# Convergence Challenges and Solutions for Next-Generation Wireless Networking

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I am going to talk to you today about the next generation of wireless convergence. We'll focus on the challenges both on the handset side and the infrastructure side.

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We'll start at a very general level and address some of the broader challenges we face in this industry.

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First let's talk about consumers and what consumers of wireless technology want. Consumers of wireless devices, applications and services are first and foremost looking for simplicity. They want simplicity, security and access to their information, data and entertainment in a safe, secure way—especially as it pertains to any of their confidential and private information. Enterprises want that as well; they want to know that their employees are accessing confidential data in a secure way.

Security is also important to content providers because they want to make sure that their digital content is appropriately protected and distributed. Carriers strive to deliver stable, reliable networks that can deliver the promises of multiple services, applications and rich media content to consumers wherever they might be.

As consumers we want this in a personalized way, whether we are in the house, the office, the car, or just wandering around. We want wireless access in varying ways. I might not be interested in watching television on a train or an airplane using a mobile device, but many kids would be.

All of us as consumers have different bents and angles but there is one consistent theme—simplicity. I want access to my email at 30,000 feet in real time with all the attachments opening seamlessly in a small screen. We're not quite there yet.

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4G in principle is still a "dirty word," especially in Europe. Every European carrier will go as far as specifying 3.99G, but they will not say 4G because they're worried the government will tax them more.

4G is really a dirty word in other parts of the world where carriers want to recover their investment in 3G infrastructure. By 4G, I don't mean just another radio access network. I mean a network of networks that integrates seamlessly and allows people to move between different types of radio technologies in a seamless way, with consistent access to applications and technologies. And that is a pretty ambitious type of network. It requires multiple changes in technology and network infrastructure, in handsets and software. Huge amounts of innovation are going to be necessary to deliver on that kind of promise.

I believe that a 4G network will depend and rely entirely on a full Internet Protocol (IP) wireless infrastructure. This will give us the ability to fully exploit the capabilities of the Internet.

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Let's talk about some of the challenges in realizing the 4G vision. First, power consumption is critical because we are adding multiple processing and communication elements to drive higher levels of MIPS [throughput] in mobile devices. All of these elements will increase current drain.

Additional hardware acceleration technology is going to be required to manage power in this kind of environment. I view the emergence and use of OFDM-based technology as crucial to manage some of the process streams and power challenges in these kinds of applications and devices. Parallel processing techniques that will enable widely deployed OFDM-based technologies are essential innovations. With these techniques we can manage current drain and improve battery drain for better battery life. No one wants to see their movie end three-quarters of the way through.

The second major challenge I see in realizing the 4G vision is spectral efficiency. This is largely a matter of availability. We have a couple of choices. In order for more spectrum to be made available, we'll either have to re-farm existing spectrum in 2G and analog broadcast TV or open up higher-frequency bandwidths.

Further improvements in spectral efficiency can be derived through the use of cognitive radio. Dramatic innovations will be required to deliver on that promise.

Even with these steps, the 4G radio access network will need to provide significantly better spectral efficiency, on the order of 10 MIPS per hertz compared to only 1 or 2

MIPS per hertz available today from 3G systems. This is possible with the use of the technology we've been discussing today.

A third significant challenge in realizing a 4G vision is cost. This isn't just about cost of infrastructure or operating costs or cost of handsets. It's about the cost of deploying services. There are a variety of challenges in this area that come along with the network topology required for a 4G system. First of all, to deliver the spectral efficiency and coverage required, we'll have to see a dramatic growth in the number of basestations. To support the kinds of services that consumers increasingly expect, we'll need as many as three times more basestations to deliver a 10X increase in data rate.

One way to reduce basestation density is by applying advanced antenna techniques such as MIMO and Space-Time Coding (STC). These techniques can improve spectral efficiency to reduce the number of basestations and the growth of basestations. They can do this and still achieve the kind of coverage required to deliver the bandwidth necessary for the applications consumers want.

So this is an important factor: growth in the number of basestations required to deliver coverage at high data rates. There are capital costs associated with that. On the handset side, there are significant challenges in continuing to drive down the cost of integrating greater and greater processing capability in multimode RF technology.

From a carrier perspective, the affordability of managing, billing and distributing content over these networks to drive revenue to recover those higher operating costs is another challenge in realizing a 4G vision.

