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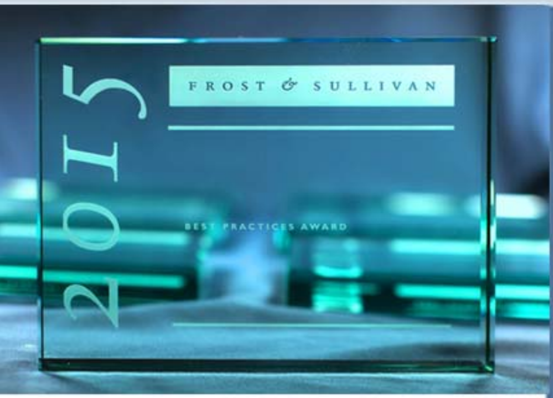
2015 Global Video Encoding and Transcoding Technology Innovation Leadership Award



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50 Years of Growth, Innovation & Leadership

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Industry Challenges

Video compression is a challenging business. At its core, it is a push industry, where new technological advances open up new capabilities and drive demand for state-of-the-art solutions. Innovate too quickly, and customers become frustrated because current equipment becomes obsolete before its time. Innovate too slowly, and competing proprietary technologies or disruptive vendors can step in and change the 'status quo' on their own terms. Where video was once a technology-intensive science that was the domain of a chosen few, today it is a vastly commoditized ecosystem. At the same time, truly reliable, scalable and high efficiency systems remain rare. The ability to maintain premium pricing for these high-end, R&D-intensive products while remaining competitive with run of the mill, economy-grade offerings, is among the most pressing challenges that encoder and transcoder vendors are facing today.

Traditional wisdom in this industry says that for highly demanding applications, hardware cores are a necessity. ASICs, DSPs and FPGAs all offer power-efficient, performance-efficient platforms upon which to build dense, reliable and compression-efficient encoders and transcoders. Moreover, the cost of hardware-based products has typically been significantly lower than software based systems. On the other hand, hardware based systems suffer from one key drawback; they cannot be modified or significantly upgraded once they are built and deployed. In the days when video technologies remained stable for several years at a time, this was a reasonable trade-off for cost, density and performance gains. However, in today's world, consumers and CE device vendors are driving the state-of-the-art in video expectations, and technologies are evolving at a breathtaking pace. With business models as yet uncertain, resolutions and optimal configurations quickly changing, and video standards themselves in flux, one thing is clear; operators cannot be expected to commit to major investments in currently state-of-the-art appliances that may be obsolete within months.

The rise of commoditized hardware benefited the industry in some sense by slashing encoder prices, but it brought along two side effects that have begun to stifle the industry. First, when every vendor has more or less the same silicon core implementation, they lose the ability to differentiate from each other. Certainly there is some room for unique value-add in terms of interfaces, packaging and sales strategy, but the cores were becoming essentially identical. Second, with average sales prices plunging and saturation simultaneously setting in, revenue growth rates were plummeting and companies were finding it essentially impossible to profitably innovate. As very few companies had the resources to develop their own custom chipsets, and commoditized chipsets stifled both differentiation and pricing power, the need to change the underlying playing field was becoming more and more urgent.

Amidst this frustration came two more curveballs: the rapid rise of interest in cloud-based and software-defined video processing infrastructure deployments and the impending rise of the new HEVC codec coupled with 4K programming aspirations. The notion of fixed-capacity hardware appliances is at odds with the inherent promise of scalability of the cloud, which began to delay purchases and have customers look for other alternatives. Moreover, the promise of yet another wave of innovation close on the heels of an investment cycle was worrisome to those who remembered all too clearly the dilemma faced by operators who had invested in MPEG-2 HD systems only to have state-of-the-art AVC technology be released shortly after.

It was clear that a new architectural paradigm was needed to solve these several proverbial 'catch-22' dilemmas at once. The platform needed to be powerful yet reconfigurable and power-efficient. It needed to be software-based, but match hardware in terms of throughput, reliability and density. It needed to provide enough computational horsepower to process HD and even 4K video in real time with best in class compression efficiency, but provide total cost of ownership competitive with other economical alternatives. It needed to provide silicon-level acceleration, but allow individual product vendors to innovate and differentiate so as to maintain the vigor and profitability of the overall industry. It needed to cater to the task-intensive, machine-aware characteristics of video transcoding while playing well in virtualized scenarios and in software-defined architectures.

