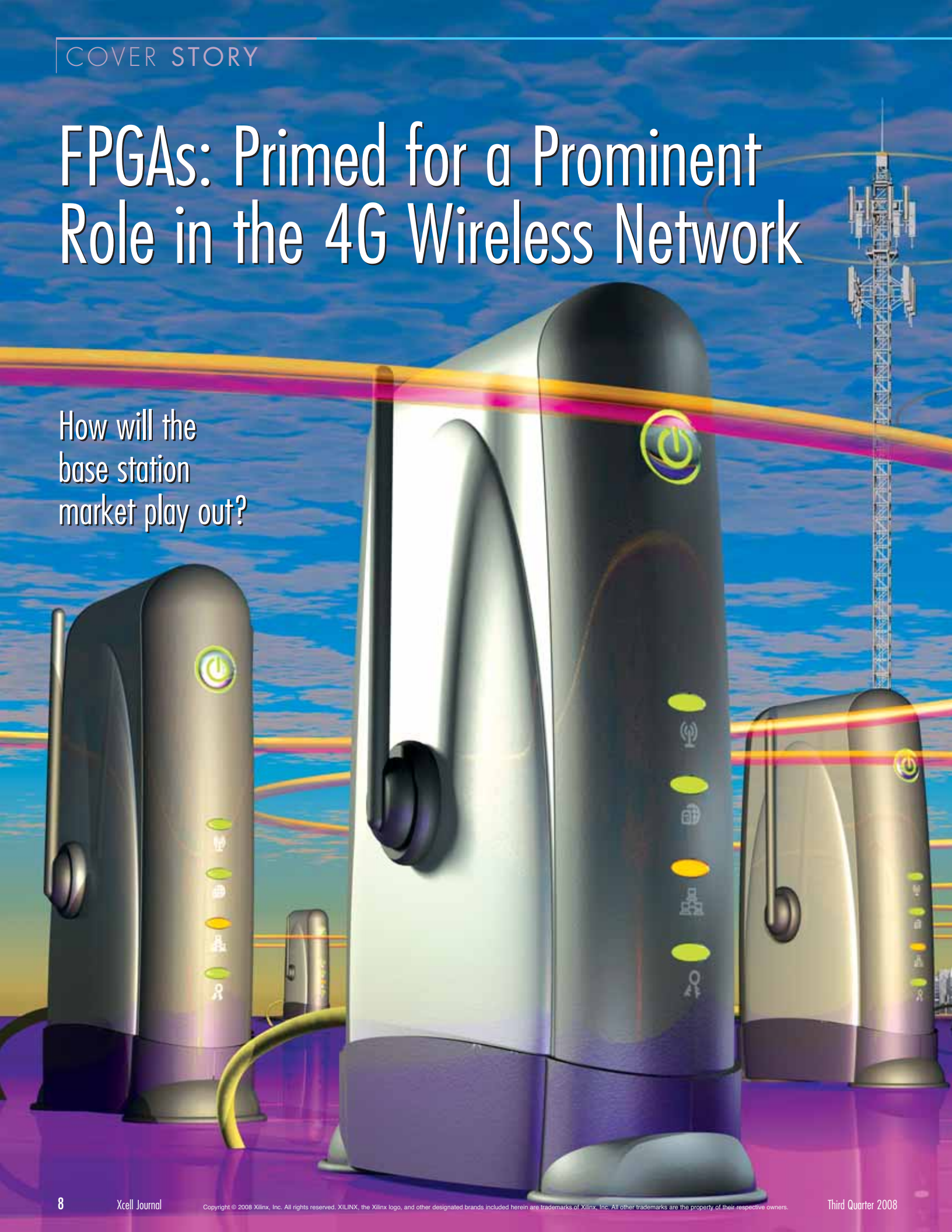


FPGAs: Primed for a Prominent Role in the 4G Wireless Network

How will the base station market play out?



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The impending convergence of third-generation (3G) CDMA2000 and WCDMA/GSM wireless network standards into the 4G LTE (Long Term Evolution) wireless network standard presents developers of next-generation base stations with a bit of a challenge. How do you create a next-generation base station that will support current 3G communication standards as well as next-generation standards, and perhaps go the extra mile to outpace your competition and offer a solution that can accommodate whatever successive standard(s) the communications industry picks after LTE?

Stepping up to this challenge, many design groups are now in the process of creating multimode (also known as multi-standard) base stations that will support 3G and 4G standards – perhaps multiple variants of these standards – while being flexible enough to adapt to any changes that may arise in the design specifications or even the wireless standards the design targets. Many are giving FPGAs a more central role in multimode base station design (see Figure 1).

