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THE STOREWIDTH PARADIGM

As all our readers know, the supreme force of industrial change in the coming era will be optical bandwidth. Petabits (10 to the 15th) per second of traffic will explode down the paths of light into…what? Windows? Smithereens? A new economy in the sky with diamonds, holograms, and transcendental trashcans along streets paved with IPO gold? To catch and cache the big bang of photonics and bring it to intelligent life on earth, the explosion of bandwidth requires a complement of "storewidth."

This new storage paradigm, now commanding between two and five percent of the market, will take it over during the next five years

The familiar Sun epigram, "the network is the computer" will not suffice unless the network morphs into a colossal storage system. Today the Internet contains a trove of 340 million web pages, growing at a pace of a million new pages a day. One famous portal, **Excite.com**, consumed 49 terabytes (10 to the 12th) of storage in less than two years, according to a report from Alex. Brown; **Amazon** (AMZN) consumed 42 TB in six months, and more recently **Mail.com** (MAIL) filled 28 TB in 45 days. Twenty eight terabytes approximates the total traffic per *month* on the entire Internet three years ago. Total storage attached to the net already sums up to the hundreds of petabytes; exabytes (10 to the 18th) are coming soon.

In This Issue:

Making all this possible so far is one of the most unexpected and least understood technological feats of the age. For the last decade, in a colossal upset, hard drive storage technology has improved at least 50 percent faster than computing power. As **Intel** (INTC) engineers increasingly confess, this differential may grow while wafer fabrication processes founder with feature sizes below .13 microns.

Metal oxide disk technology confronts no such limits. A miniscule spot on a magnetic or optical disk is simply easier to create than a transistor doing logic or tapping random access memory capacitors. Microprocessors are essentially two dimensional devices that have to be interconnected by labyrinthine patterns of microscopic wire. Magnetic domains that store a bit of data on a hard drive do not have to be interlinked at all, and can be inscribed on top of one another in three dimensions.

Horribly underestimating this electro-mechanical miracle in my book *Microcosm*, I confidently predicted that "cheap and dense non-volatile" silicon memories would displace disk drives. Instead the displacement is going in the other direction with tiny disk devices substituting for flash memories even in the narrow confines of smart cards and handheld computers. Applying microchip wafer fab tools to a technology with a greater number of relatively independent vectors of improvement, disk drive engineers follow a compound learning curve of accelerated disk rotation speeds and microchip Moore's Law advances. They are refining the magneto resistive drive heads that read the tiny magnetic domains. They are upgrading the digital signal processors that convert the analog disk's magnetic flux into readable digital bits. They are racing forward with integrated controllers for the motors that spin the disks and regulate the actuator arm.

Until recently the record setting drives in production have been Toshiba devices. The chief flawed product in Toshiba's storage operation is its American legal counsel that early this month persuaded it to give \$2.1 billion in a "glad handing" settlement–including \$147.5 million for their plaintiff pals–for alleged floppy disk controller problems not more significant than any one of the tens of thousands of bugs in Windows 2000 or any other complex computer product. If **Microsoft** (MSFT) executives think they are

The heads on IBM's drive fly 75 billionths of a meter above the surface, smaller than any critical dimension on the surface of a microchip

being molested by ignorant government anti-trust (and they are), just wait until they face the trial lawyer extortion racket. Perhaps Bill Gates will discover causes for his foundation more important than promoting depopulation of the Third World.

With Tosiba's storage operation crippled, **IBM** moves to the fore. It has announced a drive with an areal density of 35Gb/square inch, a 75 percent increase over the 20 billion bit milestone set by the company less than five months ago. IBM in June introduced a one inch diameter drive that holds 340MB at a cost of $1.47 per megabyte, about half the cost of rival silicon flash memory.

In these amazing devices, the read-write heads fly above the surface of the disk at a height of just 75 nanometers–75 billionths of a meter is smaller than any critical dimension on the surface of a microchip–while the disk rotates at a speed of 10 thousand rotations per minute (about 85 miles per hour). As has been observed, adapting for scale, this feat resembles the Concorde flying at mach speed a few inches above the surface of the ocean.

TI in overdrive

Crucial to these hard drive capabilities is our **Texas Instruments** (TXN), the market leader in controller chips for disk drives. Positioning the read write heads quickly and accurately over ever more densely packed bit-storing domains, TI's single chip solutions helped boost access time by about 30% per year (to about 5 milliseconds) and raised the data transfer rate some fourfold in just the past year to some 160MBps in **Quantum's** (HDD) latest 36GB model. The current serial data transfer rate into the computer is limited not by the disk drive but by the current 528Mbps pace set by silicon buffer memories that receive the data from the disk and pass it on to the processor or other device, such as a graphics card.

Enabled by TI and led by IBM and Toshiba, Quantum and **Seagate** (SEG), disk technology will continue to double its density every year while processor technology doubles its performance every two years. Over five years, disks should improve 32 fold while processors improve five fold. General purpose Pentiums no longer shape the future of information technology. The speed of light limit favors specialized distributed processors, doing their work on location, optimized for disk access, database search, and other thin client applications on the Net. The most common processors will become microcontrollers for disks.