Intel has admirably risen to the challenge of crafting an outstanding line of enabling chipsets and technologies that manage to enable all of the above. Intel successfully combined a deep understanding of the dilemmas facing vendors, the changing needs of the industry and the changing nature of video processing itself with the core competency that comes from the company's rich and long history with digital media technologies. The result is a wave of innovation underway from vendors who are leveraging Intel's building blocks to build cutting edge, disruptive, profitable and highly effective video encoders and transcoders.

Technology and Implementation Excellence

Commitment to Innovation

Intel architectures follow a tick-tock innovation cycle on an 18-month cadence. A "tock" represents a new processor architecture which typically introduces significant new capabilities, while a "tick" cycle optimizes the previous microarchitecture to lay the foundation for further innovation while bringing down costs for present state-of-the-art. A large community of vendors plans their own product innovations around this upgrade cycle.

Intel had first optimized these applications on the Xeon X56xx family, based on the Nehalem architecture. In 2010, the Intel Xeon was being optimized for live transcoding applications. From its first release of the QuickSync Video (QSV) SDK on the Xeon E3 in 2011, through the Sandy Bridge and Ivy Bridge releases and now at the present Haswell architecture, Intel has steadily improved its own encoder, decoder and transcoder implementations.

From 2nd to 4th generation architectures, Intel has tripled its balanced mode encoding performance while approximately doubling compression quality; high quality (HighQ) performance has also improved significantly. This enables higher densities and faster throughputs in software applications that leverage its hardware building blocks and its SDK. Another aspect of performance is power efficiency: Haswell provides 5X the video processing throughput at half the power consumption using a number of sophisticated silicon-level enhancements and memory management strategies. The chipset also features 20x idle power reduction, low power IO, and link power management[1]. QSV is available as a turnkey solution to those who want it (typically for consumer and semi-professional software packages), but it also supports customized encoders and transcoders, as well as virtualized and cloud-based use cases.

In terms of specifics, Haswell features a number of core improvements over Ivy Bridge (the previous microarchitecture version) such as 10% higher IPC (instructions per cycle) deeper buffers, and better branch prediction. Haswell also enables "higher core counts and provides higher bandwidth per core, better performance per watt, reduced latency, lower average memory latency and increased PCIe bandwidth and latency tolerance". The chip also provides better management of and performance tolerance against so-called "noisy neighbors" which are tasks (such as, ironically, transcoding) which tend to capture a disproportionate share of computing resources and thus starve other processes.

As software-defined architectures rise to the forefront of modern data processing, and as video becomes a first class citizen in the data universe, Intel has a clear strategy of enabling the re-architecting of data centers. In the company's own words, "The E5-2600 v3 is at the heart of an agile data center and is designed to enable compute, storage and networking to work better together". The third generation of the E5-2600 CPUs feature 18-core chips, use the 22nm 3D transistors process and introduce support for DDR4 memory and 40GbE networking capabilities. With content transcoding volumes soaring, operators quickly running out of computational capacity, and even cloud service vendors beginning to be overwhelmed, Intel's advances in enabling dense, high throughput and high quality transcoders within virtualized environments are playing a critical role in broader solution development. As we will discuss in the commercial success factor below, a wide range of ecosystem participants are taking advantage of Intel's ongoing strategic innovation to craft products and solutions that are successfully meeting today's content transformation, packaging and delivery needs. Intel-powered servers themselves perform

[1] http://www.hotchips.org/wp-content/uploads/hc_archives/hc25/HC25.80-Processors2-epub/HC25.27.820-Haswell-Hammarlund-Intel.pdf

well enough, but when augmented with specialized hardware such the SharpStreamer acceleration card[2], a single standard server can be used to transcode nearly 4,000 HD frames per second. This solves the scalability and cost problem of putting all daily live content online for catch-up viewing on demand on a next-day basis, and plays an enabling role in bringing online video services to parity with live linear bouquets.

