History of Multimedia

1. **Newspaper**: perhaps the *first* mass communication medium, uses text, graphics, and images.
2. **Motion pictures**: conceived of in the 1830's in order to observe motion too rapid for perception by the human eye.
3. **Wireless radio transmission**: Gugliemo Marconi, at Pontecchio, Italy, in 1895.
4. **Television**: the new medium for the 20th century, established video as a commonly available medium and has since changed the world of mass communications.
5. The **connection** between **computers** and ideas about **multimedia** covers what is actually only a short period: 1945 -- Vannevar Bush wrote a landmark article describing what amounts to a hypermedia system called **Memex**.

History of Multimedia cont'd

1960 Ted Nelson coined the term **hypertext**.

1967 Nicholas Negroponte formed the **Architecture Machine Group**.

1968 Douglas Engelbart demonstrated the **On-Line System** (**NLS**), another very early hypertext program.

1969 Nelson and van Dam at Brown University created an early hypertext editor called **FRESS**.

1976 The MIT Architecture Machine Group proposed a project entitled **Multiple Media** | resulted in the *Aspen Movie Map*, the first hypermedia videodisk, in 1978.

1985 Negroponte and Wiesner co-founded the **MIT Media Lab**.

1989 Tim Berners-Lee proposed the **World Wide Web**

1990 Kristina Hooper Woolsey headed the **Apple Multimedia Lab**.

1991 **MPEG-1** was approved as an international standard for digital video | led to the newer standards, **MPEG-2**, **MPEG-4**, and further **MPEGs** in the 1990s.

1991 The introduction of **PDAs** in 1991 began a new period in the use of computers in multimedia.

1992 **JPEG** was accepted as the international standard for digital image compression | led to the new JPEG2000 standard.

History of Multimedia cont'd

1992 The first **MBone** audio multicast on the Net was made.

1993 The University of Illinois National Center for Supercomputing Applications produced **NCSA Mosaic** -the first full fledged browser.

1994 Jim Clark and Marc Andreessen created the **Netscape**

1995 The **JAVA** language was created for platform-independent application development.

1996 **DVD video** was introduced; high quality full-length movies were distributed on a single disk.

1998 **XML** 1.0 was announced as a W3C Recommendation.

1998 **Hand-held MP3 devices** first made inroads into consumerist tastes in the fall of 1998, with the introduction of devices holding 32MB of flash memory.

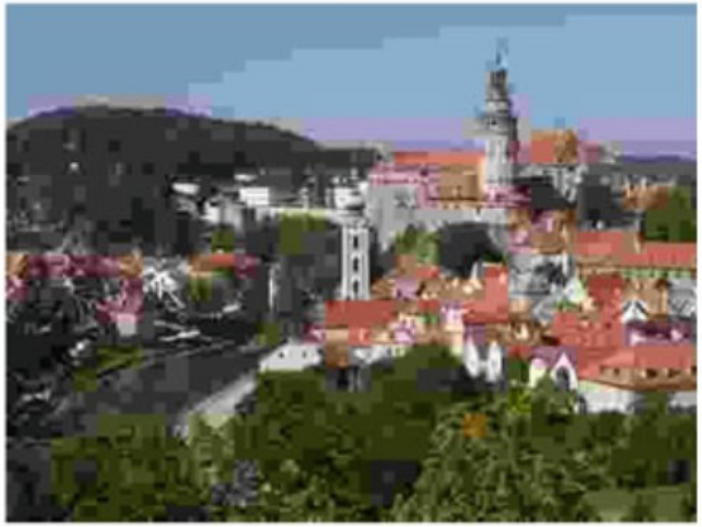
2000 WWW size was estimated at over **1 billion pages**.

Multimedia Compression - JPEG

(a)

(b)

(c)



(d)

Multimedia Compression - JPEG

Quality factor (qf)	Compressed file size	Percentage of original (%)
–	529,620	100
75	37,667	7.11
25	16,560	3.13
5	5,960	1.13

- Tradeoff between compression and quality
- How do we choose?
- Some factors to considered:
  - Bandwidth
  - Storage
  - Intended use (E.g., medical use?)
  - Image content (E.g., a lot of details?)
  - User expectations
  - Any other factors you can think of?

In the New Millennium

- Year 2000-, your time …
- Image/Audio
  - Huge/cheap HDD/SSD
  - High bandwidth/unlimited data plan
    - 3G/4G/5G
    - ADSL, Fiber
  - Cloud/data center
  - No worry anymore ?
    - 4K-8K UHD (ultar-high definition)
      - 48-200 Gbps uncompressed
    - VR/AR
      - 16K video
      - Near zero delay

In the New Millennium

- **2001** The first peer-to-peer file sharing system, Napster, was shut down by court order. First commercial 3G wireless network.
- **2003** Skype: free peer-to-peer voice over the Internet.
- **2004** Web 2.0 promotes user collaboration and interaction. Examples include social networking, blogs, wikis.

  Facebook founded.

  Flickr founded .
- **2005** YouTube created.

  Google launched online maps
- **2006** Twitter created: 500 million users in 2012, 340 million tweets/day.

  Amazon launched its cloud computing platform.

  Nintendo introduced the Wii home video game console -- can detect movement in three dimensions.
- **2007** Apple launched iPhone, running the iOS mobile operating system. .

  Goolge launched Android mobile operating system.

In the New Millennium

- **2009** The first LTE (Long Term Evolution) network was set, an important step toward 4G wireless networking.

  James Cameron's film, Avatar, a surge on the interest in 3D video.

- **2010** Netflix migrated its infrastructure to the Amazon's cloud computing platform.

  Microsoft introduced Kinect, a horizontal bar with full-body 3D motion capture, facial recognition and voice recognition capabilities, for its game console Xbox 360.

- **2012** HTML5 subsumes the previous version, HTML4. Able to run on low powered devices such as smartphones and tablets.

- **2013** Twitter offered Vine, a mobile app that enables its users to create and post short video clips.

  Sony released its PlayStation 4 a video game console, which is to be integrated with Gaikai, a cloud-based gaming service.

