Fujitsu's Approach to H.264/AVC and Application Trends

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This paper outlines H.264/AVC features and application trends, describes implementation problems and technology developed by Fujitsu to solve these problems, and introduces H.264/AVC products developed by Fujitsu. The H.264/AVC video coding system — which achieves more than twice the compression ratio of the existing MPEG-2 standard — became an international standard in 2003 through the joint efforts of ITU-T and ISO/IEC. Its high-performance features are making it attractive for a wide array of applications from mobile communications to HDTV. Nevertheless, there are many problems that must be solved in the development of practical H.264/AVC systems such as an encoding complexity ten times that of MPEG-2 and the difficulty of coding control. To address these problems, Fujitsu has developed an original coding control algorithm that achieves low encoding complexity and high picture quality while capitalizing on a compression ratio twice that of MPEG-2. This original technology is being used in the development of H.264/AVC-compliant products for a wide range of fields taking advantage of Fujitsu's technical expertise ranging from device to network technologies.

1. Introduction

The ITU-T H.261 video coding standard targeting videophones first made its appearance in 1990. Since then, the digitization of video fields has been progressing steadily, and in last ten years, in particular, almost all video fields including broadcasting, video recording, and video transmission have converted to digital technology using coding systems centered about the MPEG-2/MPEG-4 standards. In recent years, moreover, dramatic progress in high definition television (HDTV), broadband networks, and large-capacity disk drives has heightened expectations for new services like IPTV that merge the fields of broadcasting, home appliances, communications, and information, and the need for a coding system with an even higher compression ratio than existing systems has grown.

Against the above background, research and development toward a compression ratio that is significantly higher than that of existing coding systems has been progressing at international standardization organizations. In particular, the H.26L project, which began in 1998 in the Video Coding Expert Group (VCEG) of ITU-T, aimed to achieve a compression ratio far higher than existing technologies through the efforts of many researchers. The work of this project was inherited by the Joint Video Team (JVT) established by ITU-T and ISO/IEC in 2001, eventually resulting in the ITU-T H.264/MPEG-4 AVC (advanced video coding) standard (referred to below as H.264/AVC) based on a Standard Draft compiled by the JVT in 2003.[1),2)] The application domain of the H.264/AVC standard is broad, ranging from low bit rates of several tens of kb/s for mobile applications to high bit rates of several tens of Mb/s for HDTV video transmission achieving more than twice the coding efficiency of existing video coding standards such as MPEG-2/MPEG-4. The H.264/AVC standard has already been slated for use in next-generation DVD and one-segment broadcasting for mobile terminals, and it is expected to spread rapidly to a variety of video fields such as HDTV broadcasting and IPTV.

This paper outlines the features and application trends of the H.264/AVC standard and problems in its implementation, describes technology developed by Fujitsu to overcome those problems, and explains Fujitsu's approach to H.264/AVC products.

2. H.264/AVC features

The H.264/AVC standard does not use revolutionary technology with respect to the existing MPEG series of international standards. Rather, it thoroughly reexamines all of the video processing procedures involved in encoding and achieves a compression performance twice that of MPEG-2 through the accumulation of small improvements in efficiency by finely tuned optimization, addition of more encoding modes, and other means.[3] This section describes technologies and video coding tools for achieving the high performance of H.264/AVC and the profile definitions that comprehensively cover video applications over a wide range of fields from mobile communications to HDTV (**Figure 1**).

2.1 Main technologies used in H.264/AVC

The technologies used by H.264/AVC to achieve a significant improvement in coding efficiency with respect to the existing MPEG series of international standards can be broadly divided into technology for improving the efficiency of picture prediction (indicated by ● in Figure 1), technology for improving entropy coding (■), and technology for improving

