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**ITU-R**  
Radiocommunication Sector of ITU

**Report ITU-R BT.2268**  
(05/2013)

**Integration of an SDI infrastructure  
with an IP-based infrastructure**

**BT Series**  
**Broadcasting service**  
**(television)**



International  
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*Note: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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## REPORT ITU-R BT.2268

**Integration of an SDI infrastructure with an IP-based infrastructure**

(2013)

**Summary**

The broadcasting and related production and post-production industry sectors are rapidly migrating from a serial digital interface (SDI) infrastructure to file transfer infrastructure. In addition there is a desire to replace serial digital interface technology with Internet Protocol technology utilizing available network structures and hardware.

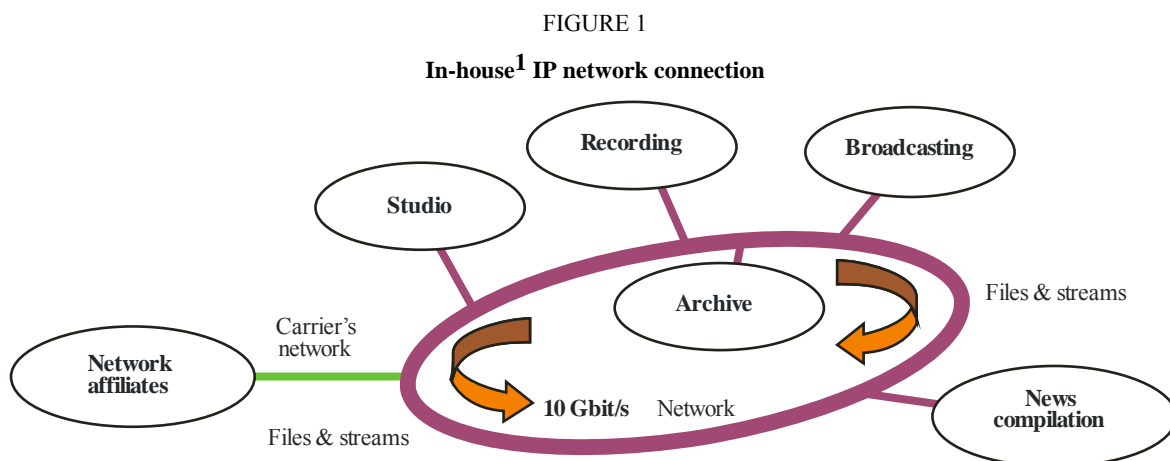
ITU-R Study Group 6 (Working Party 6B) is interested in establishing a pool of information that could result in new Recommendations. This new report represents a use case implementation of an IP based distribution as part of a hybrid SDI installation.

**1 Introduction**

This Report is the first use case dealing with the IP (Internet Protocol) implementation in the professional broadcasting environment.

A circuit control centre works as a gateway of a broadcasting station to manage signals incoming to and outgoing from the station and to distribute signals to in-house destinations as well as to outside network affiliates.

An IP network technology, which requires that every signal be presented in an IP compatible format, handles streams and files in a unified manner. Figure 1 illustrates various destinations in a broadcasting station that are connected with an IP network, the connection which is represented by a pink solid line.