  4K resolution TV started to be available in the consumer market.

In the New Millennium

- **2015** YouTube launched support for publishing and viewing 360-degree videos.

  AlphaGo, a computer program that plays the board game Go, became the first program to beat a human professional player. The event attracted significant attention from the general public, particular on its core technology, deep learning, which, in the coming years, has seen success in multimedia content understanding and generation.

- **2016** HoloLens, a pair of mixed reality smartglasses developed and manufactured by Microsoft, started to be available in the market.

  Pokémon Go, an augmented reality (AR) mobile game, was released and credited with popularizing location-based and AR technologies.

  Netflix completely migrated to the Amazon AWS cloud platform, so for Skype to move to the Microsoft Azure platform.

In the New Millennium

- **2017** TikTok, a video-sharing social networking service for creating and sharing short lip-sync, comedy, and talent videos, was launched for the global market (it's Chinese version, Douyin, was launched in 2016).

- **2018** World's first 16K Ultra High Definition (UHD) short video film, Prairie Wind, was created.

- **2019** 5G cellular systems started deployment, providing enhanced mobile broadband and ultra low latency access.

  WiFi 6 (802.11ax) standard was released, offering theoretical maximum throughput of 1 Gbps.

- 2020 Due to the outbreak of coronavirus (COVID-19) around the world, work/study from home became a norm in early 2020.

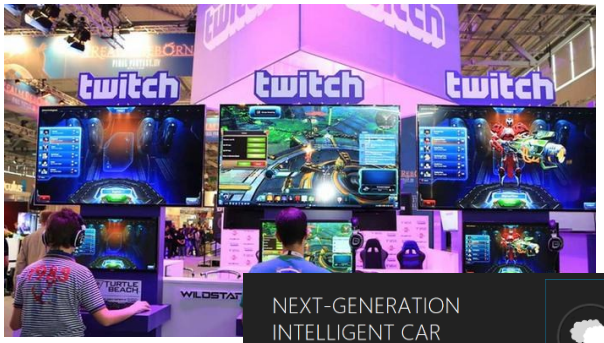
- Multimedia-empowered online meeting and teaching tools, e.g., Zoom, Google Class, and Microsoft Teams, have seen booming use during this period.

Past Decade

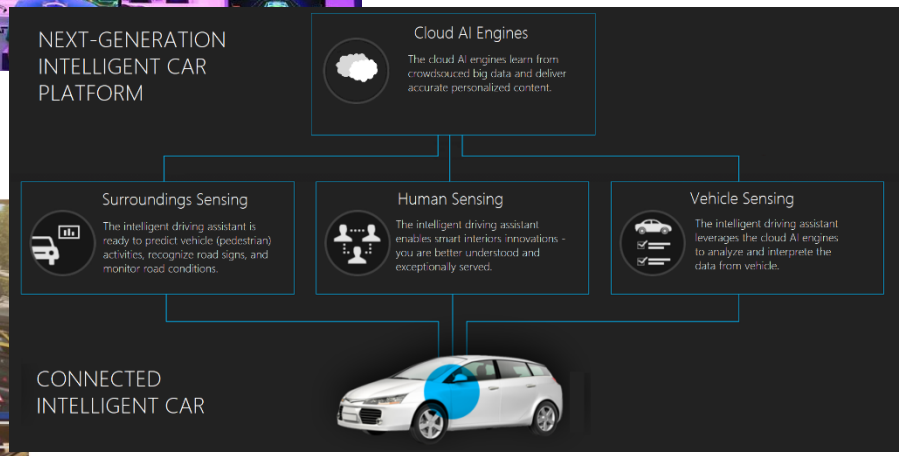
- **Skype/YouTube/Netflix**
  - Replacing phone, movie theatre, TV !

- **AR/VR immersive media**
  - Pokemon Go !, MS Hololens …

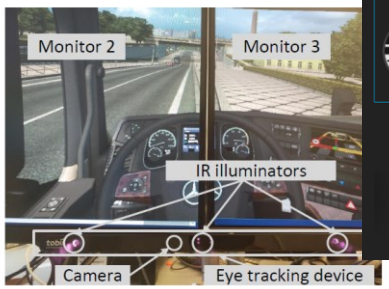
- **Cloud gaming**
  - Onlive, Gaikai, Sony …



