Advances in Video Compression

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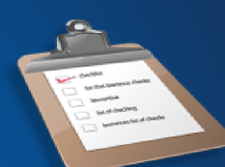
VP International Standards
Ericsson, CTO Office

Chalmers (online lecture)
28 April, 2020

1

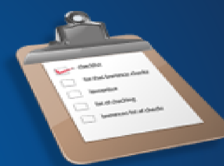
Outline



- Introduction
- Video Coding
  - Basic Image and Video coding
  - Codec Evolution & High Efficiency Video Coding
- Focus areas
  - 3D: Historical snapshots & How do we achieve 3D?
  - UHD: 4K & High Dynamic Range
  - Virtual Reality
  - 5G Standardization

2

Outline



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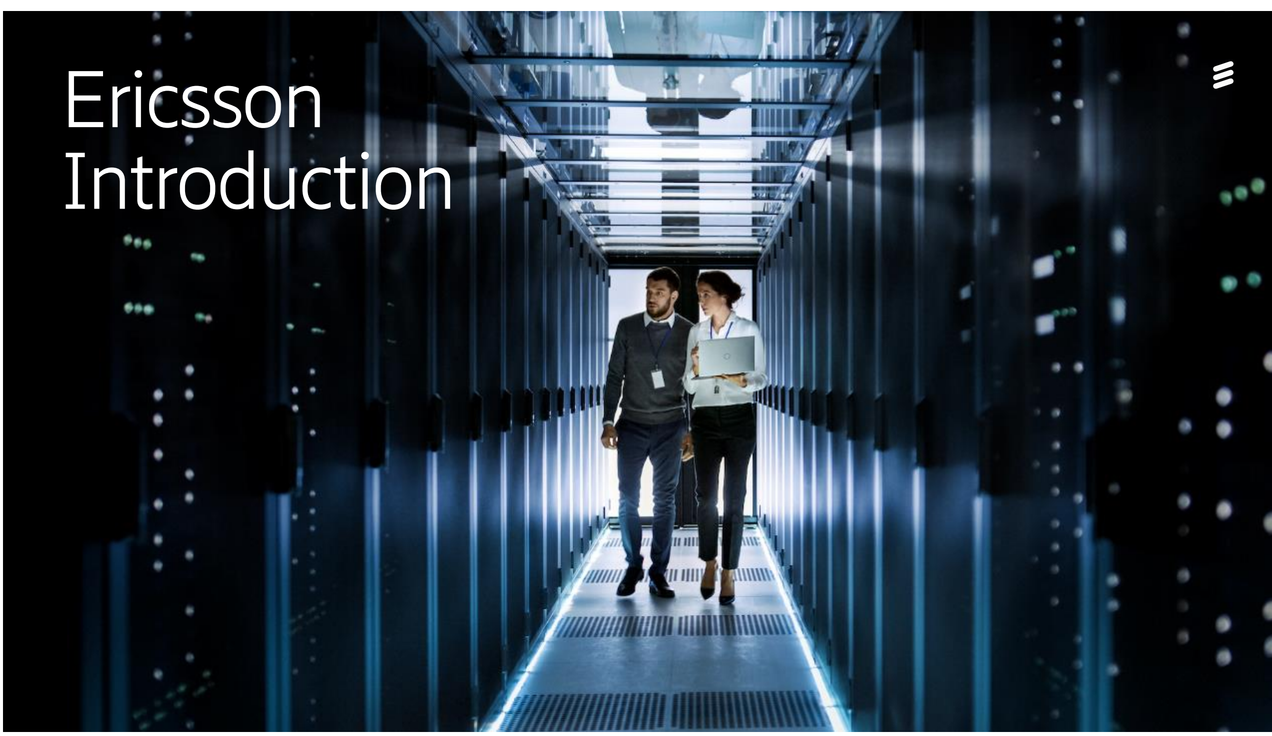
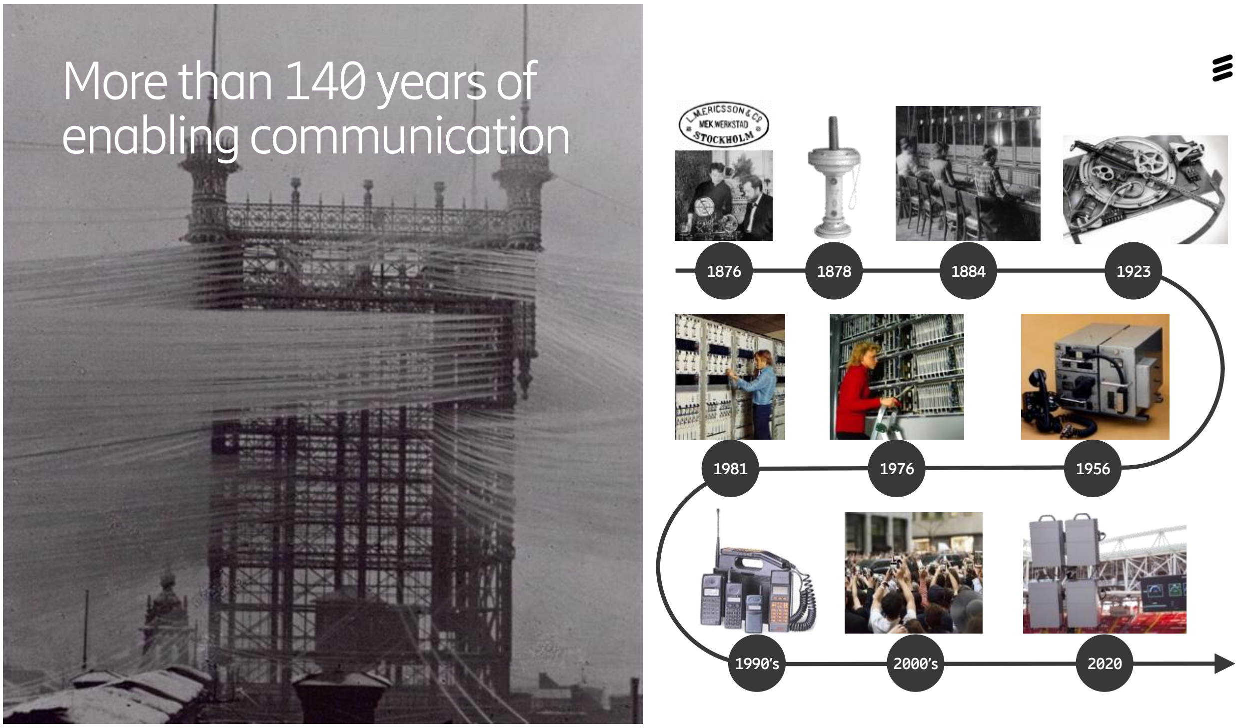
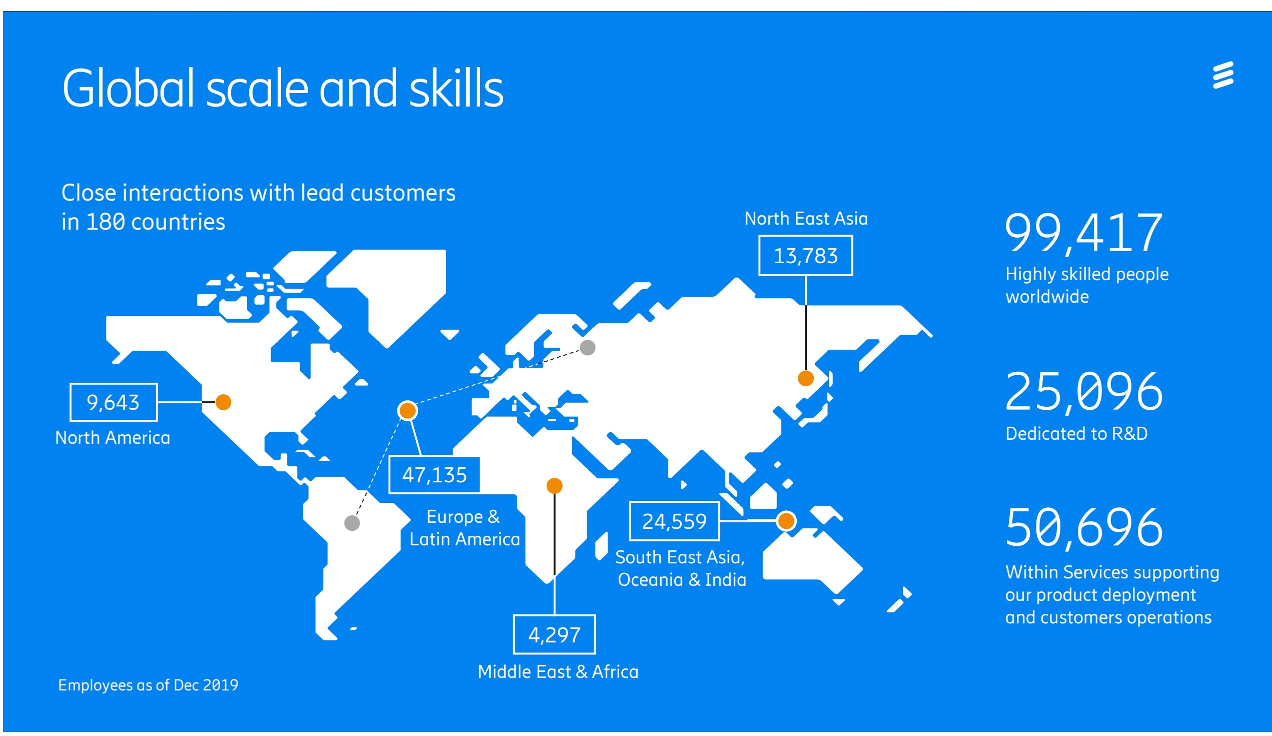
3



4


More than 140 years of enabling communication
L.M. ERICSSON & Co. MEK.WERKSTAD STOCKHOLM
1876
1878
1884
1923
1956
1976
1981
1990's
2000's
2020

5


Global scale and skills
Close interactions with lead customers in 180 countries
North East Asia
13,783
9,643
North America
47,135
Europe & Latin America
24,559
South East Asia, Oceania & India
4,297
Middle East & Africa
99,417
Highly skilled people worldwide
25,096
Dedicated to R&D
50,696
Within Services supporting our product deployment and customers operations
Employees as of Dec 2019

6

Ericsson at a glance

Enabling the full value of connectivity for service providers

Business areas:
- Networks
- Digital services
- Managed services
- Technologies and new businesses

By the numbers:
- 180+ countries
- 227,2 b. SEK in sales
- 99,417 employees
- 54,000 patents

Image: Ericsson headquarters, Kista, Sweden

Full year 2019 figures

7

About me

Physicist
- MSc 88 Teknisk Fysik, Chalmers
- PhD 93 Chalmers & Imperial College (London)
- Post Docs Seattle & Copenhagen
- Docent 99 Stockholm University

Ericsson Research 00-12
- Head of Video Research (07-12)
- Standardization: MPEG, ITU, 3GPP, JPEG, W3C

Ericsson CTO Office 12-20
- Director Media Standardization
- Vice President International Standards

E-mail: per.frojdh@ericsson.com

Standards-related appointments

- SIS TK302	Chair Multimedia
- DASH IF	Board, Chair Promotions
- DVB	Steering Board
- MC IF	Board, Vice President

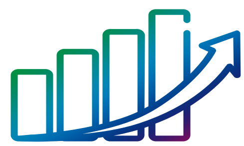
8

Video Everywhere

Resolution revolution

Device explosion

Immersion



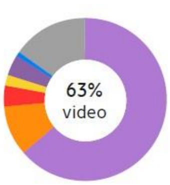
Traffic growth

9

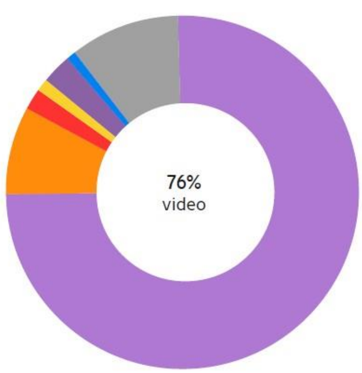
Mobile Data Traffic by application

Video | Social networking | Web browsing | Audio | Software download and update | P2P file sharing | Other segments

Mobile video traffic is forecast to grow by around 30 percent annually through 2025 to account for 76 percent of all mobile data traffic.



2019
38EB
per month



2025
160EB
per month

In 2025, nearly half of mobile data traffic will be carried by 5G networks.

