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## Möbius: More Than the Sum of Its Parts

October 3, 2003



*Bell Labs' Möbius team -- (from left) Swarup Acharya, Bhawna Gupta, Anurag Srivastava, Pankaj Risbood and Yuh-Jye Chang -- have created a technology that is having broad impact on Lucent products and services.*

**I**f you've never seen a Möbius strip, it's not hard to make. Take a long, thin strip of paper, give it a half twist, and tape the ends together. Draw a continuous line on the strip's surface, and you'll find something amazing: you wind up right back where you've started. You've done what seems to be impossible -- you've created a two-dimensional object that has only one side.

In very simple terms, that principle describes the core function of Bell Labs' Möbius technology, a complex set of algorithms that brings together the multiple layers of a network and manages them as one. The Bell Labs team that invented the technology has applied for five patents for their work, and components of the technology are being brought to market in not one but three very different offerings for Lucent, with potential for even greater impact in the future.

"Having an asset that can be shared by different businesses really does point out the excellence of the team's work," said Robert Hu, system engineering technical manager, Network Operations Software (NOS), in Holmdel, N.J. Hu is responsible for system engineering for the *Navis*® Provisioning Manager, which uses one of the Möbius components in its December 2003 release. "It's a single investment in research that can be used by multiple business units. This drives down the cost of providing this technology to the customer."

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Robert Hu

### Origin of an Idea

In 2000, Lucent released the Optical Services Manager, a management system for the LambdaRouter® All Optical Switch. The research team, led by Swarup Acharya, technical manager, Network Software Research Department, in Murray Hill, N.J., designed the OSM as a way to make the traditionally inflexible optical transport layer flexible by providing such capabilities as point-and-click bandwidth provisioning. "It was a total change in the way people thought of the optical network," said Acharya.

A subset of the OSM team -- Yuh-Jye Chang, Bhawna Gupta, Pankaj Risbood, Anurag Srivastava (all in Murray Hill) and Acharya -- decided to continue exploring what such flexibility might mean for the network. The result of that curiosity was Möbius, a complex technology that aims to create an intelligent, self-tuning core network by leveraging cross-domain information to provide multi-layer network management and optimization -- in other words, a fully optimized and flexible network.

To understand how Möbius works, first think of the network as a stack. At the bottom is the optical transport layer, then ATM, then the IP layer, and so on. In some sense, the network operates on a kind of client-server hierarchy, with each layer above acting as a client of the layers below. In an ideal world, the network would optimize itself by tuning the lower layers to meet the needs of the upper layers.

That is the goal of Möbius. It optimizes the end-to-end network by individually tuning each layer in response to input from the layer above it, not just to improve the performance of that first layer, but to optimize the layers above. It bridges the gaps between the layers, allowing them to be managed as an integrated whole. "Networks have traditionally been looked at as a layered architecture," said Acharya. "It is increasingly becoming apparent that those layers are all merging together."

Even more impressively, Möbius has algorithms to do it all on the fly. It provides the technology for service providers to react to changing traffic patterns day-by-day, without disrupting service. "It's a paradigm shift for the optical transport layer," said Acharya. "What would take weeks and months to do before can now be done in minutes."

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Unfortunately, in part because of the constrained economic environment, the market wasn't quite ready for such a paradigm shift. "In some sense," said Acharya, "Möbius was ahead of its time."

Swarup Acharya

That wasn't the end of the project, however. When building Möbius, the team had learned to optimize each layer of the network on its own in order to optimize the end-to-end network as a whole. The team realized that, by breaking Möbius into its parts, each designed to work on the optical transport and the IP layers, they would create new technologies that could be applied today.

The team's work resulted in not one but three different applications, all usable technologies that have launched, or will soon do so, as part of Lucent products or services. Those applications include an algorithm incorporated in the LambdaUnite® Multiservice Switch; software that will soon be part of the Navis® Provisioning Manager; and Lucent Worldwide Services' Bandwidth Recovery Service, now in trials.

