# IIJ Initiatives Following the Advent of IP-Enabled Broadcast Equipment

The Tokyo 2020 Olympic and Paralympic Games will be held just five years from now. Five years ahead may seem like a lot of time, but the athletes that wish to compete there must incorporate each and every year into their strategy. Outside the world of sports, the same could be said for the systems supporting the Olympic and Paralympic Games. Prime examples of this are the 4K and 8K broadcasts that are currently being pushed from the experimental towards mainstream adoption. Unlike the Internet, where the pace of development is said to be measured in dog years, the evolution of legacy broadcasting systems requires time, coordination, and innovation. Here we will examine the advent of IP-enabled devices, which are making waves in the world of broadcasting.

Below we show a diagram of a broadcasting system, using sports relay broadcasts as an example (Figure 1). Footage of events held at stadiums or other venues must of course be shot and recorded. It is then necessary to transfer the footage shot at the venue to the broadcaster so that it can be made into a program and provided for broadcast or online streaming. When broadcasting at a later date, you can simply transport the memory card or hard disk from the camera the footage was shot on, but this is not possible for relay broadcasts. As video editing (the addition of captions, etc.) is also carried out at the broadcasting office, video must be transferred to the broadcaster in real time while retaining the highest quality possible. Broadcasters use a range of techniques to achieve this. Typically, base stations and relay stations for microwave or satellite relay are set up. Cheap, consumer access lines are used for devices such as weather cameras, and in emergencies mobile carrier data communication is also sometimes employed. Another alternative is purchasing a dedicated line service for video from a communications carrier. Generally, more stable methods are preferred when the emphasis is on quality, while portability is preferred when speedy reporting is a higher priority. This form of networking, in a broad sense, is called “contribution” in the industry. In contrast, the delivery of footage from the broadcaster to viewers by way of terrestrial waves, BS, CS, or OTT is known as “distribution.”

The physical media used for contribution and for transfer within broadcasting offices is the coaxial cable. This is the same technology that connects the antenna to your TV at home. The coaxial cable was invented in the 19th century, and it excels at the transmission of high frequency signals. It was once even used for Ethernet for a time (10BASE2, 10BASE5). This technology is also still widely used in the radio and video fields. At broadcasters it has been used to transmit video since the old analog days, and to this day it handles the transmission of full HD video via a standard called SDI (Serial Digital Interface).

