The Personal Server

By Roy Want and Trevor Pering, Intel Research

A radical computer design supporting the digital media revolution.

There is little argument that the age of digital media is in full swing. In that vein, society, over the last two decades has experienced a revolution in the way media is represented. The first major change was the move from LPs to CDs (640 MB). Now, digital pictures are replacing film. And, typical DVDs (4.7 GB with 4 times that capacity just around the corner) are rapidly making VHS tapes history.

A parallel is occurring in rewritable digital storage as well. Magnetic disks have been doubling in density every year since 1960, and solid-state flash memory doubles approximately every two years, well in line with Moore's Law. Today it is possible to buy a commercial 4 GB CompactFlash card, which occupies about 1 square inch and is capable of storing 4,000 minutes of MP3 coded music.

Now that rewriteable storage has caught up with the capacities of read-only optical disk technologies, the opportunity presents itself for mobile computers to acquire, store and play back large caches of digital media along with more conventional documents, spreadsheets, and presentations. Small devices will soon have the capacity to store an entire working set of documents and entertainment media in a form factor that comfortably fits into a person's pocket. However, while storage density has undergone dramatic improvements, there are other technologies employed by mobile devices that are limiting this potential.

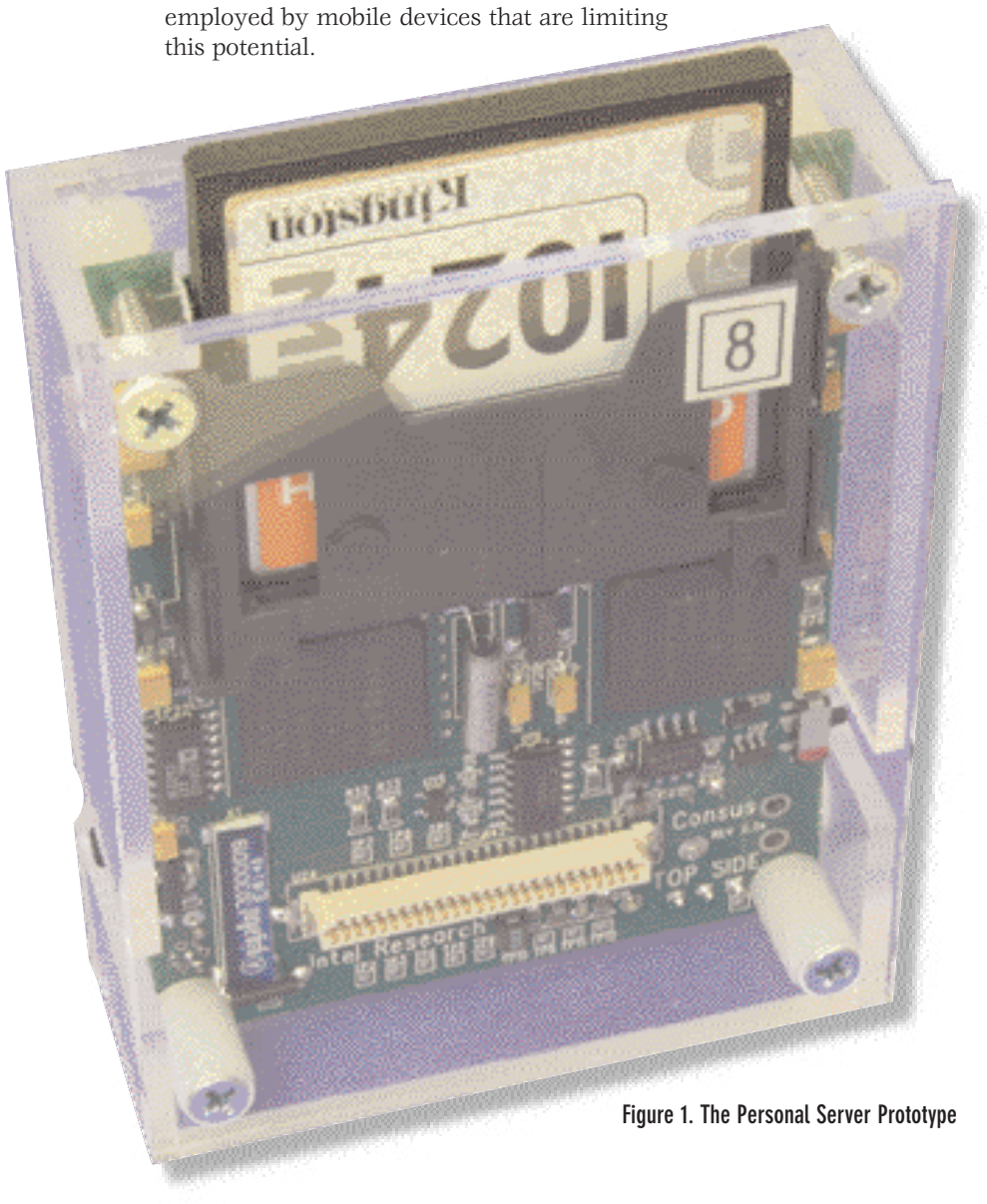

Figure 1. The Personal Server Prototype

and fingers can make use of them. For example, a modern PDA is a remarkable feat of engineering, but the small color display is not very useful for drafting a large document or preparing a PowerPoint presentation. For these applications, the PC laptop computer is needed — not because the processor is more capable, but because the I/O devices are well suited. Thus, further reduction in the size of a storage component may not be realized in the device carrying it.

Computers on a Personal Level

Separating personal digital content from the device we use to view it, is gaining traction. Such an approach could make it possible to build a considerably smaller and more personal computers, since the user would not have to carry the larger I/O components with them.

The wireless standards that have evolved since the late 90s, Wi-Fi and Bluetooth, have opened up an opportunity in this space. In the hard interconnect space, fiber optic technology and the hardware behind it has provided the platform for untethered wireless freedom. With these innovations, a mobile device need not have its own display and keyboard. Instead, it can reach out via wireless network to interact with other computers found in the locality, and use the displays of these other computers. The text, graphics, and digital media that would normally appear on the mobile device screen would be wirelessly projected onto a nearby PC desktop or notebook computer. The media could also be projected onto other wirelessly enabled peripherals such as audio headsets, or even PDAs when the applications are suitable for handheld access.

