White paper

Axis Zipstream technology

Cut the storage. Not the quality.

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AXIS COMMUNICATIONS

Summary

Axis Zipstream technology makes it possible to use higher resolution and increase forensic usability, while reducing storage cost. The intelligent compression method ensures that important image details get enough attention in the video stream, while unnecessary data is removed.

Most networked video surveillance systems today are limited by bandwidth and storage for the recorded video. Zipstream is a radically improved, standard-compatible video encoder implementation, which lowers bandwidth and storage requirements by an average of 50% or more, compared to standard compression. Important details and motion are preserved with high video quality, while the Axis-unique compression enhancement can filter the rest of the image information harder to make optimal use of the available bandwidth.

Zipstream consists of a collection of algorithms that analyze the video stream in real time:

> Dynamic ROI (regions of interest)
  The dynamic ROI identifies regions of interest based on objects, people, or motion in the scene, and applies the correct level of compression from a forensic perspective.

> Dynamic GOP (group of pictures)
  With dynamic GOP, the camera will send bandwidth-intense I-frames less frequently when there is no motion in the scene.

> Dynamic FPS (frames per second)
  The dynamic FPS reduces the bitrate when there is no, or low-level, motion in the scene. The camera is capturing and analyzing video at full frame rate, but unnecessary frames are not encoded.

Zipstream is continuously improved with additional features, as well as support for additional camera types. Since its introduction to the market in 2015, Zipstream enhancements include PTZ camera functionality, support for 4K Ultra HD, multi-megapixel, and 360-degree-panoramic cameras, dynamic FPS limitation, and dynamic FPS frame skipping.

In selected products, Zipstream has H.265 support. These products support both H.265 and H.264 in parallel, to enable flexible migration during an extensive transition period. H.264 will continue to be the dominant video compression standard for a long time ahead, since H.265 is still not yet fully adapted to surveillance.

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1. Introduction

Camera technologies such as sensors, optics, and embedded image processing have evolved rapidly over the last ten years, resulting in video with higher resolution, frame rate and dynamic range, capturing more details of a scene. The development has improved the quality of video evidence and forensic analysis, such as face identification, but only when it is possible to retrieve the video from the right place, at the right time, and with the right quality. Due to the higher bitrate, the requirements on storage and bandwidth have increased.

Optimized for video surveillance, Axis Zipstream technology is a standard-compatible video encoder implementation that is radically more efficient than standard encoders, lowering bandwidth and storage requirements by an average of 50% or more. Zipstream is a collection of intelligent compression algorithms which ensure that important details in the image get enough attention in the video stream, while unnecessary data is removed.

Zipstream is continuously improved with additional dynamic features as well as support for additional types of network cameras.

2. Video compression algorithms

Before video from surveillance cameras can be efficiently stored on any media it has to be processed to fit into the allowed space. To fit video with high resolution and full frame rate onto SD™[1] cards, which are the most popular and cost-efficient media for embedded applications, the original information has to be encoded. This is done using video compression algorithms that encode video data by reducing and removing redundant information. These algorithms locate regions in the video that have already been transferred, so that redundant sending in the next image frame can be avoided. The algorithms also identify places in the video where details can be removed without reducing the visual quality.

State-of-the-art video compression methods that function well together are grouped into an international standard, which is a video stream syntax created for storing, sharing and viewing video. Today, the most used video compression standard is H.264, which is efficient enough to reduce several days of surveillance video onto one single SD card. The new standard H.265 is being introduced in the consumer and broadcast markets, and is predicted to play a significant role in future security surveillance. H.265 is primarily designed to reduce the storage needs of low-noise video with a lot of motion.

The H.264 and H.265 standards do not stipulate the actual video compression method. Only the syntax and the method to perform playback is standardized. This enables improved video encoding solutions to be created while keeping the file format for interoperability (decoder compatibility).

Axis Zipstream is a more effective implementation of an H.264/H.265 video encoder for surveillance applications. It includes various surveillance-unique methods that enable networked cameras to produce video with significantly lower bitrate.

