A Generation Ahead: SMARTER NETWORKS

Introduction

Communications and networking is a huge, global, and competitive business. As one of the top three semiconductor suppliers to networking and communications equipment vendors, Xilinx has been assembling, developing, and purchasing new technologies and expertise to help equipment vendors to be even more successful by allowing them to offer ever more value to their customers through significant product differentiation.

Over the past several years, Xilinx has been making a transition from the leading FPGA vendor to a provider of All Programmable Solutions for Smarter Systems. But just what do those words mean? It means that the FPGA fabric, the fundamental building block of all Xilinx silicon products—All Programmable FPGAs, 3D ICs, and SoCs—has reached a critical threshold at the 28nm process node. This threshold marks the transition where FPGAs have evolved to the point where they are large enough and fast enough to implement complete systems. At 28nm, Xilinx is capable of replacing entire ASSPs and ASICs, which means that a Xilinx All Programmable device equipped with the right IP and software may well be the only significant integrated circuit needed to implement many end products. Incontrovertible proof of this seemingly bold statement appears later in this backgrounder.

To get to this point, Xilinx has invested more than a billion dollars in silicon products, IP development, and acquisitions. Development has included the design and successful introduction of three major types of five unique All Programmable FPGA families based on 28nm process technology:

- The first system-optimized FPGA families: Virtex®-7, Kintex™-7, and Artix™-7
- The first All Programmable 3D ICs based on Virtex 7 FPGA technology and Stacked Silicon Interconnect Technology
- The first All Programmable SoC—Zynq—which fuses a dual-core, ARM® processor-based system with Xilinx 28nm FPGA fabric

These advances create an All Programmable Portfolio that serve as the bedrock foundation for All Programmable Solutions. However, Xilinx customers cannot and have never been able to exploit the full capabilities of Xilinx silicon without sophisticated tools that shape the devices for a specific task and the Xilinx families of 28nm devices are no different. In fact, they require even more sophisticated tools because the raw silicon abilities have entered the realm of complex ASSP and ASIC devices.

Consequently, these 28nm devices require new tools that are able to fully exploit their capabilities. That's why Xilinx spent four years and hundreds of person years to develop the Vivado™ Design Suite, which is the first SoC-strength design suite ever developed for All Programmable devices. The Xilinx Vivado Design Suite supports the development of large designs targeted for the immense, generation-ahead capacity of the Xilinx Virtex-7 2000T 3D IC with nearly two million logic cells and it does so while delivering a 4x productivity advantage that's required to get such large designs into production—and to do so quickly.

At the same time, the Xilinx Vivado Design Suite supports the growing use of IP blocks—because no design team can or even wishes to design every block of a complex design. For example, there's no added value in designing yet another Ethernet controller or a PCIe® interface, while there's tremendous value in incorporating such blocks in a system-level design. Such elements are now handled as pre-designed, pre-verified, proven IP blocks. These blocks are critical to the design and implementation of complex networking and communications systems, which is why Xilinx has spent the past several years investing in strategic acquisitions and partnerships—to bring critical IP in house so that system vendors can develop their designs with Xilinx All Programmable Solutions.

Over the course of the past few years, Xilinx has made strategic acquisitions to support the development of complete systems using its 28nm All Programmable devices, with an emphasis on networking. Acquisitions include:

- Omiino (OTN IP solutions)
- Modelware (traffic management and packet processing IP solutions)
- Sarance (Ethernet and Interlaken IP solutions)
- Modesat (microwave and E-band backhaul IP solutions)

