UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

AMAZON.COM SERVICES LLC,
PETITIONER
v.
INTERDIGITAL, INC.,
PATENT OWNER.

IPR2026-00192
U.S. Patent No. 12,143,606

DECLARATION OF DR. CLIFFORD READER, Ph.D.

Declaration

I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

By: c reader

Clifford Reader, Ph.D.

Contents

I, Dr. Clifford Reader, do hereby declare:

1. I am making this declaration at the request of Amazon.com Services LLC ("Amazon" or "Petitioner") in the matter of *Amazon.com, Inc. v. Interdigital Inc.,* IPR2026-00192.

2. I am being compensated for my work in this matter at my standard hourly rate of $850 for consulting services. My compensation in no way depends on the outcome of this proceeding or the content of my testimony.

3. In preparing this Declaration, I specifically considered the following materials, along with the exhibits that I cite throughout this declaration:

(a) Enlarging MB size for high fidelity video coding beyond HD ("VCEG-AJ21") (Exhibit EX-1006 to the above-identified matter).

I. Professional Background

Summary

4. I am a digital media consultant providing technical, business development and intellectual property consulting services in the areas of digital media including digital imaging, digital video, digital audio and digital speech. Applications include consumer audio and video transmission and storage, video, audio and speech compression, real-time video processing and display, digital speech processing, image/video/audio systems architecture, and image/video/audio

chip architecture. I have held this position since 2001 and have consulted for over 80 clients.

Education

5. I received my Doctoral degree in 1974 from the University of Sussex, England. My thesis was titled "Orthogonal Transform Coding of Still and Moving Pictures". The research for my thesis was performed in residence at the Image Processing Institute, University of Southern California, Los Angeles.

6. I received my B. Eng. Degree with Honors in 1970 from the University of Liverpool, England, in the field of electronics.

Work Experience

7. From 1970 to 1973 I performed my graduate research in video compression. I was one of the first to perform a type of image coding (adaptive block transform coding) and the first to apply this type of coding to video. This is described in my thesis[1] and summarized in an SPIE paper[2]. These techniques underlie the audiovisual coding standards known as MPEG (Moving Picture Experts Group), H.26x, and virtually all other video compression schemes today.

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[1] Reader C., "Orthogonal Transform Coding of Still and Moving Pictures", U. Sussex, England, 1973.

[2] Reader C., "Intraframe and Interframe Adaptive Transform Coding", SPIE Vol. 66, 1975.

8. From 1975 to 1981 I studied, designed and developed systems for military imaging systems including realtime image and video reconnaissance systems and battlefield management systems.

9. In the early 1980s I taught classes at Santa Clara University, California in digital signal processing and digital image processing.

10. From 1982 to 1989 I architected and led hardware and software engineering teams in the design of systems for realtime imaging for military, medical and earth resources applications.

11. From 1990 to 2001 I architected and led hardware and software engineering teams in the design of semiconductor chips and systems for realtime imaging in digital consumer audio/video applications, including videoconferencing (with speech coding), broadcast TV and DVD.

Standardization

12. In 1990 I became an accredited delegate to the Moving Picture Experts Group – MPEG. I, and my team contributed to the technical work for all three parts of the standard – Systems, Video and Audio – and I participated in the management of MPEG.

13. I was Head of Delegation (HoD) to MPEG for the United States in 1991-1992, and Editor in Chief of the MPEG1 standard. I personally reviewed and

edited all three parts of the standard in detail, and wrote much of the informative annex for the MPEG1 standard.

14. I chaired the implementation subcommittee that analyzed MPEG1 Audio (Levels I & II aka MUSICAM; Level III aka mp3), Dolby AC3 and other proposed audio compression algorithms including legacy algorithms for complexity and cost of implementation.

15. I was a co-founder of the MPEG4 standard and chaired the subcommittee from inception for 2-1/2 years, beginning in 1993, following which I chaired the MPEG4 Requirements subcommittee for a further 2 years. These subcommittees established many of the fundamental principles of the MPEG4 standard, including object-based coding, software-based implementation, and development of the bitstream as a syntactic language[3]. MPEG4 focused on audiovisual low bitrate coding, including low bitrate speech coding.

16. I was instrumental in establishing the work on Advanced Audio Coding (AAC).

17. I initiated the work in Synthetic-Natural Hybrid Coding (SNHC), and personally contributed to the work on compression of 3D graphics in the area of error resilient coding.

[3] Reader C, "MPEG4: Coding for Content, Interactivity, and Universal Accessibility", Optical Engineering, Vol. 35, No. 1, pp. 104-108, Jan 1996.

18. I was an invited expert to the H.264/MPEG4 Pt. 10 JVT standard development and participated in several meetings in person.

19. I have chaired the AVS China IPR [Intellectual Property Rights] Subgroup for over 20 years and attend multiple meetings each year.

Intellectual Property Rights

20. In 1993 I was hired by CableLabs to be the technical expert for establishing the MPEG Patent Pool (Now MPEGLA). In the course of creating a list of essential IP to practice the standard, I reviewed approximately 10,000 abstracts and 1,000 patents. This is summarized in a chapter of the MPEG book by Mitchell et al.[4]

21. In 2002 I was hired by 10 companies to evaluate the standards essential patent environment for the nascent H.264 standard. Specifically, the 10 companies had a goal to provide a royalty-free profile for the standard. I was an invited expert to the Joint Video Team (JVT) established by ISO and ITU to develop the H.264 standard (Also denoted MPEG4 Pt. 10, AVC).[5]

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[4] "MPEG Video Compression Standard", Edited by J. L. Mitchell et al, Chapter 16, "MPEG Patents", pp.357-362.

[5] Officially, MPEG4 Part 10 is ISO/IEC 14496-10. AVC is an abbreviation of Advanced Video Codec.

22. In 2003 I was hired to evaluate the standards essential patent environment for the nascent national China AVS standards.

23. In 2013 I was hired to evaluate the standards essential patent environment for the emerging AV1 standard.

24. In 2017 I was hired to evaluate the standards essential patent environment for the H.265/HEVC standard.

25. I am the Co-Director of the China AVS Patent Pool Administration. I lead the negotiations for sub-licensing of the AVS standards.

26. I have performed expert consulting and expert witness work for patent holders and defendants in patent licensing negotiations and litigation.

Curriculum Vitae

27. Additional information concerning my professional publications and presentations in the field of digital video and cases in which I have served as an expert are set forth in my current Curriculum Vitae, a copy of which is attached as Appendix A. This Curriculum Vitae lists many publications authored or co-authored by me; and lists the cases in which I have testified via depositions and trials.

II. Legal Standards

28. I understand that 35 U.S.C. § 102 sets forth the requirements for a reference to be considered "prior art," which can include among other things: patents and patent applications that were filed and/or published before the patent-at-issue's

priority date, *see, e.g.*, 35 U.S.C. § 102(b), (e), or "printed publications" that were published before the patent-at-issue's priority date, *see, e.g.*, 35 U.S.C. § 102(a), (b).

29. I understand that for a reference to be considered a "printed publication" under § 102, it must have been disseminated and publicly accessible to at least the pertinent part of the public who would be interested in the subject matter to which the reference pertains. In other words, a POSITA exercising reasonable diligence must be able to locate it.

30. For instance, I understand that if a reference is indexed or cataloged in some way (e.g., by a library or industry group), or if research tools were provided, such that a POSITA exercising reasonable diligence could locate it, that may be sufficient to demonstrate the reference constitutes a "printed publication," but simply e-mailing a document to a select group of individuals may not. But I also understand that whether a reference constitutes a printed publication depends on the facts of each particular case. I also understand that whether a reference qualifies as a printed publication does not require showing a member of the public actually located and read the reference.

III. Enlarging MB size for high fidelity video coding beyond HD was available as of October 2008

31. Before addressing the prior art, it is worth providing an overview of the standardization process followed by standardization organizations such as the ITU-VCEG and ISO-MPEG – two of the dominant organizations in developing video-coding standards. In my opinion, a POSITA would have understood the general procedures of the standardization process, and a POSITA interested in video coding would have been following video-coding standards developments closely, as many in the industry did to ensure any product involving video coding would be compliant with the relevant standards as soon as the standard was published.

32. For context, the ITU is a "United Nations specialized agency for information and communication technologies (ICTs)." Appendix B. The ITU is headquartered in Geneva. Id. The ITU's Telecommunication Standardization Sector ("ITU-T") facilitates the development of international standards, called ITU Recommendations, that help define a global infrastructure of information and communication technologies. See Appendix C. Within ITU-T is a working group called the Video Coding Experts Group ("VCEG"), which focuses on standards for compression coding of video signals.

33. MPEG is a subcommittee under a joint venture between the International Organization for Standardization ("ISO") and International Electrotechnical Commission ("IEC"), and, like the ITU VCEG, develops

"international standards for compression, decompression, processing, and coded representation of moving pictures." Appendix D.

34. Although I am not a member of the ITU, I have been accredited to ITU as an invited expert, I am aware of the ITU's website – including as of the earliest possible priority date of the '606 patent – the accuracy of the dates on the ITU's website and the process for documents being uploaded to the ITU's website. I am also intimately familiar with the MPEG's website.

35. The ITU-VCEG's and ISO-MPEG's development of video coding standards generally comprises a two-stage process. In the first so-called competitive phase, the standards body conducts a requirements analysis to determine market need for a new standard and develops specific requirements for functionality and performance to meet those needs. The committee evaluates the evolving state of the art in relevant technologies to assess the degree to which a new standard would out-perform a current standard. The standards body develops a call for proposals that typically includes a provision of test materials that will allow the proposals to be evaluated on equal terms, test procedures that lay out what each proponent must provide and how evaluation will be conducted, as well as written submission requirements to describe the proposed coding tools and complexity/cost of implementing such tools.

36. The proposals are received, evaluated, and ideally one is selected to be the foundation of the new standard. In practice, the foundation may comprise an amalgam of several proposals.

37. The second so-called collaborative phase then begins, with the establishment of a "working draft" of the standard, plus a "test model" and "reference software," that will support a recursive development process over a succession of meetings. Although the final video coding standard will only normatively specify the coded data format and decoding process, the test model and reference software comprise an end-to-end encoding and decoding process, so that independent parties can conduct experiments that are directly comparable.

38. At each meeting, proponents can submit contributions that may comprise proposals for enhancing existing video coding tools or adding new tools. The proposals will generally include testing of the proposal by implementing it on the reference software and testing it with the test sequences. Other parties cross-check or validate each proposal by reading the description provided by the proponent and independently implementing the proposal on the reference software and testing it. This is facilitated by the uploading of such proposals before a meeting and of course open access to such documents. At the corresponding meeting, the standards body can review the proposal and test results from both the proponent and cross-checkers, and can decide whether or not to adopt the proposal into the draft standard.

If adopted, the proposed tool will be added to the working draft, test model and reference software. In this manner, the standard recursively advances toward maturity.

39. At meetings, the standards body may specify "core experiments" that describe in detail a particular problem or area of work where advancement is needed. Between meetings, the standards body may establish "ad hoc groups" – open to everyone – that may collaborate on specific developments, e.g., core experiments and exchange ideas via email.

40. At each meeting, the chairpersons develop a meeting report, published at the end of the meeting. The meeting report provides a summary and disposition of each contribution to the meeting, summaries of ad hoc group reports, results of core experiments, and administration activities, such as reminders of obligations under the IPR policy. In some cases an "AgendaWithNotes" running account of activities is created progressively during the meeting and is posted online.

41. The openness and timeliness of this process means that any interested person can track the development of the standard – even without attending the meetings. For example, semiconductor companies can have their research and product development departments port the reference software to their proprietary firmware environment after it is updated each meeting and simulate the nascent standard on their own chip development platform. In that way, the companies can

be prepared to release new chips supporting the new standard as soon after the final specification is frozen as possible.

42. I have been asked to provide my knowledge of public availability and accessibility of documents published by VCEG, and in particular, the accessibility of Enlarging MB size for high fidelity video coding beyond HD (VCEG-AJ21). For background, VCEG was a working group of ITU-T, falling under Study Group 16, Question 6 (ITU-T SG16). VCEG was video experts group in a long line of such groups that developed a succession of standards in the ITU-T's H.26x family. The first meeting of the first such study group was in December 1984. VCEG was concerned with standards for compression coding and transmission of video, images, audio, and other signals for audiovisual communication (*e.g.*, videoconferencing). The goal of the VCEG was to produce ITU-T recommendations for video coding and image coding.

43. In the beginning of 2001, VCEG established an Intellectual Property Rights ("IPR") policy to govern the development of the next generation standard.[6] In particular, it established a goal for a baseline profile of the standard to be royalty-free. To implement this goal, the committee adopted a requirement for all

[6] ITU - Telecommunications Standardization Sector STUDY GROUP 16 Question 6 Video Coding Experts Group (VCEG) Twelfth Meeting: Eibsee, Germany, 9-12 January, 2001 Document VCEG-L37 (Appendix E).

contributions to the standard to include an IPR statement, declaring the terms under which the contribution would conform from an IPR standpoint.[7] These were consistent with ITU IPR policy.

44. Because of my involvement with the field, I was well aware of and followed the activities and publications of VCEG during the relevant time period of 2008. As a general policy, VCEG's activities were intended to be public, and the Rapporteur and other members would periodically publish in technical journals work related to VCEG activities. Based on the general policy, VCEG documents were uploaded onto the VCEG's servers and would have been available for download by individuals interested in the development of multimedia and video coding standards. Also, there were no restrictions for downloading documents available from the VCEG sites. According to the general policy by VCEG, the VCEG-AJ21 document also would have been uploaded on the VCEG's servers and made available for download either before or at least by the beginning of the San Diego Meeting in October 2008 where the VCEG-AJ21 was scheduled to be discussed. *See, e.g.*, VCEG-AJ01_d1, p.2 (referencing VCEG-AJ21) (*See* Appendix G).

[7] ITU - Telecommunications Standardization Sector STUDY GROUP 16 Question 6 Video Coding Experts Group (VCEG) Fourteenth Meeting: Santa Barbara, 2427 September, 2001 Document VCEG-N70 (Appendix F).

45. Based on my personal recollection, the version of VCEG-AJ21 filed as EX-1006 is a true and correct copy of the document distributed in or before October 2008 and is substantially identical to the version I have in my personal archive, which is attached as Appendix H.

46. Based on my personal experience and recollection, VCEG's documents were available at the VCEG website, as I was able to access them through that website at the time. Accessing these documents on the VCEG website did not require a username or password.

47. According to the VCEG website for the October 2008 San Diego VCEG meeting, https://www.itu.int/wftp3/av-arch/video-site/0810_San/, VCEG-AJ21.zip was uploaded on October 5, 2008. That is in line with my personal recollection, as well as my understanding of VCEG policies. Based on my personal knowledge, that archive site was available to the public on that date.

48. Based on my personal knowledge of this document around the relevant time period (2008), and the general policies of the VCEG, it is my opinion that VCEG-AJ21 would have been publicly available on the VCEG website on or about October 5, 2008. It also would have been relatively easy to locate and access this document with reasonable diligence by anyone interested in the matter.

IV. Additional Remarks

49. I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

APPENDIX A

Cliff Reader, Ph.D.

Expertise

- Real-time Processing and Display
- Video coding (MPEG-HEVC)
- Audio coding (MPEG-AAC)
- Imaging/Video Systems Architecture
- Imaging/Video Chip Architecture
- Videoconferencing
- Speech Processing
- Consumer audio/video
- Reconnaissance Imaging
- Medical Imaging

Professional Summary

Dr. Reader has over fifty years of work experience in digital imaging, digital video & audio and digital speech processing. In the 1970's and early 1980's, he was one of the leaders in the digital imaging field, performing extensive work in areas of compression, real-time processing, real-time display, image enhancement, and others. Applications included reconnaissance imaging, medical imaging, earth resources management and videoconferencing. This work anticipated much of the technology being used in contemporary consumer digital video systems. He has in-depth experience of the commercial history and when key parts of technology were first developed and published.

Dr. Reader's career includes technical work in areas of algorithm design, system design, and semiconductor chip design; and business development, marketing and sales work in areas of market analysis, product roadmap development and direct sales.

Dr. Reader has held many leadership roles in standards development: US Head of Delegation to MPEG (1991-1993); chief editor of the MPEG1 standard (1991-1993); instigator of the successful effort to make MPEG2 the market standard for digital TV over proprietary competitors in the US and national competitors in Europe and Japan (1992); MPEG4 Subcommittee Chairman (1993-1996); AVS (China) Subgroup Chairman (2003-Present). He is an expert in all major audio-video standards. MPEG audio (Layer I, II, mp3, AAC), Dolby AC3, MPEG video (1, 2, 4), H.264, Windows Media 9 (VC-1), H.265 (HEVC), AVS and AV1. He is also an expert in DVD standards, including formatting, navigation and authoring.

Dr. Reader has extensive experience in patent licensing and patent pools. He was the technical expert for developing the initial list of potentially essential patents for the first MPEGLA patent pool (MPEG2 video and systems). He is the Co-Director leading the pool formation and license negotiations for the AVS patent pools. Dr. Reader has experience in the valuation of patents and the acquisition and sale of patent portfolios.

Dr. Reader has authored over twenty technical papers, two book chapters and two patents in digital video processing, display, and compression. He taught digital signal processing and image processing at Santa Clara University in the early 1980s and as an Adjunct Professor at Peking University, Beijing, China.

Employment History

From:	2001	**Independent Consultant**
To:	Present	Escondido, CA

Provide technical and marketing consulting services in the areas of digital imaging, digital video, digital audio and speech including:

- consumer video
- real-time processing and display
- image and video & audio compression (specializing in standards)
- imaging/video systems architecture
- imaging/video chip architecture
- audio/video transmission, including optical & wireless networks

Over 80 clients including Amazon, Apple, AT&T, Adobe, Broadcom, Canon, China Central TV, Chinese Academy of Sciences, Cisco, Comcast, DirecTV, Dish Network, Disney, EchoStar, ETRI, Facebook, Fujifilm, Gateway, GE, Google, Haier, Hisense, HP, Hulu, IBM, Intel, Johnson Controls, KAIST, Lenovo, LG, Matsushita, MediaTek, Microsoft, Motorola, Netflix, Nikon, Nokia, ON2, OPPO, Peloton, Philips, Quanta, Riverbed, Samsung, Sharp, Siemens, Sony, Starz, Sun Microsystems, Toshiba, TPV, Tyco, US Department of Justice, Verizon, Vimeo, Vizio, Wistron, Xiaomi, Yahoo, Zoran and ZTE.