- **Livecast**
  - Twitch.tv …
  - eSports broadcast …

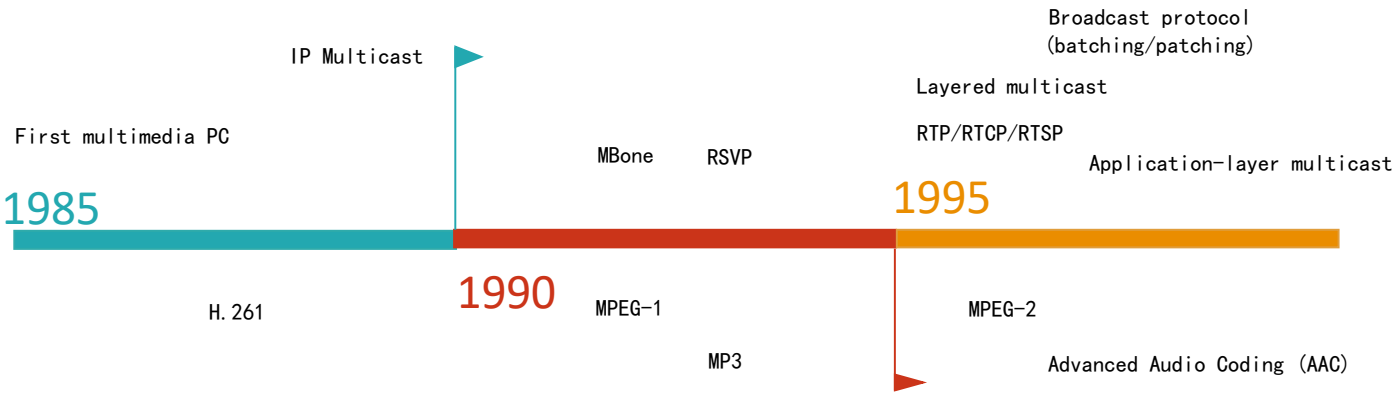


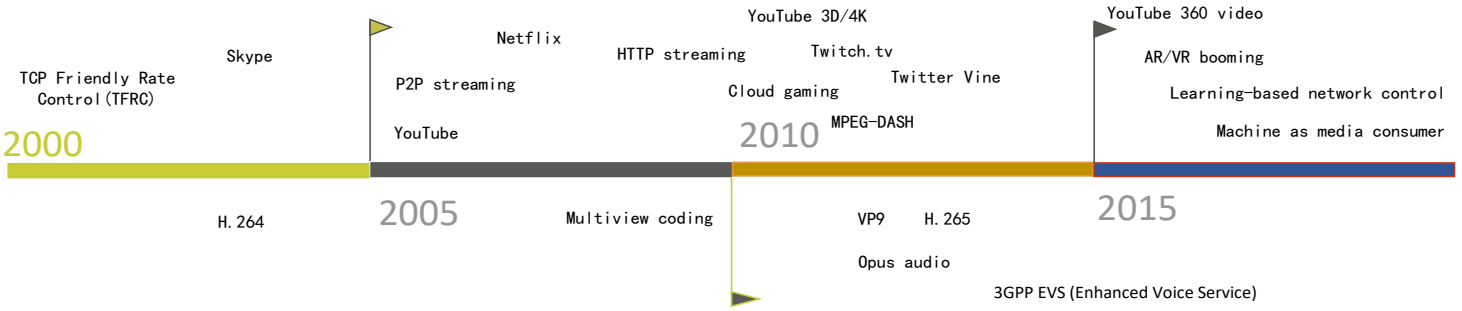
- **Drone/car**



- **Deep learning**

Digital Media Timeline

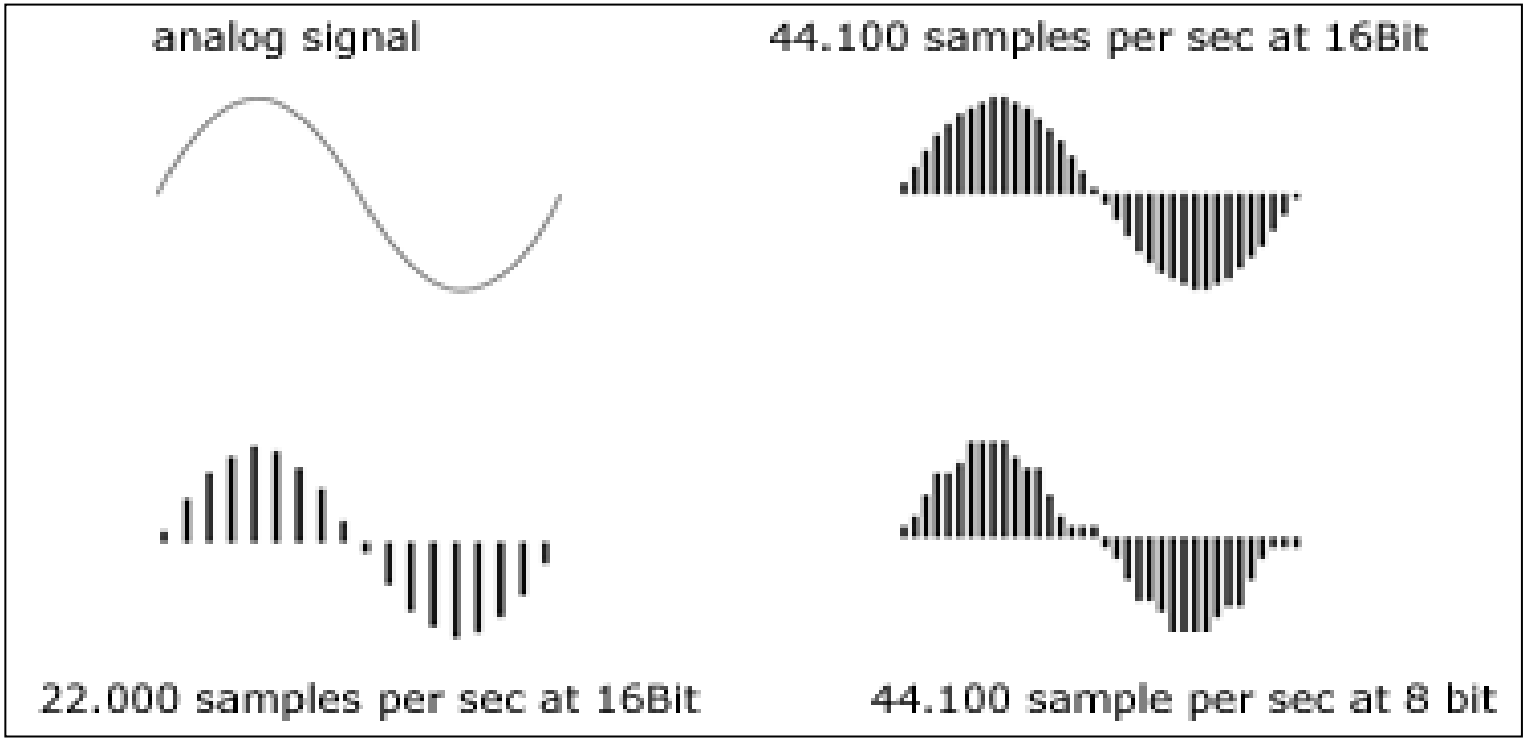




Outline

- Course information
- What is multimedia? A brief introduction
  - Concepts
  - Representation
  - Compression
  - Communication
- Popular multimedia tools
- Summary

Audio Digitization (PCM)



Representation ? ➔ Digitization for computers

Digital Media

- What do you mean by **digitized** ?
  - Audio/visual signals from the natural world is Analog
    - Continuous in time and space
    - Conventional storage/playback: LP (audio record), tape, CRT TV (old TV), film
    - Can't be handled by computer
  - A/D conversion
    - to 1/0 discrete signals