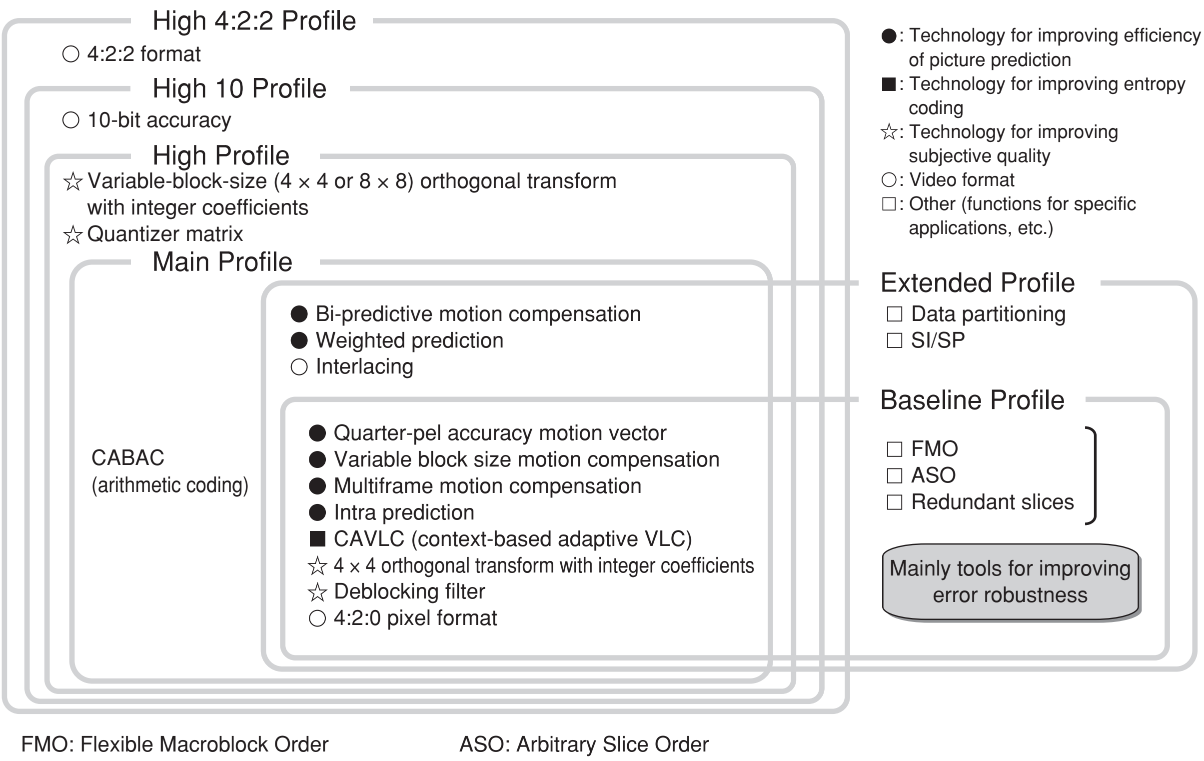

Figure 1
H.264/AVC main profile definitions and coding tools.

subjective quality (☆). These three classes of technologies are explained below.

1) Technology for improving efficiency of picture prediction

One feature of H.264/AVC that stands out against MPEG-2 and other existing standards is the use of many techniques for raising the accuracy of the prediction picture and minimizing the prediction error that must be transmitted. Some examples of these techniques are the use of quarter-pel accuracy motion vectors to improve the accuracy of motion compensation, variable block size motion compensation for achieving prediction in accordance with object shape, multi-frame motion compensation that can be effective for prediction of the background, intra prediction for performing extrapolation in pixel space, and weighted prediction, which is particularly effective in fade sequences.

2) Technology for improving entropy coding

The H.264/AVC standard uses both context-based adaptive variable length coding (CAVLC), which switches between variable length codes according to the number of coefficients of neighboring blocks, and context-based adaptive binary arithmetic coding (CABAC), which is a form of arithmetic coding that adaptively selects a probability table using the correlation between symbols. Although the processing performed by CABAC is complex compared with that of CAVLC, the former can improve efficiency by up to 20–30% more than the latter.

3) Technology for improving subjective quality

In addition to technologies for improving coding efficiency, H.264/AVC also uses technology for improving subjective quality. One of these is a deblocking filter, which is a filter applied between blocks to reduce block noise. Another is a variable-block-size (4 × 4 or 8 × 8) orthogonal transform with integer coefficients, which suppresses the spread of mosquito noise in the spatial direction.