The Promise of 4G: LTE and WiMAX

LTE promises to bring wireless customers data rates of 100 Mbps or higher, which is a 10x improvement in performance over current 3G networks. This data-rate increase paves the way for carriers and mobile handset makers to offer customers more advanced features on their respective networks and mobile devices, such as mobile TV, advanced video, and even gaming in addition to Internet, e-mail, and voice.

This means that mobile device makers will be able to sell more advanced phones to carriers, while carriers will be able to offer more expensive mobile phone plans and increase their average revenue per user (ARPU).

But of course, carriers must install a wireless network infrastructure before all that can happen.

Currently, 70% of the world uses GSM-based networks (in particular 3G WCDMA), while North America and

South Korea primarily use 3G CDMA2000 networks. Carriers in Japan are scheduled to conduct a trial run later this year of the Orthogonal Frequency Division Multiple Access (OFDM) modulation scheme underlying LTE, essentially kicking off LTE adoption.

Manuel Uhm, senior marketing manager for the Wireless business at Xilinx, notes that carriers currently employing CDMA2000 networks will likely move to LTE as well, because Qualcomm's proposal for a follow-on to CDMA2000, UMB, didn't gain industry support.

Indeed, one of those CDMA2000 carriers, Verizon, recently announced that it will be installing LTE in the 700-MHz spectrum in North America. It recently won the 700-MHz spectrum in a Federal Communications Commission auction.

Still, the industry doesn't expect LTE to be in large-scale deployment until the 2012 time frame, so many wireless carriers shopping for next-generation base stations will be looking for hardware that will allow them to offer customers support for their current networks while providing an upgrade path to a faster 4G wireless network. Simultaneously, they will want to minimize the operational expenses of each system and the entire network, including reducing the base station power and thus utility costs.

Although CDMA2000 and WCDMA seem likely to converge on LTE, it's uncertain whether the rest of the world will also adopt LTE networks. Carriers in some countries are embracing data-centric networks such as WiMAX and WiBro (South Korea), which carriers can enhance to carry voice over packet. WiMAX and WiBro will compete with LTE.

But Loring Wirbel, director of *EE Times'* market intelligence unit and longtime communications editor, points out that LTE and WiMAX standards are very similar – reportedly 80% percent of the baseband functionality is the same – which opens the door for base station vendors to attempt to build one base station that can support 4G standards while still supporting legacy 3G networks.

But even if the world converges on LTE, it isn't likely to be the last network carriers

