

Case Study.

Driving the Cellular
Revolution with
the Help of High
Performance
Computing



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Since 1986, Motorola has been using high performance computing to model cellular networks and telephones, an approach that has given them a clear competitive advantage and made the company a leader in wireless communications. The firm accesses the supercomputers at the NSF-funded University of Illinois National Center for Supercomputing Applications to create highly complex models of their wireless devices and infrastructure as different communications technologies emerge. They are now creating models that reflect the newest generation of cellular systems. Their work continues to help Motorola retain its leadership position in the global wireless marketplace.

A wireless phone is a small miracle that fits in the palm of your hand. It includes a display screen, keyboard, compact speaker, microphone and microprocessors that rival any desktop PC. Not long ago, the electronics crammed into these tiny form factors would have filled a large briefcase.

Equally amazing is the infrastructure that makes communications possible. A wireless phone is really a very sophisticated and complex radio that sends and receives signals and is connected to a network. This allows the phone to call any telephone anywhere in the world, access the Internet and take advantage of a variety of data services.

The wireless network operates on a grid that divides cities or regions into small cells that can range from a few city blocks to several hundred square miles. Each cell uses a set of radio frequencies or channels to provide service in its specific area. A base station in each cell consisting of a wireless antenna and other radio equipment links callers into the local telephone network, the Internet or another wireless network.

Those are the basics. From this point on, it really gets complicated and makes life interesting for people like Gerry Labeledz, a Dan Noble Fellow at Motorola Labs. (Only 0.3% of Motorola's technologists receive this title from the company's board of directors.) Understanding

cellular infrastructures has kept Labeledz occupied for nearly three decades. It also turned him into a major fan of supercomputing.

Motorola Inc., headquartered in Schaumburg, IL, is a leader in wireless and broadband communications with sales of \$42.9 billion in 2006. For 20 years, Labeledz and his fellow researchers have been leveraging the power of high performance computing (HPC) to create the wireless products and services that have made Motorola a household name around the world.

Launching the Cellular Revolution

"Yeah, it all started centuries ago," Labeledz says with a grin. "Well, actually, it was in the 1980s when a new method for sharing radio communications channels called Global System for Mobile Communications (GSM) was introduced."

For the first time, voice was converted into numbers and digitally transmitted over a radio channel. As Labeledz explains, "We literally chopped up your voice, put it in a buffer and sent it so fast that many people could use the same radio channel and not hear each other." The cellular revolution was born. But the ubiquitous use of cell phones was a future that few could imagine.

Labeledz recalls that when GSM was launched, the

computations required to model and simulate the performance of a GSM network were generally considered to be unfeasible. The primary variable that needed to be considered was the radio link itself, and how the radio transmitter and receiver in the wireless device would communicate with the radio receiver and transmitter in the cellular tower. That determines the nature of the cellular telephone – not only how complex it has to be, but whether or not you can even build something that will fit in a person’s pocket. Other considerations include the range for each cellular phone in the cell, how many people can the cell serve, and the configuration, placement and capabilities of the cellular towers (also built by Motorola).

“Wireless communications is a very technical, highly mathematical field,” Labeledz says. “For example, if you want to solve the capacity question – ‘How many people can this particular cellular network serve?’ – you are dealing with a mathematically intractable problem. There are no existing equations, no books that you can refer to – you have to simulate the entire system.”

Labeledz and his team tried tackling these problems using the workstations that were available at the time, but even after months of effort, the answers were just not forthcoming. So they enlisted the help of the HPC facility at the University of Illinois National Center for Supercomputing Applications (NCSA), one of the National Science Foundation Supercomputer Centers.

“Suddenly we were getting a lot of answers in a big hurry,” Labeledz says. And with these answers, Motorola emerged as the undisputed world leader in providing GSM networks to telecommunications firms and wireless phones to individuals.

But technology does not stand still.

Enter CDMA, a New Technology with New Challenges

Technological change is inevitable. In 1995, Qualcomm Incorporated introduced Code Division Multiple Access (CDMA). The term refers to new communications protocols and a method of digital wireless transmission that provides a way for sharing radio frequency spectrum.

The cellular concept didn’t change. Voices still were converted to numbers and transmitted digitally. But the technology for sharing the radio frequency spectrum was radically different from GSM. With CDMA, each digital transmission is coded so that groups of them can be sent at the same time over the same radio frequency without interfering with each other. As a result, Motorola had to start over again and create new computational models of the cellular system, and even the inside of the wireless telephone.

