H.264/AVC Codec System for IP Networks

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The start of digital terrestrial broadcasting and the popularization of widescreen TV have initiated a recent shift in video content to the high-definition (HD) format. Meanwhile, thanks to high-speed, low-cost networks, video distribution services via IP networks have become more familiar. Also, the recent needs for collecting and delivering HD video contents with a large data volume via low-cost IP networks have become more conspicuous.
To address these demands, Fujitsu has developed a video codec called IP-9500 based on the latest video coding technology H.264/AVC that enables more than twice the data compression ratio compared with conventional coding technology. This product is the world's first example of commercializing real-time transmission of HD video contents via IP networks. This paper describes the IP-9500, which leads to the realization of versatile visual solutions domestically and internationally.

1. Introduction

Since the commercialization of TV conference equipment with analog transmission in 1968, Fujitsu has been engaged in the research and development of video coding technology for nearly 40 years. Meanwhile, as a member of a standards working group, Fujitsu has contributed to the promotion and development of several international video coding standards such as the ITU-T H.26x series and ISO/IEC MPEG series, while the technologies developed by Fujitsu have also been adopted as standards.[1)-3)]

Based on its excellent technical know-how for video coding, Fujitsu has developed a broadband video solution via IP networks called Broadsight using the experience obtained through the development of TV meeting equipment (the VS series) and video transmission equipment (the FEDIS series). Actively using Fujitsu's expertise in network and server technologies, the new series provides total solutions that can be optimally used for each specific purpose such as monitoring disasters and preventing crime, as well as collecting and distributing video contents. Currently, Fujitsu is making efforts to spread the video solution business using the next generation video codec system H.264/AVC.

This paper describes the applicable markets for H.264/AVC technology as well as the characteristics and technical aspects of H.264/AVC codec IP-9500, which is Fujitsu's first product integrated with this technology.

2. Applicable markets for H.264/AVC

Broadcasting, IPTV, video monitoring and digital AV home appliances markets are considered to be suitable markets for the excellent characteristics of Fujitsu's H.264/AVC codec (**Figure 1**).

1) Broadcasting market

Fujitsu's IP video transmission technology used in its Broadsight series is being applied to systems where news material is distributed flexi-

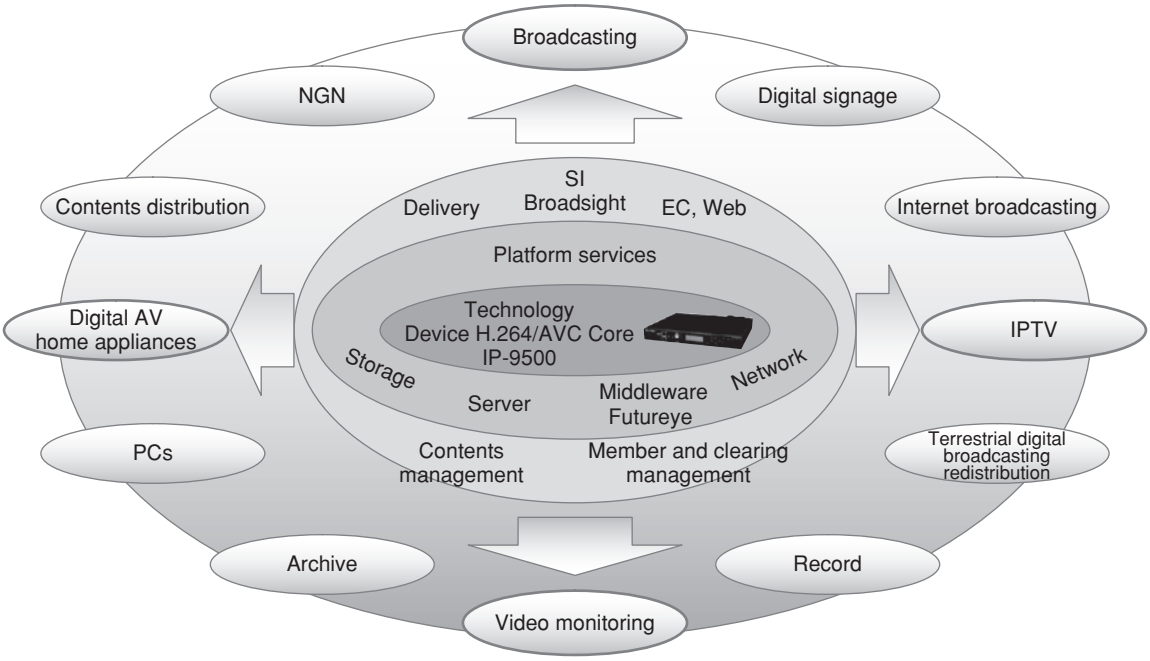

Figure 1
H.264/AVC application market which Fujitsu is considering.