Main drivers for video traffic growth
- Video part of most online content (news, ads, social media, etc.)
- Video sharing services
- Video streaming services
- Changing user behavior – video being consumed anywhere, any time
- Increased segment penetration, not just early adopters
- Evolving devices with larger screens and higher resolutions
- Increased network performance through evolved 4G and 5G deployments
- Emerging immersive media formats and applications (HD/UHD, 360-degree video, AR, VR)

Ericsson Mobility Report (Nov, 2019)

10

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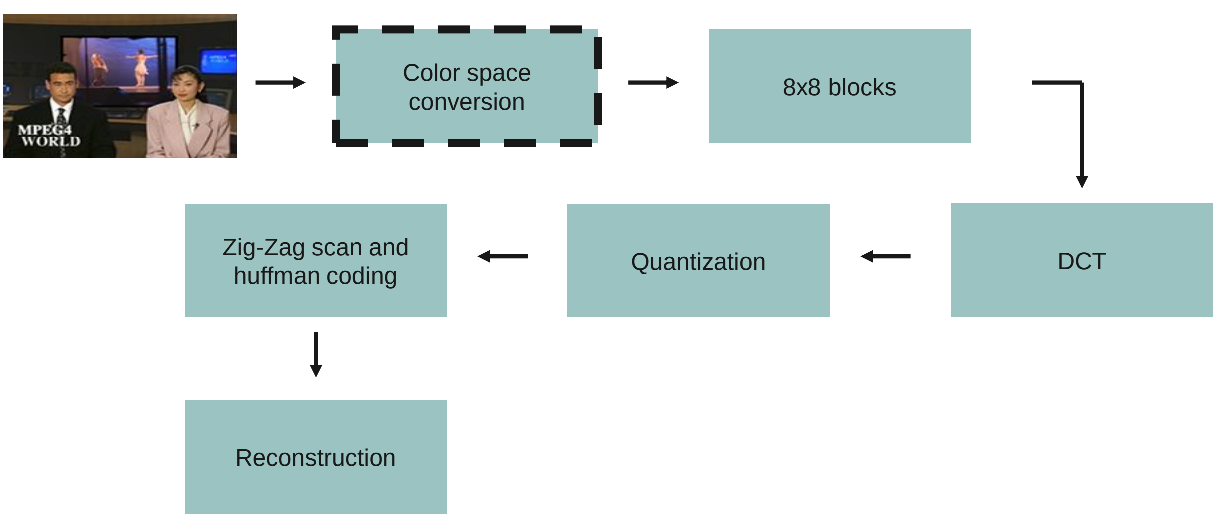
11

JPEG Encoding Chain



12

The YUV Image Format

RGB

Color Space Conversion

2x compression

Y = luminance

C_b =“bluish” **C_r = “redish”**

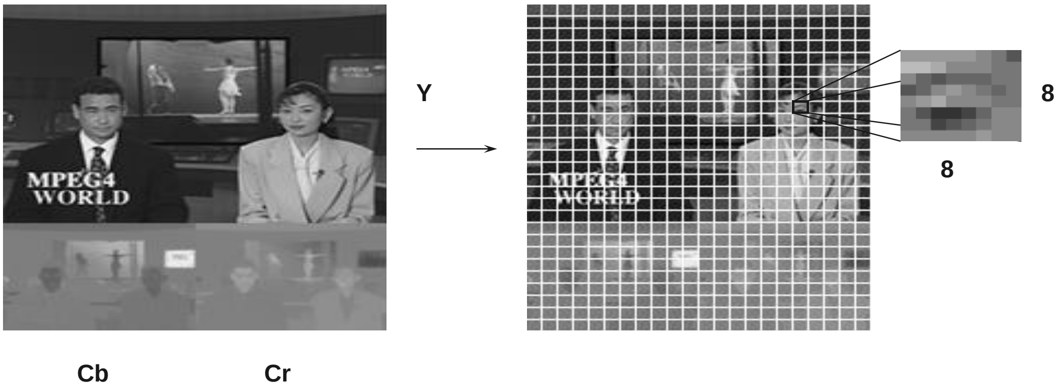
13

JPEG Encoding Chain

→ Color space conversion → 8x8 blocks → DCT → Quantization → Zig-Zag scan and huffman coding → Reconstruction

14

JPEG, 8x8 blocks



15

JPEG Encoding Chain

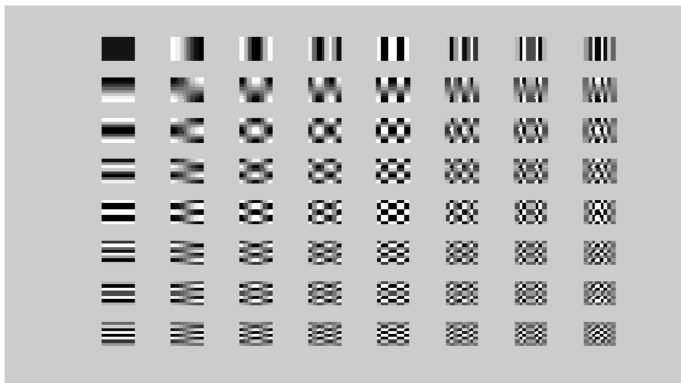
Color space conversion → 8x8 blocks → DCT → Quantization → Zig-Zag scan and huffman coding → Reconstruction

16

2D DCT Basis Functions

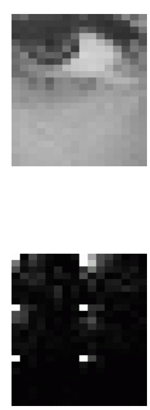
$$F(u,v) = \frac{C(u)C(v)}{4}\sum_{j=0}^{7}\sum_{k=0}^{7} f(j,k)\cos\left[\frac{(2j+1)u\pi}{16}\right]\cos\left[\frac{(2k+1)v\pi}{16}\right]$$

$$C(0) = 1/\sqrt{2},\ C(x) = 1,\ \text{for}\ \ x \neq 0,$$



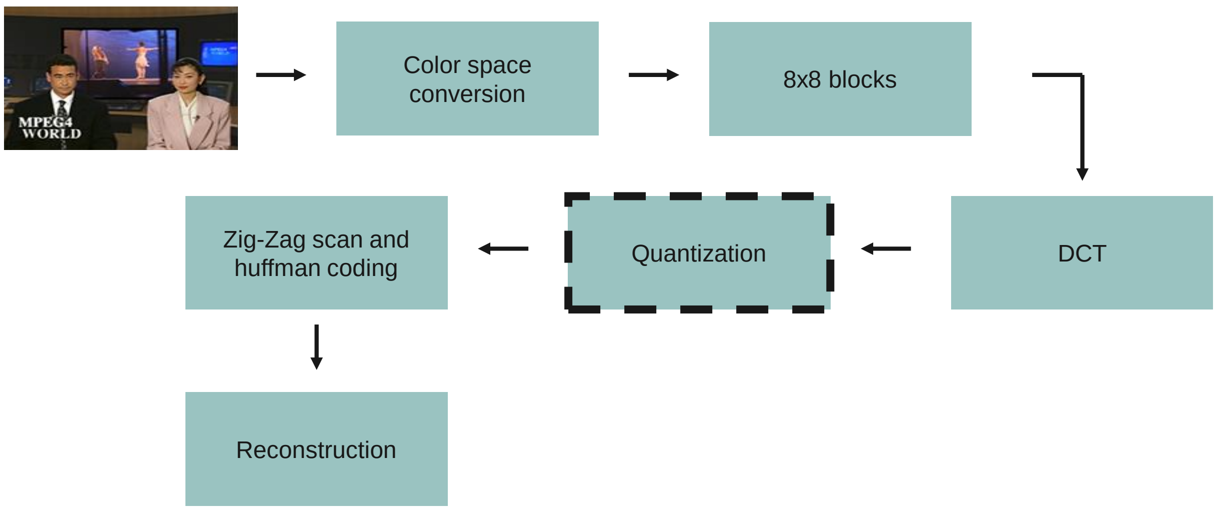
17

Energy Concentration



18

JPEG Encoding Chain



19

Quantization

$$F'(u,v) = \frac{F(u,v)}{Q(u,v)}$$

$$F(u,v) = \begin{bmatrix} 1260 & -1 & -12 & -5 & 2 & -2 & -3 & 1 \\ -23 & -17 & -6 & -3 & -3 & 0 & 0 & -1 \\ -11 & -9 & -2 & 2 & 0 & -1 & -1 & 0 \\ -7 & -2 & 0 & 1 & 1 & 0 & 0 & 0 \\ -1 & -1 & 1 & 2 & 0 & -1 & 1 & 1 \\ 2 & 0 & 2 & 0 & -1 & 1 & 1 & -1 \\ -1 & 0 & 0 & -1 & 0 & 2 & 1 & -1 \\ -3 & 2 & -4 & -2 & 2 & 1 & -1 & 0 \end{bmatrix}$$

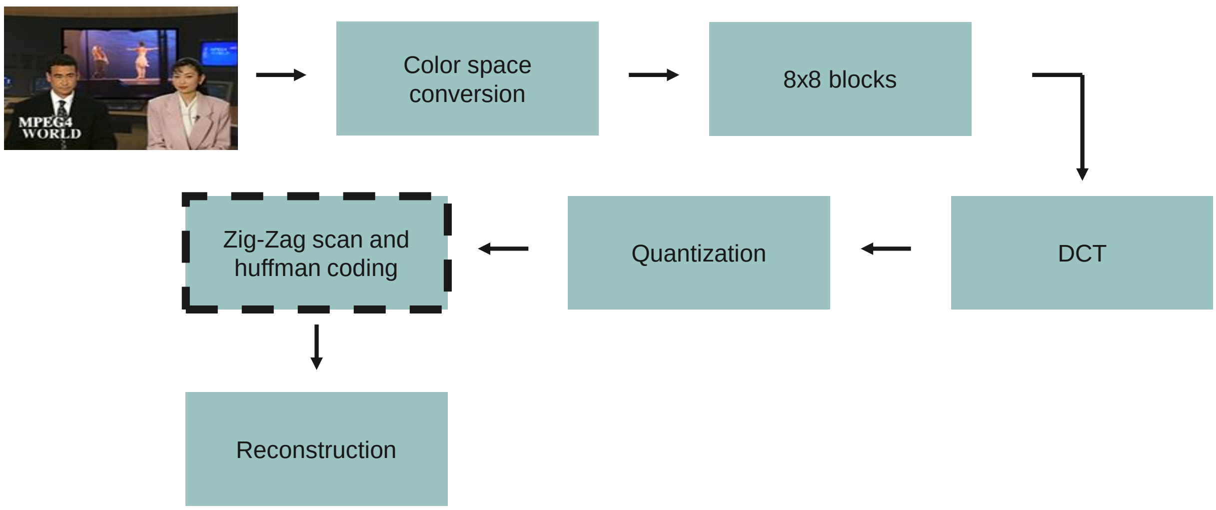
DCT Coefficients

$$F'(u,v) = \begin{bmatrix} 79 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ -2 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Quantized Coefficients

20

JPEG Encoding Chain



Zig-Zag Scanning

$$F'(u,v) = \begin{bmatrix} 79 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ -2 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Quantised Coeffs

$$\begin{bmatrix} 0 & 1 & 5 & 6 & 14 & 15 & 27 & 28 \\ 2 & 4 & 7 & 13 & 16 & 26 & 29 & 42 \\ 3 & 8 & 12 & 17 & 25 & 30 & 41 & 43 \\ 9 & 11 & 18 & 24 & 31 & 40 & 44 & 53 \\ 10 & 19 & 23 & 32 & 39 & 45 & 52 & 54 \\ 20 & 22 & 33 & 38 & 46 & 51 & 55 & 60 \\ 21 & 34 & 37 & 47 & 50 & 56 & 59 & 61 \\ 35 & 36 & 48 & 49 & 57 & 58 & 62 & 63 \end{bmatrix}$$

Scanning Order

Resulting Information to code: 79 0 -2 -1 -1 -1 0 0 -1 EOB
The DC component (79) is differentially coded.
The coefficients are coded using a composite run-length encoding and typically results in 35 bits (8 for the DC).
The compression ratio is: 512/35 = 14.6

JPEG Encoding Chain

Color space conversion → 8x8 blocks → DCT → Quantization → Zig-Zag scan and huffman coding → Reconstruction

Inverse Quantisaton & IDCT

$$\hat{F}(u,v) = F'(u,v) * Q(u,v)$$

$$f(j,k) = \begin{bmatrix} 139 & 144 & 149 & 153 & 155 & 155 & 155 & 155 \\ 144 & 151 & 153 & 156 & 159 & 156 & 156 & 156 \\ 150 & 155 & 160 & 163 & 158 & 156 & 156 & 156 \\ 159 & 161 & 162 & 160 & 160 & 159 & 159 & 159 \\ 159 & 160 & 161 & 162 & 162 & 155 & 155 & 155 \\ 161 & 161 & 161 & 161 & 160 & 157 & 157 & 157 \\ 162 & 162 & 161 & 163 & 162 & 157 & 157 & 157 \\ 162 & 162 & 161 & 161 & 163 & 158 & 158 & 158 \end{bmatrix}$$

Original Pixel Values

$$\hat{f}(j,k) = \begin{bmatrix} 144 & 146 & 149 & 152 & 154 & 156 & 156 & 156 \\ 148 & 150 & 152 & 154 & 156 & 156 & 156 & 156 \\ 155 & 156 & 157 & 158 & 158 & 157 & 156 & 155 \\ 160 & 161 & 161 & 162 & 161 & 159 & 157 & 155 \\ 163 & 163 & 164 & 163 & 162 & 160 & 158 & 156 \\ 163 & 163 & 164 & 164 & 162 & 160 & 158 & 157 \\ 160 & 161 & 162 & 162 & 162 & 161 & 159 & 158 \\ 158 & 159 & 161 & 161 & 162 & 162 & 161 & 158 \end{bmatrix}$$

Decoded Reconstructed Pixel Values

Reconstruction Error, PSNR

$$e(j,k) = f(j,k) - \hat{f}(j,k)$$

$$RMSE = \sqrt{\frac{1}{64} \sum_{j} \sum_{k} e^2(j,k)} = 2.26$$

$$PSNR = 20 \log_{10}\left(\frac{255}{RMSE}\right) = 41.0\text{dB}$$

$$e(j,k) = \begin{bmatrix} -5 & -2 & 0 & 1 & 1 & -1 & -1 & -1 \\ -4 & 1 & 1 & 2 & 3 & 0 & 0 & 0 \\ -5 & -1 & 3 & 5 & 0 & -1 & 0 & 1 \\ -1 & 0 & 1 & -2 & -1 & 0 & 2 & 4 \\ -4 & -3 & -3 & -1 & 0 & -5 & -3 & -1 \\ -2 & -2 & -3 & -3 & -3 & -2 & -1 & 0 \\ 2 & 1 & -1 & 1 & 0 & -4 & -2 & -1 \\ 4 & 3 & 0 & 0 & 1 & -3 & -1 & 0 \end{bmatrix}$$