It is also worth noting that Intel offers a powerful development platform to build high-performance software on its chipsets. Intel Media Server Studio allows developers to "code more efficiently from the very beginning of the product cycle". Video compression software is computation-heavy and memory-intensive, leading to aggressive use of multi-core, parallelized and multi-threaded programming strategies, in addition to intensive use of memory optimization techniques. Intel Media Server Studio allows development of high-quality, high-performance code while simplifying testing and improving reliability.

Commitment to Creativity

Intel clearly recognizes that standardized video compression ecosystems succeed because decoders are fully standardized while encoder vendors are free to innovate in how they generate compressed streams, and how they make tradeoffs between speed/latency and compression efficiency, or power consumption and compression efficiency. Rather than force vendors to make a choice between uniform, commoditized hardware or performance-inefficient software, Intel took the strategic enabling path of opening up their APIs and internal tools to allow companies to choose native QuickSync where appropriate, but innovate deeply in a combination of hardware and software when necessary. Because of this strategic direction, Intel chipsets are able to serve every application from low-cost or free laptop compression software to the highest-end contribution encoders and multi-screen transcoders. Notable market participants leveraging Intel (Xeon E3 and/or Xeon E5) include ActiveVideo, ATEME, Envivio, Elemental, Harmonic, Vanguard Video, Vantrix and Thomson Video Networks, among many others. The same design paradigm is now playing a crucial enabling role as 4K HEVC encoders and transcoders are prototyped and developed. By freeing up the creativity of R&D engineers in the most demanding video applications, Intel has – as discussed above – changed the competitive and technological dynamic of the video compression industry.

Commercialization Success

Nearly every leading encoding/transcoding vendor is placing Intel-powered products at the head of their portfolio. Elemental, arguably the fastest growing transcoder vendor in the market today, is powered by Intel. Vendors like Vantrix leverage Intel to build cutting-edge high density transcoders in partnership with servers like HP Moonshot and Kontron Symkloud, bringing business-enabling economies of scale to operators such as VideoTron

[2] https://www.artesyn.com/computing/products/product/sharpstreamer-pcie-7207

a leading Canadian MSO. iStreamPlanet built a high-density transcoder in-house, powered by Intel, to maximize their internal throughput capacity in order to keep pace with the growing OTT traffic they are handling. ATEME and Envivio are developing high-flexibility, high-performance transcoders using Intel cores. Online video server Wowza uses QuickSync for their just-in-time transcoding plug-in which dramatically simplifies the process for enterprises to distribute online video to multiple devices. Conservatively, we estimate that a third of total multi-screen transcoding revenues are directly or indirectly powered by Intel; for HEVC 4K, over 80 percent of revenues are from products powered by Intel.

Intel architectures are also slowly making inroads in other encoder markets traditionally dominated by fixed hardware. This includes a growing presence in contribution encoding, where approximately 10% of revenue in 2013 was powered by Intel, which we estimate to have grown to 15% in 2014. Pay TV encoders are – as a whole - slower to make the transition. While market leaders such as Ericsson base their primary product line on custom chipsets, they partner strategically with vendors such as Envivio and Elemental – who, as discussed above, heavily leverage Intel in their products. As a broad trend, software-defined infrastructure is playing a growing role as convergence and CAPEX-OPEX considerations drive consolidation across live-linear and on-demand multi-screen workflows, particularly in green field deployments. Having been designed with computationally-intensive video processing in mind, and with features intended to optimize cloud-based performance, Intel has become the core of choice for these architectures. Often encoding (and decoding) programs and appliances are built using third party cores or libraries. Intel is the platform of choice for leading codec library vendors as well, including Vanguard, MainConcept, Star Labs and others. These codec vendors are leveraging Intel platforms not only for new HEVC products (where all-hardware silicon implementations have not yet really hit the market), but also for mainstream AVC products.

On the server side, vendors such as HP are building servers designed to take optimal advantage of Intel's latest capabilities. The new HP Moonshot M710 cartridge claims to be the first server to incorporate the Xeon platform and Intel® Iris Pro Graphics in a single server, making it a high-performance choice for media transcoding applications. Other state of the art products in this category include Kontron SymKloud, Dell servers with Artesyn cards, and the Artesyn SharpStreamer solution.

