Special Report

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Applications for wireless technologies continue to expand, even as bandwidth becomes limited, into areas far beyond traditional communications systems.

WIRELESS EXTEND FAR

Wireless technology was once synonymous with cellular communications and the portable telephone. But just as cellular networks and cell phones have evolved over the years, so too have the myriad applications for wireless technologies, with wireless connections being made from the shortest distances to the highest frequencies. Wireless equipment suppliers are now faced with requirements that can essentially include frequencies from DC through the millimeter-wave range, with communications distances ranging from less than an inch to back and forth between satellites. Over the next decade, it appears that wireless technology will only continue to expand into a variety of different markets.

1. Prototype devices working at 28 GHz are designed to increase the data rates of next-generation wireless cellular systems. [Photo courtesy of Samsung (www.samsung.com).]

Cellular communications systems are in the thick of ongoing buildups based on fourth-generation (4G) Long-Term-Evolution (LTE) equipment and technology. Nevertheless, such companies as Intel Corp. (www.intel.com) are already promoting the expected capabilities of fifth-generation (5G) cellular networks, even if those networks are not expected until 2020 or later. As the use and ownership of mobile/wireless devices continues to increase, the demands for wireless network bandwidth grow, with available bandwidth quickly consumed by voice traffic and wireless data.

Service providers working with 4G LTE capabilities are exploring the benefits of smaller cell sites and what are being known as heterogeneous networks (HetNets). These are combinations of Wi-Fi stations, cell towers, and smaller cell sites. (See the sidebar, "Building Base Stations For Use In Homes.")

Intel's interest in 5G wireless networks is quite logical, given the number of opportunities for the company's microprocessor chips represented by 5G products. Intel has claimed to have invested at least $3 million so far in support of wireless research towards 5G technologies at more than 10 universities. Intel is also working in partnership with Verizon on wireless research for 5G, under the auspices of Intel Labs and the Intel Strategic Research Alliance (ISRA).

Another company with strong belief in the potential for 5G cellular communications, Samsung (www.samsung.com), has already prototyped portable wireless devices working at 28 GHz. The firm has demonstrated error-free data rates to 256 Mb/s and data rates with minimal error to as high as 512 Mb/s *(Fig. 1)*. These data rates are considerably higher than the theoretical maximum of 75 Mb/s possible with 4G LTE technology, and Samsung claims that its wireless technology can support data rates in excess of 1 Gb/s over distances to 2 km. The tradeoff for such high-frequency signals is high atmospheric attenuation and limited transmission range, although these prototype tests have been demonstrated over distances as great as 200 m without line of sight and with moving transmitters and receivers.

Samsung's technology, which is sometimes referred to as "millimeter-wave cellular" communications, involves sophisticated beam-forming techniques: Some 64 antennas are used in both the transmitter and receiver, with rapid switching among the antennas. The antennas are switched in a matter of milliseconds as a handset moves, so as to acquire the best signal for the environmental conditions. Of course, one of the challenges inherent to this unique approach is finding some means of fitting 64 antennas into a mobile wireless device.

An emerging, rapidly growing segment of wireless technology is in the area of near-field-communications (NFC) applications. This is essentially the use of wireless technology to exchange different types of information—such as telephone numbers, personal files, or payment information—across a

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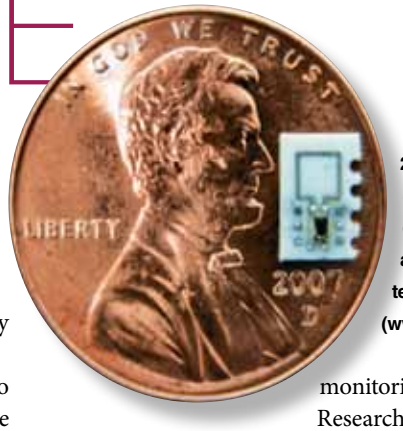
short distance, as between mobile telephones or other wireless devices. The technology is centered on the 13.56-MHz frequency of radio-frequency-identification (RFID) devices and data rates to about 424 kb/s at distances to a few inches. The technology is supported by the NFC Forum (www.nfc-forum.org), a non-profit industry association started in 2004 by Nokia, NXP, and Sony.