XILINX SMARTCORE IP ACROSS THE COMMUNICATIONS INFRASTRUCTURE

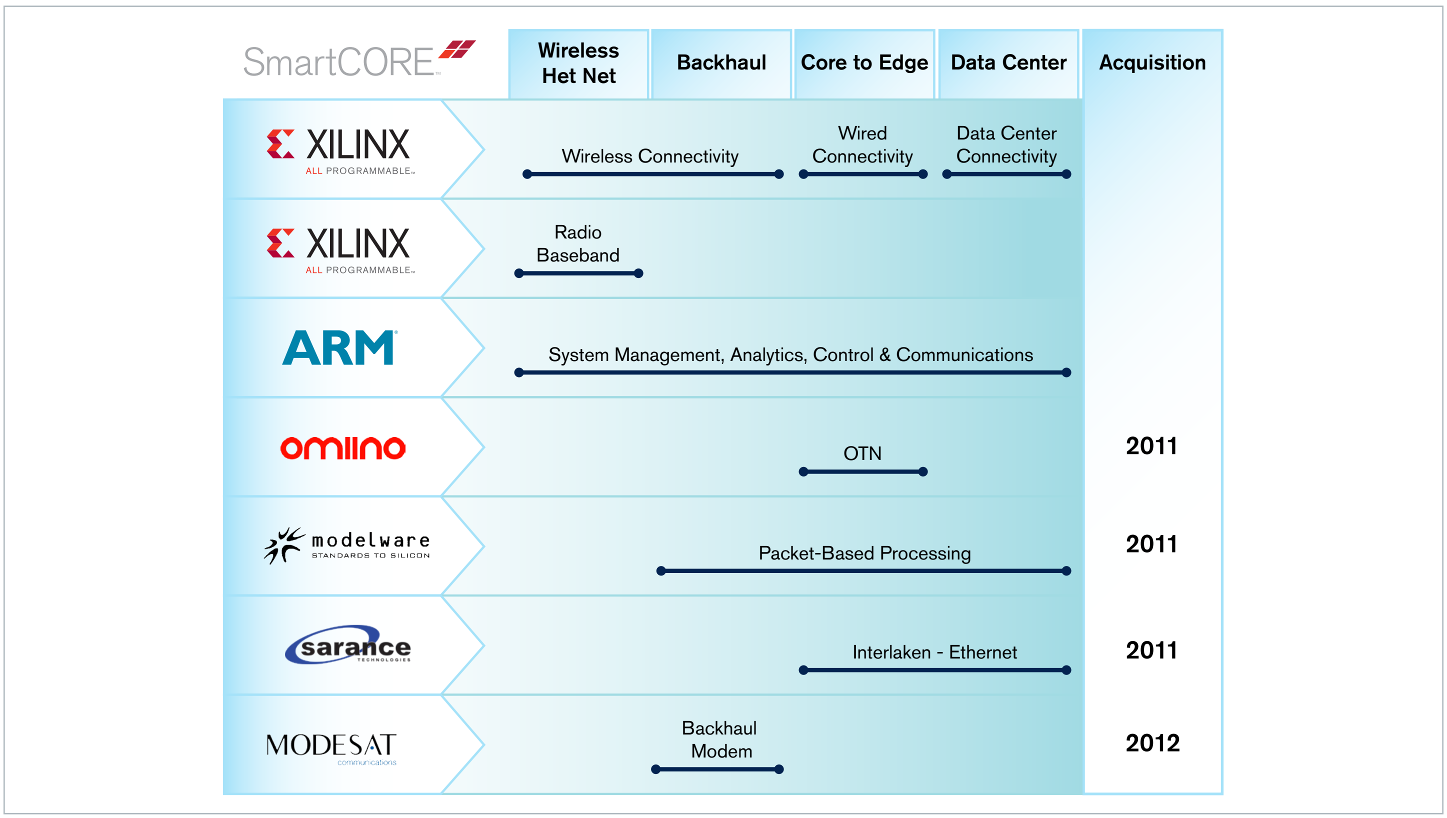

Figure 1

Together with internally developed IP that address wireless infrastructure and data center applications, these acquisitions and internally developed IP enable Xilinx to offer a comprehensive set of IP cores that allow customers to design Smarter Systems for networking, communications, and data center applications. Xilinx is calling this set of IP cores, SmartCORE™ IP, because they are the critical application-specific building blocks needed to develop smarter networking and communications systems. SmartCOREs complement the existing set of Xilinx LogiCORE™ IP, which are the fundamental building blocks and interfaces needed for all digital system designs across a broad range of markets and applications.

XILINX ALL PROGRAMMABLE™

What are Smarter Systems?

You probably have an intuitive feel for the word "Smart." In the context of Smarter Systems, "Smart" refers to performing tasks in an automated manner so that people no longer need to perform those tasks, either because the tasks are frequent, repetitive, and boring or because the tasks are extremely complex and need the constant attention best provided by a machine.

