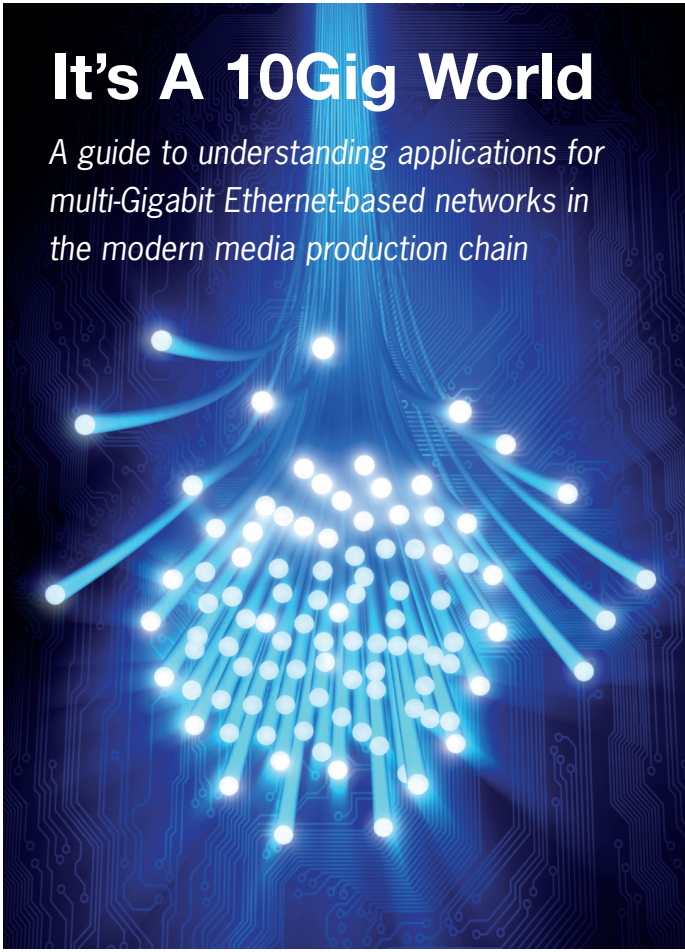
It's A 10Gig World

A guide to understanding applications for multi-Gigabit Ethernet-based networks in the modern media production chain



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1. Introduction

The media production industry is reliant on constant changes in technology to deliver media assets and finished content quicker and in ways that reduce costs.

While TV was broadcast in standard definition, and while HD was new and expensive for everybody, and therefore not used widely, television post production became collaborative thanks to systems like Avid's Unity. Editors worked using compressed, offline-quality [1] video. At that time, film post production using uncompressed DPX files [2] was necessarily non-realtime and largely non-collaborative. To stream even SD video [3] in real-time required specialist technology using the Rec. 601 standard [4].

Modest networks built on Gigabit Ethernet [5] - GbE, or 1 GigE - could cope with the throughput for those file-based SD, HD [6] & digital cinema [7] workflows, though only in real-time at compressed resolutions.

Now, HD is the norm for TV production, high-end post production is done at 2K [8], and both 4K [9] and

stereoscopic 3D [10] are in our midst. The old video streaming standards are increasingly reserved only for niche applications, tape is all but dead, workflows are largely file-based, and 1 GigE cannot adequately cope with the requirements of high-end digital film postproduction:

- Real-time playback at 2K resolution
- Storage networking
- LAN [11] support
- WAN [12] support
- MAN [13] support
- Moving files to/from render (server) farms [14]

10 Gigabit Ethernet [15] - 10GE, 10GbE, 10 GigE, or just 10Gig - is now a widely-used, widely understood technology that is fast enough to deliver what the media production industry needs, enabling facility-wide networking and true collaborative workflows at resolutions up to 2K.

These faster networks more-or-less eliminate the need for video switching as well as tape, since most applications can play straight off the server.

Although alternative networking technologies can also meet the performance and networking requirements, 10Gig offers an unprecedented combination of high performance and low price. The ability to use commodity protocols, the ready availability of skilled technicians, and the ability to build a single, unified infrastructure to carry both production and office data traffic also make 10Gig attractive for IT Managers, and FDs.

