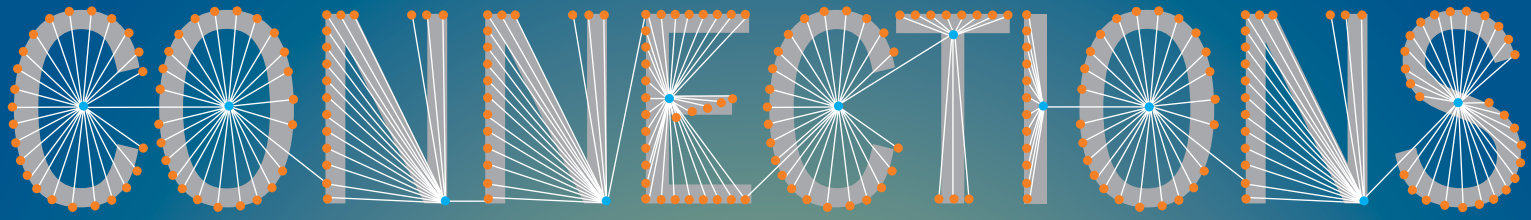
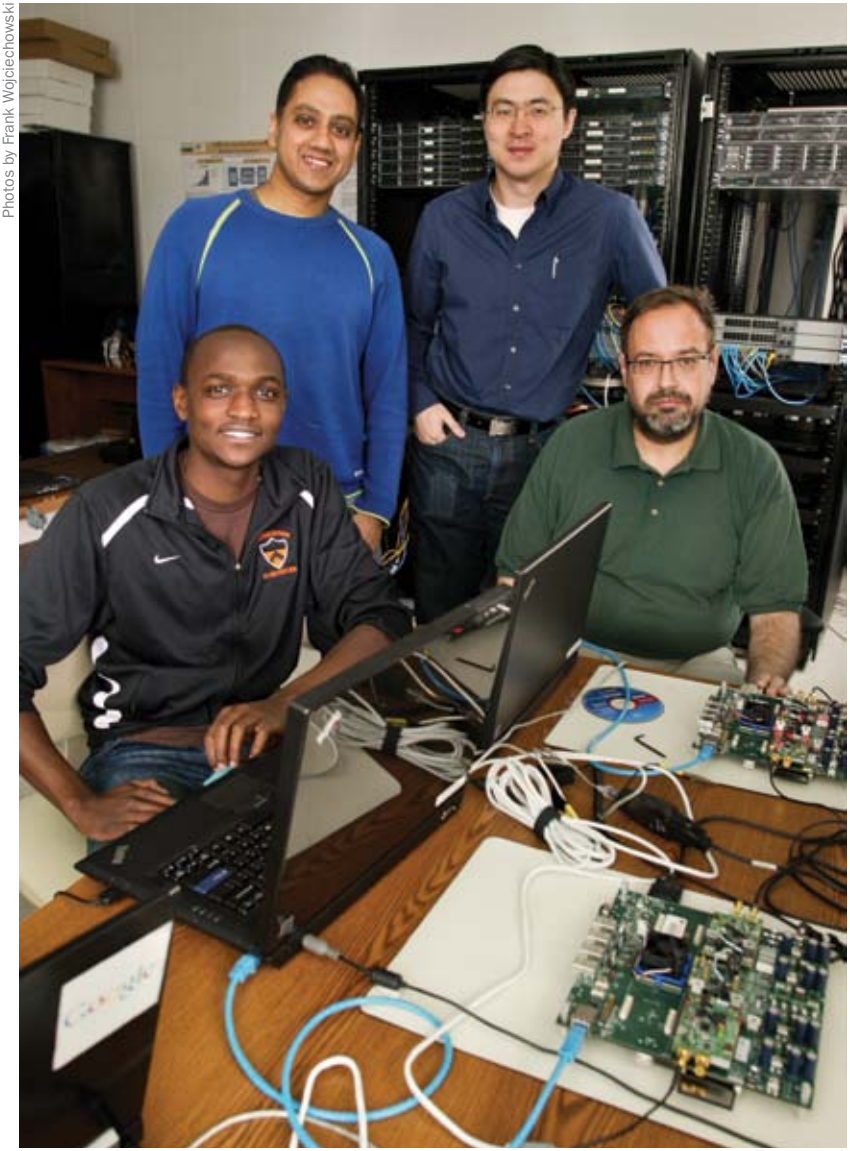


Princeton engineers straddle the divide between fundamental research and real-world problem solving, testing new ideas and technologies while giving students hands-on experience and helping industry meet consumer demand. Here, *EQuad News* highlights collaborations between Princeton academics and industry researchers, from delivering Internet video to mobile phones to pricing the wind energy that powers homes and businesses. These are stories of how faculty and students work with industry to develop new knowledge and make a difference in people's lives.

Photos by Frank Wojciechowski



KEEPING THE DATA FLOWING AS OUR APPETITE FOR VIDEO GROWS

Mung Chiang (third from left) with three members of his research team, from left: electrical engineering senior Josphat Magutt and postdoctoral researchers Amitabha Ghosh and Haris Kremo.

By Chris Emery

If you adore Netflix, YouTube, Hulu, Skype or any other wellspring of Internet video goodness, you're not alone.

Demand is soaring for movies, television shows and amateur videos delivered via the Internet and mobile networks. According to the networking Company Cisco, Internet consumption on mobile devices alone—smartphones, tablet computers such as the iPad and devices yet to be invented—will grow by 65 times over the next five years, and video will represent 70 percent of that traffic by 2015.

What most people don't know is that our enormous thirst for moving pixels is fast outpacing the capacity to deliver video to viewers' screens.

