Dejero *Hybrid Encoding Technology*

Delivering high-quality, low-latency live video
from field environments

Dejero

Dejero

+1 519 772 4824
connect@dejero.com
www.dejero.com

Table of Contents

Executive Summary

Digital video encoding seeks to maximize video quality subject to a range of operational constraints imposed by use cases and economics. Because encoding context varies, there isn't any single superior or "best" encoding implementation and choosing an appropriate encoding solution requires situational consideration of many factors, including:

- End-to-End System Context
- Video Quality
- Latency Sensitivity
- Bitrate Sensitivity
- Power Efficiency
- Transport Sensitivity
- Ease of Use
- Field Upgradeability

Low-latency, live video contribution is a particularly challenging use case which requires carefully managing two crucial functions:

- Encoding: Optimizing a complex, dynamic interplay between video quality, bitrate, latency, and power demands
- Transport: Ensuring available connections are leveraged in a manner which optimizes reliability, throughput, and latency

While there is some choice when it comes to implementations, many encoding a pplications—including low-latency, live, and remote contribution use cases—are best-served by a hybrid architecture. This approach combines the speed and efficiency of hardware with the flexibility, adaptability, and upgradeability of software.

Dejero has developed a highly specialized *Hybrid Encoding Technology* ideally suited for low-latency, live video contribution scenarios.

This solution works in concert with our Emmy® award-winning *Smart Blending Technology* to form a tightly integrated system which maximizes video quality by responding in real time to changes in network characteristics and video content.

Dejero

Introduction

Digital video encoding is a foundation of much of today's broadcast and media industry, and is an emerging technology in public safety and other important fields.

> Video encoding doesn't exist in isolation—it's one part of an end-to-end system extending from the camera to the display

By converting raw digital video into a compressed format, encoding optimizes storage and transport, enabling high-quality video to be transmitted from a range of environments—some of which impose very challenging restrictions—and distributed around the world, often in only a few seconds.

While this paper focuses on video encoding, it's important to recognize that video encoding doesn't exist in isolation; rather, it's one part of an end-to-end ("glass-to-glass") system extending from the camera capturing raw frames to the display upon which the content is ultimately viewed.

> Encoding typically comes down to optimizing a complex, dynamic interplay between picture quality, bitrate, latency, and power consumption

The demands and characteristics of this end-to-end system dictate (or at least strongly influence) the criteria and priorities when choosing between different encoding, transmission, and transport implementations. Encoding under all but ideal circumstances comes down to optimizing a complex and dynamic interplay between picture quality, bitrate, latency, and the power consumption of the encoding and transport processes.

In practice, there is no one single superior or "best" encoding implementation—rather, particular use cases favor particular encoding characteristics.

> Remote production use cases are hugely dependent upon network quality and reliability

For instance, consider the production scenario of field contribution for live broadcast teams in remote locations. This use case leverages battery-powered mobile devices to transmit live video, thus demanding low-latency, highly power-efficient encoding. This is in stark contrast to use cases with dedicated rack-mount encoders that have ample power supply and hardwired fiber connections, as remote productions must grapple with the constraints and implications of often-unreliable (prone to temporary loss of connectivity) and highly variable communications uplinks, which means the encoding must account for the complications and restrictions imposed by dynamic latency and bitrate.

There is some flexibility—and there are some trade-offs—when it comes to encoding implementations: hardware offers some strengths, as does software, while hybrid approaches strive to leverage the best of both worlds.

> There is no "best" encoding solution—different use cases impose different requirements

This paper explores video encoding, its place within an end-to-end system for low-latency, live field contribution, and different implementation architectures so that readers searching for a solution are aware of the myriad factors which should be considered when making a decision—foremost among which is a keen understanding of production use cases and environments.

Overview of Digital Video Encoding

Digital video encoding is the process of converting raw (unencoded) digital video into a compressed format which consumes less space when stored or transmitted.

> The encoder's function is to maximize video quality subject to constraints imposed by factors including bitrate (or storage) limitations or operating targets, latency demands, and power restrictions

The encoder's function is to maximize video quality subject to constraints imposed by factors including bitrate (or storage) limitations or operating targets, latency demands, and power restrictions. Over the years, different approaches to encoding video and measuring the quality of the encoded video have been developed.