<u>Personal database of patent analysis:</u>
-Evaluation of all the US patents in the MPEG2, H.264 and H.265 patent pools.
-Evaluation of the US patents and published applications underlying the H.264 and H.265 standards.
-Personal archive of over 2000 audiovisual patents.

<u>Personal database of audio and video prior art.</u>
-Virtually complete collection of all contributions to the H.26x and MPEGx families of standards from 1985 to today.
-Many hundreds of technical journal and conference articles documenting the first invention of key technologies.
-Work-in-progress book on the history of video compression.
-Historical collection of technical data from the earliest digital video, image processing and real-time image display systems in the 1970s and 1980s.

From:	1999	**nDSP Corporation**
To:	2001	Campbell, CA
	Title:	*Vice President of Marketing and Acting Vice President of Sales*

Responsible for marketing and sales in a startup company providing high-quality video signal processors to TV manufacturers. Developed product specifications and roadmap. Built and managed sales and marketing team of 6 direct and contractor staff in the US and Japan to provide technical sales, sales support, application engineering, Marcomm and PR. Established distribution in China, Japan and throughout the Far East. Secured first sales as company moved into production phase with design wins in China, Japan and Europe. Initiated and secured major design wins in emerging Progressive DVD business, with production volumes beginning in 4Q00 at an annualized rate of $3.5M. Established strategic partnership with Pixelworks in LCD chip business. Pixelworks acquired nDSP in 2001.

From: 1997 **CagEnt Technologies, Inc. (wholly owned by Samsung)**
To: 1998 Santa Clara, CA
Position: *Vice President of Sales, Digital Video Products*
Responsible for a line of PC-based real-time MPEG2 and Dolby Digital encoders. Established distribution agreements for third-party DVD authoring software. Secured OEM contracts for the products. Built the sales channel worldwide. Built sales to break-even point in 9 months leading to sale of the product line.

From: 1993 **Samsung Semiconductor, Inc.**
To: 1997 San Jose, CA
Position: *Director of Marketing, Digital Media Products;*
Acting Director of Software Engineering
Developed business plans for digital audiovisual semiconductor chips. Managed team of over 50 software engineers in US and Korea for development of a media processor. Established strategic partnerships with Microsoft and IBM for media processor

From: 1990 **Cypress Semiconductor, Inc.**
To: 1993 San Jose, CA
Position: *Business Development Manager*
Founding member of new business unit chartered to develop a "video DSP". Jointly developed a complete business plan, and personally initiated and developed relationships with Philips, Sun Microsystems, Apple Computers and IBM. Chief architect for this early media DSP design, capable of complete MPEG1 decode in real time. (Fully validated by cycle-accurate simulation). Managed R&D team of 10 hardware and software engineers.

Head of US Delegation to MPEG, 1991 to 1992. Chief Editor of the MPEG1 standard. Technical Expert for establishing the

		MPEGLA Patent Licensing Pool.
From:	1988	**Sun Microsystems, Inc.**
To:	1990	Mountain View, CA
	Position:	*Program Manager*
		Developed requirements and specifications for real-time imaging system. Managed a team of 20 engineers to develop the architecture and high-level design. Interfaced with two key customers – Philips Medical Systems and Lockheed. Developed design for single-board real-time medical and reconnaissance image display.
From:	1981	**International Imaging Systems, Zoran, Virtual Imaging**
To:	1988	Design and development of real-time image processing and display systems. Details available on request.
From:	1975	**Ford Aerospace & ESL (A Division of TRW)**
To:	1981	Details available on request.

Consulting History

Date	2025	**Undisclosed Client**
To:	Present	
	Duties:	Consultant
Date	2025	**Hisense**
To:	Present	
	Duties:	Consulting Expert in VideoLabs matter
Date	2025	**Lenovo**
To:	Present	
	Duties:	Consulting Expert in Truesight Comm. matter
Date	2024	**Google**
To:	Present	
	Duties:	Consulting Expert in ACT matter
Date	2024	**Undisclosed Client**
To:	Present	
	Duties:	Consulting Expert on speech processing
Date	2024	**Undisclosed Client**
To:	Present	
	Duties:	Consultant

Date	2024	**Comcast**
To:	2025	
	Duties:	Consultant

Date	2023	**Amazon**
To:	2025	
	Duties:	Consulting Expert

Date	2023	**Intel**
To:	2025	
	Duties:	Consulting Expert

Date	2023	**Disney**
To:	2024	
	Duties:	Consulting Expert

Date	2023	**Samsung**
To:	2024	
	Duties:	Consulting Expert in ACT matter

Date	2023	**Peloton**
To:	2025	
	Duties:	Consulting Expert in NEC matter

Date	2023	**Alps Alpine**
To:	2025	
	Duties:	Consulting Expert in DivX matter

Date	2022	**Undisclosed Client**
To:	Present	
	Duties:	Consultant

Date	2023	**Fish & Richardson**
To:	2024	
	Duties:	Consultant

Date	2023	**Oppo**
To:	2024	
	Duties:	Consulting Expert on speech processing in Nokia matter

Date	2022	**Samsung**
To:	2023	
	Duties:	Testifying Expert on speech processing in Jawbone matter

Date	2022	**Asus, Lenovo, MSI**

To:	2023	
	Duties:	Consulting Expert in VideoLabs matter
Date	2022	**Google**
To:	2023	
	Duties:	Consulting Expert on speech processing in Jawbone matter
Date	2022	**Starz**
To:	Present	
	Duties:	Consulting Expert in VideoLabs matter
Date	2022	**Meta Platforms (Facebook)**
To:	Present	
	Duties:	Consulting Expert in VideShare matter
Date	2022	**Oppo**
To:	Present	
	Duties:	Consulting Expert in InterDigital matter
Date	2022	**Apple**
To:	2023	
	Duties:	Consulting Expert on speech processing in Jawbone matter
Date	2021	**Verkada**
To:	2022	
	Duties:	Testifying Expert in Motorola Solutions matter
Date	2021	**Facebook**
To:	2022	
	Duties:	Consulting Expert in EyesMatch matter
Date	2021	**Videoconferencing company**
To:	2023	
	Duties:	Testifying Expert
Date	2021	**Canon**
To:	2022	
	Duties:	Consulting Expert in WSOU Investments/Brazos Licensing matter.
Date	2021	**Axis**
	Duties:	Consulting Expert
Date	2021	**nVIDIA**
To:	2022	
	Duties:	Consultant

Date	2020	**Xiaomi**
To:	2021	
	Duties:	Consulting Expert in InterDigital matter
Date	2020	**LG**
To:	2021	
	Duties:	Consulting Expert DivX matter
Date	2020	**Vizio**
To:	2023	
	Duties:	Consulting Expert VDPP matter
Date	2020	**Netflix**
To:	2022	
	Duties:	Consultant
Date	2020	**Oppo**
To:	Present	
	Duties:	Consultant
Date	2020	**IdeaHub**
To:	Present	
	Duties:	Preparation of declaration for Inter Partes Review proceedings. (Unified Patents matter)
Date	2019	**Google**
To:	2021	
	Duties:	Preparation of declarations for Inter Partes Review proceedings (PMC matter)
Date	2019	**Google**
To:	2021	
	Duties:	Consulting Expert (Multiple projects)
Date	2019	**LG**
To:	2020	
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (Uniloc matter)
Date	2019	**Klarquist, Sparkman**
To:	2021	
	Duties:	Consulting Expert (Multiple projects)
Date	2019	**Netflix, Hulu**
To:	2021	

	Duties:	Preparation of declarations for Inter Partes Review proceedings. (DivX matter)
Date	2019	**MediaTek**
	Duties:	Consulting Expert in American Patents matter
Date	2019	**AT&T**
	Duties:	Consulting Expert
Date	2019	**KAIST/KBS**
To:	2021	
	Duties:	Consulting Expert for Inter Partes Review proceedings. (Unified Patents matter)
Date	2019	**Vimeo**
To:	2020	
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (BT matter)
Date	2019	**Apple**
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (Red.com matter)
Date	2019	**Adobe**
To:	2021	
	Duties:	Preparation of declarations for Inter Partes Review proceedings and consulting expert. (Realtime matter)
Date	2018	**Toshiba**
To:	2019	
	Duties:	Testifying expert concerning valuation of essential patents for ATSC standards
Date	2018	**Hisense**
	Duties:	Analysis of essential patents for AAC standards
Date	2018	**HTC**
To:	2020	
	Duties:	Analysis of essential patents for the H.265 standard
Date	2018	**Cisco**
To:	2020	
	Duties:	Consulting expert in Realtime matter
Date	2017	**Dish Network**
To:	2023	

	Duties:	Consulting expert in ClearPlay matter
Date	2017	**Apple**
To:	2019	
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (Uniloc matter)
Date	2017	**Dish Network**
To:	2020	
	Duties:	Testifying expert in Realtime matter
Date	2017	**CustomPlay**
To:	2020	
	Duties:	Preparation of declaration for summary judgment in Amazon case.
Date	2017	**Vizio, Funai, LG, MediaTek, MStar**
	Duties:	Testifying expert in Broadcom case.
Date	2017	**Apple**
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (Nokia matter)
Date	2017	**Vizio**
	Duties:	Preparation of declarations for Inter Partes Review proceeding. (Lightside Technologies matter)
Date	2016	**Dell, Riverbed, EchoStar, Dish Network**
To:	2019	
	Duties:	Testifying expert in Realtime matter
Date	2016	**Sharp, Vizio, ON**
To:	2018	
	Duties:	Testifying expert in WiLAN matter
Date	2016	**Avid**
To:	2017	
	Duties:	Testifying expert in Harmonic matter.
Date	2016	**Apple**
	Duties:	Testifying expert in PUMA matter.
Date	2016	**Vizio**
	Duties:	Testifying expert in PMC matter.
Date	2016	**US Dept. of Justice, Dept. of Homeland Security, DoD, FBI, NSA, & Others**

To:	2021	
	Duties:	Consulting expert in Discovery Patents (3rd Eye Surveillance) matter. Declarations in support of six Inter Partes Reviews.
Date	2015	**ST Micro**
To:	2016	
	Duties:	Consulting expert in Avago matter.
Date	2015	**AT&T**
	Duties:	Consulting expert in Raniere matter.
Date	2015	**Motorola**
To:	2016	
	Duties:	Consulting expert in PUMA matter.
Date	2015	**TPV**
To:	2016	
	Duties:	Consulting expert in Thomson licensing matter.
Date	2015	**Tyco (Exacq, Johnson Controls)**
To:	2019	
	Duties:	Consulting expert in JDS Technologies matter.
Date	2015	**Tyco**
	Duties:	Declaration in support of Inter Partes Review petition in Hawk Technology matter.
Date	2015	**Sceptre**
	Duties:	Expert reports in licensing matter concerning MPEGLA MPEG2 pool patents.
Date	2015	**Samsung**
	Duties:	Consultant and fact witness in case asserting Samsung patents of which I am a named inventor, against NVidia.
Date	2015	**Nissim**
To:	2016	
	Duties:	Consultant expert for patent holder in 20th Century Fox, MGM, and Paramount cases concerning patents related to DVD navigation. Testified at Markman hearings.
Date	2015	**Nikon**
To:	Present	
	Duties:	Consultant.
Date	2015	**Humax**

	Duties:	Search and analysis of prior art.
Date	2015	**Apple**
	Duties:	Analysis of patent portfolio potentially essential for the H.264 standard.
Date	2014	**Haier**
To:	2018	
	Duties:	Analysis of patent portfolios for smart consumer devices.
Date	2014	**Cisco**
To:	2021	
	Duties:	Consultant.
Date	2014	**ZTE, Sony, LG, Samsung, Nokia, GoPro**
To:	2015	
	Duties:	Consulting expert.
Date	2014	**Tyco**
To:	2015	
	Duties:	Expert reports; declaration in support of Inter Partes Review in Trover matter.
Date	2013	**Humax**
	Duties:	Consultant.
Date	2014	**GE Licensing**
To:	2015	
	Duties:	Consultant.
Date	2014	**HikVision & Axis**
To:	2015	
	Duties:	Declaration in support of Inter Partes Review. Expert reports in Trover matter.
Date	2014	**Sharp**
To:	2016	
	Duties:	Declaration in support of Inter Partes Review in Wi-Lan matter.
Date	2013	**InterDigital**
To:	2015	
	Duties:	Consulting expert in support of licensing a patent portfolio.
Date	2013	**Apple**
	Duties:	Consulting expert in National Cheng Kung University matter.
Date	2013	**Acer, ASUS, TPV**

To: 2014
Duties: Testifying expert in Florida Atlantic University matter.

Date 2013 **Toshiba**
To: 2014
Duties: Testifying expert in WiLAN matter.

Date 2013 **Grass Valley Group**
Duties: Consulting expert for defense in FastVDO matter.

Date 2013 **TI**
To: Present
Duties: Consulting expert.

Date 2012 **Vizio**
Duties: Consulting expert in Innovus Prime matter.

Date 2012 **Haier & Shandong Provincial Government**
To: 2014
Duties: Foreign expert advisor for developing and acquiring patent portfolios for innovative consumer products. Development of a patent pool for patents essential to standards for wireless power.

Date 2012 **Vizio**
To: 2014
Duties: Consulting expert in MIT matter.

Date 2012 **Nokia**
To: 2013
Duties: Consulting expert.

Date 2012 **TPV & Vizio**
To: 2013
Duties: Testifying expert for defense in Hitachi matter.

Date 2012 **Samsung**
Duties: Consulting expert in Myport matter.

Date 2012 **Verizon Wireless (Cellco) & T-Mobile**
To: 2013
Duties: Testifying expert for defense in Realtime Data matter.

Date 2011 **Apple**
Duties: Consulting expert in Technicolor matter.

Date 2012 **Microsoft**

To:	2014	
	Duties:	Consulting expert for plaintiff in Motorola matter.
Date	2012	**Apple & LG**
To:	2014	
	Duties:	Testifying expert for defense in MPT matter.
Date	2011	**Sanyo & Olympus**
	Duties:	Consulting expert for defense in FastVDO matter.
Date	2011	**Apple**
	Duties:	Consulting expert for defense in FastVDO matter.
Date	2011	**Sony**
	Duties:	Consulting expert for defense in FastVDO matter.
Date	2011	**Philips**
To:	2014	
	Duties:	Consulting expert for licensing essential patents.
Date	2011	**Apple**
	Duties:	Consulting expert for defense in MobileMediaIdeas matter.
Date	2011	**Video264Innovations**
	Duties:	Consulting expert.
Date	2011	**Nikon, Fujifilm & Panasonic**
	Duties:	Consulting expert for defense in FastVDO matter.
Date	2011	**Haier**
To:	2014	
	Duties:	Consultant for standards, patent pools and patent licensing.
Date	2011	**Susman Godfrey**
	Duties:	Consultant for patent analysis.
Date	2011	**Vizio**
	Duties:	Testifying expert for defense in MPT matter.
Date	2011	**Tivo**
	Duties:	Consulting expert.
Date	2011	**Nikon**
To:	2013	
	Duties:	Consulting expert for defense in MPT matter.

Date	2011	**Broadcom**
	Duties:	Consulting expert.
Date	2010	**Lionsgate Entertainment**
	Duties:	Consulting expert in MPEG licensing matter.
Date	2010	**Verizon**
To:	2012	
	Duties:	Testifying expert for defense in ActiveVideo Networks matter.
Date	2010	**Lenovo**
To:	2011	
	Duties:	Consulting expert for defense in licensor matter.
Date	2010	**Sonic, Cyberlink & Joint Defense Team**
	Duties:	Consulting expert for defense in Mediostream licensor matter.
Date	2010	**Wistron**
To:	2011	
	Duties:	Consulting expert for defense in Toshiba licensor matter.
Date	2010	**Panasonic, Pioneer**
To:	2011	
	Duties:	Consulting expert for defense in VES licensor matter.
Date	2010	**Zoran**
To:	2011	
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date	2010	**Intravisual**
To:	2015	
	Duties:	Consulting expert for patent licensing.
Date	2009	**Apple**
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date	2009	**SanDisk**
	Duties:	Consulting expert re Audio and Video coding patents
Date	2009	**Lenovo**
To:	2011	
	Duties:	Consulting expert for defense in MPEGLA licensor matter.
Date	2009	**Polycom**

To:	2010	
	Duties:	Consulting expert for defense in MPT matter.
Date	2009	**DirecTV**
To:	2011	
	Duties:	Consulting expert for defense in MPT matter.
Date	2009	**EchoStar**
To:	2010	
	Duties:	Consulting expert for defense in MPT matter.
Date	2009	**Vizio**
	Duties:	Consulting expert for defense in Sony matter.
Date	2009	**Vizio**
To:	2010	
	Duties:	Consulting expert for defense in LG matter.
Date	2009	**Vizio, TPV, Amtran**
To:	2010	
	Duties:	Technical report & video presentation to US Customs on design issues related to Funai matter. Testified in ITC hearing, March 2010.
Date	2008	**Humax (Korea)**
To:	2009	
	Duties:	Audio patent and prior art review.
Date	2008	**IC Media (Canada)**
To:	2009	
	Duties:	Design of digital signage.
Date	2008	**AVS Patent Pool Administration (China)**
To:	Present	
	Duties:	Co-Director, leading license negotiations among domestic and multinational licensors.
Date	2008	**DirecTV**
	Duties:	Prior art search for DirecTV's appeal against Finisar.
Date	2008	**Pure Digital**
	Duties:	Prior art research and analysis.
Date	2008	**Wragge (UK)**
	Duties:	Prior art review for two video coding patents.

Date	2008	**Microsoft**
	Duties:	Extensive non-infringement analysis for patents asserted by Multimedia Patent Trust (MPT).
Date	2008	**iPotential**
To:	2010	
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date	2008	**Alba (UK) aka Harvard Research**
To:	2009	
	Duties:	General education on essential patents, licensing, prior art related to the MPEG2 video standard.
Date	2008	**Philips (Holland)**
	Duties:	Review of patents for essentiality.
Date	2008	**Proview**
	Duties:	Prior art search for TV display features.
Date	2008	**Nissim**
To:	2014	
	Duties:	Consultant expert for plaintiff in Time-Warner case concerning patents related to DVD navigation.
Date	2008	**Comcast**
	Duties:	Technical analysis of MPEG2 systems, DSM-CC, and carousel operation in the cable TV network environment. Contribution to expert's report in Comcast's successful litigation against Finisar.
Date	2007	**Sun Microsystems**
To:	2009	
	Duties:	Chief architect of royalty-free video codec: OMS Video. Extensive supporting patent analysis and technical publication analysis for prior art review.
Date	2008	**SanDisk**
	Duties:	Technical analysis of patents and prior art searching for audio coding.
Date	2008	**Stammberger (Munich)**
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date	2008	**Trigem America Liquidating Trust**
	Duties:	Preparation of expert reports concerning litigation between Toshiba and Trigem.