However, "Smart" also reaches beyond mere task automation. "Smart" processes can also become far more efficient. For example, consider a "Smart" factory. "Smart" machines in a factory need far less human supervision. When those "Smart" machines combine to create a "Smart" factory, new efficiencies result. For example, if part of a production line becomes more efficient due to a hardware or software upgrade, the entire factory may also be able to speed up production resulting in much larger productivity gains through just-in-time ordering, scheduled deliveries, and raw-material discounts. A Smart factory constantly adjusts itself for maximum efficiency.

What are Smarter Networks?

Another analogy, the road system, hits closer to the mark for Smarter Networks. Consider the Silicon Valley commuter who needs to drive every day from Livermore to San Jose, California and back. There's a small mountain range (the Diablo Range) to cross and there are two routes over these mountains: Interstate 580 and California State Highway 84. Normally, the Interstate route is somewhat faster but it is usually clogged with slow traffic during rush hours. Accidents can stop Interstate 580 cold. In such cases, Highway 84 is the better choice. Once over the mountains, there are again two choices for getting into San Jose: Interstates 680 and 880.

A substantial amount of daily traffic flows through Interstates 580, 680, and 880 and they are often clogged. Most drivers wish for more traffic capacity on these routes. The "dumb" way to add traffic capacity to these roads would be to add more lanes—an approach that's been tried in the past. However, land in the San Francisco Bay area is expensive and traffic volume tends to increase as soon as new capacity is added, which is often true of communications networks too. Once the new capacity is fully exploited, slowdowns recur.

There are "Smarter" ways to add road capacity. One way is to understand the context of the traffic and act accordingly. That's what happens when you add an HOV (high-occupancy vehicle) lane to a Freeway. Cars with more than one passenger (or individual drivers who are willing to pay the HOV toll in exchange for a shorter commute time) get priority and move though the road network more quickly. Another approach to intelligent traffic management is to use metering lights that regulate the introduction of relatively slow-moving traffic into the high-speed flow to minimize the impact of this slower traffic.

A third approach is to use real-time traffic information to pick the best route (I-580 versus State Road 84, I-680 versus I-880). Human drivers can use this information now, received via mobile phone from Google Maps or a similar service. Eventually, when vehicles become more automated, the vehicle itself may make the choice. Traffic load balancing with take another leap in efficiency when vehicles start communicating with each other and a regional traffic-management system.

Systems designers are beginning to look at similar ways to increase capacity in communications networking systems. Fixed routing systems are giving way to software-defined networks (SDNs) that can intelligently manage network traffic based on context-aware algorithms that consider the priority and service-level agreements for traffic in addition to the resources available to the network at each level. Examples of such "Smarter" networking equipment in the wireless space include cloud-based RANs (CRANs) and distributed antennas with centralized baseband processing.

The trend to Smarter Networking addresses many issues involving network scaling and profitability.

These issues are not theoretical; they're real. Here are two examples that prove the point:

1. In the year 2000, nearly everyone in Silicon Valley received a PC for Christmas. A week later, everyone connected their PCs to the Internet via modem. The PSTN—which had been designed for an assumed average usage load of five 3-minute voice calls per line per day—came to a crashing halt as computers stayed online for hours at a time. Increasing the capacity of the circuit-switched system was clearly impractical. The situation quickly ushered in the adoption of packet-switched phone communications.

2. Around Christmas of 2012, many people got a Netflix streaming account. As a result, Netflix servers crashed on Christmas Eve that year and those servers stayed down for 20 hours because of the huge jump in traffic. According to Netflix Cloud Architect Adrian Cockcroft, the problems stemmed from errors on Amazon Web Service's Elastic Load Balancing.

Why are system designers moving towards the design of Smarter Networks? Because traffic explosions such as the two illustrated above are becoming more frequent as new and exciting ways of consuming bandwidth are introduced. Services such as Facebook and Twitter can disrupt network traffic patterns and bandwidth capacity.