Advanced Video Coding (AVC)

Video encoding standards ensure interoperability between devices; by far the most commonly used format for recording, compressing, and distributing HD video content is Advanced Video Coding (AVC), which is also referred to as H.264 or MPEG-4 Part 10, Advanced Video Coding (MPEG-4 AVC).[1]

AVC processes video frames using a block-oriented, motion-compensation-based approach implemented by a handful of processes executed in serial: analysis, prediction, transformation, quantization, and bitstream generation (see Figure 1).

> By far the most common format for recording, compressing, and distributing HD video content is Advanced Video Coding (AVC)

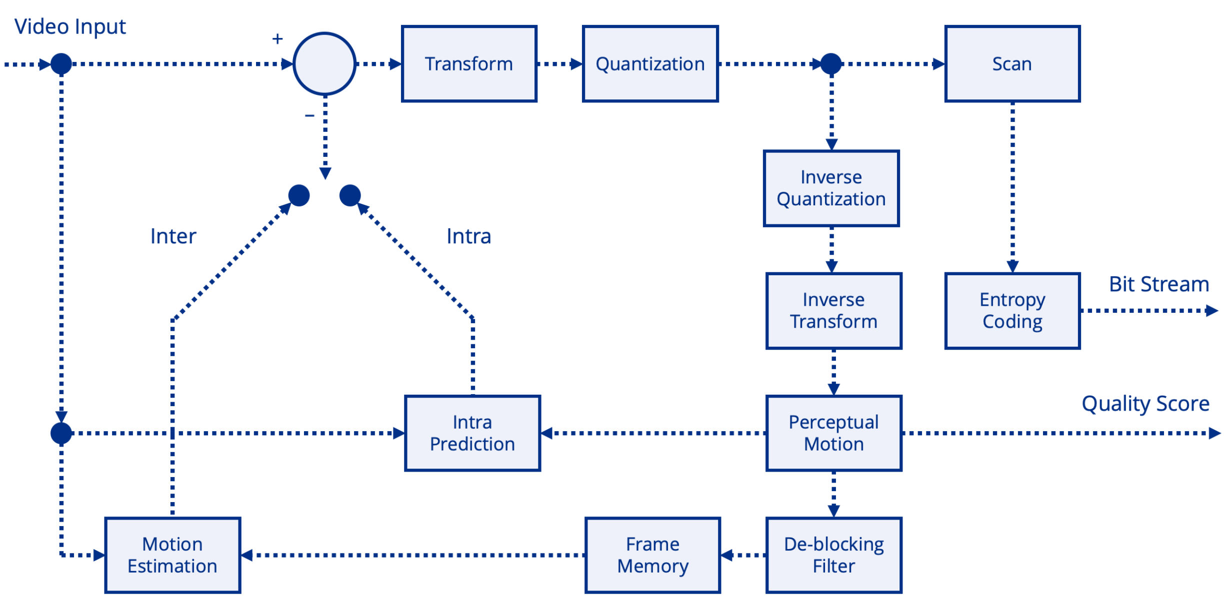

Figure 1 — Block diagram showing AVC workflow (adapted from Wikipedia's AVC page)

[1] Bitmovin's 2019 Video Developer Report suggests that AVC is used by 91% of video industry developers.

To enable compression while preserving quality, the analysis, prediction, and transformation processes each employ techniques to remove redundancy, including:

- Separating frames into macroblocks: 4x4 (pixels), 16x16, or larger sections
- Macroblock processing, including intra-frame and inter-frame prediction, which is used to predict the contents of a macroblock within a frame (intra) or across successive frames (inter) and which incorporates motion estimation
- Macroblock processing by transform (for instance, an integer discrete cosine transformation—or DCT—in AVC) which outputs coefficients that represent the macroblock efficiency in the frequency domain

The output from the transformation process is a set of coefficients which represent the video in an efficient (compressed) manner. The next stage, quantization, is a lossy compression technique which reduces the precision of the transform coefficients. The output from the quantization process is then formatted (encoded) into a compressed bitstream (entropy coded) which is then stored or transmitted.

> High Efficiency Video Coding (HEVC) is designed to be the primary successor to AVC

High Efficiency Video Coding (HEVC) and Versatile Video Coding (VVC)

High Efficiency Video Coding (HEVC)—also known as H.265 and MPEG-H Part 2—is designed to be the primary successor to AVC. HEVC is intended to offer better data compression at the same level of video quality or substantially improved video quality at the same bitrate.[2]

In pursuit of these objectives, HEVC extends AVC by:

- Processing information in Coding Tree Units (CTUs): whereas AVC's macroblocks can span 4x4 to 16x16 block sizes, CTUs can be as large as 64x64
- Improving intraframe prediction within the same picture
- Improving motion prediction, region merging, and compensation filtering

While Version 1 of HEVC was available in April 2013, adoption was slowed by concerns and complications arising from patents, licensing, and royalties.