Date	2007	**Susman-Godfrey**
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date:	2007	**Wong-Cabello**
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date:	2007	**Sisvel**
	Duties:	Technical assistance in licensing audio patents to a third party.
Date:	2007	**Quanta**
	Duties:	Technical assistance in litigation related to DVD.
Date:	2006	**CCTV (China Central TV)**
	Duties:	Technical analysis of patents potentially related to MPEG2, H.264, AVS and VC-1 video coding standards and MPEG-AAC and Dolby audio coding standards.
Date:	2006	**MediaTek**
	Duties:	Technical analysis of MediaTek patents potentially related to video coding standards.
Date:	2006	**Alcatel**
	Duties:	Technical analysis of Alcatel patents potentially related to video coding standards.
Date:	2006	**Motorola**
	Duties:	Analysis of technologies contributed to the H.264 standard.
Date:	2005	**Nokia**
	Duties:	Analysis of technologies contributed to the H.264 standard.
Date:	2005	**Avid**
	Duties:	Technical analysis of patents potentially related to coding standards.
Date:	2005	**IBM**
	Duties:	Analysis of technologies contributed to the H.264 standard.
Date:	2005	**HP**
	Duties:	Analysis of selected audio coding patents.
Date:	2005	**ComVentures**
	Duties:	Due diligence review of a start-up company in the video semiconductor business.

Date:	2005	**nVidia**
	Duties:	Prior art search for a set of third-party patents.

Date:	2004	**Microsoft**
	Duties:	• Working with a major financial services company, developed a procurement model for managing licensing costs. • Assisting development of non-infringement positions for a set of patents. (Not in suit).

From:	2004	**SAGEM (France)**
To:	2005	
	Duties:	Technical analysis of potential infringement by SAGEM of a set of third-party patents.

From:	2004	**Polycom Inc.**
To:	2005	
	Duties:	Technical analysis of Polycom patents potentially related to video coding standards.

From:	2004	**Sony Corp.**
To:	2006	
	Duties:	• Technical analysis of potential infringement by Sony of a set of third-party patents. The parties settled without litigation. • Analysis of a third-party patent per Sony’s direction.

Date:	2004	**On2 Inc**
	Duties:	Delivery of the comprehensive set of reports on IPR potentially related to the emerging H.264 standard.

Date:	2004	**Matsushita Avionics**
	Duties:	Technical analysis of potential infringement of Matsushita patents by a third party.

Date:	2004	**Connex Inc.**
	Duties:	Teaching the details of key complex algorithms in the H.264 standard.

Date:	2004	**DoCoMo (Japan)**
	Duties:	Delivery of the comprehensive set of reports on IPR potentially related to the emerging H.264 standard.

From:	2004	**DivX Inc.**
To:	2006	
	Duties:	Analysis of technologies contributed to the H.264 standard

Date:	2004	**Cues, Inc**

Duties: Assisted evaluation of infringement by Cues' products of a patent asserted by a third party. The parties settled without litigation.

From: 2003
To: 2004
GE Licensing

Duties: Working with a major financial services company, developed a business, market and financial model for valuation of a portfolio of patents through their expiration.

From: 2003
To: Present
Institute of Computing Technology, Chinese Academy of Sciences

Duties:

- Preparation of IPR Report for IPR potentially related to the AVS Video standard. This effort involved review of over 2500 abstracts and over 450 patents.
- IPR Subgroup Chairman of AVS. Formed an IPR Experts group to establish a legal foundation for AVS IPR. This group comprised approximately 20 attorneys and business development managers from eight multinational companies representing the PC, consumer, semiconductor and communication industries. (Broadcom, IBM, Intel, Matsushita, Microsoft, Nokia, Sony, Sun Microsystems). The group drafted a member agreement, bylaws and a formal IPR policy governing licensing commitments, disclosure obligations, and protection of license holder rights. AVS Members approved these documents in September 2004.
- Co-Director of AVS Patent Pool. Leading the drafting and negotiation of patent pool management and licensing agreements.
- Adjunct Professor, supervising a graduate student project on deinterlacing algorithm development.

Date: 2003
Yahoo

Duties: Prior art search to provide background information per Yahoo's request.

Date: 2002
To: 2007
Gateway, Inc.

Duties: Extensive prior art search and assistance with claim construction in a litigation matter with Lucent Technologies.

From: 2002
To: 2007
Apple Computer

Duties:

- Technical analysis of Apple patents potentially related to H.264.
- Prior art search for various patents per Apple's request.

Date: 2002
Siemens (Germany)

Duties:

- Technical analysis of Siemens patents potentially related to H.264.
- Delivery of the comprehensive set of reports on IPR potentially related to the emerging H.264 standard.

Date:	2002	**JVT Committee (Apple, Cisco, Nokia, Polycom, Sun Microsystems, Tandberg, Teles, Texas Instruments, UBVideo, VideoLocus)**
	Duties:	Developed a comprehensive set of reports on IPR potentially related to the emerging H.264 standard. The reports included a technical review of legacy and new patents for video coding, and analysis of the patent statements provided by all companies whose contributions were adopted into H.264.
Date	2002	**Intervideo**
	Duties:	Advised on market opportunities in the emerging MPEG4 marketplace.
Date:	2001	**Proskauer Rose LLP**
	Duties:	Provided background support in MPEGLA's (successful) effort to license MPEG2 to the major PC manufacturers.
Date	2001	**Pixonics**
	Duties:	Developed marketing plan and marketing support materials for this incubator-stage company.
Date	2001	**Eltron, (Taiwan)**
	Duties:	Provided overview of the digital video semiconductor market.
Date	1999	**nDSP Corporation**
	Duties:	Drafted the sales and marketing plan for this early-stage company. Joined nDSP full-time.
Date:	1998	**IBM Corp.**
	Duties:	Assisted with participation in the ATSC DASE (datacasting) standard.
Date	1998	**Spruce Technologies**
	Duties:	Assisted with transition of Cagent MPEG encoder product after it was sold to Spruce.
From:	1997	**Samsung Advanced Institute of Technology**
To:	1999	
	Duties:	Supported Samsung researchers in MPEG4 standard development. Led effort to provide error-resilient 3D-mesh coding.
Date	1997	**MPEGLA LLC**
	Duties:	Review of opportunity for an MPEG4 patent pool
From:	1993	**CableLabs**
To:	1994	
	Duties:	Teamed with a patent attorney to develop the initial essential patent list for MPEG2. Reviewed approximately 10,000 abstracts and 1,000 patents

for the MPEG2 Video and MPEG2 Systems standards. This effort led to the MPEGLA patent pool.

Litigation Support Experience

Quinn Emanuel Urquhart & Sullivan, LLP, San Francisco, CA

Case	Motorola Solutions vs. Verkada, **Investigation No. 337-TA-1281**
Project:	Expert report, deposition and trial testimony on invalidity of Motorola patents.
Status:	Final determination found Verkada not infringed
Filed:	August, 2021
Location:	United States International Trade Commission, Washington DC

Orrick, Herrington & Sutcliffe, LLP, New York, NY

Case	ClearPlay vs. Dish Network & EchoStar Technologies, **Case No .: 2:14-cv-00191**
Project:	Expert report, deposition and trial testimony on invalidity of ClearPlay patents.
Status:	ClearPlay patents not infringed
Filed:	March 13, 2014
Location:	United States District Court for the District of Utah

Akin Gump, Fish & Richardson, Finnegan, Baker Hostetler, Washington, DC

Case	Broadcom vs. Vizio, LG, Funai, MediaTek, MStar, **Investigation No. 337-TA-1047**
Project:	Expert report and deposition on non-infringement of Broadcom's patent.
Status:	Final Determination in favor of Respondants.

Jones Day, Cleveland, OH

Case	Avid Technology vs. Harmonic, **Case No. C.A. No. 12-627-GMS**
Project:	Expert reports and deposition on infringement of Avid's patent.
Status:	Parties settled before trial.

Haynes and Boone, Dallas, TX

Case	Realtime vs. Riverbed, **Case No. 6:1S-CV-463-RWS-JDL**
Project:	Expert report, deposition and trial testimony (E. District Texas) on invalidity of Realtime patent.
Status:	Jury found Realtime patent invalid at trial.

Akin Gump, LLP, Irvine, CA

Case	Personalized Media Communications "PMC" vs. TPV et al, **Case No.**

2:15-cv-01366-JRG-RSP

Project: Declaration in support of claim construction brief.
Status: Parties settled.

Feinberg, Day, LLP, Menlo Park, CA

Case Parthenon Unified Memory Architecture "PUMA" vs. Apple, **Case No. 9:12-cv-80701**
Project: Expert report and deposition concerning unified memory architecture.
Status: Trial stayed at request of PUMA. Parties settled.

Carey, Rodriguez, LLP, Miami

Case *Twentieth Century Fox Home Entertainment, LLC, Paramount Pictures Corp., vs. Nissim Corp., **Case No. 14-81349/813450-cv-MARRA**
Project: Expert witness for patent owner in counterclaims for infringement. Declaration and expert testimony at Markman Hearings concerning DVD standards essential patents.
Status: Parties settled before trial.

*Nissim asserted its patents against Twentieth Century Fox and Paramount. The latter filed a complaint seeking a declaratory judgment of non-infringement and invalidity.

TechKnowledge Law Group, Turner Boyd LLP & O'Melveny & Myers LLP, Los Angeles,

Case Florida Atlantic University Research Corporation vs. Acer, ASUS & TPV, **Case No. 9:12-cv-80701**
Project: Expert testimony at Markman Hearings concerning scan converter design. Expert reports and deposition testimony.
Status: Parties settled before trial.

Finnegan, Henderson, Farabow, Garrett & Dunner, LLP

Case WiLAN vs. Toshiba, **Case No. 1:12-Civ-23744**
Project: Expert reports & deposition testimony concerning digital television design.
Status: Parties settled before trial.

O'Melveny & Myers LLP, Los Angeles & Akin Gump LLP, Dallas

Case Hitachi vs. TPV, **Case No. 2:10-CV-260-JRG**
Project: Expert reports, depositions & trial testimony (E. District Texas) concerning digital television design.
Status: Jury found no infringement of Hitachi's patents by TPV and found Hitachi's patents invalid. (Partially reversed by JMOL)

Fish & Richardson P.C. San Diego

Case Multimedia Patent Trust vs. Apple & LG, **Case No. 10-cv-2618 H**
Project: Expert report, & deposition testimony concerning development of technology, standards and patents for video coding.

Status: Jury found no infringement of MPT's patents and found MPT's patents invalid.

Gibson Dunn LLP, Palo Alto

Case Realtime Data vs. Verizon Wireless & T-Mobile, **Case No. 6:10-cv-00493-LED**

Project: Expert reports, depositions and testifying expert in jury trial (E. District Texas) concerning infringement and validity of patents related to data transmission.

Status: Jury found no infringement of Realtime Data's patents by T-Mobile, and found Realtime Data's patents invalid.

O'Melveny & Myers LLP, San Francisco

Case MobileMediaIdeas vs. Apple, **Case No. 10-258-SLR**

Project: Expert reports and deposition, concerning infringement and validity of patents related to MPEG Audio Layer III ("mp3") coding.

Status: Trial bifurcated.

Jones Day, Cleveland

Case Multimedia Patent Trust Vs. Vizio, **Case No. 09-CV-0278-H (CAB)**

Project: Expert report, concerning infringement of patents related to H.264 video coding. (Slated for deposition and jury trial)

Status: Parties settled on the day before my deposition.

Kellog, Huber, et al, Washington, DC

Case Active Video Vs. Verizon, No. 2:10-cv-00248-RAJ-FBS; 2011

Project: Expert report, deposition and testifying expert in jury trial concerning infringement of patents related to video-on-demand

Status: Jury finding of infringement with significantly reduced damages and no finding of willful infringement.

Jones Day, Washington, DC

Case Funai Vs. Vizio, et al, ITC Investigation No. 337-TA-617; 2010

Project: Expert report, deposition and testifying expert in ITC hearing concerning infringement of a patent related to ATSC broadcast standards

Status: Parties settled after the hearing following reports adverse to complainant.

Wilson Sonsini, Goodrich and Rosati, Palo Alto, CA.

Case Terayon vs. RGB Networks; 2007

Project: Expert report for defendant in a contract dispute alleging violation of a non-compete agreement.

Status: Mediation hearing resolved the dispute to the satisfaction of both parties.

Wilmer Cutler Pickering Hale and Dorr, Boston, MA

Case Qualcomm Inc. vs. Broadcom Corp. No. 05 CV 1958 B (BLM); 2007

Project:	Expert report and deposition on behalf of Broadcom against assertions of infringement of patents concerning video encoding and decoding, and on Qualcomm's compliance with the policies and procedures for IPR policy in the H.264 standards committee (JVT of ITU-ISO/IEC).
Status:	Broadcom found not guilty of infringing Qualcomm's patents. The patents were determined to be not essential for implementing the H.264 standard. Qualcomm found guilty of inequitable behavior in the manner of their participation in the H.264 standards committee. Qualcomm's patents held unenforceable against H.264.
	Greenberg Glusker Fields Claman Machtinger & Kinsella.
Case	DTS vs. MediaTek; 2005
Project:	Expert report for defendant in a contract dispute related to hacking into semiconductor chips to enable functionality for which a license fee was payable.
Status:	Mediation hearing resolved the dispute to the satisfaction of both parties. The Mediator personally thanked me for the clarity of my report, which covered technical, business and licensing issues.
	Arvay Finley Barristers, Victoria, BC, Canada.
Case	AVT Audio Visual Telecommunications vs. University of British Columbia; 2005
Project:	Expert report and testimony on behalf of AVT in a contract dispute related to mobile video communication including failure to disclose intellectual property.
Status:	Arbitration hearing resulted in adverse ruling to AVT.
	Thelen Reid & Priest, San Jose, CA.
Case	Toshiba Corp. vs. Trigem Computer Inc. & Trigem America Corp. Case No. CV-03-4558-GHK(AJWx); 2005
Project:	Expert report on behalf of Trigem regarding invalidity of patents relating to video and sub-picture data in multimedia computer systems.
Status:	Suspended due to insolvency of Trigem.
	Morrison & Foerster LLP, San Francisco, CA.
Case	Tivo Inc. vs. Echostar Communications Corp., Echostar DBS Corp., Echostar Technologies Corp ,& EchoStar LLC, Case No. 2-04CV-01; 2005
Project:	Expert report and deposition on behalf of Echostar against assertions of infringement of a patent concerning personal video recorders (PVR).
Status:	Adverse ruling to Echostar.
	Pinsent Curtis Biddle, Leeds, UK
Case	Thomson Licensing S.A. and Deutsche Thomson Brandt GmbH vs. Pace Micro Technology PLC. Case No. HC 2000 No. 1584; 2001

Project:	Expert report and slated to testify on behalf of Pace arguing invalidity of patent and defending against assertions infringement of a patent concerning interlaced video coding.
Status:	Parties agreed to settlement on the second day of trial. Settlement terms were very favorable to defendant, and shortly after the trial, Thomson joined the MPEGLA patent pool.

Education

1974	University of Sussex, England	Ph.D., Applied Sciences (EE/CS) Thesis on "Orthogonal Transform Coding of Still and Moving Pictures". All research performed in residence at the Image Processing Institute, USC Los Angeles, CA.
1970	University of Liverpool, England	Bachelor of Engineering with Honours, Physical Electronics

Publications (Partial List)

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C. Reader, "Intraframe and Interframe Adaptive Transform Coding." SPIE Vol. 66, pp. 108-117, *Efficient Transmission of Pictorial Information* (1975).

C. Reader, W.H. Chen, "Local Retransmission of Compressed Imagery Data", SPIE Vol. 149 pp. 196-204, *Applications of Digital Image Processing* (1978).

L. Hubble, C. Reader, "State of the Art in Image Display Systems", SPIE Vol. 199, pp 2-8, *Advances in Display Technology* (1979).

C. Reader, W. D. Flanagan, "Design Considerations for Real-Time Image Processing", SPIE Vol. 180, *Real-Time Signal Processing II,* (1979).

C. Reader, L. Hubble, "Trends in Image Display Systems", Proc. IEEE, Vol. 69, No. 5, pp. 606-614, (1981).

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C. Reader, et al, "A New Architecture for Real-Time Image Processing," SPIE Vol. 534, pp. 72-78, *Architectures and Algorithms for Digital Image Processing II* (1985).

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B. Thacker, R. Rinaldi, C. Reader, "Multiwindow Displays of Text, Graphics and Images", SPIE Vol. 757, pp. 104-110, *Methods of Handling and Processing Imagery* (1987).

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O. Avaro, P.A. Chou, A. Eleftheriadis, C. Herpel, C. Reader, J. Signes, "The MPEG4 Systems and Description Languages: a Way Ahead in Audio Visual Information Representation", Signal Processing: Image Communication, Vol. 9, No. 4, pp. 385-431 (1997).

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W Gao, S Ma, C Reader, "An End-to-End Application System of AVS: AVS-IPTV in China". PCM 2007: 50-57

C Reader, "Technical design & IPR analysis for royalty-free video codecs". PCS 2010: 102-105

J Chen, F Xu, Y He, J D Villasenor, Y Han, Y Xu, Y Rong, C Reader, J Wen, "Efficient Video Coding Using Legacy Algorithmic Approaches". IEEE Trans. Multimedia 14(1): 111-120 (2012)

W Gao, T Huang, C Reader, W Dou, X Chen, "IEEE Standards for Advanced Audio and Video Coding in Emerging Applications", Computer, vol.47, no. 5, pp. 81-83, May 2014.

Ma S, Huang T, Reader C, Gao W, AVS2-Making video coding smarter [Standards in a Nutshell], IEEE Signal Processing Magazine, vol. 32, no. 2, pp. 172 - 182, 2015.

Wang R, Huang T, Park S-H, Kim J-G, Jang E S, Reader C, Gao W, The MPEG Internet Video-Coding Standard [Standards in a Nutshell], IEEE Signal Processing Magazine, Vol. 33, No. 5, pp. 164-172, Sep. 2016.

Reader C, Patent Landscape for Royalty-Free Video Coding, SPIE Vol. 9971, Sep., 2016

Patents

Patent Number	Date Issued	Title
6,192,073	2000	Methods and apparatus for processing video data
5,845,112	2000	Method for performing dead-zone quantization in a single processor instruction.

Academic Positions

Taught "early bird" classes at Santa Clara University in Image Processing and Digital Signal Processing

Adjunct Professor of the National Engineering Laboratory for Video Technology, in the Computer Science Department at Peking University, Beijing, China.