2.2 Profiles

The H.264/AVC standard specifies nine profiles, each of which combines optimal tools for specific classes of applications. The main profile definitions, which are shown in Figure 1, are explained below.

1) Baseline Profile

This profile is configured with a minimal combination of tools to achieve a codec with low encoding complexity applicable to mobile applications and bidirectional communications, as in videophones.

2) Main Profile

This profile combines video coding tools that achieved maximum compression efficiency under version 1 of H.264/AVC. It adds tools like CABAC, bipredictive motion compensation, and interlacing to the tools provided by the Baseline Profile.

3) Extended Profile

Directed at applications like video streaming, this profile adds tools like Switching I (SI) and Switching P (SP) to the tools of the Main Profile. It cannot, however, use CABAC.

4) High Profile

This profile was specified for version 3 of H.264/AVC in December 2005 and is designed so that the Main Profile is upwardly compatible. It combines tools applicable to the coding of high-definition video such as HDTV and next-generation DVD, adding, in particular, tools like an 8 × 8 orthogonal transform and a quantizer matrix, which are used in MPEG-2, to the Main Profile. The High Profile can achieve video quality corresponding to the maximum H.264/AVC performance for various types of video.

5) High 10, High 4:2:2, and other profiles for professional applications

These profiles are intended for professional applications such as the transmission of video materials supporting bit depths of 10 bits or more and video formats like 4:2:2 in addition to 4:2:0. In recent years, the High 4:4:4 Profile, High 10 Intra Profile, and High 4:2:2 Intra Profile have been added.

3. H.264/AVC application trends

Thanks to its high coding efficiency and high extendibility features, H.264/AVC is slated to be used in a wide range of video applications. The following introduces H.264/AVC application trends.

1) Next-generation DVD

The dramatic spread of HDTV has stimulated the need for a next-generation DVD format supporting the recording and playback of full HD with a maximum resolution of 1920 × 1080 pixels. This need has resulted in the recent formulation of the Blu-Ray Disc, which uses the H.264/AVC High Profile in addition to MPEG-2 used in conventional DVDs.

2) Next-generation digital broadcasting

The broadcasting field is adopting specifications for both mobile-terminal and HDTV services, and each of these specifications uses H.264/AVC. Examples of specifications for services directed at mobile terminals include one-segment broadcasting (Japan), DVB-H (Europe), and T-DMB (Korea). Each of these incorporates the H.264/AVC Baseline Profile. In HDTV broadcasting, the H.264/AVC High Profile is being used in DVB-S2, the European satellite broadcasting specification, and in the ATSC digital broadcasting specification in North America. In Japan, a specification based on the H.264/AVC High Profile was standardized by the Association of Radio Industries and Businesses (ARIB) during 2007, initially for communications satellite (CS) broadcasting.

3) IPTV

The expansion of broadband IP networks and HDTV in recent years has stimulated worldwide activities toward IPTV with the aim of providing new services such as bidirectional TV via the Internet. As part of this trend, ITU-T established the IPTV Focus Group (IPTV FG) to promote the standardization of IPTV-related technologies. This focus group has been holding discussions since June 2006 with an eye to linking up with Next-Generation Network (NGN) efforts. In 2007, IPTV FG expanded into the IPTV Global Standards Initiative (IPTV-GSI). In Japan, as well, the IPTV Forum was established centered on the Ministry of Internal Affairs and Communications (MIC) with participants including carriers, IP providers, broadcast stations, and home appliance manufacturers. Discussions of a similar nature are under way. At the same time, services for delivering HD video coded in H.264/AVC via IP are now being launched, and looking to the future, we can expect the use of H.264/AVC to expand to the field of IPTV.

4. H.264/AVC problems and Fujitsu solutions

The high coding efficiency and broad range of applications of H.264/AVC that we have introduced so far are generating high expectations for this coding standard. There are still, however, a number of major problems that must be solved to achieve a practical implementation of H.264/AVC. This section describes these H.264/AVC problems and introduces Fujitsu's approach to solving them (**Figure 2**).