3. How does Zipstream work?

Axis Zipstream technology is a collection of algorithms that lets the camera analyze the video stream in real-time. Interesting details and motion are preserved with the given video quality while the Axis-unique method can filter other areas harder to optimally use the available bandwidth.

Zipstream is not in any way a replacement for High Efficiency Video Coding (HEVC)/ITU Telecommunication Standardization Sector (ITU-T) H.265, which was jointly developed by ISO/IEC Moving Picture Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG). Zipstream is a video encoder enhancement, which can be applied on many video compression standards, including H.264 or H.265, with minor adaptions.

[1] microSDXC and SD marks and logos are trademarks of SD-3C, LLC.

3.1 Configuration options

Zipstream adapts the compressed video stream based on four factors:

> Scene motion
> Scene content
> Ambient light level
> Configuration options

Configuration options that affect Zipstream:

> Compression
> Group of pictures (GOP) length
> Frame rate
> Strength
> Dynamic GOP
> Dynamic GOP limitation
> Dynamic frames per second (FPS)
> Dynamic FPS limitation
> Dynamic FPS frame skip mode

The strength parameter defines the effort level for Zipstream, as follows:

Strength	Effort level	Visible consequences
Off	Off	None
10	Low	No visible effect in most scenes
20	Medium	Visible effect in some scenes: less noise, and slightly lower level of detail in regions of lower interest
30	High	Visible effect in many scenes: less noise, and lower level of detail in regions of lower interest
40	Higher	Visible effect in even more scenes: less noise, and lower level of detail in regions of lower interest
50	Extreme	Visible effect in most scenes: less noise, and lower level of detail in regions of lower interest

All strength parameter settings are compatible with all existing software applications, while still reducing the bitrate.

Other parameters can be configured as follows:

Dynamic GOP	Explanation
Off	Dynamic GOP adjustments, disabled
On	Dynamic GOP adjustments, enabled

Dynamic GOP limitation	Explanation
Actual value	Maximum allowed dynamic GOP length

Dynamic FPS	Explanation
Off	Dynamic frame rate adjustments, disabled
On	Dynamic frame rate adjustments, enabled

Dynamic FPS limitation	Explanation
Actual value	Minimum allowed dynamic FPS

Dynamic FPS frame skipping mode	Explanation
Empty	Frame skipping, disabled
Dropped	Frame skipping, enabled

By default, networked cameras supporting Zipstream are configured with the strength parameter set to 10 and dynamic GOP/FPS disabled. The default setting is compatible with all existing applications, while still reducing the bitrate.

3.2 Bitrate reduction algorithms

The bitrate reduction can be derived from either the dynamic ROI of Zipstream or its dynamic GOP or dynamic FPS.

Dynamic ROI (region of interest)
By real-time analyzing, the dynamic ROI identifies regions of interest based on objects, people, or motion in the scene and applies the correct level of compression from a forensic perspective. This process is performed for all image content, resulting in a totally flexible dynamic ROI. It will automatically expand, shrink, change shape, split, merge, disappear, and reappear depending on content, for the benefit of tuning the instant bandwidth.

Since it is unknown in which parts of the image relevant information may appear, Zipstream prepares the system for unexpected events. This dynamic automatic ROI is much more convenient than other traditional ROI implementations where the region is set manually.

Dynamic GOP (group of pictures)
With dynamic GOP, the camera will send bandwidth-intense I-frames less frequently when there is no motion in the scene. Video from typical surveillance scenes with limited motion can be compressed to an extremely low bitrate without any loss of detail. This algorithm makes a real-time adaption of the GOP length on the compressed video according to the amount of motion. Note that not all clients or video management systems (VMS) may support smooth playback of video with this algorithm enabled even though the compressed video stream conforms to the H.264 standard.