bly among affiliated stations to promptly deliver video of events and accidents in remote locations, or, where video from live cameras installed on the tops of buildings are constantly transmitted to and stored in stations.

Also, for cost-saving purposes the recent trend is for video transmissions via satellites and leased lines to be replaced by more inexpensive IP video transmission. In the past few years, IP video transmission has been introduced to live broadcasts from election campaign bases and disaster sites.

While the mainstream area of IP video transmission in these applications has conventionally been Standard Definition (SD) video, demands for High Definition (HD) video are increasing with the popularization of terrestrial digital broadcasting.

IP video transmission based on conventional technology (MPEG-2) needs to ensure a transmission bandwidth higher than 20 Mb/s, for which, during the process of popularization, it was necessary to keep the line cost equivalent to that for SD video transmission equipment (bandwidth of less than 10 Mb/s). Because a data compression ratio twice as high as in the conventional method is possible, H.264/AVC has realized the transmission of HD video contents via IP networks.

One-Segment Broadcasting started in spring 2006 and adopted H.264/AVC. Currently, shifting to the HD format is being considered for CS broadcasting by the Association of Radio Industries and Businesses (ARIB) and H.264/AVC is scheduled to be adopted.

Further, as a consequence of these trends, we believe that a shift to IP and H.264/AVC will occur in the near future with the increased adoption of the Next-Generation Network (NGN) systems also in the area of program video transmission among affiliated stations, for which digital broadcasting networks based on Asynchronous Transfer Mode (ATM) have been used so far.

2) IPTV market

While SD video has been the mainstream format in the conventional IPTV market, we

assume there has been a shift to the HD format since the second half of 2007. Unlike broadcasting waves, IPTV uses IP networks. Because of this, the issue of network bandwidth will become more conspicuous with the increase in the video bandwidth and number of subscribers. To transfer a large volume of HD video contents, H.264/AVC with its high compression ability is considered essential. Adoption of H.264/AVC is also being considered for retransmitting terrestrial digital broadcasting contents for similar reasons.

We expect to be able to put Fujitsu's experience and all-round performance to good use in this market, where various abilities such as technologies related to video distribution, member account and clearing management, contents management, Electronic Commerce (EC), Websites, storage, servers and networks are required in addition to video coding technology.

3) Video monitoring market

Remote monitoring systems using IP video transmission is one of the strongest areas for Fujitsu based on its long-fostered technology.

As a result of frequent leakage of customer information in recent years, video recording has increasing needs for thorough access control to the area where confidential information is handled. To address these needs, constant video recording is carried out by stationary cameras in each location. Also, because there are increasing demands for higher image quality and prolonged recording duration, we expect active use of H.264/AVC to be an effective way of minimizing the volume of data stored.

4) Digital AV home appliances and overseas markets

H.264/AVC has been adopted in almost all home appliances including video cameras, digital cameras, the next generation of disc recorders, flat panel TVs and cell phones.

As explained above, we expect the mainstream format of video coding technology will shift to H.264/AVC in the future. Because Fujitsu has excellent capabilities in all the related areas such as member account and clearing management, contents management, EC, Websites, storage, server, networks, video coding technology and device technologies, we are confident that we will be able to fully commit to each of these markets by consolidating our engineering strengths.

Figure 2
IP-9500.

3. Outline and characteristics of IP-9500

This section describes the outline and characteristics of H.264/AVC codec IP-9500, a key device newly developed for application in the markets that was explained in the previous section.

3.1 Outline of IP-9500

IP-9500 is a piece of H.264 video transmission equipment for full HD developed as a new model in the Broadsight series (**Figure 2**).

