



CAN YOUR CAR

HOW DID WE EVER GET ALONG WITHOUT GPS TECHNOLOGY – THAT COAXING VOICE AND SMALL SCREEN THAT DIRECT US TO OUR DESTINATION WHILE DRIVING? WHAT WAS ONCE AN EXOTIC GADGET IS NOW A NECESSITY, LIKE THE CELLPHONE.

TALK TO MY PHONE?

And if the work of NJIT Associate Professor Cristian Borcea is an accurate social barometer, we've seen only the beginning of our interconnection with computers, wireless communications devices, and billions of sensors spanning locations from cars and the pavement to home appliances and even our bodies.

Translated into one real-world driving scenario, Borcea says that “Integration of these technologies could automatically alert us to an accident miles ahead, sense congestion and tell us how much to slow down for safety, and place calls to people at work letting them know how late we’ll be for a meeting.”

Recipient of the university’s 2009 Excellence in Teaching Award for Graduate Instruction, Borcea is a member of the Department of Computer Science. The scenario he envisions on the highway reflects extensive research into mobile and ubiquitous computing, ad hoc and sensor networks, and distributed systems. His efforts complement work on other aspects of wireless technology carried out by NJIT’s Center for Wireless Communications and Signal Processing Research and the Department of Electrical and Computer Engineering.

INFORMATION EVERYWHERE

A primary reason why such an experience behind the wheel could become reality is that small sensors with the requisite capabilities are proliferating at an amazing rate. They are already present in every car – for example, accelerometers to trigger airbags upon impact and many more to monitor the engine and other onboard systems. Looking ahead, Borcea suggests that “appropriately designed wireless sensors could be distributed along the road to monitor the speed of vehicles and the volume of traffic, leading to the creation of ‘intelligent’ roads.”

Wireless sensors could ultimately be embedded everywhere.

A parking meter could let you know that a space is available on the next block. A bridge, sensing metal fatigue, could signal that repairs are necessary. At home, your refrigerator may call to remind you to pick up a quart of milk – knowing to place the call because it can no longer detect the minute wireless identification tag embedded in the milk carton.

Concurrently, in just a few years, cellphones have become devices that do much more than allow us to talk. “We still like to use the term ‘phone’ for want of a better name,” Borcea says. “It’s handy, maybe easier than saying ‘smart phone.’ But the devices we carry around these days do a great deal more. For instance, they include GPS and allow us to connect with the Internet at any time, no matter where we happen to be. Many people envision that the phone will become the personal computer of the future.”

Our communications devices are thus becoming repositories of information about who we contact, what we read, where we shop, what restaurants we like. Today, millions upon millions of “phones” are digital warehouses for vast amounts of information about many millions of people.



Associate Professor Cristian Borcea

PHOTO: JOHN MICALE

utility of this information by enabling multitudes of such devices to interact as needed, or as requested by users.

It’s a multi-faceted challenge that Borcea has also addressed in collaboration with NJIT colleagues Associate Professor Quentin Jones, Assistant Professor Guiling Wang, and with the help of graduate students. Their work has received substantial funding from the National Science Foundation.

COORDINATED COMMUNICATION

One part of the connectivity challenge is creating and managing ad hoc networks. With information gathered and stored by so many different devices in so many places,

Borcea and others in the field foresee services that are not based on central servers. Rather, they would be provided through coordinated communication among numerous devices as needed and authorized, in an ad hoc manner.

Borcea explains, “Among the innovations required are new and sophisticated ‘middleware’ programs to manage the underlying layers of software and hardware. That’s in addition to ensuring effective and reliable wireless communication under widely varying environmental conditions, and meeting the power demands of numerous distributed sensors.”

In the scenario described earlier, the road has to talk to your car, and your car has to talk to other cars as well as to your cellphone – at exactly the time when this inclusive interaction is essential. The software systems and network elements involved are heterogeneous, mobile, and distributed over wide areas. There are constraints of bandwidth and memory, as well as of power. Accordingly, Borcea states, “Substantial system and networking research will be necessary to build applications that are robust and able to adapt quickly to changing operational contexts. This means real-world testing on a large scale.”

It also seems that wireless communications devices are never beyond reach. One recent TV commercial for wireless phones opens with a young man waking up to his cellphone alarm as the voiceover says, “It’s the first thing you use in the morning and the last thing you see at night.” Perhaps that’s not much of an exaggeration given the number of people who no longer have landline service and appear never to turn their phones off.

As a January 31 article in *The New York Times* put it, “The cellphone is a constant companion – immediate and intimate, always there to inform, remind and prompt.” The article, “Smart Dust? Not Quite, but We’re Getting There,” described the fast-shrinking size of sensors, their fast-growing capabilities, and the potential of merging these capabilities with wireless communications technology.