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From the perspective of 4G applications, everybody is still wondering what the killer 3G application is, and it seems like voice is still pretty good. But as we get into 4G technologies, mobile media players, Internet access, broadcast technology and other types of corporate aggregations will become more robust and will drive ARPU (average revenue per user) in the carrier space.

We have an example of a device on the screen — the all-in-one wireless handset device that does everything. Not everybody wants all of this functionality in one device. But consumers are looking for these types of functionalities in mobile devices with various size screens to deliver an experience that is appropriate for the type of application that a service provider is delivering.

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Now let me talk about more specific challenges in handset and infrastructure applications.

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I have talked about some of the larger challenges for 4G in general, and these challenges also apply to the area of handsets.

Miniaturization challenges include power reduction, cost, size and product-development cycle.

Multimode technology in 4G means we have to be able to hand off the different types of radio access technologies in a seamless way. There are significant software, billing, carrier interoperability and enterprise carrier interoperability challenges.

On the multimedia side, it is obvious that with rich digital media content come dramatic processing challenges for mobile devices.

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A wide range of advanced technologies will be required to enable 4G. For bulk CMOS process technologies, we will continue to evolve and provide higher performance at lower power as the semiconductor industry migrates from 90- to 65- to 45- to 32-nanometer technology. Many of the technological risks are not completely resolved. But the path to resolution is fairly clear over the next five to 10 years with respect to these evolving bulk CMOS technologies. On the RF side, for RF CMOS, we continue to scale RF CMOS to enable high-speed high-resolution A/D converters, and we are developing isolation techniques in the industry and at Freescale for multiple radio operation and single-chip die integration.

Further advances in integration are happening at the packaging level where we are integrating the RF module and system package module. Increasingly we are integrating embedded passives as critical elements for manufacturers to integrate multiple radios into a single device.

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Let's talk about advanced architectures to enable 4G. In WCDMA, we have two variables at our disposal: coding and time. With OFDM-based 4G, we use frequency, space and time as variables to extract the data. With OFDM, information is separated into small sub-bands, and the information in each of these bands can be signal-processed independently in a parallel fashion. We are moving as an industry to increasing parallel processing. The net result of this is that a high-speed, low-power drain OFDM engine architecture can be developed to support 4G data throughput requirements.

OFDM is typically discussed in the industry as being a WiMAX technology. One of the reasons we see WiMAX as an important technology is not so much because we believe in the base business model behind broadband wireless access, but because from the perspective of next-generation cellular technologies, OFDM will be an important technology to support the kind of data rate that we all expect in cellular technologies.

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We are looking at very high levels of integration to enable 4G evolution and convergence. At Freescale, we have driven some of this integration in the 3G world by combining the baseband processor, the application processor, the power amplifier, the power management solution and some other ICs into single-chip Freescale solutions we call the Mobile Xtreme Convergence Platform or MXC.

In a 4G model we envision integrating an MXC platform and an OFDM Engine to be able to support 4G types of applications with extremely low pin counts, small die size and small power envelopes.

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4G is not going to be driven by a single entity or organization. It will require a tremendous number of partnerships and a robust ecosystem so we can exploit the capabilities that are available to us in wireless technologies. Given the sweeping changes in the world of technology, it's really going to require multiple standards bodies, corporations and government entities to come together to drive standards-based interoperability and the opportunity to deliver 4G networks. Governments will have to manage spectrum in different parts of the world, and this will have a dramatic impact on how we can exploit the capabilities that are available to us in wireless technologies.

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Let's explore the challenges in the infrastructure side of wireless as we evolve from 3G to 4G networks.

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To enable triple-play merged services delivered over wired and wireless networks, equipment providers are looking for affordability, simplicity, interoperability and reliability as requirements that come to them from their customers—the carriers. As we move from circuit-switched networks to IP networks, some of the challenges include packet acceleration, traffic management, data integrity, security and quality of service, which all represent different challenges for us on the infrastructure side compared to the traditional network infrastructure.

This notion of high performance in a very constrained power envelope continues to be a significant challenge for the semiconductor industry, as well as for equipment vendors and carriers. Open standards continue to be an issue in the semiconductor industry, and resolving open standards and interconnectivity issues is an increasing challenge for all of us.