4.1 H.264/AVC problems

The following describes these problems in H.264/AVC implementation.

1) Reducing encoding complexity

The H.264/AVC standard provides more than 100 times the number of coding modes of MPEG-2, and H.264/AVC achieves a compression ratio more than two times that of MPEG-2 by selecting the best coding mode from among them. As a result, the encoding complexity of the encoder processing is about ten times or more that of MPEG-2 when H.264/AVC JM reference software distributed by JVT is used (JM: joint model). In addition, the memory bandwidth required for processing increases in proportion to the encoding complexity. To achieve a practical implementation of H.264/AVC, a significant reduction in encoding complexity must be achieved while maintaining coding efficiency.

2) Improving subjective quality

In the case of coding with about half the amount of information of MPEG-2 due to the improved coding efficiency of H.264/AVC, it is known that there will be a degradation in subjective quality that is not noticeable in MPEG-2 if we use the same type of coding control as used for MPEG-2. This degradation may take the form of a loss of picture details or flicker noise in each intra-coded picture (I-picture) generated by decoding independently without referring to other scenes. Achieving stable subjective quality for all kinds of scenes requires coding control with a level of accuracy far higher than that of MPEG-2.

4.2 Fujitsu solutions

Fujitsu has succeeded in developing original technology to solve the problems described above based on original video-coding know-how and evaluation technologies that it has accumulated over the last twenty years. In the development process, a huge number of simulations must be performed to optimize many types of algorithms and parameters. To this end, we make use of the CyberGRIP[4] grid-computing environment to radically shorten development time. This environment provides massive parallel processing through the use of several hundred personal computers. The following outlines these original solutions.

1) Solutions for reducing encoding complexity

To achieve low encoding complexity while minimizing picture degradation, the following algorithms have been developed for motion compensation and block-division-mode decision processing, which generate most of the processing load in the encoder while affecting picture quality.