By adopting an original LSI that integrates unique coding control technology, this model has achieved the lowest bit rate (6 Mb/s), the lowest power consumption (less than 60 W) and the minimal space required (a 19-inch rack 1 U size with 6 L capacity) as H.264 video transmission equipment for full HD.

Its main applications include a video transmission system (**Figure 3**) for HD live broadcasting (news, sports, live camera, etc.), and intersite transmission of HD broadcasting material (material transmission from branches to

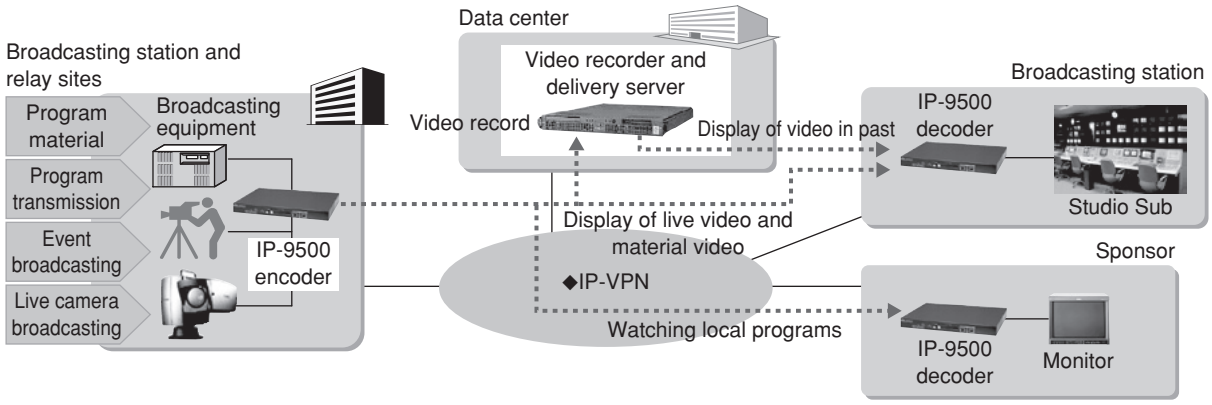

Figure 3
Video transmission system.

the main station, program material transmission from the main station to branches).

3.2 IP-9500 characteristics

1) Fujitsu's unique coding control technology

Fujitsu has been engaged in the development of video coding technology for many years in collaboration with communications enterprises and broadcasting stations. In this process, the Fujitsu has accumulated know-how on achieving the optimal video quality under the various limitations that accompany product development and commercialization. Based on this experience, we believe there are two main challenges to be addressed in the commercialization of H.264/AVC coding technology, as outlined below:

The first challenge is the issue of the increased scale of the circuit (about 10 times as large as the circuit scale for MPEG-2) because of the enormous volume of data to be processed. The second challenge is the issue of compromised video quality caused by coding at a high compression ratio.

To solve the first challenge, we have developed a step-by-step exploration system using a reduced screen size and a method of determining the optimal solution for motion estimation processing, which is the most demanding processing in the encoding operation. As a consequence, we were able to reduce the processing volume to one-fifth, while maintaining the chip size equivalent to the chip size used for MPEG-2 by applying the 90 nm rule to the coding chip manufacturing process.

To meet the second challenge, we significantly improved the overall video quality by allocating a larger amount of data to the targeted sections on which the effect of the compromised video quality is particularly serious (such as images of people's faces and slowly moving objects) by realizing a continuous tracking function with fewer processing operations. Many professionals in the broadcasting industry who evaluated our demonstration gave very positive comments, saying that "no block noise such as is frequently seen in MPEG-2 was observed at such a low bit rate, even when images that are difficult to encode were entered", thereby endorsing this model as being of the highest quality in the industry.

2) Measures for full HD video

HD video normally has 1920 × 1080 pixels. However, most of the widely-used HD coded video formats are created by encoding the image with a reduced number of pixels in the horizontal direction (1440 × 1080 pixels) owing to the limited transmission and recording rate, and cost and scale factors (e.g. HDV based on the HD camera standard for home applications and terrestrial digital broadcasting video).

Because optimal preservation of the quality of the video material (amount of information) is important in the arena of the video production industry, coding at the 1920 × 1080 size (full HD size) is essential if a system is to be adopted.