Adding "dumb" network bandwidth is a bad solution because each type of information service introduces new usage patterns with different capacity requirements. The introduction of the MP3 compression standard permitted audio streaming but at the time, in the late 1990s, streaming video was out of the question. Today, video is one of the fastest growing drivers of broadband bandwidth consumption. The introduction of more efficient video compression coupled with the replacement of dial-up Internet connections with broadband connections took individual consumer bandwidth consumption to another level. The introduction of smartphones has done the same for wireless networks.

Ultimately, communications carriers are faced with the problem of being in a race to the bottom with respect to the provision of simple "dumb" pipes. They need to reduce the cost of bit transmission while finding ways to provide new services that boost revenue/bit.

Smarter Networks that are aware, efficient, and adaptable offer a way forward.

The Insatiable Need for Bandwidth

The biggest driver in the communications and networking markets is the insatiable need for bandwidth as traffic explodes well beyond the capabilities of networks to support that traffic. For example, Xilinx already has a very large number of customers worldwide actively developing and deploying systems based on 100Gbit Ethernet and many of these customers are already eyeing 400Gbps and Terabit Ethernet systems.

NETWORK CAPACITY AND THROUGHPUT EXPLOSION

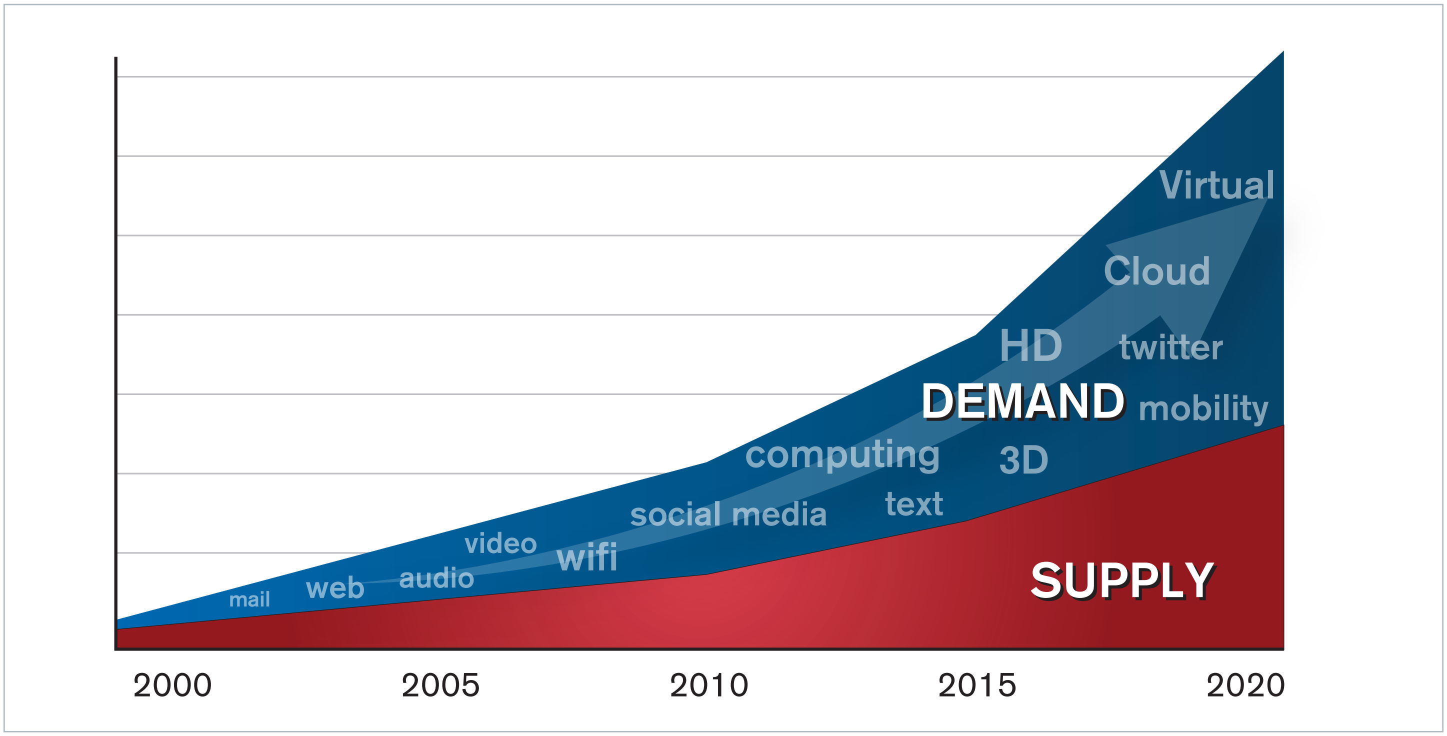

Figure 2: Source *Cisco VNI Global Forecast 2011*

However, the need is definitely not bandwidth or transmission capacity at any cost. It's really a need for more bandwidth and more capacity at lower and lower cost in both wireless and wired networks. The only way to reduce the costs associated with bandwidth or capacity is to make the systems that deliver that bandwidth more intelligent. Here, intelligence means several things including:

- The ability to eke more bandwidth from the same transmission medium while meeting quality-of-service requirements
- The ability to forge heterogeneous wireless or wired networks and data centers into a seamless bandwidth delivery system
- The ability to efficiently and quickly adapt to changes in network configuration, network usage, and market requirements

All of these abilities require multiple forms of programmability. For example, cellular services providers need to reconfigure their base stations as new and better algorithms are introduced and would prefer to avoid a truck roll to accommodate these changes. Data center managers need ways to quickly provision for new usage patterns without having to send a person walking down an aisle to change patch cords or install new network appliances in every fourth rack in the building.

The Programmable Imperative

Xilinx calls this need for programmability the "programmable imperative." No networking or communications system, no Smarter Network from this point forward can be designed without multiple forms of embedded programmability because doing so guarantees quick obsolescence and shortened end-product life.

Further, Xilinx believes that the programmable imperative is as much a mandate for Xilinx as it is for the company's networking and communications customers, which is one of the key reasons behind the development of the company's 28nm portfolio. (Actually, the mandate applies to all system vendors because intelligence and programmability are already growing in systems used across all markets.)