1 GigE networks generally operate over twisted pair copper cable [16]. 10Gig operates best over fibre optic cable [17]. Despite being up to ten times faster than its predecessor, 10Gig is totally compatible with 1 GigE, retains the same architecture, and isn't anywhere near ten times more expensive.

10Gig can also be used to link LANs to WANs to form unified, high speed networks spread across multiple sites, enabling even wider collaborative working, though with limitations as distances become greater. Products such as Connect:Direct [18], a data transfer product with its roots in mainframe computing, can

also facilitate data movement across great distances.

As things stand, the main obstacle to the wholesale creation of metro- and wide-area networks is cost, not technical limits on bandwidth. Latency [19] is also an issue for wide-area networks, but this usually can be resolved by careful choice of system architecture. Fibre optic cabling offers a clear roadmap now for multi-Gigabit networks, with 40Gig and 100Gig [20] on the technology horizon.

In this booklet we will cover the use of 10Gig-based networked architectures to create complete storage, server, router, and workstation environments throughout the media production chain; from ingest to distribution. The booklet covers the business benefits and the technical aspects of these environments, though technical concepts are not examined in depth. To aid understanding, the glossary includes links to relevant Wikipedia pages that explain terms and concepts in detail, with links to other sources of information.

2. 10Gig & the marketplace

10Gig is a cost-effective replacement for more expensive alternative storage and server networking technologies:

- Fibre Channel [21]
- SONET [22] OC-3 & OC-12 links
- Legacy ATM [23] & PDH [24] data links
- HiPPI [25]
- Some storage-over-Infiniband applications

Principal applications in media production for 10Gig-enabled infrastructures include:

- Collaborative working at HD resolutions & above
- Remote collaborations over distance
- Remote backup
- Storage-on-demand
- Remote rendering
- Centralisation of network management
- Business continuance / disaster recovery
- Streaming media at high resolutions

Across the world, companies have invested heavily in cabling, equipment, processes, workflows, and training based on the Ethernet protocol. Due to its ubiquity, the cost of Ethernet technology has been kept low, with prices constantly being driven down.

The creative software applications used in film, TV & rich media production are becoming increasingly bandwidth-hungry. Even standard desktop workstations and laptops can now run software that produces files in resolutions up to 4K. That's 50MB per frame!

Currently, most computers used in media production only have 1 GigE ports. The arrival of affordable 10Gig PCIe [26] cards and 10Gig ports will change this soon. From the desktop to the storage and server environment, across LANs and WANs, 10Gig is becoming the standard link speed. Additionally, modern computer bus architectures and multicore processors [27] can support sufficient parallelism [28] to keep data flowing at the required rate.

Commodity protocols like IP over 10Gig operate best when they're not pushed to the limit. Use the

technology as it is intended and it will work in your favour. Fortunately, 10Gig provides substantial headroom for most media applications. Even working well below the limits of 10Gig wire speed [29] - usually around 60% of the theoretical maximum - it is possible to significantly increase productivity, and therefore profitability, in the media production chain.

Another factor that works in the favour of 10Gig is that buyers are not tied into single or limited vendor relationships. 10Gig is defined by the IEEE in a series of global standards. Proven interoperability, and a low Total Cost of Ownership in terms of equipment acquisition, support costs, and the availability of a skilled IT pool, give 10Gig an edge over current alternative technologies.

Scaled, intelligent, multi-Gigabit networks, backbones, server, and, eventually, workstation connections, will also help companies develop new services (and profit centres); ingest, distribution, storage-on-demand, remote storage management, and remote rendering.

Alternative networking technologies can struggle to

deliver this kind of flexibility of service and architecture. They are subject to problems concerning proprietary protocols or niche industry standards, relatively high prices for switches and adaptors, interoperability with other network technologies without the use of expensive routing and switching devices, and the lack of a skilled but affordable IT pool.

10Gig replaces all these technologies as the industry-standard, next generation network interconnect for both storage and server networks, and creates two scenarios:

- Shared links; between servers, backbones and collaborating groups
- Dedicated links; meet specific workstation's/workgroup's performance requirements, using non-blocking switches [30]

Larger models of non-blocking switches - up to 384 ports at the time of publication - and data bridging standards [31] that deal with packet flow [32] and flow control [33] issues facilitate the creation of these scenarios.