Versatile Video Coding (VVC) is the successor to HEVC; the final standard is planned to be completed in 2020.

> HEVC is intended to offer better data compression at the same level of video quality, or substantially improved video quality at the same bitrate—under ideal processing and content scenarios

Other Encoding Standards

Beyond the MPEG collection of standards—which include AVC, HEVC, and VVC—there are additional encoder options, some of which are open and royalty-free. Two relevant standards are:

- VP9: Developed by Google as the successor to VP8. Initially, VP9 was mainly used on YouTube, but the emergence of the Alliance for Open Media (AOMedia) and its support for the ongoing development of the successor AV1, led to growing interest. In contrast to HEVC, VP9 support is common among web browsers
- AV1: AOMedia Video 1 (AV1) was developed as a successor to VP9 to specifically enable high-quality, royalty-free distribution of HD/UHD video content to end users

> A video is perfect quality if the output—the video being viewed on a display device—perfectly replicates what was captured by the camera; such perfection is only possible with lossless video compression

[2] Compared to AVC, HEVC offers from 25% to 50% better data compression at the same level of video quality—under ideal processing and content scenarios (we will return to this caveat in a few pages).

Measuring Video Quality

Earlier, we mentioned the need to preserve quality while achieving compression—but what does that really mean? A video is perfect quality if the output—the video being viewed on a display device—perfectly replicates what was captured by the camera.

While conceptually the notion of video quality is simple, developing an objective measure for what is a subjective experience from the viewer's perspective is a challenge.

> Three popular full-reference video quality metrics are the Structural Similarity Index (SSIM), Video Multimethod Assessment Fusion (VMAF), and Peak Signal-to-Noise Ratio (PSNR)

Three popular full-reference metrics—meaning that the output is compared against the raw uncompressed video—are the Structural Similarity Index (SSIM), Video Multimethod Assessment Fusion (VMAF), and Peak Signal-to-Noise Ratio (PSNR). Each attempt to objectively quantify video quality, but they take different approaches to doing so:

- SSIM incorporates elements of human visual neurobiology and perception
- VMAF attempts to predict subjective video quality based on a reference and distorted video sequence
- PSNR measures the quality of reconstruction of lossy compression codecs

In recent years SSIM has been extended by researchers and companies to better account for additional factors which impact viewer perception of quality. SSIMPLUS is an improved example of SSIM, and is discussed more in a later section.

> Video encoding and transport must attempt to preserve quality in trying circumstances

There are also reference-less approaches to assessing video quality, which are applied to the encoded video without direct comparison to the raw source.

Quality Considerations

Given unlimited processing resources and time, and combined with no concern for latency or buffering, preserving video quality would be significantly less challenging than it is in the real world.

In practice, video encoding and transport must attempt to preserve quality in trying circumstances, including (possibly all at once):

- Remote environments where cellular network coverage is unreliable and bandwidth is limited
- Using low-power, portable equipment
- Live, real-time use cases where latency must be minimized and encoders don't have the luxury of looking ahead to upcoming video frames
- Extremely dynamic content (which limits the effectiveness of motion-prediction algorithms)

Consequently, evaluating video encoding quality in a meaningful way requires considering performance over a wide range of bitrates, network conditions, equipment requirements, input content (for instance, a reporter standing in front of a static scene versus a drone's-eye-view of a disaster scene or parade crowd) and power restrictions.

> Evaluating encoding quality in a meaningful way requires considering performance over a wide range of bitrates, network conditions, equipment requirements, input content, and power restrictions

Encoding Challenges in the Real World

It's important to recognize that encoding doesn't exist in isolation; rather, it's applied within an end-to-end ("glass-to-glass") system starting with the camera and extending to the display upon which the content is ultimately viewed (Figure 2).

The demands and characteristics of this end-to-end system dictate—or at least strongly influence—the criteria and priorities when choosing between different encoding and transport implementations.