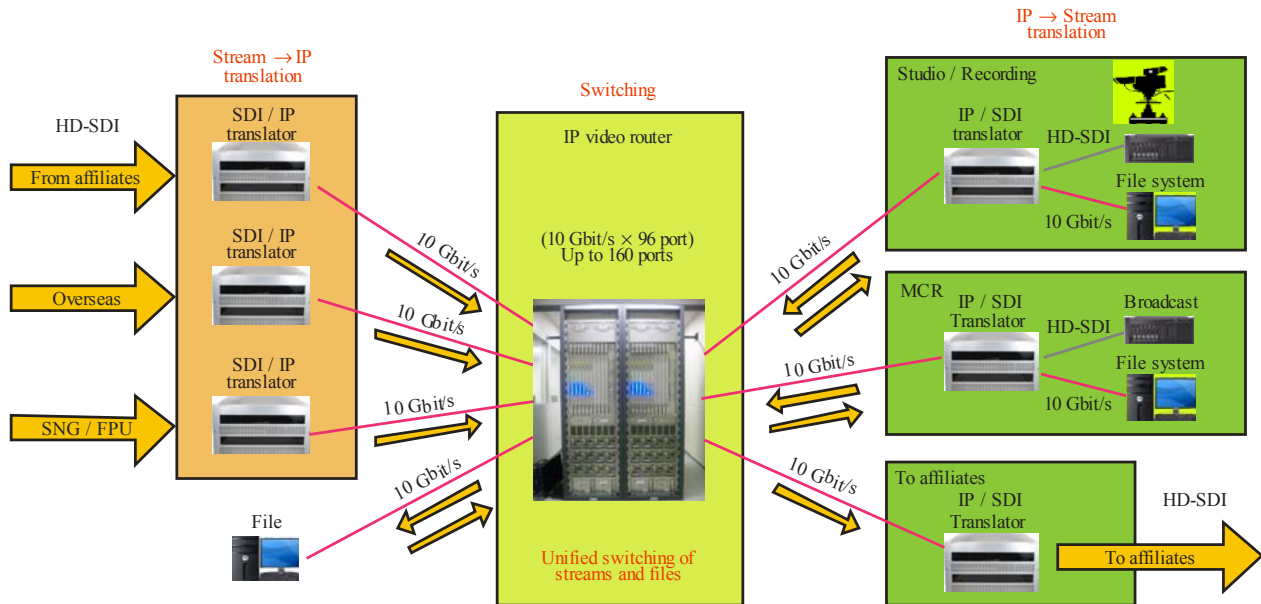
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Specifically, a 10 Gbit/s IP network was built in the station centred on new Layer-2 switchers (hereinafter called IP video router) installed in the circuit control centre (hereinafter called the

<sup>1</sup> In-house as used in this Report is intended to indicate interfaces as used or implemented by a single company.

centre). The IP video router, with the switching capability of 3.2 Tbit/s, switches streams and files in a unified manner while not adversely affecting real time streams. Signal flows surrounding the IP video router are illustrated in Fig. 2.

FIGURE 2  
Signal flows in the circuit control centre



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### 1.1 Stream switching

Video and audio signals that reach the centre first undergo necessary processes (e.g. level adjustment and format conversion) in the stream domain, and then they are encapsulated into Ethernet frames, where up to five uncompressed HD-SDI signals are multiplexed into a single stream of 10 Gbit/s Ethernet frames. The Ethernet frames are then duplicated and fed into two IP video routers which switch them to specified destinations. Every destination reproduces the original video and/or audio signals from the received frames and sends them out after the station-level clock synchronization.

Each destination can also convert its own programme contents into IP frames to pass to the IP video router for distribution.

A stream switching path is established statically on the basis of a set of operator commands issued at one of the destinations or a set of scheduled instructions generated in the centre.

With an approximately 1.2 ms of IP encapsulation time, the maximum stream delay within the centre system including the time for level adjustment, frame synchronizer processes, etc. does not exceed 34.7 ms.

## 1.2 File switching

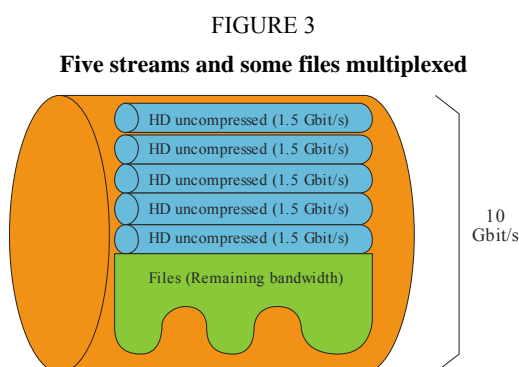
The IP video router is a Layer-2 (the data link layer in the OSI reference model) switcher to perform switching on the basis of such information as MAC addresses, VLAN Tag (IEEE802.1Q), RSTP (rapid spanning tree protocol, IEEE802.1w), and priority tag (IEEE802.1p). File transport paths are dynamically established in accordance with the switching table information, which is automatically updated to reflect the ever-changing connection status.

Connections between the IP video router and the outside file systems are either direct or via the IP/SDI translator, but the interfaces are the same 10 GBASE-LR. In case of the direct connection where one port of the IP video router is exclusively used for file transport, a 10 Gbit/s bandwidth is always available. In the case of the connection via the destination IP/SDI translator, on the other hand, only the unused bandwidth (of 10 Gbit/s) by stream transport can be allocated to file transport, and therefore the available bandwidth for file transport dynamically changes depending on the number of multiplexed streams.

