example, the re-farming of GSM spectrum by deploying more efficient base stations can gain additional voice users on a single carrier, allowing for other carriers to be assigned to 3G or 4G services. This is exemplified by VAMOS (Voice services over Adaptive Multi-user channels on One Slot) techniques which essentially enable the transceiver peak capacity to double improvements over 3G systems.

The challenge of operation and maintenance for today’s wireless operators is two fold. First, to be able to effectively manage the challenges of multistandard support as outlined above, operators seek remote control of the base stations and the ability to rapidly modify the base station configuration as subscriber conditions change. For capex and time to market reasons, operators want base stations in place that can quickly be reconfigured to adapt to changes in standards usage. Not only does the reuse of the physical base station equipment benefit the operator, but labor costs are saved by remote configuration. The increasing deployment of remote radio heads which can be reconfigured without retrofit is putting pressure on the base station vendors to also support remote reconfiguration.

With software upgradeability, base stations can now serve in the field for over ten years and therefore help optimize operator capex. Deployment of common base station platforms that are line-card configurable and standard extensible reduces technician service and maintenance costs as well as spares and inventory costs. Field technicians can build expertise on a focused set of equipment. As such, operation and maintenance costs are reduced, optimizing opex costs in addition to the capex savings.
OEMs respond

OEMs have the challenge of providing products for a wide range of wireless standards to support operators in the scenarios just outlined. They need to provide base stations that support existing technologies, and support the ability to migrate to future standards. They must offer operators solutions that are scalable, remotely configurable, as well as cost and power effective to meet the operator opex and capex goals. This is quite a formidable challenge. To be successful, OEMS need to provide these base stations cost effectively and with R&D and support costs that fit their business objectives.

So, how do OEMs manage this balancing act? Building unique platforms for each standard and field configuration is not the answer. Like most businesses, base station vendors have business profitability goals that limit R&D and product support costs and are rewarded for excellent allocation of resources. Ideally they have a base station platform design from which they spawn multiple configurations to meet varying operator needs. Since software represents a significant investment and is a large portion of a base station design, a solution that offers software portability and reuse is essential. OEMs need a common hardware platform that can be leveraged for multiple wireless configurations with limited redesign, optimizing R&D costs and time to market. The solution to this challenge is found in a common base station System-on-Chip (SoC) platform that optimizes software development and reuse.

TI provides the solution

TI offers a common SoC platform that enables base station OEMs to design multistandard platforms and create standard specific platforms. TI is uniquely positioned for this. TI’s powerful and innovative KeyStone architecture provides for multiple devices based on a common hardware/software platform, supporting all common wireless standards for solutions ranging from small cell to macro cell configurations. The KeyStone platform enables OEMs to achieve the multistandard goals of the operators in two ways, detailed in the following section.

The first step to multistandard support lies in TI’s KeyStone architecture. The KeyStone architecture utilizes an advanced DSP core (C66x) that offers both fixed- and floating-point processing, allowing for OEM and operator differentiation in today’s deployments as well as for future, advanced antenna and algorithmic configurations. This core, along with the common IO and SoC infrastructure, makes for simple software reuse and portability. The platform includes a common set of tools, optimizing R&D efforts, and reduces time to market when developing multiple products from a single solution base. The KeyStone architecture is shown in Figure 1.

The KeyStone multicore SoC architecture is the first of its kind to provide full multicore entitlement. KeyStone provides non-blocking access to all processing cores, peripherals, coprocessors, and I/Os. Some of the KeyStone innovations that unleash full, multicore entitlement are: Multicore Navigator, TeraNet, Multicore Shared Memory Controller (MSMC), and HyperLink.
Multicore Navigator – TI’s Multicore Navigator is an innovative packet-based manager that controls 8,192 queues and abstracts the connections between the various subsystems. With a unified interface for communication, data transfer, and job management, Multicore Navigator enables higher system performance with fewer interrupts and reduced software complexity with a “fire and forget, zero copy” paradigm.

As an example of how Multicore Navigator operates, Multicore Navigator is able to schedule jobs and can instruct the next free DSP core to read a job and process it without the need for external management. This simplifies the software architecture and improves performance of base stations with:

- Dynamic resource/load sharing
- Offloading CPU overhead/delay related to inter-subsystem communications
- Hardware-based task prioritization
- Dynamic load balancing
- Common communication methodology for all IP blocks (software, I/O and accelerators)

The Multicore Navigator controls data flow without CPU intervention, freeing CPU cycles on data movement and boosting on chip communication by up to 20 million messages per second. It also enables simpler software architectures allowing shorter development cycles and better utilization of the resources.
**TeraNet** – TeraNet provides a hierarchal switch fabric that combines to deliver more than two terabits of bandwidth for data transfer within the SoC. This virtually guarantees that the cores or coprocessors are never starved for data and can deliver the entitled processing horsepower. Because the switch fabric is hierarchical instead of a flat crossbar, overall power consumption is much lower in idle states and delivers high performance with minimal latency; a key requirement in next-generation base stations.