The demands and characteristics of the end-to-end system dictate—or at least strongly influence—the criteria and priorities when choosing between different encoding and transport solutions

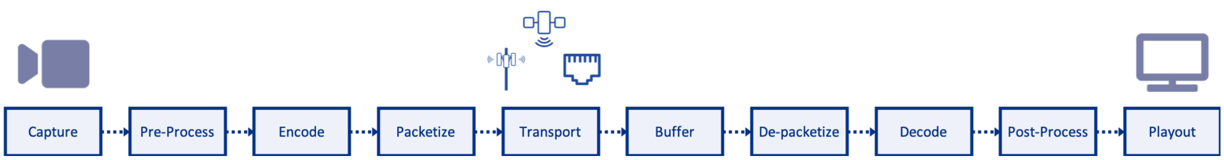

Figure 2 — Encoding exists within an end-to-end ("glass-to-glass") system

Example: Offline Video Production vs. Remote, Live Video Contribution

To illustrate how different encoding use cases impose different requirements, consider the two broadcast scenarios in Table 1: a studio-based production for later consumption ("Offline") and remote contribution for live broadcast ("Remote, Live").

Exceeding the cellular bitrate causes latency to soar due to bufferbloat, while exceeding the satellite bitrate creates pixelation

Remote production—particularly for live contribution—is very sensitive to uplink characteristics including latency, jitter, bandwidth, and reliability

	Offline	Remote, Live
Latency Sensitivity[3]	None Because video will be stored for later consumption, there is practically no sensitivity to latency; two-pass encoding—where the encoder effectively looks into the future—can be used with a variety of encoders	Very High Because video is for live delivery, there is very high sensitivity to latency at every stage of the end-to-end system, including encoding; as a result, the encoding must be optimized for minimal latency, subject to constraints outlined here

[3] In terms of sensitivity to the overall time it takes for a single frame of video to transfer from the camera to the viewer's display (consider that just to capture a single frame at 30 frames/second takes 33ms).

	Offline	Remote, Live
Bitrate Sensitivity	Very Low Generally, the viewer will favor the highest quality video possible on the viewing device and network conditions, and a fixed rate will be selected from a set of available rates to achieve the best possible quality	Very High Remote production leverages networks with highly variable characteristics, so adaptive bitrate and adaptive resolution are required to achieve the best possible quality
Power Sensitivity	Low Reducing compute to optimize power consumption is more of an economic consideration than a practical production limitation	High Remote production relies on battery-powered portable devices and requires high compute—and power-optimized solutions will achieve the best video quality
Transport Sensitivity	Very Low Content is stored and served from distributed datacenters and distribution networks with reliable, high-capacity, highly consistent terrestrial links; some buffering on the last mile is acceptable and is a consequence of the viewer's environment	Very High Remote production—particularly for live contribution—is very sensitive to uplink characteristics including latency (particularly differences between connections), jitter (variation of latency within a single connection), bandwidth (availability and variation), and reliability (packet drops)

Table 1 — The demands imposed by different end-to-end video use cases vary enormously

When it comes to quality, the difference between the offline scenario and the remote, live scenario is even more pronounced. In many cases, the video produced offline will be encoded into separate files, each with either a different resolution or maximum bitrate. That is, quality is the major factor which determines encoding characteristics.

> In offline production, quality determines encoding characteristics; latency, power demands, connection reliability and even bitrate have little influence

In contrast, in the remote, live contribution scenario, quality is a goal to be maximized, but is subject to limitations imposed by the end-to-end system characteristics.

> There isn't any single "best" encoding implementation—rather, particular encoding use cases favor particular solution characteristics

Ultimately, there isn't any single superior or "best" encoding implementation—rather, particular encoding use cases favor particular solution characteristics.

Key Takeaways for Remote, Live Contribution Scenarios

It's clear that the two scenarios impose very different requirements on the video encoding function. In particular, the remote contribution for live broadcast scenario demands low-latency, highly power efficient encoding.

> Remote, live contribution requires carefully managing encoding and transport; ideally, encoding incorporates real-time feedback from the transport function

Moreover, this scenario must also grapple with the constraints and implications of often-unreliable (prone to temporary connectivity interruptions) and highly variable communications uplinks—it's not as straightforward as simply configuring to a particular quality and letting it operate; instead, the encoding must account for the complications and restrictions imposed by dynamic latency and varying bitrate.

In practice, contributing high-quality live video from remote locations requires carefully managing two crucial functions:[4]

- Encoding: Optimizing a complex, dynamic interplay between picture quality, bitrate, latency, and power demands
- Transport: Ensuring available connections are leveraged in a manner which optimizes reliability, throughput, and latency

Moreover, the encoding operation should incorporate feedback from the transport function to optimally utilize available communications without exceeding bitrate limitations (Figure 3).