Three Critical Aspects of a Smarter Network

A Smarter Network …

1. Adjusts itself to traffic, demand, QoS, and its own health.
   - *The network is content- and context-aware.*
2. Allows Communications Service Providers and Carriers to maximize consistent and predictable service delivery at the lowest per-bit cost.
   - *The network is bandwidth and cost efficient. It is compact and power-efficient to minimize floor space and heat load in the data center as well as the radio on the antenna mast.*
3. Self manages or can be remotely managed with respect to multiple operating parameters including demand, performance, health, availability, and power consumption.
   - *The elements of the network are intelligent, scalable, adaptable, and reusable.*

Smart decision-making for networks seeks answers to questions such as:

- Is this a high throughput, low latency application?
- Is the data mission-critical for some medical service?
- Is this somebody who is watching a YouTube video?

Smarter Networks integrate intelligence and analytics across the network domain to answer these types of questions. With answers to these questions, the network can configure itself to operate efficiently, at maximum utilization, and at minimum cost.

Predictive analytics can optimize the entire range of wired and wireless networks including cellular sites and data centers, which is increasingly difficult in a world where carrier networks must handle high-definition video, multichannel audio, voice, and simple sensor traffic through the same pipes. Better optimizations become possible as carriers transition to self-organizing or software-defined networks (SONs and SDNs) which Xilinx All Programmable and Smarter Solutions are well suited to support.

Addressing the Growing Gaps with ASICs and ASSPs

At the same time, ASICs and ASSPs targeting the Communications, Networking, and Data Center equipment markets have been disappearing at a surprisingly rapid pace due to many factors including escalating IC-design costs and the need for much greater levels of intelligence and adaptability—all driven by wide variance in application and device requirements. Additionally, the equipment markets no longer accept "me too" equipment design, which means that ASSP-based equipment design has almost vanished due to limited flexibility. These growing gaps are pervasive across all markets.

In-house ASIC design teams and merchant ASSP vendors are:

1. Severely challenged to meet the combined requirements for intelligence, flexibility, and adaptability in next-generation systems
2. Struggling with fragmented and rapidly changing networking and data-center standards and application demands
3. Incapable of enabling customers to effectively add differentiation through their own "secret sauce"

These challenges, coupled with the rapidly increasing design costs and lengthy design cycles for both ASICs and ASSPs have created significant solution gaps for equipment design teams. ASSPs and ASICs are either too late to market to meet OEM or operator requirements, are significantly overdesigned to satisfy the superset requirements of many diverse customers, are not a good fit for specific target applications, and/or provide limited ability for customers to differentiate their end products. Equipment vendors face many or all of these gaps when attempting to use the solutions offered by ASIC and ASSP vendors.