Let's consider power in infrastructure. While power is something we talk about a lot in the handset space because of battery life, power in infrastructure poses an interesting challenge as well. Recently, I was talking to a customer in the server business, and he mentioned that one of his company's largest customers (a household name in the Internet world) has huge data centers, and they just crossed over a threshold where the cost of electricity for their data centers is now greater than the amortization of the servers in the room.

A year ago I met with the CTO of NTT DoCoMo, the largest infrastructure carrier in Japan. His told me his No. 1 business challenge is power. NTT DoCoMo is increasingly viewed as environmentally unfriendly because of the amount of power they use. That is an infrastructure issue. So power is something we should all consider from the infrastructure perspective and the challenges we face.

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Let's talk about the 4G radio access network. I believe a 4G radio access network will use an advanced form of OFDM, at least for the downlink and quite possibly for the uplink as well. This will require some improvements in transmit power efficiency. To improve overall spectral efficiency, 4G will draw from the family of multi-input/multi-output (MIMO) technologies, such as space-time-coding and adaptive antennas.

Another key technology for 4G is in the area of mesh networking and relay base stations. The greater base station density required by 4G will increase backhaul costs. MIMO and advanced antenna technologies will help alleviate this cost. Passive relay and mesh networks will also help reduce transmit power in mobile devices. A 4G radio access network will use additional tricks, such as adaptive modulation and coding and ARQ (Automatic Repeat reQuest).

A 4G LAN will plug into an all-IP network. Every equipment provider, every carrier is making steps to migrate their existing networks to all-IP networks. The latency issue we see for VoIP has a different challenge in wireless VoIP. You must employ header suppression techniques to reduce the load on the radio network. We'll also see the use of SIP and IMS in all-IP wireless networks.

When I talk about 4G as being not just a 4G radio access network, it's the notion that it has to interoperate with other networks. 4G will be a network of networks that will incorporate WLAN, wireless PAN (personal area network) and broadcast. We see technologies such as ultra wideband being adopted and deployed for personal area networks.

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Let's shift gears and talk about IP network security, QoS and traffic control. Traditional equipment vendors have historically operated at layers 1 through 3. Wireline Internet access is being increasingly challenged to improve security. Security has multiple elements, much more than just moving encrypted traffic at faster and faster rates across the network. It's also about denial of service attacks and digital rights management. These are all becoming carrier problems. Improved security and QoS require being able to identify video packets and prioritize them so that viewers get an uninterrupted stream of video content if they are watching a movie on demand or a TV show on demand. These security/QoS capabilities are going to be key elements of how we manage the network in both wireless and wireline infrastructure.

All this is creating new challenges for us as we see a migration in next-generation networking to support elements above Layer 3 up to Layer 7. From the processor perspective, if you look at microprocessors and network processors that have historically played in networking applications, the network processor has been exceptionally efficient at driving performance at Layer 2 and 3 but has a significant drop-off in performance in Layer 4-7 protocols. A general-purpose microprocessor does not deliver the kind of performance at Layer 2 even and does a little better at Layers 4 through 7 but does not achieve the level of performance networks require. Today's communications processors use hardware acceleration techniques to achieve better performance in the lower levels and do slightly better in the higher levels. But there is still a significant gap, which I call the content processing gap in terms of microprocessor, network processor and communications processor technologies.

Clearly one of the requirements from a semiconductor perspective is the ability to provide a solution that does not just forward headers and IP packets. We need to inspect those packets, connect those packets and do stream processing instead of packet processing.

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From a perspective of basestation size- and cost-constraints, there is a trend for more basestations covering smaller areas while managing multiple power output limits, frequencies and standards.

Customers want to reduce power amplifier (PA) cost. The PA cost of a basestation is the single largest expense. Every operator and every silicon vendor is under tremendous pressure to reduce those costs.  Freescale knows this space very well, because we provide high-power RF amplifiers for this market. We have an extremely high market share, and we are under price competition, resulting in average selling price (ASP) reductions averaging 15 to 25 percent a year. The laws of physics in the semiconductor industry don't support those kinds of ASP reductions just on the basis of a straight-line path in process technology. So more and more innovation is going to be required to drive proliferation of basestations for 4G networks.