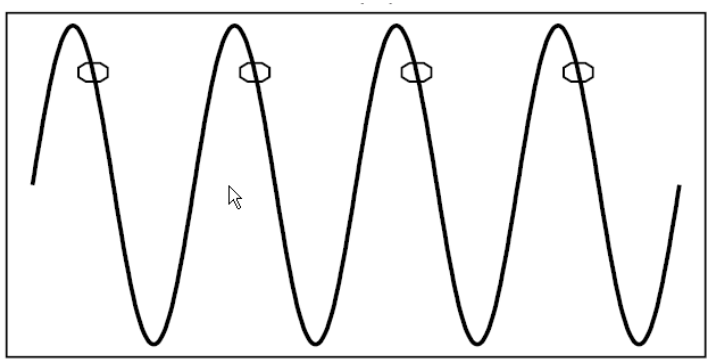
- Why **digitized** ?
  - Bulky storage (space, cost, lifetime)
  - Poor quality
  - Poor/no compression
  - Poor portability/mobility/editibility

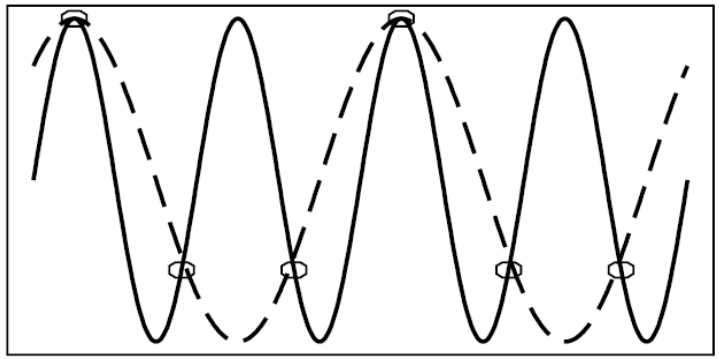
    MP3 player, iPod, YouTube ? No way

    Film -> Polaroid -> Digital camera

Sampling Rate

- Sampling theory – Nyquist theorem

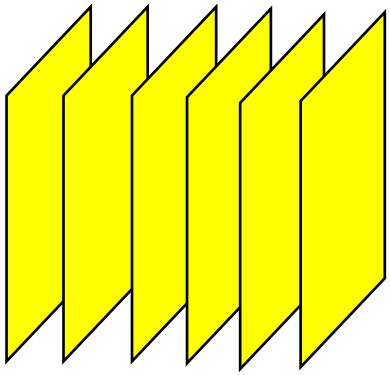




Image/Video Digitization

- Digital image is a 2-D array of pixels
- Each pixel represented by bits
  - R:G:B

  - Y:U:V
    - Y = 0.299R + 0.587G + 0.114B (Luminance or Brightness)
      U = B - Y (Chrominance 1, color difference)
      V = R - Y (Chrominance 2, color difference)
- Video is sequence of images (frames) displayed at constant frame rate
  - e.g. 24 images/sec



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Why Compression ?

- Multimedia data are too big
  - "A picture is worth a thousand words ! "

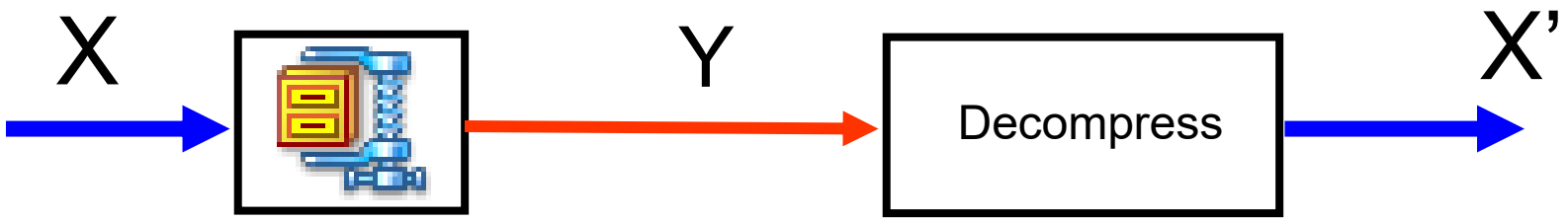
File Sizes for a One-minute Audio CD Clip

Sampling Rate	Resolution	Channels	Bit-rate (bps)	File Size (Bytes)
44,100Hz	16 bits	2	1,411,200	**10,584,000**

File Sizes for a One-minute QCIF Video Clip

Frame Rate	Frame Size	Bits / pixel	Bit-rate (bps)	File Size (Bytes)
30 frames/sec	176 x 144 pixels	12	9,123,840	**68,428,800**

