Storing Your Life Consumer Digital Storage— Personal, Shared, Hierarchical and Virtual **Thomas Coughlin Coughlin Associates** www.tomcoughlin.com



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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



 $(1.30 \times 1.30 \times 1.30) = 220\%$

\$199.99/220% = \$90.90 BOM Cost

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



Storage and streaming bandwidth for music and video formats

Format	Bandwidth (Mbps)	Storage Capacity/Hour (GB)	
MUSIC FORMATS			
MP3	~0.128	~0.057	
Loss-less Compressed	~0.700 min.	~0.315	
CD			
CD Quality	1.400	0.630	
DVD Audio	9.600 max.	4.320	
VIDEO FORMATS			
Format for iPOD	~0.750	~0.337	
(MPEG-4)			
DVD MPEG 2	11.080	2.700	
MPEG 4	~1.400	~0.630	
SDTV	~8.000	~2.000	
Blu Ray/HD DV D	36.550	3.750	
HDTV	~19.300	~8.890	
Ultra-HDTV	~295.000	~133.000	





Media Units vs. Storage Capacity for Various Resolution Photos, Music, and Video Files

- Here is storage required for various applications at various resolutions:
- A 4-megapixel photo viewer with 20,000 images needs 20 GB, 8-megapilxel needs 40 GB
- A 10,000 song MP3 player needs 40 GB, HiD (e.g. compressed DVD audio) needs 1.5 TB
- A 100 movie player at VGA resolution needs 70 GB, at DVD resolution need >400 GB
- A combination 20k 4-Mpixel photo, 10k MP3 song, 100 VGA movie player needs 130 GB
- A combination 20k 8-Mpixel photo, 10k HiD song, 100 DVD movie player needs 1.75 TB





Accumulated Digital Content Per Average Household



•Consumer Survey on Digital Storage in Consumer Electronics (Coughlin Associates, January 2008)

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Drivers of Consumer Digital Storage

- Ease of content 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.



Storage capacity for content sharing between interacting nodes (3 GB file, units in GB)

- Metcalfe's law:
 - "The value of a telecommunications network is proportional to the square of the number of users of the system (*n*2)."

• Reed's law:

 "Not only is a member connected to the entire network, but also to many significant subsets of the network. These subsets add value independent of either the individual or the network.

IFFF

Number of Nodes Participation Factor Metcalf Reed 10 0.2 3 3 100 0.05 30 78 1,000 0.007 63 360 10,000 0.0008 84 741 100,000 0.000085 96 1,058 1,000,000 1.506 0.000009 108 10,000,000 0.0000095 121 2,141 100.000.000 0.0000001 135 3,039

With sharing a 3 GB file can get multiplied by 1,000 X over the network



Estimated growth of personal and commercial content in CE devices

(storage units in exabytes)

Year	Commercial	Self Generated	Shared	Total
	Content	Personal	Personal	
		Content	Content	
2006	4	5	0	9
2007	8	9	0	17
2008	16	13	0	29
2009	30	24	1	55
2010	48	35	3	86
2011	69	113	7	189
2012	93	274	17	384
2013	120	603	39	762
2014	150	1,279	88	1,517
2015	184	2,664	194	3,041

Digital Storage in Consumer Electronics, Thomas Coughlin, Newnes, March 2008



Exabytes Shipped for Consumer (OPTICAL DISK, HDD AND FLASH MEMORY)







The CE Storage Hierarchy

Митрій Ивановичъ Менделъевъ

Traditional computer storage hierarchy

- Computer scientists often refer to the characteristics of various memory devices as constituting a *storage hierarchy*. The concept of a storage hierarchy allow sorting various memory products based on important attributes or characteristics for the applications for which they are to be used.
- This figure gives a typical example of a computer storage hierarchy based upon data access speed.





Mobile consumer electronics storage hierarchy



- In this figure we construct a mobile consumer electronic storage hierarchy
- We look at Flash, HDDs and optical storage as a function of importance performance and cost considerations





HDD Advances



- Hitachi introduced a 500 GB 2.5-inch drive, 320 GB in notebook form factor by several manufacturers
- Toshiba introduced a 160 GB 1.8-inch drive (Samsung announced)
- Hitachi, Seagate, Western Digital and Samsung producing 1 TB 3.5-inch drives
- In Mobile 2.5-inch HDDs in 2007
 - FDE drives with in-drive encryption (Trusted Computing Group)
 - Hybrid drives with non-volatile flash used for HDD write cache (Hybrid Drive Association)



HDDs in Consumer Applications



19

Flash Memory



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Samsung ²⁰

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 degredation rather than catastrophic failure)
- Flash can also be stacked allowing denser volumetric storage



Flash Memory in Consumer Applications



More synergy than competition between flash and HDDs

- Most of flash memory used in CE applications where content is first downloaded to HDDs and then "temporary" copy loaded on flash memory for playout
- Many flash memory applications such as digital cameras usually reuse the flash memory, downloading the captured content to HDDs
- Both commercial and personal content (such as photographs) are often backed up requiring even more HDD content



Comparison of price and storage capacity of flash memory and hard disk drives in mid-2007



24

Optical Disks





Optical Formats

The Winner!