Given the explosive rate of PC adoption in the home, at work, and in numerous public settings, this approach leverages the abundance of displays which already exist in our surroundings rather than requiring people to carry displays with them. It removes the burden of size and weight typically associated with supporting an integral high-quality display and an ergonomic keyboard. The Personal Server (see Figure 1) is a research project at Intel that sets out to explore this novel architecture.

The Personal Server is well suited to the needs of people "on the go," both for business and personal entertainment, in comparison to most mobile products today. The device is designed to be small, currently about the size of a deck of cards. In the future it is expected to be integrated into a small cell phone, taking advantage of a footprint and application that is already mainstreamed. The device contains a high-density digital storage card, wireless connectivity based on Wi-Fi and Bluetooth, and a high performance processor. Notably, it contains no appreciable display and has no keyboard.

The Personal Server is designed to be accessed through other computers. When near a PC that is Personal Server aware, it simply shows up as a new icon on the PC desktop (see Figure 2). If clicked, this icon opens up to a window and presents the contents of the device in a familiar graphic form. Data can be copied to the Personal Server by dragging existing files onto the window, and data can be transferred from the Personal Server to the PC by dragging objects from the window to the host desktop.

An even richer experience can be obtained by accessing the device through a Web browser. Since the Personal Server supports a Web server, it allows documents and media to be organized in a pleasing graphical and hyperlinked format. The user can effectively navigate to the required material using the familiar "WWW" interface. Furthermore, applications hosted on the mobile device can be accessed through the web interface, utilizing the full graphics rendering capability of the local desktop system.

Bandwidth Issues

One of the difficulties of using a wireless device to support multimedia data is that the wireless bandwidth available is generally less than that provided by a cable network. A large file may take several minutes to copy over, and a full-length video considerably more. If the basic HTTP protocol is used to transmit the file incrementally, a media file will appear jittery, starting and stopping as chunks of data are received and played. The Internet has solved these problems by using media

and played. The Internet has solved these problems by using media streaming protocols, such as RTSP (real time streaming protocol) to break up the large data files, dynamically adjusting the buffers and dropping frames when necessary. The Personal Server prototype is frequently used to show video clips that are tens of megabytes long. RSTP allows for the smooth playback of the real-time media. The only obvious observation is that with RTSP typically takes a couple of seconds before the media smoothly begins to play.

