Easing the Move to Multicore

Technology Innovation at Work
white paper series

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Introduction

The ever-increasing global appetite for computing power and performance has put embedded computing squarely on the path to multicore systems. This migration poses a complex set of questions: How do I migrate legacy software to work with multicore hardware? Do I need virtualization for better performance? How can I get the performance I need in a power envelope I can afford? Freescale can help you answer these questions and more with a combination of high-performance hardware; powerful, user-friendly software and tools; and an extensive, open ecosystem.

Although the move to multicore began in high-end applications such as networking and wireless infrastructure, multiple cores are appearing in less-traditional areas such as automotive, the safety-critical aspects of industrial applications and even printer and imaging applications—any application that could use more speed and power. The move toward global network connectivity is straining networks and increasing the need for more processing power. Single-threaded performance can't continue to improve without geometrically increasing power, which is counterproductive in terms of system cost and reliability. To keep power at manageable levels, applications must move to multicore instead of continuously increasing frequency.

Achieving multicore performance levels is not as simple as putting more cores into a system. There are complex issues surrounding the migration of legacy software from single-core to multicore hardware. Software engineers lack training in this kind of migration, and in multithreaded programming in general. Virtualization, which is necessary to get the most out an investment in multicore hardware, is a completely different way of thinking about operating systems and resource partitioning. And multicore systems certainly cannot avoid the problem that happens when you add more processing power to any solution: power consumption.

Freescale is a worldwide leader in embedded processing, with more than 300 million communications processors shipped to date. Our multicore QorIQ communications processors, QorIQ Qonverge platform for base-station-on-chip wireless systems and VortiQa software solutions—plus a worldwide base of seasoned field engineers and a strong, open partner ecosystem—are bringing our embedded processing heritage into the next era of networking.

The Software Problem

Two big roadblocks on the path to multicore involve software. The first problem is one of migration. Millions of lines of legacy code for single-processor sequential programs must be migrated to preserve investments. Until that mapping and transition becomes easier and more efficient, it will be somewhat painful to move from single-core to multicore systems. The second problem is a lack of basic knowledge about programming for multicore systems. It's fairly easy to install multiple cores from a hardware perspective, but programming for multicore requires a different mindset, and different education, than traditional single-core programming.

Freescale has invested in training and tools to make the transition to multicore easier. Development tools such as the QorIQ multicore software development kit (SDK) and CodeWarrior development tools help with the porting process. Freescale and our partners also provide tools for simulation and modeling analysis, including "what if" analysis of processor partitioning. Developer education has been a focus. Real-life case studies follow the process of re-mapping a sequential application onto a multicore processor, and Freescale develops application notes, presentations and articles for developers based on these studies.

Freescale estimates that between 60 and 70 percent of multicore research and development budgets is spent not on hardware, but on software. With that in mind, Freescale made multicore products very software friendly. Freescale has designed many capabilities into the QorIQ platform architecture that improve the software engineer's productivity, both in terms of migrating old code and writing new code. Of the 60 to 70 percent of software R&D time previously mentioned, it's estimated that more than 50 percent of that time is spent debugging software and optimizing performance. Freescale products help reduce this time and make software engineers more productive.
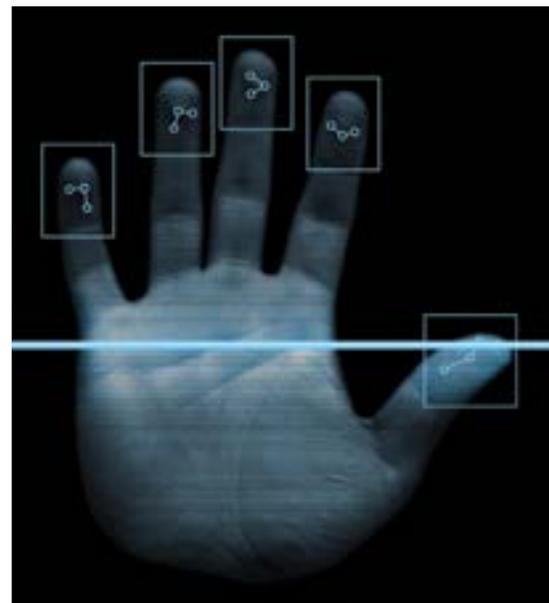
For example, Freescale user space data path acceleration architecture (USDPAA) software can provide substantial performance improvement over traditional kernel-mediated access to drivers. This software consists of hardware components that support simplified sharing of networking interfaces and accelerators by multiple CPU cores. Queue manager and buffer manager components provide the infrastructure to pass packets to and from cores, hardware accelerators and interfaces. Software accesses the data path acceleration architecture through hardware components called portals. USDPAA is a software framework that allows Linux® user space applications to directly access the portals in a high-performance manner. USDPAA helps make development and porting of legacy Pthread/user space applications very simple.