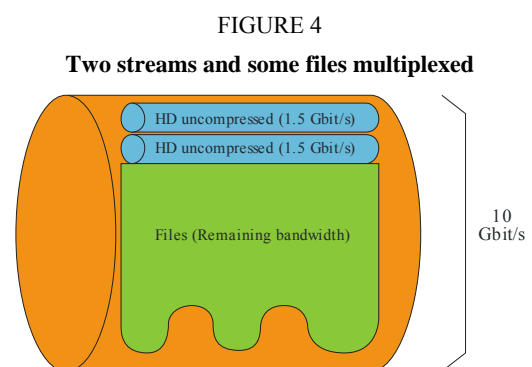
## 2 Key design feature

### 2.1 Stream/File compatibility with Quality of Service (QoS) technology

The stream/file compatibility is achieved by using a QoS technology based on the previously mentioned VLAN Tag and priority. VLAN IDs are separately defined for streams and files, and the highest priority is given to the stream frames. This scheme allows priority control and bandwidth management so that no stream frames can be discarded during traffic congestion. Streams are serviced by a bandwidth-guaranteed service in which necessary bandwidths are always available, and files are serviced by a best-effort service in which only an unused bandwidth by streams can be allocated to files. This centre system consists of hundreds of switches simultaneously performing these two types of switching. Figures 3 and 4 illustrate streams and files multiplexed into a single 10 Gbit/s bandwidth.



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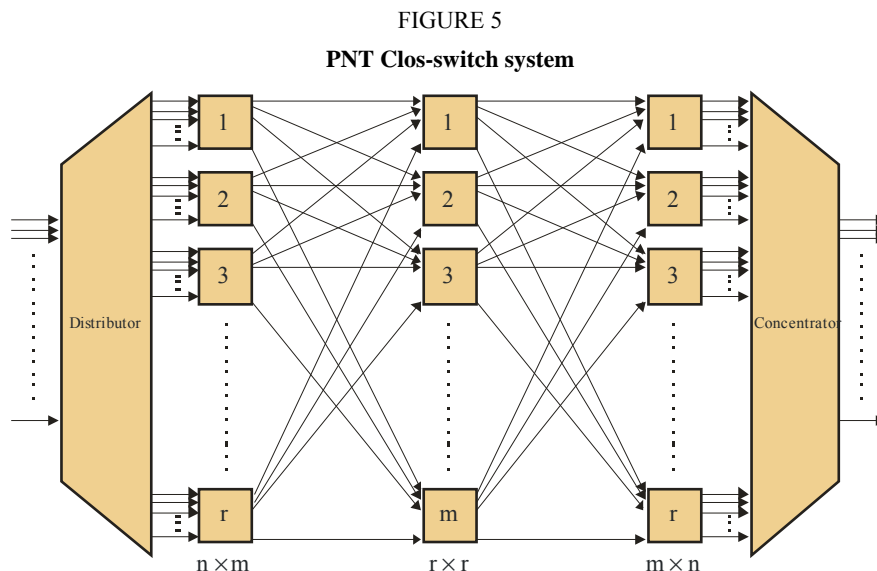
### 2.2 Stream continuity under multi-sourced, multicast environment

It is mandatory in a broadcasting station to be able to distribute a programme material to multiple destinations. That is to say a multicast mode of network operation is required. Moreover, the destinations frequently vary depending on the contents or programmes, and even an instantaneous disruption of delivery is not acceptable. To satisfy such requirements under the multicast mode of operation, a new transport path needs to be established and an obsolete path

needs to be released without causing any frame loss in any operating paths. Furthermore, a 10 Gbit/s input port accepts up to five multi-destination HD streams, and a 10 Gbit/s output port delivers up to five multi-sourced HD streams. Continuity needs to be ensured over all such HD streams passing through the IP video router.

As a typical switching technology, there is the Clos-switch system, a multi-stage switching system proposed by Charles Clos in Bell Telephone Laboratory in 1953 that consists of multiple stages of small switches. However, the Clos-switch system does not strictly ensure the stream continuity under the multi-sourced, multicast application environment. For the IP video router to solve this problem, a distributor function in the input stage and a concentrator function in the output stage were developed and integrated with a new unique path selection algorithm.

With these technologies, the perfect non-blocking technology (PNT) Clos-switch system was successfully fabricated to ensure the continuity (non-blocking) of streams under the multi-sourced, multicast application environment, thus fully satisfying the requirements of broadcasting stations. At the same time the total number of switches was successfully reduced to allow a minimal configuration that could not be achieved under the concept of the conventional Clos-switch system. Figure 5 illustrates the scheme of the PNT Clos-switch system.