"People take the Internet for granted, but Internet usage has exploded," said Mung Chiang, a Princeton professor of electrical engineering. "Our success at building and using these incredible networks may collapse under its own weight if we don't keep innovating."

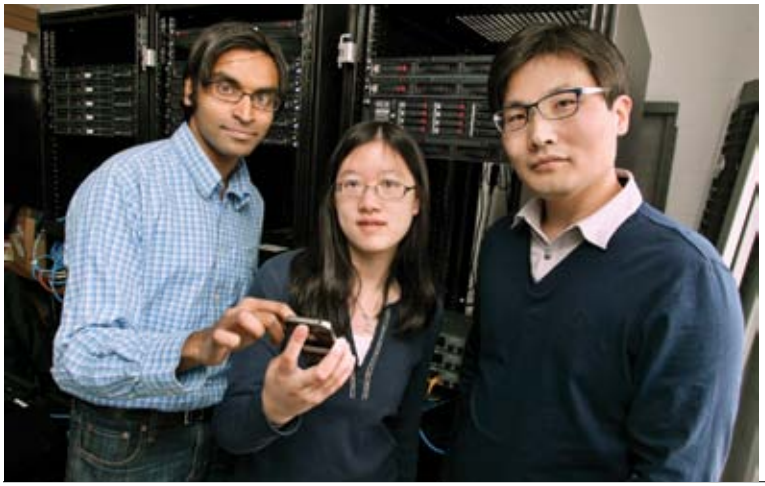
Fortunately, Chiang and his team are on the case. Over the past two years, they have methodically pieced together a replica of the global Internet and mobile networks, squeezing the scaled-down components into a Princeton laboratory.

Now they are using this miniaturized version of the global communications network, dubbed the EDGE Lab, to develop new ideas and systems that will help ensure that the networking infrastructure of the future will meet consumer demand.

To build the laboratory, he and his team worked with manufacturers of the equipment that runs various aspects of these networks. The devices are often proprietary, with their inner workings inaccessible to end users, but the Chiang lab negotiated to buy devices that were realistic yet flexible enough to examine and modify for experiments.

Among Chiang's corporate collaborators are AT&T, Hewlett-Packard, Intel, Telcordia, Qualcomm, Google, and Microsoft.

"In EDGE Lab, we're trying to make a difference in the actual networking world, and to make a fundamental difference based on analytic rigor," he said. "It's also important



Three members of Chiang's research group with a mobile phone they use for testing an application to help customers pinpoint when to download data at lower prices. Pictured (from left) are Soumya Sen, a postdoctoral researcher; Carlee Joe-Wong '11, a mathematics major; and Sangtae Ha, a postdoctoral researcher.

that we do this here, in academia, because we need to develop long-term solutions that aren't always tied to the product cycle."

At the same time, a benefit of having a laboratory that's working closely with industry, Chiang said, is that students get hands-on experience translating what they're learning to practical problems. "They learn network theory and then get to apply it to real networks," he said. "They can actually see the difference made by the theory they are working on, so it's more intuitive and engaging."

Carlee Joe-Wong, a mathematics major who graduated in May and who has worked in Chiang's lab since the fall of 2009, said the experience changed her perceptions of how research is conducted. "I always had this impression that academia and industry are completely separate," she said. "It's been eye-opening to see that companies are in interested in these very abstract models and want to put them to use."

Chiang's research focuses on so-called "edge networks," technologies within about two miles of the end user, including familiar services such as 4G, WiFi, U-Verse and FiOS. The name of the lab stems from this focus, and also serves as a metaphor for an edge connecting academic theory and real-world applications, a rarity in the field of networking research.

The EDGE Lab is filled with racks and tables of black boxes, covered in blinking lights and connected to one another by wireless antennas and the bundles of networking cables snaking around the room.

Most of the boxes are servers, routers, radios and other computers that are the workhorses of our modern digital networks. Others are machines Chiang and his students use to experiment on their mock Internet.

The lab is also littered with devices more familiar to the average person: laptops, tablet computers, smartphones and a high-definition television mounted to one wall. The researchers use these devices to understand how altering the way the network operates changes the end user's experience.

One problem is that Internet servers can often become inefficient at delivering content from one place to another, sometimes routing the data through long, convoluted paths. Along with Professor Jennifer Rexford '91 and their joint graduate student, Joe Jiang, of the computer science department, Chiang is experimenting with new ways to store and deliver content that could reduce Internet bottlenecks, such as intelligent ways to spread traffic among the available paths and to distribute files from the right servers or other user's computers on the network, called "peers."

Another major thrust of Chiang's research is helping service providers develop new pricing methods as consumer demand for bandwidth continues to surge. "Imagine that you go to a buffet but your appetite doubles every year," Chiang said. "Starting last year, service providers in the U.S. are saying they can't keep serving a buffet because customers are starting to eat too much relative to the cost of making the food. Either they have to double the price of the buffet or find a cheaper, more efficient way to dish up the food."

To address this, Chiang and his collaborators developed the mathematics and a prototype for TUBE, short for "Time-dependent Usage-based Broadband price Engineering," that gives consumers more information and thus control over when they use the Internet and how much they pay.

He is working with AT&T on a trial that began April 27 with 40 customers at Princeton—faculty, staff, and students—to test the system.

H. Vincent Poor, dean of the engineering school and an expert in communications networks himself, said Chiang's research offers a unique combination of mathematical rigor and practical impact.

"Netflix streaming an HD movie to the TV in our family rooms, watching YouTube on our iPhones or laptops, talking on our cell phones—these are just a few examples of times when we rely on edge networks," Poor said. "Mung's research on networks, especially edge networks, has been at the forefront of improving the quality of these experiences and in creating seamlessness among them." E