

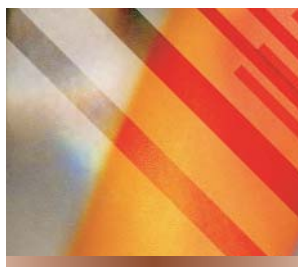
# Creating and Protecting Digital Worlds

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Over the past year, mobile storage capacities have skyrocketed as prices have plummeted. CompactFlash (CF) memory cards that store one gigabyte are now available for about the cost of a 128-Mbyte card one year ago. Tiny rotating media is keeping up: Hitachi is boosting the capacity of its Microdrive, used in the iPod Mini, from 4 to 10 Gbytes. Larger-format 2.5-inch notebook hard drives can now store up to 100 Gbytes.

The exponential growth in flash and disk storage is likely to continue for several years as manufacturers digitally encode more types of media and demand increasingly compact formats. For example, Secure Digital flash-memory cards, which now store up to two Gbytes, will hold eight times as much data by 2009, while the capacity of 2.5-inch magnetic disks will soar from 80 to 500 Gbytes.

One use for such large mobile storage capacity is to help deal with information overload. In today's fast-paced world, people don't have time to process the overwhelming amount of content available on TV, the radio, the Web, and other media sources. Mobile devices with high memory capacity can personalize and filter media streams in the same way that personal video recorders (PVRs) such as TiVo make it possible to manage hundreds of cable and satellite TV channels.



**Users can now personalize large collections of digital data and access it in real time.**

These technical achievements highlight the ongoing "invisible computing" revolution that is enabling people, for the first time, to use large amounts of digital data in their everyday activities. Mobile devices are becoming smarter and less reliant on wireless communication, giving users real-time access to an entire digital world.

However, as the industry approaches miniature mobile storage devices that can hold 1,000 songs or a 2-Mbyte snapshot from every minute in a day, the danger of losing that world also increases, necessitating simpler and more reliable backup solutions.

## PERSONAL DIGITAL VIDEO

In 2004, numerous portable media players (PMPs) hit the market including the 20-Gbyte Creative Zen Portable Media Center, Samsung's Yepp YH-999 Portable Media Center, the iRiver PMC-140 series (available in 20- and 40-Gbyte versions), and the 80-Gbyte Archos AV480 Pocket Video Recorder.

At this year's International Consumer

Electronics Show (CES), manufacturers displayed PMPs like the one shown in Figure 1 that are a step beyond portable DVD players because they can connect to a PC or set-top box and download content for later viewing. The most powerful of these pocket-sized devices can store up to 320 hours of movies, TV programming, or home video.

In the next decade, the availability of vast storage capacity could significantly change the way we use PMPs. Instead of specifying which TV programs, movies, and so on to store, users will store content that has general interest for them, and then use

video-search software to find exactly what they want. For example, if a user enters "Lord Sainsbury of Turville" in the blinkx search engine ([www.blinkx.tv](http://www.blinkx.tv)), it will select digitized TV clips and cue them up to the point where they mention the British Minister for Science and Innovation.

Simple video-search engines can extract information from the program guide such as a show's title, description, cast, and credits. They can also work at a deeper level by extracting text-based keywords from closed-caption transcripts or using an audio-mining system that processes speech into a stream of text and then indexes the text with references to the original audio track.

Looking further into the future, PMPs could become proactive. For example, after you purchase a tour package from an online travel service, your PMP could extract information from your notebook's Web browser and present a series of Travel Channel clips corresponding to your itinerary. A future PMP might likewise notice



**Figure 1.** Portable media players can store hundreds of hours of video.

that your digital wallet receipt includes a purchase of Portland cement and then prepare a do-it-yourself masonry video using clips from *This Old House* and other shows.

Massive video storage capacity enables users to personalize a large media collection and access it in real time. With no network connection to backend servers, latency is low and availability is high. With the push of a button, a user can fast-forward to specific entertainment or educational content.

### PERSONAL DIGITAL AUDIO

Portable music players use solid-state flash memory to store from tens to hundreds of hours of MP3, Windows Media Audio (WMA), Advanced Audio Coding, and other digital music files. For example, the 1-Gbyte version of the palm-size SanDisk Digital Audio Player can store up to 32 hours of audio—roughly equivalent to 480 songs—in 64-kbps WMA format. Within the next few years, the availability of 32-Gbyte flash memory will allow such devices to store more than 10 days' worth of audio content.

With so much storage, manufacturers are looking for new ways to flow media into devices. A recent feature

appearing in portable music players is an FM tuner with a record mode to capture fresh content. Although FM is not very high fidelity, music capture of digital radio is also at hand: The Delphi MyFi stores five hours of high-quality XM Satellite Radio content without a computer download.

A new digital radio format is appearing in automobiles and could have a huge impact on recordable music players. With high-definition radio, AM and FM station owners can broadcast digital-CD-quality audio using the existing infrastructure and spectrum in a way that coexists with analog signals. Unlike XM Satellite Radio and Sirius Satellite Radio, which charge a subscription fee, HD radio is free for consumers who have purchased receivers from select manufacturers.

Digital radio transmits song title, artist, and other meta-information using standards such as ID3 ([www.id3.org](http://www.id3.org)). This stream of descriptive data makes it feasible to record particular audio content—for example all the Beatles songs, traffic reports, or BBC news—over the course of a day, offering the same time-shifting capability for audio that PVRs provide for video. Moreover, many of the features of personalized Internet radio will soon

be available on wireless Internet radio devices.