THE CHALLENGE OF CONNECTING

Although cellphones, computers and a wide variety of distributed sensors represent a huge pool of information, it’s a reservoir whose true collective usefulness has yet to be tapped. The challenge is to realize and maximize the

THE CONVERGENCE OF COMPUTING, COMMUNICATIONS AND SENSING COULD ALSO HAVE POSITIVE SOCIAL IMPLICATIONS THAT ARE, LITERALLY, GLOBAL.

HARVESTING SOCIAL KNOWLEDGE

Borcea's work at NJIT may automatically bring you and friends together, silence your cellphone at the start of an important meeting, or help medical professionals save your life. Each time we call or text, surf the Internet, tweet on Twitter, or visit the universe of Facebook friends, we make a social statement about ourselves. This encompasses numerous facets of life – our location at the moment, who our friends and professional associates are, political inclinations, leisure interests, favorite foods, products for which we've been shopping. It's a digital portrait that grows ever more comprehensive and nuanced.

The straightforward goal of research into the complex technical issues involved is to enrich the social utility of mobile electronic interaction. This would combine the GPS-based locational awareness of mobile communications devices with continually evolving portraits of individual users and groups of users.

While driving past a mall, you could be alerted to a sale on a product whose price you've recently checked online. In an unfamiliar city, prompted by your social profile, it would be possible for a wireless service to inform you of an interesting movie or museum exhibit. "Conceivably, your movements in the workplace could be tracked to indicate that you've entered the office of a manager," Borcea says. "Doing so would then automatically silence your cellphone – an application that I think many people would welcome."

Services that network "trusted users" might tell you when friends are nearby, or that people you don't yet know at a large gathering share interests similar to yours. A hungry group discussing where to eat could ask for suggestions about nearby restaurants likely to please the majority – based on "social knowledge" collected about each person over time. These and comparable applications will depend on capturing social and location information for large user communities, underpinning

the development of what Borcea refers to as "geo-social recommendation services."

THE BEST SAFEGUARDS POSSIBLE

The technical aspects of achieving the interconnection envisioned are many and complex. But equally significant are the social considerations of personal privacy, identity protection, and even physical safety. An increasing number of individuals and groups are intent on breaching the security of software systems at every level. Awareness of the possibility of international "cyber attacks" on financial institutions, power grids, industrial plants and defense installations has risen to the point where such intrusions are viewed as threats to the security of the entire country.

Those who design and deliver services must therefore build the best safeguards possible into their products, and remain on high alert with respect to security. "Every service must give users the greatest degree of protection, and genuine control over how and with whom personal information is shared," Borcea emphasizes.

Some question whether the benefits of digital socializing, or being notified that a favorite brand of clothing is on sale, is worth even the slightest risk of unauthorized access to personal data. The past decade's explosive growth of wireless communications and Internet commerce would seem to offer a clear answer – that we do want to be linked electronically.

While the business models for newer services such as social media are still evolving, there can be little doubt about their appeal and economic potential. The longer historical view also underscores that if a technological advance appears feasible and its benefits are broadly attractive in daily life, it will be attempted, despite introducing new risks as well. It is clearly necessary to guard against identity theft and other negative aspects of digital interaction. But it is also necessary to weigh the great benefits – as we have done with using electricity, driving and flying.

Tweeting and friending aside, it is hard to dispute the value of applications that increase safety on the road as mentioned, and truly enhance our well-being in other ways, even if they require storing and allowing access to very personal information. For example, Borcea says, "A sensor monitoring a person's heart could warn a doctor of a condition requiring immediate care through that individual's phone, with the doctor authorized to check medical records stored in the phone. If needed, first responders could be dispatched to assist the person, guided by the phone's GPS position."

A GLOBAL PORTRAIT

The convergence of computing, communications and sensing could also have positive social implications that are, literally, global. The same *New York Times* article that spoke wryly about the intimate relationship we seem to have with our cellphones described how phones might include minute sensors designed for a definitely beneficial purpose. They could monitor and measure temperature, air quality, and other environmental parameters.

Using phones equipped with such sensors would involve people in automatically gathering this information throughout the day. It's possible that there may eventually be billions of these information sources, all contributing to databases that become increasingly valid as they grow. Collecting personal travel and location data has the potential to assess how individual activities impact the environment in different parts of the world. Recording exposure to pollutants would be valuable for medical research.

The technology that one day helps us locate a friend in a crowd could engage us to a much greater extent with the global community in very important ways. ■

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