### LambdaUnite®

In 2001, the LambdaUnite® software development team reached out to Bell Labs for assistance in developing a system for meshed restoration in optical transport networks. One of the Möbius algorithms -- for intra-port link defragmentation -- fit the bill and was incorporated in release 4.0, which was generally available in March 2003. This algorithm, and a companion algorithm for inter-port link defragmentation, will help Lucent customers better use their transport network capacity when using meshed restoration by recovering lost bandwidth.

"Customers were impressed to see this feature in LambdaUnite," said Sigrid Hauenstein, director of research and development for LambdaUnite® software development, INS, in Nuremberg, Germany. "We received a lot of valuable feedback from the demos and trials."

### **Navis® Provisioning Manager**

In December 2003, the second Möbius-related application -- this one for Multiprotocol Label Switching (MPLS) provisioning -- will make its debut as part of the *Navis®* Provisioning Manager (NPM) release 4.0. In this case, Möbius is being used to provision and traffic engineer label switch paths for Juniper and Cisco products and is playing a central role in meeting Lucent's commitment to the Juniper partnership.

As part of NPM, Möbius will not only offer the ability to provision MPLS label switch paths on a per-request basis, but will be able to reroute existing paths on a trunk without tearing them down. This ability is a key differentiator for the product and can be used to address a variety of customer needs, including rebalancing or optimizing traffic in the network or moving services off a network element for maintenance.

### **Bandwidth Recovery Service**

That brings us to the latest entry in the list of Möbius-related applications: the Bandwidth Recovery Service, now being trialed with LWS customers. Inspired by the work on LambdaUnite®, the team recommended a new service that will take advantage of Möbius' optical transport layer functionality, but at a much deeper level, allowing our Services teams to map out and perform full SONET/SDH network optimization, even for service providers with non-Lucent network elements.

What does that mean? Traditionally, capacity in a SONET network is allocated in a fairly rigid procedure, where specific chunks of bandwidth are allocated to specific users. The system is not very dynamic. Over time, as these big chunks are allocated, small pieces of bandwidth are stranded in different areas of the network. "Networks fragment in the same way that disk drives become fragmented," said Lawrence Cowsar, director, Scientific Computing Research, in Murray Hill, a member of the team bringing the service to market. "They become less efficient, and bandwidth becomes stranded in the network. You can't use it. By doing some sophisticated analysis and rearranging the bandwidth, you can make use of this stranded capacity. Möbius gives us the tools to do that."

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Lawrence Cowsar

The value proposition for our customers is fairly straightforward. In this constrained environment, service providers need to do one of two things. They either need to make more efficient use of their existing network so they can expand service without increasing their investment in equipment, or they need to reduce the size of their network so they can reduce their operating expenses. And because they cannot take their networks down to perform this type of maintenance, they need to be able to do this on the fly -- which Möbius is uniquely positioned to do.

Though other companies offer similar services, LWS will be able to offer several key advantages. Combined with LWS's highly skilled and experienced delivery resources, the Möbius technology ensures not only highly increased speed and accuracy through automation, but the promise of a solution that provides little to no disruption to subscribers.

Another advantage is that it is being applied to so many different systems. Noted LWS Professional Services Product Manager Nancy Lengel, in Holmdel, N.J., who is helping to turn the Möbius technology into a new service offering, "The contributions of Bell Labs enable Lucent to offer our customers the best technology available -- whether they are purchasing a service or a product. Applying the most comprehensive use of Möbius across our product and service offerings makes sense internally as well as externally, by accommodating a

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range of needs and price points with a relatively consistent methodology for meeting those needs."

Nancy Lengel

### **Adding It Up**

Möbius started as a vision of the future, a concept of a world where networks tune themselves, self-optimizing to meet the day-to-day needs of their users. By breaking Möbius into its primary components and bringing those to market individually, we are, in some measure, realizing that vision. "We are able to solve many problems," Acharya said, "just not in the manner we originally thought."

Rod Alferness, senior vice president, Optical Networking Research, agrees that Bell Labs' ability to adapt solutions and solve problems for the business is key. "This team is driven by their desire to innovate, to do quality research that has a real impact on the business," he said. "That's a model that's as important to research as it is to the business."

— by Marike Estep