These products and servers are being built to capitalize on the growing cloud-based video transcoding opportunity – not only for media and entertainment (broadcasting, Pay TV, online video, and more) but also for enterprise applications (house of worship, education, aerospace & defense, and more). Thus, in terms of application diversity, we see Intel's impact across the full gamut of business applications (consumer-oriented through professional 4K+), across a variety of verticals (M&E and enterprise) and across a variety of form factors (appliances, servers and the cloud).

Stage Gate Efficiency

Stage gate efficiency refers to the speed with which Intel itself is able to translate new ideas into new product features, but also the degree to which it can impact time to market for new products in the broader marketplace. As a best practice example, we consider the published use case of Thomson Video Networks, who based its implementation of the ViBE™ XT1000 Xtream Transcoder, which runs the company's proprietary Mustang video encoding algorithms, on Intel® Quick Sync Video (Intel® QSV) technology. In the company's own words, they "collaborated with Intel® to develop this hybrid architectural approach, which delivers best-of-breed density, feature flexibility, and scalability to the ViBE XT1000, a high-density video transcoder."

As discussed earlier, Thomson would have considered a range of design options for this new product, all the way from ASICs to pure-software implementations. Certainly the benefits of flexibility and future-proof design were a consideration. Also important was the ability to build Mustang's differentiated video compression capabilities into the product. At the same time, density, run time performance and power efficiency were important competitive considerations. Intel's balance between silicon components and software interfaces, as well as performance-boosting features such as zero-cost memory copies, allowed Thomson to achieve target density levels (54 HD or 180 SD channels in a 2RU appliance) while also delivering "maximum software flexibility". The company stated that the ability to leverage QSV and integrate it optimally with Mustang algorithms allowed them to "release ViBE XT1000 to the market in record time".

While our discussion so far has focused on M&E applications, it is worth noting the tremendous potential impact of the Xeon E3 with IrisPro on enterprise productivity as well. Last year, Intel's enabling technology was harnessed in HP's Moonshot. On Moonshot, Citrix's rich application virtualization stack XenApp is able to run sophisticated graphics and desktop streaming applications at game-changing levels of performance, density and cost. Intel and HP jointly stated that, on account of its high graphics performance and low power consumption, 10 processors (equivalent to 40 cores) can be fit into a single unit blade, and can deliver "stunning graphics" at "1/3rd the power of discrete graphics". The technology enables a huge leap forward in desktop virtualization performance, allowing graphics-intensive functions such as rendering in Autodesk; browsing and zooming in geospace applications; sophisticated filters in Photoshop; and animations in HTML 5; to be rendered beautifully, with very low latency and in high resolution and/or high frame rates. In the company's words, the graphics are "compelling and profound", and set a new standard in desktop publishing and desktop streaming. In terms of implications, "delivering graphics in the past for rich applications or content that call for OpenGL, OpenCL, and Web GL has always been a challenge when graphics cards were not present. With the HP Moonshot ProLiant m710 for XenApp, powered by Intel, a user achieves on-demand enablement of graphics for those scenarios."

Technological Sophistication

From a traditional perspective, sophisticated hardware that is custom-built to optimally handle video processing has been the starting point of choice for high-performance video encoders and transcoders. Intel's introduction of QuickSync, beginning with the Intel® Xeon® Processor E3 family, began to change this equation for the better. Coupled with Intel® Media Server Studio 2015, this technology enables access to acceleration hardware within the Xeon CPU for the major media transcoding algorithms by providing essential building blocks (such as the DCT and iDCT), and multiple APIs that permit flexible and tailored access to underlying resources, enabling the development of differentiated broadcast-grade products.

Intel's hardware acceleration provides a dramatic improvement in processing throughput over pure-software approaches, while also reducing cost and permitting higher flexibility as compared to customized hardware solutions. Some examples of specific features that enable this compromise are described below.