By using the aforementioned unique coding technology, Fujitsu has succeeded in reducing the size of the circuits and achieving a real-time coding of a full HD size video based on H.264 HP@L4 by using A5-sized hardware.

3) Variety of interfaces

To address the demands of the broadcasting industry, various interfaces have been integrated into this system:

- High Definition Serial Digital Interface (HD-SDI)

For connection with professional broadcasting equipment

- High-Definition Multimedia Interface (HDMI)

For connection with consumer HD equipment (cameras, monitors)

- Analog interface

Analog balanced audio I/O and National Television Standards Committee (NTSC) output ports are integrated to ensure connectivity with existing equipment

- Intercom

Interface for IP voice communication for monitoring and communication between remote sites and stations, as in the case of live broadcasting

- DVB-ASI I/O (optional)

For connection with various types of transmission equipment and digital Field Pickup Units (FPUs)

4) Measures for broadband networks

When using inexpensive broadband networks, data error that is attributable to factors such as defective packets is inevitable. Because the defective data will immediately cause a disturbance in the received video during video transmission, it is necessary to secure video quality through powerful error correction features.

As an error correction algorithm in real-time transmission, Fujitsu is developing a new algorithm that combines a Forward Error Correction (FEC) algorithm and an Automatic Repeat-reQuest (ARQ) algorithm. In FEC, parity is calculated based on the video data to be transmitted and the parity data is sent together with the video data. Meanwhile, ARQ allows retransmission of a packet corresponding to the real-time communication by applying a time limit for receiving the retransmitted data. In this FEC + ARQ hybrid system, the advantages of both systems are combined.

Also this error correction algorithm is integrated in IP-9500, resulting in an excellent error correction performance on a real-time basis. Further, because this system is compatible with Point to Point Protocol over Ethernet (PPPoE), it can be connected directly to networks without using a broadband router.

5) Recording and file transmission

Because IP-9500 integrates a Compact Flash (CF) card interface in its unit, coded video and speech can be recorded on the integrated CF card.

Because the recorded file can be downloaded from remote locations, HD video transmission can be achieved even in a narrow bandwidth network environment.

To facilitate control of IP-9500 in downloading and replaying recorded files from remote locations, a new piece of control software called Futureye II VideoCaster Lite was also developed (**Figure 4**).

6) Measures for encoder and decoder

In conventional systems, the encoder and decoder are separate pieces of equipment, where only one-way data transmission is available from the encoder to the decoder. To address this issue, we needed to establish a bidirectional transmission system by investing an amount of money that was twice as much as an ordinary investment amount.

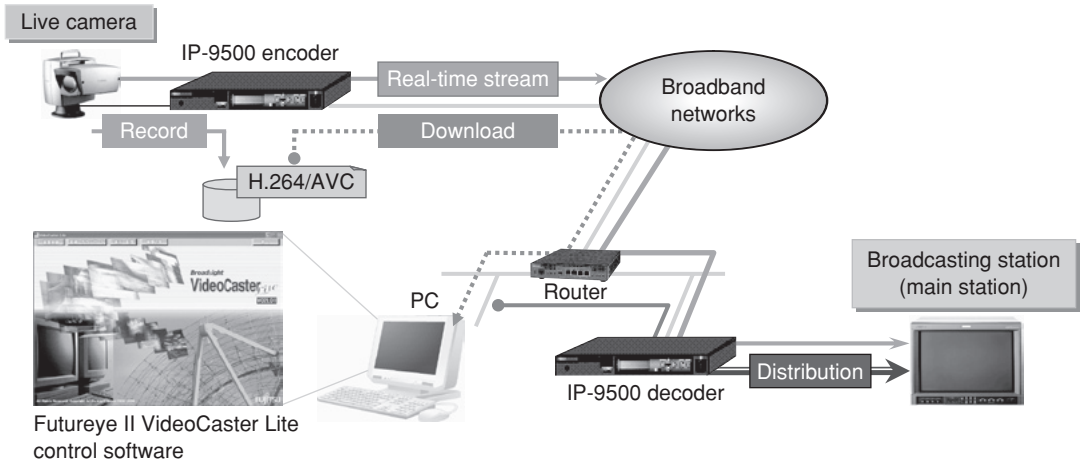

Figure 4
Example of system using Futureye II VideoCaster Lite.