25

JPEG Quality

26

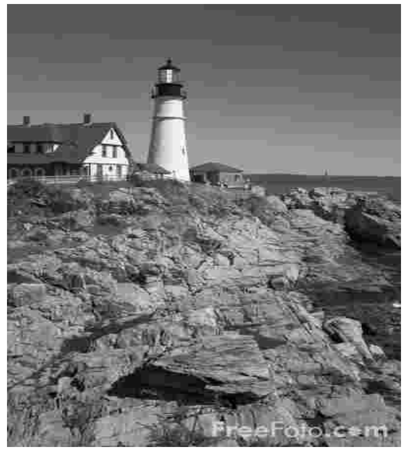
JPEG at 0.125 bpp (64 times compression)

27

JPEG at 0.25 bpp (32 times compression)

28

JPEG Coding Artifacts



Coding errors are less visible in highly textured areas

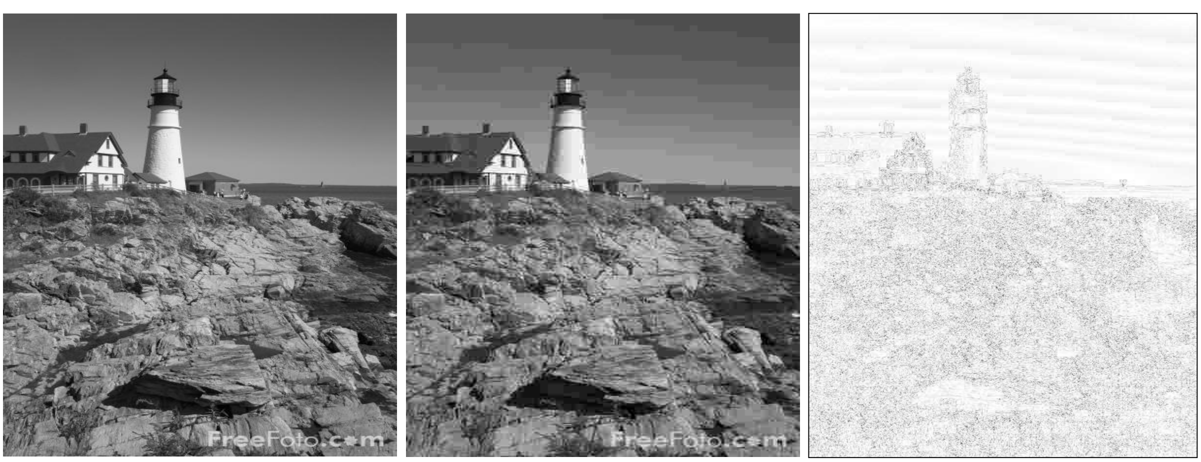
Coding errors are more visible in plain areas such as skies

Visually annoying blockiness can be reduced by post-filtering the image.

For video there is both spatial and temporal masking

29

JPEG Coding Artifacts



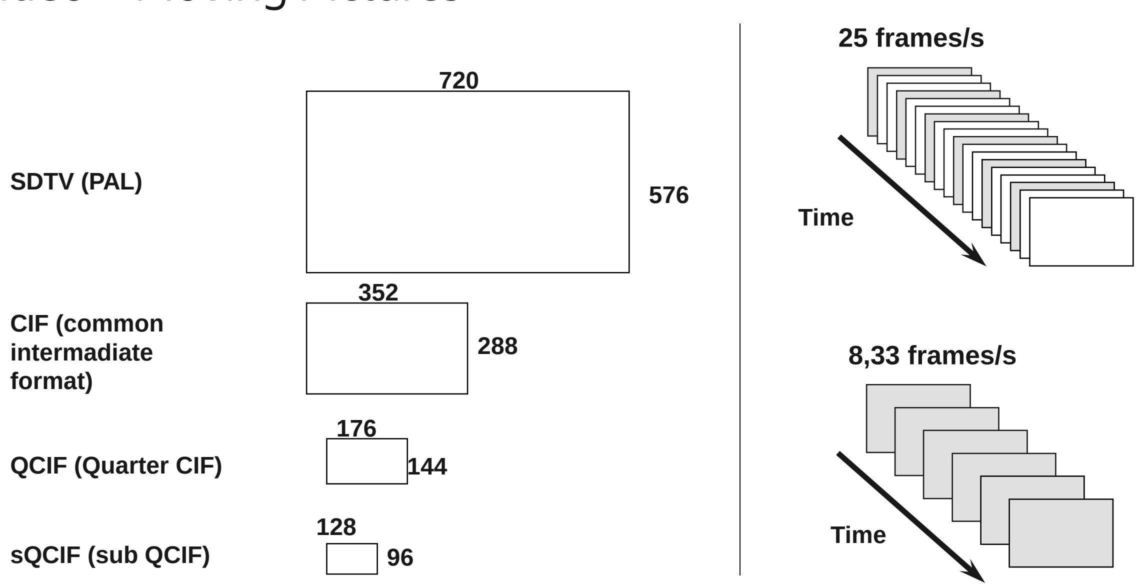
Source **Coded** **Coding error**

30

Video Coding Basics

31

Video = Moving Pictures



32

The YUV Image Format

RGB

Color
Space
Conversion

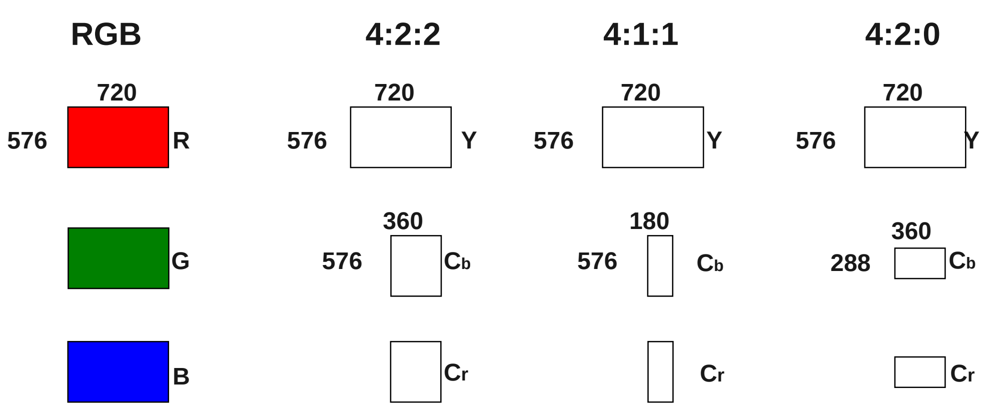
2x compression

Y = luminance

C_b =“bluish” C_r = “redish”

33

Subsampling

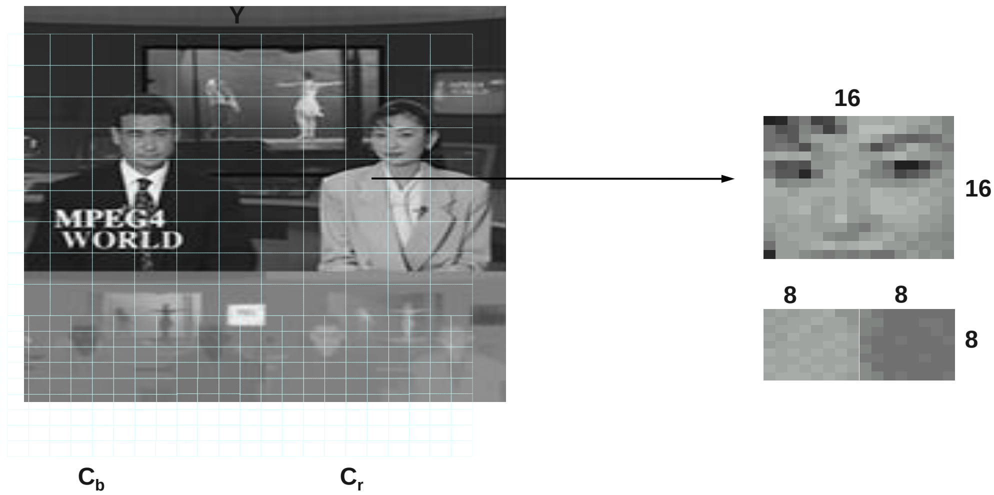


	RGB	4:2:2	4:1:1	4:2:0
Samples per picture	1,244,160	829,440	622,080	622,080

34

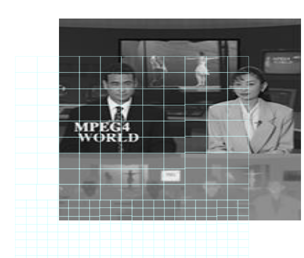
Macroblocks (MB)

A picture is commonly divided into macroblocks, 16x16 pixels
Each picture is then encoded as a sequence of macroblocks

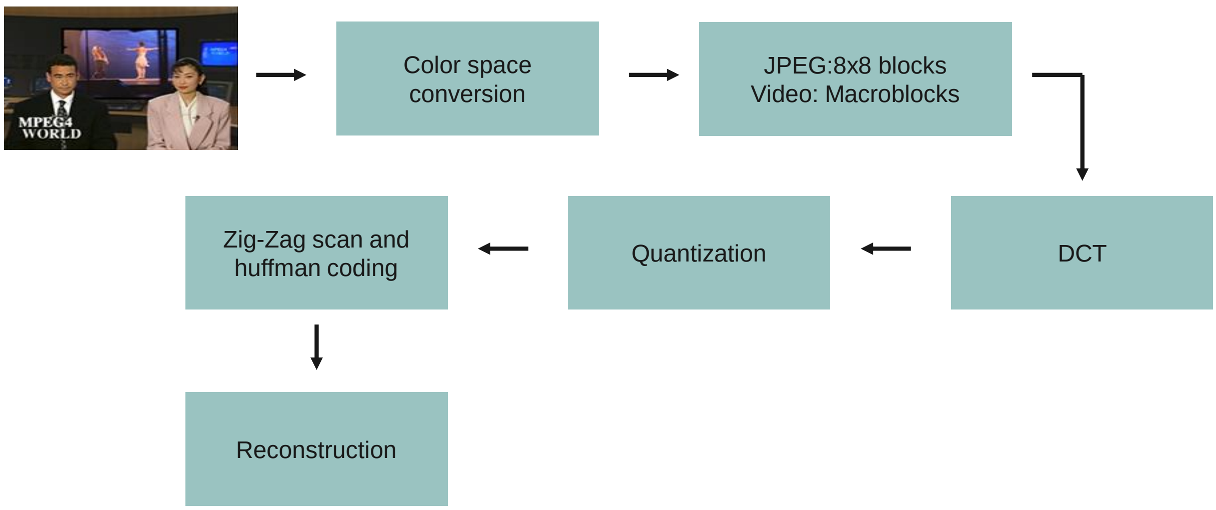


Intra and Inter

- Coding mode is decided on macroblock level
- A macroblock can be coded in two ways:
  - **Intra coding (I)** Still image,
  - **Inter coding (P)** Difference image
- I pictures
  - All MB are intra coded
    - Motion JPEG
    - DV
    - First Picture in Video
- P pictures
  - MBs are I, P or skipped
    - all major video standards

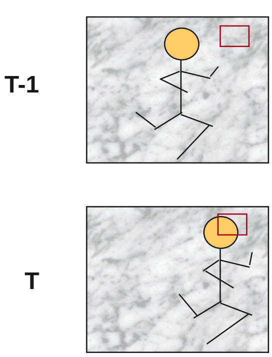


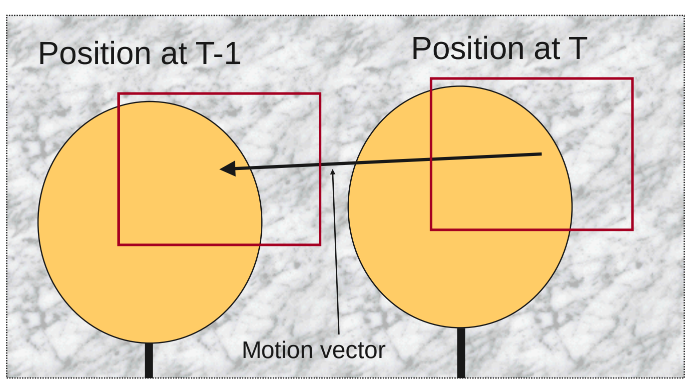
Intra Coding – Similar to JPEG



37

Inter Coding



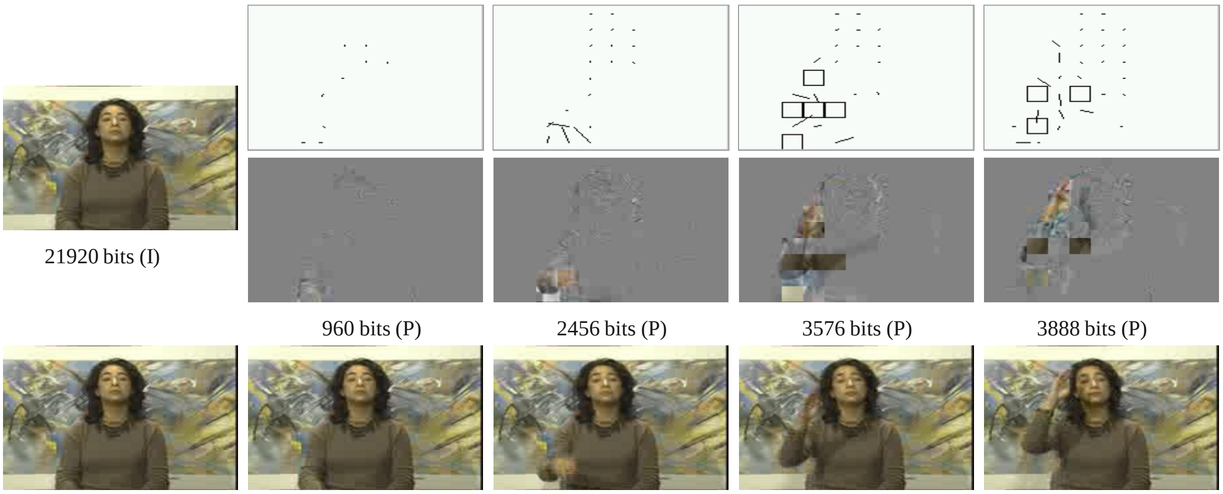


For each 16x16 macroblock, the encoder tries to find a 16x16 block in the previous image that matches the current block.