Server Architectures and Wireless Wonders

In order to support file sharing, HTTP Web access, and streaming, the Personal Server runs three core, open source software servers: Samba for file shares, Apache for the Web, and Darwin for streaming media. Linux was chosen as the operating system for our current prototype, enabling fast development with a wealth of tools and applications available through the open source community.

The combination of Wi-Fi and Bluetooth provides an excellent mix of capabilities. Bluetooth has been used extensively in the Personal Server prototypes because of its low-power usage while idle and its low-cost implementation. The Bluetooth discovery mechanism on a PC is employed to periodically discover any Personal Servers that are nearby.

While Bluetooth provides sufficient bandwidth for many applications, there are other applications that need the higher data rates provided by Wi-Fi. Since the Personal Server supports both technologies, and assuming the local PC does too, it is possible to switch to Wi-Fi when applications demand high bandwidth, then switch back to Bluetooth when the demand decreases. Based on the peak throughput of Bluetooth, this crossover point is about 500 kb/s.

This process leverages the superior bandwidth capabilities of Wi-Fi without incurring the full impact of its power drain, which is about five times that of Bluetooth. In addition, Wi-Fi has no low-power discovery mechanism, whereas Bluetooth was designed explicitly to operate in a cell phone, without significantly impacting the battery life. It can listen for wireless discoveries at less that 2 mW. In essence, the Personal Server model uses Bluetooth discovery to enable, on average, low-power Wi-Fi operation.

Both Bluetooth and Wi-Fi use sophisticated discovery mechanisms and TCP/IP networking, and thus support the usual range of Internet protocols without any special modifications. However, this alone does not allow a PC to discover the Web and streaming services of a newly discovered Personal Server. A UPnP (Universal Plug & Play) broadcast is made periodically by our prototype that is picked up by a UPnP control point running in the PC (available with Microsoft Windows XP). The broadcast contains an URL that points back at the Web server on the device. If a user visits Network Places found on the Microsoft standard desktop, the Personal Server will show up by name, and on selection can launch a Web browser that shows the contents of the Personal Server Web site. Files and streaming media can be accessed without special configuration of the PC. However, if a more user friendly interface is required to make the initial connection, the Web site provides a "bootstrap link" that if selected can download our own Neighborhood Manager program to the PC. A convenient icon in the task bar can report Personal Servers that are nearby and allow direct connections to be made to their wireless Web servers.

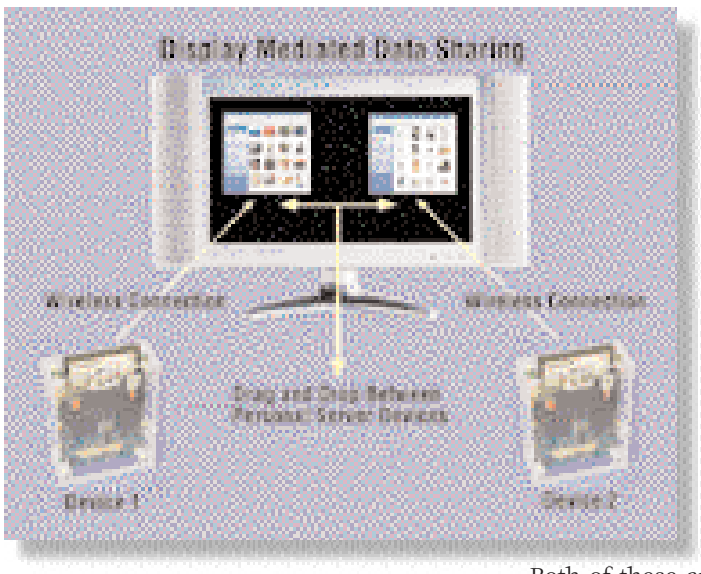

Figure 2. Using a large display to facilitate peer-to-peer data sharing.

Applications and Usage Models

Using the capabilities described here, Personal Servers could easily enable access to static items such as documents or presentation files. It could also offer real time streaming-media applications, being pushed by aggregators and IP content providers. Audio could be wirelessly streamed to nearby computers or a wireless headset, and movies could be stored and viewed over a wireless link. As the industry moves closer to the integration of the home PC and the home entertainment center (TV and stereo), new products that link the two are now being tested in the marketplace.