XILINX ALL PROGRAMMABLE AND SMARTER SOLUTIONS ADDRESS ASIC & ASSPS GAPS

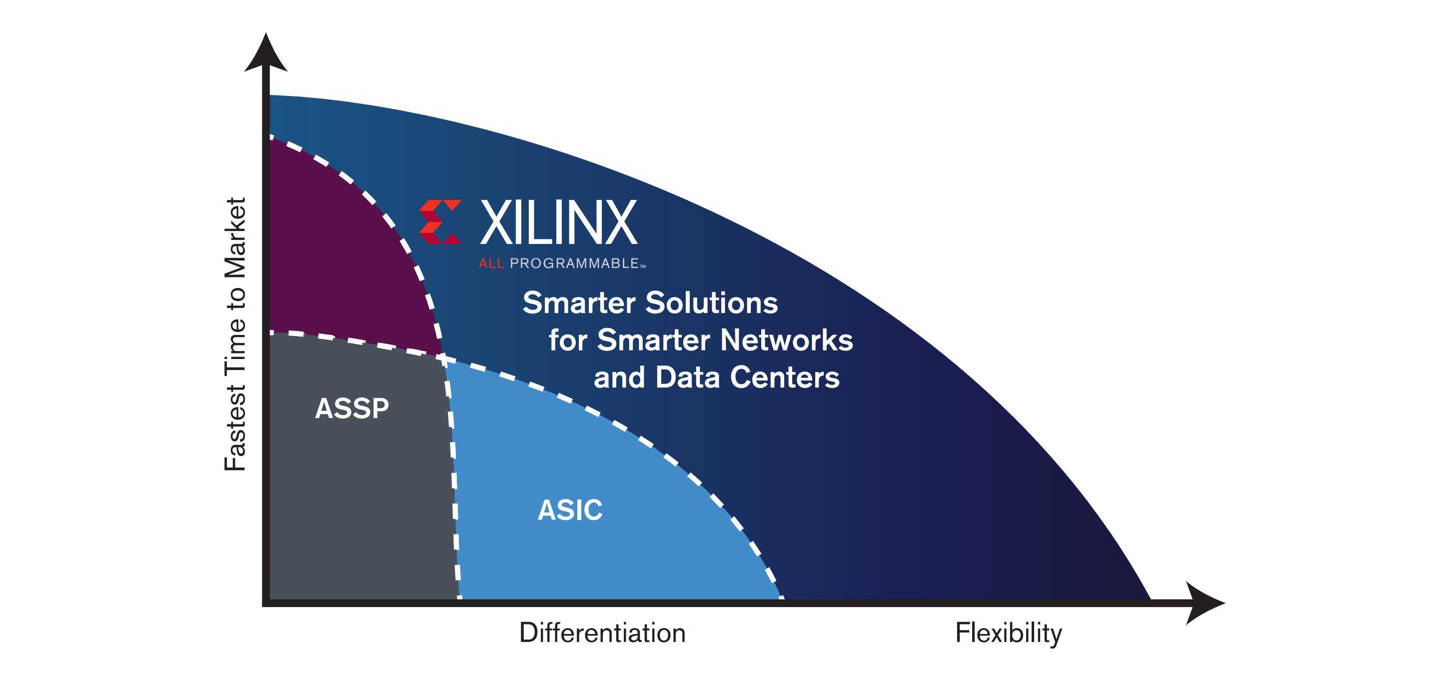

Figure 3

Through internally developed technology and strategic company acquisitions, Xilinx has focused on helping its customers develop and deliver Smarter Network and Data Center equipment through a combination of All Programmable, Generation Ahead silicon (FPGAs, 3D ICs, and All Programmable SoCs); unique and proven domain-specific IP; and domain-specific specialists. These domain-specific specialists have expertise with a wide range of technologies including packet processing and traffic management; mobile, microwave, and e-band backhaul; OTN; and a broad portfolio of communications-based connectivity standards. The potent combination of these three elements allows for the development and deployment of equipment that meets the needs of tomorrow's next-generation Smarter Networks and Data Centers.