Each macroblock is coded by a motion vector and a difference block.

38

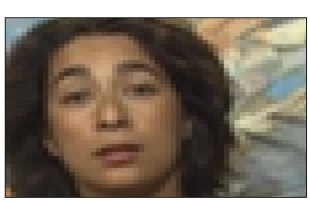
Video Coding example (I & P)



Coding Artifacts

- Blocking (8x8 pixels)
- Color bleeding
- Loss of sharpness
- Ringing

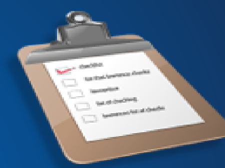
QCIF, 20 times compression



Detail of Original

Detail of compressed image

Outline



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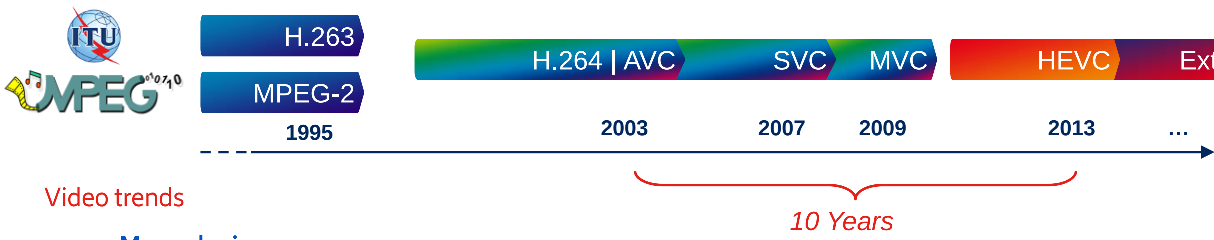
41

Who Standardizes Codecs?

- International Telecommunication Union (ITU)
  - Emphasis on conferencing & mobile video
  - H.261, H.263, H.264/AVC, H.265/HEVC, H.266/VVC
- Moving Picture Experts Group (MPEG)
  - MPEG-1 (VCD, Audio Layer 3 = MP3)
  - MPEG-2 (Video DVD, DVB)
  - MPEG-4 (MP4, DivX, AAC, ...)
  - MPEG-4 AVC/H.264 (HDTV, Blu-Ray)
  - MPEG-H HEVC/H.265 (UHDTV, HDR)
  - MPEG-I VVC/H.266 (5G, VR)
- Joint Photographic Experts Group (JPEG)
  - JPEG, JPEG 2000, JPEG XR, JPEG PLENO
- 3rd Generation Partnership Programme (3GPP)
  - Speech & audio codecs for 3G & 4G
  - AMR, AMR-WB, AMR-WB+, EVS, IVAS

42

Video Codec Evolution

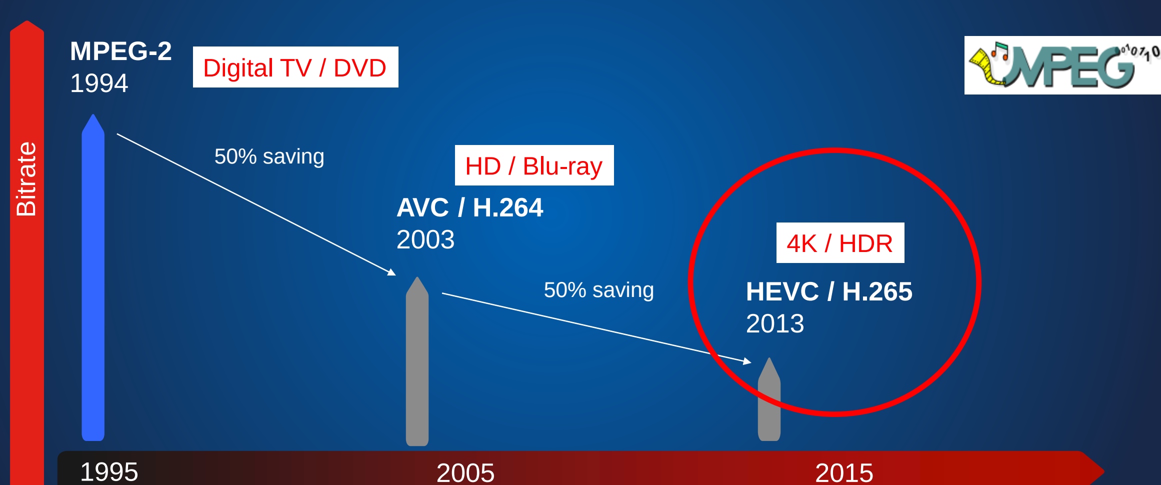


Video trends

- Many devices
- Personal viewing: large displays & short distance
- High resolutions: HDTV -> Ultra HDTV (8Kx4K, 4Kx2K)
- Architecture: Multi-core, Scalable
- Issues: Complexity (battery), Compression ratio, Licensing cost

43

Video Coding Standardization



44

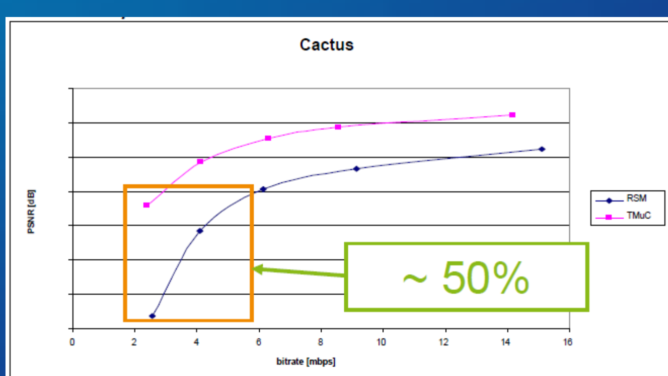
High Efficiency Video Coding (HEVC)

- MPEG and ITU (HEVC/H.265)
- Requirements
  - UHDTV (8Kx4K, 4Kx2K), HDTV, VGA
  - 60fps, 14 bits
  - Clean-sheet design
  - 50% bitrate reduction compared to H.264
- Competition
  - 27 Proposals – Subjective evaluations April 2010
  - Ericsson Nokia Cisco – fastest codec
- Standardisation process
  - 2010-2012 Collaborative development
  - April 2012 Functionally mature
  - July 2012 Technically frozen design (hosted by Ericsson in Stockholm)
  - Jan 2013 Finalization

45

AVC vs HEVC – Performance

720P sequence: moderate difficulty



46

H.264 vs HEVC demo, frame 400

47

H.264 vs HEVC demo, frame 1310

48

H.264 vs HEVC demo, frame 2100

49

H.264 vs HEVC demo, frame 2900

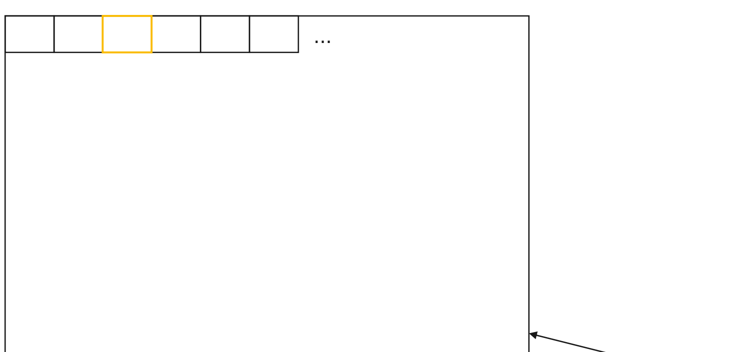
50

H.264 vs HEVC demo, frame 3800

51

H.264 Coding Structure

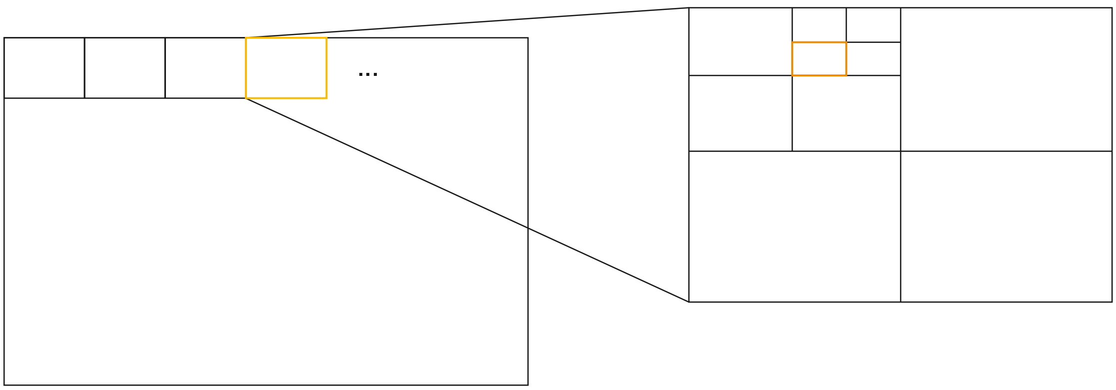
- Frame divided into Macroblocks (16x16)
- Macroblocks are coded in raster-scan order
- Macroblock contains prediction data and transform data



52

HEVC Coding Structure

- Frame divided into Treeblocks (64x64)
- Treeblocks hierarchically split into Coding Units



53

AVC VS HEVC – High Level Tools

AVC / H.264	HEVC / H.265
16x16 Macroblock size	64x64 Treeblock size
Inter partitions 16x16 to 4x4 6-tap ¼-pel filters	Inter partitions 64x64 to 4x4 8-tap ¼-pel filters
9 Intra modes	34 Intra modes
8x8 and 4x4 transform sizes	32x32, 16x16, 8x8 and 4x4 transform sizes
Deblocking filter	Deblocking filter Sample adaptive offset filter

54

More on HEVC

sverigesradio
Vetenskapsradion
2015-03-16

Bättre videokomprimering kan ge fler tevekanaler

Inget av det vi ser på teve skulle vara möjligt utan videokomprimering. Nu har det kommit en ny standard för videokomprimering som är dubbelt så effektiv som dagens Mpeg-4-standard.

http://sverigesradio.se/sida/artikel.aspx?programid=406&artikel=6116214

Ericsson Review
The communications technology journal since 1924 2013 • 6

April 24, 2013

Next generation video compression

MPEG and ITU have recently approved a new video-compression standard known as High Efficiency Video Coding (HEVC), or H.265, that is set to provide double the capacity of today's leading standards[1].

PER FRÖJDH, ANDREY NORKIN AND RICKARD SJÖBERG

http://www.ericsson.com/news/130424-next-generation-video-compression_244129228_c

55

56

AWARDS NEWS

September 27, 2017

69th Engineering Emmy Awards Recipients Announced

Kirsten Vangsness Slated to Host This Year's Awards Ceremony on October 25 at Loews Hollywood Hotel

The Television Academy today announced the recipients of the 69th Engineering Emmy Awards honoring an individual, company or organization for developments in broadcast technology. Kirsten Vangsness, star of the critically-acclaimed CBS drama *Criminal Minds*, will host the awards for the second consecutive year on Wednesday, October 25, at the Loews Hollywood Hotel.

https://www.emmys.com/news/awards-news/engineering-awards-170927

57

Recipient: **High Efficiency Video Coding**

The development of High Efficiency Video Coding (HEVC) has enabled efficient delivery in ultra-high-definition (UHD) content over multiple distribution channels. This new compression coding has been adopted, or selected for adoption, by all UHD television distribution channels, including terrestrial, satellite, cable, fiber and wireless, as well as all UHD viewing devices, including traditional televisions, tablets and mobile phones. The Emmy goes to the Joint Collaborative Team on Video Coding (JCT-VC), a group of engineers from the Video Coding Experts Group (VCEG) of the International Telecommunication Union (ITU) and the Moving Picture Experts Group (MPEG) of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) for the development of High Efficiency Video Coding.