Video processing is memory intensive, particularly for operations such as motion estimation, predictive coding/decoding, and rendering. Beginning with the Sandy Bridge decoder, Intel introduced a very large and high bandwidth L3 cache, which allows for very fast decoding and consequently accelerated transcoding. In the first generation Core series processors, video decode acceleration was split between fixed function decode hardware and the GPU's EU array. With Sandy Bridge and the second generation Core CPUs, video decoding is done entirely in fixed function hardware, which improves power efficiency and performance. Intel's encoder functionality was introduced in this release as well. Haswell introduces a large 128MB eDRAM cache, with attributes including high throughput and low latency; flat latency vs. sustained bandwidth curve, and fully shared memory between graphics, media, and cores for very efficient multi-media computing. Because memory is shared between the CPU and GPU, memory copy costs essentially fall to zero. The benefit of this multiplies exponentially as resolutions rise from SD to HD to 4K.

Haswell also sports a newly designed Video Quality Engine (VQE), and supports an extensive suite of higher level video processing functions including de-noising and de-interlacing filters, skin tone detection and enhancement, adaptive contrast enhancement, and gamut compression. New in Haswell are built-in features for gamut expansion, skin tone tuned image enhancement, frame rate conversion and image stabilization.

The result of these enhancements is impressive: the chipset is capable of 4-12X real-time transcoding (depending on the selected quality mode), and can perform faster than real time 4K encoding or support multi-stream 4K decoding. The decoder is power-efficient, allowing over 10 hours of video playback on the latest model of the Apple MacBook Air.

Conclusion

As video data swamps the Internet, economical, fast, and high quality transcoding of content becomes critical to support user demands. However, the specific formats and standards being used to compress, package and render this content is changing at an increasingly rapid pace, even as it skyrockets in volume. Systems built with special purpose hardware will struggle to keep up with these changing demands, while naïve software implementations will be unable to meet performance, density and cost-benefit considerations.

Quick Sync Video provides many advantages over other architectures when considering transcoding. Traditional hardware fixed functions provide solutions with low power, and high performance, but are unable to move quickly should there be an update required for the code, while software codecs provide complete flexibility at the expense of power and performance. By utilizing hardware for the functions of a codec that don’t change and software running on compute elements in the GPU for functions that can, Quick Sync Video enables a balanced solution to deliver high performance at low power while maintaining much of the flexibility required to improve the codec over time. For giving “Intel Inside” a whole new meaning, Frost & Sullivan pleased to recognize Intel with the 2015 Technology Innovation Leadership Award in the Global Video Encoding and Transcoding market.

Significance of Technology Innovation Leadership

Ultimately, growth in any organization depends upon finding new ways to excite the market, and upon maintaining a long-term commitment to innovation. At its core, technology innovation or any other type of innovation can only be sustained with leadership in three key areas: understanding demand, nurturing the brand, differentiating from the competition. This three-fold approach to nurturing innovation is explored further below.

Understanding Technology Innovation Leadership

Technology innovation begins with a spark of creativity that is systematically pursued, developed, and commercialized. That spark can result from a successful partnership, a productive in-house innovation group, or the mind of a singular individual. Regardless of the source, the success of any new technology is ultimately determined by its innovativeness and its impact on the business as a whole.

Key Benchmarking Criteria

For the Technology Innovation Leadership Award, we evaluated two key factors—Technology Excellence and Implementation Excellence —according to the criteria identified below.

Technology Excellence

Criterion 1: Commitment to Innovation
Criterion 2: Commitment to Creativity
Criterion 3: Stage Gate Efficiency
Criterion 4: Commercialization Success
Criterion 5: Application Diversity

Implementation Excellence

Criterion 1: Vision Alignment
Criterion 2: Process Design
Criterion 3: Operational Efficiency
Criterion 4: Technological Sophistication
Criterion 5: Company Culture

Decision Support Criteria: Technology Excellence

Criterion 1: Commitment to Innovation

Requirement: Conscious, ongoing development of an organization culture that supports the pursuit of groundbreaking ideas

Criterion 2: Commitment to Creativity

Requirement: Employees known for pushing the limits of form and function, and who are unafraid to pursue "white space" innovation

Criterion 3: Stage Gate Efficiency

Requirement: A process that moves creative, groundbreaking concepts quickly and profitably from early-stage investments to late-stage prototyping