Professional Associations and Achievements

- ISO/IEC Certificate of appreciation for development of the MPEG4 standard.
- Senior Member IEEE.
- Member SPIE.
- Member ACM.

- Member AES.
- Member SMPTE.

Contact Information

- 1654 Hillstone Ave.
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- cliffreader Skype
- CliffReader WeChat
- cliff@reader.com
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APPENDIX B

About International Telecommunication Union (ITU)

ITU is connecting the world – and beyond. As the United Nations specialized agency for digital technology, we are working towards harnessing innovation and connecting everyone to ensure a better future for all.

WHO WE ARE

ITU is the United Nations specialized agency for information and communication technologies (ICTs). The Organization is made up of a membership of 193 Member States and more than 1000 companies, universities and international and regional organizations. Headquartered in Geneva, Switzerland, and with regional offices on every continent, ITU is the oldest agency in the UN family – connecting the world since the dawn of the telegraph in 1865.

WHAT WE DO

We facilitate international connectivity in communication networks. We allocate global radio spectrum and satellite orbits, develop the technical standards that ensure networks and technologies connect seamlessly, and work to improve access to digital technologies in underserved communities worldwide. ITU works to bring digital connectivity to everyone, providing a trusted, multilateral platform to broker international agreements and standards, share knowledge, build capacity, and work with members and partners to spread access to technology around the world.

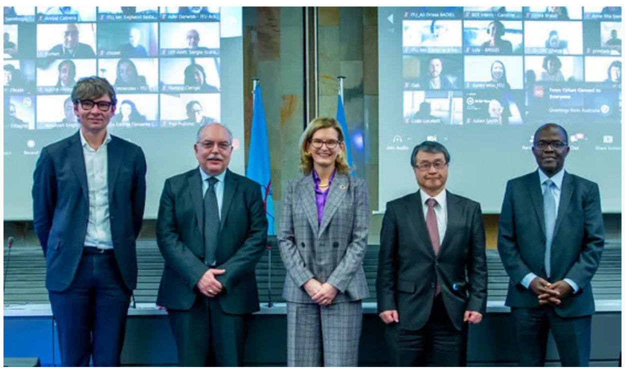
WHY WE MATTER

Technology has become the backbone of modern life. Networks and devices everywhere rely on ITU's work. Every time we use a mobile phone, send an e-mail, access the Internet, watch TV or streaming services, take a plane, consult the weather forecast, or use satellite images to navigate or explore, we are relying on ITU's work. 2.6 billion people, largely in developing countries, remain unconnected. ITU works to close this digital divide through universal connectivity and sustainable digital transformation. Play the video

ITU Management team

ITU Member States from around the world elected the Organization's top five officials during the 21st Plenipotentiary Conference (PP-22) in September and October 2022.

Meet the team



2023 Year in review

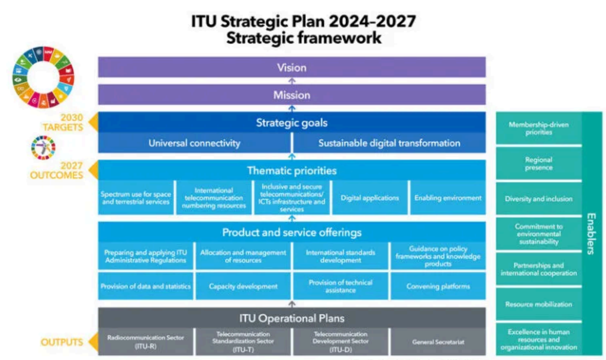
Over the course of a difficult year marked by growing humanitarian crises and conflicts, ITU has kept stepping up landmark initiatives in pursuit of universal connectivity and sustainable digital transformation.

Check out the highlights

ITU Strategic Plan 2024-27

ITU Member States have set two clear strategic goals for the Union for 2024 to 2027: universal connectivity and sustainable digital transformation.

Learn more



Organizational entities

Radiocommunication

Standardization

Development

General Secretariat

Not a member yet?

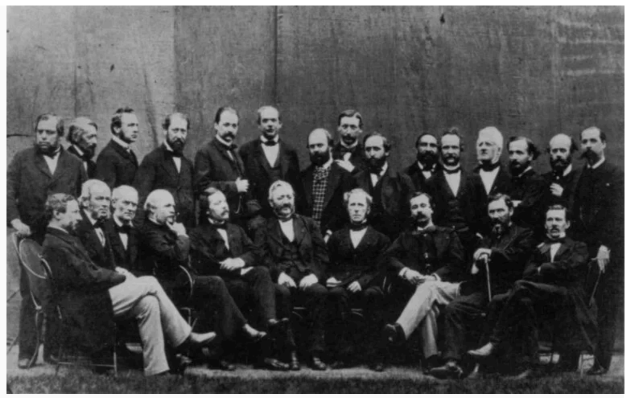
With 193 Member States and over 1000 Sector Members, ITU is a powerhouse in the world of technology. Join ITU as a member to have a direct voice in the decisions impacting your business, organization, or economy.

Learn more

ITU history

ITU's story is one of innovation. Established in 1865 to manage the first international telegraph networks, ITU has worked ceaselessly since then to connect the world. Over the years, the Union's mandate has expanded to cover the invention of voice telephony, the development of radiocommunications, the launch of the first communications satellites, and most recently, artificial intelligence and metaverse.

Visit the History of ITU Portal



Data protection

The protection of personal data has become increasingly crucial for intergovernmental organizations in general, the organizations of the United Nations system, and ITU in particular. Read more. ITU is committed to protecting the personal data it processes and respecting the right to privacy of individuals. ITU adopted its own Data Protection and Privacy Policy in 2023. For any questions or requests concerning the processing of your personal data by ITU, please contact here.

FOLLOW US

Contact us Privacy notice Accessibility **Report misconduct**

APPENDIX C

ITU-T in brief

The Study Groups of ITU's Telecommunication Standardization Sector (ITU-T) assemble experts from around the world to develop international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs). Standards are critical to the interoperability of ICTs and whether we exchange voice, video or data messages, standards enable global communications by ensuring that countries' ICT networks and devices are speaking the same language.

International ICT standards avoid costly market battles over preferred technologies, and for companies from emerging markets, they create a level playing field which provides access to new markets. They are an essential aid to developing countries in building their infrastructure and encouraging economic development, and through economies of scale, they can reduce costs for all: manufacturers, operators and consumers.

From its inception in 1865, ITU-T has driven a contribution-led, consensus-based approach to standards development in which all countries and companies, no matter how large or small, are afforded equal rights to influence the development of ITU-T Recommendations. From its beginnings as a body standardizing international telegraph exchange, through its formative role in telecommunications, and in today's converged ICT ecosystem, ITU-T has provided the world's best facilities to the global standardization community and remains the world's only truly global ICT standards body.

Based at ITU's headquarters in Geneva, the Telecommunication Standardization Bureau (TSB) provides secretariat support to ITU-T Study Groups through sophisticated electronic working methods and state-of-the-art facilities in Geneva accommodating the six official languages of the Union – Arabic, Chinese, English, French, Russian and Spanish. Headed by an elected official with the title Director, it is the body responsible for providing cohesion to ITU-T's standards development process.

ITU-T News | ITU-T News Channels

An unexpected error occurred processing your request. Check the logs for details and correct the problem.

ITU STANDARDS IN ACTION

APPENDIX D

About MPEG

The Moving Picture Experts Group (MPEG) is a working group of ISO/IEC in charge of the development of international standards for compression, decompression, processing, and coded representation of moving pictures, audio and their combination.

MPEG usually holds four meetings a year. These comprise plenary meetings and subgroup meetings on Requirements, Systems, Video, Video coding, 3D Video Audio, 3D Graphics and Communication. Participation is open to experts duly accredited by an appropriate National Standards Body. On average a meeting is attended by more than 400 experts from some 20 countries representing more than 200 companies spanning all industry domains with a stake in digital audio, video and multimedia.

MPEG is currently exploring new opportunities for standards serving the needs of the media industry. A partial list is:

Audio Synchronization	Using audio to synchronise devices
Immersive Video	definition of the standardisation field of Free-viewpoint Television (FTV)
Additional Support for Coding of Interlaced Video in HEVC	Exploration on the possible addition of interlace-specific coding tools in HEVC
3D Printing	A 3D Printer is seen as an actuator in MPEG-V
Real Time Streaming of Files	Further MMT and DASH specification
Big Media	Architecture for Big Data applied to Media
Network Distributed Media Coding	Support for transcoding
Hybrid Natural/Synthetic	File format for 3D scenes

Scene Container	
In advance signalling of MPEG containers content	Signalling in advance of MPEG containers content
Adaptive delivery and access to Immersive Media	To define an interface to deliver and access immersive media
Data Compression	Investigations on possible new areas requiring compression standards
MPEG-21 Based Smart Contracts	To express MPEG-21 contracts as Smart Contracts of specific blockchains
Video Coding for Machines	The MPEG activity on Video Coding for Machines (VCM) aims to standardize a bitstream format generated by compressing both a video stream and previously extracted features. The bitstream should enable multiple machine vision tasks
Video Coding for Machines	The MPEG activity on Video Coding for Machines (VCM) aims to standardize a bitstream format generated by compressing both a video stream and previously extracted features. The bitstream should enable multiple machine vision tasks

MPEG standards

For a full list of MPEG Standards, see here.

APPENDIX E

Twelfth Meeting: Eibsee, Germany, 9-12 January, 2001

Question: Q.6/SG16 (VCEG)

Source: Istvan Sebestyen
Siemens, ICN M SR3
81359 München
Germany
Tel: +49 89 722 47230
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Email: istvan.sebestyen@icn.siemens.de

Title: IPR Strategy and Guidelines for H.26L

Purpose: Information

This document was approved in this modified form by VCEG at their 12th meeting (Eibsee Germany, January 2001).

---

1 H.26L Basic IPR Principles

Regarding Intellectual Property Rights (IPR) for the future ITU-T H.26L, Q.6/SG16 (VCEG) has agreed to the following basic principles:

- H.26L should have a simple license free "baseline mode" (both on the encoder and decoder) in order to promote the wide implementation and use of ITU-T H.26L. All implementations should have such a common "baseline mode" core, in order to allow minimal interoperability among all H.26L codecs. The above requirement means that all technology applied in the "baseline mode" shall have either no, or expired IPR, or valid but license-fee-free IPR (according to Box 1 of the ITU Patent Statement and Licensing Declaration, attached below) .
- Special, more advanced profiles of the H.26L standard may contain patents per Box 2 of the ITU Patent Statement and Licensing Declaration (reasonable terms and conditions).

2 Collection of IPR information during the standardization process

According to the ITU-T IPR policy, ITU-T members/experts are encouraged to disclose as soon as possible IPR information (of there own or anybody else) associated with any standardization proposal (of their own or anybody else). Such information should be provided on a best effort basis.

For collecting such information, VCEG has decided to use the same patent declaration form that is to be submitted to the ITU Director when the contributed technology becomes part of the final standard.

Therefore, **VCEG requires all technical (algorithmic) proposals include one or more of**:

Attached at the end of each technical contribution, **a fully filled-out ITU "Patent Statement and Licensing Declaration"** (attached below). At the contribution stage, this form is for information only, and **may be signed by an expert or left unsigned**. The form **need not be submitted to the TSB at this stage, but must be included in the contribution to VCEG**,

or, the following statement:

“The contributor(s) are not aware of any issued, pending, or planned patents associated with the technical content of this proposal.”,

or, the following statement:

“The contributor(s) believe(s) one or more third-parties may have issued, pending, or planned patents associated with the technical content of this proposal.”

Note that the submission of the ITU Patent Statement and Licensing Declaration to VCEG at the proposal stage does not have the same formal status as the final IPR declaration to the TSB.

Such information provided to the Rapporteur will be tabulated in a “IPR status list” (e.g. a simple Word table) of the information received. Not relevant information (e.g. if a proposed method was not accepted) will be removed from the “IPR status list” as early as possible. The “IPR status list” is a living document of VCEG.

3 Formal submission of IPR statements to the ITU TSB Director

In the final stage of standardization such formal IPR statements have to be forwarded to the ITU TSB Director. This should be done by a responsible member (e.g. IPR Department) of the IPR holder. To avoid formal IPR statements on proposals not included in the final Recommendation, it is suggested that this submission be done only after the H.26L standard has been finalized for the “consent” process in the Study Group. The last call of the standard can only be issued by the TSB when all formal IPR statements have arrived to the ITU.

4 Outlook

It is hoped that the above implementation would facilitate to achieve the goals outlined under paragraph 1.

Patent Statement and Licensing Declaration

(Typically one per ITU-T Recommendation)
This declaration does not represent an implied license grant

Please return to: Director
Telecommunication Standardization Bureau
International Telecommunication Union
Place des Nations
CH-1211 Geneva 20, Switzerland
Fax: +41 22 730 5853

Patent Holder/Organization:
Legal Name ____________________

Contact for license application:
Name & Department ____________________
Address ____________________
____
Tel. ____________________
Fax ____________________
E-mail ____________________

ITU-T Recommandation:
Number ____________________
Title ____________________

Licensing declaration
The Patent Holder believes to hold granted patents and/or pending applications, whose use would be required to implement the above ITU-T Recommendation and hereby declares, in accordance with the Statement on ITU-T Patent Policy (see ITU-T web site), that (check one box only).

☐ 1 The Patent Holder is prepared to grant – on the basis of reciprocity for the above ITU-T Recommendation – a free license to an unrestricted number of applicants on a worldwide, non-discriminatory basis to manufacture, use and/or sell implementations of the above ITU-T Recommendation.

☐ 2 The Patent Holder is prepared to grant – on the basis of reciprocity for the above ITU-T Recommendation – a license to an unrestricted number of applicants on a worldwide, non-discriminatory basis and on reasonable terms and conditions to manufacture, use and/ or sell implementations of the above ITU-T Recommendation.
Such negotiations are left to the parties concerned and are performed outside the ITU-T.

☐ 3 The Patent Holder is unwilling to grant licenses according to the provisions of either 1 or 2 above. In this case, the following information must be provided as part of this declaration:

- patent registration/application number;
- an indication of which portions of the Recommendation are affected.
- a description of the patent claims covering the Recommendation;

Signature
Organization ____________________
Name of authorized person ____________________
Title of authorized person ____________________
Signature ____________________
Place, Date ____________________

Patent Information (desired but not required)			
No.	**Registration Number/ Country**	***5*** **Title/ Inventor**	**Status** [granted/ pending]
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APPENDIX F

ITU - Telecommunications Standardization Sector
STUDY GROUP 16 Question 6
Video Coding Experts Group (VCEG)

Document VCEG-N70r3
Filename: VCEG-N70r3.doc
Generated: Jan '01
Updated: Sep '01

Fourteenth Meeting: Santa Barbara, CA, 24-27 September 2001

Question: Q.6/SG16 (VCEG)

Source: Istvan Sebestyen
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Title: IPR Strategy and Guidelines for H.26L

Purpose: Information

This document was approved in this modified form by VCEG at their 14th meeting (Santa Barbara, 24-27 September 2001). This replaces the earlier document VCEG-L37r2.

1 H.26L Basic IPR Principles

Regarding Intellectual Property Rights (IPR) for the future ITU-T H.26L, Q.6/SG16 (VCEG) has agreed to the following basic principles:

- H.26L should have a simple royalty free "baseline mode" (both on the encoder and decoder) in order to promote the wide implementation and use of ITU-T H.26L. All implementations should have such a common "baseline mode" core, in order to allow minimal interoperability among all H.26L codecs. The above requirement means that all technology applied in the "baseline mode" shall have either no, or expired IPR, or valid but license-fee-free IPR (according to Box 2.1 or 2.2.1 of the VCEG Patent Disclosure form, attached below) .
- Special, more advanced profiles of the H.26L standard may contain patents per Box 2.2 of the VCEG Patent Disclosure form (reasonable terms and conditions).

2 Collection of IPR information during the standardization process

According to the ITU-T IPR policy, ITU-T members/experts are encouraged to disclose as soon as possible IPR information (of there own or anybody else) associated with any standardization proposal (of their own or anybody else). Such information should be provided on a best effort basis.

For collecting such information, VCEG has decided to use it's own Patent Declaration form – note that this is distinct from the *Patent Statement and Licensing Declaration* that is to be submitted to the ITU Director when the contributed technology becomes part of the final standard.

Therefore, **VCEG requires all technical (algorithmic) proposals include one or more of**:

Attached at the end of each technical contribution, **a fully filled-out "<u>VCEG Patent Disclosure form</u>"** (attached below). At the contribution stage, this form is for information only, and **may be signed by an expert or left unsigned**. The form **must be included in the contribution to VCEG**,

Note that the submission of the VCEG Patent Disclosure form at the proposal stage does not have the same formal status as the final IPR declaration to the TSB.

Such information provided to the Rapporteur will be tabulated in a “IPR status list” (e.g. a simple Word table) of the information received. Not relevant information (e.g. if a proposed method was not accepted) will be removed from the “IPR status list” as early as possible. The “IPR status list” is a living document of VCEG.

3 Formal submission of IPR statements to the ITU TSB Director

In the final stage of standardization formal IPR statements using the ITU-T *Patent Statement and Licensing Declaration* have to be forwarded to the ITU TSB Director. This should be done by a responsible member (e.g. IPR Department) of the IPR holder. To avoid formal IPR statements on proposals not included in the final Recommendation, it is suggested that this submission be done only after the H.26L standard has been finalized for the “consent” process in the Study Group. The last call of the standard can only be issued by the TSB when all formal IPR statements have arrived to the ITU.

4 Outlook

It is hoped that the above implementation would facilitate to achieve the goals outlined under paragraph 1.

International Telecommunication Union
Telecommunication Standardization Sector

Video Coding Experts Group - *Patent Disclosure Form*

(Typically one per contribution and one per Recommendation)

Please send to:

Q.6/16 Rapporteur Gary Sullivan, Microsoft Corp., One Microsoft Way, Bldg. 9, Redmond WA 98052-6399, USA
Email (preferred): Gary.Sullivan@itu.int Fax: +1 425 706 7329 (+1 425 70MSFAX)

This form provides the ITU-T Q.6/SG16 Video Coding Experts Group (VCEG) with information about the patent status of techniques used in or proposed for incorporation in a Recommendation. VCEG requires that all technical contributions be accompanied with this form. *Anyone* with knowledge of any patent affecting the use of VCEG work, of their own or of any other entity ("third parties"), is strongly encouraged to submit this form as well.

This information will be maintained in a "living list" by VCEG during the progress of their work, on a best effort basis. If a given technical proposal is not incorporated in a Recommendation, the relevant patent information will be removed from the "living list". The intent is that the VCEG experts should know in advance of any patent issues with particular proposals or techniques, so that these may be addressed well before final approval.