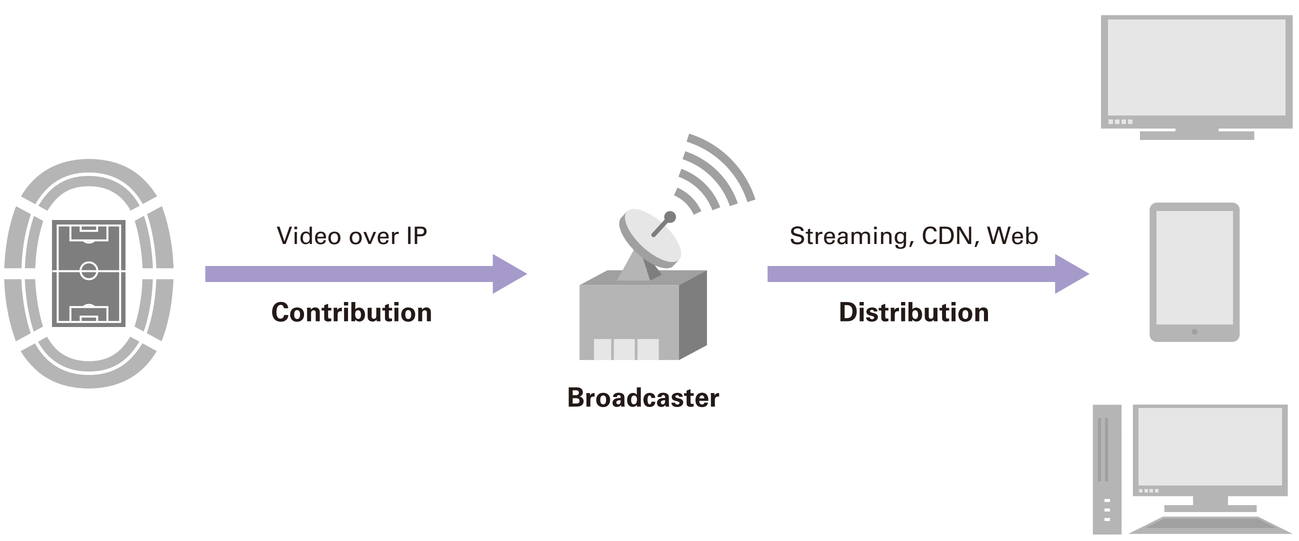


Figure 1: Broadcaster-Centric Contribution and Distribution

There are moves to seek a successor for stable technology like this that is past its prime, stemming from the shift to 4K and 8K broadcast video. These video formats result in extremely large volumes of data when compression is not used. For example, 4K uses four times as much data as full HD video. Currently, transmitting 4K video by coaxial cable would involve dividing the screen into four quadrants, resulting in the need for four coaxial cables. Coaxial cables are heavy and hard to handle, so if four of them were required, it would certainly be more difficult to manage them. It has also been pointed out that coaxial cables would be stretched to the limit with respect to the high frequency characteristics required to transmit large amounts of data such as 4K/8K video signals.

As a result, the focus has shifted to optical fiber. This technology has spread like wildfire in the communications industry over the past decade or so. It is used for the internal wiring of NOC and data centers, as well as in home network connections, as demonstrated by the term "FTTH," which stands for "fiber to the home." As it is less likely to be affected by electromagnetic waves, and more than capable of transmitting large amounts of data, it is being used in broadcasting and video devices more and more these days. As indicated by the "SDI" (serial digital interface) standard name, the video signal is digital data, so in a sense the barrier between broadcasting and data communication has already been broken down. It is said that in the near future fiber will take the place of the physical media used for transmission with broadcast equipment.

The adoption of optical fiber in broadcasting and communication devices will also trigger further changes to upper layer protocols. Until now SDI was considered a key component of broadcasters and their ecosystems, but more and more people are suggesting that broadcasting ecosystems will eventually migrate to IP-based systems. At the International Broadcasting Convention (IBC) held in Amsterdam in September 2013, one company displayed posters on site proclaiming in large letters that "SDI must die." In a way, this message could be interpreted as self-rejection of the industry, but I remember feeling a sense of anticipation for the upcoming technology that is set to blaze new trails in the near future.

In the U.S., broadcasting standards are determined by an organization called the SMPTE (Society of Motion Picture and Television Engineers). The SMPTE has begun recommending "SDI over IP" technology in its standards. These are discussed and evaluated by an industry group called the Video Services Forum (Table 1).

| Standard | Title |
|---|---|
| SMPTE 2022-1 | Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks |
| SMPTE 2022-2 | Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks |
| SMPTE 2022-3 | Unidirectional Transport of Variable Bit Rate MPEG-2 Transport Streams on IP Networks |
| SMPTE 2022-4 | Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks |
| SMPTE 2022-5 | Forward Error Correction for High Bit Rate Media Transport Over IP Networks |
| SMPTE 2022-6 | Transport of High Bit Rate Media Signals over IP Networks (HBRMT) |
| SMPTE 2022-7 | Seamless Protection Switching of SMPTE ST 2022 IP Datagrams |

**Table 1: SMPTE Standard 2022 Series Titles**

Products supporting the SMPTE 2022 standards have rapidly increased over the past year. They continued to gain momentum at the NAB Show held in Las Vegas in April 2015, as well as at the IBC held in Amsterdam in September this year. Leading broadcast equipment manufacturers such as Sony, Evertz Microsystems (Canada), and Grass Valley (United States) have all adopted SMPTE 2022, not only due to the standards supporting 4K/8K, but also because they sense the potential of video transmission using IP networks, and want to lead the industry in that field. In Japan, companies such as Sony, Media Global Links, and PFU have also begun supporting SMPTE 2022.

This kind of “SDI over IP” will first start from local areas. I believe that the scope will be limited at first, only covering individual chassis or racks. That said, coverage will soon go beyond the rack, until an SDI over IP network in the form of a local area network that spans an entire floor is realized. This is the scope covered by the coaxial cable networks that IP networks are set to replace.

However, the true potential of IP networks lies in internetworking. In most cases, office and campus networks over a certain size are generally comprised of a number of interconnected networks. When networks are associated with a variety of groups and purposes, dividing up the network clarifies its usage, allowing people to connect without sacrificing user-friendliness. The exact same thing could be said of video networks. Remote networking is another major advantage that IP networks have. This allows remote locations and local area networks to be interconnected. The Internet is a typical example of this, and it goes without saying that this opens up new worlds of possibility for video networks as well.

