Storing Your Life

Consumer Digital Storage—Personal, Shared, Hierarchical and Virtual

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Outline

• Drivers for Digital Storage in the Home
• The Consumer Electronics Storage Hierarchy
• New and Emerging Digital Storage Applications
• Intelligence in CE Storage Devices
• Connecting Everything in the Home and Home Virtualization
• Conclusions
Drivers for Storage in the Home
The Cosmic Wheel of Storage Karma

Content Creation
Content Editing
Content Archiving
Content Distribution
Content Reception
Consumer Storage Mark-up Through the Retail Distribution Chain

Hard Disk $50.00 → CE Device HDD Value $65.00

30% Markup

Distributor

HDD Value $84.50 → Retailer HDD Value $109.85

30% Markup

Retailer

30% Markup

Consumer MSRP $199.99

$199.99/220% = $90.90 BOM Cost

$50.00/$90.90 = HDD is 55% of BOM

(1.30 X 1.30 X 1.30) = 220%
# Storage and streaming bandwidth for music and video formats

<table>
<thead>
<tr>
<th>Format</th>
<th>Bandwidth (Mbps)</th>
<th>Storage Capacity/Hour (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MUSIC FORMATS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP3</td>
<td>~0.128</td>
<td>~0.057</td>
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<tr>
<td>CD Quality</td>
<td>1.400</td>
<td>0.630</td>
</tr>
<tr>
<td>DVD Audio</td>
<td>9.600 (max)</td>
<td>4.320</td>
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<tr>
<td><strong>VIDEO FORMATS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iPod (MPEG-4)</td>
<td>~0.750</td>
<td>~0.337</td>
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<tr>
<td>DVD (MPEG-2)</td>
<td>11.080</td>
<td>2.700</td>
</tr>
<tr>
<td>SD TV</td>
<td>~8.000</td>
<td>~2.000</td>
</tr>
<tr>
<td>HD TV</td>
<td>~19.300</td>
<td>~8.890</td>
</tr>
<tr>
<td>Blu-ray Disc</td>
<td>36.550</td>
<td>~12.500</td>
</tr>
<tr>
<td>Ultra-HDTV (8K X 4K)</td>
<td>~195.000</td>
<td>~133.000</td>
</tr>
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</table>
• Consumer Survey on Digital Storage in Consumer Electronics (Coughlin Associates, 2008)

• Assume 100 M American Households, each with an average of 11.8 TB of storage
• This is 1.8 B TB of storage or 1,800 Exabytes of storage in US households by 2014
• Of this amount ~26 Exabytes are user generated content
Drivers of Consumer Digital Storage

- Ease of content viewing/capture/creation: Being built into many modern consumer devices e.g. cameras, digital recorders—
- Growth of User Generated Content (UGC)
- Content Sharing: Easy to multiple digital content 1,000 or more through on-line sharing.
- New methods of creating metadata automatically so content can be used easier.
- New ways to share and coordinate data around the home.
- Multitasking

IEEE Spectrum, 10/09
## Estimated growth of personal and commercial content in CE devices

(storage units in exabytes)

<table>
<thead>
<tr>
<th>Year</th>
<th>Commercial Content</th>
<th>Self Generated Personal Content</th>
<th>Shared Personal Content</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>2007</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>17</td>
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<tr>
<td>2008</td>
<td>16</td>
<td>13</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>2009</td>
<td>30</td>
<td>24</td>
<td>1</td>
<td>55</td>
</tr>
<tr>
<td>2010</td>
<td>48</td>
<td>35</td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>2011</td>
<td>69</td>
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<td>7</td>
<td>189</td>
</tr>
<tr>
<td>2012</td>
<td>93</td>
<td>274</td>
<td>17</td>
<td>384</td>
</tr>
<tr>
<td>2013</td>
<td>120</td>
<td>603</td>
<td>39</td>
<td>762</td>
</tr>
<tr>
<td>2014</td>
<td>150</td>
<td>1,279</td>
<td>88</td>
<td>1,517</td>
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<tr>
<td>2015</td>
<td>184</td>
<td>2,664</td>
<td>194</td>
<td>3,041</td>
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*Digital Storage in Consumer Electronics*, Thomas Coughlin, Newnes, March 2008
Exabytes Shipped for Consumer (OPTICAL DISK, HDD AND FLASH MEMORY)