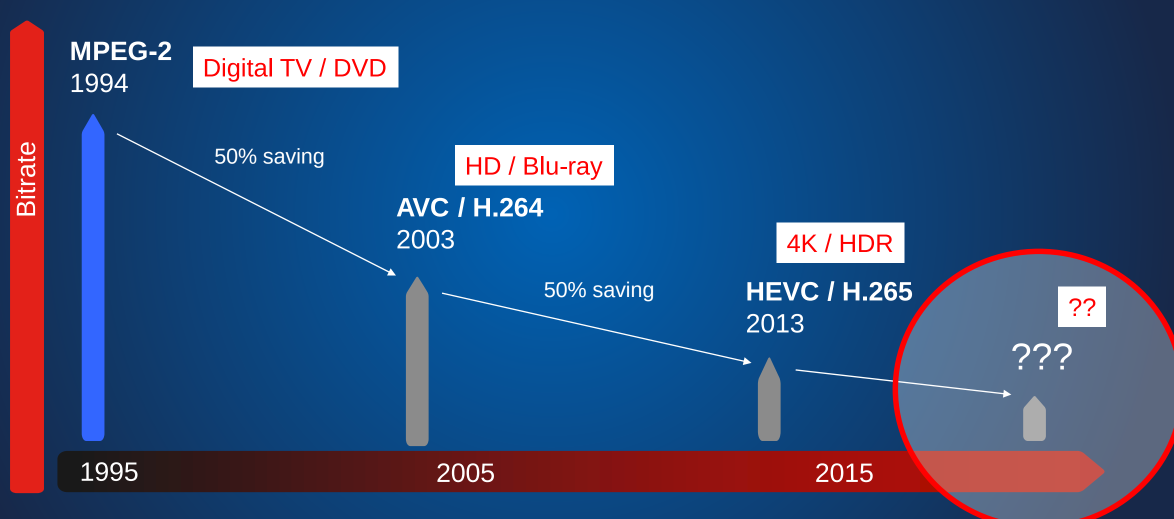
58

Emmy Award to HEVC, 25 Oct 2017

Gary Sullivan (Microsoft) and Per Fröjdh (Ericsson)

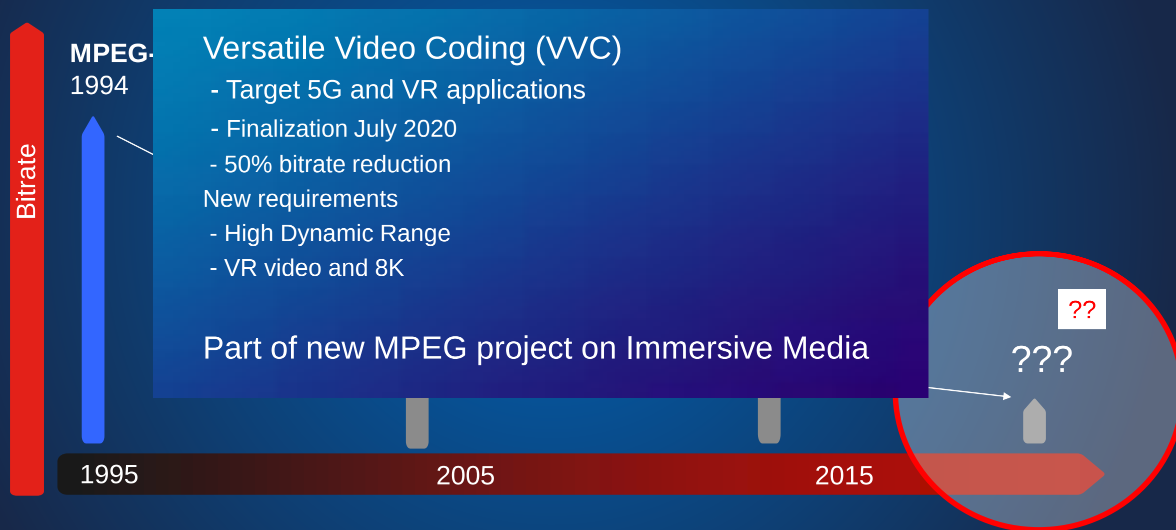
59

Video Coding Standardization



60

Video Coding Standardization



61

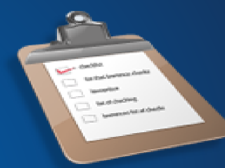
MPEG Standards on Immersive Media

Coded Representation of Immersive Media (ISO/IEC 23090)

1 Architectures for Immersive Media (Technical Report)
2 Omnidirectional MediA Format v2 [Jul 2020]
3 Versatile Video Coding [Jul 2020]
4 Immersive Audio [~ 2022]
5 Point Cloud Coding – Video [Apr 2020]
6 Immersive Media Metrics [Apr 2021]
7 Immersive Media Metadata [Apr 2021]
8 Network-Based Media Processing v2 [Jan 2021]
9 Point Cloud Coding – Geometry [Oct 2020]
10 Carriage of Point Cloud Data
… Explorations on Immersive Video for 3DoF+, 6DoF and Dense Light Fields

62

Outline



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  - UHD: 4K & High Dynamic Range
  - Virtual Reality
  - 5G Standardization

63

Motivation

3D

New paradigm – free viewpoint

Standardization

64

Exciting Applications

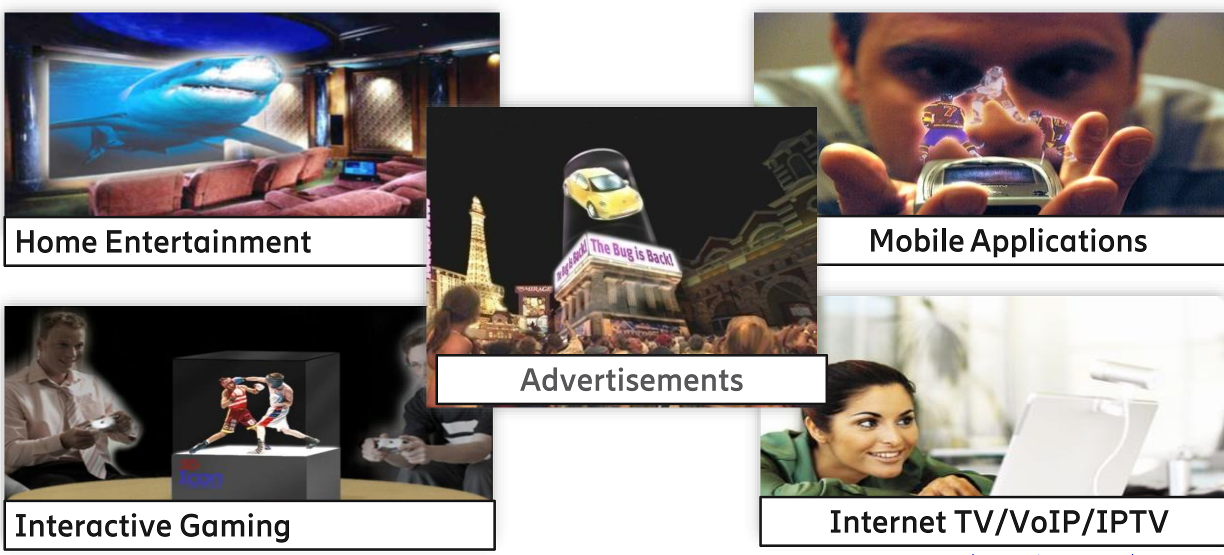
Three Dimensional TV

Which goal post side you want to seat ?

Free Viewpoint TV

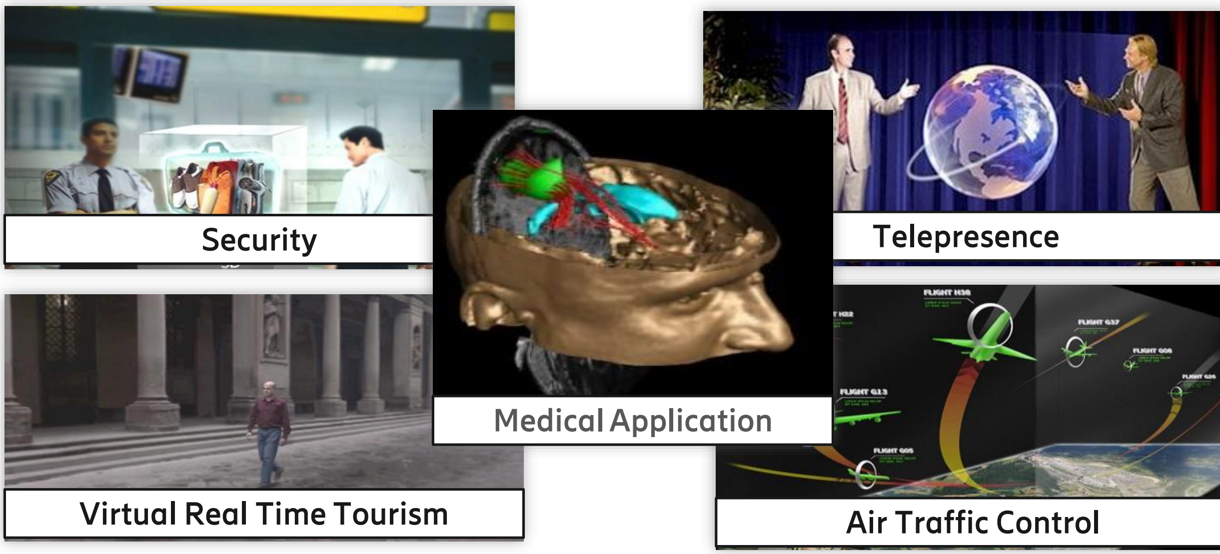
(KTH, Pravin Kumar Rana)

Exciting Applications



(KTH, Pravin Kumar Rana)

Exciting Applications



(KTH, Pravin Kumar Rana)

67

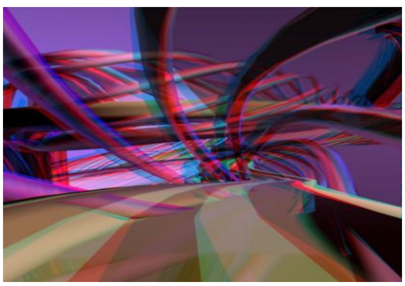
Historical Snapshots

68

Anaglyphic stereo (1853)

Projection through colour filters

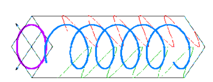
Left - Red
Right - Blue



Polarized stereo (1936)

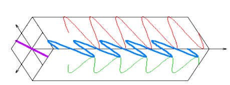
Projection through polarized filters

Circular



or

Linear



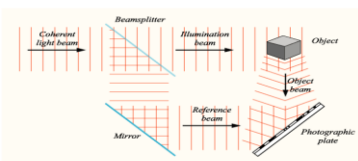
“3D movie craze” (1952-1955)

IMAX 3D

Holographic 3D (1947)

Coherent light
- Scattered (object)
- Recorded (film)

View film for
- Reconstructed image



Hologram Artwork at MIT Museum

71

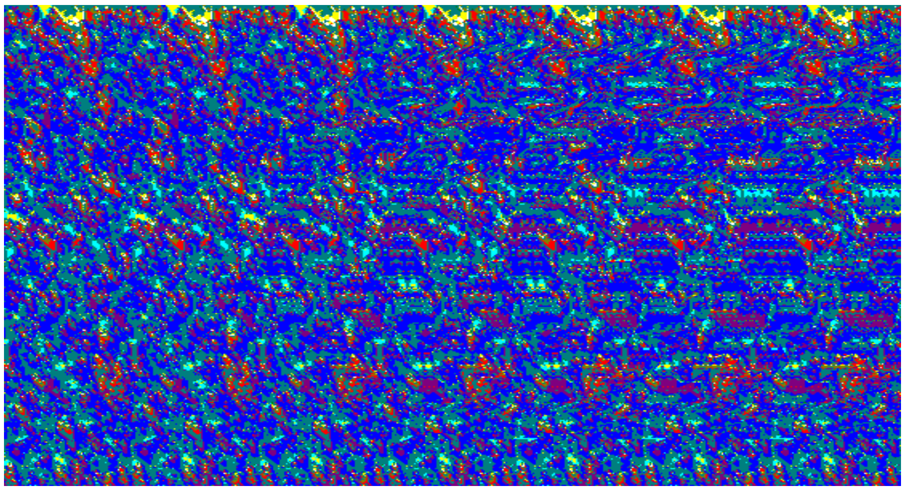
Holographic 3D

Star Wars hologram – R2D2 projects Princess Leia

Famous – but physically impossible

72

Autostereogram (~1979)



73

How do we achieve 3D?

74

What is 3D?

3D ≠ Left + Right ? !

Can be 1, 2 or even multiple views

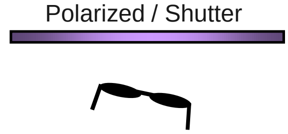
3D Displays and Techniques

1 view
(conventional display)

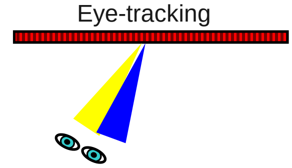
- eye/head tracking
- view selection
- utilize depth cues

2 views
(stereo)

Polarized / Shutter

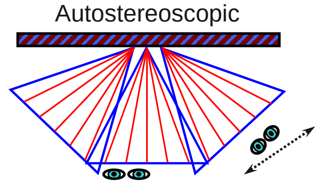


Eye-tracking



Multi-view

Autostereoscopic



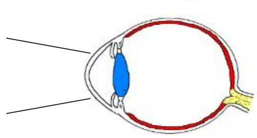
How does the brain perceive 3d?