Virtualization and Visibility

Another way that multicore development differs from single-core development is how software and hardware are integrated. The first generation of multicore processors had multiple instantiations of the same core. The Freescale QorIQ Qonverge platform, on the other hand, has a mix of processing elements on a single piece of silicon: a Power Architecture® core, a StarCore DSP and several accelerating engines. The future will bring both more cores on a single die and a mix of different types of cores on a single die. The big difference is that all the cores will be virtualized. In a virtualized system, each task of an application needs to be mapped to the appropriate processing block. Currently, this process is very labor intensive. There must be tighter integration of partitioning tools, mapping tools and decomposition tools that allow a software engineer to quickly visualize the partitions, perform a "what if" analysis based on performance, power, memory, etc., then pick the target implementation and execute it.

The next step is to debug the application. The key to this step is the ability to observe all levels of these complex chips. Most chips will have visibility at the processor core level, but you ultimately need complete internal visibility, including the I/O, the memory controller and the acceleration engine. Once you have

visibility, you need controllability. Can you control these highly complex chips, with many cores and different kinds of cores, in a very granular way? Can you control how your data moves? To find out, you perform a quick "what if" analysis of how the data moves. This allows you to gain visibility into your system. Then you have a "knob" that you can turn to get better performance from the target scenario that came from the "what if" analysis. This involves both software and hardware. There is no visibility without the right debug hooks in silicon. If the debug hooks exist, but the APIs don't expose them to the tools and debugger, there is no visibility. There is no controllability without the silicon hooks, and the hooks should be integrated with the tool suite.

Freescale QorIQ multicore SDK and CodeWarrior development tools embed extensive visibility and access into our processors so that the developer can fully utilize the cores and resources, as well as debug the complex on-chip interactions.

Freescale's embedded hypervisor—the first and highest performance in the embedded communications processing space—is important for virtualization. A hypervisor is system-level software that allows multiple operating systems to access common peripherals and memory resources and provides a communication mechanism among multiple cores. In a multicore system, a task should not be physically mapped to a processing resource. If resources are

virtualized, then any task can access any virtual resource to get its job done. This makes computing resources flexible, elastic and not hard-bonded to any task. The Linux kernel-based virtual machine (KVM), for example, is supported on Freescale Power Architecture-based multicore SoCs as a choice for virtualization in embedded applications. This is a very complex area where Freescale is investing heavily to provide our customers one of the most important benefits of multicore systems: flexible resource use.

Hardware Designed for Multicore

As multicore processors and more processing power are added to systems, there is a need to leverage hardware across applications that may be running concurrently and performing different tasks within the overall system solution. In a multicore system, many different applications are requesting access to peripherals and to the SoC. For example, you can plug multiple cores into an SoC, but you can't always increase corresponding I/O into the system because you are limited by the number of pins on the chip. To put eight cores into an SoC and to be able to have two Ethernet ports appear as multiple Ethernet ports available to different cores, you have to add virtualization that isolates different parts of the SoC for different applications. Slices of software run on that single SoC while perceiving that the underlying hardware has a significantly larger amount of resources available to it.

One of the Freescale differentiators is how we apply that virtualization, and increase performance, in the SoC. When Freescale began developing multicore SoCs, we needed to provide a secure and reliable way to partition them in many different ways based on different types of applications. One common approach to developing multicore SoCs based on existing SoC infrastructure is to use shared buses. This approach, however, limits bandwidth and latency. Freescale addressed these architectural challenges the right way at the start. With right-sized interconnects, SoC components don't compete with each other because the SoC itself is a small network. From the beginning, Freescale has made multiple architectural and application-level decisions about the best way to provision a multicore device into our customers' systems.