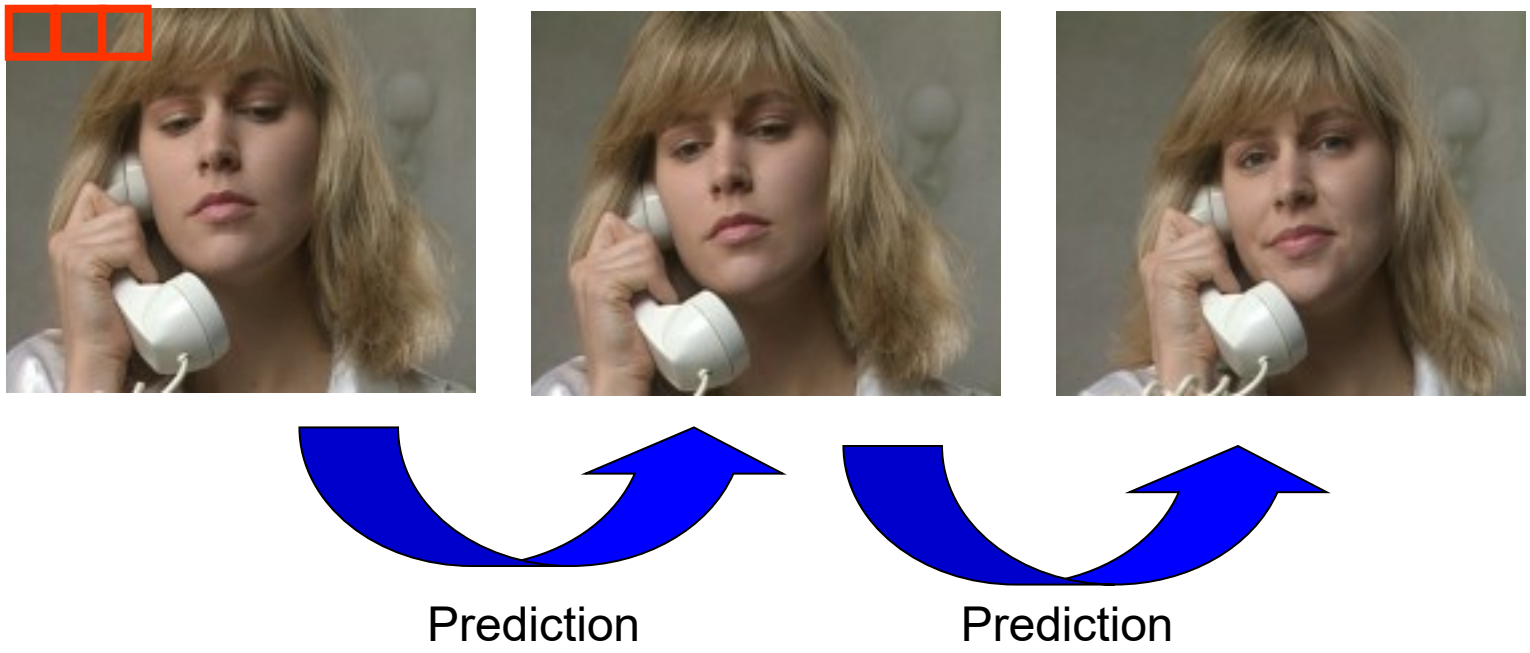
Data Compression



- Lossless Compression: X'=X
  - Example: Computer file compression
  - Low compression ratio
- Lossy Compression: X' ≠ X
  - Many applications do not require lossless compression
  - Our eyes and ears cannot identify some details
  - High compression ratio

Essential of Compression

- Remove redundant information:
  - Spatial redundancy:
    - Neighboring samples have similar values
  - Temporal redundancy:
    - Neighboring frames in a video sequence are similar



