



Video Compression Standards

Exploring the Options

A Verint Systems Technical Brief

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Preface

Digital video requires high data rates, necessitating powerful hardware and large bandwidth for the transmission of high-quality video scenes. This technical brief examines the most popular video compression standards used in video surveillance applications to help you select the standard that best meets your project requirements, while optimizing use of your valuable network resources.



As the market leader in IP video management solutions, Verint should be on the short list of every enterprise buyer.

Frost & Sullivan

The Nextiva Portfolio of Video Solutions

Nextiva is an integrated portfolio of networked video solutions for enhancing security and operational effectiveness. Nextiva enterprise and vertical market solutions address the needs of a wide range of industries, from banking and critical infrastructure to retail and mass transit. Nextiva wireline and wireless edge devices and embedded DVRs capture images from virtually any stationary or mobile location. Nextiva's advanced analytics rapidly detect events in vast amounts of video and enterprise data. And Nextiva's robust video management software, intelligent video distribution, and system-wide monitoring and diagnostics simplify management of large, geographically-distributed operations.

Nextiva optimizes use of valuable network resources with flexible video compression, dual streaming, and dynamic bandwidth allocation. Open, standards based, and IT friendly, Nextiva solutions provide superior system availability, interoperability, and value.

Verint. Powering Actionable Intelligence.®

Verint® Systems Inc. (NASDAQ: VRNT) is a leading global provider of analytic software-based solutions for security and business intelligence. Verint solutions help organizations make sense of the vast voice, video, and data available to them, transforming this information into *actionable intelligence* for better decisions and highly effective performance.

Since 1994, Verint has been committed to developing innovative solutions that help global organizations achieve their most important objectives. Today, organizations in over 50 countries use Verint solutions to enhance security, boost operational efficiency, and fuel profitability.

Introduction

Most networks are designed to handle approximately 100 Mbits/s of data. Uncompressed video generally exceeds a network's bandwidth capacity, does not display properly, and requires too much disk space for storage purposes. Consequently, it is not practical to transmit video sequences without using compression.

Image and video compression techniques reduce the high bit rate and large file sizes associated with digital video and allow the efficient transmission and storage of video data. In essence, these compression technologies reduce the quantity of data used to represent video content, making video files smaller with little perceptible loss in quality. Compressed files are easier to transmit over a network and easier to store.

Most compression techniques register the differences within a frame or between frames in order to reduce the quantity of data used to represent video content. For differences within a single frame, compression techniques take advantage of the fact that the human eye is unable to distinguish small differences in color. These areas are "averaged out" without perceptible change to the viewer. For differences between frames, only the changes from one frame to the next are encoded. By ignoring redundant pixels, only the changed portion of a video sequence is compressed, thereby reducing overall file size.



Image and video compression allow video data to be efficiently transmitted and stored.

What is a Video Codec?

A video codec is a software module that enables video compression or decompression of digital video. The word *codec* is a combination of any of the following: Compressor-Decompressor, Coder-Decoder, or Compression/Decompression. Codecs encode a stream or signal for transmission, storage, or encryption and decode it for viewing or editing.

There are many different codecs available. Many vendors offer proprietary codecs with a variety of performance claims and rationales. While this may be useful in some instances, network-based video applications are generally built using industry-standard codecs. Reduced cost, future expansion capabilities, and compatibility with other systems are the key advantages that industry-standard codecs have over proprietary codecs.

Most professional MPEG-based video codecs use motion compensated differential coding, known as **P** and **B** frames, to improve compression. These codecs generate key frames, also known as **Intra** or **I-frames**, which are set at user-defined intervals (for example, 1 key frame every 5 frames). Motion compensated differential coding compares two compressed images to be transmitted over a network and uses the first compressed image as a reference frame (I-frame), sending only the parts of the following images (B- and P-frames) that differ from the reference image. A network viewing station then reconstructs all images based on the reference image and the “difference data” contained in the B- and P-frames.

Lossy vs. Lossless Video Compression

Video compression can be performed using either lossless or lossy compression methods. With lossless compression, each pixel is kept unchanged, resulting in an identical, bit-for-bit image after decompression. With lossy compression, the resulting video sequence will be different from the original, but good enough for use. In most cases, a lossy method can produce a much smaller compressed file than any lossless method, while still meeting the requirements of the application.

Video Codec Profiles and Levels

A video codec profile specifies different tool parameter settings to compress and encode video to achieve the most advantageous image quality/bit rate ratio for a video sequence. In other words, a profile imposes some boundaries to the full syntax and defines which tools or functionalities may be used to produce a bit stream. Each profile exists at different levels. A level is defined as a set of constraints on the values within a particular profile. In simpler terms, levels specify the maximum bit rate, the supported resolutions, and other parameters related to a profile in order to simplify the connection between encoders and decoders from different companies.