The rapid gains in bandwidth and "storewidth"–compared to the slower advances in microprocessor MIPS–have radically changed the nature of computing. From an autonomous calculating engine commanding a few thousand bits of storage, computers have become teleputers or telestores indexing, searching, sorting, and managing hundreds of petabytes of heterogeneous files and other objects across the Net. On the net, the most striking successes have been Netscape**,** creator of a browser for access to remote (or nearby) storage, **Yahoo** (YHOO), creator of a storage based service and portal, **Inktomi** (INKT), supplier of a search engine used by portals, and **AOL** (AOL), chiefly a huge server farm and database.

Replay's TV killer

Beyond these stars on the user interface level, storage companies remain obscure. But the Internet will change this condition. It will be handling not merely HTML files but a huge variety of photographs, TV shows, documentaries, documents, catalog transactions, record albums, consulting services, video conferences, multimedia courtships, newspapers, virtual mall cruises, and full bore software applications, such as Sun MAJC and Star Office. It will accommodate the full marketing and sales, viewing and trialing process of a typical commercial transaction. These applications will require massive, heterogeneous, dynamic distributed storage systems that are as capacious as today's centralized mainframe systems and as flexible as the World Wide Web.

Precursors include **Replay** and **TVO** which are in the business of enabling automated management and time shifting of TV programs. These firms are usually seen as mere VCR replacements or TV enhancements. But in fact they are spearheading a TV-killer invasion of computer technology into consumer electronics. The two firms sell a 20 gigabyte drive with embedded controls for $600 and will soon move to 50 gigabyte drives capable of storing, indexing, and processing some 50 hours of randomly accessible programs (as opposed to the random pile of unlabeled videotapes tumbling out of your closet). These new disk technologies can serve as a substitute for jitter free video bandwidth and thus as a substitute for quality of service featuritis on the network. The system illustrates not only the power of disk storage in the consumer video space but also the new role of storage as an independent appliance rather than a computer peripheral.

Today, storage devices such as disk drives, disk arrays, and RAID systems (Redundant Arrays of Inexpensive Disks) are linked to client computers only through various adapters and cable connections called SCSI (Small Computer Storage Interface), FibreChannel, SSA (IBM's Serial Storage Architecture), Firewire 1394 (Apple's contribution now adopted by Microsoft), ATA (Advanced Technology Attachment), IDE (Integrated Drive Electronics), and ISA (Industry Standard Architecture) as well as wide, fast, ultra, jumbo, turbo, HIPPI, and other hypes and enhancements of most of the above, which jack up their bandwidth to approximately a gigabit per second.

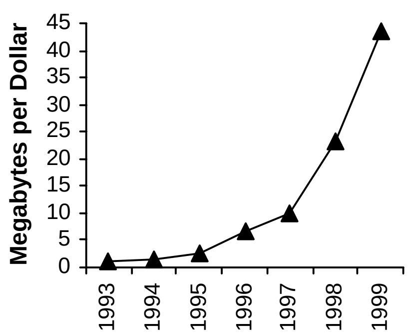
Called "captive" or "tethered storage"–or proprietary profit pipes–these specialized "master-slave" architectures were needed because no generic systems could link processor to storage at adequate speeds. Linking storage devices directly to the network as independent agents was impractical because the network itself was too slow to serve as a connector between storage and the rest of the computer. Ethernets ran at nominal 10 megabits per second, but often at a third of that rate in practice and were frequently full of other client server traffic. Because of these limits on network speed, storage had to be enslaved to a single computer or server. Without the option of a stand alone storage device attached directly to the network, there was no reason to build into disk arrays any of the other capabilities of a free standing appliance, such as the modest processing power they would need to stand on their own.

The resulting master-slave architecture, with the contents of a storage device available only through its master computer, added cost and complexity. But for most of the history of the industry, this arrangement was acceptible.

Storage needs were modest and mostly local–modest in fact because they were mostly local, comprising only that data likely to be used by the server or its own clients. But the Web makes this cozy arrangement intolerable; storage needs are no longer either modest or mostly local, and placing a general purpose master server between the storage device and the world is as extravagant as it is inconvenient. Like a crosstown taxi ride in a Manhattan rush hour, it may be more expensive than walking, but at least it is slower.

Chart 1

Disk Drive Capacity per Dollar Soars



Source: Disk Trend

The NAS Model

Nevertheless as recently as last year, captive storage still held a full 98 percent of the market. The server was king and the client computer was a baronial boss, while the disks were peripherals. Like many establishments, captive storage is being disrupted from outside. In the early 1990s a company called **Microtest** (MTST) was selling tower configurations of compact disks (CD-ROMs) and wished to avoid buying a computer to interface between the towers, which were a kind of CD jukebox, and their various users. The answer was a "thin client," an appliance designed to perform only that specialized function of linking CD towers to their users.

Embedding the thin client as a card in the tower and linking the entire storage device to its users over a local area network based on Ethernet, Microtest pioneered the idea of what is now known as Network Attached Storage (NAS). Look Ma, no computer, no SCSI interface, no Fibre Channel, just an array of vertically arranged CDs or hard drives and an Ethernet card. But because this contraption was an appliance and Ethernet still slower than the specialized links used in captive storage, the vendors of client server technology hardly noticed this homely device out of left field.