Looking at unshared links first, an uncompressed 2K frame occupies 12.5 MBytes. At 24 frames per second, that's 2,400 Mbits/s. An uncompressed 4K frame is 50MBytes. At 24 frames per second, that's 9,600 Mbits/s. For streaming, an unshared 10Gig link should operate at 60-75% capacity. Uncompressed 2K streaming over 10Gig is practical. Two simultaneous streams can be supported without a problem. Since headroom is needed when using commodity protocols, uncompressed 4K streaming is not practical over a single 10G link. 'Near real-time' data transfer is.

A stream of ultra-high-quality, near-lossless compressed 1080p [34] HD is more-or-less 250 Mbits/s. Over a shared link, again at 60% capacity, 10Gig can support 24 streams of high quality HD video, or 100 streams at "Blu-ray [35] quality", 54 Mbits/s.

10Gig & LANs

LANs are essential for the successful operation of any file-based workflow. 10Gig-based networks allow busy creative departments using bandwidth-hungry

applications to cost-effectively share increasingly larger files without delays or compromises

10Gig & WANs/MANs

Thanks to city-wide dark fibre [36], 10Gig interfaces and optical adaptors, NAS [37] and SAN [38] infrastructures can now be shared between company sites and collaborating companies at 10Gig wire speed. This was not possible with 1 GigE connections, which were simply too slow to make it worthwhile

10Gig-based WANs & MANs allow companies to locate departments on different sites without impacting their ability to share files. WANs & MANs also allow businesses to be more flexible about the location of storage repositories & server farms. Distances of up to 10km are comfortably achievable. Greater distances are possible with specialist hardware and configuration skills, though a possible impact on performance has to be taken into account when operating at the extremes of 10Gig's capabilities.

Latency and the resulting bandwidth-delay it produces is the biggest issue in fast WANs. Speed-of-light delay

is the major source of latency in 10Gig networking. To maintain a constant data flow, many packets need to be in flight at once. Good TCP [39] stacks and OS tuning are essential to achieve high performance.

Workstation efficiency

Delivery of files to and from workstations with 1 GigE connections is greatly improved with the use of 10Gig networks, making creative departments more efficient and productive. Reduced network congestion, the over-provisioning of bandwidth between switch, server & storage, and the speed of the 10Gig link compensate for the 'bursty' nature of data movement in these environments over standard 1 GigE workstation connections

Server Consolidation

A server connected to a network by 10Gig has the available bandwidth to perform the same tasks as several servers doing different jobs connected by 1 GigE. Significant savings can be achieved when servers and processes are consolidated.

3. The business benefits of using 10Gig

Ethernet is by far the best-established networking technology for use in business environments. Most businesses involved in the production of media already have Ethernet in their buildings. Ethernet's ubiquity keeps prices low, and users can combine technologies from different vendors, to suit their budgets and fit in with corporate purchasing policies.

Trained IT professionals understand Ethernet. Skilled staff are not at a premium, and therefore expensive to employ. The switch from Gigabit to 10 Gigabit does not involve extensive, expensive re-training.

Working in small creative teams with instant access to files over 10Gig-based LANs improves productivity and creativity. Digital artists, animators, colourists and colleagues performing similar tasks don't want the delays and distractions caused by network congestion to get in the way of creativity. They thrive on being able to work collaboratively, free of restrictions,

compromises and time lost to frustrating IT issues. 10Gig infrastructures remove these bottlenecks, so creative staff are happier, more efficient, more effective, and probably more profitable as a result.

Creativity, efficiency and cost-effectiveness across greater distances can be achieved using WANs and MANs. Teams from the same company working at different locations and companies collaborating on projects can operate as one, seamlessly sharing projects and assets over 10Gig.

The faster network connection also allows businesses to take advantage of services being offered remotely by third-parties. These include remote backup & restore, storage-on-demand, remote rendering and deep archiving. One of the attractions is that they are offered from locations where space, power, cooling and staffing are less expensive than at its primary location. Rather than invest in its own infrastructure - with the associated costs of power, cooling, staffing, not to mention physical space - a business can outsource many of these essential tasks to specialist

companies capable of offering services supported by formal Service Level Agreements (SLAs).