Saving Power

Freescale has a multi-year history of being focused on multicore energy management. Conforming to protocols such as EnergyStar in the U.S., Top Runner in Japan and the EU Code of Conduct enables our customers to save power over time. Our PowerQUICC 8315 and 8536 processors and the QorIQ P1022 processor have capabilities such as packet lossless Ethernet that can put a device into deep sleep mode. This mode shuts down cores and caches and removes power supplies for the SoC. Portions of the SoC are active and able to handle some critical events, and can wake up the device at the right time, under the right conditions. Once the payload is processed, it returns to deep sleep mode. The QorIQ P1022 processor is being used by EnergyStar devices such as printers to meet energy requirements such as 200–300 milliwatt dissipation in deep sleep mode.

Another power-saving technique that Freescale pioneered is called cascading power management. This technique steers tasks to a smaller number of cores during non-peak activity periods so that the idle cores can enter a minimal-power or "drowsy" state. When packet traffic increases again, the technique allows a rapid return to fully loaded conditions. Cascading power management is not simply a power-saving technique; it

is also a workload management technique that distributes packet processing in a more efficient way.

Partners for Multicore Success

A critical component of multicore migration success is an extremely knowledgeable global field staff. Freescale—the same company that helped our customers take products with high-performance embedded processors to market in the world before multicore—has one of the largest field engineer bases in the world in the embedded processing space. Software for multicore applications is very complex. Experienced partners can help you architect, debug and optimize it.

Freescale continues to collaborate closely with leading software and tools companies in the embedded industry through our Freescale Connect Partner Program to help ensure comprehensive solutions that take full advantage of the QorIQ architecture. Freescale has an open and broad ecosystem to streamline the migration to multicore architectures. Our preferred partners include Enea, Green Hills, Mentor Graphics and QNX, who provide integrated solutions optimized for maximum performance on QorIQ platforms. A wide array of partners including 6Wind, Critical Blue and Wind River help accelerate migration to multicore and reduce time to market.

The industry is nearing the point where throwing more cores at a performance problem will no longer provide necessary performance improvements. The market is moving from a brute strength approach to more sophisticated power management and software techniques.

What's Next for Multicore?

The future of the multicore market will be driven by the demand for faster hardware to handle more workload and address the cost pressures that tax existing networks. Service providers and OEMs have to respond with much higher performance systems to sustain traffic quality in networks. There will be a progressive increase in I/O performance, in what kind of I/O can be handled and how many cores and memory caches can be used in SoCs to handle those increasing payloads.

Although hardware may be the market's engine, software will determine its course. Ordinarily, development tools lag behind technology changes. In multicore, however, the progress should happen the other way around. The market will see much more effort to help developers create and optimize multicore applications. Software contributes to overall system performance, so there will be a lot of tool support to optimize applications. Much more multicore software content will be delivered with these systems—not just enablement drivers for the device but more middleware and virtualization software, and other reference applications on top of that. Tuned operating systems for multicore will become more available to help with scheduling these devices.

Conclusion

Multicore solutions enable connected societies to live a better life. Whether it's for the world's networks, the mobile wireless infrastructure, the smart grid, the automated factory, the intelligent hospital or aerospace and defense, our advanced multicore hardware, enabling software and Freescale's global expertise can help ease your move to multicore.

QorIQ Communications Processors

The QorIQ communications portfolio delivers a smarter approach to multicore—providing a coherent migration path from single core to multicore—and from 32-bit to 64-bit. Now over 25 products strong, the QorIQ platform is the industry's broadest portfolio of communications processors, which enable customers to address opportunities and deploy their solutions across a wide range of performance, energy dissipation and cost points from power-constrained devices to the highest performance multicore devices. While the QorIQ portfolio has been widely deployed in a large number of networking segment applications, these high-performance SoC solutions are continuously being adopted by industrial markets as well. All QorIQ processors provide an optimal balance of architecture with high-performance cores, accelerators, memory controllers and data path architecture. Secure boot technology, which creates a trusted system that boots and executes only authentic code to protect essential systems from being compromised, is a cornerstone of the QorIQ platform's trust architecture. The QorIQ portfolio is unparalleled in breadth, offering solutions for a wide range of performance, energy dissipation and cost points from small form factor power-constrained devices to compute-intensive multicore devices for telecom, networking and industrial connectivity applications.

