Moving Uncompressed Video Faster than Real Time

Don Deel, Marc Friedmann and Howard Green

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Moving Uncompressed Video Faster Than Real Time

By Don Deel, Marc Friedmann, and Howard Green

Economic methods are now available to move production and post-production data faster than real time in networked environments. Using ANSI-standard Fibre Channel serial interfaces on Silicon Graphics workstations and servers with optimized hardware and software, computer-to-disk and disk-to-disk communications have been demonstrated to transfer digital image data at a sustained throughput up to 600 Mbits/sec. Incorporating these interfaces, production and post-production facilities are achieving order-of-magnitude improvements in response time when accessing and transferring large files. Video server applications can use these interfaces for both storage access and communications for transporting up to 100 compressed streams simultaneously through a single port.

Fibre Channel is an inexpensive, expandable interface standard defined to achieve faster-than-real-time digital video data transfers among servers, workstations, disk drives, scanners, recorders, and displays. Fibre Channel combines the best attributes of a channel with those of a network through a simple technique: it transfers data between a buffer at the source device (e.g., a video server) and another buffer at the destination device (e.g., a workstation). Fibre Channel ignores the data itself and how it is formatted and simply takes what is in the sending buffer and transports it to the receiving buffer. Able to operate with multiple protocols simultaneously, Fibre Channel is an excellent interface for environments involving a wide variety of computing and video equipment.

An adapter card provides Fibre Channel connectivity for Silicon Graphics Indigo2 and Challenge M computers, which support the 64-bit version of SGI's Graphical I/O (GIO) Bus. Performance-enhancing hardware and software techniques result in the very highly sustainable throughput performance necessary for faster-than-real-time digital video data transfers. Occupying a single bus slot and providing either one or two independent, fully functional Fibre Channel ports, the hardware for the adapter card has been optimized for high data throughput.

Specific emphasis is placed on high-performance software. Innovative software facilities called "Transporter" and "IOFS" (input/output file system) offer throughput performance improvements for transfers of large video data files. Transporter is a protocol for making very efficient memory-to-memory data transfers between computers. IOFS is a file access protocol that uses Transporter to provide enhanced network access of files over Fibre Channel. These facilities will be discussed later in this paper.

The Need to Move Data Faster

With the advent of nonlinear editing, video servers, graphics special effects, and compositing, computers now play an increasingly important role in the movie and video production and post-production environment. They reside directly in the production and revenue flow, being ever more broadly used to automate and accelerate functions such as painting, retouching, rotoscoping, color correction, titling, image repair, glass painting, and wire removal. As computer capabilities advance and the number of computer-literate artists grows, project size has increased and the need for broad-based artistic collaboration has risen rapidly. Rapid and responsive communication between computer-based artists, editors, and producers is becoming a critical factor as the ramp-up in digitally processed images accelerates.

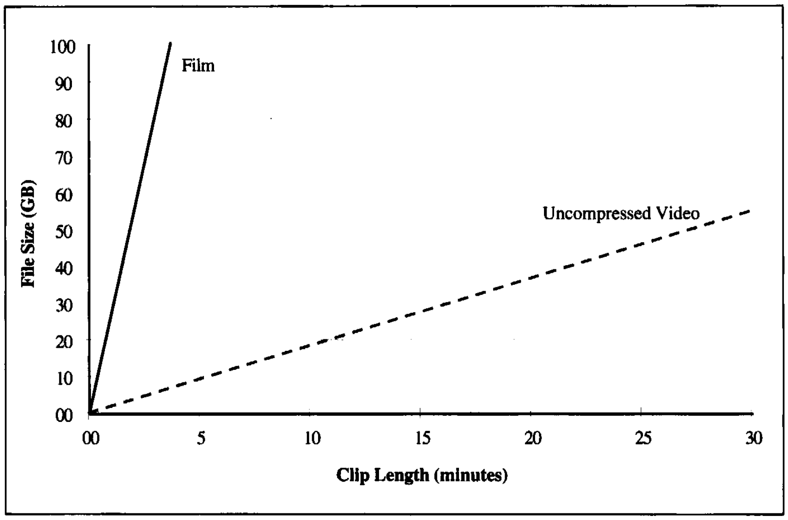

Figure 1. Digitized film and digital video file size.

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When translated to digital format, the video images used in studio applications are among the most data intensive. At 1 to 40 Mbytes/frame, even a clip of a few seconds in length rapidly grows to more than a gigabyte file (Fig. 1). Moving files this size from central storage or to a collaborator using traditional networks can take 10 min or more, and real-time viewing of uncompressed digital video stored on remote servers has not been possible. Production and post-production requirements are rapidly exceeding the limits of traditional network approaches and are driving the need for new network solutions. These solutions must address both hardware and software performance bottlenecks in computer-to-computer and computer-to-disk communications.