Labeledz explains, “Every time a really new wireless system is introduced, companies like Motorola have to figure out not only how to work with the new technology, but do it in such a way that we’re miles ahead of the competition.”

Once again, Labeledz and his team tapped into the resources at NCSA. This time they found even more powerful supercomputers than had been available previously. Now Motorola could enhance its models to include the unique physical characteristics that affect the transmission of signals within each market. For example, Chicago and New York with their skyscrapers, the many islands that make up Stockholm or Seattle, which Labeledz calls an “absolute nightmare” with a lake running through its center and innumerable bridges, some just six feet off the water. Every person with a wireless phone walking or driving through the area has to be accounted for.



Motorola engineers install a WiMax access point on a rooftop in Chicago. Image courtesy of Motorola, Inc.

“In the case of GSM, the breakthrough was that we were able to model the radio link,” he says. “But we were never able to model much of the geography. We had to take pieces of it because there wasn’t enough computing power to do the whole thing. With CDMA, our breakthrough was to model the essentials of the whole system by simulating major pieces of the geography. However, even with the NCSA’s massively parallel machines, there was not enough computing power to model the entire cellular network.”

Another Decade, Another Technology Leap

Now, a decade later, the Motorola group is pushing the boundaries of supercomputing once again. This time it is Orthogonal Frequency Division Multiplexing (OFDM), a technique for transmitting large amounts of digital data over a radio wave. OFDM is the basis of WiMAX technology, a new global standard for mobile broadband service that is starting to have worldwide deployments. Also on their plate is Wi-Fi, another technology standard that permits products such as cell phones, gaming consoles and MP3 players from different manufactures to interoperate with each other.

“What happens is that wireless systems keep getting insanely more complicated and therefore insanely more difficult to model,” Labeledz comments. “The new systems work in radically different ways, so we have to start all over from the beginning. Each system – GSM, CDM, OFDM – has a different approach to sharing the radio spectrum, so you have to go back to square one and create new models for those geographies and the devices. You can’t do this on a trial and error basis – you have to be right the first time. This level of modeling can only be accomplished on a supercomputer.”

HPC Competitive Impact: Creating Market-Capturing Products and Services

“In the final analysis, our ability to access high performance computers and expertise at NCSA helps us grow our business,” Labeledz notes. “Frequently a potential customer will be interested in incorporating one of the radio technologies into a new product and will approach Motorola to see if we can meet their needs. When we demonstrate our in-depth understanding of these technologies based on the HPC modeling we have been doing, we build a foundation of confidence and trust that is invaluable. This is crucial – the customers are not only spending a great deal of money, but betting their careers, even their company, on Motorola’s products.

“The cellular infrastructure business is like a marriage,” he concludes. “You have to have confidence in your partner and be ready for the long haul. Our customers need to know we will be there for them with the latest technology as their business expands or they run into unexpected competition. The modeling expertise that we have developed and demonstrated over the past 20 plus years is unique to Motorola. We know the value of HPC and it is key to maintaining our competitive edge.”

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Gerry Labeledz, Dan Noble Fellow, Motorola Labs

In Brief

Key Challenges

- Capture and extend market leadership in the global wireless communications market through each successive generation of communications technologies, such as GSM, CDMA, OFDM and Wi-Fi

Solutions

- Create sophisticated computational models and simulations of each generation of cellular system and wireless device from the ground up – something that none of Motorola's competitors have been able to do as successfully
- Access the high performance computers needed to create and run these models and simulations at the University of Illinois National Center for Supercomputing Applications

Key HPC Benefits

- Creates and runs increasingly accurate models and simulations of the radio links, wireless devices and infrastructure needed to develop world-class wireless products and services
- Creates new models that respond to new generations of cellular system technologies – from GSM to CDMA to today's systems, such as OFDM and Wi-Fi
- Builds a high level of customer confidence and trust in Motorola's capability to develop state-of-the-art wireless products, ensuring and enhancing Motorola's position as a global leader in the field of wireless communications

Web Site

- www.motorola.com



Instead of using 100% virgin paper, we used paper that has been 30% Post-Consumer Recycled and made with 100% wind-generated electricity. We saved:

5 trees preserved for the future

1667 gal of water flow saved

276 lbs of solid waste not generated

509 lbs of greenhouse gasses prevented

3 million BTUs of energy not consumed

Environmental impact statements were made using the Environmental Defense Fund Paper Calculator.

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