The attraction of these services is that a business doesn't carry the investment in technology on its books as depreciating assets, worry about the cost of resource overheads, or pay additional rent to accommodate the equipment needed to perform the tasks.

In addition, these services are generally located where real estate and fibre connectivity are inexpensive, and have the advantage of being able to take advantage of economies of scale. These services are offered to a wide range of businesses, not just media companies. The market is competitive, and thus service providers are not in a position to charge premiums to businesses who they think can afford to pay more.

Over time, a business may be happy enough with the service it is receiving and the stability of the 10Gig infrastructure to consider locating some internal services remotely. All because it can connect to this remote location over 10Gig without worrying about

bottlenecks, compromises, time lost while suites are not operational, courier costs, loss of productivity while staff move between locations . . . the list goes on.

On-demand services over 10Gig can be very appealing. Again, why buy an 'all-you-can-eat' service that may offer more than you need at any given time when you can buy and pay for services based on your specific requirements? Some examples:

Storage-on-demand over 10Gig

Need to temporarily access a few hundred Terabytes temporarily while you back up your SAN for maintenance?

Need to back up a client's rushes & project data while they're in your control to satisfy their insurers?

Need to temporarily shuffle data around to free up your online & nearline [40] storage so you are flexible enough to cope with an unexpected rush of business without a) investing in new technology & b) waiting for that new technology to be delivered, commissioned and integrated into your existing system?

Remote back-up over 10Gig

Peace-of-mind and lower insurance premiums are driving a demand for remotely backed-up data. 1 GigE networks cannot support the required data flow without disrupting other activities. 10Gig networks can cope with the extra traffic while coping with day-to-day tasks

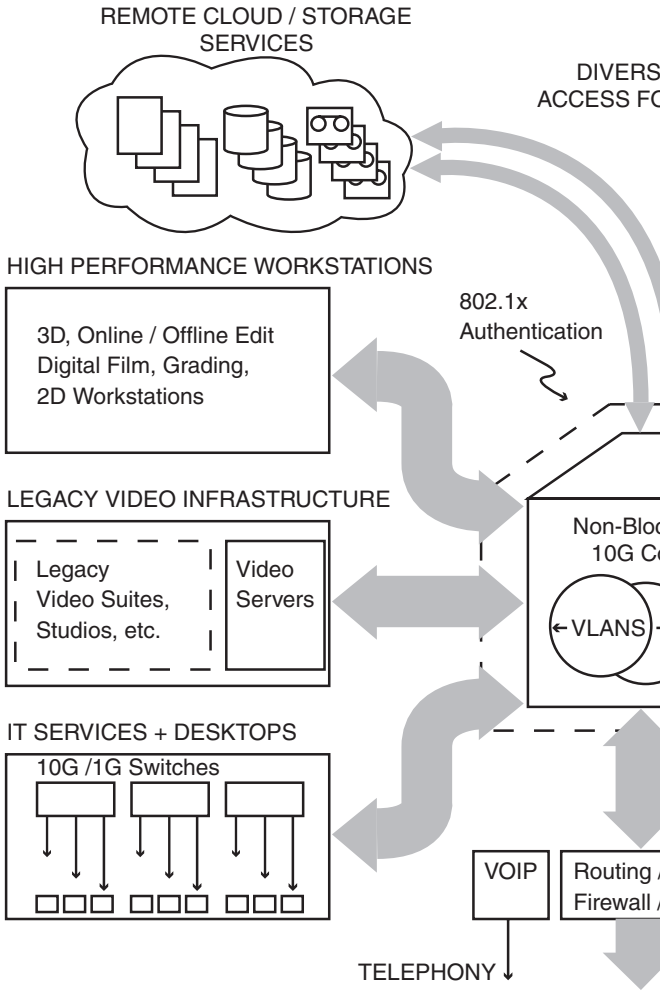
Faster backups can be performed at quiet times of the day such as 'the graveyard shift', causing next to no disruption and making efficient use of your network

Offsite back ups satisfy a number of business needs:

- Full disaster recovery and business continuance in the event of fire, flood etc.
- Minimises disruption during storage maintenance and troubleshooting
- Staff can access assets for remote working, increasing productivity

For many reasons, as you can see, installing a 10Gig infrastructure gives a business a distinct competitive advantage. Ethernet is a global IT standard, not a specialist technology championed by niche vendors.