A new paradigm had been born, however, in which storage was autonomous. Dataquest predicts that this new paradigm–now commanding between two and five percent of the market–will take it over during the next five years. At the same time, storage, long a cheap peripheral, is expected to account for over 75 percent of all expenditures on computer hardware during this period. Storage demand from Forbes 500 companies is doubling every year.

The new system of autonomous storage feeds on a network bandwidth breakout and a traffic transformation. Ethernets are rising to gigabit and even ten gigabit speeds while e-commerce, digital video teleconferencing, video on demand, training video, video editing, audio and other multimedia threaten to swamp all existing storage systems, which come from a world of compressed text documents, charts, and hundred kilobyte GIF files. Internet Service Providers, Application Service Providers, Data Warehouses, e-commerce hubs, portals of all kinds, photo libraries, collocation centers, storage farms (often misleadingly termed "server farms" as if the server were still central) will comprise much of all hardware deployment. All of these storage nodes will need to be accessed by a variety of outside computers and appliances. Lo and behold, the best model for this kind of arrangement is that humble disk tower with an embedded controller attached to a fast Ethernet with a cheap network interface card (NIC).

In this Network Attached Storage model, gone are storage facilities enslaved to a specific server operating system with a specialized file format and expensive proprietary features. Adding storage to a system ruled by a general purpose server is predictably expensive (in engineer time needed to conform to the server's imperious OS), inevitably inefficient (because neither server hardware nor OS are optimized for storage), and ultimately unnerving (because what comes down, like a server to which storage systems are being added, usually comes back up more slowly and expensively than planned). In the new model, storage is primary and the computers, now satellites of the storage resource, no longer make the rules and dictate the architectures.

Leading NAS vendors typically preen about the uncanny "intelligence" of their products. But the slender processing power and compact real time operating systems that drive Network Attached Storage boxes represent a small fraction of the intelligence required by multiple master slave interactions across

Bandwidth outside the computer is growing some ten times faster than bandwidth inside, tearing systems apart and wreaking new paradigms

The Future Arrives

Mobile Snips Landlines, Grabs Data, Boosts Chips, Crowds PCs

Driven by price cuts US mobile phone subscribers doubled from the GTR's first issue in July '96 to over 76 million in June 1999, boosting wireless revenues 73% even as monthly bills declined 18%. (**Chart 3**). This "elasticity of demand", in which falling prices are more than covered by rising sales, also allowed **Sprint PCS** (PCS), using efficient **Qualcomm** (QCOM) CDMA to bring in $54 per month, per subscriber, 35% higher than the industry average while offering one of the lowest pricing plans in the industry. Sprint PCS subscribers jumped 169% from 3Q99 to 4.7 million in 3Q99.

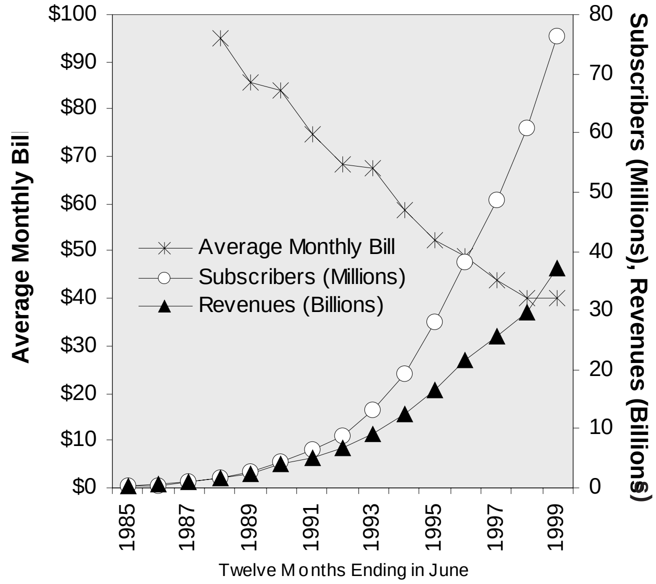
The trend will accelerate with wireless actually replacing landlines as wireless rates fall an average of 15% annually. Already 15% of Bell South's Louisiana wireless customers are wireless only. In Finland so many households have given up their tie down phones that more have mobiles than immobilizers and there are more mobile-only households (21%) than totally tethered (20%). And that's with wireless still overpriced, accounting for 55% of Finnish calling charges but only 29% of calls and 17% of calling minutes. (**Chart 4**)

Mobile subscribers are moving out to pass the permanently parked in Hong Kong, Japan and South Korea; Lebanon and Israel; Italy and Portugal; Norway and Sweden; Paraguay and Venezuela. The trend is actually strongest in poorer countries short on capital for copper cage completion. In Cambodia mobile subscribers lead the left at homes 2.5 to 1, and in Rwanda runabouts also hold the lead. Venezuela and Peru are both leaving their copper cages less than half complete as new mobile installation pushes new fixed-line installation aside. (**Chart 5**) Worldwide in 1998 there were twice as many new mobile connections as new fixed lines, and mobilized topped 300 million. (**Charts 6 and 7**)

As repeatedly predicted in the GTR, tethered traditional telephony is now clearly a collapsing business as even modest growth in international calling fails to offset steadily declining