77

Depth cues

Realistic 3D requires depth cues

Psychological



Physiological

78

Psychological depth cues

Occlusion

(Images from Roger Olsson, 2009)

79

Psychological depth cues

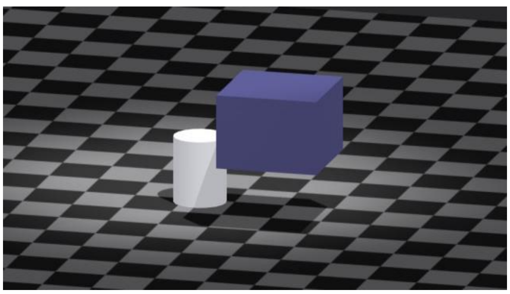
Light and Shadow

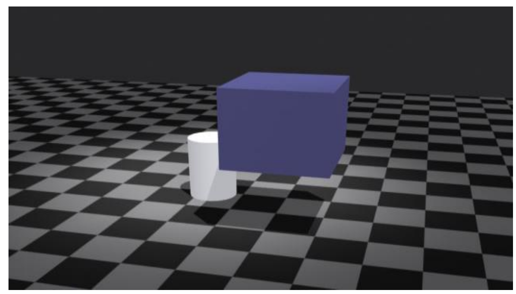
(Images from Roger Olsson, 2009)

80

Psychological depth cues

Linear perspective





(Images from Roger Olsson, 2009)

81

Psychological depth cues

Retinal size

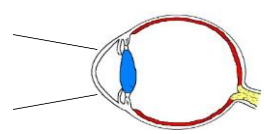
82

Psychological depth cues

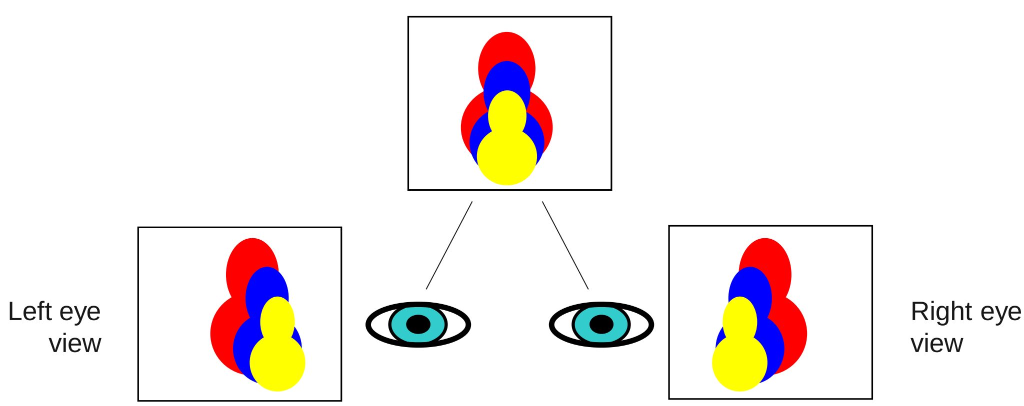
Texture gradient

83

Physiological depth cues

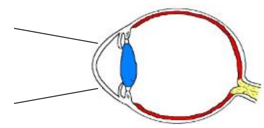


Binocular parallax (disparity)

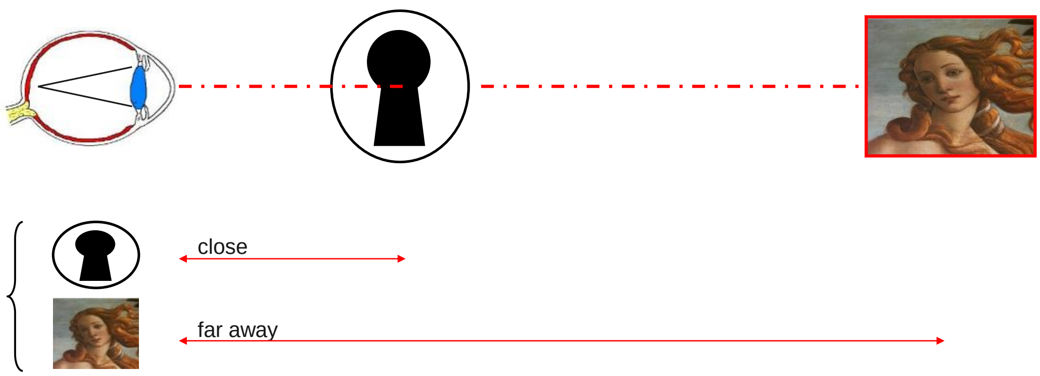


84

Physiological depth cues

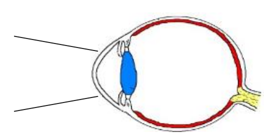


Accomodation (lens focus)

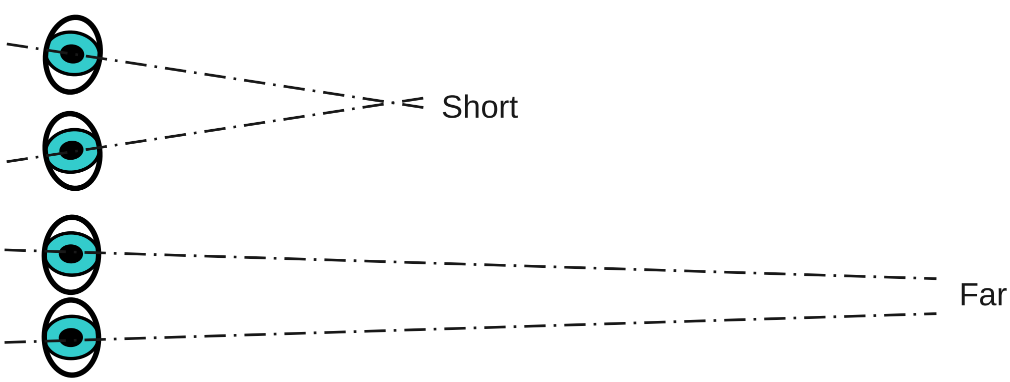


85

Physiological depth cues

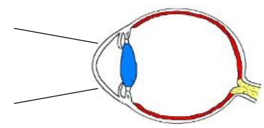


Convergence (rotation)



86

Physiological depth cues



Motion Parallax

(Photos by Henri Clément)

Observer
moves and changes view

moving direction

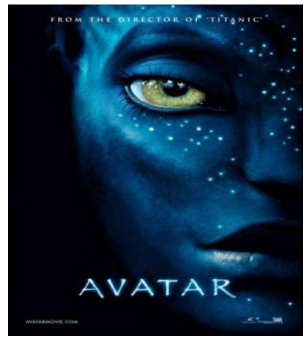
87

Where will we use 3D?

88

3D Cinema

3D versions of movies
3D cinema in every city



Stereo – everyone gets the same picture

89

3D Conferencing

Virtual Meetings

Immersion/
Telepresence

3D audio & video

CO_2 friendly

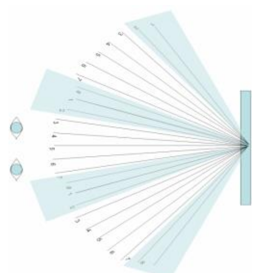
Challenge: avoid glasses

CISCO 3D collaboration trial system

90

Home 3D

Stereo



Multiview

Or conventional TV with
Free-view control

91

Virtual Reality

Playstation VR

HTC Vive

Google Cardboard

92

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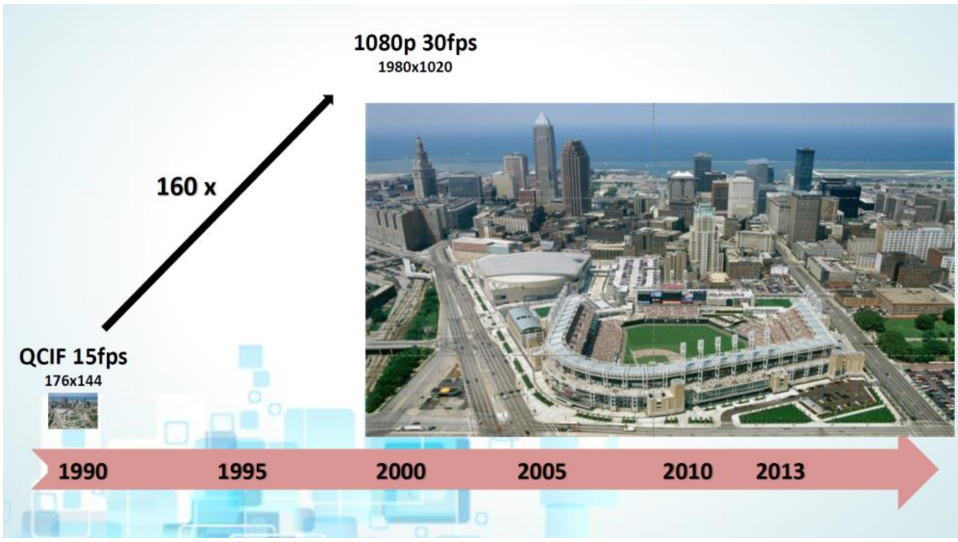
93

UHDTV – 4K Television

- Several dimensions
  - Picture Resolution — 3840 x 2160
  - Color Space — BT.709 or BT.2020
  - Frame Rate — 50/60 or 100/120
  - Bit Depth — 10
  - High Dynamic Range — peak luminance 1000-10000 nits

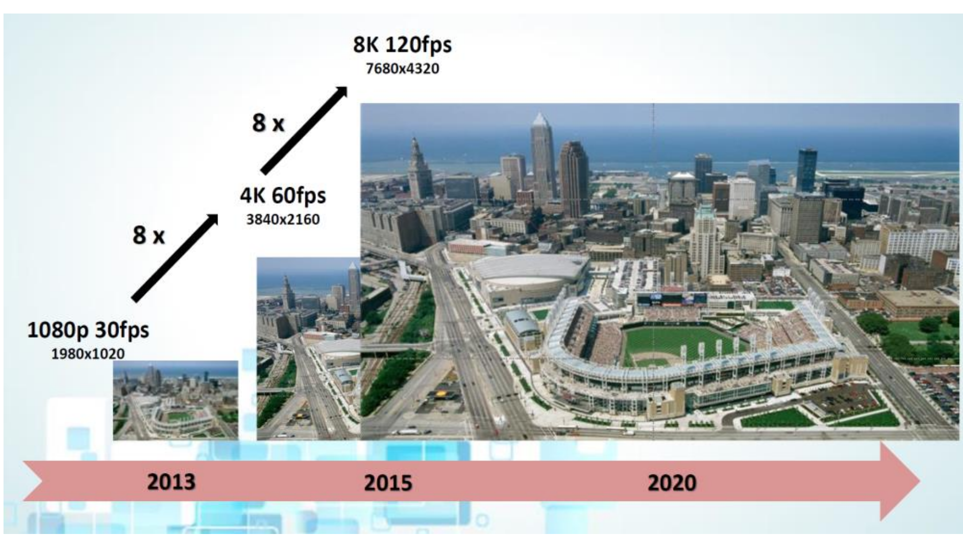
94

Resolution 1990-2013 (160x)



95

Resolution 2013-2020 (64x)



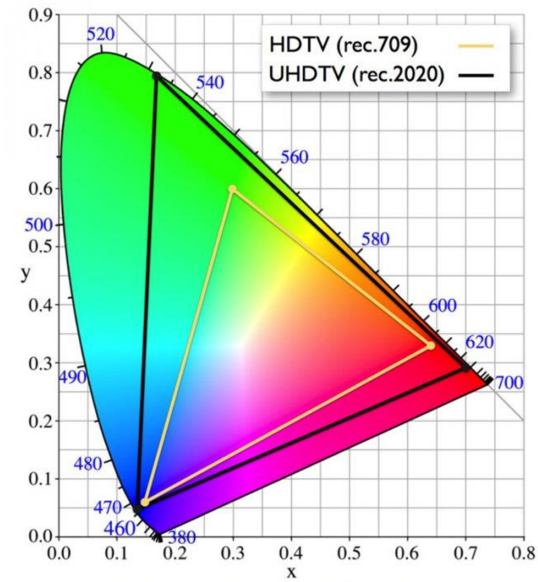
96

Color Space

— All colors visible to the average human eye are contained insidie the diagram

— HDTV subset, smallar than

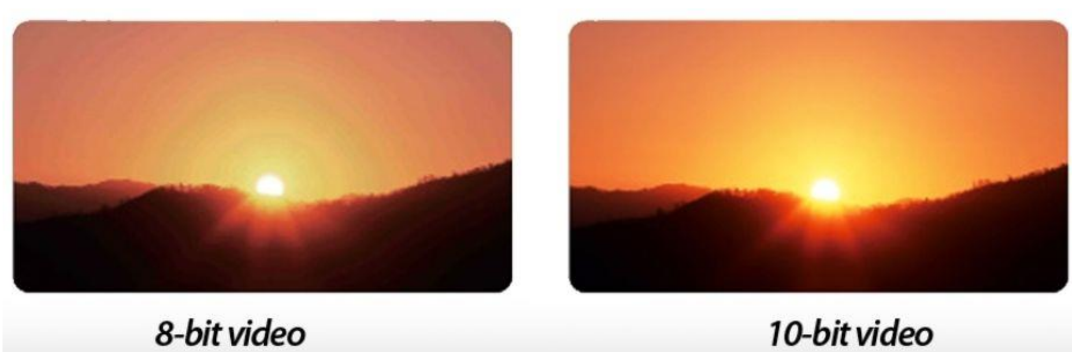
— UHDTV subset



UHDTV vs HDTV Color Gamuts

Higher Bit Depth

— Avoid banding by increasing the bit depth



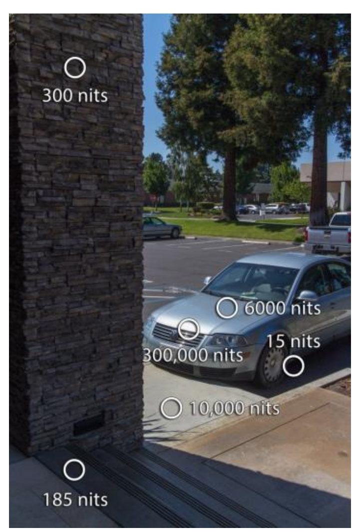
High Frame Rate (HFR)

- The benefit with higher resolution is sharper pictures
- We also want sharpness during motion scenes
  - E.g. football where the sharpness of the grass depend on camera pan speed
- Shorter shutter time solves this
  - Needs to be shorter, the higher the resolution
  - A shutter open during the pan of 2 pixels in HD is open during 4 pixels in 4K

99

High Dynamic Range - Nits

- NIT
  - Candela per square meter (cd/m2)
- Some NIT values:
  - Cinema – 55 nits
  - Old or budget Laptops – 200-300 nits
  - Budget LCD TV – 350 nits
  - HDTV – 400-1000 nits
  - 100-watt lightbulb – 18,000 nits
  - Dolby Pulsar display 4,000 nits
    - Liquid cooling



100

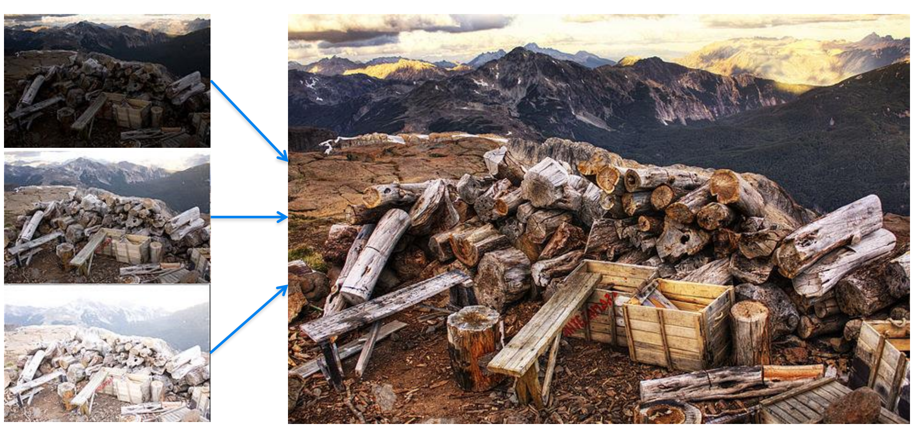
Standard Dynamic Range

Current capture/display technology loses detail

No choice of exposure captures contrast at all luminances.

