Smart phones: the next embedded interface

By Warren Webb, Technical Editor -- 1/6/2005
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AT A GLANCE

- Replacing the user interface of an embedded design with an off-the-shelf smart phone may significantly reduce the development effort.
- Designers can choose short-range Bluetooth and 802.11 networks or longer range cellular data transmission for smart-phone interaction.
- Drop-in Web server or transceiver modules offer device OEMs an easy way to upgrade embedded devices to smart-phone operation.

With excess computing power, built-in programmable graphics, and multiple communications options, smart cellular phones provide a convenient and capable mobile user interface for many of the growing multitude of intelligent embedded devices. A few clicks on a portable smart phone can directly connect a user to security systems, industrial controllers, access-control systems, medical devices, environmental controls, and home-automation systems, and a smart phone can even replace the array of remote controls in most living rooms. For example, a production supervisor might receive a smart-phone e-mail alert at home directly from an ailing factory-automation device. Without returning to work, he could then bring up the device's remote-control panel on his smart phone to query operating parameters, make adjustments, or activate self-test programs. He could even connect to and control other systems in the same factory using the same handheld device. With custom application software, a smart phone can also emulate the look and feel of many proprietary products and provide a user experience that mimics a built-in embedded hardware interface.

The ultimate goal of a pervasive-computing interface is to provide contextual and transparent interaction, so that users will not realize they are dealing with a computer. Facial recognition, iris identification, voice recognition, and fingerprint analysis are a few of the available technologies to identify users with little or no effort. Other experimental user sensors, such as eye-tracking, lip-reading, or hand-motion analysis may also provide future noncontact inputs to embedded products. Similarly, global positioning systems and video-signal processing can deliver precise position-location information. Although some forms of these technologies are already available, they are not sufficiently advanced for embedded-system applications, and most of today's systems still require a user interface for data input and information display.

Although embedded-system designers can integrate a built-in keyboard/display, a dedicated wireless interface terminal, or a remote networked PC for a user interface, smart phones provide a capable, off-the-shelf alternative that deserves consideration. Although performance and features vary widely, a "smart phone" is routinely defined as a convergence device that includes a cellular telephone, programmable information-management features, and Internet access. Anand Chandrasekher, vice president and general manager of Intel's Mobile Platforms Group says, "More than half a billion cellular handsets were sold in 2003, and the smart-phone segment, which combines application processors and communications, is a sweet spot in the industry—with a compounded annual growth rate of about 100%."

A portable-smart-phone interface allows users immediate access to multiple embedded devices and allows designers to reduce product cost, size, and complexity. Depending on the capabilities of the embedded system and the phone, they can exchange wireless data over short-range technologies, such as infrared or Bluetooth; medium-range 802.11 networks; and long-range cellular systems. Smart-phone software, which includes built-in data-communications and custom graphics, can also be remotely updated to repair bugs, change characteristics, or incorporate new features. With an Internet connection, a smart handset interface may also have access to remote servers to display large data items, such as user manuals, hardware schematics, training videos, or troubleshooting information.

Cell networks

Most smart phones operate on CDMA (code-division multiple access) or GSM (Global System for Mobile communications) cellular networks. With CDMA, the transmission frequencies are determined by a spread-spectrum hopping code, and only a receiver following the same set of frequencies can detect it. In addition to voice services, most operators provide CDMA circuit-switched data connections at 14.4 kbps or high-speed packet-data services at up to 307 kbps. GPRS (General Packet Radio Service), another packet-switched service, allows devices to send and receive data over the worldwide GSM communications voice network. GSM uses a variation of TDMA (time-division multiple access) and operates in the 900-, 1800-, or 1900-MHz frequency bands. GPRS offers as much as 171 kbps, depending on the network availability, channel-coding scheme, and terminal capability. Most cellular technologies have a third-generation evolution path to extend data rates for high-bandwidth applications.