A Typical Image Compression System

Transform

Quantization

Entropy coding

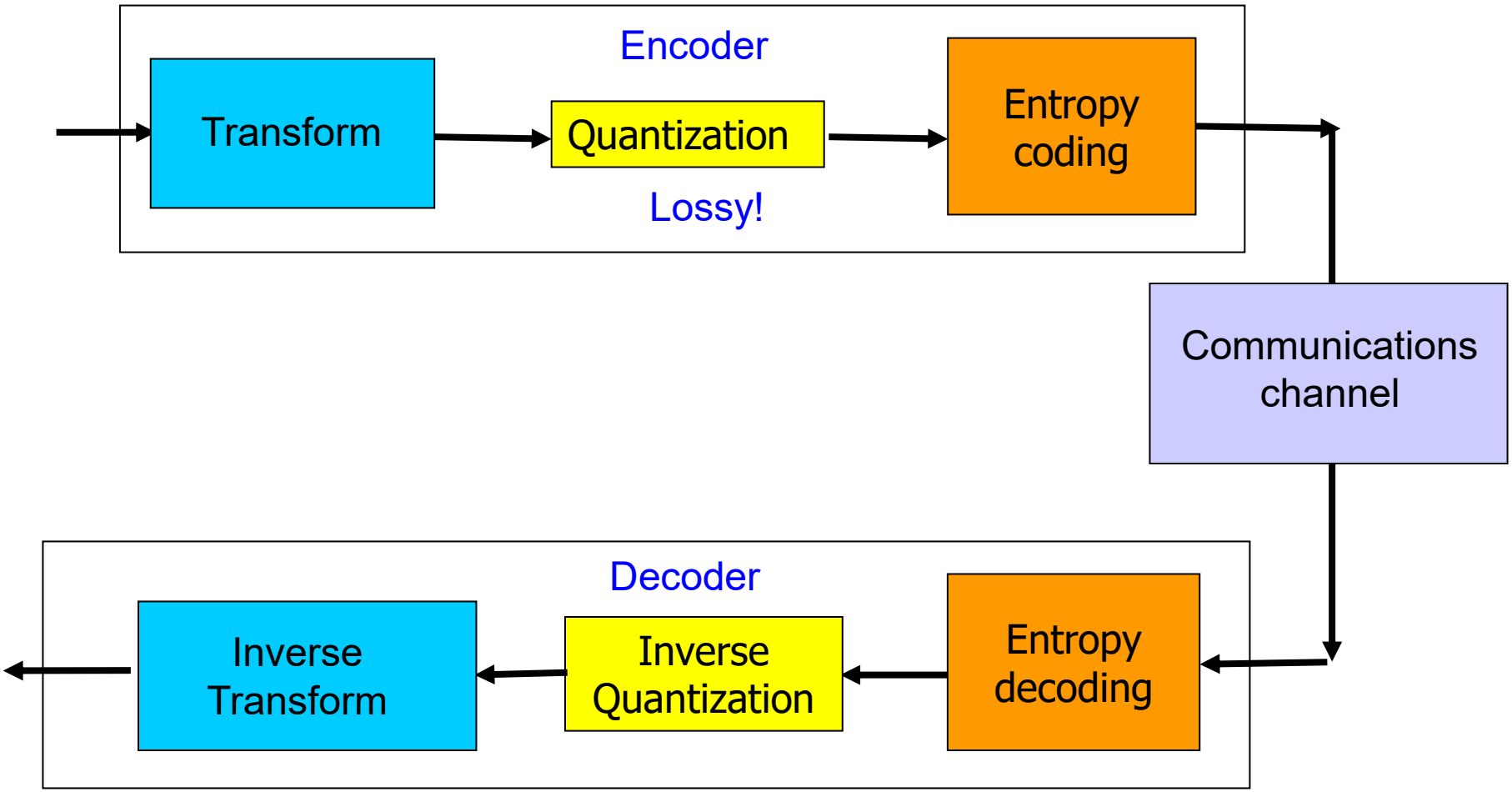
Compressed bitstream

Exploit the spatial redundancy: DCT, Wavelet, lapped transform

Eliminate smaller coefficients that cannot be perceived

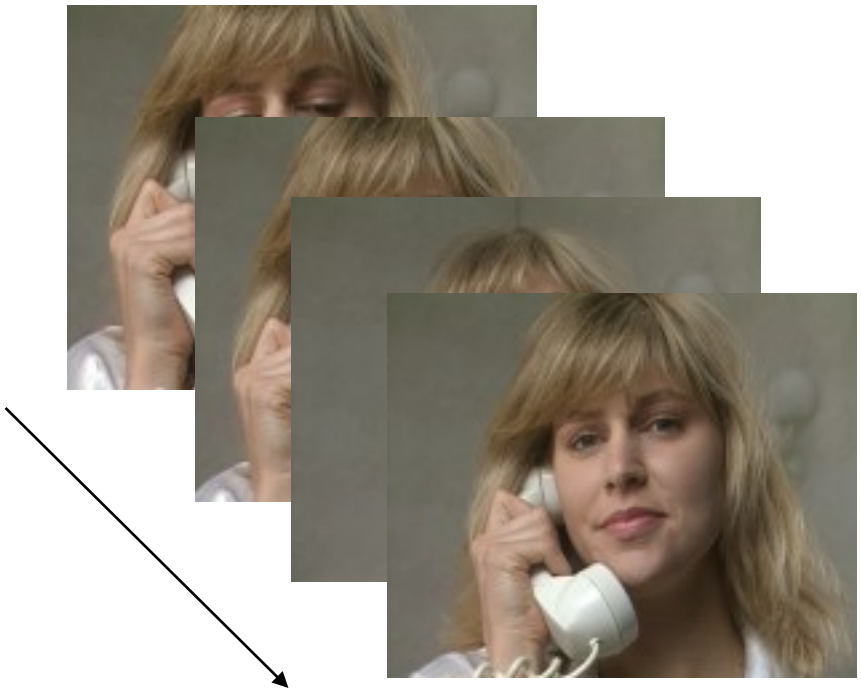
Huffman or arithmetic coding: Assign shorter codes to more probable symbols.

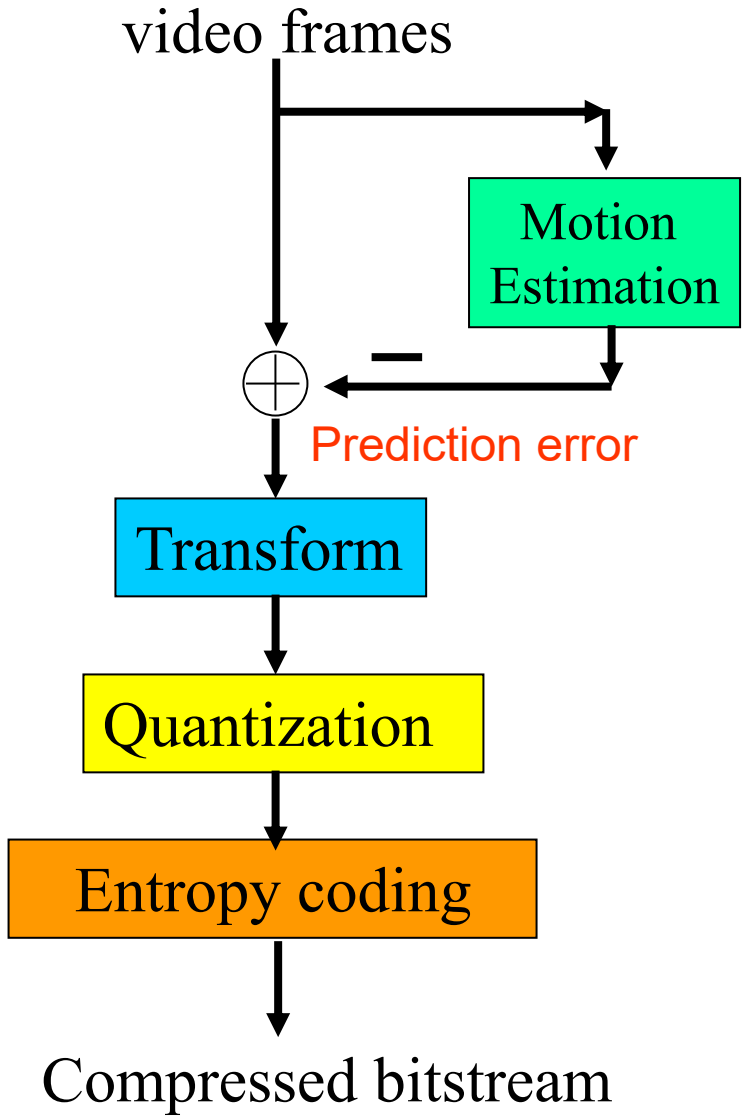
Decoder


Encoder
Transform
Quantization
Lossy!
Entropy coding
Communications channel
Decoder
Inverse Transform
Inverse Quantization
Entropy decoding

A Typical Video Compression System

Remove temporal redundancy





Compression Standards

- Why standards
  - A standard allows products from multiple vendors to communicate
    - Yet, users have flexibility in selecting equipment or software
  - Assures a large market for a particular piece of equipment or software
    - encourages mass production, VLSI technologies etc
    - lower costs.
  - Patent war !
    - Qualcomm, InterDigital

- Standard does not prevent innovation (?)
  - Only decoder is specified by the standard.
  - Encoder can still be improved.
  - Example: MPEG-2

    Bit rate has been reduced from 8Mbps in 1994 to 2Mbps now, offering the same quality.