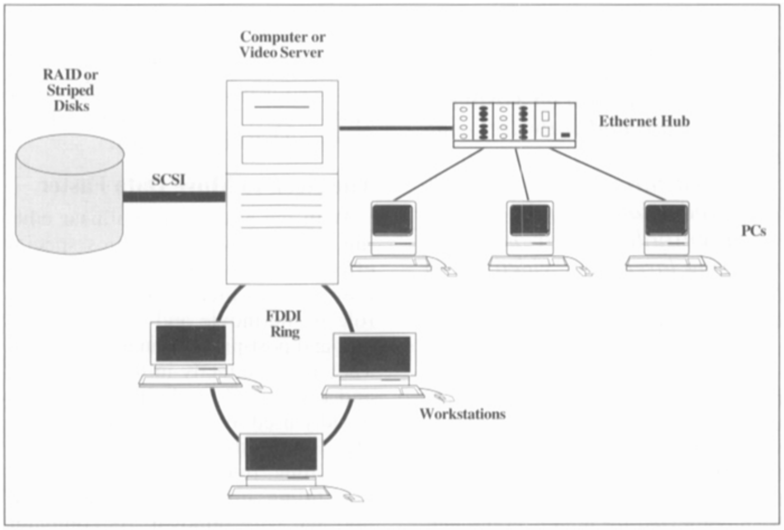

Figure 2. Client-server architecture.

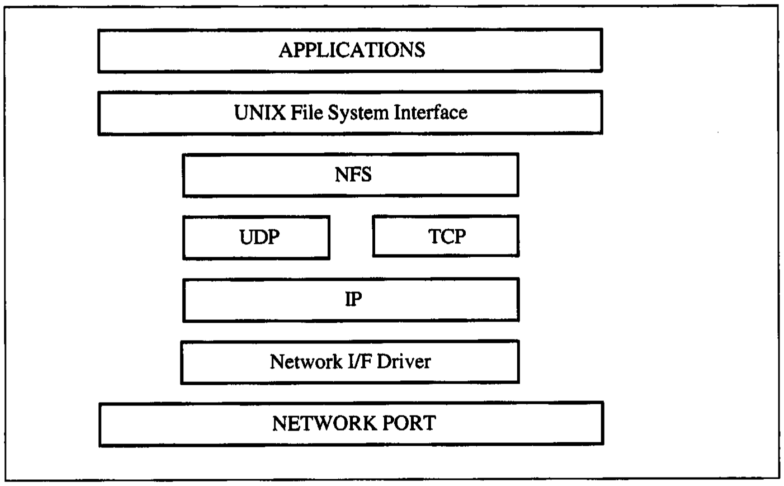

Figure 3. IP-based NFS protocol stack.

Table 1 — Network Line Rate vs. Throughput

Network Standard	Line Rate (Mbits/sec)	Throughput (Mbits/sec)
ATM	155	80
FDDI	100	30
Ethernet	10	1

Traditional Network Approaches

Faster-than-real-time access to uncompressed digital video data stored in large disk-based files is becoming a key objective in today's studios. Using either the traditional computer or video server approach, many studios have adopted the popular client-server architecture, which centralizes storage access through a large, high-speed processor (Fig. 2). Local workstations access files through the server, which delivers them to local memory or disk. Centralized storage attached to the server can be quite large, frequently exceeding one terabyte, while local storage may be a few gigabytes. Interface from the server-to-storage must be as rapid as possible and is therefore generally in the form of striped disks or a redundant array of inexpensive drives (RAID). To maximize performance, fast/wide SCSI is used for the server to storage connection. This yields transfer rates approaching 20 Mbytes/sec, which is well below the 34 Mbytes/sec required for uncompressed real-time digital video.

File access across the network is in a packetized format using Internet protocol (IP)-based file transfer protocol (FTP) or network file system (NFS) (Fig. 3). While the use of NFS is straightforward and offers flexible file access, its small packet sizes (typically less than 8 kbytes) and the considerable management of each packet by the operating system significantly reduces data throughput rates. Since FTP procedures are disk-to-disk transfers, they are limited to the throughput rate of the slowest disk interface involved. Applications seeking performance higher than NFS or FTP may use the UNIX remote procedure call (RPC) directly, which operates as a much faster computer memory-to-

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memory transfer. However, even RPC-based transfers are ultimately limited by the transfer rate capability of the network.