Chart 2

US Mobile Price Cuts Drive Revenue Growth



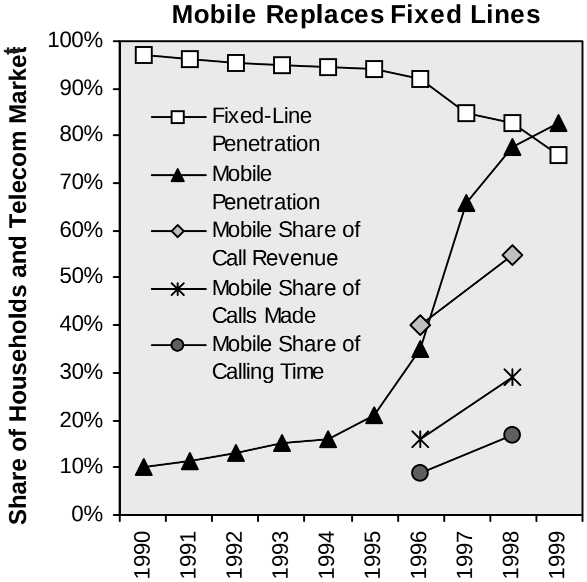
Source: CTIA

domestic revenues. Significant growth is coming only from mobile, the Net, and other data and non-traditional services. (**Chart 8**)

As digital mobile phones add data and Internet capabilities, our frequent prediction that the most common computer in the Telecosm will be a wireless phone is already coming to pass. In Asia, penetration of mobile phones already exceeds that of PCs, while the two are neck and neck in Europe. Even in PC laden America the gap is narrowing. (**Chart 9**) Globally, more mobile phones (analog and digital combined) shipped in 1996 than PCs,

Chart 3

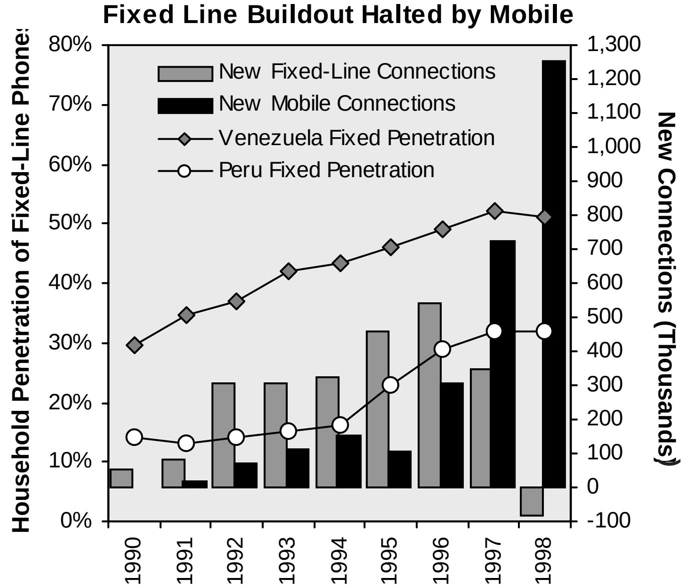
The Future Arrives First in Finland Mobile Replaces Fixed Lines



Source: Statistics Finland, ITU

Chart 4

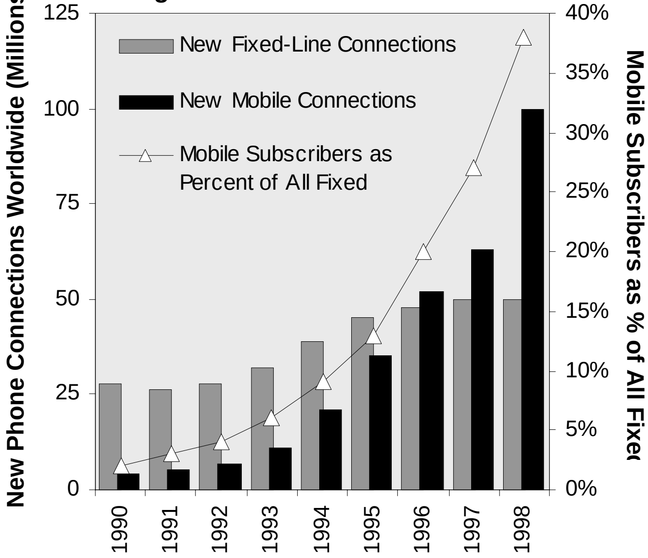
In Venezuela and Peru, Fixed Line Buildout Halted by Mobile



Source: ITU

Chart 5

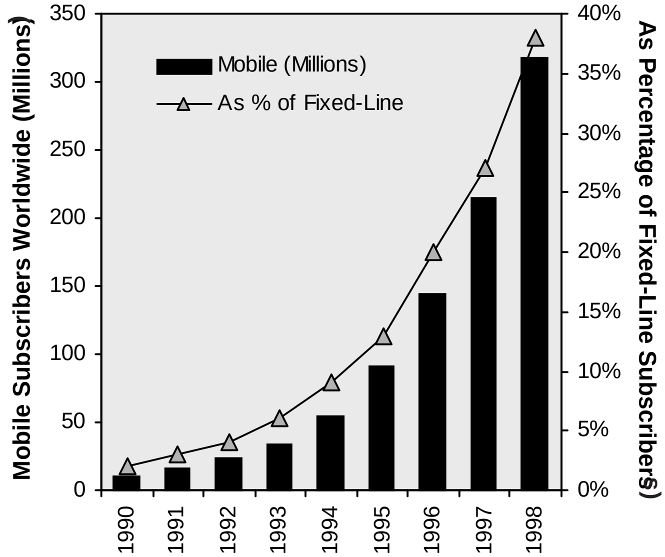
New Mobile Connections Surge to Double New Fixed-Lines