10Gig draws on most of Ethernet's inherent strengths and adds many of its own.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HIGH PERFORMANCE WORKSTATIONS
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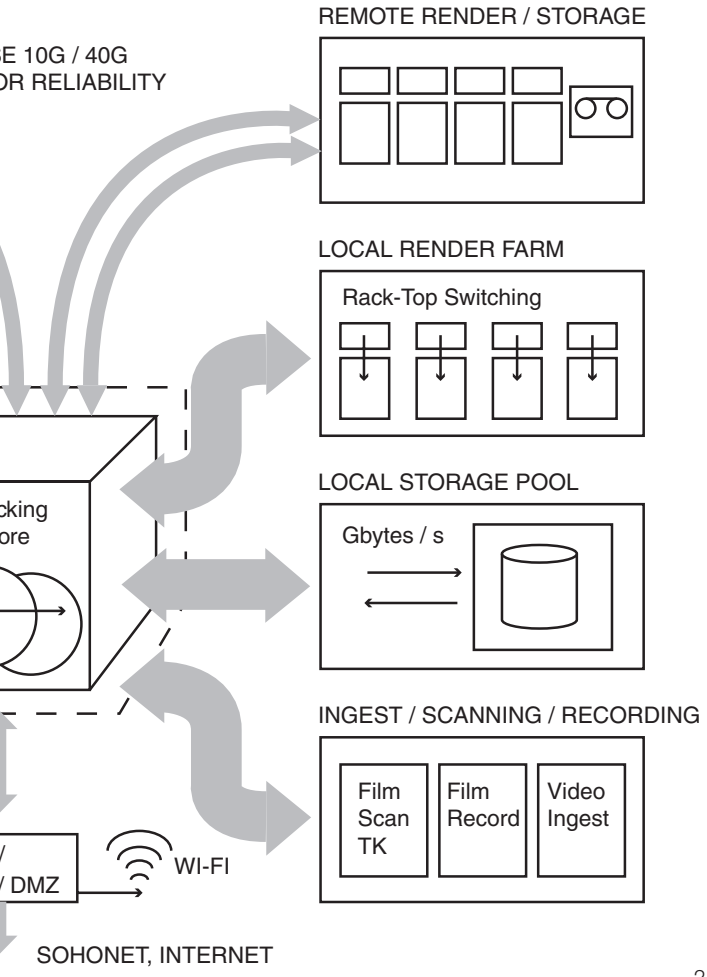
Digital Film, Grading,
2D Workstations
802.1x
Authentication
LEGACY VIDEO INFRASTRUCTURE
Legacy
Video Suites,
Studios, etc.
Video
Servers
Non-Bloc
10G C
VLANS
IT SERVICES + DESKTOPS
10G /1G Switches
VOIP
Routing /
Firewall /
TELEPHONY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Film Scan TK
Film Record
Video Ingest
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/ DMZ
WI-FI
SOHONET, INTERNET

4. Networked storage and 10Gig

Modern storage systems designed for use in media content production have to fulfill a number of requirements and meet the demands of different parts of the business:

- Performance - read and write speeds must be fast enough to satisfy demanding creative departments where bottlenecks interrupt creativity & productivity, compromising project delivery schedules and ruining 'client attend' sessions
- Data protection - never lose data, ever
- Reliability - high availability is a pre-requisite. Downtime = lost revenue. Data loss = a lost client & possibly worse
- Scalability 1 - add more storage and users as required without storage architecture, storage operating system or underlying technology limitations
- Scalability 2 - grow a storage system beyond your company's physical boundaries; share assets freely, without compromises

NetApp storage & 10Gig

NetApp's [41] software-led approach to data storage meets these challenges head-on.
NetApp's Data ONTAP [42] operating system is responsible for performing most of the tasks required to ensure performance, security, reliability and scalability, leaving its hardware to do what it does best; providing underlying raw speed and redundancy for the file system

NetApp's main focus is on reducing complexity in storage management. By making things simple, costs can be reduced. Systems that are less complex to administrate also require fewer staff, and those staff members can be at a lower skill level.

How does NetApp simplify data storage and reduce costs in a file-based media production environment?