Dynamic FPS (frames per second)
The dynamic FPS reduces the bitrate by avoiding unnecessary encoding of video frames. This is done by omitting them from the stream. A static surveillance scene will be encoded with radically reduced frame rate even though the camera is capturing and analyzing video at full frame rate. Since scene motion is used as a control variable, a small moving object far away may not render at full frame rate. Objects approaching the camera increase the frame rate to capture every important detail. The number of delivered frames per second is restricted automatically by the camera, which will save a substantial amount of data in many scenes.

The dynamic FPS limitation parameter can be used to configure a lower limit of the dynamic FPS. A dynamic frame rate between the stream FPS and the configured minimum FPS will then be selected, enabling use with supporting systems with minimum-FPS requirements, as well as with systems that require higher FPS.

Some video management systems may not support smooth playback of video with dynamic frame rate even though the compressed video stream conforms to the H.264/H.265 video standards. In these cases, disabling the frame skipping (setting the dynamic FPS frame skipping mode to "empty"), makes it possible to still use dynamic FPS. The video frame rate will vary while full stream frame rate is maintained. Disabled frame skipping works as a compatibility mode that enables all users to gain from the dynamic FPS, even though the bitrate saving will be smaller than when frame skipping is enabled.

Legal requirements may prevent the use of dynamic frame rate in some surveillance cases. By choosing the right minimum-FPS value, the dynamic FPS algorithm can still be used.

3.3 Bitrate reduction expectations and examples

Zipstream reduces the average bitrate by using real-time scene information. The total bitrate reduction can be estimated by evaluating the bitrate savings for each algorithm independently, and combining the results. Expected bitrate reductions are shown in the below table. Note that all examples and figures in this section were created using H.264 compression.

Zipstream algorithm	Bitrate reduction	Influenced by
Dynamic ROI	10-50%	Zipstream strength parameter, scene motion and content
Dynamic GOP	0-50%	Scene motion
Dynamic FPS	0-50%	Scene motion

Figure 1 and figure 2 below show examples of bitrates under different conditions. Figure 1 includes dynamic GOP and figure 2 includes dynamic FPS.

The example in Figure 1 plots the instant bitrate from a video with four different motion scenarios A, B, C and D, with two different Zipstream configurations compared to when Zipstream is disabled. All streams are variable bitrate (VBR) streams with GOP length=32. Each I-frame update is clearly visible as bitrate spikes and the instant bitrate can be read on the vertical axes.