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Let's talk a little bit about Freescale and some of our technologies on the infrastructure side. We are the No. 1 supplier of communications processors for both wireless and wireline infrastructure. We also have market-leading devices with leading market shares. Our DSP portfolio is based on StarCore technology. We are the No. 2 supplier of DSP technologies. We're No. 1 in RF power transistors for cellular infrastructure. And we offer semicustom solutions for customers, as well as development tools and software to enable our customers to get to market.

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With regard to wireless infrastructure, let's look at the different technologies that are used in 3G--in the Node B, the modem card, controller cards, network interface cards and RF power amps. And for router technology, the GGSN and SGSN routers and media gateways are becoming completely reengineered as we move from 3G to 4G networks. Freescale plays in these applications with all of our product portfolios. Communications processors and host processors play in controller cards; DSPs are deployed in modem cards and media gateways. Communications processors are also used in the radio network controller. And our RF devices play in the basestation. In summary, we have a strong footprint and a lot of exposure throughout the wireless infrastructure market.

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From the communications processing standpoint between layers 4-7 processing, I mentioned that the communications processors in most wireless infrastructure are Freescale PowerQUICC™ devices. We know very well that to close that content processing gap, we had to integrate other types of functionality in our PowerQUICC family of products. We had to be able to support stream/flow management and pattern matching so that carriers can deliver the kind of QoS that customers are expecting for different kinds of applications depending on their primary needs. If it's voice technology, you want voice packets. If it's video technology that a customer is subscribing to, then video packets need to be prioritized.

In addition, all the issues around encryption technology put an added burden on processors. They have the effect of degrading performance in a system, unless you supplement that with some kind of coprocessing element in security technology — all of which are now fully integrated in our communications processors.

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In the RF world, we are advancing technologies for base stations. I mentioned severe price pressure in the basestation market, especially the PA module. Customers are trying to put higher and higher power devices into equipment, which has the effect of straining our capabilities on the packaging side. At the same time, dissipating and managing power in passive devices has required and driven us, not just from a cost perspective, but also from a reliability perspective to look at alternatives to ceramic technology. So plastic packaging has been a key part of the solution for managing this intense pressure on ASPs.

Multistage power ICs are another area where we are trying to integrate more functionality. We're also addressing higher efficiency and power gain challenges. This continuing evolution taxes us in terms of LDMOS technologies. We see increasing possibilities for gallium nitride as a technology that could serve as a possible replacement for RF LDMOS technologies. Gallium nitride has significant manufacturing challenges, as well as other commercial challenges, in terms of bringing those kinds of technologies to market. We think that is going to be essential as we move down the road to 4G and post-4G kinds of networks.

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Seamless mobility is really what Freescale is most passionate about. "Seamless" and "Mobility" are the two words we try to live and breathe everyday as we try to tackle the challenges I have articulated for our industry.

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To summarize, consumers, both at the personal level and in the enterprise, are driving the wide range of requirements for emerging 4G infrastructure. Clearly the appetite for seamless mobility is increasing as customers get a taste of what could be. Perhaps you saw Apple's announcement with ABC so that consumers can now watch "Desperate Housewives on an iPod. That is just wetting consumer appetites for more … more timely, more anywhere, bigger stream, more power, more battery life, instant-on anywhere regardless of where they are in the world. This drives hand-off issues in networks. Consumers don't care if they are at home or in a car or on a train; they want continuous service everywhere.

Other challenges include effects of power consumption and efficiency, spectral efficiency, and the cost of deploying not just infrastructure but the services on top of it.

And for handsets, the challenges are myriad: miniaturization; multimode technology, the ability of a handset to support multiple different air interfaces in a seamless way; and multimedia challenges which drive an increasing amount of processing requirement and drive up power consumption, which has to be managed effectively. There are financial challenges in realizing that at every node throughout the ecosystem of providers—whether it is base technology suppliers, component suppliers, software or services providers or carriers—a significant investment is required to enable the next-generation 4G network.

On the infrastructure side, more intelligence is required in the network to be able to provide quality of service and a quality user experience in an adequately secure way, not just for consumers but also for the providers that make that content available to carriers. This is driving complex service provider requirements, including security, QoS, and traffic control.

I mentioned power in infrastructure as well, which is one of the most poorly understood issues in the wireless infrastructure industry today but one that is becoming a very, very high priority for major operators.

And finally I talked about our solutions, the fact that we have a passion and love for this business that resonates throughout our organization in the handset business, as well as in the infrastructure business, as we try to help change the world in which we live and make it a better place.

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