Source: ITU

Chart 6

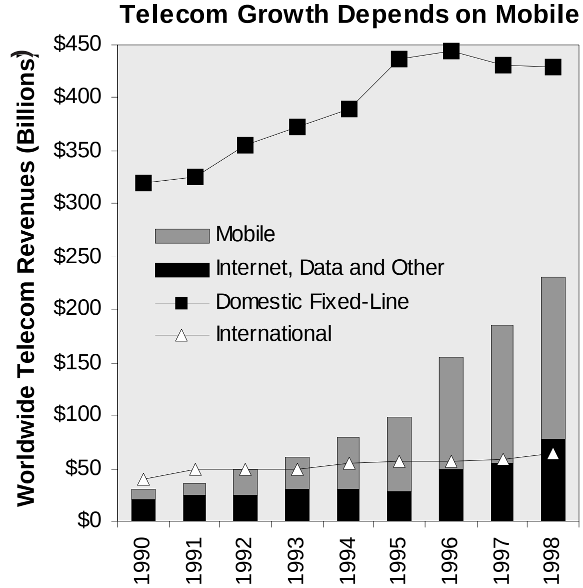
Mobile Subscribers Top 300 Million



Source: ITU

Chart 7

Telecom Growth Depends on Mobile



Source: ITU

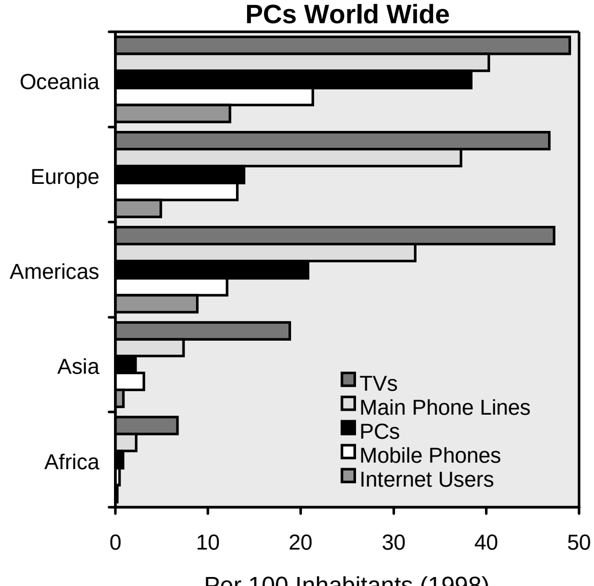
and digitals alone passed PCs last year. For 1999, Texas instruments predicts digital phone shipments will hit 260 million, some 130% higher than likely PCs shipments. (**Chart 10**)

Much of the progress in mobile is occurring at the silicon level, and the Semiconductor Industry Association credits the wireless boom for much of September's 24% rise in worldwide semiconductor sales. Leading the technology–in addition to Qualcomm are such Telecosm companies as **Conexant** (CNXT), leading vendor of CDMA power amplifiers for handsets; **LSI Logic** (LSI), developing single-chip systems for wireless phones, **National** (NSM), **Atmel** (ATML), **Xilinx** (XLNX), **Texas Instruments** (TXN) whose DSP and analog chips can be found in some 80% of the world's wireless devices, and **Analog Devices** (ADI).

-Ken Ehrhart

Chart 8

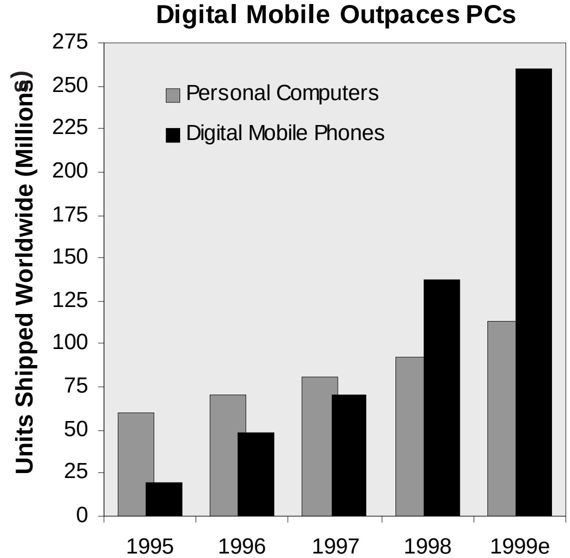
Mobile Phones will Outstrip PCs World Wide