One cutting-edge direction for the Personal Server is the enhanced model that allows people to bring their media with them when visiting friends or family, and to use their host's home entertainment systems to share the media. In that direction, there are two promising commercial developments that could be useful for enabling a Personal Server to be used more effectively in the home. They are:

- The Digital Media Adapter (DMA), that allows the PC in your den to be wirelessly connected (or with wired Ethernet) to the TV in your living room via a set-top box.
- The PC Media-Center, an augmented PC that sits alongside the typical stack of home HiFi components.

Both these devices are currently commercially available in various forms. In fact, at the Consumer Electronics Show (CES) 2004 in Las Vegas, one manufacturer showed a PC form factor that looked very much like a standard 17" enclosure for a DVD player. Several others showed set-top boxes that would interface with their owner's PC.

Both of these approaches use a traditional IR remote control device. Using this device, the user can sit on the couch and select media which has been stored on a local or remote PC, and play it on the familiar home TV. Assuming a wireless capability in the home, this is yet another place where the Personal Server can tap into today's large, high-quality displays and sound systems, which far exceed the experience that could be achieved with a small mobile device.

An alternative approach to the Personal Server would be to store a person's content on a server on the Internet and retrieve this content on demand — wirelessly or through wired ISP connections — at the user's current location, wherever that may be. However, the logistics of this approach are storage intensive and expensive to implement. Even if this approach becomes viable at some point in the future, these two issues combined are likely to remain expensive. Given the plummeting cost of storage, it is more likely people will choose to load their portable devices with most of the media they'll need, perhaps only resorting to wireless Internet access for the latest email or stock quotes.

Perhaps, A Typical Scenario

To appreciate the possibilities of this technology, consider a situation in which one might like to listen to music throughout the day. The sequence of events might be as follows:

At home, one selects a sequence of albums, CDs, DVDs, tapes, MP3s, or other source using menus provided by the DMA device, attached to the TV. The music begins playing through your stereo speakers, sourced from the Personal Server in the user's pocket. Then the "follow-me" feature is activated, which tells the Personal Server to find the best device available in the locality to continue playing your music. As one takes the trip in a car, the augmented car radio is discovered and music is streamed to it from your Personal Server. While walking from the car to the shopping mall, one turns on the wireless headset and the audio stream is rerouted to the headset. As the day continues and one reaches the office, the music continues to play quietly through your PC speakers (until you really get down to serious work).

Personal Data Sharing

A significant benefit of using a Personal Server is in the application area of personal data sharing. Most portable PDA devices have the ability to transfer data files between them, but it is generally complicated to do because tiny menus need to be navigated. In the Personal Server model, a large display can provide an interaction point for several Personal Servers at once, providing a window into each one independently. Files (represented as graphical icons) can be transferred from Personal Server to desktop by dragging and dropping, and can also be transferred to the window of another Personal Server, thus initiating a transfer between the two (see Figure 2). Because this is accomplished on a large high-quality display, a user-initiated transfer of this kind is both fast and intuitive, and thus supports peer-to-peer activities that conventional mobile devices perform poorly.

The Future

The Personal Server opens up new possibilities and products that are expected to change the way we think about mobility. It draws on the capabilities being enabled by the myriad of wireless, flash-memory, and processor products. Combining emerging wireless network standards such as Bluetooth and Wi-Fi can implement ubiquitous connectivity without compromising battery life or available bandwidth.

Utilizing this basic wireless capability, personal content, stored on a user's mobile device, can be viewed on displays found in the environment — without having to carry a display. Based on many technologies that already exist, this new model of media access is not that far around the corner and may soon find its way to a TV set-top box near you!

Appendix 10

Technical specifications of the current Intel personal server model

- Intel® XScale™ PXA255 (400 MHz) processor
- 64MB SDRAM
- 64MB Intel® Strata Flash Memory
- 2 C-Flash slots (Wi-Fi™ & High Capacity Memory card fitted for PS operation)
- Bluetooth™ Radio (onboard)
- 1 USB Master, 1 USB slave
- Status LED
- Ethernet daughter card
- Battery operation from 920 mAhr (4.5hrs for continuous operation)

References

A version of the hardware can be obtained commercially from Crossbow:
http://www.xbow.com/Products/productsdetails.aspx?sid=85
The Stargate Compatible Linux release for this board can be downloaded from Sourceforge at: http://sourceforge.net/projects/platformx