- By 2014 about 900 Exabytes of storage shipped annually for CE applications

Digital Storage in Consumer Electronics 2009
(Coughlin Associates)

<table>
<thead>
<tr>
<th>Year</th>
<th>ODD</th>
<th>HDD</th>
<th>NAND</th>
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<tr>
<td>2006</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2007</td>
<td>17</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>2008</td>
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<td>58</td>
<td>21</td>
</tr>
<tr>
<td>2011</td>
<td>113</td>
<td>96</td>
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<tr>
<td>2012</td>
<td>170</td>
<td>162</td>
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<tr>
<td>2013</td>
<td>190</td>
<td>262</td>
<td>138</td>
</tr>
<tr>
<td>2014</td>
<td>200</td>
<td>427</td>
<td>274</td>
</tr>
</tbody>
</table>
Threats to long-term assets

- Large-scale disaster
- Human error
- Media faults

- Component faults
- Economic faults
- Attack
- Organizational faults

Long-term content suffers from more threats than short-term content

- Media/hardware obsolescence
- Software/format obsolescence
- Lost context/metadata

Sam Fineberg, HP, Digital Forgetfulness, SV 2010
© 2010 Coughlin Associates
The CE Storage Hierarchy
Storage Devices Used in CE

- Hard disk drives
  - Capacity drives (SATA)
- Optical Discs
  - CD, DVD, Blu-ray
- Flash Memory
  - Card formats
  - SSDs
Hard Disk Drives

Toshiba

Seagate

Fujitsu
HDD Advances

- 1.5 TB 2.5-inch drive introduced by Seagate (not notebook format)
- Toshiba introduced a 320 GB 1.8-inch drive
- Hitachi, Seagate, Western Digital and Samsung producing 3 TB 3.5-inch drives (over 4 TB in 2011?)
External Storage and Backup

Clickfree Backup

Wireless USB Drive

HP Media Server, V2

iVDR external storage

Plug Computer: Any storage device becomes networked storage

© 2010 Coughlin Associates
Flash Memory

Sandisk Ducati

Corsair

Inexpensive PCs

SanDisk

Intel Z-P140

Samsung

© 2010 Coughlin Associates
Increasing Flash Storage Density

• Line width reductions with semiconductor process development

• Multi-level cells increase storage capacity
  – However wear out faster with MLCs by a factor of 10X per doubling of per cell capacity
  – Smart flash controllers with wear leveling can hide most of this wear from the user (gradual degradation rather than catastrophic failure)

• Flash can also be stacked allowing denser volumetric storage
Higher Capacity, Higher Speed SD Cards

- In 2009 the SD card association announced the SDHC format (up to 2 TB and 300 MB/s)
- In 2010 Toshiba was showing product
- CE Devices using this available by 2011
Flash Memory for Content Distribution

- Optical discs are disappearing from laptop computers—content distribution on-line or with flash devices such as USB drives or cards
- Will flash memory displace optical media for physical content distribution?
Symbiotic Relationship Flash and HDDS

- Almost all consumer flash applications require HDDs
  - Music and video players
  - Cameras
- Consumer flash applications have created greater demand for HDDs
  - Downloads
  - Uploading photos and videos
  - Backup of Consumer Content

White Paper: Flash and HDD: Symbiosis or Survival of the Fittest? (Coughlin Associates & Objective Analysis)
Dual Drive and Hybrid HDD Approaches

• Dual Drive/Storage Tiering
  – Marvell HyperHDD
  – Hitachi-LG HyDrive
  – Intel dual drive
  – Other companies potential dual storage products

• Hybrid solid state HDD
  – Seagate Momentus XT
Hybrid Flash Memory/HDD
(Seagate’s Momentus XT)

SYSmark 2007 Testing

- Adaptive Memory™
  - Algorithms monitor data access transactions
  - Qualified data is placed in the SSD
  - Maintains frequently used data vs. not used data
- Dynamically improves response time and application load times based on usage
- Customizes system performance to the user
- Maximizes the performance and minimizes the amount required

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Optical Discs
Developments in Blu-ray Package Media

Blu-ray Developed by Panasonic, Sony, Philips, Fox, Disney ...