Conventional data protection

Traditional backups are a problem:

- they take too long to perform
- they cannot be controlled

- they are prone to failure
- they slow the storage system down
- not always easy to restore

NetApp data protection

NetApp Snapshot-based data protection gives users a distinct advantage.

SnapShots [43]

- create point-in-time backups
- use less space - only saves block-level changes
- reduce I/O actions during the backup procedure
- automatic, almost instant, and transparent
- almost no impact on performance
- happen within the NetApp storage environment
- NetApp storage is 99.999% operationally reliable
- 255 Snapshot per volume can be performed
- SnapShots can be retrieved almost instantly

SnapRestore [44]

- Backups can be restored completely in minutes
- Recovery requires no data movement
- Data can be retrieved at file, volume or system level
- Easily retrieve volumes for large files

• saves time and effort

SnapShots and SnapRestore are just two of the ways NetApp makes managing storage more efficient and less costly.

Conventional storage management

Some file system and hardware configurations are known to have inefficiency issues. For example, data must be written to the outside of disks to reduce read-write latency. The number of filer heads and drive spindles required to achieve performance increases costs; space, power, cooling, maintenance. Drive fragmentation is a major problem, resulting in periods of expensive downtime.

Connectivity is another issue. System performance is achieved using expensive, specialised networking protocols and interconnects. Skills are at a premium.

Many conventional storage systems are susceptible to double disk failure, which will bring any production workflow to a standstill. This can be fixed with the use of disk redundancy. Regular RAID [45] protection levels

5, 6, and 10 either affect performance or need lots of disks (affecting consumption and generating heat), and ultimately cost more money. NetApp has its own RAID control, RAID-DP [46].

RAID-DP

RAID-DP prevents double disk failures from occurring, and does so without significantly impacting storage system performance. Traditional single-parity RAID protects a system from single disk failure. The expectation with conventional RAID is that no other disk will fail, and no bit-level data loss will occur while the failed disk is replaced.

The use of ever larger storage pools increases the chance of irreparable data loss to unacceptable levels, since error frequency remains the same.

The file system remains fully operational during a double disk failure when under RAID-DP control, whether using Fibre Channel or SATA [47] disks.

NetApp storage management

NetApp's Data ONTAP OS has its own file system, WAFL [48]. WAFL is the 'secret sauce' of the NetApp storage system. It manages the distribution of files across the disk arrays in a highly efficient way, so that they're quick and easy to retrieve.

WAFL automatically defragments [49] the storage array, so the system never slows down due to inefficient data distribution across the drives. WAFL also controls SnapShots (the read-only copy of the file system that makes for fast, reliable data backups), and FlexClone [50] (a read-write backup).

NetApp storage can operate in one of two modes: 7-Mode [51] & Cluster-Mode [52].

7-Mode

7-Mode is suitable in environments where High Availability [53] is of primary importance. 7-Mode provides fastest possible access, as well as ensuring storage efficiency, data security and reduced storage management complexity.

Cluster-Mode

Cluster-Mode offers linear, multi-node scaling of a storage system, and global namespacing [54].

Multi-node scaling

Start small, and grow a system linearly in terms of performance and capacity. Same operating system, same hardware. Add controllers and disk shelves to increase capacity, users served, performance.

Global namespacing

An abstraction layer that allows the construction of a clustered storage network, also known as a storage grid. Clustering allows users of applications to collaborate & share projects; move, change and manage files in an environment to which users all have access, regardless of geographical location. Global namespacing and clustering allow this to happen with no impact on performance or workflow.

Cluster-Mode also allows for ‘scale-out’ storage - grow in size horizontally, without the need to grow vertically (ie. add capacity and access without adding more computing power to give the necessary performance).

Crucially, NetApp storage is able to achieve all of this using 10Gig for connectivity, while rival storage technologies often rely on other, more specialised technologies that are less appealing, for reasons explained elsewhere in this booklet.

5. Server Farms & 10Gig

Server farms, most typically used for animation and VFX rendering, video processing or content distribution in the media production chain, accomplish computing needs way beyond the capabilities of single computers. Tasks and workloads can be distributed across multiple servers or processors to dramatically reduce run time and increase efficiency.