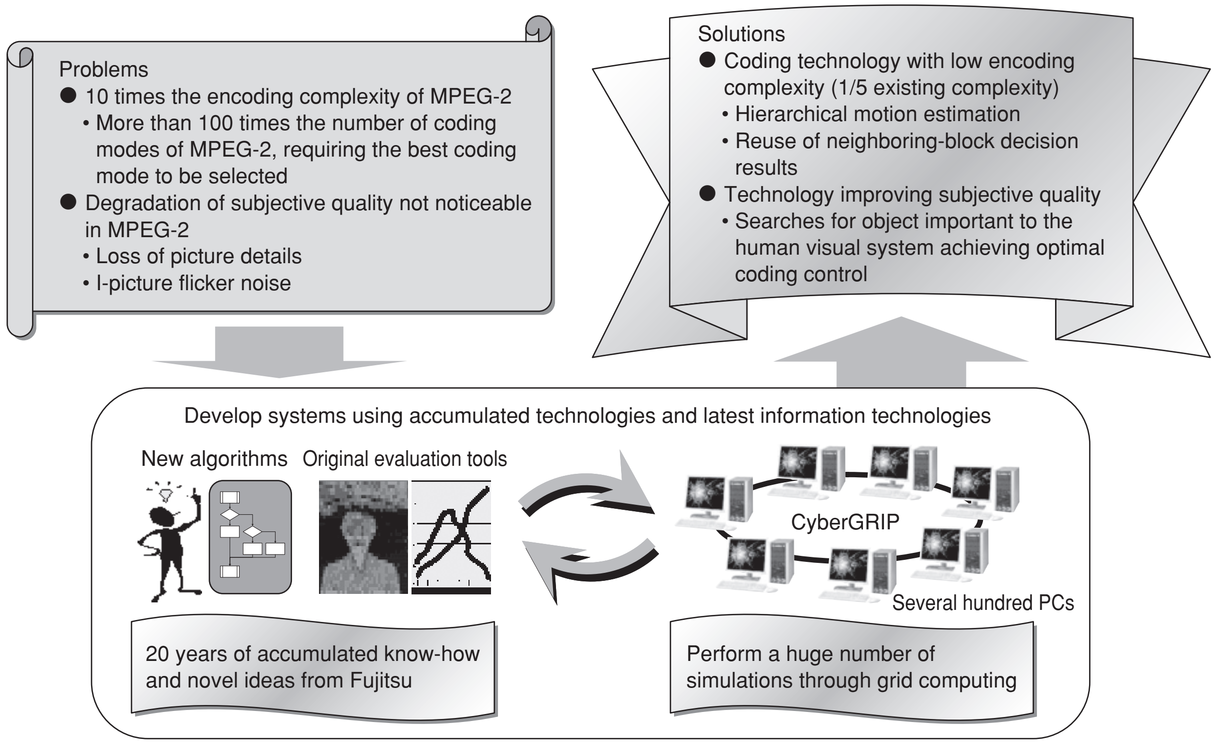

Figure 2
H.264/AVC problems and solutions.

- Adaptive motion compensation system based on hierarchical motion estimation taking into account the features of H.264/AVC technology for improving the efficiency of picture prediction
- Effective mode decision that reuses the decision results from neighboring coded blocks

Compared with the JVT-provided reference software called JM, these algorithms reduce the processing load of motion compensation and block-division-mode decision processing to about one-fifth the existing value without affecting the efficiency of picture prediction.

2) Solution for improving subjective quality

A new type of degradation in subjective quality such as loss of picture details and I-picture flicker noise can be seen in H.264/AVC. Fujitsu has developed a coding control algorithm that achieves stable subjective quality for any scenes while maintaining low encoding complexity by detecting that portion of the picture that is important to the human visual system and performing optimal coding control (balance control) based on that result. **Figure 3** compares the coding performances of the reference software (JM) mentioned above and Fujitsu's original encoder software applying the above algorithm. Even though the encoding complexity required by the developed algorithm is only about one-fifth that of the reference software (about twice that of MPEG-2), the encoded picture exhibits a significant improvement.

(a) Coding performance of reference software

(b) Coding performance of developed scheme

Using an ITE test chart

Figure 3
Comparison of coding performances of JVT reference software and Fujitsu's developed scheme (720 × 480 pixel image encoded at 2 Mb/s).

5. Fujitsu's approach to H.264/AVC products

In combination with its world-class semiconductor technologies such as 90/65-nm processes and system-in-package designs and industry-leading IP network technologies including quality-of-service (QoS) and server technologies, Fujitsu is developing an extensive array of H.264/AVC-compliant products centered on its original low-encoding-complexity and high-picture-quality technologies described above (**Figure 4**).

First, in the field of semiconductors, Fujitsu has completed the development of the world's first HD-compliant H.264 codec LSI (MB86H50/51)[5] conforming to the H.264/AVC High Profile and the development of an MPEG-2-to-H.264 transcoder LSI (MB86H52).

Next, in the field of video transmission, Fujitsu has developed encoder/decoder equipment (IP-9500)[6] that can be used to construct a contribution and distribution system in which HDTV picture quality will not deteriorate even on an inexpensive best-effort line such as fiber-to-the-home (FTTH) access. Furthermore, by applying a very-low-bit-rate system[7] supporting the HE-AAC audio codec developed by Fujitsu and H.264/AVC high-picture-quality technology, Fujitsu has succeeded in developing a prototype encoder[8] for terrestrial digital broadcasting (one-segment broadcasting) targeting mobile terminals.

Fujitsu's objective for the future is to use these world-class products as a strategic asset toward achieving the top share in the video-related markets shown in Fig.4, ranging from device markets oriented to consumer appliances to professional markets for broadcasting, content production, and monitoring.

6. Conclusion

In recent years, HDTV and broadband services have spread rapidly to ordinary households, and new and novel services that merge the fields of broadcasting, home appliances, communications, and information like IPTV are about to take off. H.264/AVC, which achieves a compression ratio twice that of MPEG-2 and boasts features supporting a wide range of fields from very-low-bit-rate mobile terminals to high-reality HDTV, is a video coding standard that meets the needs of the times. We foresee practical H.264/AVC technologies and related products becoming a powerful tool for carving out new opportunities in the video field.