This is not a binding legal document; it is provided to VCEG for information only, on a best effort, good faith basis. Please submit corrected or updated forms if your knowledge or situation changes.

This form is *not* a substitute for the ITU-T *Patent Statement and Licensing Declaration*, which should be submitted by Patent Holders to the TSB Director before final approval of any Recommendation.

Submitting Organization or Person:

Organization name ______________________

Mailing address ______________________

Country ______________________

Contact person ______________________

Telephone ______________________

Fax ______________________

Email ______________________

Place and date of submission ______________________

Relevant Recommendation and, if applicable, Contribution:

Number (ex: "H.26L") ______________________

Title ______________________

Contribution number ______________________

(Form continues on next page)

Disclosure information – Submitting Organization/Person (choose one box)

☐ 2.0 The submitter is not aware of having any granted, pending, or planned patents associated with the technical content of the Recommendation/Contribution.

or,

The submitter (Patent Holder) has granted, pending, or planned patents associated with the technical content of the Recommendation/Contribution. In which case,

☐ 2.1 The Patent Holder is prepared to grant – on the basis of reciprocity for the above ITU-T Recommendation – a <u>free</u> license to an unrestricted number of applicants on a worldwide, non-discriminatory basis to manufacture, use and/or sell implementations of the above ITU-T Recommendation.

☐ 2.2 The Patent Holder is prepared to grant – on the basis of reciprocity for the above ITU-T Recommendation – a license to an unrestricted number of applicants on a worldwide, non-discriminatory basis and on reasonable terms and conditions to manufacture, use and/ or sell implementations of the above ITU-T Recommendation.

Such negotiations are left to the parties concerned and are performed outside the ITU-T.

☐ 2.2.1 The same as box 2.2 above, but in addition the Patent Holder is prepared to grant a "royalty-free" license to anyone on condition that all other patent holders do the same.

☐ 2.3 The Patent Holder is unwilling to grant licenses according to the provisions of either 2.1, 2.2, or 2.2.1 above. In this case, the following information must be provided as part of this declaration:

- patent registration/application number;
- an indication of which portions of the Recommendation are affected.
- a description of the patent claims covering the Recommendation;

*In the case of any box **other than 2.0** above, please provide the following:*

Patent number(s)/status ____

Inventor(s)/Assignee(s) ____

Relevance to VCEG ____

Any other remarks: ____

(please provide attachments if more space is needed)

(form continues on next page)

Third party patent information – fill in based on your best knowledge of relevant patents granted, pending, or planned by other people or by organizations other than your own.

Disclosure information – Third Party Patents (choose one box)

☐ 3.1 The submitter is not aware of any granted, pending, or planned patents *held by third parties* associated with the technical content of the Recommendation/Contribution.

☐ 3.2 The submitter believes third parties may have granted, pending, or planned patents associated with the technical content of the Recommendation/Contribution.

For box 3.2, please provide as much information as is known (provide attachments if more space needed) - VCEG will attempt to contact third parties to obtain more information:

3rd party name(s) ______________________

Mailing address ______________________

Country ______________________

Contact person ______________________

Telephone ______________________

Fax ______________________

Email ______________________

Patent number/status ______________________

Inventor/Assignee ______________________

Relevance to VCEG ______________________

Any other comments or remarks:

[end]

APPENDIX G

Opening remarks

Coffee breaks 10:30 and 4:00

IPR policy reminder

Doc alloc.

Attendance & qualification

The agenda approved in April by SG 16 is listed as follows:

- Consideration of proposals for new enhancements of Recs. H.264, H.264.1, H.264.2, H.271, and T.8x.
- Consideration of proposals and organizational work toward eventual development of an "H.265".
- Maintenance of H.26x, H.271, and T.8x video and image coding standards.
- Collection of non-normative content to aid in the study and implementation of H.264.
- Study and coordination relating to use of video and image coding in systems.
- Review, planning and coordination for work of Q.6 and JVT.
- Coordination and communication with other organizations on video and image coding related topics, particularly including ISO/IEC MPEG and JPEG / JBIG
- Other business as necessary for Q.6/16 consideration.

The 36th (San Diego) VCEG meeting is planned for Wednesday the 8th to Friday the 10th of October 2008. The current document registration list is below.

I have suggested a deadline of Saturday the 4th for registrations and uploads. That was a couple of days ago.

Two more (administrative category) documents have been added below (VCEG-AJ04 and VCEG-AJ05) -- based on new information arriving through the SG 16 secretariat.

No docs missing since Monday, except VCEG-AJ30, which was uploaded but inadvertently not made available until Tuesday.

Please send any additional document registration requests to me.

Meeting logistics information was previously sent to this reflector. If you did not get it, please send me or Ajay Luthra a request for a copy.

A document template is now available at http://ftp3.itu.int/av-arch/video-site/0810_San/VCEG-AJxx.dot. It is also attached. It contains important instructions and policy information. Please read it (and use it if drafting a contribution).

For uploading, please use ftp with user ID avguest and password Avguest to site ftp3.itu.int and put the document in the video-site/dropbox directory.

VCEG-AJ00 [G. Sullivan] List of Documents (this list)
VCEG-AJ01 [G. Sullivan] <reserved for> Report of San Diego VCEG meeting

VCEG-AJ02 [M. Horowitz] AHG computational efficiency
VCEG-AJ03 [T. Wedi & T. K. Tan] AHG coding efficiency

VCEG-AJ04 [TSB] Decision taken at WP 3/16 meeting (Geneva, 3 October 2008) concerning the media coding toolbox
VCEG-AJ05 [AVS China WG] Reply LS on IPTV video coding

VCEG-AJ11 [D.-Y. Kim, K.-H. Han, Y.-L. Lee (Sejong Univ), H.Y. Kim (SK Telecom)] Adaptive intra mode bit skip in intra coding
VCEG-AJ12 [S.C. Lim, H.C. Choi, S.Y. Jeong, J.S. Choi (ETRI)] Integer Sine Transform for Inter Frame
VCEG-AJ13 [T. Chujoh, G. Yasuda, N. Wada, T. Watanabe, T. Yamakage (Toshiba)] Improvement of Block-based Adaptive Loop Filter
VCEG-AJ14 [M. Takahashi, M. Yamaguchi (Hitachi)] A new method for improving motion vector coding
VCEG-AJ15 [K. Nakamura, M. Takahashi, T. Yokoyama (Hitachi), K. Akie, S. Mochizuki, K. Iwata (Renesas Tech)] An Extended VLC for Coding Modes
VCEG-AJ16 [D. Sim et al (ETRI, Kwangwoon Univ., and Kyunghee Univ.)] Unidirectional 4x4 intra prediction
VCEG-AJ17 [D. Sim et al (ETRI, Kwangwoon Univ.)] Modification of Deblocking Filter for Improvement of Coding Efficiency
VCEG-AJ18 [Steffen Kamp, Benjamin Bross, Mathias Wien (RWTH Aachen Univ.)] Fast Decoder Side Motion Vector Derivation
VCEG-AJ19 [B. Lee, M. Kim (ICU), C. Park, S. Hahm, I. Cho (KBS)] RDO based controls of rounding and reconstruction level offsets for quantization <<withdrawn>>
VCEG-AJ20 [S. De Cock, S. Notebaert (Ghent Univ.)] Extended Partitioning with Shape-Adapted Transform
VCEG-AJ21 [J. Kim, T. Na, C. Kim, B. Lee, M. Kim (ICU), C. Park, S. Hahm, I. Cho (KBS)] Enlarging MB size for high fidelity video coding beyond HD
VCEG-AJ22 [B. Haskell, X. Shi (Apple)] Quality Metrics for Coded Video Using JND Models
VCEG-AJ23 [P. Chen, Y. Ye, M. Karczewicz (Qualcomm)] Video coding using extended block sizes
VCEG-AJ24 [Y. Ye, H. Wang, M. Karczewicz (Qualcomm)] Simulation results on MDDT and comments on intra coding
VCEG-AJ25 [R. Panchal, M. Karczewicz (Qualcomm)] Simulation results and comments on Cleaned up KTA2.0 software
VCEG-AJ26 [T. K. Tan, C.S. Boon, A. Fujibayashi (NTT DoCoMo, Inc)] New video coding test sequences

VCEG-AJ27 [L. Shangwen, L. Yu (Zhejiang Univ.)] Additional Results of Second Order Prediction (SOP) in P Slice
VCEG-AJ28 [S. Seo (Konkuk Univ.), Y. Choe, Y.-G. Kim (Yonsei Univ.), Y. Choi (Konkuk Univ.)] A Simulator for Complexity Measurement
VCEG-AJ29 [M. Karczewicz, Y. Ye, P. Chen, G. Motta (Qualcomm)] Single Pass Encoding using Switched Interpolation Filters with Offset
VCEG-AJ30 [M. Karczewicz, Y. Ye, P. Chen, G. Motta (Qualcomm)] Experimental Results of Interpolation Filters on High-Definition Sequences
VCEG-AJ31 [V. Sze (MIT/TI), U. Demircin (TI), M. Budagavi (TI)] CABAC throughput requirements for real-time decoding
VCEG-AJ32 [S. Sekiguchi, S. Yamagishi, Y. Yamada, Y. Kato, K. Asai, T. Murakami (Mitsubishi Electric)] Comments on common test conditions for high-quality coding experiments
--End of List--

On media coding toolbox document

VCEG-AJ04 [TSB] Decision taken at WP 3/16 meeting (Geneva, 3 October 2008) concerning the media coding toolbox

This document is to inform Q6/16 meeting that the discussion and agreement at the recent WP 3/16 meeting (Geneva, 3 October 2008) concerning the media coding toolbox.

The following is an excerpt of COM16-R30 (not yet published):
…
3.5 Media coding toolbox
Q6/16 provided an update on their discussions concerning the toolbox for content coding in TD 372/WP3. Q23/16 also worked in the issue during its Rapporteur group meeting and prepared an updated version of the toolbox as found in TD 385/WP3.
The issue of how the toolbox would evolve was discussed at the Plenary. It was pointed out that a pragmatic approach should be taken, first by issuing the toolbox for content coding as a SG 16 Technical Paper – which would not preclude later on making it another type of publication (e.g. a Recommendation or Supplement). WP 3/16 was strongly urged to be more active in IPTV matters of its competency.
After discussion, WP3/16 decided that as a first step the toolbox for content coding will be published as a SG 16 Technical Paper (informative in nature). The audio part will be ready for approval in January 2009; it is hoped that the same will apply to the video part. Mr Hervé Taddei will be editor of the general part and of the audio part of the document. Q6/16 was asked to appoint an editor for the video part at its upcoming Rapporteur meeting in San Diego, USA, 10-12 Oct 2008.
…

Q6/16 experts are requested to review the issue and appoint an editor for the video coding part and invited to progress it aiming at approval of a SG 16 Technical Paper in the Jan-Feb 2009 meeting of SG 16.

VCEG-AJ05 [AVS China WG] Reply LS on IPTV video coding

On the 26th AVS meeting in Tianjin China, Sept. 23-27, the liaison letter "LS to SMPTE and China AVS on IPTV video coding" from ITU-T Q6/16 was reviewed. This letter is an answering liaison letter to the input liaison letter. The information about the characteristics and capabilities of the AVS1-P2 in relation to the IPTV application are provided.

AVS1-P2 is a short name for The Standards of People's Republic of China GB/T 20090.2—2006, Information Advanced 2: Video. AVS1-P2 has several profiles and levels. A "profile" is a subset of the syntax elements, semantics, and algorithmic features of the AVS standard. A "level" is a specified set of limits on the syntax elements and the values that may be taken by the syntax elements of a certain profile.

AVS1-P2 Jizhun profile is reportedly applied in the IPTV applications in China. It was reported to provide good quality and save at least half bandwidth used by the popular standard H.262. A summary of features are briefly introduced in the document TD 528 (GEN/16).

Question: Are there other profiles? Comment: Under development, there is a "movie" profile, and an "advanced" profile, a "surveillance" profile, and a "mobile" profile that are under development / finalization.

Question: Is interlace supported in Jizhun profile? Comment: Yes.

AVS1-P2 is reportedly a hybrid video codec with spatial and temporal prediction, integer transform and entropy coding. The basic encoding unit is a macro block, which consists of four 8x8 luma blocks and two 8x8 chroma blocks (for 4:2:0 format). The integer DCT transformation, quantization and two dimensional adaptive VLC are performed to the 8x8 pixel blocks. The AVS1-P2 bit stream is defined as a hierarchy of layers. Generally a sequence consists of several GOP (group of pictures, leading by an I picture), which could be a random access point. The other layers between a GOP and a macro block are pictures and slices. AVS1-P2 reportedly has many coding tools, which include deblocking, interlace coding, forward, backward and symmetrical prediction using up to two reference pictures, or four reference fields, variable block size motion compensation down to 8x8 block size, spatial-domain intra prediction with 5 directions, 2D-CAVLC entropy coding, 8x8 integer transformation, as well as weighted prediction, etc.

Level, bit rate, picture sizes, etc. were provided in a table included in the LS.

The latest exact reference of AVS1-P2 is reportedly GB/T 20090.2-2006. It was reportedly approved by the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China in February 2006, taking effect starting March 1, 2006 in China officially. An AVS WG translation of the GB/T 20090.2-2006 is attached with the liaison letter for the GSI IPTV standardization and document referrencing purposes. It was declared in the LS that the Chinese version of AVS1-P2 is the unique official version. If there is any inconsistency between the understanding of Chinese version and English translation, the standard in Chinese version prevails. AVS Working Group reportedly shall not take the responsibility for the inconsistency and any result related with the inconsistency.

The LS suggested that it is impossible to use one unique video coding standard for the global market since the market has already existed for some years. It was reported that MPEG-2/H.262 is used (for IPTV purposes) in some regions (of China?), and in the mean time, AVS or H.264 are reportedly used in other regions.

The AVS group indicated that they would like to closely cooperate with the ITU-T GSI IPTV standardization work in the future.

The complete LS with attachments was available to TIES subscriber ITU-T members at http://ties.itu.int/u/tsg16/sg16/documents/irls/AVS-Reply-LS-to-ITU-TSG16-Q6.zip.

To answer the question of "how the video coding standard is used in current IPTV application deployments", an example from CHINA NETCOM company IPTV application report was attached to the LS. That document reported (p. 7) a deployment of AVS P2 based IPTV with service to the public starting in March 2008, currently with approximately 200k subscribers, with further deployment growth projected. Some quality-of-experience test results were provided for several configurations of the deployed system (sec. 4.2). It was reported that there are currently about 1.5 million IPTV subscribers in China, and IPTV was reported to be a steady growth market.

Comment: There was no comparison to other systems, clear description of these configurations, clear description of how to interpret the reported data, or clear connection to video syntactical capability.

Question: Is AVS used in broadcast? Other IPTV systems?

Comment: This seems to be basically a closed/proprietary system deployment. Aspects other than the video codec are unknown.

Attached to the LS was also an unofficial English translation of AVS1-P2. (The official standard is published only in Chinese – there is no official publication in English – this document was produced by the Working Group.) It appears to contain only one profile (the Jizhun profile).

Comment: No reply yet from SMPTE.

Comment: Basically, toward the desire to assess comparative capabilities in order to consider the possibility of making a selection as advocated in prior contributions, there has been no progress in our understanding of the situation since July.

Defer, revisit.

Meeting plans:

Hawaii? Meeting fee?

VCEG-AJ02 [M. Horowitz] AHG computational efficiency

This report summarized the Computational Efficiency Ad hoc activities between Q.6/16 VCEG meeting held in Berlin, Germany (16 to 18 July 2008) and the current Q.6/16 VCEG meeting in San Diego, USA.

There was no activity on the VCEG-experts email reflector related to this Ad hoc group.

Contributions to this meeting relative to this topic can be summarized as follows:
- VCEG-AJ11 focuses on encoder complexity reduction with a minor (but normative) impact on decoder complexity.
- VCEG-AJ18 discusses computational complexity of a proposed coding efficiency feature, which has overall higher complexity than the current H.264 scheme.
- VCEG-AJ25 proposes complexity reduction for reference encoding software algorithms (with no normative impact).
- VCEG-AJ28 discusses and proposes methods to measure complexity in simulation experiments.
- VCEG-AJ31 provides analysis of throughput requirements for CABAC entropy coding to justify proposed alternative entropy coding technology which is asserted to have lower computational requirements.

VCEG-AJ11 Adaptive intra mode bit skip in intra coding
At the last meeting, an adaptive intra mode bit skip was proposed for improving intra coding performance, in which the proposed method was applied to Intra4×4 and chroma Intra8×8 modes at baseline profile. In this contribution, the proposed method shows the average bit saving of 2.69% and encoding time saving of 17% ~ 59% at baseline profile.

The proposed method also shows the average bit saving of 1.41% and encoding time saving of 17% ~ 59% at high profile when it is applied to Intra8x8 mode.

VCEG-AJ18 Fast Decoder Side Motion Vector Derivation
Decoder-side motion vector derivation (DMVD) using template matching has been shown to improve coding efficiency of H.264/AVC based video coding. Previously, DMVD was performed using a full template matching search in a limited search range. This document provides results for reduced complexity DMVD, where a candidate based fast search algorithm replaces the full search. BD-Bitrate savings of 6.5% averaged over CIF and HD sequences (7.8% for HD sequences) according to the VCEG common conditions for IPPP high profile are observed. By further omitting sub-pel refinement for DMVD, average savings observed for CIF and HD are 5.7% (7.2% for HD sequences).

VCEG-AJ25 Experimental Results on Simplified JMKTA 2.0 Software
Experimental results for simplified version of JMKTA 2.0 are presented. The simplifications include a modified frame level RD decision for B frames and the disabling of the tools not used in the common test conditions. The average complexity reduction for hierarchical B configuration exceeds 50% for HD sequences with 0.12% BD bit rate increase.

VCEG-AJ28 A Simulator for Complexity Measurement
In the 35th VCEG meeting of Berlin, a complexity measurement method was presented (VCEG-AI28). The presented method proposed to measure three complexities for a given algorithm, which enables to deliver more meaningful analysis. For such complexity measurement, the method employs a processor simulator which is easy to use and reasonably accurate. This contribution shows how simple and convenient to use the simulator is and the benefits of the simulator, providing its necessity. For the simplicity of the simulator, the simulation process of the simulator is compared to an execution process using a desktop PC. This comparison shows that these two processes are almost identical and thus, users do not require any education for the simulator. To prove the necessity of the simulator, provided are the problems that might incur when the complexity of a given algorithm is measured utilizing desktop PCs. Additionally, this contribution evaluates and compares the complexity of KTA algorithms to give an insight on what the complexity measurement method utilizing a processor simulator can deliver. For the completed version of the contribution, this document will be revised before it is presented.