### 2.3 Fast path-selection algorithm

To perform a high speed, time-controlled stream switching, an optimal available path must be found under the current state of connections immediately. For this project, a fast path selection algorithm was developed to satisfy the requirement, with which a path search engine runs in the IP video router with the privilege of supervising and managing the entire system performance. Our measurement shows that more than 10,000 paths can be searched every second to enable a microsecond order high-speed switching.

## 2.4 Station-level clock synchronization at the destinations

The conventional system-design for broadcasting stations has generally required the station-level clock synchronization of video streams to be performed at the stage of signal input. On the basis of the design, a row of TV frame synchronizers have been installed in front of a circuit switching system to synchronize all the externally supplied signals to the in-house synchronizing signals. These synchronized signals are then distributed to their in-house destinations.

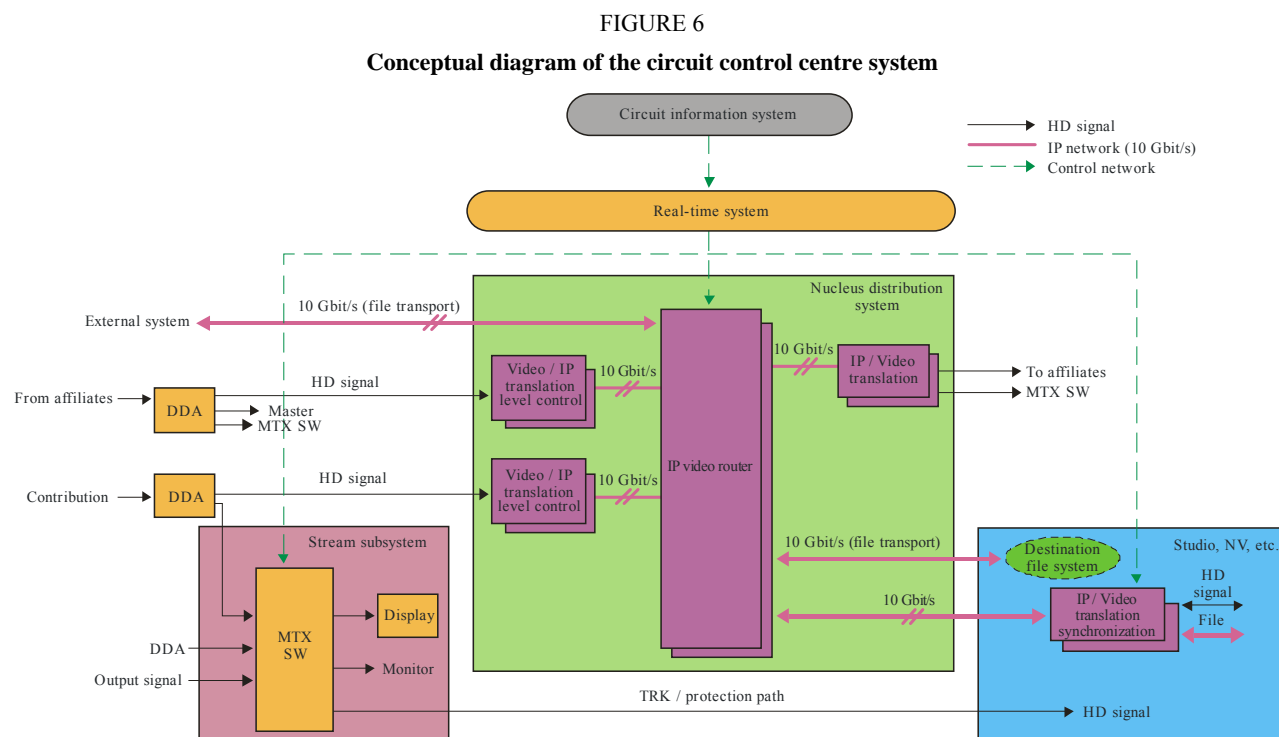
Because the IP-transport-induced wander varies the signal phases and the facility space is preferably made as small as possible, the frame synchronizer function was developed and implemented within each destination device to correct any network timing issues.