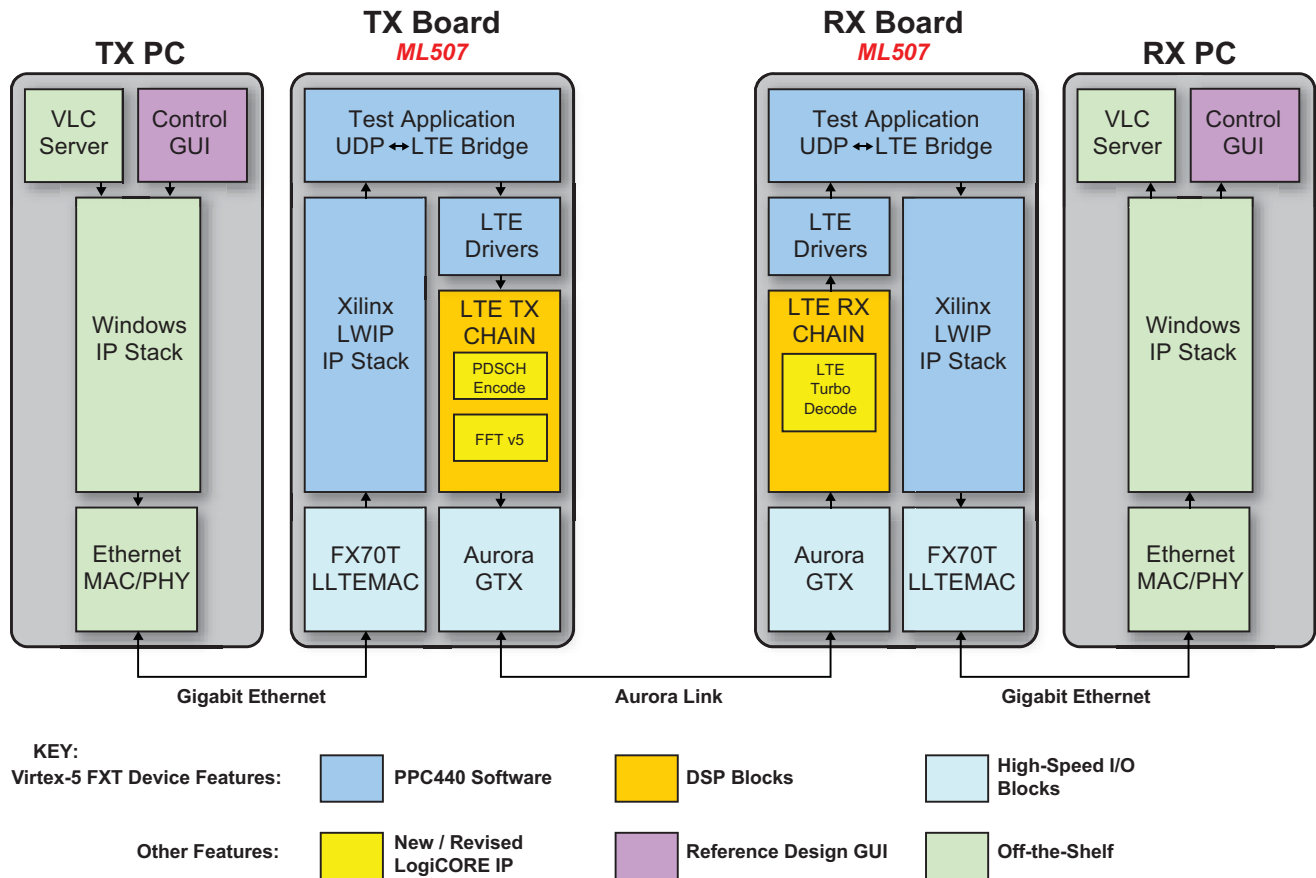


Figure 1 – Xilinx LTE baseband reference design

install. “WCDMA was supposed to be the convergence of air interface standards, but that wasn’t the case,” Uhm noted.

Indeed, if history is any indication of future behavior, it likely means that as soon as LTE gets established, some new need – be it network performance, new functionality/services, or even something political – will spur the need for a 5G solution, or perhaps an intermittent tweak to extend the life of LTE.

In fact, the industry is already laying the groundwork for 5G networks such as LTE advanced, even though the 3GPP (the international body that defines GSM network standards, including LTE) hasn’t fully completed its definition of LTE, and the industry is only starting to roll out LTE equipment.

This uncertainty – which network will be best, what standard will really materialize (and in what form), and what new

applications will it need to support – has to make carriers a bit more apt to hedge their bets and lean toward systems that are more adaptable, more expandable, and easily and ultimately less expensively modified to suit changes in 4G standards. In short, next-generation base stations need to be flexible, though to what degree is debatable.

Undefined Standards and Multimode Opportunity

Because the 3GPP has yet to fully define the standard, companies building base stations today, especially those trying to be first to market, must build flexibility into their designs. The question is: how much flexibility?

Traditionally, flexibility has come in the form of sending out maintenance crews to replace entire cards in each base station and then tweaking the software running on

those cards. But carriers shopping for 4G are looking for a greater degree of flexibility.

Indeed, wireless network standards (and wireless networks for that matter) comprise two fundamental layers: hardware (PHY) and software. The PHY layer, or physical layer, defines the performance and functionality requirements of the hardware the network will need to support the standard. The software layer defines the functionality that various software applications will need in order to adhere to the basic network standard.

Carriers can add software and even enhanced hardware (above and beyond the basic PHY and software requirements of the standard) to woo customers to their particular network. But with 4G, many believe base stations need to be more flexible than ever.

Some are anticipating that this will be the era where the industry produces the Holy Grail in base station technology: soft-

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ware defined radio (SDR), in which one system can support every standard simply by software reprogramming the base station hardware on the fly to adapt to any incoming signals.

Wirbel noted that in the dawning of the 3G era, several startups offered specialty chips with programmable logic cores and hard-wired high-performance blocks. These devices, however, “were insanely hard to program and insanely expensive.” SDR has yet to fully deliver on its Holy Grail vision, but some vendors are starting to produce innovative SDR subsystems using commercial FPGAs. Perhaps sometime in the near future those subsystems will debut in base stations.

Still, some analysts (Wirbel among them) are not easily convinced that next-generation base stations will truly be as expandable and as multimode as many developers in the market predict (or hope).