Source: ITU

Chart 9

Digital Mobile Outpaces PCs

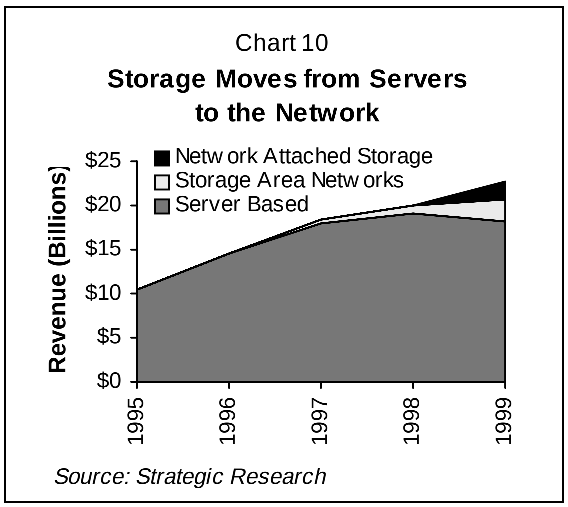


Sources: Dataquest, IC Insights, TI

Replay and TVO, usually seen as TV enhancements, are spearheading a TV-killer invasion of computer technology into consumer electronics

many computer language and protocol barriers. Indeed, the new paradigm might be depicted better as “stupid storage.” Just as dumb bandwidth is increasingly taking over from complex managed or intelligent bandwidth, dumb “storewidth” will displace smart captive storage.

The pattern was set in the early 1990s when hierarchical storage management systems were briefly the rage. Storage hierarchies make obvious sense. They relegate little used data to large cheap slow memories such as tape devices, and keep recently accessed data in fast silicon caches, either flash or static RAM. Hierarchical storage management systems were designed to automate this process throughout the enterprise, so data would always be in the right place at the right time. How could such as system fail? As Jon William Toigo explains in his new book, *The Holy Grail of Data Storage Management* (Prentice Hall, 2000), it failed because of “the sharp decline in hard disk prices, dramatic increases in hard disk capacities, and ... of RAID…technology.” The rapidly collapsing price of storage dictates architectures that waste storage and economize on processing and customer time. Intelligent hierarchical storage systems did just the opposite. As in bandwidth so in storewidth, abundance trumps intelligence nearly every time.



Driving all these changes are the imperial dynamics of the World Wide Web. Toigo’s book is full of descriptions of the baffling problem of heterogeneous file formats generated by different operating systems. Microsoft executives told him that this was no problem; everyone should just shift to Windows 2000. But with both UNIX, Linux, and mainframes, hugely more stable than Windows, and Macintosh Video Editors gaining market share in these new data warehouses and repositories, the all Microsoft solution is farther away than ever. On the World Wide Web, heterogeneous file formats will give way to IP, HTML, and its more flexible metadata successor XML, with Java a likely champion in database access. The magpies’ nest of ports and interconnects, contrived to deliver speed in an era of slow networks will surrender to various forms of Ethernet, Ethernet interface cards, and Ethernet based ten gigabit systems running on WDM.

SAN hyped

For specialized storage systems that need very tight management, such as Video “non-linear” editing, multimedia post production systems, and streaming video centers, a more complex and intelligent–and more hyped–technology is finding a niche: Storage Area Networks. Consisting of multiple storage devices linked by specialized Fibre Channel hubs and software sold by **Vixel** (VIXL), **Brocade** (BRCD) and **Gadzooks**, and governed by master servers mediating between the SAN and the network, SANs are an ambivalent transitional step toward the new paradigm. But Network Attached Storage hardware and World Wide Web software and standards, are the wave of the future.

Fibre Channel marginalized

SANs are dependent on finicky Fibre Channel, limiting them to enterprises that find their IT departments underworked and have a compulsion to hire more network engineers starting at $80,000 per year. As David Doering of TechVoice.com quips, “IT managers aren’t worrying about thin clients *or* thin servers, what’s on their mind are thin staffs.” Fibre Channel is not viewed as helpful. Brocade recently partnered with Vixel on a way to relieve some of these problems by combining complex SANs with NAS.

The defense of SANs is essentially a defense of smart Fibre Channel against the threat from dumb gigabit Ethernet. The case reads exactly like a defense of SONET (see GTR October 99). Fibre Channel is specialized for input-output (I-O) and requires expensive local integration. Ethernet is a familiar, modular, largely plug-in network system. And with the advent of 10 gigabit Ethernet, created and tested at **Lucent** (LU) and **Cisco** (CSCO), demonstrated all over the floor at Networld+Interop, and even deployed (in Canada’s Canarie next generation IP network), Ethernet will be not only cheaper and simpler but faster as well. The throughput gains, guaranteed quality of service, processor cycle savings, and other performance features claimed for Fibre Channel all will be amply supplied by the tenfold greater bandwidth of ten gigabit Ethernet, plus the advances in processors from companies such as **AMCC** (AMCC) and **Broadcom** (BRCM). Otherwise needed functions can be incorporated in software, perhaps in programmable DSPs and Field Programmable Gate Arrays (FPGAs) from **Xilinx** (XNLX), which now run at up to 40 gigabits per second.

Like all specialized I/O links, Fibre Channel faces the future as an increasingly marginal technology. The entire architecture and topology of the computer system–indeed its very existence as an integrated unit–reflects a time when bandwidth inside the computer was greater than bandwidth outside it. Today, however, not only is bandwidth outside the computer generally larger than inside, but outside bandwidth is growing some ten times faster. Such divergent deltas–different rates of change–tear systems apart and wreak new paradigms.