Standardization Bodies

- ITU: International Telecommunications Union
  - ITU-T: ITU Telecommunication Standardization Sector (CCITT)
- ISO: International Standards Organization
- IEC: International Electro-technical Commission
- SMPTE: Society of Motion Picture and Television Engineers

- JPEG (ISO/IEC Joint Photographic Experts Group)
- JBIG (ISO Joint Bi-level Image Experts Group)
- MPEG (ISO Motion Picture Experts Group)
- VCEG (ITU-T Video Coding Experts Group)

Image Coding Standards

- JPEG:1993 (JPG file format)
  - DCT-based block transform
- JPEG2000: Dec. 2000
  - Wavelet-based
  - Much more complicated than JPEG
- JBIG: Joint Bi-level Image Experts Group (1993)
  - for lossless bi-level image compression (fax)
  - can also be used for grayscale images
- JBIG2: 1999
  - Supports both lossless and lossy compression

Video Coding Standards

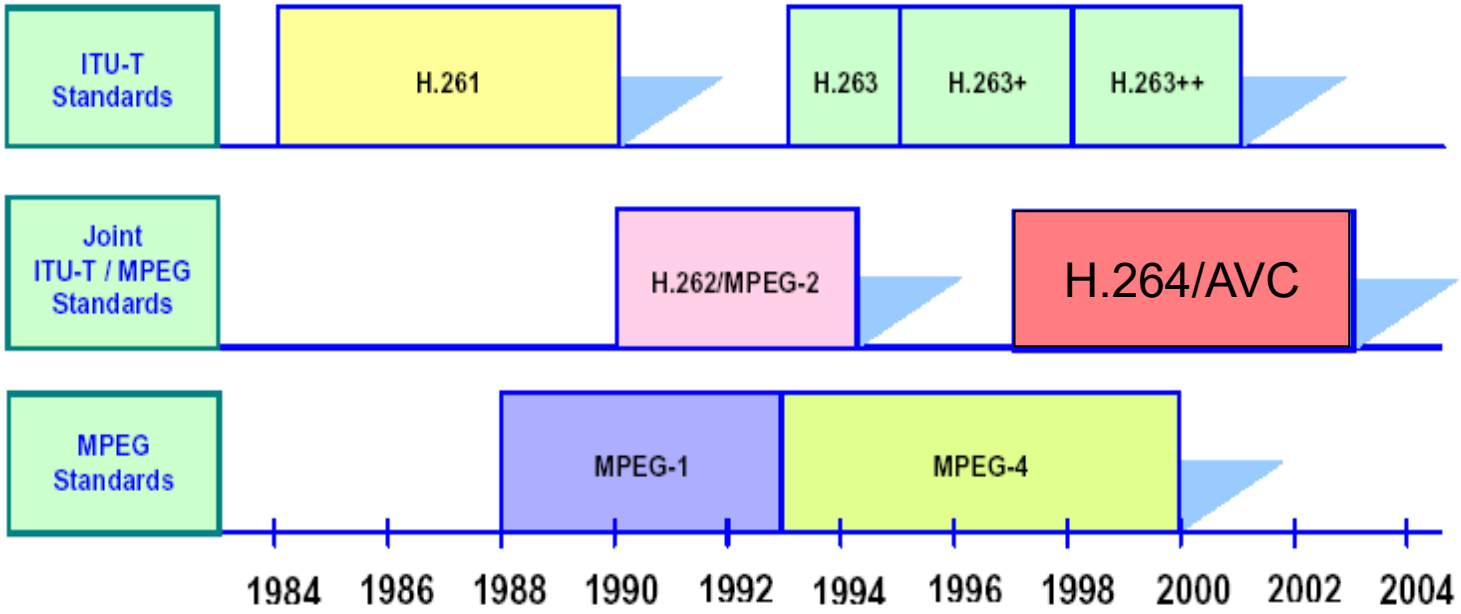
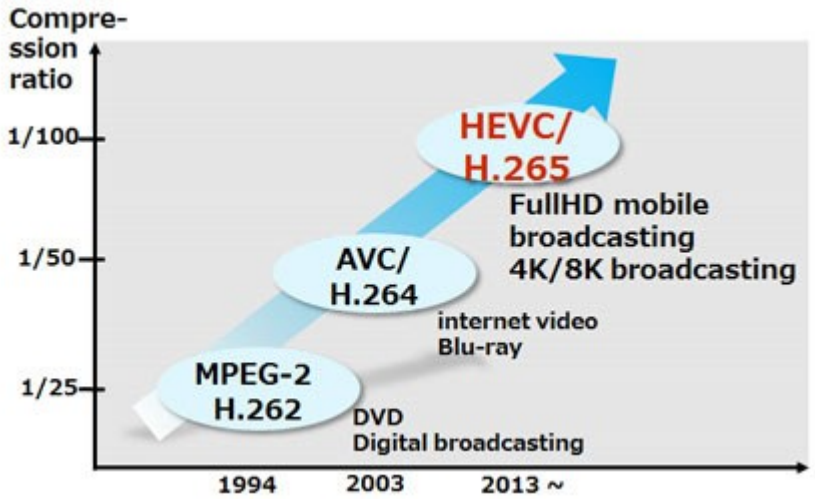


Figure 1. Progression of the ITU-T Recommendations and MPEG standards.

H.264/AVC: ITU-T H.264 / MPEG-4 (Part 10) Advanced Video Coding (AVC)
- Finalized in May 2003 (for general purpose)
- Fidelity Range Extensions (FREXt): 2003-2004 (for professional)