Almost all standards have a baseline Simple Profile and one Advanced Profile, often called the *Main Profile*. The compression performance of a standard that uses all of the tools in a Main Profile will be different from the same standard using the Simple Profile tools.

Codec Standards

This section describes popular standard codecs used in video surveillance and security applications. All of the following codecs are lossy; this means that the reconstruction of an image after compression will not be exactly like the original.

Today's most popular codecs are categorized as either video codecs or still image codecs. Still image codecs can be used for video compression purposes, in which case the video is interpreted as a series of still images. They are considered less efficient than video codecs because each frame is considered a key frame and is independent of the previous one.

Still image codecs are better than video codecs for error resilience, but since they generate more bits, they can result in a higher probability of generating errors. A video codec usually provides better compression results.

Video and still image codec standards are developed and maintained by two international organizations.

- The International Telecommunications Union (ITU) publishes standards for videophone and videoconferencing applications, including H.264.
- The International Standards Organization (ISO) publishes computing standards through the Joint Photographic Experts Group (Motion JPEG) and Moving Pictures Experts Group (MPEG).

Video Codec Standards

MPEG-2

MPEG-2 was approved as a standard in 1994 and was designed for high frame and bit rates. MPEG-2 extends the earlier MPEG-1 compression standard to produce high quality video at the expense of a lower compression ratio and at a higher bit-rate. The frame rate is locked at 25 (PAL)/30 (NTSC) FPS, as is the case for MPEG-1.

MPEG-2 was successful in the broadcast market, so there are many hardware implementations using this standard. The MPEG-2 Simple Profile uses very similar technologies to MPEG-4, so the compression rate and image quality are roughly similar.

MPEG-4

MPEG-4 is now the most widely used codec for video security. It offers improved quality relative to MPEG-2. This codec is designed to operate within a wide range of bit rates and resolutions, so it is well suited for the video surveillance industry. Resolution can be supported from CIF 3.75 FPS at 128 kbps to D1 30 FPS @ 6 Mbits/s. Typical video surveillance implementations use the Simple (SP) or Advanced Simple Profile (ASP).

A good ASP implementation can reduce the bit rate by about 15%, but requires twice the processing power. Many MPEG-4 codecs are optimized for lower bit rate video, which often gives the wrongful impression that MPEG-2 provides better quality. MPEG-4 generates better quality images at an equivalent bit rate than JPEG-based codecs.



A video codec generally provides better compression results than a still image codec.

H.264 (MPEG-4 AVC)

H.264 is also known as MPEG-4 AVC or MPEG-4 part 10. It is an emerging standard that offers new tools to improve video compression when compared to MPEG-4 and MPEG-2. AVC stands for *Advanced Video Coding*. It is a broad standard with many suggested (but not mandatory) tools. This means that from one implementation to another, there can be a wide difference in the resulting compression rate.

The Baseline Profile is the most popular implementation, providing a bit rate reduction of 10% to 30% over MPEG-4 compression, but it requires up to twice the amount of CPU power. An overly simple H.264 implementation may produce worse results than a proper MPEG-4 implementation.

The Main Profile is used in the broadcast market and requires a tremendous amount of CPU power. H.264 contains a number of significant advances related to compression. The intent is to achieve very high data compression results. This standard is capable of providing good video quality at bit rates that are substantially lower than previous standards.

MPEG-2 and MPEG-4 will slowly be replaced by H.264 as processing power increases.

WMV9 (VC-1)

Microsoft originally developed the Windows Media Video version 9 codec as a proprietary codec for low bit rate streaming applications. The standard was officially approved by the Society of Motion Picture and Television Engineers (SMPTE) in March 2006 as SMPTE 421M WMV version 9 (also known as VC-1).

VC-1 is perceived as a competitor to H.264 and has a chance of becoming a popular standard now that it is no longer a proprietary codec. MPEG-2 and MPEG-4 are expected to slowly be replaced by VC-1 as processing power increases.

M-JPEG (Motion JPEG)

M-JPEG is an informal name for multimedia formats in which each video frame of a video sequence is separately compressed as a JPEG image. M-JPEG uses intra-frame coding technology that is similar to the I-frame method used in MPEG-based codecs, but does not include interframe prediction, which results in a loss of compression capability. M-JPEG is commonly used by IP-based video cameras via HTTP streams, but it is not a format defined by international standards, such as MPEG.