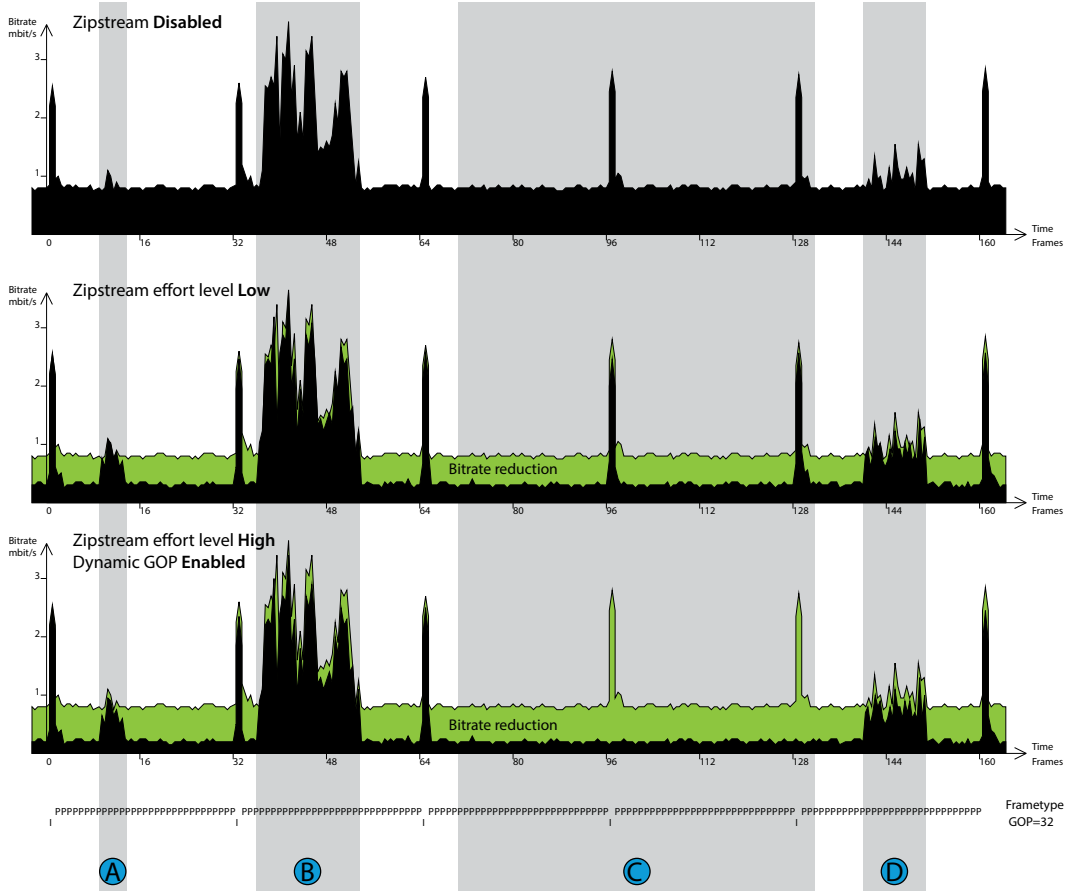

Figure 1: Illustration of instant bitrate in four different scenarios.

The example in figure 1 highlights the behavior of Zipstream under different conditions:

A. Time period with short small motion. The small motion is detected, and adding bits in that region can preserve the quality of the moving part of the video.

B. Period with large longer motion needs more space but still it is possible to save storage during this motion, since the dynamic ROI detects areas where non-prioritized information can be removed.

C. Periods without motion are detected and the dynamic GOP algorithm removes unnecessary I-frame updates.

D. Period with small longer motion.

The example in figure 2 shows the instant bitrate and frame rate from a video with four different motion scenarios E, F, G, and H, with dynamic FPS enabled.

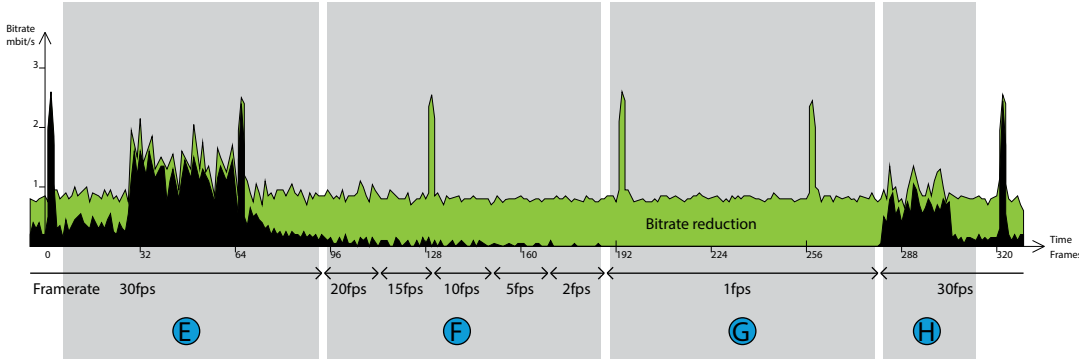

Figure 2: Illustration of instant bitrate and dynamic frame rate in four different scenarios, with Zipstream and dynamic FPS enabled.

The example in figure 2 highlights the behavior of Zipstream with dynamic FPS in four different scenarios:

E. With motion in the scene, the camera produces data at 30 fps.

F. When the motion decreases, the frame rate drops substantially. The bitrate decreases when the frame rate is reduced since less data is transferred.

G. During a period without any motion in a completely static scene, the frame rate decreases to almost zero between I-frames. Sparse, spread I-frame updates are the only bitrate source.