However, the future of unprotected digital radio remains in doubt. The Recording Industry Association of America has submitted a brief to the US Federal Communications Commission arguing that consumers should be able to record digital broadcasts for later playback but not split a broadcast into individual songs.

### CREATING A DIGITAL WORLD

The ability to store large collections of digital video and audio as well as other data and access it anytime, anywhere has emerged as a killer application. As portable device storage capacity increases, so will the diversity of things the devices can store and their utility.

Table 1 shows the size of various types of media ([www.sims.berkeley.edu/research/projects/how-much-info-2003/execsum.htm#stored](http://www.sims.berkeley.edu/research/projects/how-much-info-2003/execsum.htm#stored)), which begs the question, how much is enough?

Ideally, users would like to combine entertainment content with personal data. Today, advances in mobile solid-state and magnetic storage capacity are enabling portable devices to store not only video and music, but all types of digital data.

Following the same downward price trends as CF cards, Universal Serial Bus (USB) flash memory sticks have become ubiquitous in the past five years. In addition to backing up spreadsheets, presentations, and other business data, these devices, with storage capacities exceeding one gigabyte, serve as a readily available archive of contacts, documents, photos, music files, e-mail, Web bookmarks, and other personal information that mobile professionals can access serendipitously as opportunities arise.

If you use a typical 50-Gbyte notebook for mobile computing, you won't need to delete any content for the machine's lifetime. In addition, when it's time to upgrade in three to five years, you'll be able to transfer all of the old data, which will occupy a fraction of

the new laptop's advertised capacity.

As personal collections of digital data grow, users are finding it increasingly difficult to manually organize this information on their computer. As one partial response to this problem, Google, Yahoo, and Microsoft are adapting their popular search-engine technologies for all PC content. For example, with Google's Desktop Search (<http://desktop.google.com>), users can search the full text of viewed Web pages, e-mail, chats, and document files in various formats, updating information continuously.

Declining media prices are providing new opportunities for value-added services based on digital content. For example, manufacturers could preload read/write disks or flash-memory cards with gigabytes of compelling content. In the case of audio and video, this would avoid the long delays and costs associated with downloading files from a network—particularly for mobile devices that only have access to low-bandwidth cellular connections.

Developers could use well-known cryptographic techniques to protect copyrighted media. To access this content, a user could simply purchase the appropriate cipher key to decrypt specific files. In addition, to prevent burdening users with undesirable preloaded information, a simple profile describing personal preferences could determine which encrypted data to write over.

## PROTECTING YOUR DIGITAL WORLD

As mobile devices gain the capacity to store entire digital worlds, the danger of losing all that information in a single disk crash also grows. Ironically, the very technology that makes it possible to create that world can fail catastrophically, causing it to disappear in an instant.

Although most users recognize the importance of backing up data, many computing systems remain vulnerable to this kind of calamity. One reason for this is the increasing reliability of disk drives over the past 15 years. A combi-

nation of various safety features, small size, and low head mass has made today's disk drives less susceptible to damage when dropped or exposed to sudden acceleration. Further, disk-drive failure rates are just low enough to lull users into a false sense of security.

This problem is becoming more critical with exponential increases in disk capacity. Not only can you lose more information than ever before, but it takes longer to backup the system, strengthening the psychological barrier to do nothing about it.

Solutions abound—the challenge is finding one that suits you and being disciplined enough to use it on a regular basis. Organizations with well-administered computer systems typically make tape backups at night, but for home computing, most people rely on various disk-based technologies.

This was once the domain of floppy disks, which writeable CD-ROMs have replaced. However, it takes more than 78 640-Mbyte CD-ROMs to back up a fully loaded 50-Gbyte drive. Reasonably priced writeable 4.7-Gbyte DVDs have been available for a couple of years, but creating these disks remains a long, monotonous process.

Not to worry—more optical disk capacity is on the way. The latest double-layer Blu-ray Disc format ([www.blu-ray.com](http://www.blu-ray.com)) holds 50 Gbytes of data, offering 10 times more storage than a standard DVD—the right ballpark for notebook computers. However, this new technology is expensive, and by the time it drops to an affordable price, notebook disks will have moved up the exponential memory density curve.

A popular alternative to the relatively safe optical disk backup solution is an external (but conventional) disk drive connected either by a USB 2.0 or FireWire cable. It's highly unlikely that both disks will crash simultaneously, and if so, one would probably survive. In addition, external drives are available for less than \$1 per gigabyte that let users initiate a backup by simply pressing a button on the side.

By combining ease of use with a

**Table 1. How much media is enough?**

Media	Size
Typewritten page	5 Kbytes
Low-resolution photo	100 Kbytes
Short novel	1 Mbyte
Minute of MP3 audio	1 Mbyte
High-resolution photo	2 Mbytes
Minute of high-fidelity sound	10 Mbytes
Hour of standard-definition video	2 Gbyte
Hour of high-definition video	10 Gbytes
10,000 songs in 128-Kbps AAC format	40 Gbytes
Library floor of academic journals	100 Gbytes
Academic research library	2 Tbytes
US Library of Congress print collections	10 Tbytes

pragmatic 300-Gbyte capacity, external disk drives currently offer the most attractive solution to the problem of protecting mobile digital worlds.

**S**torage density for hard disks has been outpacing Moore's law for some time, with density approximately doubling every year. A palm-size computer can now store large quantities of digital video, audio, and data, making a digital world readily available to mobile users.

At the 2005 CES, a bewildering array of personal media devices were on display. Currently, MP3 and photo-slideshow players rule, but in a few years, full PMP capability will be available on even the smallest devices. However, with more to lose than ever before, backing up data will be a necessity, not an option. ■

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## Invisible Computing