Wireless technology is expected to expand significantly into medical areas for a number of different applications. These include remote monitoring of patients, fast access of medical data for medical professionals, and tracking dementia patients by means of Global-Positioning-System (GPS) devices. Combining wireless communications with the growing number of sensors used for health applications makes it possible for a doctor to remotely check on a patient.

Some of the growing number of wireless solutions for healthcare applications are expected to fall under the category of "machine-to-machine" (M2M) applications. These are applications in which remote sensors may be communicating via the Internet and with wireless technologies with automated monitoring stations.



2. Implantable in-body medical devices draw power from external EM fields operating at about 1 GHz. [Photo courtesy of Stanford University (www.stanford.edu).]

Research being performed as part of the WISERBAN project (www.wiserban.eu) seeks to improve the state of electronic body implants (such as pacemakers) with improved communications capabilities, lower power consumption, and reduced size. The project is focused on the miniaturization of wireless body-area-network (WBAN) devices, applying a number of different technologies, including RF/microwave and microelectromechanical-systems (MEMS) devices. So far, the organization has succeeded in combining these technologies into the fabrication of a low-power radio measuring just 4 x 4 x 1 mm. It combines MEMS and CMOS integrated-circuit (IC) technologies to save size and power.

BUILDING BASE STATIONS FOR USE IN HOMES

QUALCOMM (www.qualcomm.com) has long been an innovator in wireless/cellular communications technology. Now, the company has proposed an idea for extending the cellular communications infrastructure inside the home. Earlier this year, Qualcomm Chief Technology Officer Matt Grob unveiled a cellular base station small enough to fit within a set-top box.

In fact, Qualcomm is experimenting with a number of these prototype miniature cellular base stations in and around its San Diego, CA office headquarters, with the intent of replacing more traditional cell-phone towers. Cellular subscribers traveling through the area are unaware of the lack of cell-phone towers, since their smartphones hop quickly among the many small base stations and they are provided with excellent service. But this is just a start, notes Grob: "Our next step is to do a larger test, with a network operator and an infrastructure vendor."

Engineers at Qualcomm have estimated that providing cellular network coverage through such an "in-home" fashion will be less expensive than erecting additional conventional cellular towers, provided that home wireless services users do not see a loss in performance (such as in Internet access speed). Although some current service providers offer small cellular base stations for personal use, Grob says that any expansion of the cellular infrastructure in this way should be done with the knowledge of the consumers—if they purchase a small home cellular station that will be part of the public infrastructure, that capability should be made clear beforehand.

In the United States, The Federal Communications Commission (FCC) has already set aside spectrum in the band from 2.36 to 2.40 GHz for the use of WBAN devices. By employing such devices in hospitals, clinics, and doctors' offices, the hope is to eliminate the clutter of cables currently used to operate devices for patient monitoring.

In addition to refining software in support of these WBAN devices, WISERBAN has developed system-on-chip (SoC) devices that integrate MEMS devices, radio circuitry, and digital-signal-processing (DSP) circuitry on a single silicon die. WISERBAN has also created miniature antenna prototypes capable of covering the entire 2.4-GHz frequency band. The organization has also developed a dedicated protocol stack for low-power communication with body-sensor networks.

Stanford University (www.stanford.edu) has also been active in researching emerging wireless technologies for healthcare applications. Stanford Assistant Professor Ada Poon has developed self-propelled, wirelessly powered medical devices capable of controlled motion through blood and other bodily fluids. The medical devices can be implanted or injected into the human body and powered wirelessly, by means of an applied electromagnetic (EM) field. These devices could potentially be used to travel through the bloodstream to deliver drugs, provide analyses, and remove plaque from arteries.

Implantable medical devices have traditionally been challenged by their need for power, from batteries, which limited how small the devices could be made. These new devices draw power from an EM field and can be made extremely small without batteries *(Fig. 2)*. Poon's work required a rethinking of how human tissue responds to EM energy, with her modeling tissue as a low-loss dielectric material. She was able to use a higher frequency, at 1 GHz, for powering the implanted devices, and use smaller antennas for them. mw