H. When motion is detected again, the camera immediately returns to 30 fps.

3.4 Zipstream parameter settings

The original compression parameter is still used when Zipstream is enabled. This parameter controls the amount of compression applied to important forensic details. Compression is usually set to 30 and this value is recommended also when Zipstream is enabled.

The bitrate controller built into the encoder can be combined with Zipstream to enforce a maximum bitrate (MBR) limit. MBR is a variable bitrate (VBR) configuration that includes an upper limit to protect the system from temporary bandwidth spikes. However, the MBR limit must be sufficient to capture the details of moving objects in the scene to enable the full potential of Zipstream and VBR.

To limit the bitrate for increased storage time, cloud-connected cameras or cameras using edge storage should be configured with the strength parameter set to 30 (effort level High) and dynamic GOP enabled. This setting is suitable to combine with motion detection triggering and/or MBR systems where the bitrate is allowed to adapt to changes in complexity. Edge storage is a capability in Axis network cameras and video encoders that enables video recording directly to an onboard SD card or a network-attached storage device (NAS).

The dynamic GOP and dynamic FPS algorithms can be used simultaneously for increased bitrate reduction. If the VMS or other client software cannot handle the varying GOP length, select a shorter maximum GOP length, or disable dynamic GOP altogether. If the software cannot handle the varying frame rate, disable the dynamic FPS frame skipping or set a minimum allowed dynamic FPS.

3.5 Comparison measurements

Figure 3 shows examples of surveillance scenes where Zipstream can reduce storage needs. The measured total bitrate reduction is shown, together with the Zipstream effort level and whether dynamic GOP and dynamic FPS were enabled.

	**Retail:** Well-lit indoor detailed scene, sparse medium-sized movements.		
	Zipstream strength: Low	Dynamic GOP: Off Dynamic FPS: Off	Total bitrate reduction: 25%
	**City surveillance:** Daytime overview, many small car movements most of the time.		
	Zipstream strength: High	Dynamic GOP: On Dynamic FPS: Off	Total bitrate reduction: 50%
	**Constant recording:** Nighttime overview, very noisy scene with sparse small and fast car movements.		
	Zipstream strength: High	Dynamic GOP: On Dynamic FPS: Off	Total bitrate reduction: 90%
	**City surveillance:** Continuous surveillance of scenes with limited motion.		
	Zipstream strength: Extreme	Dynamic GOP: On Dynamic FPS: On	Total bitrate reduction: 73%
	**Constant recording:** Nighttime constant recording of scenes without motion or with very small and sparse motion.		
	Zipstream strength: Extreme	Dynamic GOP: On Dynamic FPS: On	Total bitrate reduction: 99.7%
	**City surveillance:** Daytime overview, many small movements most of the time.		
	Zipstream strength: Extreme	Dynamic GOP: On Dynamic FPS: Off	Total bitrate reduction: 85%

Figure 3: Examples of surveillance scenes where Zipstream can reduce storage needs.

[2] The bitrate reduction will vary depending on the light and movement conditions and details of the scene.

4. Zipstream for specific camera types

4.1 PTZ cameras

The algorithm for PTZ cameras enables Zipstream to reduce bitrate even when the camera is panning, tilting, or zooming. The algorithm reduces bitrate in real-time by automatically updating the dynamic ROI that is used to preserve important image details. To further improve PTZ usability and reducing system requirement, a dynamic bitrate controller has been added to avoid bandwidth peaks caused by camera movements. It does this by reducing the general video quality while still preserving reference points that the operator can use for navigation, in order to maintain the orientation and the tracking of important objects during fast camera movements.

4.1.1 Enhanced dynamic ROI

In a PTZ camera, dynamic ROI compensates for both scene motion and camera motion (panning, tilting, and zooming) simultaneously. This algorithm reduces bitrate with the same method while the camera is panning, tilting, or zooming. During camera movements, some areas of the video are identified as more important and prioritized, while other areas are compressed more to reduce bandwidth usage. This part of the algorithm reduces the average bandwidth and storage, while still keeping forensic details.