Transmitting uncompressed 4K video over IP networks is no easy task. For 13 Gbps of bandwidth, two 10 gigabit Ethernet lines would be required. That is where compression technology comes into play. Currently, the JPEG 2000 (J2K) format is popular in Europe and the United States. This is a lossy compression format, but it is said to achieve “visually lossless” compression with about 800 Mbps of bandwidth. Bringing the bandwidth under 1 Gbps makes the IP transmission of 4K video a real possibility. The use of two 10 gigabit Ethernet lines would entail enormous costs, but making a 1 gigabit Ethernet line viable enables the selection of multiple reasonable services using low-cost network devices.

The potential of IP networks has already been explored with weather camera transmissions and on-the-spot broadcasts using portable networks. Relay broadcasts from remote locations that were either expensive or somewhat limited in the past will soon be easily achievable. In fact, devices such as weather cameras are now growing in popularity as equipment for casual users. Systems integrators combine components that already exist around the world, rather than designing large-scale systems themselves. This approach is commonly seen in the Internet age. I think the ongoing success of this approach has led to the dynamic shift towards IP-enabled broadcast devices.

From the perspective of broadcast equipment manufacturers, the move to IP-enabled devices has created an urgent need to choose a way forward, as they must incorporate new technology such as fiber optics and IP in addition to the SDI technology they already have experience with. IP ties into the key components of broadcast equipment, so the question of how to tackle it is probably tricky to answer. Broadcast equipment features devices called routers that are separate from the IP components. As the name suggests, these determine the pairing of video sources and destinations, and it is necessary to construct the video routing function at a level above the IP switch device. This requires in-depth knowledge of both application layers and transport layers.

One company taking an aggressive approach is Evertz Microsystems. They have advocated a concept known as the "Software Defined Video Network (SDVN)" for the past few years, and they are making progress with the implementation of IP technology on their equipment. Although it borrows from previous concepts, they are really creating an SDN for themselves. This intrigued me, and I took the opportunity to interview engineers in charge of SDVN at Evertz Microsystems. They originally worked in video engineering, but told me they began acquiring Ethernet and IP technology from around 2010 as part of company policy. I believe they have the advantage of being able to comprehensively design and implement IP and video layers.

Meanwhile, at the NAB Show in 2015, Grass Valley announced they were partnering with Cisco Systems, a leader in the network industry. Many manufacturers also partnered up with companies like Juniper Networks and Arista Networks. The general feeling is that it will be better when IP network devices, which are now fully commoditized, are usable in a casual manner. Rather than developing IP technology in-house, it is more desirable to be paired with multifunctional, mass-produced devices. This is certainly an insightful outlook. Above all, this is a logical approach to IP networks.

One thing that must be considered is whether there are any discrepancies between how each IP network device manufacturer and broadcast equipment manufacturer envisages IP networks. IP networks have prospered because they were generic. Email, Internet, and streaming can all be accessed from the same IP network device. Meanwhile, in the extreme, broadcast equipment manufacturers are looking for IP networks that prevent broadcast accidents from occurring. That leads to a large gap in understanding. Routing protocols are used to implement redundancy on IP networks. This makes it possible to switch over to a backup or bypass routes when communications are interrupted. When browsing the Web or using video chat, for example, this process is usually invisible to the user. However, in the world of SDI over IP where a constant 60 frames per second is required, the switchover may be jarring.

In the broadcasting industry, an active-active "Line A/Line B" configuration is used. Applying this to SDI over IP would involve transmitting Line A and Line B feeds of JPEG 2000 4K video in parallel, with the receiver adopting one signal or the other. For the most critical purposes, a configuration like this is the only option. However, this Line A/Line B system has the disadvantage of requiring double the investment in equipment. The challenge is to come up with a configuration that takes advantage of the casual nature of IP networks. Striking a balance between the benefits of networks and SDI over IP poses another problem.

Of course, target-oriented IP networks have also been created. One example of this would be the trading networks that process online transactions at the nanosecond level. I believe the question of whether or not IP networks that meet these extremely high level demands are attainable can only be answered by IP network device manufacturers, as well as network service providers like IIJ.

In light of this, IIJ began proof-of-concept tests for SDI over IP, with the goal of creating a commercial service based on SMPTE 2022. Of course, we used our own backbone for these tests. We tried multiplexing this kind of mission critical video traffic over our backbone, which already carries the traffic for our other customers. A dedicated line is not used, so the traffic receives no special treatment. Consequently, we decided to perform the tests over sections with spare bandwidth (Figure 2).

In both cases, video was input and output at 4K60p. However, each manufacturer uses different encoding. This comes down to a difference in how much of a penalty developers consider the time required to compress and decompress video to be. Either way, this is only an extremely short delay (a few frames), but for the purpose of broadcasting, faster is always better. The difficult part is deciding where to set the minimum requirements, as technical requirements in the broadcasting industry often have a sensory aspect to them.