Visit **freescale.com/QorIQ** for additional resources, including a QorIQ product overview brochure.

QorIQ Value-Performance Tier Processors

The value-performance tier of QorIQ communications processors offers entry-level devices with scalable performance, high integration and advanced power management. This tier offers pin-compatible families that feature aggressive performance-per-watt profiles targeting small form factors and fanless designs by delivering up to 1.4 GHz CPU core performance under 10 watts.

QorIQ Mid-Performance Tier Processors

The mid-performance tier of QorIQ communications processors optimizes packet processing performance and I/O richness for control, service and mixed data plane processing while delivering up to 1.8 GHz CPU core performance under 25 watts. Devices in this tier offer pin compatibility from the value tier to maximize R&D investment in both hardware and software. Additionally, the mid-performance tier devices offer significant performance increases generation to generation while optimizing power and cost.

QorIQ High-Performance Tier Processors

The high-performance tier of QorIQ communications processors continues to offer additional feature sets for control, service and mixed data plane processing while delivering up to 2.4 GHz CPU core performance within an embedded power envelope. This tier of devices offers scalability from value- and mid-performance tiers with upward migration to maximize R&D investment in both hardware and software. The high-performance tier devices offer balanced compute performance density within a fine-grained power envelope from generation to generation.

QorIQ Qonverge platform

The QorIQ Qonverge platform is a highly integrated base-station-on-chip portfolio built on advanced heterogeneous multicore technology. The platform combines our SoC expertise with:

- e500 and e6500 Power Architecture cores
- SC3850 and SC3900 StarCore DSP cores
- Multi-accelerator platform engine (MAPLE) technologies
- Acceleration engines for security and data path

freescale.com/QorIQQonverge

QorIQ Multicore Software Development Tools

CodeWarrior Development Studio

Integrated within the Eclipse development framework, Freescale CodeWarrior development tools for Power Architecture technology combine Linux build tools and highly advanced multiprocessor and multicore debugging with software analysis capabilities, allowing you to build, debug and optimize the performance of Freescale Power Architecture-based multicore applications.

Features

- Eclipse IDE
- Flash programmer
- Hardware diagnostics
- Linux application debug
- Bare-board multicore debug (restrictions based on suite)
- Integrated GCC build tools/project management
- Linux trace (Linux-based software)
- Linux kernel debug (restrictions based on suite)
- CodeWarrior build tools (restrictions based on suite)
- Trace (bare metal [selected cores only]) (restrictions based on suite)

  freescale.com/CodeWarrior

VortiQa Software

The VortiQa software product line offers production-ready applications software addressing specific vertical market segments including wireless and wired infrastructure equipment, cloud, data center and small-medium business/enterprise network equipment. By using VortiQa software, customers can reduce overall product development costs and achieve accelerated time to market goals. VortiQa products are optimized to deliver maximum performance through full utilization of unique QorIQ processor technologies including DPAA, Layerscape architecture and a variety of acceleration engines. Freescale offers commercial support and maintenance services for VortiQa products. The VortiQa product family consists of the platform services package, application identification software, software-defined networking and network functions virtualization solutions for the QorIQ processing platform, as well as L1 baseband software for the QorIQ Qonverge platform.

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Processor Expert Software
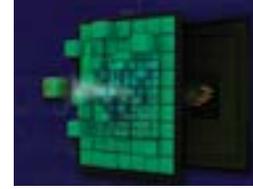
Processor Expert software is a development system to create, configure, optimize, migrate and deliver software components that generate source code for Freescale silicon. There are four offerings in the Processor Expert software suite designed specifically for our QorIQ platform. A configuration suite tool helps you set up and boot up a sophisticated mulitcore SoC in a fraction of the time for free—then browse additional packages that help you get more out of your system, including validation tools, scenario tools and more.

freescale.com/ProcessorExpert

Linux Software Development Kit

Freescale puts so much technology into our software offering that instead of calling it a board support package, we call it a software development kit (SDK). Our SDKs know how to get the most out of the advanced networking accelerators offered in QorIQ processors. Should you need even more help, our partners can go that extra mile with you.

freescale.com/Linux

For more information, visit freescale.com/multicore