“4G promises to make life easier than 3G, because what they want to do is harmonize WiMAX and LTE into one set of standards that both support OFDM. Then it’s just a little software shim as to whether it supports WiMAX or LTE at the end of the day,” Wirbel said. “At the same time, they have to support all of the RF chains and baseband issues for GSM and CDMA2000. At some point, you’ve got to make decisions about what to support or your base station becomes too complex.”

“What happens in the RF component is just as important as the baseband. It’s not the glamour part necessarily,” said Gabriel Brown, Heavy Reading’s senior analyst, who specializes in the wireless market. “You could in theory have multimode, upgradable baseband, but it doesn’t really do you any good if you don’t have the whole RF chain with either the right power output or bandwidth or frequency. Quite often you don’t; this point gets glossed over quite often.

“Yes, it’s software and it is upgradable, but you need to have the RF chain to support it. When folks typically say things are upgradable, they usually mean that it’s upgradable within the same technology stream. For example, you can upgrade from WCDMA to HSPA to HSPA+ on the same baseband hardware by upgrading the software. But the idea of jumping from generations of technologies with different modulations is a bit of nirvana – it isn’t really how things work.”

Battle at the Heart of the Base Station

At the heart of a base station’s hardware is a series of electronic systems that control much of the wireless network functions. Traditionally, these systems have mainly comprised ASICs/ASSPs and standard products such as DSPs. But those technologies are limited in how design groups can modify them to suit late changes in standards or even upgrade the hardware in the field.

Therefore, as base station vendors begin designing 4G base stations that must support the as-yet-not-fully defined LTE standard while also supporting 3G networks, they are increasingly giving FPGA technology a more prominent role in controlling those systems.

“If you looked in a base station five years ago, you wouldn’t find many FPGAs,” Uhm said. “Today they are a prominent part of the radio and channel cards.” One of the reasons, Uhm added, is that FPGAs fulfill the need for base station designs to be much more flexible than in the past.

To make changes to traditional 3G base stations, companies typically had few options. They could try to implement a software patch to rectify a problem in software or a shortcoming in hardware, but doing that often slows down the hardware and thus the overall computation of the base

station, which if anything in the emerging days of LTE needs to be faster. Or they could send a technician out to the site to physically replace a defective or older PCB containing those devices with a newer one (and possibly add a software patch as well).

If there’s a drastic change, like the need to support an extra standard, carriers may have to install new base stations, much like AT&T did a few years ago when it moved from GSM to WCDMA. Of course, sending out technicians to sites around the world to swap out hardware and program software – on top of mountains, on top of buildings, on the edges of cliffs – adds great maintenance costs to a carrier’s network. Adding new base stations and securing leasing for those sites is exponentially more expensive.

“Base station vendors would love to sell carriers a network of base stations for each of the standards, but carriers can’t afford to do forklift upgrades anymore,” Uhm said. “They are looking for the flexibility to add new revenue-generating services, higher data rates, lower power, lower maintenance costs, and of course, a great price.”

Analysts point out that many years ago, base stations cost around \$250,000, but new base stations will likely be in the \$15,000 to \$25,000 range. They note that the unit price of base station hardware is only a fraction of the overall cost, and that leasing space and maintenance costs can be exponentially higher than the base station itself.

What’s more, if a base station needs to support multiple standards, designers typically have to create an ASIC and associated PCB for each of those standards, as well as extra circuitry to negotiate how those boards will interact with the existing antennae.

In particular, ASICs are increasingly more expensive at relatively low volumes (and at volumes typical for the base station market) and are difficult to produce on

leading-edge processes, making them increasingly less attractive for the macrocell, microcell, and picocell base station markets.

A single 65-nm ASIC mask runs around \$1.5 million, and a 45-nm mask is double that. Adding EDA and IP costs tacks a few million more onto design costs. ASSPs are similarly expensive for silicon vendors, complicated to produce, and typically modifiable only on a software level. Given the choice of ASICs, ASSPs, or DSPs, DSPs are the most versatile for base station applications and will likely maintain a secure position in 4G base stations. But only the software is modifiable, limiting flexibility if designers want to make changes to their designs in the field.

“When the issue was just GSM vs. CDMA for voice, it was best to do everything in DSP. But when people started adding data services such as EDGE and HSDPA, it really made a lot more sense to look at an FPGA solution,” Wirbel said. “That transition started to take place around 2002 or 2003.”

It’s for all of these reasons that designers are starting to give FPGAs a more central role in the era of multimode base stations. Some are even making FPGAs the primary devices for software defined radio implementations of multimode base stations.