Today's computer-based studios generally use Ethernet or FDDI for network communications. To improve throughput, some installations are beginning to experiment with ATM. Ethernet, FDDI, and ATM local area networks have been optimized as enterprise-wide networks, which are dominated by small message traffic rather than the large block transfers common with digital video files. Although specified line rates may range from 10 to 155 Mbits/sec, the combination of network and file system structures yields an observed actual throughput of 1 to 80 Mbits/sec under moderately loaded conditions (Table 1). Transfer of a gigabyte file, common in studio environments, requires two minutes to two hours at these data rates. As the number of editors and artists using workstations within a facility continues to grow, the load is rising and the need for much higher speed networks is increasing dramatically.

Table 2 — Fibre Channel Features

Feature	Fibre Channel
Line rate	266, 531, or 1062.5 Mbits/sec
Data transfer rate	640-720 Mbits/sec
Frame size	2112-byte payload
Protocols	SCSI, IP, ATM, SDI, HIPPI, 802.3, 802.5
Topology	Loop, switch
Data integrity	10E-12 BER
Distance	Local and campus; up to 10 km

Faster-Than-Real-Time Interfaces

Of the new generation of interfaces, Fibre Channel offers the highest performance. Approved as an ANSI standard, Fibre Channel is a scalable interface defined to achieve high-speed data transfers among workstations, personal and large computers, disk drives, peripherals, and display devices. Using either loop or switch-based topology, it combines attributes of SDI-like channels with packetized computer networks over a serial interconnect capable of operating across campus-wide distances. Having the ability to support multiple protocols simultaneously, Fibre Channel is a hardware-intensive interface for environments involving a wide variety of computer, disk, and studio equipment. Key technical features of Fibre Channel are summarized in Table 2.

The Fibre Channel structure is defined as a multilayered hierarchy of functional levels. Five layers define the physical media and transmission rates, encoding scheme, framing protocol and flow control, common services, and the upper layer application interfaces (Fig. 4). FC-0, the lowest layer, specifies the physical features of the media, connectors, transmitters, and receivers, including electrical and optical characteristics, transmission rates, and other physical elements of the standard (Table 3). Note that video coax and the 1300-nm, single-mode fiber found in broadcast facilities are incorporated in the standard. FC-1 defines the 8B/10B encoding/decoding scheme used to integrate the data with the clock information as required by serial transmission techniques. FC-2 defines the rules for framing the data to be transferred between ports, a look-ahead sliding-window flow control scheme, different mechanisms for circuit and packet-switched classes of service, the error-detection techniques, and means of managing the sequencing of data transfer. FC-3 provides common services required for advanced features, such as striping and hunt groups. FC-4 provides the seamless integration of existing standards by accommodating a number of other protocols such as SCSI, TCP/IP, FDDI, HIPPI, SDI, ATM, Ethernet, and Token Ring.

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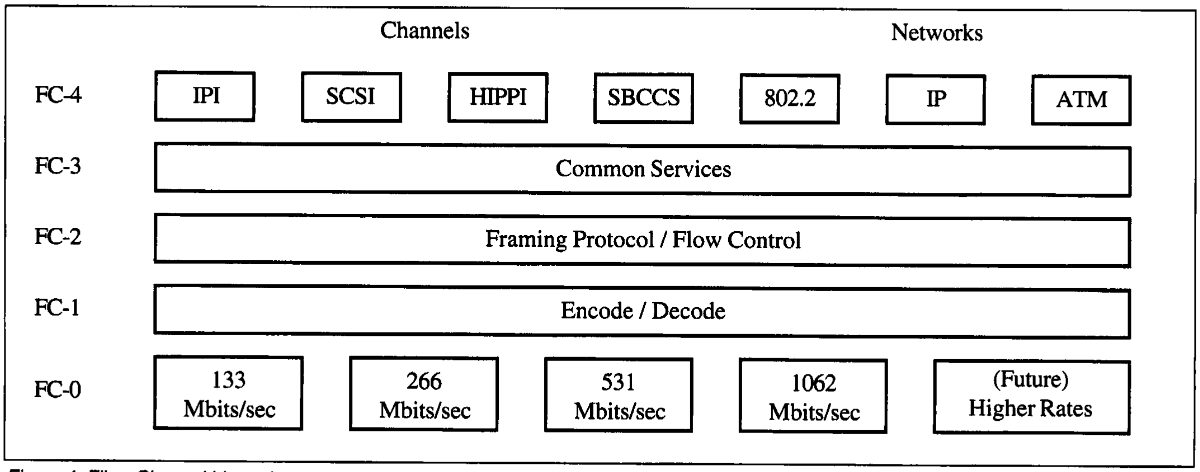

Figure 4. Fibre Channel hierarchy.