As the network becomes faster than I/O, I/O is absorbed by the network. Since I/O is the defining structure of the computer, its dissolution means that the computer disaggregates and becomes a series of peripherals attached to the network. This is the "hollowing out of the computer" that Eric Schmidt, now Novell CEO, predicted five years ago. He is now focusing on storage innovations and on directories which separate your identity from a specific machine. Your disk drive, your printer, your keyboard and finally even your processor can be anywhere on the network. Meanwhile, the heart of the information infrastructure becomes the storage repository and the increasingly object-oriented and multimedia-centric databases it contains. Embracing all will be the World Wide Web, Java, XML, IP and Ethernet, running on the vast boulevards of Wavelength Division Multiplexed optical circuits. Dumb networks and stupid storage will become the smart solution for the new millennium.

The simultaneous explosion of bandwidth and storage dictate a similarly massive growth in web caching, a solution that paradigmatically "wastes" these two crucial abundances, while conserving the two great scarcities of the Telecosm, the speed of light and the span of life, aka the customer's time. Banishing the World Wide Wait, the dumb paradigm embraces so called push or multicast technologies which can be integrated with ordinary customer "pull."

Akamai vs iBeam

SkyCache, Doug Humphrey's satellite cache scheme, is now joining with **Akamai** (AKAM) under CEO George Conrades to integrate satellites, fiber bandwidth and storage caches to accelerate the Internet. This powerful combination of industry leaders must compete with **iBeam Broadcasting**, which has created the world's largest satellite based network for distributing streaming audio and video across the Internet. The iBeam technology can deliver more than 300,000 simultaneous streams, three times more than any other network.

The crucial NAS company today is **Network Appliance** (NTAP) of Santa Clara. Trumping the lords of Sun, these **Auspex** (ASPX) refugees proclaim "the network is the backplane." They owe their early dominance of the market not only to their elegant, platform independent WAFL file system, but also to their ability to articulate a clear vision of radically simplified and expanded storage as the primary mission of the network.

The company announced last month that **MP3.com** (MPPP), the Internet's premiere online digital music destination, has chosen Network Appliance as its primary storage solution provider for the 154,000 songs from 26,000 artists lodged on the site. MP3.com averages more than 400,000 daily visitors on its web site. With a market cap of $7 billion, NatApp is hardly the undiscovered country, but the $250 million market of which it deservedly owns 42% today is estimated by just those sort of analysts who always underestimate the growth of the net to reach $5 billion in three years.

SkyCache and Akamai must compete with iBeam Broadcasting, the world's largest satellite network for distributing streaming video on the Net.

Caching up with Alteon

Enabling NAS based web caching and gigabit and 10 gigabit Ethernets that will be are **Alteon** (ATON) and **Foundry** (FDRY). Both make Web switches that read more deeply embeded packet data than traditional routers, enabling them to transcend packet-by-packet routing and steer whole packet streams away from network bottlenecks. That improves caching efficiency and response. Alteon is collaborating with NetApp on caching systems.

The original but now number two NAS company, Auspex, is the gloomy owner of half NetApp's market share but only 2% of its market cap. Strong technically, Auspex is positioned mid-market, head-to-head with NetApp. Both show an inclination to move up and challenge mainframe masters EMC and IBM. IBM remains the prime disk drive innovator and its mainframe storage systems are thousands of time more reliable than their low-end competition.

But in the lexicon of my GilderGroup colleague Clayton Christensen, NAS is a classic disruptive technology, shedding unneeded or overbroad functionality, cutting cost, especially lifetime cost, and adding simplicity and focused capacity. The emergence of a true disruption dictates the market will ultimately be controlled from below, not above. Burrowing up from those lower regions is **Procom** (PRCM), with a series of NAS products below $15,000. Quantum is the most agile and versatile of the leading disk drive manufacturers, taking most of the digital TV oriented disk storage slots, such as Replay, and even pioneering with inovations in tape storage. Quantum's (DSS, Quantum's tracking stock for its storage group) Snap NAS line out of its Meridian acquisition is similarly directed at the soft underbelly, featuring an OS that weighs in at only 3 MBs and offering a 32GB system that starts at $995.

The new paradigm is already manifesting itself. Dataquest estimates that between 1998 and 2002 the proportion of the storage market commanded by master-slave arrangements will drop from 98 percent to 10 percent. Taking over the market will be disk arrays and other storage systems linked directly to networks rather than linked to networks only through powerful computers. The key complement of the new paradigm of bandwidth abundance is cornucopian storage. Together they will consummate the Internet as an ultimate global database over the next five years.