“FPGAs add another level of flexibility and performance to a base station that ASICs, ASSPs, and DSPs cannot, enabling operators to increase ARPU by adding new bandwidth-intensive applications,” Uhm said. “FPGAs are attractive for multimode base stations because they have a mix of reconfigurable resources for high-performance signal processing.”

Joe Byrne, a senior analyst with the Linley Group, notes that one reason the FPGA is looking more attractive in the base station market is because LTE employs OFDM modulation. “The downstream modulation scheme in LTE is OFDM, which is a different scheme than WCDMA,” Byrne said. “It’s conceivable that next-generation base stations will essentially be one piece of equipment with two different processing modules: one that does the legacy protocol and another that does the new protocol.

But I think the opportunity is to create equipment that does both, and for that you need something that is programmable. The programmability can come from FPGAs or something with more traditional software programmability, such as a DSP.

“The thing with OFDM is that instead of being a signal carrier, there are a lot of signals conveyed on a lot of carriers in parallel. That means the processing

has to be done in parallel. So from an FPGA perspective, if you have these thousands of carriers to process, you can take your big FPGA and partition it into these processing units in parallel and do the processing of each carrier. That is something that an FPGA would be well suited for, instead of doing it in sequence.

“There’s an opportunity for doing it with a logic-based approach, such as an FPGA, as opposed to a software-based

Base Station 101

To date, wireless network carriers have traditionally employed two types of base stations (commonly referred to as cells). The first is the macrocell (see Figure 1), which usually consists of a tall tower with transmit and receive radio antennae at the top of the tower (receive is usually at the very top).

These antennae run signals, through fiber-optic cable, down the tower to electronics systems traditionally located at the base. The electronic systems coordinate the transmit and receive functions up to the antennae, negotiate coverage with other base stations, and transmit call data to the rest of the network as customers move from one base station’s coverage area to another, racking up billable minutes. Macrocells typically have large coverage areas; carriers deploy them in rural areas or along long stretches of highway.

The second type of traditional base station is called a microcell. Wireless carriers typically deploy these in densely populated areas like cities. The coverage area of a microcell is smaller than the coverage area of macrocell, but a cluster of microcells allows more people to access their carrier’s wireless network.

In recent years, the industry has produced two other types of base stations: the picocell and femtocell. The picocell is for smaller, even more densely populated areas such as airports, conference centers, and sporting venues. The femtocell targets home and small office use, whereas the macrocell, microcell and picocell are traditionally sold to networks. Femtocells will likely be sold at retail directly to consumers or perhaps bundled in with services such as cable or satellite TV.

“So far, femto has been over-hyped and under-delivered,” Wirbel said. “We don’t even know if it will be a real market and what the price points will be.” Still, it could be an interesting play as more devices in the home become wireless.

Analyst Richard Wawrzyniak addresses the promises and challenges of the picocell market as the “Xpert Opinion” in this issue of *Xcell Journal* (see page 8).



Figure 1 – A typical macrocell base station with receive antennae at the top, transmit antennae below the receive antennae, and the control system at the base.

approach, such as a DSP. Some fine tuning will always take place. The physical layer may be pretty well understood but the actual algorithm to extract the best performance out of the physical layer may change. It's good to have some flexibility, especially in the early days of the market."

Wirbel agrees with Byrne and believes that next-generation base stations will

likely have a healthy mix of DSPs and FPGAs. "I think that the future lies in mixing and matching major DSP architectures on the top, with separate channels for multiple FPGAs in the middle. I think that's where the base station market is going," said Wirbel.

Designers are considering several architectures for 4G base stations. Figures 2

and 3 illustrate two of the many uses for FPGAs in those architectures. Analysts point out that in addition to flexibility, performance will also be a key to 4G networks. In fact, it's such an issue that many next-generation base station designers are moving more of the compute power up the base station tower, closer to the antennae, to physically shorten the amount of time it takes for the antennae and base station control system to communicate.

Uhm said that the latest generation FPGAs are up to the performance requirements and many employ high-speed I/O.

5G and Beyond

While analysts seem to agree that FPGAs will play a stronger role in 4G networks, they all doubt that any manufacturer will be able to build a multimode base station that will also be able to anticipate and handle the data rates and feature set requirements of 5G base stations.

"Carriers have been doing incremental upgrades to their 3G base stations for several years now," Byrne said. "They've upgraded from 7.2 Mbps to 10 Mbps with a software upgrade to the baseband processor, which is now a DSP or FPGA. I think that with LTE, we will see a lot of incremental upgrades. If you do a bigger upgrade than that, you'll essentially need new hardware."