First BD-LIVE
Blu-ray BD-LIVE Player (Profile 2.0) 2008
First BonusView
Blu-ray BonusView Player (Profile 1.1) 2007
Best Picture Quality Fantastic 4 Silver Surfer

BD-LIVE Concept 2008
Best Concept Alien vs Predator

BD+ Copy Protection 2007
Best Interactive Pirates/Caribbean III

Direct Digital Encode 2007
Best Blu-ray Title Pirates/Caribbean II

AVC (MPEG4 HP) Interactive 2006
The Hollywood Reporter

Format Launch
Best CE Company Blu-ray Development

Panasonic Blu-ray R&D
High Value Added Products

Key Component OEM Products

Infrastructure

Slim Drive
HD Home Theater
AVC HD
Pro Systems

Mobile

Media
HH Drive

Devices

Disc manufacturing spin coat methods
MPEG-4 AVC encoder
Blu-ray Java authoring

Content protection

Panasonic ideas for life
Optical Disc Storage Development

Maxell Writable Blu-ray Media

Ritek Writable Blu-ray Media

• 100 GB Blu-ray Disc with SuperRENS
• Holographic storage: 1 TB/disc (???)
New and Emerging Digital Storage Applications
Technology Enablers

• Longer lasting batteries, easier recharging or power sources, e.g. as fuel cells
  – Microprojectors (even HD content)
  – Constant connectivity
  – Continuous content capture

• Lower power and flexible displays
  – Use products longer and in more places

• More immersive experiences (displays, sound and other senses)
  – Drives demand for richer content—which requires greater storage capacity (and greater bandwidth requirements)

• Greater access to data both locally and on-line
  – Larger (or smaller) built-in storage
  – More content from the cloud
  – Faster direct attached interfaces and internet BW (such as USB 3.0)
Media Content Size Trends

Data Rate (Mbps)

Multimedia Object Size

- One page ASCII text
- CD Quality Stereo Audio
- DVD Movie (MPEG-2)
- HD Movie
- Ultra HD Movie
- Virtual Reality, 3D Movie

© 2010 Coughlin Associates
Driving Factors—Mobility and Video

Mobile Bandwidth

- 1G 1983
- 2G 1991
- 3G 2001
- 4G 2009 (LTE)
- 5G ~2017

Kbps

Minimum Bandwidth

Maximum Bandwidth

Video Bandwidth

- 4K2K
- 1080p
- 720p
- 1080i
- 480p
- SD

Streaming Bandwidth (Mbps)

2010 Designcon Keynote, Vincent Hu, Altera
Metadata

• Metadata--information about a file or data object that allows easier search and use of the content

• Currently most metadata is entered manually

• Automated generation of metadata using content robots and sensors

• With inexpensive storage, metadata could become unlimited,
Metadata Layer Model

- We need a consumer metadata standard that obeys 4 criteria:
  - Flexible
  - Scalable
  - Upgradable
  - Simple
- Plus something that can also integrate the professional standards

T. M. Coughlin and S. L. Linfoot, a Novel Taxonomy for Consumer Metadata, Presented at 2010 ICCE Conference

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Our children will be capturing their lives on digital storage

- My kids text their friends all the time.
- They also send pictures to each other
- They watch YouTube Videos
- It’s only a matter of time before we have the technology for them to record what they do every day
- When it is available I know that they will use it and share their daily experiences
- This will use a lot of storage and combined with other user generated and commercial content will result in petabyte homes in the next decade
Total Recall!

**VIEVU PVR-PRO 2**
- Enhanced low light
- Improved resolution
- 4 hours of recording
- 4 GB memory
- Waterproof
- $399.95

**PEN VIDEO CAMERA FOR FUN, TO SPY, TO WRITE!**
A pen with all the works. Why stop at writing, when you can record, replay and reuse? Leave the load at home. The MP9 is the latest in pen camera technology that offers all the benefits of a pen without carrying a camcorder around. Fully functional, portable, and well priced, the pen camera does not weigh down your pocket or your wallet.

