



Cell phones will create ad hoc mobile radio networks by communicating with one another and forwarding conversations without routing signals to base stations.

# Fusing Ad Hoc and P2P

*In the future, conversations will hop from cell phone to cell phone and even skip over areas with no coverage. That's the vision being pursued by Siemens and the Technical University of Munich.*

Mobile telecommunications aren't really all that mobile. Normally, a connection can be established only if there's a nearby base station with permanently installed transmitting and receiving antennas, and the base station is in turn linked to a relay center via cable. But that may change. Researchers around the world are working on a much more flexible mobile radio network — one in which cell phones and laptop computers will be able to establish contact with one another directly, without detouring through base stations. The devices will then spontaneously form connections among themselves — “ad hoc networks,” as they're called. Such networks

would make it possible to receive data even in areas not covered by cellular networks. Starting from the last reachable base station, a conversation would simply hop from cell phone to cell phone until reaching its targeted device. This new concept allows radio cells to be flexibly and spontaneously extended (ad hoc) in accord with demand, because the more cell phones are in an area, the better it works. The current system, on the other hand, becomes increasingly clogged as the number of users simultaneously placing calls increases.

But there's more behind the idea of ad hoc networks than just improved flexibility.

The main reason this technology is important is that high fundamental frequencies will be needed for future multimedia transmissions, because such frequencies transport more data. However, they have one major drawback: Their range is shorter than that of the frequencies used today. That's why critics are concerned that tomorrow's multimedia communications environment could require even more mobile phone masts. Ad hoc networks could keep that number under control.

Considering all of this, Siemens scientists are working with the Technical University of Munich (TUM) on a number of research projects regarding the next — the fourth — gen-

eration of mobile radio technology, which could be market-ready in about ten years.

Prof. Jörg Eberspächer, head of the TUM's Communications Networks Institute, is sure cell phones will be so intelligent before then that they'll be capable of comprehensive ad hoc communication. And for users, flexible networks promise lower priced mobile communications since calls will not need to be detoured through a central switching station.

Nevertheless, a number of thorny technical questions need to be resolved before ad hoc networks become practical. For one thing, handsets will have to manage some of the work now handled by relay centers — things like recording information and forwarding it to the correct address. Furthermore, the ad hoc connection's stability must be guaranteed.

As part of IPonAir (Internet Protocol on Air), a project funded by the German Ministry of Research, Eberspächer and his colleagues are working with Siemens and other companies to solve such problems. In simulations, TUM engineers have demonstrated that the risk of a dropped connection can be reduced by setting up multiple ad hoc paths between transmitter and receiver. In other simulations, the researchers are studying how buildings affect the properties of an ad hoc network. To what degree is the signal scattered by the corners of buildings? When does disruptive interference occur? And, since ad hoc participants will be constantly in motion, how will mobile terminals react spontaneously to sustain communication? One crucial question is the level of transmitting power needed. Researchers working under Prof. Joachim Hagenauer, head of the TUM Institute for Communications Engineering, have found that, for ad hoc “hopping” of conversations, the radiated power of the cell phone can be reduced to as little as one sixteenth of its current level. That's because the phone will only have to transmit its message to the next handset.

**Communications Democracy.** Intensive cooperation is now underway in another communications technology that's similar to the ad hoc principle in its basic features: peer-to-peer communication (P2P). This concept became popular a few years ago with the emergence of Internet file-sharing services, in which music files, for instance, are sent from one computer to another without detours through central servers. “Peer” refers to an individual computer or user. At present, P2P accounts for over half the traffic on the Internet — a huge burden on broadband connections

— because each request spreads like an avalanche across data lines until finally, purely by chance, it hits a computer somewhere that has the desired file stored on it. It's entirely possible that the request will cross oceans and continents even when the computer being sought is in the house next door.

With a view to resolving this problem, researchers at Siemens are developing processes that structure data traffic. In a project called PeerThings, information is spread among thousands of peer computers. To achieve this, each piece of information, such

*A simulated P2P network connected 1.5 million users without using central servers.*

as a music recording, is automatically converted into a numerical value. Each computer in the P2P community is in turn responsible for a certain section of the number. For example, a piece of music with the ordinal number “60,000” would be stored on a computer that manages values between 50,000 and 65,000. If a user sends a query into the Internet, the search focuses specifically on the corresponding numerical value. “Of course, such a system works only if users' computers are connected to the Internet,” says Dr. Markus Böhm, PeerThings Project Manager, who is with Siemens Communications. But considering that a growing number of users already pay flat rates for their connections, and are thus always online, a system of this kind makes sense.

The underlying technology for this is the Resource Management Framework invented and refined three years ago by a team led by Alan Southall and Steffen Rusitschka of Siemens Corporate Technology. This is a software framework containing the computational rules for managing and operating the P2P database. The team used this framework to develop a system mature enough to be used in an application. In the course of this work, TUM engineers from Jörg Eberspächer's group simulated the framework. The results were promising. The system worked with as

many as 1.5 million participants. What's more, it remained stable even though users were online only about one hour on average, because data was present at multiple locations. Eberspächer has faith in this global network of knowledge. “I think the most important thing in the future won't be that we'll know where we can find information, but simply that it will become available to us in the shortest possible time,” he says. His vision is the fusion of ad hoc and P2P technologies. One of his favorite examples is the search for a taxi in a major city. In the future, it might be enough to simply press a button and send a request from cell phone to cell phone through a “multihop” ad hoc network to the nearest peer — and that person could be the taxi driver around the corner. ■ *Tim Schröder*

## BRIDGE FOR NEW PARTNERSHIPS

**Working together to foster talent and innovation** is a top priority for Siemens and the Technical University of Munich (TUM). That's why both parties have been running the Center for Knowledge Interchange (CKI) since 2001. “The CKI merges the practical experiences of researchers at Siemens with the scientific expertise of their TUM colleagues,” explains Martin Zibler, who manages the CKI for the TUM. It provides professional contacts for both sides and ensures that cooperative agreements can be implemented without a lot of bureaucratic red tape. Since the terms and conditions are clarified in principle, only a few agreements are required for the start of a new cooperative project. “Naturally, the CKI also opens up career prospects for young researchers engaged in joint projects — particularly for those with entrepreneurial spirit who can combine technological expertise with business sense,” says Prof. Hubertus von Dewitz, Siemens CKI Manager. Over the course of the last two years, the CKI has overseen more than 50 projects. For further information, visit: [www.tum.de/cki](http://www.tum.de/cki)