VCEG-AJ31 CABAC throughput requirements for real-time decoding
The objective of this contribution is to quantify the H.264 context adaptive binary arithmetic coding (CABAC) decoder throughput requirements for real-time decoding. The necessity for enabling parallelism in CABAC decoding is demonstrated with computations and experiments. This study is expected to provide guidance for the next generation video coding standard CABAC design.

VCEG-AJ03 [T. Wedi & T. K. Tan] AHG coding efficiency

The following summarizes the Coding Efficiency Ad hoc activities between Q.6/16 VCEG meeting held in Berlin, Germany (16 to 18 July 2008) and the current Q.6/16 VCEG meeting in San Diego, USA.

1 Status of KTA-Software

Two new releases of the KTA software were announced by HHI, the software coordinator on 24 and 29 September 2008:

The JM11.0KTA2.1 software (http://iphome.hhi.de/suehring/tml/download/KTA/jm11.0kta2.1.zip) contains addition of

- RDOQ fixes.
  - Compatibility with CAVLC
  - Chroma
- QMS (Toshiba)
  - Replace AQMS with FQMS
- AIF related
  - Based on VCEG-AI12 (Tandberg)
- FDIF: fixed directional filters
- SFP: Special filter position
- LDCO: Local DC offset
  - Based VCEG-AI35 (Qualcomm)
- Frame-level selection among set of fixed filters
- Rounding control for B frames (like H.263+) [using syntax – encoder will indicate to round down if reference and round up in non-reference]
- Encoder B weighting trick (weighting based on the temporal distance) for AIF – consider as a bug fix
  - EAIF based on VCEG-AI38:
- Adaptive interp filter plus integer position filter plus custom per-position offset when doing AIF (all selected on a frame basis)
- Post Filter
  - Post Filter method based on VCEG-AI34

The JM14.2KTA1.0 software (http://iphome.hhi.de/suehring/tml/download/KTA/jm14.2kta1.0.zip) contains addition of

- Entropy Slice (Sharp)

o Adopt base on VCEG-AI32 into the latest JM14.0 version (create a new branch of KTA)

o A bug fix for rate control in combination with SliceMode=2 (constant number of bytes).

2 New Test Material

A total of 43 potential test materials ranging from 1024x768 to 1920x1080 were collected. These sequences were documented in a spreadsheet that was included in the contribution archive. Several comments were also received regarding the selection of the test material and are documented below. It is recommended that these sequences be reviewed and the selection process be discussed during the VCEG meeting.

2.1 Comments on sequences (generally agreed):

• Many of the sequences still have a reduced spectrum (lack of high-frequency detail) or contain a lot of camera noise. It is highly desirable to obtain sequences that have been captured by new cameras.

• Try to remain implementation-independent – the content inside a sequence should be as coherent as possible (rather than, e.g., containing two sections of video content with significantly different characteristics within the same sequence, there should be only similar video characteristics within one sequence); It's pointless to compute average PSNR on incoherent sequences.

• Try to have many test sequences in common conditions, instead of 4-5 (so the outliers will not have a big impact on the average numbers). This issue may, however, have a significant impact on the difficulty of performing experiments. Suggestion: Create an agreed subset of common conditions for those contributions that cannot provide results for the full (larger) set, rather than just having such proponents choose their own subsets. For example, a full set of 15 sequences and a half size set. Remark: One set of complete common conditions results currently takes more than a week with one (dual core) PC. Needs further discussion - breakout.

• Try to have sequences from different sources (cameras) as was mentioned in Berlin.

• The collection of VCEG test material should cover the range “normal” to “complex” sequences. We do not see a reason to include very simple material – assuming that there is something like a broadcast spectrum of material ranging from “simple” (news reader) to “normal” (drama scene) to “complex” (sports?).

2.2 Specific requests:

There is a desire to select sequenced with the following features

• Less regular (content) motion.
• Less regular camera motion for mobile encoding use-cases.

- Focus change (such as the Raven sequence), possibly with multiple focus planes in the picture.
- Spotlight / flash / local lightning. Flash and local lightning are represented in crew, but spotlight is a very different issue.
- Trees, leaves, and grass remain very challenging.
- Confetti is very often used in TV shows; they are mixed with fireworks in almost every sports event. That's a typical use case for broadcast encoders. Such sequences exhibit bit rates as high as 12 Mbps when encoded with the JM at QP 51! More generally, erratic motion has to be considered.
- Straight lines / curves, along with a slow camera pan / rotation / zoom. Typically, lanes in a track and field stadium with slow motion will create aliasing (alias is a major issue both for motion estimation and residual coding, as shown by the current work on interpolation).
- Shadows on highly textured area (for instance, players during a night soccer match).
- Face deformations. Faces should be included in almost every sequence, as a non-expert viewer will immediately identify coding artifacts and color changes on faces.
- Fades (in / out / cross) and text overlay.

2.3 Recommendations:

It was recommended that the collection of sequences be reviewed (including subjective viewing) and if necessary hold a breakout group during the VCEG meeting to discuss the selection of the sequences in depth. Suitable sequences should be shortlisted and unsuitable (eg. very noisy or dark) sequences should be excluded.

3 Coding Efficiency contributions to this meeting

The following contributions related to coding efficiency have been registered for this meeting. The coding efficiency contributions can be clustered as follows:

Information / Common Conditions / Test Sequences / Evaluation Methods:

- VCEG-AJ03 [T. Wedi & T. K. Tan] AHG coding efficiency (Section 2)
- VCEG-AJ22 [B. Haskell, X. Shi (Apple)] Quality Metrics for Coded Video Using JND Models
- VCEG-AJ25 [R. Panchal, M. Karczewicz (Qualcomm)] Simulation results and comments on Cleaned up KTA2.0 software
- VCEG-AJ26 [T. K. Tan, C.S. Boon, A. Fujibayashi (NTT DoCoMo, Inc)] New video coding test sequences
- VCEG-AJ32 [S. Sekiguchi, S. Yamagishi, Y. Yamada, Y. Kato, K. Asai, T. Murakami (Mitsubishi Electric)] Comments on common test conditions for high-quality coding experiments

Spatial Prediction:

- VCEG-AJ16 [D. Sim et al (ETRI, Kwangwoon Univ., and Kyunghee Univ.)] Unidirectional 4x4 intra prediction

Temporal Prediction:

- VCEG-AJ18 [Steffen Kamp, Benjamin Bross, Mathias Wien (RWTH Aachen Univ.)] Fast Decoder Side Motion Vector Derivation
- VCEG-AJ27 [L. Shangwen, L. Yu (Zhejiang Univ.)] Additional Results of Second Order Prediction (SOP) in P Slice
- VCEG-AJ29 [M. Karczewicz, Y. Ye, P. Chen, G. Motta (Qualcomm)] Single Pass Encoding using Switched Interpolation Filters with Offset
- VCEG-AJ30 [M. Karczewicz, Y. Ye, P. Chen, G. Motta (Qualcomm)] Experimental Results of Interpolation Filters on High-Definition Sequences

Prediction partitioning and transform coding:

- VCEG-AJ12 [S.C. Lim, H.C. Choi, S.Y. Jeong, J.S. Choi (ETRI)] Integer Sine Transform for Inter Frame
- VCEG-AJ20 [S. De Cock, S. Notebaert (Ghent Univ.)] Extended Partitioning with Shape-Adapted Transform
- VCEG-AJ21 [J. Kim, T. Na, C. Kim, B. Lee, M. Kim (ICU), C. Park, S. Hahm, I. Cho (KBS)] Enlarging MB size for high fidelity video coding beyond HD
- VCEG-AJ23 [P. Chen, Y. Ye, M. Karczewicz (Qualcomm)] Video coding using extended block sizes
- VCEG-AJ24 [Y. Ye, H. Wang, M. Karczewicz (Qualcomm)] Simulation results on MDDT and comments on intra coding

Entropy coding of mb_type and mb_skip_run

- VCEG-AJ15 [K. Nakamura, M. Takahashi, T. Yokoyama (Hitachi), K. Akie, S. Mochizuki, K. Iwata (Renesas Tech)] An Extended VLC for Coding Modes

Intra Prediction Mode Selection:

- VCEG-AJ11 [D.-Y. Kim, K.-H. Han, Y.-L. Lee (Sejong Univ), H.Y. Kim (SK Telecom)] Adaptive intra mode bit skip in intra coding

Motion Vector Selection / Coding:

- VCEG-AJ14 [M. Takahashi, M. Yamaguchi (Hitachi)] A new method for improving motion vector coding

Post / Loop Filter:

- VCEG-AJ13 [T. Chujoh, G. Yasuda, N. Wada, T. Watanabe, T. Yamakage (Toshiba)] Improvement of Block-based Adaptive Loop Filter \
- VCEG-AJ17 [D. Sim et al (ETRI, Kwangwoon Univ.)] Modification of Deblocking Filter for Improvement of Coding Efficiency

Other (computational efficiency):

- VCEG-AJ28 discusses and proposes methods to measure complexity in simulation experiments.
- VCEG-AJ31 provides analysis of throughput requirements for CABAC entropy coding to justify proposed alternative entropy coding technology which is asserted to have lower computational requirements.

Characteristics of contributions tabulated below:

	Category	Past Related Contribution	Common Conditions Used	Platform used	IPR statement
VCEG-AJ11	Intra Mode Skip	C.433 VCEG-AI23	VCEG-AI10	KTA 1.9r1	Yes
VCEG-AJ12	Integer Sine Transform		VCEG-AE10r1	KTA 2.0	Yes
VCEG-AJ13	Loop Filter	C.402 VCEG-AI18	VCEG-AE10r1	KTA 2.0	Yes
VCEG-AJ14	Motion Vector Coding		VCEG-AI10	KTA1.8	Yes
VCEG-AJ15	mb_type coding		VCEG-AI10	KTA 2.0	Yes
VCEG-AJ16	Intra Prediction			KTA1.8	Yes
VCEG-AJ17	Deblocking filter	VCEG-AI21		KTA1.8	Yes
VCEG-AJ18	Decoder side MV derivation	VCEG-AG16 VCEG-AH15	VCEG-AH10r2	JM13.2	Yes
VCEG-AJ20	Partitioning and Shape Adaptive Transform			KTA1.6	Yes
VCEG-AJ21	Larger MB Size			JM12.0	Yes
VCEG-AJ22	Quality Metrics		N.A.	N.A.	Yes
VCEG-AJ23	Larger MB Size		VCEG-AE10r1	KTA 2.0	Yes
VCEG-AJ24	MDDT	VCEG-AF15 C257 VCEG-AG11 VCEG-AH20	VCEG-AE10r1	KTA 2.1	Yes
VCEG-AJ25	Encoder Simplification		VCEG-AI10	KTA 2.0	Yes
VCEG-AJ26	New Test Sequences		N.A.	N.A.	Yes

	Category	Past Related Contribution	Common Conditions Used	Platform used	IPR statement
VCEG-AJ27	Second order prediction in P	VCEG-AG20 VCEG-AI27	VCEG-AH10	JM10.1	Yes
VCEG-AJ28	Computational efficiency	VCEG-AI28	N.A.	N.A.	Yes
VCEG-AJ29	Switched Interpolation Filter	C.463 VCEG-AI35		KTA 2.0	Yes
VCEG-AJ30	Temporal Prediction – results of interpolation filters	Various	VCEG-AI10	KTA 2.0 and 2.1	Yes
VCEG-AJ31	Computational efficiency	COM 16 – C 334	VCEG-AH10	JM 12.0	Yes
VCEG-AJ32	Common Conditions for 4:4:4 and HD	VCEG-AI30	N.A.	N.A.	N.A.

VCEG-AJ22 [B. Haskell, X. Shi (Apple)] Quality Metrics for Coded Video Using JND Models

In this contribution, it was proposed to use video quality measures for coded video that are based on a Just Noticeable Difference (JND) distortion visibility model. JND visibility models are much more reliable than traditional scoring models that attempt to predict the average quality scores that viewers would give to coded video in subjective tests. A JND visibility model reportedly need only predict if a majority of the viewers can see a difference between the coded video and the original. If they cannot, then a JND = 0 is assigned.

It was proposed to use quality metrics for coded video that are based on JND visibility models.

One such metric is the minimum bit rate for which JND = 0. While easy to describe, this metric requires multiple encodings in order to search for the minimum bit rate.

Another suggested metric is the minimum viewing distance (MVD) for which JND = 0. It was reported that viewing distance is part of the process of computing these JND metrics. It was proposed that this distance be measured as a multiple of pixel height.

Thus for ordinary TV viewing, a value of about 3000 was suggested to be desirable. This metric allows the comparison of different algorithms at the same bit rate.

Depending on the JND visibility model, other metrics that are derived from parameters in the model may reportedly also be feasible.

For constant quality coding, instead of setting qp constant, we specify a desired quality Q and then code each macroblock with the mode and parameters that give the minimum bit rate subject to MVD < Q.

This approach is more of a worst case error metric rather than an overall averaging metric.

Question: Is this metric something well documented that we are allowed to implement and use? (The word "proprietary is in the first sentence of the first reference, and the completeness of the description in the second reference is unknown.) Comment: Access to the technology seems limited.

Comment: Work would need to be done to develop confidence in (and an understanding of) such a metric, and we would need experience with it.

Suggestion: Issue an open call for a distortion metric (or other quality measurement methodology – subjective or objective) suitable for use in our work (not for purposes of approving such a metric to be a standard, but for purposes conducting our experiments). Reaction: Sounds like a good idea.

Revisit related aspects such as whether we can get feedback on our prior LS.

VCEG-AJ25 [R. Panchal, M. Karczewicz (Qualcomm)] Simulation results and comments on Cleaned up KTA2.0 software

Experimental results for a modified version of JMKTA 2.0 were presented. The modifications were reportedly made to simplify the encoding operation. The asserted simplifications include a modified frame level RD decision for B frames and the disabling of the tools not used in the common test conditions. The average complexity reduction for hierarchical B configuration reportedly exceeds 50% for HD sequences with 0.12% BD bit rate increase. The average complexity reduction for IBBP configuration is about 36% for HD sequences with 0.03% BD bit rate increase.

The simplification is to reduce the number of encoding passes, while applying rules to optimize weighted prediction decisions.

Disabling of experimental tools not used in the common test conditions – also seems desirable as a general clean-up issue.

Should be trivial to incorporate into latest KTA software.

Seems obviously desirable.

JVT decision: Adopt (subject to coordination with Karsten and clarification of relationship with RDO-Q). Integration into JM also encouraged.

VCEG-AJ26 [T. K. Tan, C.S. Boon, A. Fujibayashi (NTT DoCoMo, Inc)] New video coding test sequences

This document describes and introduces a set of WVGA and WQVGA resolution video coding test sequences that are made available to VCEG by NTT DoCoMo, Inc. Additionally two other WQVGA resolution sequences were also cropped from available 720p50 and 720p60 test sequences.

Comment: Restrictions on use are undesirable.

Comment: "Nuts" sequence may have too much variation in scene-cut behavior.

Comment: Water in some scenes.

Comment: Don't like "Optis" sequence – too easy.

Comment: Crowd run is better.

Comment: Too many simple sequences in current set.

Include these in the list of available sequences.

Tuesday noon test sequence viewing planned.

Revisit common conditions discussion.

VCEG-AJ32 [S. Sekiguchi, S. Yamagishi, Y. Yamada, Y. Kato, K. Asai, T. Murakami (Mitsubishi Electric)] Comments on common test conditions for high-quality coding experiments

This contribution proposes some recommended changes to the current common test condition for coding efficiency tests so that the conditions can accommodate high-quality coding tests including high-resolution (>= HDTV) and 4:4:4 chroma format.

Contribution subtopic 1: Qp range for reference – The current test condition recommends to use Qp range [22,27,32,37] (for I-slices). One suggested candidate of modified Qp range may be [20, 24, 28, 32].

Remark: Note that steps of 6 cause repetition of the position in the 6-step QP cycle.

Suggestion: How about [20, 25, 30, 35]?

Suggestion: Consider different QP ranges for different test sequences.

Question: Rough PSNR for these values? QP = 21 perhaps 41 dB.

Remark: The test range should cover 37-40 dB (perhaps some outside as well).

Remark: Although QP = 37 has substantial quality degradation, it does represent a useful thing to test, as such low quality is sometimes experienced by users, and worst case quality tends to have a substantial impact on viewer experience.

Remark: Note prior contribution discussion on having two areas of focus: both high quality and low quality ranges.

Further study needed to refine plan.

Contribution subtopic 2: New high-quality video sources

Some recommended candidate sequences discussed. Mitsubishi Electric indicated that they may be able to provide new high quality sequences in addition to those already available.

Contribution subtopic 3: On smaller motion blocks

The contribution reports that motion blocks smaller than 8x8 do not appear beneficial for 720p and higher resolution encoding.

Comment: Summarizing the results in terms of common conditions average BD-Rate and BD-PSNR (for the relevant subset of sequences) would be the right way to measure this.

Question: Is it because of a lack of high frequencies in the source material? Which sequences were tested? How about City sequence?

Comment: This can be a profiling issue as well as a common conditions issue.

Question: What is the software simulation run-time impact of turning off small block inter prediction? Response: May not be major – this is perhaps really more of a profiling comment than a common conditions topic. Suggestion: If it's not a testing issue, perhaps it's better to keep small inter prediction block size support in the common conditions to maximize consistency of settings across different tests and to ensure best quality.

Question: What about the transform? Haven't checked, but that is a less important issue in terms of computational efficiency (except for deblocking impact) than motion block size.

Contribution subtopic 4: Evaluation method for 4:4:4 coding performance

Common conditions do not include 4:4:4. The contribution suggests to include this in some form.

Suggests PSNR metrics to measure as being both of
- luma only (Rec. BT.709 assumptions)
- average of MSE of R, G, B per picture, convert to PSNR, then average across all pictures in sequence

Question: Encoding color space?

Question: What is the color format of the available source sequences? Response: Some form of RGB. Question: What kind of RGB (color primary chromaticity, white point, scaling, offsets)? Response: Unknown.

Revisit to review specific suggested changes to issue in modified CC document.

Spatial Prediction:

VCEG-AJ16 [D. Sim et al (ETRI, Kwangwoon Univ., and Kyunghee Univ.)] Unidirectional 4x4 intra prediction

This contribution proposed a "unidirectional 4x4 intra prediction" for improvement of intra-frame coding efficiency of H.264. The current H.264 has 4x4, 8x8, and 16x16 intra prediction modes. For 4x4 intra prediction, coding gain is achieved by accurate prediction with small block size.