## 3 Elements of the centre system

Figure 6 illustrates the conceptual diagram of the centre system. The DDA passes the stream input to both the nucleus distribution system and the Matrix switcher ( $576 \times 576$ ) which, is a primary monitoring point, and can compare the input stream before IP encapsulation with the reproduced output stream. The output stream can then be routed to studios, other in-house destinations or outside network affiliates.

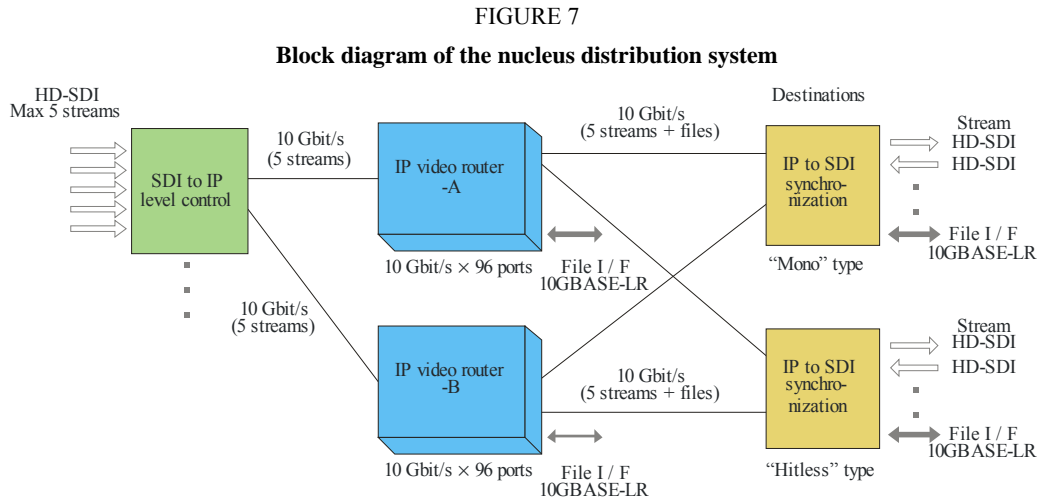
The centre system handles all streams in a standardized format, HD-SDI (1080/59.94/I). All stream inputs other than in the standard format are converted into the standard format at the input to the centre system.

The file inputs are fed to one of the dual IP video routers either through a dedicated 10 Gbit/s port or through a shared port, and distributed to a target file system through a dedicated 10 Gbit/s port or through the IP/SDI translator installed in the destination.



### 3.1 Nucleus distribution system

The nucleus distribution system consists of multiple SDI/IP translators to convert HD-SDI signals into IP frames, dual IP video routers to switch IP frames to destinations, and IP/SDI translators installed at every destination to perform two-way conversion between IP frames and HD-SDI signals. Figure 7 illustrates the nucleus distribution system.



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#### 3.1.1 SDI/IP translator

The SDI/IP translator translates HD-SDI signals into IP frames. A chassis of SDI/IP translators (with eight slots) can translate up to 40 streams simultaneously. A total of seven chassis are installed in the nucleus distribution system. Up to five (5) translated streams are then multiplexed into a group and output in a 10-Gbit/s (10GBASE-LR) data rate, which is duplicated and fed to the IP video routers –A and –B. The SDI/IP translator has a video and audio (eight out of 16 channels) level control capability which can be remotely controlled from the centre operation room. The SDI/IP translator also has capabilities of audio permutation and mixing (with down mixing) and can process Dolby-E signals if the level control is bypassed.

IP frames are generated with the Reed-Solomon code appended and interleaved to enhance robustness against possible bit errors in the communication channel.

#### 3.1.2 IP video router

The set of two IP video routers works as a core of the centre. With the maximum installation of  $160 \times 10$  Gbit/s ports, each unit is a huge Layer-2 switcher to have a 3.2 Tbit/s switching capability. In terms of HD-SDI signals, the unit can switch 800 input HD-SDI signals into 800 output HD-SDI signals.

Though each of the current installation is  $96 \times 10$  Gbit/s ports (1.92 Tbit/s), the capacity can be easily expanded by inserting additional boards. The unit consists of IOSW (to interface with SDI/IP translator and an IP/SDI translator), MIDSW (in to out switching), and CPU CNT (controller). The physical port interface with a SDI/IP translator or IP/SDI translator unit is a 10GBASE-LR optical fibre.

#### 3.1.3 IP/SDI translator

The IP/SDI translator consists of 10G-Ethernet, SW-CNT, Rx, Tx, and 10G-Hub boards and has a two-way translation function between IP frames and HD-SDI signals.