> in remote, live video contribution, quality is a goal to be maximized, but is subject to limitations imposed by the end-to-end system; latency, available bitrate, connection reliability, and power demands each play an enormous role

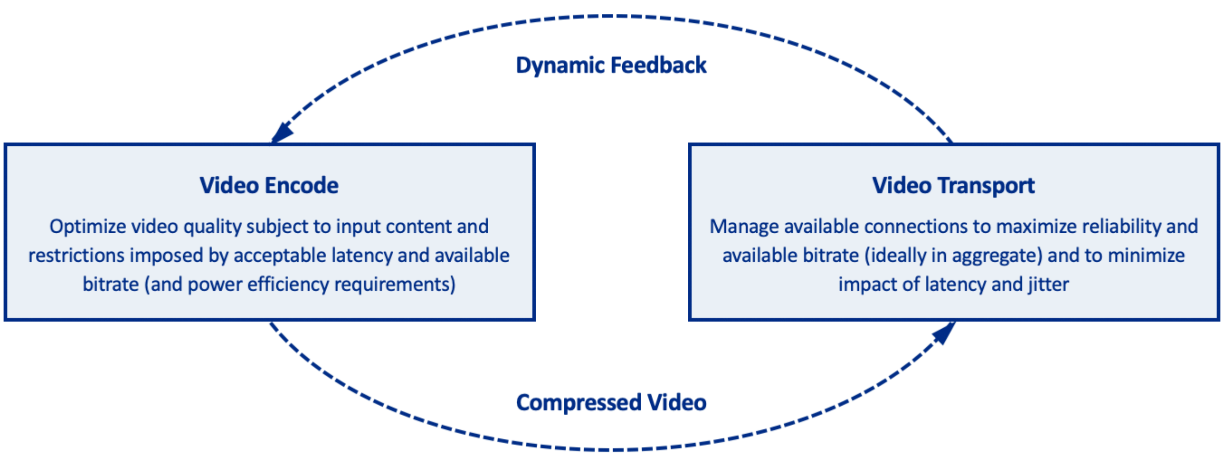

Figure 3 — Within the end-to-end system, there is a crucial and dynamic (varying in real time) relationship between the encoding function and the transport function

[4] Although omitted from discussion, transmission also plays a vital role; in this regard the capabilities of the antenna are very important.

Implementing High-Performance Video Encoders

As is the case with many technologies, there is some flexibility—and there are some trade-offs—when it comes to implementation. Broadly, there are two divergent approaches:

- **Hardware-centric:** Implement the entire video encoding process in hardware using an FPGA, an ASIC, or a similar solution
- **Software-centric:** Implement the entire video encoding process in software, perhaps leveraging some basic hardware acceleration like GPUs or multimedia acceleration features

> There is some flexibility—and there are some trade-offs—when it comes to implementing encoding: hardware is fast and power-efficient, but inflexible; software is flexible and upgradeable, but can demand more power

The hardware-centric approach is very power efficient, but is inflexible and not upgradeable. Moreover, while hardware-centric designs are generally quite good at fulfilling common use cases, their rigidity means that they can be challenged by corner cases and unexpected demands (for instance, extremely dynamic scene changes or highly constrained bitrates).

In contrast, the software-centric approach is very flexible and highly upgradable, but can demand more power for encoding computation.

> Many encoding applications are best-served by a hybrid architecture which delivers the best of both worlds

Different Demands

Analysis of video encoding reveals that there are a number of computationally intensive functions within the encoding process which are highly predictable (including motion estimation and discrete cosine transforms) and other functions which are variable and unpredictable.

Moreover, beyond the standard encoding functions and flow outlined above there are proprietary, non-standard optimizations which vary by solution provider—which is why even vendors using identical components can deliver different performance and capabilities.

Given these realities, many encoding applications are best-served by a hybrid architecture which benefits from the best of both approaches:

> The encoding process is a mix of highly predictable, computationally intensive functions, and functions which are variable and cannot be predicted

- Hardware for the computationally intensive, power-hungry functions which are done frequently and predictably
- Software for the less computationally intensive, less power-hungry functions and/or functions which are customized for, or variable based upon, the specific application

Table 2 summarizes the relative strengths and weaknesses of the three architecture families.

	Hardware-Centric	Software-Centric	Hybrid
Efficiency	Very High	Low	High
Flexibility	Low	Very High	High
Upgradeability	Low	Very High	High

Table 2 — Summary of relative strengths and weaknesses of different encoding architectures

Choosing a Solution: Hardware, Software, or Hybrid?