**Multicore Shared Memory Controller (MSMC)** – MSMC is a unique memory architecture for enhanced performance. MSMC allows the cores to directly access shared memory without using any TeraNet bandwidth. The MSMC arbitrates access to shared memory between the cores and other IP blocks, eliminating memory contention. The DDR3 external memory interface (EMIF) ties directly to the MSMC, reducing the latency associated with external memory fetches and providing the speed increase and support needed for base station applications.

**HyperLink** – With 50 Gbps total throughput, HyperLink is an interconnect that allows low protocol and high-speed communication and connectivity to other KeyStone, FPGA or ASIC devices; it provides transparent memory map access to the companion device from the main device. This simplifies the software programming and provides OEMs a seamless path to scalable solutions.

This set of powerful and flexible SoC elements is critical for designing efficient multistandard base stations. Considering the range of complexity between 2G, 3G, and 4G as well as the challenges of frequency division systems versus time division systems and finally the regional deployment variation, using a common SoC across all platforms would be impossible without a solid base to start from.

The second key factor in achieving multistandard success is through TI’s acceleration strategy. The DSP has always been the key element in wireless base station baseband processing. Its optimization for signal processing is well suited for wireless applications. Even so, for cost and power consumption reasons, some of the routine and standard-defined functions are better suited to be implemented in hardware. While this can be done in external hardware logic, TI is able to offer base station manufacturers a lower cost and lower power alternative by including these functions in KeyStone-based SoCs. Since 2003, TI has been providing integrated DSP-based SoCs for the wireless base station market. The company continually releases newer generations as silicon technologies progress and wireless standards evolve, providing OEMs with the most competitive solutions to meet operator demands.
Figure 2 shows TI’s progression and leadership in the wireless base station SoC market. First generation SoCs served early 2G wireless deployments such as GSM and CDMA, by including viterbi and turbo decoders. As wireless standards progressed beyond voice services and into data, TI enhanced the DSP and the associated coprocessors for increased capacity. The third generation SoC brought more support all standards with the first multicore DSP with wireless coprocessors and improved support for WCDMA with the inclusion of the receive accelerator – as WCDMA adoption increased on a worldwide scale. Today’s fourth and current generation of solutions enhances performance for existing wireless standards by adding a broad and powerful coprocessor set for all 3G and 4G. These coprocessors include transmit spreading for WCDMA, bit rate processing for all standards, Fast Fourier Transforms, and more powerful turbo decoding. In addition to supporting the PHY or Layer 1 portions of the standard as described, the current generation SoC includes support for the Layer 2 functionality and a network coprocessor.

\[ Fig. 2 - TI's implementation history: Wireless standards in base station SoCs \]
TI's newest base station SoC, the TMS320C6618, is based on the KeyStone platform and includes over 250 GHz worth of DSP cycles of standard specific, configurable hardware acceleration. These accelerators support all common wireless standards in use today including GSM, WCDMA, TD-SCDMA, WiMAX and LTE. The coprocessor implementations are carefully chosen based on standards functions that are mature and consume significant processing cycles. For more details on the acceleration in this latest device, refer to TI's white paper entitled: *Delivering performance, efficiency and differentiation with TI's multistandard base station SoCs*.

At each step of the way, TI has been the leading provider of wireless base station SoCs and is in the unique position to gain cycles of learning by having live, working deployments based on TI technology. At each new process node, new technology is introduced and existing technology is enhanced based on real-world experience and feedback. TI's currently deployed SoC, the TCI6488, has shipped many millions of units and is deployed by over 200 operators' worldwide. It is by far the most prevalent 3G wireless base station SoC in the field today. TI is uniquely positioned to provide field-hardened standards-based acceleration as part of its SoC, reducing OEM risk.

**Conclusion**

It is clear that with the challenges the wireless operators face, deploying multistandard base stations is essential to success. These common platforms will allow for growth to the future technologies without major retrofit or redeployment of equipment. Progressive base station manufacturers are finding ways to meet the operator challenges while meeting their own business goals. Having a common wireless base station SoC platform that supports both large and small cells, as well as all wireless technologies deployed today and in the future, is key to their success. Being able to rely on an architecture that allows for software scalability as standards evolve, and software portability as new solutions dictate, is essential for OEMs to achieve time to market and business goals. TI provides all of this and multistandard support to the base station manufacturers through its KeyStone platform by leveraging multiple generations of proven, worldwide deployment experience and expertise.

For more information about TI's KeyStone architecture and base station SoCs, visit [www.ti.com/c66multicore](http://www.ti.com/c66multicore).
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