- **1GB** $24.99
- **2GB** $29.99
- **4GB** $34.99
- **8GB** $39.99

Add to cart

**Capacity (GB)**

- Commercial Content Capacity
- Personal Content Capacity

Publish Date
September 2009
Everything a Recording Device
Personal Cloud Storage

• Much of the content consumers will access in the future will come from the Internet and other remote sources (the Cloud)
  – According to In-Stat by 2014 US On-Demand Revenues will be greater than $10 B
• Some of this content will stay on the cloud with access through streaming or temporary buffering
• Many consumer devices are play only and are limited on local storage—these rely on cloud storage
• Other consumer devices create content—e.g. cameras and thus require larger local storage (User Generated Content--UGC)
• Some of this UGC may end up in the cloud but how much and would this really be the only copy?
Intelligence in CE Storage Devices
Putting Applications on Storage Devices

• For many applications the digital storage device is highest cost items in the BOM
• Many CE applications are reaching a level of maturity that they could be implemented as a sequence of standard command calls in the hard drive electronics
• Reduced cost of CE products by eliminating second circuit board and integrating product test into drive test

Modern hard disk drive printed circuit assemblies (PCAs) are much smaller, typically occupying only a fraction of one side of a 3.5-inch hard disk drive.
Example of Applications on a Hard Disk Drive

- Disk Drive SoC (CPU, Elec. Channel, ECC, Servo and Interface Control)
- Motor and VCM Control Electronics
- Analog Application Electronics (Antenna Interface, Display Driver and Human Interface)
- Flash Memory and Proprietary PMP Program (Possible 2nd CPU, CE Interface)
- Other Electronics and Drive Connections

Give designers new ways to improve performance and save money!
Home Virtualization: Connecting and Managing Everything in the Home
Home Storage Utility

- Things won’t look like they do now
- Everything will be connected
- Content and storage will be shared and there will be many copies—storage is cheap and capacities are large
- Content is managed, indexed and automatically backed up
Home storage virtualization (user freed from storage devices)

The home storage utility should provide the following basic functions:

- content backup and deduplication in the home
- content backup outside the home (in the cloud, to provide home disaster recovery)
- content sharing in and around the home with optimal use of network resources
- indexing and organizing home content
- synchronization of content as needed
- Automatic management and control of storage and network resources
In the next decade

• A terabyte in your pocket
• A petabyte in your home
• Exabytes in datacenters
• Zetabytes in the world
Conclusions

• The demand for storage for CE applications is very elastic—if people have more storage they will use it!
• The modern storage hierarchy is more complex than in the past and includes more storage options depending upon performance and storage economics.
• Digital storage enables new applications for mobile and home devices that should make managing, organizing, preserving and using content easier.
• With the growth in personal content and content sharing through social networking, the growth of digital storage for consumer applications is virtually unlimited.
• It remains to be seen what the ultimate balance of on-line vs. local storage will be in CE.
• Managing, organizing and protecting home content will lead to new concepts applied to virtualize and aggregate digital storage in the home.
Sources

- **Digital Storage in Consumer Electronics Report 2009**, Coughlin Associates
- **Consumer Survey on Digital Storage in Consumer Electronics 2008**, Coughlin Associates
- **2010 Digital Storage for Media and Entertainment Report**, Coughlin Associates
- Presentations at **2007, 2008 2009 and 2010 Storage Visions Conferences** ([www.storagevisions.com](http://www.storagevisions.com)) and CES

For more information go to the tech papers section of [www.tomcoughlin.com](http://www.tomcoughlin.com)
Thanks
Plug Computers

- Build networked computers into everything...
- www.plugcomputer.org
Capacity Scaling - Dual Drive

• What is Dual Drive?
  – Intel® Solid-State Drive (SSD) combined with a Hard Disk Drive (HDD)
  – Intel® SSD for performance
  – HDD for capacity

• Software Configuration
  – SSD: Operating System and key applications
  – HDD: General applications and user personal data

About 40 GB of flash is enough

Shahed Ameer, Intel, IDF 2010
USB 3.0