Byrne and others note that by the time 5G makes it to mainstream, there will likely be some crazy new hardware performance and functionality requirement. That means more challenges and opportunities for designers along the full spectrum of the wireless network.

Uhm said that Xilinx is investing heavily in developing not only FPGAs for the base station market but also tools, IP, and embedded software. Xilinx is also working with its many IP and software partners to help designers meet challenges and create innovations for the 4G wireless network, especially those base stations at the heart of worldwide wireless communications. For more information about Xilinx silicon and solutions for the base station market, visit www.xilinx.com/esp/wireless.

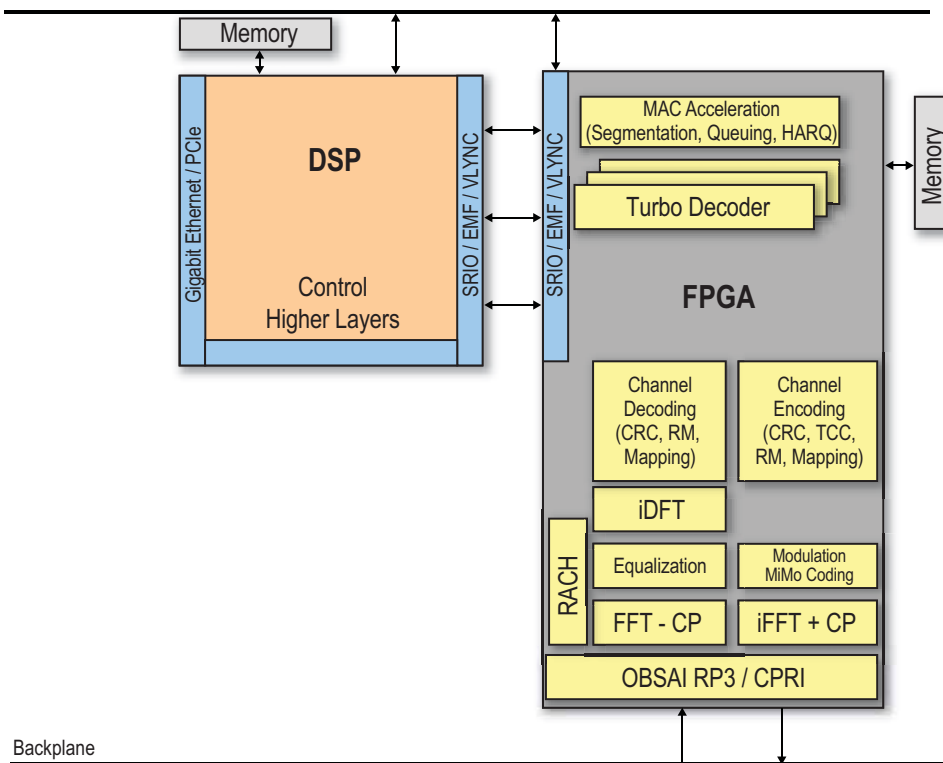


Figure 2 – FPGA preprocessing with DSP architecture

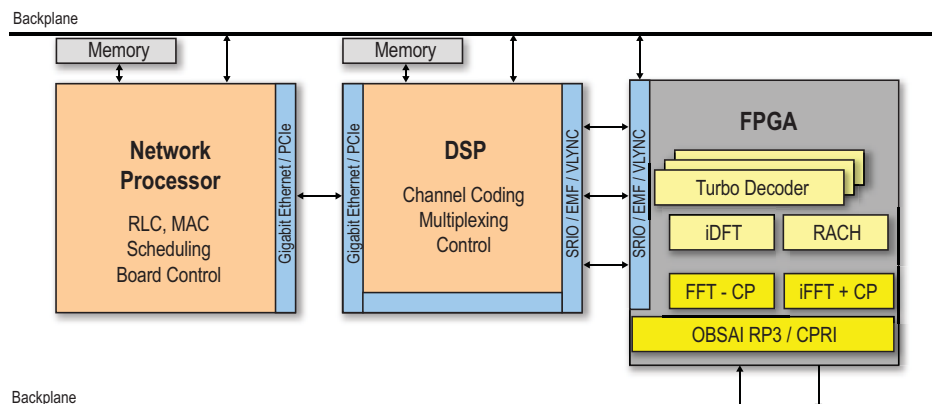


Figure 3 – FPGA as coprocessor for LTE