Ultimately, there is no singular 'right' approach, so understanding specific needs and circumstances are crucial to making the best decision:

> Ultimately, there is no singular 'right' approach — understanding specific needs and circumstances are crucial to making the best decision

- Is efficiency paramount? Then hardware might be suitable, provided flexibility and upgradeability don't matter
- Do flexibility and upgradeability matter above all else? Then explore software-centric solutions, but be prepared to cope with significantly higher power demands
- Are efficiency, flexibility, and upgradeability all important? Then look into hybrid architectures which can provide all three in equal measure

An Optimized Solution for Low-Latency, Live Video: Dejero *Hybrid Encoding Technology*

Working closely with broadcast and media organizations for over a decade, Dejero has developed a highly specialized *Hybrid Encoding Technology* ideally suited for low-latency, live video in remote contribution scenarios and challenged connectivity environments.

> Dejero has developed a highly specialized *Hybrid Encoding Technology* ideally suited for low-latency, live video contribution scenarios

Importantly, our *Hybrid Encoding Technology* works in concert with our *Smart Blending Technology* to form a tightly integrated system which responds in real time to changes in network quality and video content (Figure 4):

- *Hybrid Encoding Technology* delivers high-quality, low-latency, efficient encoding which incorporates real-time feedback to maximize video quality subject to the dynamic characteristics of the communications network
- *Smart Blending Technology* blends cellular, satellite, or any other wired or wireless IP connection from multiple providers to form a virtual network optimized for speed and reliability

> Dejero *Hybrid Encoding Technology* works in concert with our *Smart Blending Technology* to form a tightly integrated system which responds in real time to changes in network quality and video content

HYBRID ENCODING TECHNOLOGY

> Dejero employs a number of tools to ensure the encoding pipeline performs under real-world conditions

Maximizing Video Quality with Dynamic Hybrid Encoding

Our hybrid architecture surrounds a fast, efficient hardware encoder—optimized with proprietary technologies and techniques—with a flexible, field-upgradeable software pipeline which maximizes video quality by dynamically adapting encoding in real time.[5]

> Dejero's live contribution solution—which includes our *Hybrid Encoding Technology*—was recognized with a Technology and Engineering Emmy® Award

These hardware and software features combine to enable low-latency, high-quality, highly power-efficient video contribution even in the most challenging environments (Table 3). Two recurring themes in Table 3 are "automatic" and "real-time":

- **Automatic:** Dejero's solutions are engineered to simplify the experience in the field by reducing the amount of manual configuration needed
- **Real-Time:** remote production of live video is a dynamic process which can only be optimized for quality by accounting for real-time changes in transport and content characteristics

> The features of Dejero's *Hybrid Encoding Technology* combine to efficiently deliver low-latency, high-quality video even in the most challenging field conditions

[5] The field upgradeability is a major asset, as it extends the functional lifetime of equipment by allowing it to keep pace with new standards and powerful new features; for instance, we provided updates to HEVC and delivered new features (a notable example is content adaptive encoding) via software updates.