4.1.2 Dynamic bitrate controller

Even with the enhanced dynamic ROI enabled, a panning, tilting, and zooming camera requires more bandwidth than a fixed camera. This is because new information is captured at a very high rate during the PTZ camera's quick repositioning. However, since motion blur reduces the video quality anyway, a dynamic bitrate controller algorithm can be used to automatically reduce the bitrate and avoid bandwidth peaks triggered by camera motion. A PTZ camera typically performs panning, tilting, and zooming within a fraction of a second. As soon as the camera stops again, the bitrate controller immediately restores the bitrate to deliver optimal video quality.

The dynamic bitrate controller eases requirements on the entire system, such as transmission equipment (switches and routers), storage (recording servers and disk size), and viewing devices (computers and decoders). This means that remote PTZ cameras can be operated using a less complex transmission channel, while still preserving their benefits and flexibility.

4.1.3 Bitrate reduction example

The example in Figure 4 plots the instant bitrate from a video with four different motion scenarios J, K, L, and M with a configuration with Zipstream for PTZ enabled compared to when Zipstream is disabled. All streams are VBR streams with GOP length=32. The instant bitrate can be read on the vertical axes.

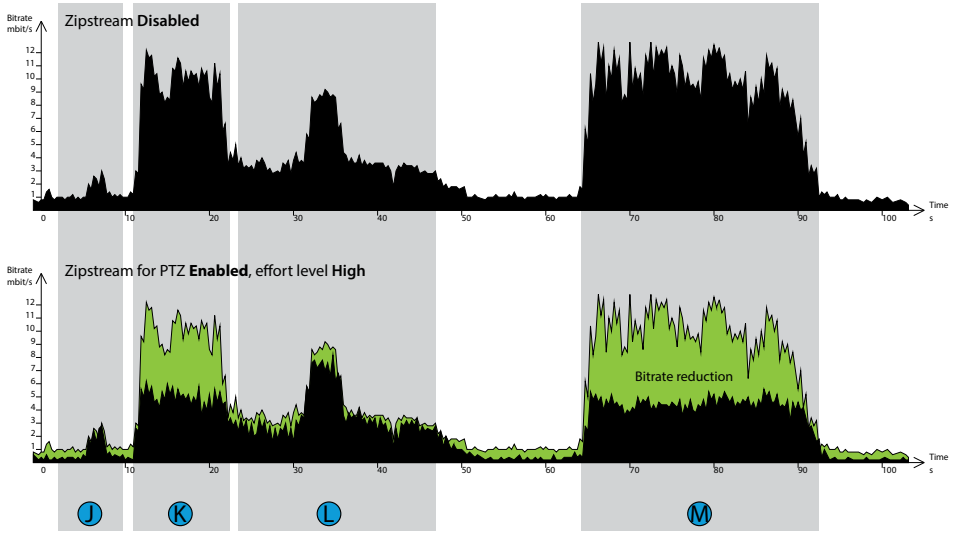

Figure 4: Illustration of instant savings in a PTZ scenario.

J. Initially, the PTZ camera is motionless in its overview position. The standard Zipstream algorithm is saving considerable amounts of storage since the camera is completely still. Suddenly the PTZ camera captures a small suspect motion.

K. The operator pans and zooms the PTZ camera to get higher resolution footage of the event. During fast motion, the dynamic bitrate controller achieves a substantial bitrate reduction.

L. The PTZ camera is recording the event in high quality video. The standard Zipstream algorithm automatically saves bitrate in non-prioritized areas of the image.

M. After the event, the operator pans and tilts to view a larger area to search for similar events. The video quality is automatically adjusted to match PTZ movements.

4.2 4K Ultra HD and multi-megapixel cameras

It is now possible to enable Zipstream for the products with the highest need for bitrate reduction: 4K and multi-megapixel cameras. While these high-resolution products are extremely efficient to capture forensic details, they have been expensive to use due to the high storage requirements. Today Zipstream can analyze a 4K stream in real time to reduce transmission and storage.