High Dynamic Range

Wide simultaneous range of nits



HEVC for 4K & HDR

4K x 2K

HEVC designed for 4K!

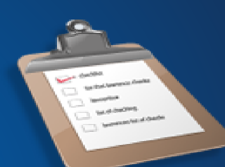
HDR

2 year HDR exploration → HEVC is state of the art!

Blu-ray Disc	MPEG	Ultra HD Forum	DVB	ATSC
HDR10	HDR10	HDR10 & HLG10	HDR10 & HLG10	HDR10 & HLG10…

103

Outline



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104

VR is here

Hardware

Content

Standardization

105

Google Cardboard

— Cost 99 SEK
— + smartphone

— YouTube 360
— Easy to make content

106

Virtual vs Augmented Reality

- **Virtual Reality (VR)**
  - synthesis of a digital environment
    - natural video (e.g. cinematic)
    - graphics (e.g. gaming)
  - filling the visual field
  - immersive experience

- **Augmented Reality (AR)**
  - visual digital overlay to reality

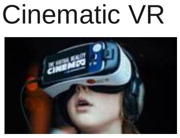
Google GLASS

Pokémon GO

107

Some Use Cases

Cinematic VR



Gaming

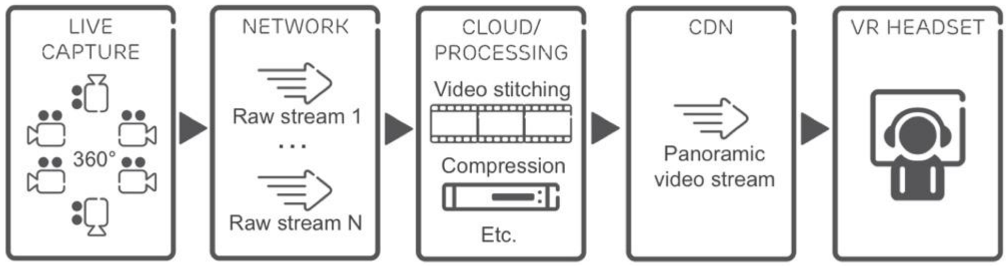
Remote control (E///)

Military training

108

Work Flow & Standardization

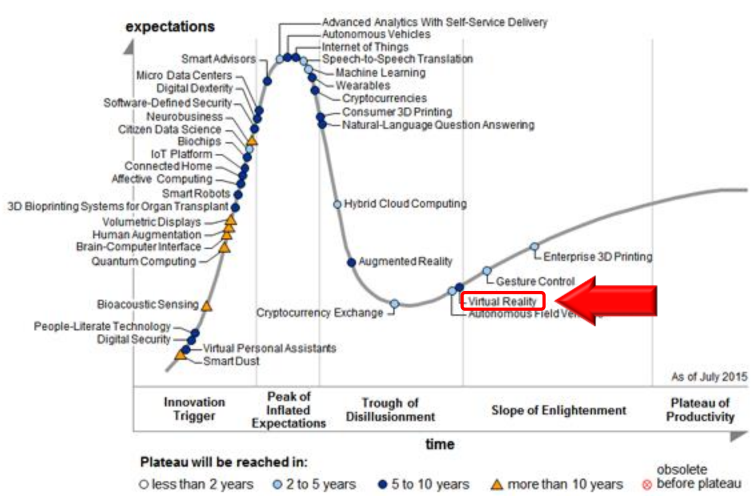
Cinematics work flow



Potential SDOs

109

The VR hype



110

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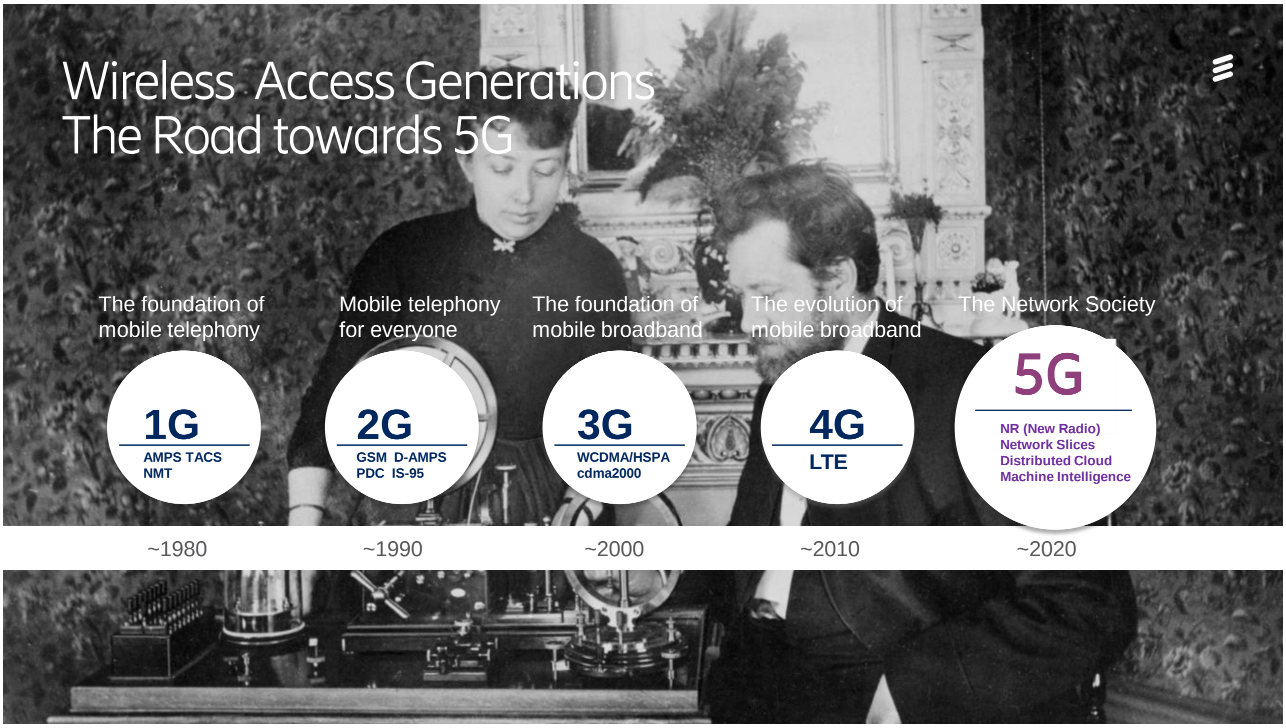
111

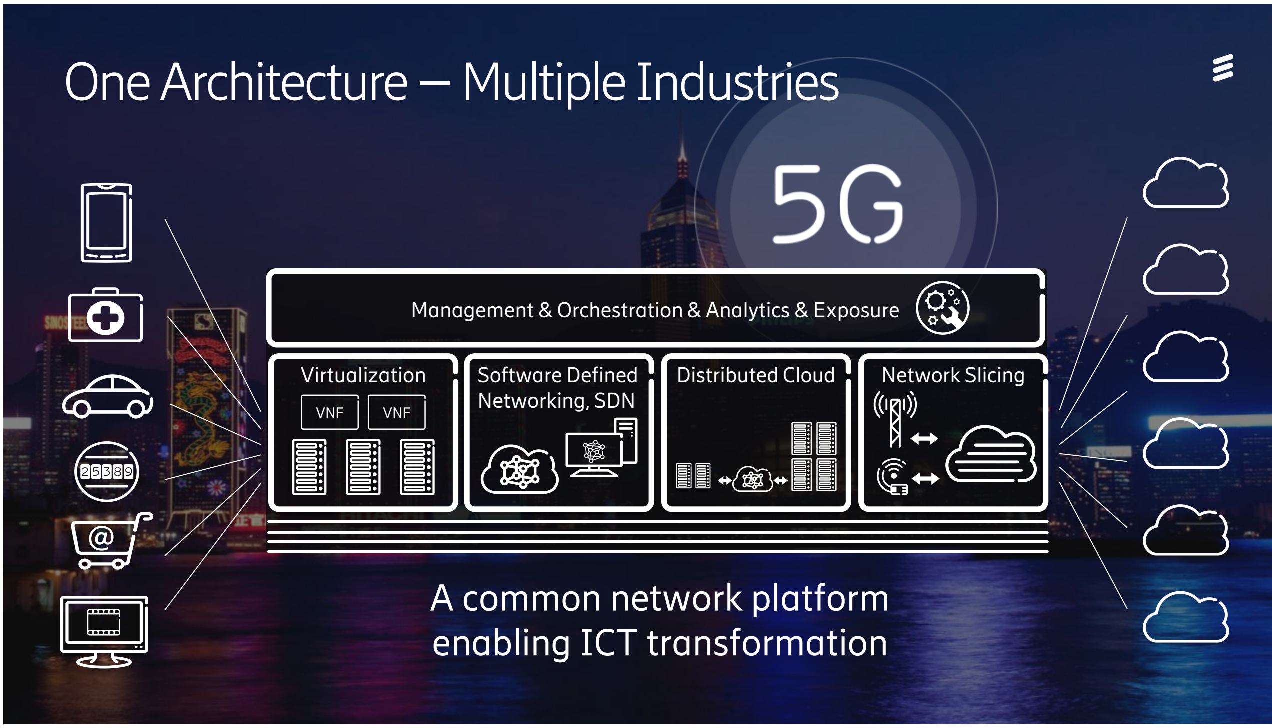
112


Wireless Access Generations
The Road towards 5G
The foundation of mobile telephony
1G
AMPS TACS
NMT
~1980
Mobile telephony for everyone
2G
GSM D-AMPS
PDC IS-95
~1990
The foundation of mobile broadband
3G
WCDMA/HSPA
cdma2000
~2000
The evolution of mobile broadband
4G
LTE
~2010
The Network Society
5G
NR (New Radio)
Network Slices
Distributed Cloud
Machine Intelligence
~2020

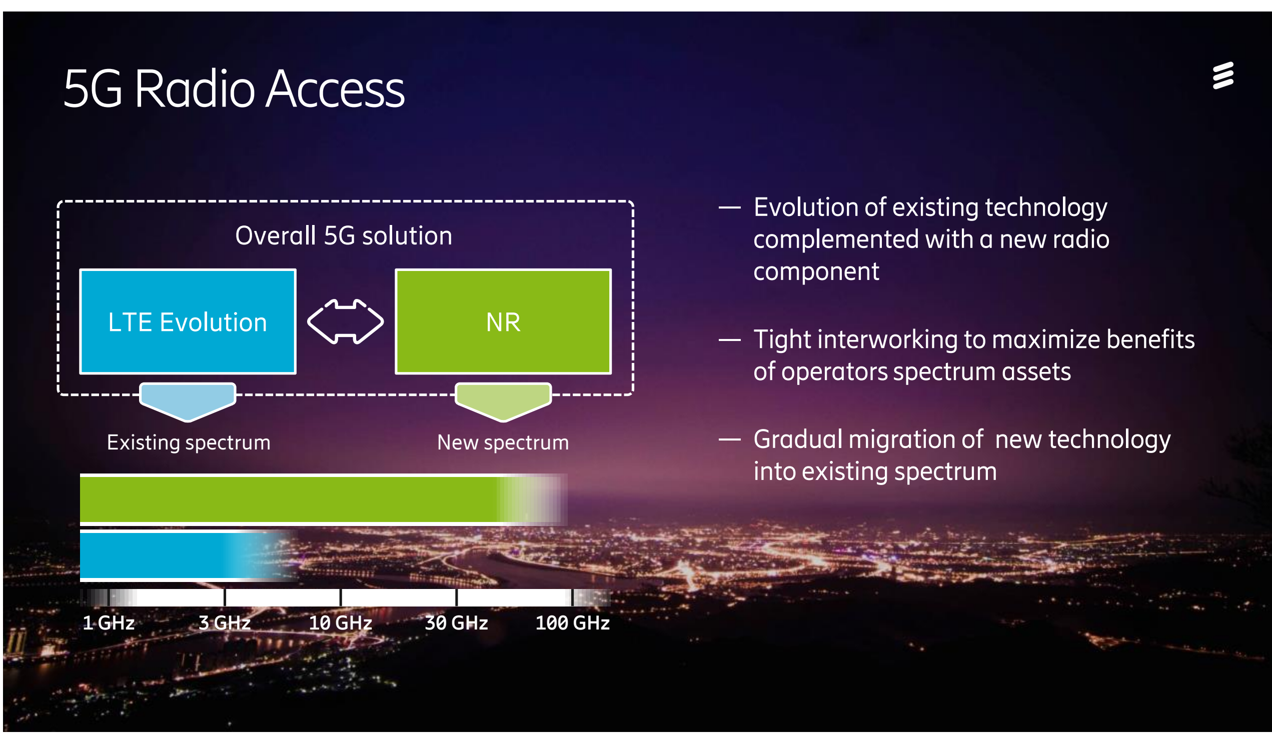
113


5G is developed from use cases
Industry and society transformations
Increased data traffic and performance
Massive machine type communication
IoT
Critical machine type communication
Enhanced mobile broadband
Fixed wireless access