Traditionally, servers, storage nodes (or trays) and switches are housed in racks and connected by 1 GigE, which is now being replaced with 10Gig to increase performance and efficiency. Put simply, jobs allocated to server / storage systems running over 10Gig can be processed up to ten-times quicker.

When creative teams are connected to those server farms over 10Gig they become correspondingly more efficient and productive. This ultimately saves time, increasing profitability. Line-rate [55] high-bandwidth switching, filtering, traffic queuing, and data centre buffering ensure smooth data flow.

When work flows, creativity flows.

Delays caused by data bottlenecks account for many of the frustrations voiced by creative teams. When they can work unhindered, see results instantly, or in a timely fashion, and collaborate effectively, they are happier, more productive, more creative, more profitable . . .

A typical data centre, with its mix of off-the-shelf blade and 19" rack servers, can waste at least 80% of its CPU and memory resources at peak periods. Server consolidation, using fewer physical servers, saving money on power, space, heat, hardware support contracts, and people time, offers a compelling argument for change.

VMC Enterprise-grade servers are just 2U in height and consume less than 450 Watts. As well as making for a smaller footprint, power and cooling costs are greatly reduced.

In-box upgrades also save money over the lifetime of the server. Components such as CPUs and power supplies can be swapped out, extending the life of the servers by several years.

6. Implementation & maintenance

10Gig is sufficiently similar to 1 GigE that it can be regarded as a go-faster version of the same thing for most intents and purposes.

We already know that installation and maintenance can be carried out by technicians with regular IT training. Employers can draw on a deep talent pool to attract the best engineers, without having to pay premium prices for skills, even for specialised work, such as with fibre optics.

Tools are more expensive, and rigorous testing is essential. These are areas where the cost of 10Gig implementation is a consideration, though scope for later expansion to 40Gig and 100Gig means costs can be amortised over time.

7. LANs, WANs, MANs & 10Gig

How can the unification of LANs, WANs & MANs over 10Gig benefit creative businesses?:

- Access to remote services:
- Remote backup
- Remote archiving
- Compute-on-demand / Software as a Service (SaaS) [56] or remote rendering
- Storage-on-demand / Storage as a Service (StaaS)
- True collaborative working between creative teams at multiple locations
- Distribution of jobs to teams best suited to do the work, without compromises

How can 10Gig networks be cost-effectively extended outside a building, into the street, and between remote locations? Outright ownership of a permanently-lit fibre optic link between a LAN and a WAN / MAN that can also be used to connect to external services was, until fairly recently, an expensive luxury for most companies involved in media production.

As the price of hardware and wholesale telecoms links drop, and service providers can lower their rates, semi-permanent high-speed connectivity has become more affordable and more desirable for any company moving large quantities of large files between sites.

In simple terms, there are three levels of service:

- Traffic engineering [57] - highly-optimised, permanently-lit, high-speed connection providing huge bandwidth that allows for real-time transfer of high-resolution media files without compromises. Expensive, and probably unnecessary in most instances
- Over-provisioning - more than enough bandwidth to cope with typical data transfer requirements, based on average use and allowing for peaks
- Best effort - equivalent to the public Internet. Bandwidth available is subject to traffic congestion & network contention. Data transfers are subject to delay and failure

The use of dispersed resources comes into its own when combined with short-term, high capacity storage

rental for overspill or backup, and with longer-term high capacity deep storage, for archiving. Both can be accessed over 10Gig fibre, though the deep storage can be just as easily accessed over slower networks on a 'trickle' basis.

10Gig enables cost-effective distribution of finished content to playout centres, publishing companies, staging servers and so on.

8. 10Gig & 'The Cloud'

The concept of using cloud-based resources has been a vexed topic since it first came to prominence. Issues of data security, control, accessibility and service levels have dogged its progress.

For now, businesses still feel safer using services that they access over private networks that offer the levels of security and stability they demand. It could be only a matter of time before attitudes soften, and more widespread use of 'the cloud' for SaaS, StaaS etc. becomes commonplace.

Glossary

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Notes:

EACS Media

(a division of EACS Ltd.)

CONTACT
EACS Ltd.
1-3 Harvard Way
Kimbolton
Cambridgeshire
PE28 0NJ

tel: 0800 8047 256
email: information@eacs.com

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