SM4

SM4 is a Verint proprietary codec. It is MPEG-4 based. SM4 is designed to encode quickly and provides good perceptual quality. It is the default setting for most Verint IP cameras and encoder boxes.

Still Image Codec Standards

JPEG

JPEG is a format specified in the JPEG still picture coding standard in which each video frame is separately compressed as a JPEG image. JPEG is a very well-known standard and is widely used in video surveillance applications and still image cameras. The first generation of DVRs all used JPEG, but this is no longer the case. Today, it is not used for video encoding purposes as often as before, except by some IP cameras that are directly accessed by many users using different frame rates.

JPEG can generate good quality images or video sequences, but with larger file sizes than video codecs. JPEG also has a lossless mode, which is hardly used at all in video surveillance applications. JPEG-based codecs generate good quality images or video sequences, but MPEG-4 generates better quality images at an equivalent bit rate.

JPEG 2000

JPEG 2000 is a wavelet-based image compression standard created by the Joint Photographic Experts Group committee that provides better compression for still image coding by filtering, sub-sampling, and “smoothing” video data, removing unnecessary details. JPEG 2000 is very scalable and brings many new tools to improve compression, but requires significantly more processing power than JPEG to encode an image. It is not expected to become a standard for use in video surveillance, except for use in some IP cameras and specialized systems. The original JPEG standard is slowly being replaced by JPEG 2000 because it outperforms it in terms of compression by almost 40%.

Choosing the Right Codec

When choosing among equivalent technologies, it is useful to remember that all codecs have inherent drawbacks and qualities. Codec performance is generally a tradeoff between bit rate and image quality. It is better to define your requirements before choosing a codec, instead of merely benchmarking various codecs prior to designing your network video project. This helps ensure that the codec you choose is appropriate to your needs.

When designing a network video application:

- Define the maximum and minimum required sustained frame rate.
- Decide if recording/monitoring is required at all times or only when motion or an event occurs.
- Define the resolution/frame rate that is required when recording motion, an event, or an alarm.
- Decide the length of time a video sequence must be stored.
- Define the level of latency that is acceptable.
- Itemize system robustness and security issues.
- Define how much network bandwidth is required.

Always compare either (1) compressed image quality at equivalent bit rates or (2) various bit rates at an equivalent level of image quality. It is advisable to test codec performance using video sequences that reflect the kind of motion and environmental conditions that will be present in the field because the type of data that is recorded will have an impact on codec performance. High-motion or low-light conditions can affect image quality at different frame rates and resolutions. When comparing bit rates, it is preferable to verify a codec's performance by recording video for a sustained period of time at different settings. Always configure product settings to your needs.

Nextiva Intelligent Edge Devices

Nextiva Intelligent Edge Devices help optimize digital video with state-of-the-art video compression and dual streaming capabilities. Verint developed the SM4 proprietary codec as the default setting for most Nextiva Intelligent Edge Devices (IP cameras and encoders). It is MPEG-4 and H.263-based and designed to encode quickly and provide good image quality, while reducing the required bit rate by about 5% when compared to the MPEG-4 Simple Profile.

Although proprietary codecs, such as SM4, are useful and provide excellent compression results, open, standards-based codecs provide even more system flexibility. Nextiva also features a well-optimized MPEG-4 Simple Profile solution that is based on the industry-standard codec for easy interoperability with other systems and devices.

A Noise Reduction Filter (NRF) is offered with the Nextiva S1704e, S1708e, S1712e, and S1724e Intelligent Edge Devices to further reduce encoding time and produce bandwidth savings without affecting image quality.



It is important to understand that a codec standard defines how to decode a compressed stream and not how to encode it. This means that two different implementations of the same standard will not always return the same compression ratio or provide the same image quality. In general, different codec implementations requiring equivalent processing power will yield equivalent results as long as a similar motion estimation engine is used. Noise reduction filters and other pre/post filters should not be overlooked as an effective means to reduce the bit rate and/or to improve image quality, regardless of the codec used.

Since choosing the right codec depends on many external factors and project requirements, the most appropriate codec to use for an application largely depends on what is most pertinent to your objectives: frame rate, image quality, latency, system robustness, or bandwidth consumption.

Supplementary Materials

The following Verint executive briefs present useful information related to this topic. To receive any of the titles listed below, contact your Verint representative or call Verint at 1-631-962-9600.

- The 3 R's of IT-Friendly Solutions: What Every Video Security Solution Should Have
- Nextiva Intelligent Edge Devices: Settings for Single and Dual Stream Performance
- Actionable Intelligence for a Safer World and a Smarter Enterprise
- Enterprise Storage Manager: Managing Video as a Strategic Asset