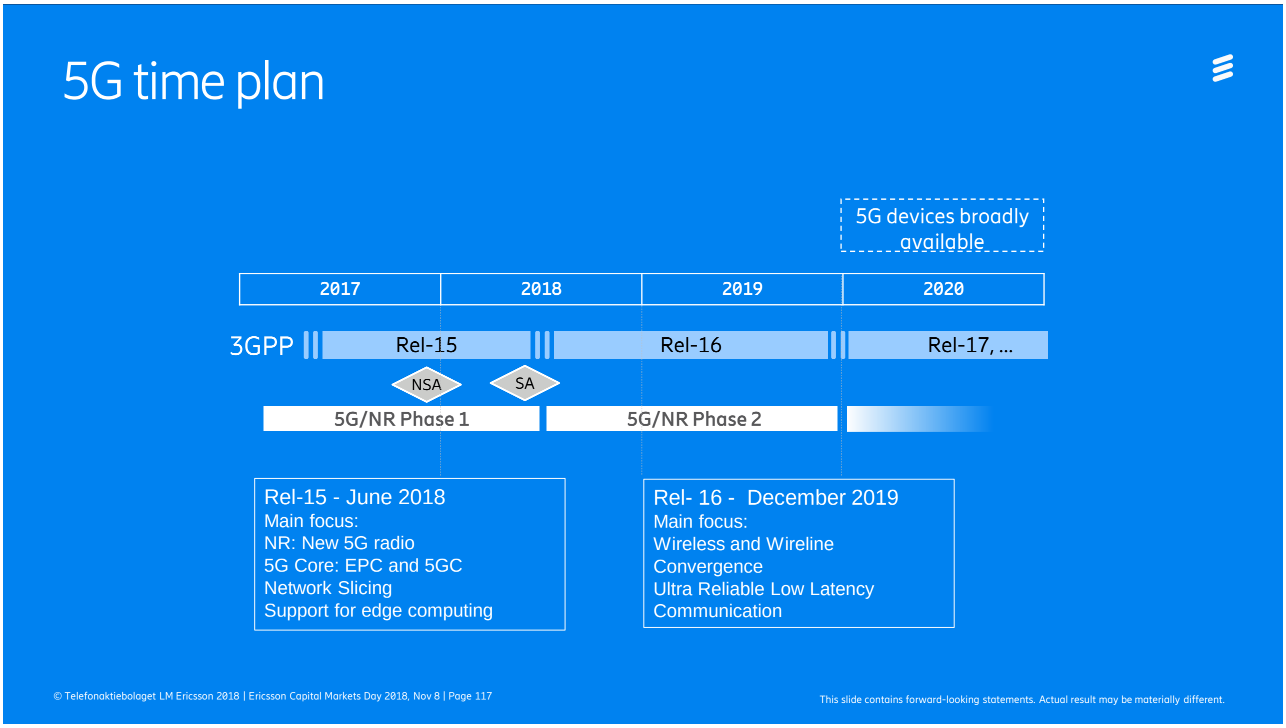
114


One Architecture – Multiple Industries
5G
Management & Orchestration & Analytics & Exposure
Virtualization
VNF
VNF
Software Defined Networking, SDN
Distributed Cloud
Network Slicing
25389
A common network platform enabling ICT transformation

115


5G Radio Access
Overall 5G solution
LTE Evolution
NR
Existing spectrum
New spectrum
1 GHz
3 GHz
10 GHz
30 GHz
100 GHz
— Evolution of existing technology complemented with a new radio component
— Tight interworking to maximize benefits of operators spectrum assets
— Gradual migration of new technology into existing spectrum

116


5G time plan
5G devices broadly available
2017
2018
2019
2020
3GPP
Rel-15
Rel-16
Rel-17, ...
NSA
SA
5G/NR Phase 1
5G/NR Phase 2
Rel-15 - June 2018
Main focus:
NR: New 5G radio
5G Core: EPC and 5GC
Network Slicing
Support for edge computing
Rel- 16 - December 2019
Main focus:
Wireless and Wireline
Convergence
Ultra Reliable Low Latency
Communication
© Telefonaktiebolaget LM Ericsson 2018 | Ericsson Capital Markets Day 2018, Nov 8 | Page 117
This slide contains forward-looking statements. Actual result may be materially different.

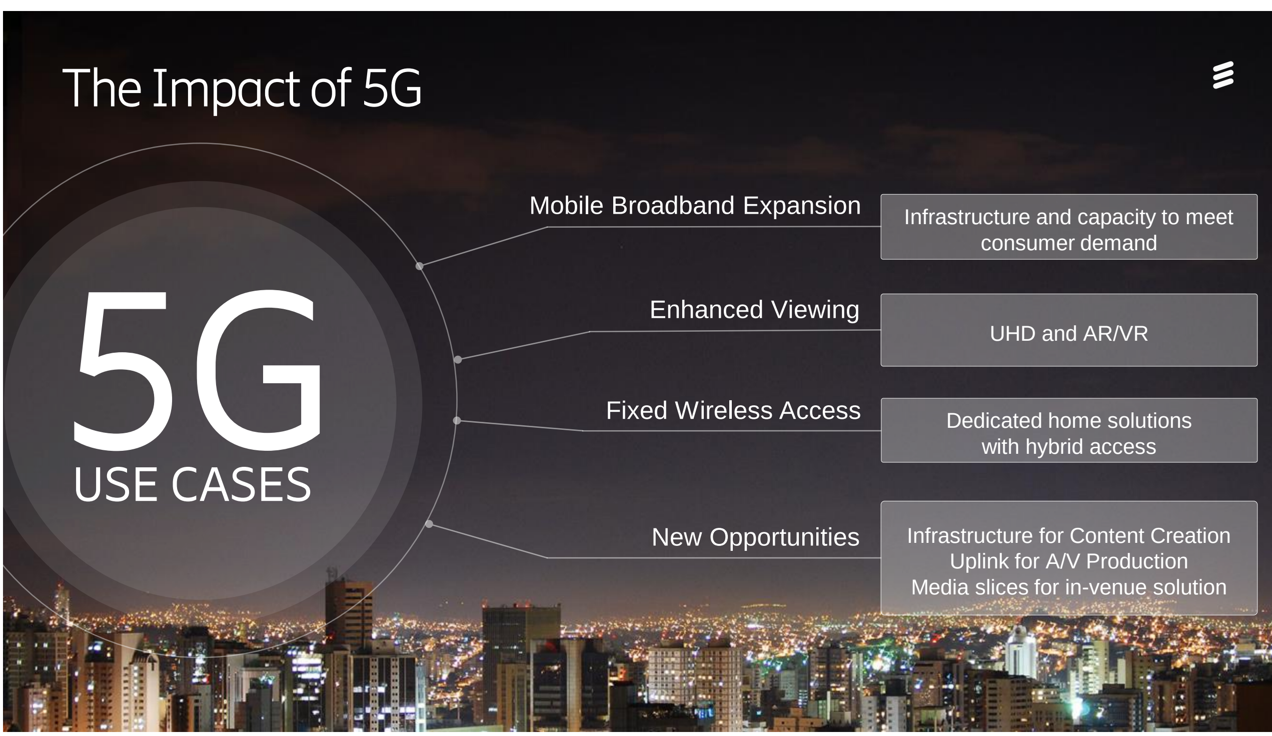
117


5G
USE CASES
Media in 5G
5G drives Media
Media drives 5G

118


Re-defining the media landscape
5G
USE CASES
1000X
Mobile Data Volumes
5X
Lower Latency
10-100X
Connected Devices
10-100X
End-user Data Rates
>10yr
Battery Life

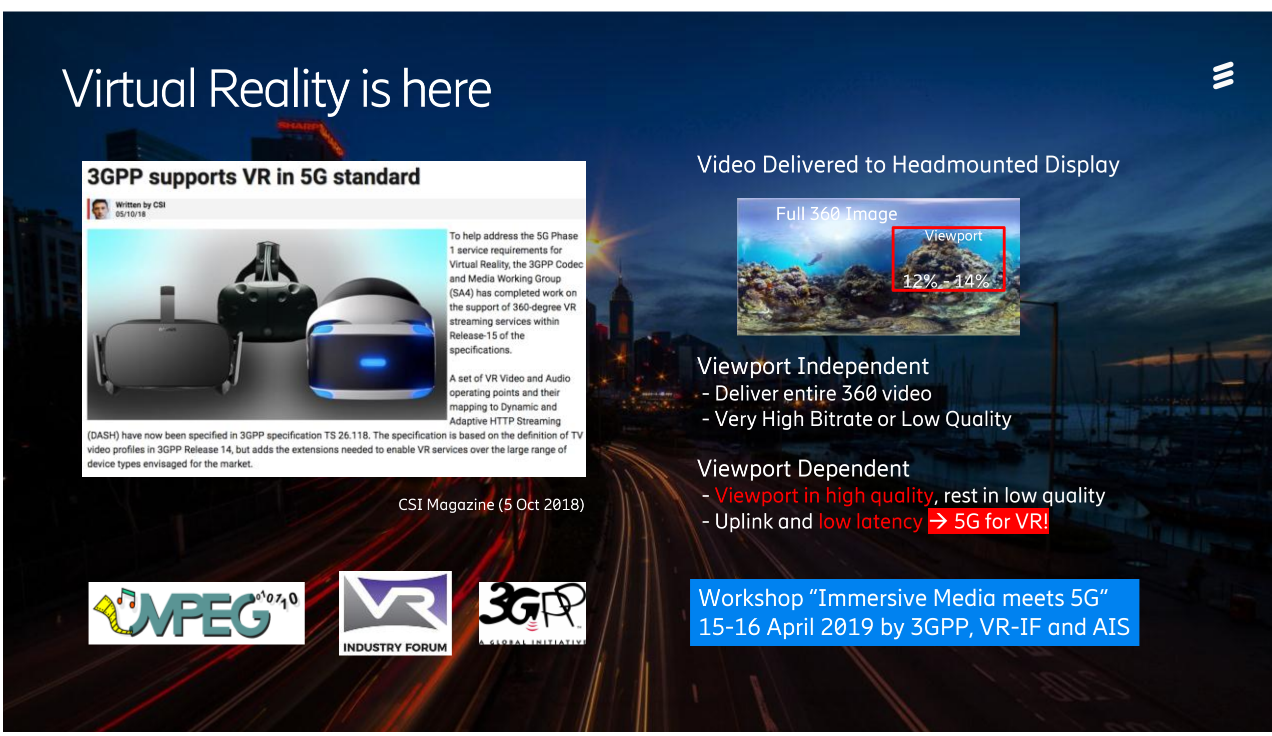
119


The Impact of 5G
5G
USE CASES
Mobile Broadband Expansion
Infrastructure and capacity to meet consumer demand
Enhanced Viewing
UHD and AR/VR
Fixed Wireless Access
Dedicated home solutions with hybrid access
New Opportunities
Infrastructure for Content Creation
Uplink for A/V Production
Media slices for in-venue solution

120


5G Key Aspects for Media
5G
USE CASES
Fixed Wireless Access
Hybrid
VR/AR/Latency
Network Slicing
In venue content

121


Virtual Reality is here
3GPP supports VR in 5G standard
Written by CSI
05/10/18
To help address the 5G Phase 1 service requirements for Virtual Reality, the 3GPP Codec and Media Working Group (SA4) has completed work on the support of 360-degree VR streaming services within Release-15 of the specifications.
A set of VR Video and Audio operating points and their mapping to Dynamic and Adaptive HTTP Streaming (DASH) have now been specified in 3GPP specification TS 26.118. The specification is based on the definition of TV video profiles in 3GPP Release 14, but adds the extensions needed to enable VR services over the large range of device types envisaged for the market.
CSI Magazine (5 Oct 2018)
Video Delivered to Headmounted Display
Full 360 Image
Viewport
12% - 14%
Viewport Independent
- Deliver entire 360 video
- Very High Bitrate or Low Quality
Viewport Dependent
- Viewport in high quality, rest in low quality
- Uplink and low latency → 5G for VR!
Workshop "Immersive Media meets 5G"
15-16 April 2019 by 3GPP, VR-IF and AIS
MPEG
VR INDUSTRY FORUM
3GPP

122

Augmented Reality

Industry application

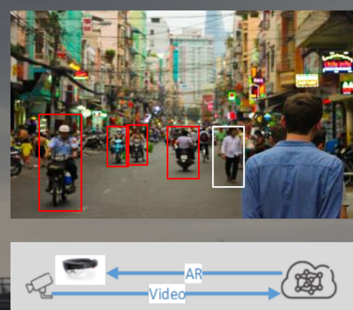


Image analysis (cloud processing)

- Truly mobile (Wireless)
- Device battery → Cloud
- Low latency
- High bitrate

→ 5G for AR!

123

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Thank you!

per.frojdh@ericsson.com

124

125