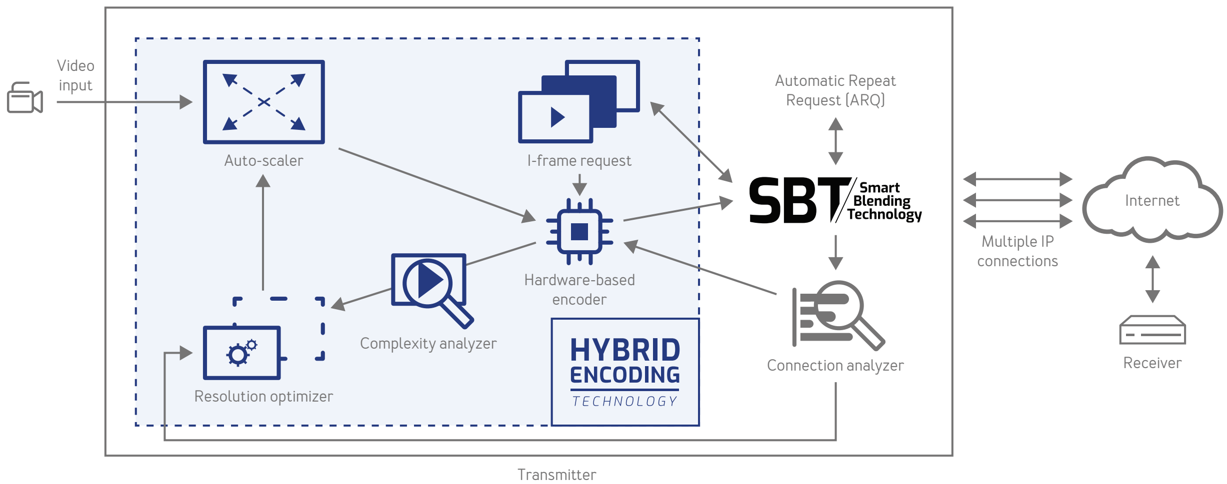

Figure 4 — Dejero's *Hybrid Encoding Technology* and *Smart Blending Technology* combine to create an integrated end-to-end system which dynamically adjusts encoding to optimally utilize multiple IP communications networks

Feature	Description
Hardware-based encoder	Highly optimized video encoder which employs proprietary techniques to ensure ultra-low latency, power-efficient encoding: • Computationally intensive and predictable operations are performed in hardware • Parameters and microcode allow fine-tuned configuration
Auto-scaler	Automatically scales video to maximize resolution which can be reliably encoded and transported
Resolution optimizer	Ensures high video quality by automatically incorporating Complexity analyzer and Connection analyzer in real-time to determine maximum resolution (spatial and temporal) which can be encoded and transported
I-frame request	Reduces required transmission bandwidth and maximizes goodput by automatically requesting I-frames only when needed
Complexity analyzer	Provides real-time feedback from the hardware encoder about the complexity of the content being encoded
Connection analyzer	Provides real-time feedback from Dejero *Smart Blending Technology* about the blended connection's throughput capacity and latency

Table 3 — The features of Dejero's *Hybrid Encoding Technology* combine to efficiently deliver low-latency, high-quality video even in the most challenging field conditions

Validating Encoding Performance and Informing Evolution

To ensure quality under real-world conditions we rigorously test the whole encoding pipeline by encoding a raw video source at a transmit unit, transferring to a receiver unit, decoding the video, and objectively measuring quality against the original source; Table 4 describes several tools we employ in this process.

This hybrid architecture surrounds a fast, efficient hardware encoder—optimized with proprietary technologies and techniques—with a field-upgradeable software pipeline which maximizes video quality by dynamically adapting encoding in real time

Quality Tool	Description
Automated Test System	Programmatic interfaces for the encode, decode, and resampling steps of our pipeline enable unit-style testing at scale
Content Library	A comprehensive library which includes a diverse collection of content types to place different demands on the encoder
SSIMPLUS®	SSIMPLUS® (by SSIMWAVE®) analyzes compressed video to calculate a Viewer Score which quantifies an end viewer's perception of video quality; SSIMPLUS extends beyond SSIM in a number of important ways, allowing us to validate encoder performance under real-world conditions and restrictions[6]

Table 4 — Dejero employs several tools to ensure the encoding pipeline performs under real-world conditions

The Role of *Smart Blending Technology*

Dejero *Smart Blending Technology* is a novel approach to connection or link aggregation which delivers both improved reliability and faster aggregate connection speeds compared to other techniques.[7]

In addition to creating a higher-capacity, more reliable blended connection over which to deliver low-latency, live video, *Smart Blending Technology* also provides valuable feedback which allows our *Hybrid Encoding Technology* to make real-time optimizations (Table 5).

Dejero *Smart Blending Technology* creates a higher-capacity, more reliable connection and provides feedback which informs real-time encoding optimizations

SBT Smart Blending Technology

[6] For a summary of reasons why SSIM itself isn't sufficient, see SSIMWAVE's Why is SSIM Not Good Enough?

[7] More information is available in the technical showcase Dejero *Smart Blending Technology*—Delivering reliable connectivity, anywhere

Feature	Description
Connection Aggregation	Blends available connections together, increasing reliability and allowing the video content to leverage the full combined potential of individual links—even when those links have different and variable characteristics
Automatic Repeat Request (ARQ)	Proprietary implementation of an error-control and packet recovery mechanism which outperforms conventional approaches[8]
Transport Feedback	Provides instantaneous feedback about the capacity (bitrate) and latency of the blended connection, so *Hybrid Encoding Technology* can dynamically adjust resolution in real-time

Table 5 — Dejero *Smart Blending Technology* creates a reliable blended connection over which to transmit live video and provides our *Hybrid Encoding Technology* with important feedback

[8] Dejero's optimized ARQ technique was a major contributing factor in our 2018 Emmy® award for Technology and Engineering

Conclusions

Digital video encoding seeks to maximize video quality subject to constraints imposed by factors including bitrate (or storage) limitations or operational targets, latency demands, and power restrictions.