For test 1, a virtual Layer 2 Network was constructed over the IIJ backbone, and the route was set as Tokyo to Osaka, and back to Tokyo again. From applications this looks like a private network, but the traffic itself is multiplexed over the IIJ backbone. The transmitter and receiver were actually in the same location, but the network encompassed a remote location (Osaka). We were able to transmit an extremely large amount of data, at 3.5 Gbps, without any issues at all. Although there was some network

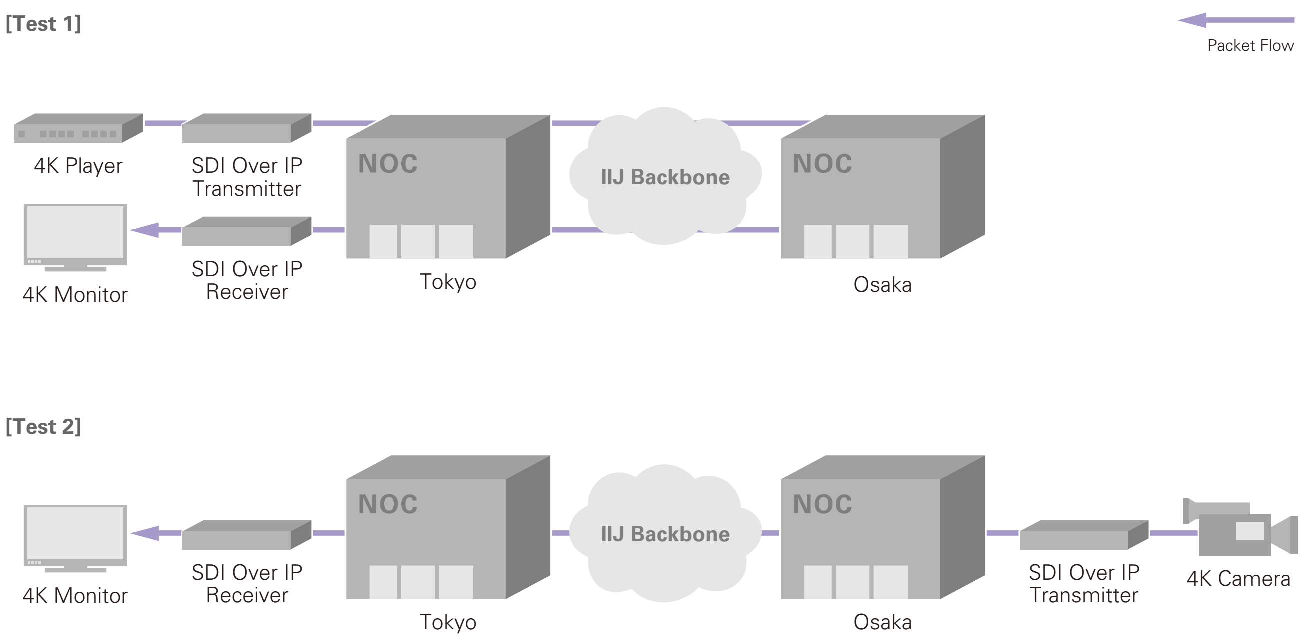


**Figure 2: SDI Over IP Tests Using the IIJ Backbone**

latency (about 23 ms), the overall latency between the transmitting video player and the receiving monitor appeared to be just a single frame. At 4K, there were 60 frames per second (59.94 frames, strictly speaking), which works out to 16.7 ms per frame. End-to-end transmission was completed within 33.4 ms, so we were able to achieve the low latency performance we had aimed for. Although the system worked as it had been designed, we were frankly surprised by this result.

For test 2, we used the Internet for all sections. Through coordination with the Cyber Kansai Project, an academic-industrial collaboration, we set up a transmitter in Osaka. 4K video was sent via the CKP internal network, and over the IIJ backbone from Osaka to Tokyo, before being output at the IIJ office. These communications were carried out using a global IPv4 address. We actually observed a negligible amount of packet loss, but we confirmed the technology was able to cover this.

In the future, we believe that SDI over IP will continue to gain traction, riding the crest of a new wave of technology. However, the ecosystem to support it must still be prepared. When broadcasters leave behind their familiar, reliable technology, and seek new options, what will the requirements be? With the Internet now a global force, and broadcasters seeking to take advantage of it, how should contribution and distribution systems be prepared? We believe the knowledge we have gained through developing, promoting, and operating IP technology in the Internet world is sure to play a vital role.

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He is mainly involved with the development of streaming technology. Among his contributions to development of the market is the organization of the Streams-JP Mailing List, which discusses this technology.