Criterion 4: Commercialization Success

Requirement: A proven track record of taking new technologies to market with a high rate of success

Criterion 5: Application Diversity

Requirement: The development of technologies that serve multiple purposes and can be embraced by multiple user types

Decision Support Criteria: Implementation Excellence

Criterion 1: Vision Alignment

Requirement: The executive team is aligned on the organization's mission and vision

Criterion 2: Process Design

Requirement: Processes support the efficient and consistent implementation of tactics designed to implement the strategy

Criterion 3: Operational Efficiency

Requirement: Staff performs assigned tactics seamlessly, quickly, and to a high quality standard

Criterion 4: Technological Sophistication

Requirements: Systems enable companywide transparency, communication, and efficiency

Criterion 5: Company Culture

Requirement: The executive team sets the standard for commitment to customers, quality, and staff, which translates directly into front-line performance excellence

The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

Frost & Sullivan's 360-degree research methodology represents the analytical rigor of our research process. It offers a 360-degree-view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan's research methodologies. Too often, companies make important growth decisions based on a narrow understanding of their environment, leading to errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry players and for identifying those performing at best-in-class levels.

360-DEGREE RESEARCH: SEEING ORDER IN THE CHAOS

Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

Frost & Sullivan Awards follow a 10-step process to evaluate Award candidates and assess their fit to best practice criteria. The reputation and integrity of the Awards are based on close adherence to this process.

STEP		OBJECTIVE	KEY ACTIVITIES	OUTPUT
1	**Monitor, target, and screen**	Identify award recipient candidates from around the globe	• Conduct in-depth industry research • Identify emerging sectors • Scan multiple geographies	Pipeline of candidates who potentially meet all best-practice criteria
2	**Perform 360-degree research**	Perform comprehensive, 360-degree research on all candidates in the pipeline	• Interview thought leaders and industry practitioners • Assess candidates' fit with best-practice criteria • Rank all candidates	Matrix positioning all candidates' performance relative to one another
3	**Invite thought leadership in best practices**	Perform in-depth examination of all candidates	• Confirm best-practice criteria • Examine eligibility of all candidates • Identify any information gaps	Detailed profiles of all ranked candidates
4	**Initiate research director review**	Conduct an unbiased evaluation of all candidate profiles	• Brainstorm ranking options • Invite multiple perspectives on candidates' performance • Update candidate profiles	Final prioritization of all eligible candidates and companion best-practice positioning paper
5	**Assemble panel of industry experts**	Present findings to an expert panel of industry thought leaders	• Share findings • Strengthen cases for candidate eligibility • Prioritize candidates	Refined list of prioritized award candidates
6	**Conduct global industry review**	Build consensus on award candidates' eligibility	• Hold global team meeting to review all candidates • Pressure-test fit with criteria • Confirm inclusion of all eligible candidates	Final list of eligible award candidates, representing success stories worldwide
7	**Perform quality check**	Develop official award consideration materials	• Perform final performance benchmarking activities • Write nominations • Perform quality review	High-quality, accurate, and creative presentation of nominees' successes
8	**Reconnect with panel of industry experts**	Finalize the selection of the best-practice award recipient	• Review analysis with panel • Build consensus • Select winner	Decision on which company performs best against all best-practice criteria
9	**Communicate recognition**	Inform award recipient of award recognition	• Present award to the CEO • Inspire the organization for continued success • Celebrate the recipient's performance	Announcement of award and plan for how recipient can use the award to enhance the brand
10	**Take strategic action**	Share award news with stakeholders and customers	• Coordinate media outreach • Design a marketing plan • Assess award's role in future strategic planning	Widespread awareness of recipient's award status among investors, media personnel, and employees

About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, enables clients to accelerate growth and achieve best in class positions in growth, innovation and leadership. The company's Growth Partnership Service provides the CEO and the CEO's Growth Team with disciplined research and best practice models to drive the generation, evaluation and implementation of powerful growth strategies. Frost & Sullivan leverages almost 50 years of experience in partnering with Global 1000 companies, emerging businesses and the investment community from 31 offices on six continents. To join our Growth Partnership, please visit http://www.frost.com.