Smart phones are available in multiple form factors from almost every handset manufacturer, operate over every cellular network, and employ a variety of operating systems. Although this diversity allows users to select the exact performance that they want, it creates integration headaches for embedded-system designers. For example, smart phones are on the market with varying versions of Symbian, Palm, Linux, Blackberry, Microsoft, and proprietary operating systems running on multiple processors. "The leading smart-phone operating system is Symbian, accounting for nearly four-fifths of 2Q04 worldwide shipments," says Gartner Research analyst Ben Wood. "Symbian will remain dominant for some time, though rival operating systems are starting to gain momentum," predicts Wood. Although some products are available to ease the problems, each operating system requires different software-development and -maintenance tools. From the enterprise-information-technology point of view, smart phones are remote computers that require software installation, hardware maintenance, and periodic updates. To simplify the support task, many organizations restrict smart-phone users to a common carrier and often a single handset model.

To take advantage of a smart-phone interface, designers must integrate communications hardware and software into the embedded device and possibly develop a mobile application for the handset. One of the simplest techniques is to add an off-the-shelf Web-server module to incorporate Internet connectivity and device management at the same time. Many of these small Web servers are drop-in boards that provide a serial interface to an embedded product on one end and an Ethernet interface on the other. The Web server contains all of the networking software, leaving the designer free to concentrate on the embedded-system application. The one-square-inch SitePlayer from NetMedia is a plug-in Web server (**Figure 1**). Users can create smart-phone-compatible Web pages using standard authoring tools and download them to the SitePlayer over the Internet. A $100 developer kit includes a host board with LEDs and switches, a temperature sensor, and a SitePlayer module. The kit also includes sample software and a library of graphical knobs, switches, LEDs, and other user-interface tools to aid in Web-page development. An interactive Web page tailored to the small smart-phone graphical display lets designers create an embedded user interface with no special software in the handset.

Bluetooth beam

Many newer smart phones offer built-in Bluetooth transceivers to wirelessly link to nearby devices, such as headsets, automotive hands-free hardware, GPS modules, other smart phones, and PCs for synchronization. The Bluetooth specification defines a number of profiles that define user scenarios and improve interoperability between manufacturers' products. The serial-device port profile interests embedded-system designers, because it emulates a serial-cable connection between two peer devices. With a range of about 10m and data rates as high as 128 kbps, a virtual serial port provides plenty of performance for user-interface applications. The Bluetooth Special Interest Group recently announced Version 2.0, with increased data rates and lower power consumption for scenarios such as streaming CD-quality audio, digital-image transfer, and laser printing. Although IEEE 802.11 Wi-Fi transceivers would provide a longer range connection, some cellular carriers are hesitant to include the capability, because a voice-over-IP connection could bypass their per-minute charges.

Nokia bases its 7710 smart phone, which features Bluetooth technology and has a 65,536-color, 640×320-pixel landscape touchscreen display, on the latest Symbian Series 90 operating system (**Figure 2**). The device includes an integrated 1152×864-pixel camera, a voice recorder, a video player, an FM radio, an Opera Internet browser, an MP3 music player, information-manager applications, and document viewers. E-mail features include SMTP, POP3, IMAP4, and APOP. Although the handset includes no hardware keypad, an on-screen keyboard and handwriting recognition provides convenient user input. The user can access a portion of the internal RAM and expand it with a plug-in multimedia memory card. At around $600, the Nokia 7710 works on GSM networks in the 900-, 1800-, or 1900-MHz bands.

With thousands of compatible third-party applications developed for the Palm Pilot, the recently introduced Treo 650 from PalmOne combines all the features of the popular PDA plus Internet access, e-mail, and a GSM or CDMA cellular connection (**Figure 3**). Admitting a fascination with science fiction, Rob Haitani, PalmOne product architect for the Treo and the original Palm user interface says, "When we designed the first Treo smart phone, it had a form factor similar to the communicators in the original *Star Trek* television series. Later, a speakerphone mode allowed you to stand there and talk into it like Captain Kirk." Powered by an 312-MHz Intel PXA270 processor, the Treo 650 runs Version 5.4 of Palm's operating system. The unit also includes Bluetooth technology; a Qwerty keyboard; an MP3 player; a VGA digital camera; and a 16-bit, 320×320-pixel color display. An integral Secure Digital I/O slot allows plug-in memory modules to 2 Gbytes plus expansion peripherals, such as bar-code readers or GPS sensors. The Treo 650 costs $600 and features a removable, rechargeable, lithium-ion battery providing more than five hours of talk time and two weeks of standby time.