At Fujitsu, we have been working aggressively on many problems related to the implementation of H.264/AVC and have succeeded in developing an original coding control algorithm that achieves low encoding complexity and high picture quality while making the most of a coding efficiency more than twice that of MPEG-2. We are also developing H.264/AVC-compliant products for diverse fields exploiting Fujitsu original technologies and its extensive know-how in a wide range of fields from devices to networks.

For the future, we plan to refine our original technologies and use the H.264/AVC technology that we have developed as a foundation to becoming the worldwide market share leader in video-related markets.

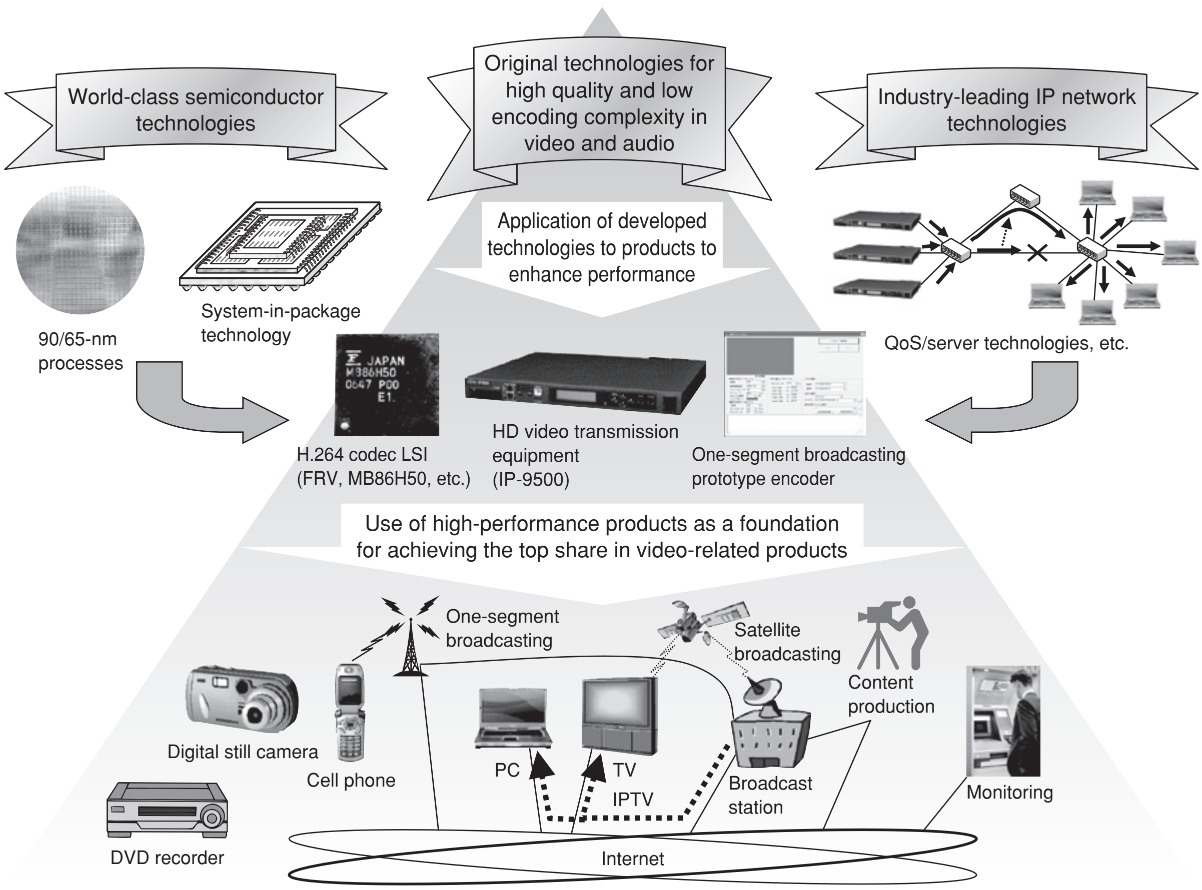

Figure 4
Expansion of H.264/AVC products to video-related markets.

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