4.3 360-degree panoramic cameras

Panoramic cameras are fixed cameras that provide wide-area coverage – between 180° and 360° – with a single camera. They are often used in surveillance, especially for monitoring activity and detecting incidents in large areas, for tracking the flow of people, and for improving area management.

New panoramic camera models combine the wide-area coverage with multi-megapixel resolution, and provide dewarped images with a high level of detail. Zipstream supports these cameras for all panoramic view options, and can reduce the storage need significantly.

4.4 H.265 support

Zipstream has now been extended to support the latest global video encoding standard H.265. However, H.265 has been developed for noise-less broadcast video and is not yet fully adapted to surveillance, where, for example, difficult lighting conditions are common.

Zipstream for H.265 is delivered with the same tools and benefits as previous versions, but with even lower bitrate for complex scenes. H.265 is very efficient for encoding moving objects with a lot of details, but in some cases Zipstream with H.264 might still deliver lower bandwidth.

Zipstream provides both H.264 and H.265 support in parallel in the same products, without any need for reconfiguration or complicated system setup. True multi-streaming with per stream selectable codec and configuration enables both types of video to be transmitted or stored, for maximum flexibility. This twin-codec approach is central for making the transition period between the two standards as smooth as possible.

5. Application areas

In high-security systems, bitrate reduction is desirable, while image quality must be maintained. Even the smallest threat must be detected, and advanced forensic work must be possible to perform after any incident. Zipstream enables continuous recordings due to the low bitrate used for static scenes.

With AXIS Companion, an even lower bitrate is desired, since system cost and easy installation is a priority. The aim is to save video of sufficient quality on cost-efficient edge storage. However, video quality should be decreased in a controlled manner, in order to easily find and understand the course of events. Zipstream reduces the amount of missed triggers by allowing longer recording segments for each motion-triggered event without generating excessive data.

Zipstream is relevant for all users that wish to reduce the cost of storage or network load. In any video surveillance system, reducing storage needs directly results in lower total cost independent of system size or storage solution. With Zipstream, less storage is needed per recorded minute. This enables increased retention time, resolution, or number of cameras, without increased storage space.

5.1 Forensic details

Axis recommends using networked video with variable bitrate (VBR) where quality is adaptive to scene content in real time. Using constant bitrate (CBR) as a storage reduction strategy is not recommended, since cameras delivering CBR video may have to discard important forensic details in critical situations due to the bitrate limit.

Zipstream makes it possible for the system installer to continue using VBR, with or without limit, for optimum video quality while reducing the storage requirements. This way the surveillance system can keep delivering high quality video. Important forensic details such as faces, tattoos and clothing patterns are isolated and preserved, while irrelevant parts such as white walls, lawns, and vegetation are smoothed out.

If a storage solution or the network requires an absolute upper bandwidth limit, Zipstream is compatible with MBR, a method which protects the system from temporary bandwidth spikes.

6. Acronyms and abbreviations

CBR	Constant bitrate
FPS	Frames per second
GOP	Group of pictures
HEVC	High Efficiency Video Coding
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-TITU	Telecommunication Standardization Sector
MBR	Maximum bitrate
MPEG	Moving Picture Experts Group
NAS	Network-attached storage
PTZ	Pan-tilt-zoom
ROI	Region of interest
VBR	Variable bitrate
VCEG	Video Coding Experts Group or Visual Coding Experts Group
VMS	Video management system

Notes

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About Axis Communications

Axis offers intelligent security solutions that enable a smarter, safer world. As the market leader in network video, Axis is driving the industry by continually launching innovative network products based on an open platform - delivering high value to customers through a global partner network. Axis has long-term relationships with partners and provides them with knowledge and ground-breaking network products in existing and new markets.

Axis has more than 2,700 dedicated employees in more than 50 countries around the world, supported by a global network of over 90,000 partners. Founded in 1984, Axis is a Sweden-based company listed on NASDAQ Stockholm under the ticker AXIS.

For more information about Axis, please visit our website www.axis.com.

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