A new smart phone from Audiovox runs the Microsoft Windows Mobile Pocket PC Phone 2003 Second Edition operating system and features a 3.5-in., 240×320-pixel, color transflective display with screen rotation; Bluetooth capability; a VGA camera; and a 1490-mAhr lithium-polymer battery (**Figure 4**). A Qwerty keyboard forms the rear of the device and slides down when needed for data entry. A 400-MHz Intel PXA263 Xscale processor with 128 Mbytes of RAM and 64 Mbytes of ROM make up the computer section, offered on the Sprint dual-band PCS 800- and 1900-MHz CDMA network. The Audiovox PPC-6601 sells for about $630.

Phone code

Microsoft bases both of its platforms for smart-phone development on Windows CE. The Pocket PC Phone edition is compatible with the large library of Microsoft and third-party applications written for Pocket PC PDAs, and the newer Microsoft Smartphone platform targets cell-phone-centric projects. Due to the rapid convergence of phones and PDAs, Microsoft plans to combine these platforms under the Windows Mobile moniker. In the meantime, there is a rather confusing array of tools for smart-phone-application development. The Microsoft eMbedded Visual Tools 3.0 tool kit includes an integrated development environment with everything necessary to develop software for the original PocketPC platforms. The tool kit is completely stand-alone and does not require Microsoft's Visual Studio. Designers can develop programs in Visual C++ 3.0 (**Figure 5**) for Pocket PC or Smartphone 2002 devices, however, the equivalent 2003 devices require eMbedded Visual C++ 4.0. Eventually, Visual Studio.NET will be the development platform for all Windows Mobile-based devices. A detailed overview of Microsoft's tools, tutorials, and sample applications is available at the Windows Mobile Developer's center (www.microsoft.com/windowsmobile/developers).

Although Palm operating-system-development tools are more mature than offerings from any other smart-phone-software supplier, the recent company split has created some confusion among new developers. PalmOne is the hardware spin-off of Palm; PalmSource maintains the Palm operating systems and works with third-party developers. However, both company Web sites offer developer information and tools. The unofficial standard development tool for the Palm OS is the Metrowerks CodeWarrior Development Studio. The latest release, Version 9.0, provides a drag-and-drop form designer, multiple-processor C and C++ compilers, project wizards, a debugger, and a Palm OS 5 software-development kit. The CodeWarrior Development Studio for Palm OS costs $399 and is available from MetroWerks' Web site.

Several third-party tool developers offer application-development software to simplify the porting of applications across multiple smart-phone handsets. For example, AppForge offers Crossfire, an add-on to Microsoft's C#, VB.NET, or Visual Basic 6.0 to simplify development of applications that run on all the leading Palm OS, Symbian, and Windows Mobile devices. Designers create Crossfire applications using specialized mobile controls, libraries, and modules that plug directly into the Visual Studio IDE. AppForge ships Crossfire with more than 30 standard controls, as well as modules and libraries for database synchronization, bar-code scanning, communications, and telephony. Crossfire applications require that a runtime client be resident on each mobile device. Gary Warren, Chairman and CEO of AppForge says, "Crossfire transforms Microsoft's C# and Visual Basic languages into a true cross-platform development environment, allowing our customers to develop and deploy applications to more than 300 mobile devices in the world, regardless of operating system." AppForge Crossfire cost $1000 per developer seat plus $25 for each runtime client.

Smart phones have the necessary performance to provide users with a convenient and portable interface for the growing number of computerized devices in our environment. These converged mobile handsets can download data to local storage, run custom applications, and wirelessly interact with multiple products. This convenience, along with overall project cost savings, should entice designers to consider a smart phone as the user interface for their next embedded design.

You can reach Technical Editor Warren Webb at 1-858-513-3713, fax 1-858-486-3646, e-mail wwebb@edn.com.

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