> The low-latency, live remote contribution use case is particularly challenging—only purpose-engineered encoding solutions are up to the task

Ultimately, there isn't any single superior or "best" encoding implementation—rather, particular encoding use cases favor particular solution characteristics.

> Many factors should be considered when evaluation and selecting an encoding solution

For instance, the remote, live contribution use case requires carefully managing two crucial functions:

- Encoding: Optimizing a complex, dynamic interplay between picture quality, bitrate, latency, and power demands
- Transport: Ensuring available connections are leveraged in a manner which optimizes reliability, throughput, and latency

> The demands and characteristics of the end-to-end system determine the criteria and priorities which matter when choosing between different encoding and transport implementations

Summary of Solution Considerations

Choosing an appropriate encoding solution requires careful consideration of many factors (Table 6). Fundamentally, the encoding use cases and environments strongly influence which considerations merit priority.

> Given challenging realities, many encoding applications are best-served by a hybrid architecture which benefits from the speed and efficiency of hardware combined with the flexibility, adaptability, and upgradeability of software

Hardware, Software, or Hybrid?

There is some flexibility—and there are some trade-offs—when it comes to encoding implementations. There are a number of computationally intensive functions within the encoding process which are highly predictable and other functions which are variable and unpredictable.

Given these realities, many encoding applications are best-served by a hybrid architecture which combines the speed and efficiency of hardware with the flexibility, adaptability, and upgradeability of software.

> Power efficiency is an often-overlooked factor, but can be crucial in remote environments

A Proven Implementation: Dejero *Hybrid Encoding Technology*

Dejero has developed a highly specialized *Hybrid Encoding Technology* ideally suited for low-latency, live video contribution scenarios.

This *Hybrid Encoding Technology* works in concert with our Emmy® award-winning *Smart Blending Technology* to form a tightly integrated system which maximizes video quality by responding in real time to changes in network characteristics and video content.

> Beyond purely functional considerations, it's important to assess a solution's ease of use

Consideration	Explanation
End-to-End System Context	Encoding doesn't exist in isolation—it's applied within an end-to-end ("glass-to-glass") system starting with the camera and extending to the display. The demands and characteristics of this end-to-end system—including encoding, transmission, and transport functions—determine the criteria and priorities which matter when choosing between different encoding and transport implementations.
Video Quality	Evaluating video encoding quality in an objective, repeatable way requires considering performance over a wide range of bitrates, network conditions, equipment requirements, and input content.
Latency Sensitivity	Some production use cases, like low-latency, live remote contribution, are extremely sensitive to the time it takes for a single frame of video to transfer from the camera to the viewer's display; others, like offline production for later consumption, have no practical sensitivity to latency.
Bitrate Sensitivity	Some production scenarios—particularly in remote and mobile environments—are extremely sensitive to the bitrate capacity of available communication uplinks; for instance, exceeding the bitrate on cellular will cause latency to jump significantly due to bufferbloat, while exceeding the bitrate on satellite will degrade quality by creating pixelation.
Power Efficiency	Production equipment and environments impose restrictions on power consumption, which may in turn be a crucial factor in deciding upon an encoding solution.
Transport Sensitivity	Transport characteristics including latency, jitter, bandwidth, and reliability can significantly influence the choice of an appropriate encoding solution; ideally, the solution can dynamically adapt—in real time—to changes in transport characteristics.
Ease of Use	Beyond purely functional considerations, it's important to assess a solution's user experience—for instance, does it require highly skilled and potentially time-consuming manual configuration, or is it engineered to automatically optimize to accommodate real-world production environments and dynamic video and transport characteristics?
Field Upgradeability	Field upgradeability extends the functional lifetime of equipment by allowing it to keep pace with new standards and to be augmented with powerful new features.

Table 6 — Summary of factors which should be considered when evaluation and selecting an encoding solution

Dejero

About Dejero

Driven by our vision of reliable connectivity anywhere, Dejero delivers fast and dependable connectivity required for cloud computing, online collaboration, and the secure exchange of video and data.

With our global partners, Dejero supplies the equipment, software, connectivity services, cloud services, and support to provide the uptime and bandwidth critical to the success of today's organizations.

To learn more:

connect@dejero.com

+1 519 772 4824

www.dejero.com