However, upon recognizing the strong demand for bidirectional video transmission we planned to widen the scope of video material transmission via IP networks by providing bidirectional transmission ability with a cost for only single-directional transmission. Based on this concept, IP-9500 integrates a coding processor to address both encoding and decoding needs, as well as an I/O interface, allowing the user to switch between encoding and decoding just by switching the operation mode.

This allows not only easy switching of the transmission direction (from "A to B" to "B to A") as required, by introducing just one set of equipment between A and B, but also allows the user to establish a system by which video material can be interchanged directly among any given points by introducing the equipment in multiple places. Thus, a new video solution called a "video material exchange" was established by positively using the strengths of IP networks.

7) Measures for dual encoder

A single piece of equipment can carry out the coding of an input video by using two different modes simultaneously, and then distribute these two types of streams simultaneously. This leads to the ability to simultaneously monitor both a wide bandwidth network and a narrow bandwidth network. In addition, a video distribution method is available depending on the network to be used.

For instance, when a single HD video is coded into both H.264/AVC 20 Mb/s and H.264/AVC 384 kb/s (after being down-converted into SD video in the latter case), an identical video can be seen from both the FTTH circuit decoder and the ADSL circuit decoder. Also, the decoder conforming to the SD video can monitor the down-converted video.

As a specific application, transmission of videos from multiple locations to a broadcasting station via a network can be considered. If the video data transmitted from all remote locations have a high bit rate of broadcasting quality, the broadcasting station will need a circuit with a significantly high capacity. However, with this new technology, the station can effectively use the circuit capacity because normal monitoring can be conducted at a low bit rate, and only the videos selected for actual broadcasting can be switched into high rate.

8) High reliability and excellent operability

Based on the know-how we have accumulated in the field of video monitoring, operation on a 24 hour, 365-day basis is achieved in a wide range of operating conditions such as a surrounding

Table 1
IP-9500 specifications.

Video	Input note 1)	HD-SDI/SD-SDI, HDMI
	Output note 2)	HD-SDI/SD-SDI, NTSC/PAL (down-conversion output), HDMI
	Sync note 2)	BB input sync, 3 values input sync
Audio	Input/Output	HD-SDI/SD-SDI embedded, analog audio cannon balance, HDMI, bidirectional audio terminal
Network	LAN	10BASE-T/100BASE-TX/1000BASE-T
	Option	DVB-ASI
Data port		RS-232C
Video coding		H.264 HP@L4, 1080 i, 720 P, 480/576 i
Audio coding		MPEG-1 L2, MPEG-2 AAC, Passthrough
External dimensions (W × D × H)		425 mm × 350 mm × 42 mm (excluding protrusions)
Weight		Approx. 6 kg
Power source		AC100 V to 240 V
Operating temperature		–10°C to 55°C (excluding cold start condition)

note 1) At encoder actuation
note 2) At decoder actuation

temperature of –10 to +55°C and a surrounding humidity of 20 to 90%. Accordingly, the equipment is suitable for transmitting images from an outdoor live camera.

The specification of IP-9500 which integrates the above-mentioned technologies is shown in **Table 1**.

4. Future development

Currently, a series of demonstrations of IP-9500 are being conducted in broadcasting stations. Most of the reactions have been very positive. Specifically, the image quality is acclaimed as being one of the best in the world.

We are planning to continue the coding control tuning to further improve the image quality in future. At the same time, we plan to expand the product lineup so that it includes a range of products, from an affordable version for SD video to a high-end version with enhanced quality.

Also, in the area of software we plan to offer a novel video platform with excellent scalability, from small-scale appliances to large-scale systems, by supporting various features such as distribution and management of contents as well as a link with Web cameras, in addition to the conventional features such as collection and storage of video data and protocol conversion.

5. Conclusion

This paper described the markets that Fujitsu considers to be suitable for H.264/AVC and introduced the characteristics and technical aspects of H.264/AVC codec IP-9500, the first product integrated with this technology.

We hope that this equipment will help promote the shift of video contents to HD format and propagate low-cost video transmission via IP networks.

We are sincerely grateful for the many useful comments offered by the broadcasting stations and video creation industry. These comments have been reflected in various aspects of our product development to make our product more convenient for customers.

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