However, it requires send 16 indications of prediction directions for a macro-block.

The proposal is to replace three of the Intra_16x16 macroblock prediction modes with intra prediction modes that operate on a 4x4 basis, but all 4x4 blocks in the macroblock use the same prediction mode, which is one of three modes: horizontal, vertical, or DC. The remaining Intra_16x16 macroblock prediction mode, namely the plane mode, is kept unchanged (didn't have time to replace that one, but could be done in principle).

For intra-frame coding, the proponent reported achieving
- 1.13 % coding gain in BD-bitrate for Baseline profile experiment conditions.
- negligible gain under High profile conditions

Remark: Perceptually, Intra_16x16 is useful for coding very smooth regions with isolated details. This scheme may harm the perceptual effect.

Remark: Consider sky areas, ramps, etc. Suggest review of old contributions from Bjontegaard on the subject.

Remark: Related contribution: VCEG-AF15.

Results also reported relative to KTA 1.8 with MDDT turned on and otherwise Baseline conditions: 1.7% overall savings reported.

Proponent suggests applying similar concept to 8x8 case as a further study topic.

Remark: Gain seems minimal (and only for all-intra), subjective impact unknown.

Contribution noted.

Temporal Prediction:

VCEG-AJ18 [Steffen Kamp, Benjamin Bross, Mathias Wien (RWTH Aachen Univ.)] Fast Decoder Side Motion Vector Derivation

Decoder-side motion vector derivation (DMVD) using template matching has previously been reported to improve the coding efficiency of H.264/AVC based video coding. Previously, DMVD was performed using a full template matching search in a limited search range. This contribution provided results for a reduced complexity DMVD, where a candidate based fast search algorithm replaces the full search.

BD-Bitrate savings of 6.5% relative to JM 13.2, averaged over CIF and HD sequences (7.8% for HD sequences) according to the VCEG common conditions for the IPPP case of High profile conditions were reported. By omitting sub-pel refinement for DMVD, average savings observed for CIF and HD was reported to be 5.7% (7.2% for HD sequences).

The new element of this contribution, relative to prior contributions, is the incorporation of fast search in the decoding process. Question: How much complexity saved? Response: Template search part of the process is reduced by a large factor (up to 40).

Question: Hierarchical B results? Not measured – not implemented yet for the B pictures.

Scheme adds an additional prediction mode, in which an average of the predictions from N "hypothesis" motion vectors obtained with

Remark: This scheme has sensitivity to decoded sample values, which has an impact on transmission error scenarios. Response: That would result in decoded picture corruption, and for skipped macroblocks, a parsing problem (unless skipped macroblocks do not use the scheme, which does not have a major impact on coding efficiency). Have not yet investigated the behavior under such circumstances.

Remark: Some interaction with rounding effects and offset effects.

Remark: There seems to be higher gain for higher frame rates and/or higher resolutions.

Hierarchical B results would be desirable.

Results with new offset and high precision filtering would be desired.

Further study encouraged.

VCEG-AJ27 [L. Shangwen, L. Yu (Zhejiang Univ.)] Additional Results of Second Order Prediction (SOP) in P Slice

Insert description.

Improvement relative to prior result described with new way to indicate modes within the 2nd-order prediction macroblocks.

* Testing with CABAC, B pictures (not yet tested)

* Testing with trellis-based quantization (not yet tested)

* testing with new offset

* Other aspects of exact alignment with common conditions – e.g., version of software used as reference.

* Other aspects of encoding search complexity

* The adaptive 8x8 and 4x4 transform use case seems the most important / relevant.

Further study planned to implement SOP on KTA platform with RDO-Q and then extend to B pictures and CABAC. Complexity study is also suggested.

Remark: What prediction modes tend to be used? A limited set is supported in this scheme (only two modes selectable at prediction block level). Is one of them always DC, for example?

Upload of presentation requested.

Further study encouraged.

VCEG-AJ29 [M. Karczewicz, Y. Ye, P. Chen, G. Motta (Qualcomm)] Single Pass Encoding using Switched Interpolation Filters with Offset

Extensions to a previously proposed method based on switching between fixed interpolation filters and sending a DC offset on the sub-pixel position level were described. The modifications allow single pass encoding. Comparing to single pass H.264/AVC encoder (JMKTA 2.0) the proposed scheme reportedly brings over 12.10% bit rate reduction for 720p sequences. Comparing to multiple pass encoding the gain is reportedly 10.74%.

Prior contributions: VCEG-AI35 and SG 16 contribution 463.

In addition to current 1/4 sample interpolation filter, 2 other fixed filter sets (6 tap 1-D or 4x4 2-D support filters) are provided. On a frame basis, for each of the 15 sub-pel positions, there is an indication of which of the three filters is to be used.

Also on a frame basis, 16 DC offsets are supplied – one for each sub-pel and full pel position.

This contribution describes a single pass encoding method of using this scheme.

Focus on High profile IPPP. (JM KTA did not have single pass hierarchical B support.)

Switchable interpolation filters with offset is already in KTA, but in the past has used multi-pass encoding. This contribution provides an alternative way to use this scheme – in a single-pass fashion – an encoder-only modification.

In the reference for comparison, WP was turned on, but was turned off when the scheme was applied.

Question: How would you use this scheme with weighted prediction at the same time?
Response: Use the scaling but not the offsets.

VCEG disposition: Adopt into KTA design.

Upload of presentation requested.

VCEG-AJ30 [M. Karczewicz, Y. Ye, P. Chen, G. Motta (Qualcomm)] Experimental Results of Interpolation Filters on High-Definition Sequences

Experimental results on the use of fixed and adaptive interpolation filters on new high-definition video sequences are presented here. Results were reported for the IPPP configuration, by following the common test conditions. Comparisons were reported in terms of BD bit rate decrease.

AIF schemes in current KTA software

- Non separable AIF
- Separable AIF
- Directional AIF
- Enhanced directional AIF (E-DAIF), which includes (5x5 nonsep) full-pel filter, filter offset, and better filter decision for each sub-pel position

Not in current KTA software

- Enhanced AIF (E-AIF) [COM 464 and VCEG-AI38], which includes (5x5 nonsep) full-pel filter, filter offset, better filter decision for each sub-pel position, and clustered 12-sample filter support

Previously, there was less data available about how these schemes would perform.

It was reported that the regions of support for E-AIF and E-DAIF are similar for most positions, while E-AIF was reported to have better compression capability (several percent benefit on some sequences).

Remark: For some positions (4 of the 16) there is a smaller region of support in E-DAIF (6 taps rather than 12) than in this scheme.

Remark: There are symmetries imposed in the E-DAIF scheme to reduce the quantity of data to send, and there is a different way to send the filter tap values – those aspects may hurt its comparative coding efficiency.

Remark: Cases other than IPPP would be desirable.

Contribution was submitted as an information contribution. Proponent indicates that this was a mistake, and it is intended as a proposal. A new version will be uploaded to reflect that.

VCEG disposition: Adopt (as 5th mode) into KTA design.

Computational efficiency

VCEG-AJ28 [S. Seo (Konkuk Univ.), Y. Choe, Y.-G. Kim (Yonsei Univ.), Y. Choi (Konkuk Univ.)] A Simulator for Complexity Measurement

discusses and proposes methods to measure complexity in simulation experiments.

Presentation deferred by request.

VCEG-AJ31 [V. Sze (MIT/TI), U. Demircin (TI), M. Budagavi (TI)] CABAC throughput requirements for real-time decoding

The objective of this contribution is to quantify the H.264 context adaptive binary arithmetic coding (CABAC) decoder throughput requirements for real-time decoding. A need for enabling parallelism in CABAC decoding was asserted. Supporting analysis and experiment results were presented. This study was suggested by the proponent to provide guidance for the next generation video coding standard CABAC design.

Prior contribution was COM 16 334.

The contribution provides analysis of throughput requirements for CABAC entropy coding to justify a proposed alternative entropy coding technology, which was asserted to have lower computational requirements. For example, level 4 would have worst-case 275 Mbins/sec, level 4.1 would have max 527 Mbins/sec, level 4.2 would have max 1116 Mbins/sec, level 5.1 would have max 2107 Mbins/sec.

Proposed changes relative to current CABAC design:
- N-ary arithmetic coder (e.g., N=2)
- Use multiplies rather than table look-ups to avoid combinatoric table size expansion (table sizes and contexts expand with N)
- Reduced number/frequency of state updates

Analysis was provided of which syntax elements dominate the throughput. It was suggested to only change the processing of those critical (approximately 12) syntax elements.

Approximately a factor of N reduction in processing cycles was reported with less than 1% bit rate penalty reported.

Remark: There are various (not a small number) current implementations that can handle stress bitstreams for High profile level 4.1. This issue is not being exhibited in today's (custom chip) products as being a problem. Response: Such implementations may use latency increases to accomplish that.

Remark: Also some of these issues are theoretical worst case evil bitstreams, not really what happens in practice.

Remark: But less complexity is a good thing.

Remark: And latency reduction is good.

Remark: And it's especially hard for general purpose CPU software.

Remark: There are implementation issues with implementing the N-ary scheme as well.

Remark: Multiplication-free operation, for example, is a nice property.

Remark: There is some parallel implementation without changing the spec.

Remark: There are High profile mobile phone chips with low power.

Remark: In future profile specifications, we should think about this throughput issue. Replying remark: Actually, we have already been doing that lately by imposing limits on the number of macroblocks in a slice.

Further study encouraged.

Prediction partitioning and transform coding:

VCEG-AJ12 [S.C. Lim, H.C. Choi, S.Y. Jeong, J.S. Choi (ETRI)] Integer Sine Transform for Inter Frame

This contribution proposed a rate-distortion optimized transform coding method that adaptively employs either integer cosine transform (ICT), also known as the integer transform of H.264, or integer sine transform (IST) for inter frames. The proposed method was reported to have been implemented into the KTA software (version 2.0) with a result of an average 2.11% of bit rate saving achieved in the IBBP prediction structure case for High Profile.

Implemented both 4x4 and 8x8 block sizes of IST.

Flag sent on MB basis or, when MB is partitioned into 8x8 sub-MBs, 8x8 basis to indicate the transform type. Question: Why not on MB basis? Response: Seemed to work better for sub-MB basis.

Remark: Consider relationship to adaptive prediction error coding (APEC). The amount of improvement seems in the same ballpark. A sine transform is more complex than no transform at all.

Remark: Ability to weight the quantization by frequency may be a benefit for considering the sine transform as a candidate – can't do that with no transform.

Further study encouraged.

VCEG-AJ20 [S. De Cock, S. Notebaert (Ghent Univ.)] Extended Partitioning with Shape-Adapted Transform

This document extends the partitioning scheme proposed in VCEG-AI25, by combining extended partitioning with shape-adaptive discrete cosine transforms. This results in the ability to transform residuals from distinct partitions separately, irrespective of their shape. This combination improves both objective and perceptual quality.

Prior contribution VCEG-AI25 (with ordinary block transforms but bi-partitioning of prediction additional macroblock mode with horizontal, vertical, and +/-45 degree partitionings with full pel positioning of the bifurcation point). This uses fewer angles of partitioning than prior VCEG-AF10, VCEG-AG13, VCEG-AH16 contributions. Partitionings with very small areas are omitted. The number of new MB modes was reduced from 90 to 50, and the number of new sub-MB modes was reduced from 42 to 22. Still substantially more things to test than in anchor case – about a factor of 5.

The prior proposal applied the block transform across the partitioning boundaries. This new contribution uses shape-adaptive DCT.

Has not been implemented with CABAC.

Improvement in coding efficiency relative to prior bifurcation scheme, although rather marginal in PSNR terms. Perceptually, the SA-DCT scheme is reportedly better – removing a significant number of artifacts.

Suggestion: Filter across boundary in prediction signal, then apply ordinary block-based transform.

Remark: Consider combination with increased macroblock size as proposed in other contributions.

Remark: Consider further investigation of shape coding issues, possibly in a more general way.

Further study encouraged.

VCEG-AJ21 [J. Kim, T. Na, C. Kim, B. Lee, M. Kim (ICU), C. Park, S. Hahm, I. Cho (KBS)] Enlarging MB size for high fidelity video coding beyond HD

In this contribution, it was proposed to extend the architecture of H.264 with enlarged MB sizes. It is suggested that the limitation of the MB size to 16x16 may be harmful to RD performance for high resolution video. This contribution considers by enlarging MB size to a maximum of 128x128. This attempt has been made with an extension to JM reference software. For this, the following aspects were redefined or extended: new MB mode types for enlarged MB, CBP for new MBs or block indexing etc. In this proposal, an extended architecture with the enlarged MB structure was proposed for ME&MC. Topics suggested for further study that were not yet addressed included new designs of transform kernels, intra prediction, luma/chroma DC transforms, CABAC context models and de-blocking filters for the enlarged MB supporting structure.

Experimental results not yet provided – this contribution just describes some interim preliminary design aspects.

Further study encouraged.

VCEG-AJ23 [P. Chen, Y. Ye, M. Karczewicz (Qualcomm)] Video coding using extended block sizes

Requested to delay presentation until Friday.

VCEG-AJ24 [Y. Ye, H. Wang, M. Karczewicz (Qualcomm)] Simulation results on MDDT and comments on intra coding

A few bug fixes for mode-dependent directional transform (MDDT) have been incorporated into the latest KTA software (version 2.1). MDDT performance gains for all prediction settings under the VCEG common testing conditions were collected and summarized in this submission. Some observations on intra coding were also discussed.

Information document reporting on latest simulation results.

Intra-only result on common conditions: 6% overall gain with CABAC enabled.

Also provides about 2% gain on IPPP, IBBP, and HierB cases on average.

Bidirectional intra prediction design reported to still be able to provide some additional gain (that scheme is not part of official KTA software).

Note: VLC changes were also previously proposed, not included in official KTA software, that can reportedly provide gain (a few additional percent) when combined with MDDT and bidirectional intra prediction, relative to CAVLC.

Note: There is no CAVLC mode of operation in the current KTA software supporting the current MDDT scheme due to lack of 16x16 transform support in current CAVLC scheme.

Updated information appreciated.

Entropy coding of mb_type and mb_skip_run

VCEG-AJ15 [K. Nakamura, M. Takahashi, T. Yokoyama (Hitachi), K. Akie, S. Mochizuki, K. Iwata (Renesas Tech)] An Extended VLC for Coding Modes

In this contribution, it was proposed to consider a modified VLC scheme for coding modes. In particular, the contribution discussed mb_type and mb_skip_run. In the proposed method, VLC tables for these syntax elements were adaptively created using statistical information for the previously encoded/decoded blocks. Experimental results reportedly show an average 0.80% (maximum 3.70%) bit rate reduction for the Baseline IPPP structure reference when disabling some modes (inter 4x4, 8x4 and 4x8) in the anchor (to simplify the effort of implementing the design modifications by not supporting some modes in the modified scheme).

Future study work suggested by proponent includes B slices and CABAC and the missing prediction modes.

Question: How does the concept of application to CABAC make sense? Response: Apply to bin string. Remark: Doubt there will be any benefit to that.

Further study encouraged.

Intra Prediction Mode Selection:

VCEG-AJ11 [D.-Y. Kim, K.-H. Han, Y.-L. Lee (Sejong Univ), H.Y. Kim (SK Telecom)] Adaptive intra mode bit skip in intra coding

At the last meeting, an adaptive intra mode bit skip scheme was proposed in VCEG-AI23 for improving intra coding performance, in which the proposed method was applied to Intra4×4 and chroma Intra8×8 modes at baseline profile. In this contribution, the proposed method shows the average bit saving of 2.69% and encoding time saving of 17% ~ 59% at Baseline profile for all-intra coding. The proposed method also shows the average bit saving of 1.41% and encoding time saving of 17% ~ 59% at High profile when it is applied to Intra8x8 mode for all-intra coding. Gain reportedly improves for low bit rates and for high resolutions.

See also notes from previous meetings.

Implemented in KTA 1.9r1 with all-Intra use.

Question: Any new information about combination with MDDT? Has this been tested together with MDDT for High profile reference configurations? Not yet.

Note decoder complexity increase (variance of neighboring samples).

Note dependency of the parsing process on the values of the decoded samples. Probably can't apply this to intra macroblocks predicted from neighbor inter macroblocks.

Question: Was encoder-only (non-normative) application of the concepts tried and compared (or other encoder-only fast intra mode selection ideas)? No.

Further study encouraged.

Motion Vector Selection / Coding:

- VCEG-AJ14 [M. Takahashi, M. Yamaguchi (Hitachi)] A new method for improving motion vector coding

Post / Loop Filter:

- VCEG-AJ13 [T. Chujoh, G. Yasuda, N. Wada, T. Watanabe, T. Yamakage (Toshiba)] Improvement of Block-based Adaptive Loop Filter \
- VCEG-AJ17 [D. Sim et al (ETRI, Kwangwoon Univ.)] Modification of Deblocking Filter for Improvement of Coding Efficiency

APPENDIX H

ITU - Telecommunications Standardization Sector
STUDY GROUP 16 Question 6
Video Coding Experts Group (VCEG)
36th Meeting: San Diego, USA, 8-10 October, 2008

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Question: Q.6/SG16 (VCEG)

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Title: **Enlarging MB size for high fidelity video coding beyond HD**

Purpose: Proposal

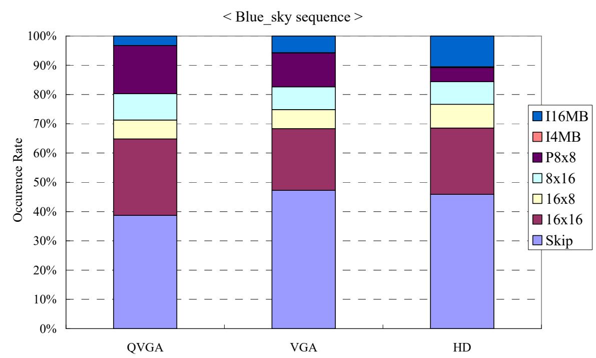
Abstract

In this contribution, we propose to extend the architecture of H.264 codec with enlarged MB sizes. Most of video codecs have lived long with MB based coding, which is now limiting to the coding efficiency toward the video coding of beyond High Definition (HD) resolutions. Even if the High profile of H.264, called FRExt tools, for high bit rate contents has been developed, it still maintains the size of the MB to be 16x16 for ME and MC based predictive coding as well as 16x16 intra coding. To limit the MB size into 16x16 might be one of the factors to restrict the RD performance in the high resolution video. Thus, we attempt to improve the coding efficiency of H.264 by enlarging MB size to the maximum 128x128. This attempt has been made with the extension to JM reference software. For this, the followings are to be newly defined, redefined or extended: new MB mode types for enlarged MB, CBP for new MBs or block indexing etc. In this proposal, the extended architecture with the enlarged MB structure are first proposed for ME&MC but new designs of transform kernels, intra prediction, luma/chroma DC transforms, CABAC context models and de-blocking filters for the enlarged MB are not yet addressed.