Xilinx's Smarter Solutions for Networks and Data Centers includes a rich set of IP and associated design expertise / specialists to addresses these three market segments:

- Smarter Wireless HetNets
- Smarter Wired Networks including Edge and Carrier Ethernet
- Smarter Data Centers

Design requirements in these three segments are well matched to the unique capabilities of Xilinx All Programmable devices.

While cellular wireless networks have historically been based upon macro base stations, wireless networks are rapidly evolving into heterogeneous networks that employ many sizes or classes of base station. In addition to macrocells, which provide area coverage, these networks now starting to employ microcells, metrocells, femtocells, and even picocells for in-fill capacity. These different base station classes incorporate different radios and handle different user loads. Consequently, there's been a real renaissance in base-station design and there is a strong desire for the ability to reuse IP and algorithms across various designs wherever possible. In addition, many of the cellular standards are in continuous flux so chip-level reprogrammability and adaptability confer big competitive benefits for equipment vendors, supporting legacy services while permitting automated, in-field provisioning of newer services.

Wired networks carry nearly all of the traffic generated by wireless networks and then some. The name of the game in this space is more bandwidth at lower power. At the top of the network is the optical transport network (OTN) and the core and edge routers. Equipment here has already entered the 100Gbps domain with 400Gbps and 1000Gbps (Terabit) data rates just around the corner. Here too, standards are in high flux. More than 1500 changes have been made to the OTN standards alone, so chip-level reprogrammability and adaptability are quite valuable here as well.

Data centers have exploded with global Internet-based SAAS offerings such as Google, Facebook, Instagram, and hundreds of similar (and popular!) cloud-based services and applications that increasingly rely on big data. The types of messages flowing from these services to users and subscribers range from 140-character Tweets to 4K UHDTV video streams, each with its own unique QoS requirements. No doubt someone will invent a new type of message stream requiring a different QoS agreement tomorrow. Data center managers need increasing amounts of reprogrammability and adaptability here as well, to handle the changing mix of message types and QoS agreements.

Conclusion

Xilinx has transformed itself from an FPGA vendor into a supplier of All Programmable and Smarter Solutions, with an emphasis on Smarter Networking systems. The company has made huge investments to develop Generation Ahead 28nm silicon. There are a range of such devices on which to map many types of system design:

- FPGAs
- SoCs
- 3D ICs

Each of these device types represents an industry first:

- ✔ Xilinx 7 series FPGAs are the first system-optimized All Programmable FPGAs.
- ✔ The Xilinx Zynq family is the first family of All Programmable SoCs.
- ✔ The Xilinx 3D ICs are the first commercially available, production 3D devices.

Xilinx has further invested in the development of IP, tools, and services to help customers develop Smarter Networking products:

- ✔ Xilinx investments in SmartCORE IP give design teams the critical solutions that are required to realize Smarter Networks that will be competitive in the tough, worldwide communications and networking arenas.
- ✔ The Xilinx Vivado Design Suite is the first SoC-strength set of design tools for IP-based, SoC-style design using All Programmable devices.
- ✔ Xilinx design specialists and the Xilinx Communications Design Center stand ready to help when needed.

These investments are also critical to addressing the growing gap with ASICs and ASSPs – which are:

- ✔ Severely challenged to meet the combined requirements for intelligence, flexibility, and adaptability in next-generation systems
- ✔ Struggling with fragmented and rapidly changing networking and data-center standards and application demands
- ✔ Incapable of enabling customers to effectively add differentiation through their own “secret sauce”

Xilinx has made these investments and undertaken the development of its Generation Ahead silicon, IP, software, and services to help customers move a generation ahead when developing the essential systems used in the creation of Smarter Networks.

These investments have transformed Xilinx’ capabilities and solutions and to addressing more than “glue” logic and bridging functionality and are now becoming pivotal in enabling customers to design and deliver the next generation of smarter networks for the wired, wireless and data centers.

Take the NEXT STEP

To learn more about Smarter Networks, please visit: **www.xilinx.com/smarternetworks**

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