Holographic Storage Professional Devices & Media

Archive for -Professional Video & Data Archive







DRIVE \$18,000 List Price

- 300 GB Capacity
- 20 MB/S; 160 Mbs Transfer Rate
- 250 ms worst case seek time
- Form factor W: 5.750" H: 4.875" L: 26"

MEDIA \$180 List Price

- Write once
- 130 mm disc
- 3 year shelf life (prior to recording)
- >50 year archive life
- No special handling required
- 5.25" X 6" X .25"

Proposed Roadmap:

300GB 20MB/s

800GB 80MB/s 1.6TB 120 MB/s



Optical Disk Drives in Consumer Applications





Roadmap to future automobile storage demand

- More integration of other functions into the electronics for navigation, entertainment, etc
- Once autonomous driving systems go into consumer transportation, riders will have time to do more than just watch the road while they drive
- Real-time traffic and road updates using a wireless network or radio system and a rewritable storage device such as a hard disk drive.
- Information on locations, commercial information on the area and other information automatically recorded in an automobile as it approached a destination



Power in CE devices

- In mobile devices power is a serious design parameter.
- New power options:
 - Fuel cells
 - Wireless charging
 - Power saving and caching
- Power brings a mobile device "POWER"
 - Personal projectors
 - Wireless communication
 - More time for capturing higher resolution content
 - Drives storage

More power = more storage!



Potentially power hungry personal projector (Novellus)



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Digital Video Recorder



Tivo DVR





Circuit Board of a Tivo DVR



Inside a Tivo DVR

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eSATA storage expansion box attached to an digital video recorder enabled set-top box.





DVR storage requirements over time (combination of internal and external storage)

Year	Internal Storage	External Storage	Comments
2006	40 GB	0	No valid ext. storage
			options
2010	80 GB	1 TB	Ext. storage options
			available
2014	160 GB	10 TB	Assumes able to retain
			considerable recorded
			programming
2018	320 GB	100 TB	Lots of stuff—some
			non-commercial
2024	640 GB	1 PB	Huge capacity
			anticipated

Digital Storage in Consumer Electronics, Thomas Coughlin, Newnes, March 2008



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,



Block diagram of personal memory assistant showing major component functions



Such a device could require 10 TB of storage capacity on-board!

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Life Log 2008



PVR-PRO WEARABLE VIDEO TECHNOLOGY

Have you ever felt like you were missing out on an event because you had to concentrate on filming?

Have you ever wanted to video record a meeting or interview?

Have you ever needed documentation of an important event?

MEET VIEVU.

We make WEARABLE personal video recording devices that allow you to capture all the details of your daily life while you concentrate on what's important. Consider it your own personal VIDEO DIARY.

- This device only has 4 GB of flash memory at present
- This device "wants" a high capacity hard drive so it can capture higher resolution content
- Plenty of room for evolution of these types of products



Affect of Personal Recording on Home Storage Demand





Personal Area Network Storage (PANS)



Seagate's DAVE

 A hard disk drivebased external storage device with wireless connectivity allows storage expansion, streaming and content aggregation





Digital Storage is a Signficant Fraction of Total Product Cost

Product	Capacity (GB)	Avg. Prod. Price (\$)	Est. Prod. Cost (\$)	Est. Cost of Storage (\$)	Ratio Storage & Prod. Cost	Туре
DVR	250	\$450	\$200	\$80	40%	HDD
Game System Ext. Storage	20	\$90	\$80	\$65	89%	HDD
Personal Video Player	60	\$390	\$195	\$130	67%	HDD
MP3 Player	4	\$240	\$190	\$140	74%	Flash
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USB-run software applications



- Flash memory devices are being created with greater intelligence and functional capability
- In essence a USB device is like a small portable computer
- Because a USB drive has its own CPU and a file system it is capable of performing applications
- USB application initiatives:
 - USB Flash Drive Alliance (UFDA)
 - **U3**



Flash Cache for HDDs

- Two approaches being promoted
 - Hybrid Drive or ReadyDrive with flash write cache in drive PCB
 - Robson or Turbo
 Cache with flash cache
 in motherboard
 - Maybe best combination of advantages of HDDs and flash memory





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44

Trusted Drives



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



Give designers new ways to improve performance and save money!



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Connecting Everything in the Home and Home Virtualization



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Typical Home in 2017 (**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 utility—home storage virtualization



The home storage utility should provide the following basic functions:

- content backup and deduplication in the home
- content backup outside the home (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





Conclusions



- The demand for storage for CE applications is very elastic—if they 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.
- Managing, organizing and protecting home content will lead to new concepts applied to virtualize and aggregate digital storage in the home.





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For more information go to the tech papers section of <u>www.tomcoughlin.com</u>



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