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Table 3 — Fibre Channel Media

Medium	Maximum Distance	Data Rate (Mbits/sec)	Signal
Single mode fiber	10 km	266, 531, 1062	Long-wave laser
50-μm multimode fiber	2 km	266, 531, 1062	Short-wave laser
67-μm multimode fiber	1.5 km	133, 266, 531, 1062	Long-wave LED
Video coax	100 m	133, 266, 531, 1062	ECL
Miniature coax	35 m	133, 266, 531, 1062	ECL
Shielded twisted pair	100 m	133, 266	ECL

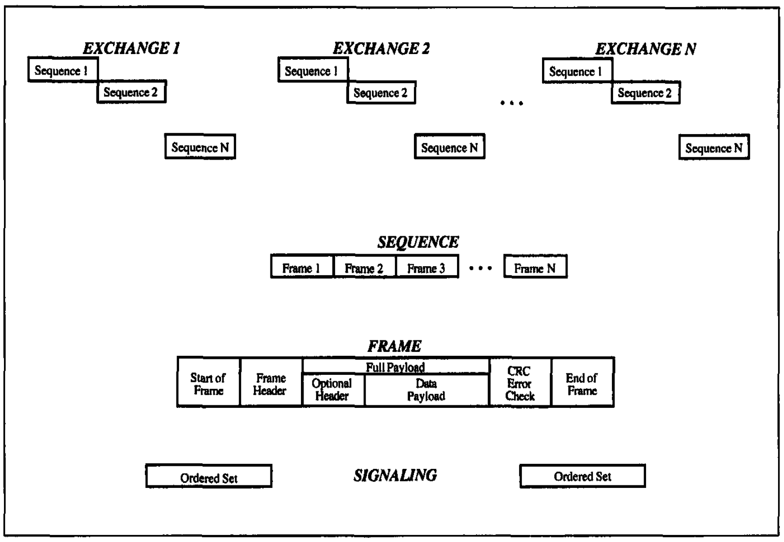

Figure 5. Fibre Channel communications structure.

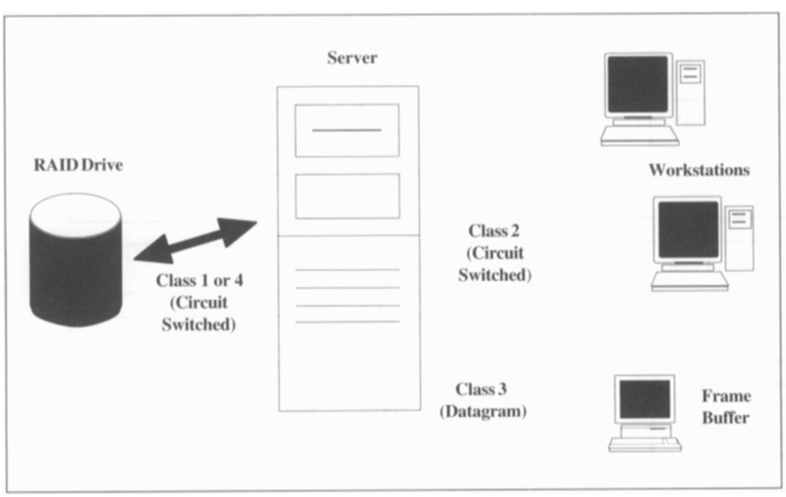

Figure 6. Fibre Channel classes of service.

Fibre Channel combines the best attributes of a channel with those of a network through a simple technique: it provides a means to transfer data between a buffer at the source device (e.g., a video server drive) and another buffer at the destination device (e.g., a workstation or frame buffer). Fibre Channel ignores the data itself and how is formatted, and simply takes what is in the sending buffer and transports it to the receiving buffer at the full bandwidth of the channel. After initial handshaking, control of the rate of data flow is handled by the receiving device indicating the amount of available memory buffer available. This low-level flow control allows Fibre Channel to avoid any data loss due to congestion. Simple error correction is handled in hardware, much like a channel. If a data transfer fails due to an error, then a retry occurs immediately without consulting system software, thus maintaining above real-time performance.

Fibre Channel has four levels of communication across the links (Fig. 5). *Signaling* occurs via ordered sets, which are sets of four 10-bit characters used for such functions as start-of-frame, end-of-frame, link start-up, and special user-defined commands. A *frame* is the smallest undivided packet of data sent over the connection. Each frame consists of a start-of-frame delimiter, a frame header, an optional payload header, a data payload holding up to 2048 bytes, a 32-bit CRC, and an end-of-frame delimiter. A *sequence* is composed of one or more related frames flowing in the same direction on a link. Sequences constitute the key unit of transfer between

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