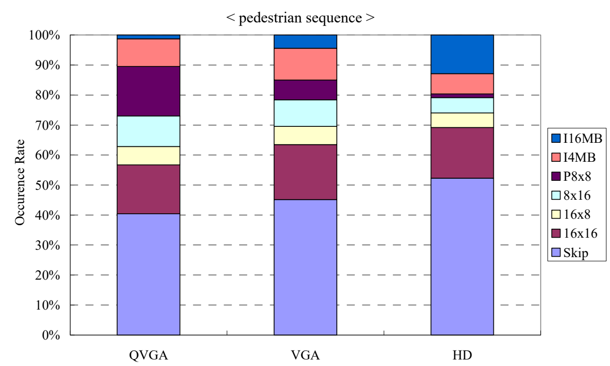
1. Introduction

The demand for HD or beyond HD such as ultra high definition videos of 4k and 8k has been increasing with increased network bandwidth and developed display technology. However, the current video encoder has much limitation to support HD or beyond HD video contents. Since the characteristics of the video signals depends heavily upon spatial resolutions, it is necessary to devise an appropriate video coding architecture to reflect the video characteristics with different sizes, especially the high resolution video contents. The High profile of H.264/AVC provides several tools such as 8x8 integer transform, 8x8 intra prediction and 8 to 12 bit-depth processing etc., which allows for better RD performance for high resolution video, for example, SD or HD video contents. Nevertheless, the maximum MB size for ME and MC is maintained with 16x16 pixels. It may not be efficient for the HD or beyond HD since the MB size of 16x16 pixels is relatively small for high resolution video contents. Fig.1 shows the relative portions of the final block mode selections according to the spatial resolutions of different video contents. These statistics of block mode distributions have been collected from the experiments with H.264

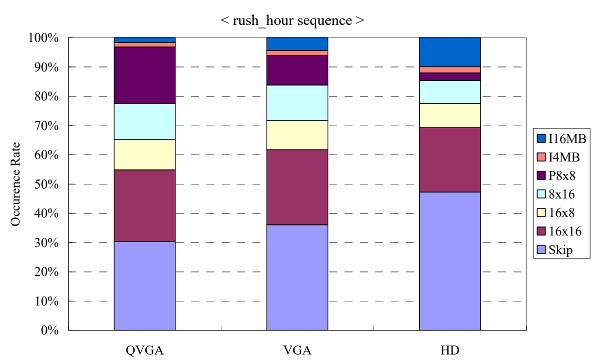
reference software, Joint Model ver. 12.0, for *Blue Sky*, *Pedestrian*, *Rush Hour* and *Station* sequences in QVGA, VGA and HD resolutions. As shown Fig.1, it can be noticed that the portions of the large block modes such as SKIP and 16x16 modes increase in proportion to the video resolution sizes. The mode selection trend shows consistent results for all the sequences with different resolutions and different QP values.



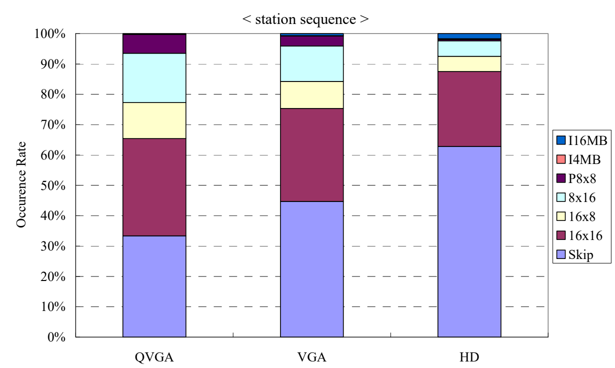
(a) Blue Sky Sequences



(b)Pedestrian Sequences



(c) Rush Hour Sequences



(c) Station Sequences

Fig. 1 Block mode distributions versus spatial resolutions of video

On the other hands, the proportions of the block modes in small spatial resolutions such as P8x8 and I4x4 significantly are reduced, especially for the HD sequences. It implies that relatively large block modes are more advantageous to the high resolution videos in terms of the Rate-distortion optimization. Motivated from these observations, we propose to enlarge the macroblock (MB) of 16x16 for HD or beyond HD video sequences.

Recently, similar works have been introduced in [1-4], and Ma *et. al*. has analyzed the advantage of larger MB with a 16x16 interger transform, a modified RD model and enlarged search ranges for ME in terms of RDO costs for high resolution videos. In this contribution, we attempt to extend with enlarged MB sizes the JM reference software architecture such that the fair comparison and backward compatibility can be supported. Furthermore, the extensions to the current syntax and the required side information for enlarged MB sizes are addressed. In Section 2, how to design the enlarged MB are first explained. Its subsequent works such as new mode definition, CBP for newly enlarged MB's, block indexing and deblocking filters are described.

2. Proposed Architecture

In order to enlarge the MB size, the extensions to H.264 (JM) should be made with a new definition of the added block modes for mb_type, the modification of the CBP definition and block indexing. Fig.2 shows a subsequent chain of the H.264 (JM) elements which are affected by enlarging the MB size. Enlarging the MB size entails the necessity of redefining block indexes of sub-blocks. Subsequently, motion estimation and mode decision are conducted based on the newly numbered block indexing. After the mode decision is completed, entropy coding is performed. Finally deblocking filters with the block indexing modified are applied.

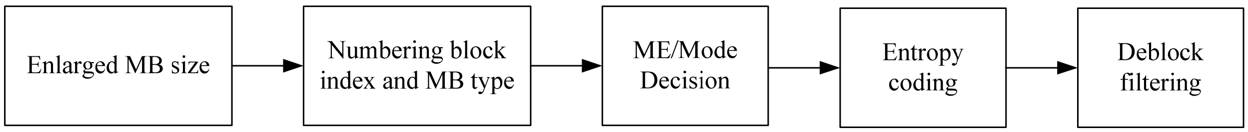


Fig. 2 H.264 (JM) elements affected by the enlarged MB's

Table 1 lists the H.264 elements that must be modified by enlarging the MB sizes. As aforementioned, this is not the exhaustive list. In Table 1, *N* indicates the maximum pixel size for the enlarged MB and can be increased with power of 2 such as 32, 64 or 128.

Table 1. H.264 elements to be modified for enlarged MB's

	H.264/AVC	Proposed enlarged MB
MB size	16x16	NxN
ME size	16x16 ~ 4x4	NxN ~ 4x4
Integer transform	4x4	4x4
CBP computation	8x8	(N/2xN/2), ⋯, 8x8
The number of SKIP mode	1	$\log_2 N - 3$
Blocking indexing	Fig.4	Fig.5
The number of mode for Inter	8	$4 \cdot \log_2 N - 8$

2.1 Hierarchical block partition structures for enlarged MB's

The proposed block modes with enlarged MB are depicted in Fig. 3. As shown in Fig.3, the MB mode partitions constitute a hierarchical structure in a top-down manner. For example, if the maximum MB size is set to 64x64, the resulting number of the partition levels is 4. The sub-block of 32x32 size constitutes the 2nd level hierarchy which can be partitioned further down to 16x16. Similarly, the 4th level hierarchy ends up with 8x8 block mode. Thus, for the case of 64x64 MB, 13 block types and 3 SKIP modes for 64x64, 32x32 and 16x16 block size can be possible. The number of block modes depends on the maximum MB size as shown in Table 1.

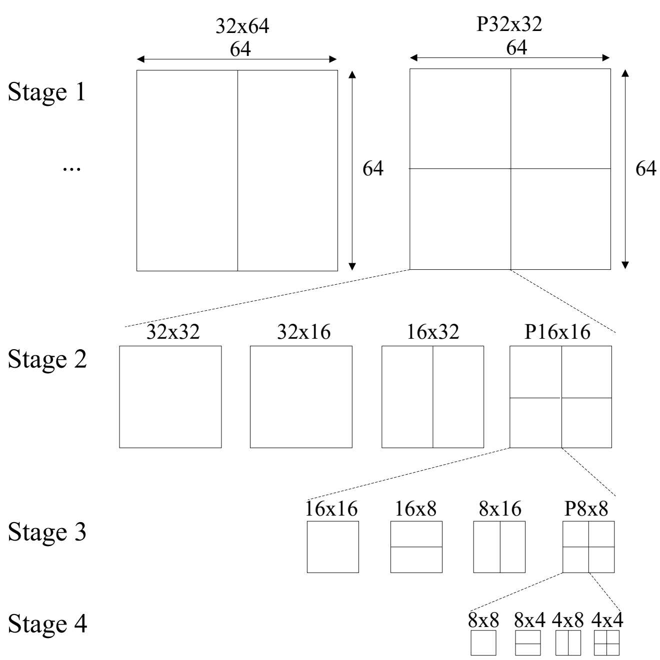


Fig. 3 An example of hierarchical block partitions for enlarged MB of 64x64

2.2 block modes for my_type

The mb_type in the MB syntax of the current H.264 is defined for the MB size of 16x16 and its partitions. The small numbers (0, 1) of mb_type are assigned for the large block modes (SKIP, Inter_16x16) while large numbers (5, 6, 7) are assigned for the block modes (Inter_8x4, Inter_4x8, Inter_4x4) of relatively small sizes. Similarly, in the proposed enlarged MB, the numbering of mb_type should be changed by assigning small numbers to the large block modes such that total bit amounts to represent mb_type become efficient. The mb_type according to the enlarged MB size is defined in Table 2.

Table 2. Possible partition block modes (mb_type) for enlarged MB's of 128x128, 64x64 and 32x32

128x128 MB size	SKIP_128x128(0), 128x128(1), 128x64(2), 64x128(3), SKIP_64x64(4), 64x64(5), 64x32(6), 32x64(7), SKIP_32x32(8), 32x32(9), 32x16(10), 16x32(11), SKIP_16x16(12), 16x16(13), 16x8(14), 8x16(15), 8x8(16), 8x4(17), 4x8(18), 4x4(19),
64x64 MB size	SKIP_64x64(0), 64x64(1), 64x32(2), 32x64(3), SKIP_ 32x32(4), 32x32(5), 32x16(6), 16x32(7), SKIP_16x16(8), 16x16(9), 16x8(10), 8x16(11), 8x8(12), 8x4(13), 4x8(14), 4x4(15),
32x32 MB size	SKIP_32x32(0), 32x32(1), 32x16(2), 16x32(3), SKIP_16x16(4), 16x16(5), 16x8(6), 8x16(7), 8x8(8), 8x4(9), 4x8(10), 4x4(11),

If an enlarged MB size is NxN, '0' is assigned to mb_type for the SKIP_NxN block mode. Hence, the largest number of mb_type is assigned to the smallest block size whose occurrence rate is the smallest among the other block modes.

2.3 Block indexing

As the MB size is enlarged, the block indexing for sub-MB and 4x4 integer transform should be modified. Fig.4 shows the block indexing for the MB of 16x16 size in the 4:2:0 YCbCr format. Once the sub-blocks are partitioned, 4x4 blocks are indexed inside one 8x8 block. However, for an enlarged MB size, the block indexing for the sub-MBs are changed accordingly. Fig. 5 shows an example of the block indexing for the MB size of 32x32. The block indexing for the enlarged MB is numbered hierarchically in a top-down manner. The encoding order according to the proposed block indexing is also shown in Fig.5.

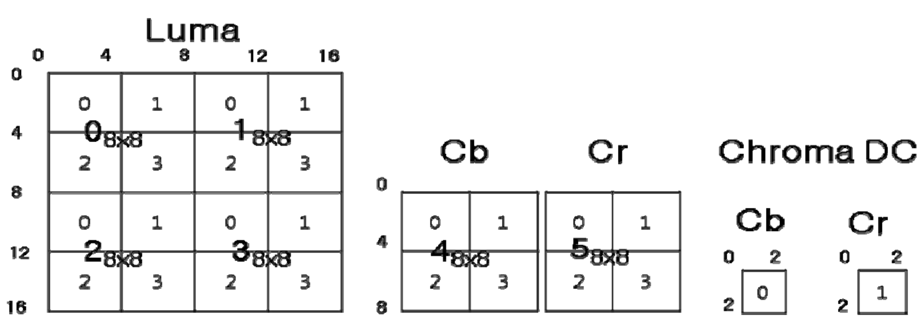


Fig. 4 Block indexing for 16x16 MB

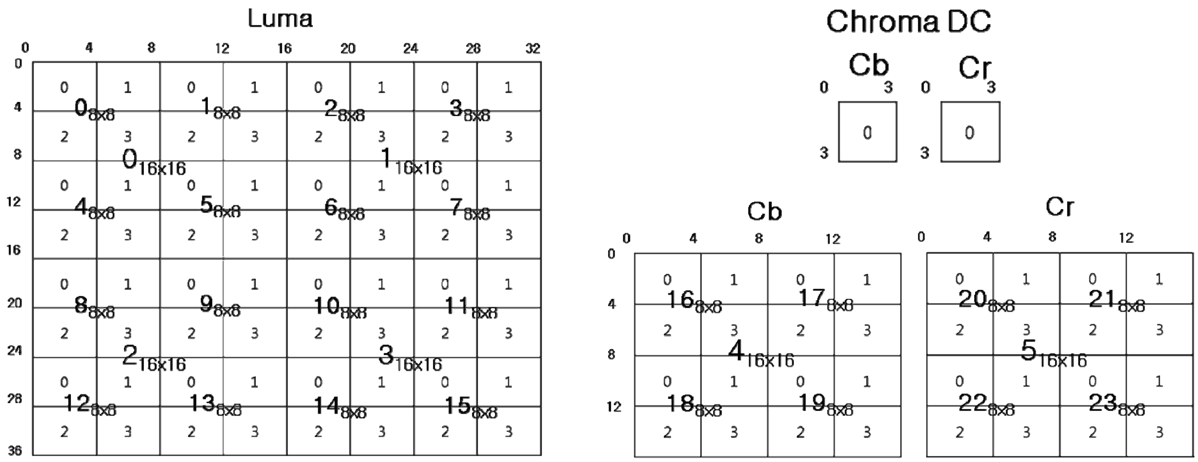


Fig. 5 Block indexing for 32x32 MB

2.4 New SKIP modes in each mode stage.

For the enlarged MB sizes, new SKIP modes are added to the block modes. The total number of SKIP modes in the current H.264 is only one for 16x16 block size while the number of SKIP mode in the enlarged MB depends on the MB size N. Since the block modes are constructed in a hierarchical tree structure, several SKIP modes may be added when the shapes of the block modes are square, for example, 32x32, 64x64, and 128x128 etc. The added SKIP modes can play an important role of enhancing the coding efficiency for high resolution video contents. By incorporating one SKIP mode into each squared block partition, the decoding syntax might be accordingly modified such that the SKIP mode is firstly checked at the beginning of parsing each squared block partition [3]. Fig. 6 shows an example of syntax parsing for enlarged MB with SKIP modes in each level of squared block modes.

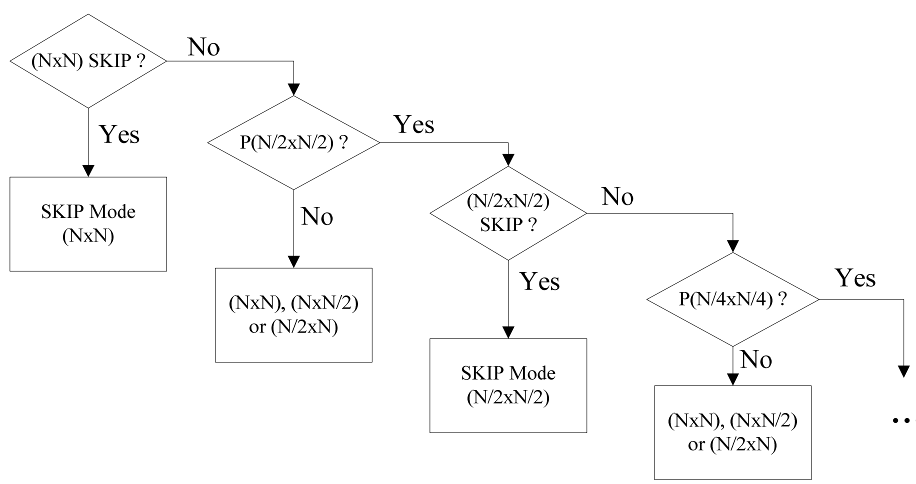


Fig. 6 MB syntax for the enlarged MB

2.5 The CBP value

The CBP value for the 16x16 MB can signal the information about all zero blocks based on 8x8 block in H.264. This is directly extended in a hierarchical manner to an enlarged MB where CBP_EMB (CBP for Enlarged MB) is newly defined to signal the context of quantized IT coefficients based on the NxN MB size. Fig. 7 shows an example of CBP_EMB for the enlarged MB of 32x32 size.

32x32 block mode

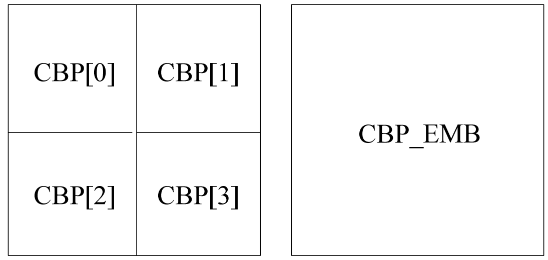


Fig. 7 CBP_EMB for 32x32 MB and CBPs for 16x16 blocks

2.6 Signaling issue for MB size information

An optimal way of signaling MB size information must be investigated by considering MB, Slice, SPS or PPS level.

3 Conclusion

We propose to extend the H.264 with an enlarged MB scheme for high resolution video coding such HD and beyond HD sequences. The statistics show that the enlarged MB can provide enhanced coding efficiency for high resolution video coding. This extension is definitely beneficial to the long-term living of H.264 for high resolution video coding beyond HD resolutions.

For enlarging MB size, the number of block partitions increases accordingly. This may cause to reduce the coding efficiency in terms of signaling the block mode information due to increase number of block partitions. Since the motivation of enlarging the MB size is targeted for high resolution video coding, the number of block modes can be reduced by eliminating the block partitions of small sizes which are rarely selected. This might be a reasonable approach because the interoperability between a very small resolution (QCIF) video and a very large resolution (Ultra HD) video may not be necessary in a single video codec with their application domains far separated.

4 References

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