George Gilder, November 11, 1999

TELECOSM TECHNOLOGIES

ASCENDANT TECHNOLOGY	COMPANY (SYMBOL)	REFERENCE DATE	REFERENCE PRICE	OCT-99: MONTH END	52 WEEK RANGE	MARKET CAP.
CABLE TECHNOLOGIES/SERVICES						
Cable Modem Chipsets	Broadcom Corporation (BRCM)	4/17/98	12 *	136 7/8	40 1/2 - 149 1/2	13.61B
CDMA Cable Modems	Terayon (TERN)	12/3/98	31 5/8	43 5/8	10 11/16 - 60 1/2	0.912B
MICROCHIP TECHNOLOGIES						
Analog, Digital, and Mixed Signal Processors	Analog Devices (ADI)	7/31/97	22 3/8	56 7/8	19 5/16 - 60 7/16	9.92B
Silicon Germanium (SiGe) based photonic devices	Applied Micro Circuits (AMCC)	7/31/98	11 11/32	79 1/8	11 15/16 - 79 1/4	4.25B
Programmable Logic, SiGe, Single-Chip Systems	Atmel (ATML)	4/3/98	17 11/16	39 7/8	11 1/8 - 42 7/16	3.99B
Digital Video Codecs	C-Cube (CUBE)	4/25/97	23	44 3/4	17 1/4 - 46 3/4	1.78B
Linear CDMA Power Amplifiers, Cable Modems	Conexant (CNXT)	3/31/99	13 27/32	47 1/2	6 1/2 - 47 3/8	4.63B
Single Chip ASIC Systems, CDMA Chip Sets	LSI Logic (LSI)	7/31/97	31 1/2	54 1/2	14 - 62 1/2	8.03B
Single-Chip Systems, Silicon Germanium (SiGe) Chips	National Semiconductor (NSM)	7/31/97	31 1/2	30 3/8	8 7/8 - 36 1/4	5.21B
Analog, Digital, and Mixed Signal Processors, Micromirrors	Texas Instruments (TXN)	11/7/96	11 7/8	89 3/8	30 9/16 - 94 1/8	70.22B
Field Programmable Gate Arrays (FPGAs)	Xilinx (XLNX)	10/25/96	16 7/16	79	21 5/8 - 79 1/8	12.48B
OPTICAL NETWORKING						
Wave Division Multiplexing (WDM) Systems, Components	Ciena (CIEN)	10/9/98	8 9/16	34 7/16	12 7/16 - 42 13/16	4.73B
Optical Fiber, Photonic Components	Corning (GLW)	5/1/98	40 15/16	79 1/2	36 3/16 - 82 1/4	19.45B
Submarine Fiber Optic Networks	Global Crossing (GBLX)	10/30/98	14 13/16	34 1/2	13 1/2 - 64 1/4	14.99B
Wave Division Multiplexing (WDM) Components	JDS Uniphase (JDSU)	6/27/97	14 1/2	169 3/4	23 3/4 - 172 5/8	29.41B
Broadband Fiber Network	Level 3 (LVLT)	4/3/98	31 1/4	68	32 1/2 - 100 1/8	23.11B
Broadband Fiber Network	Metromedia FIber Network (MFNX)	9/30/99	24 1/2	34 3/8	9 1/8 - 47 9/16	5.37B
Broadband Fiber Network	NorthEast Optic Network (NOPT)	6/30/99	15 1/16	37 1/16	5 5/8 - 45 1/8	0.596B
WIRELESS TECHNOLOGIES/SERVICES						
Low Earth Orbit Satellite (LEOS) Wireless Transmission	Globalstar (GSTRF)	8/29/96	11 7/8	22 7/8	12 5/8 - 33	1.87B
Satellite Technology	Loral (LOR)	7/30/99	18 7/8	15 11/16	13 1/2 - 22 7/8	3.83B
Nationwide Fiber and Broadband Wireless Networks	Nextlink (NXLK)	2/11/99	20 7/16	63	11 3/16 - 61 7/8	4.61B
Code Division Multiple Access (CDMA) Chips, Phones	Qualcomm (QCOM)	9/24/96	19 3/8	226 11/16	24 1/2 - 226 3/8	36.39B
Nationwide CDMA Wireless Network	Sprint PCS (PCS)	12/3/98	15 3/8	84 5/16	12 3/4 - 83 7/16	40.06B
Broadband Wireless Services	Teligent (TGNT)	11/21/97	21 1/2 *	46 1/4	27 1/8 - 75 5/8	2.49B
INTERNET TECHNOLOGIES/SERVICES						
Internet Enabled Business Management Software, Java	Intentia (Stockholm Exchange)	4/3/98	29	22 7/8	17 1/2 - 35 1/4	0.548B
Telecommunication Networks, Internet Access	MCI WorldCom (WCOM)	8/29/97	29 15/16	85 9/16	53 11/16 - 96 3/4	160.3B
Java Programming Language, Internet Servers	Sun Microsystems (SUNW)	8/13/96	13 3/4	104 1/4	28 7/16 - 107 1/8	81.37B
BROADBAND TELECOM TECHNOLOGIES/SERVICES						
Wireless, Fiber Optic Telecom Chips, Equipment, Systems	Lucent Technologies (LU)	11/7/96	11 25/32	65 7/8	40 5/16 - 79 3/4	201.8B
Wireless, Fiber Optic, Cable Equipment, Systems	Nortel Networks (NT)	11/3/97	23	62 7/8	21 1/8 - 61 15/16	84B

* INITIAL PUBLIC OFFERING

NOTE: This table lists technologies in the Gilder Paradigm, and representative companies that possess the ascendant technologies. But by no means are the technologies exclusive to these companies. In keeping with our objective of providing a technology strategy report, companies appear on this list only for these core competencies, without any judgement of market price or timing. Reference Price is a company's closing stock price on the Reference Date, the date on which the company was added to the Table. Since March 1999, all "current" stock prices and new Reference Prices/Dates are closing prices for the last trading day of the month prior to publication. Mr. Gilder and other GTR staff may hold positions in some or all stocks listed.

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