The 10G-Ethernet board interfaces with IP video routers through 10GBASE-LR, and the SW-CNT board switches IP frames between the Rx/Tx and 10G-Ethernet boards.

The Rx board has the function to translate IP frames into an HD-SDI signal to output after the frame synchronizer process to the studio or another destination. There are two output modes: one is a “Mono” mode, and the other is a “Hitless” mode. In the “Mono” mode, up to 10 independent streams can be output per chassis, five from the IP video router –A, and five from –B. In the “Hitless” mode, the Rx board receives two identical streams from the primary and protection paths so that it can continue output without any picture disruption when the primary path is in failure.

The mode is used for critical transmission to, for example, the master control room or network affiliates. Up to five streams can be output per chassis under this mode. The output supports a 16 channel audio as well as Dolby-E audio with the frame synchronizer process bypassed. The Tx board has a function to translate an HD-SDI signal from a studio into IP frames for transmission to IP video routers. Up to five streams per chassis can be processed. When a stream needs to be passed from one studio to another, it must go through the IP video routers with SDI to IP and IP to SDI translation.

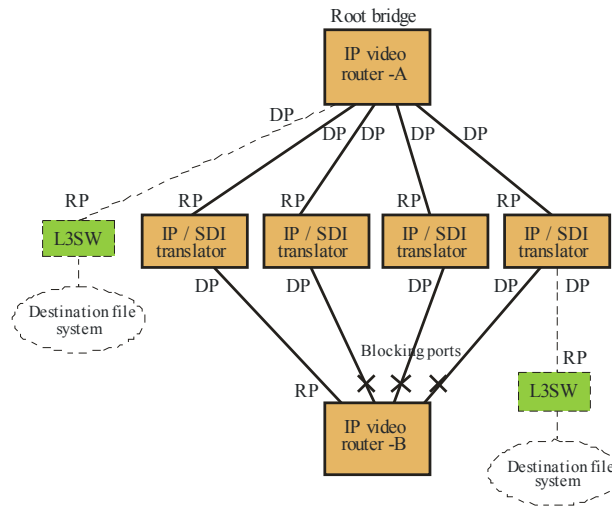
#### **3.1.4 Files**

The nucleus distribution system works as a Layer-2 IP network to switch and transport streams and files in a unified manner. The system design and verification tests of this challenging concept required various kinds of un-proven approaches. Much of our work to accomplish the development was successful only by trial and error.

To secure redundancy a loop is generally formed in such a network, but in our case it is mandatory to avoid any loop to prevent a possible broadcast storm that may disturb communication within the network. The spanning tree protocol (STP) ensures a loop does not form, but it interrupts communication for tens of seconds when the network topology changes. To avoid this difficulty, we used the rapid spanning tree protocol (RSTP) in the system to minimize such interruption time. Figure 8 illustrates the example connections in the system in a tree structure from an IP network viewpoint.

Under this structure the priority value of bridge ID (BID) is managed on the basis of the information in the bridge protocol data unit (BPDU) so that the IP video router-A can stay as a root bridge. Furthermore, on the basis of the path cost, root ports (RP), designated ports (DP), and blocking ports are determined as shown in Fig. 8.

FIGURE 8  
Connection example for file transport



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When connecting a destination file system to the nucleus distribution system, a Layer-3 switch (L3SW) is inserted between them to segment the network into two parts because of the security control consideration. The major control parameters include:

- VLAN ID (IEEE802.1Q)
- VLAN priority (IEEE802.1p)
- RSTP parameters
- Bridge ID priority
- Frame size and
- Storm control.

For the network behaviour and performance verification, we finally picked up the following items for the test or measurement after various trials:

- Throughput
- Available bandwidth subject to the change of the number of streams
- System delay
- Priority control
- Disposition of invalid frames
- Flooding impact on streams
- Path re-establishment due to the network topology transition and
- RSTP convergence time.

It is confirmed that the network topology change did not affect the performance of streams at all. In this connection, the root bridge change from IP video router -A to -B, which is a kind of topology change, does not affect the operation of streams and files.

The system delay on the root IP/SDI translator → IP video router → IP/SDI translator is 240 microseconds with the frame size of 1 500 bytes. With respect to the convergence time of RSTP, the development of which took the longest time in this project, it was finally reduced down to about three seconds after a topology change.