Video Coding Standards



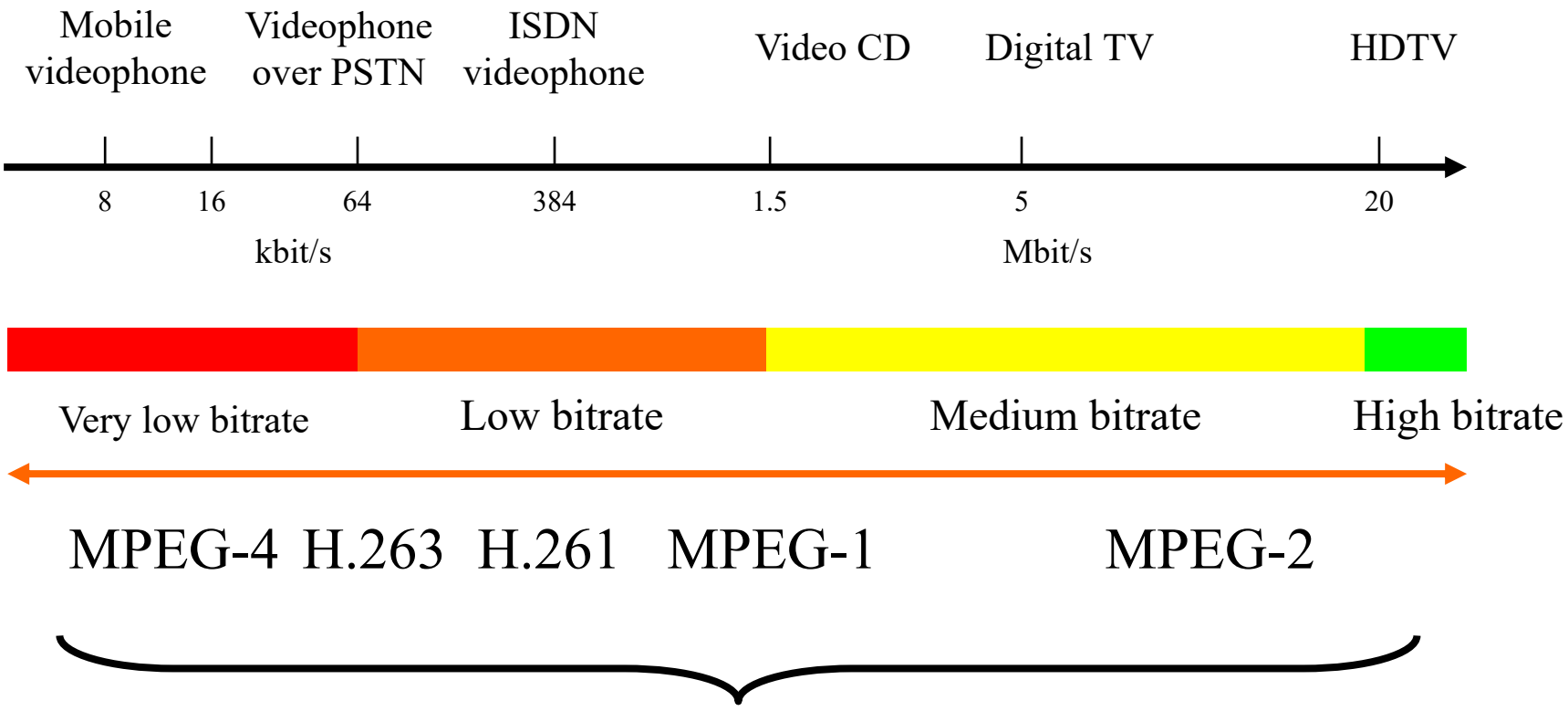
H.265/HEVC (High Efficiency)

- 50% goal (bitrate reduction)
- Start from 2010

February 2012: Committee Draft (complete draft of standard)
July 2012: Draft International Standard
January 2013: Final Draft International Standard (ready to be ratified as a Standard)
April 2013: Standard released

Google VP9 ? H. 266?

Coding Rate and Standards



MPEG-4/H.264/265/266 can do all of them!

Audio coding standards

Range of human' hearing: 20Hz - 20kHz
➔ Minimal sampling rate: 40 kHz (Nyquist frequency)

Format	**Bit Depth**	**Sampling Rate**	**Bit Rate** (2 channels)
CD Audio	16 bits	44.1 kHz	1,411,200 bps
DVD Audio	24 bits	96 kHz	4,608,000 bps

- MPEG-1 audio layer 3 (MP3)
  - CD quality at 10 : 1 compression ratio.
- MPEG-2 AAC (advanced audio coding):
  - used by XM Radio (satellite radio in US)
- MPEG-4 AAC :
  - Up to 48 channels, 96KHz
- ATSC AC-3: 1994
  - Dolby Digital (5.1 channel)
  - ATSC: Advanced Television Systems Committee
  - For DTV, DVD
- iTunes
  - AAC
  - AIFF (Audio Interchange File Format
- IETF OPUS/3GPP EVS (Enhanced Voice Service)

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Multimedia communications

- Examples of Multimedia Communication Systems:
  - World Wide Web
  - Video conferencing
  - Video-on-demand
  - Interactive TV
  - Online games

Fundamental Characteristics

- Typically **delay sensitive**
- But can **tolerate occasional loss:**
  - infrequent losses cause minor glitches
- Cf. data transmission: (e.g. FTP)
  - loss intolerant but delay tolerant

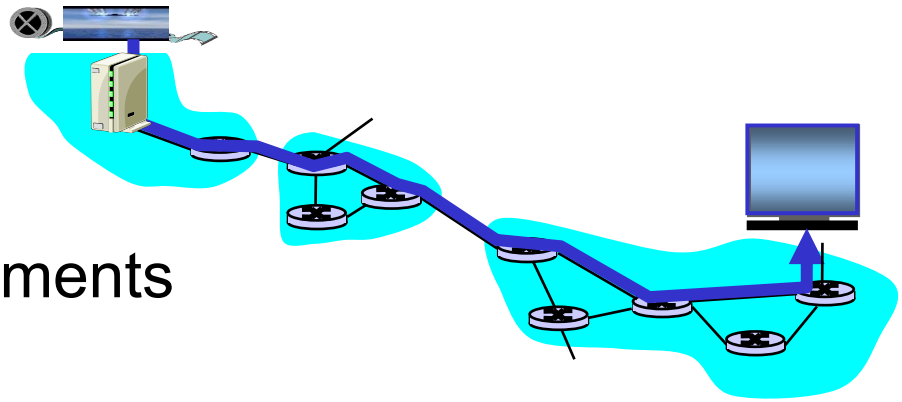
Challenges in Multimedia Communications

- Transmission of Compressed Multimedia:
  - Real-time communications
    - Delay < 0.4 sec in video conference
  - Sequencing within the media
  - Synchronization (e.g., between video & audio)
  - Robustness to transmission error

- We will learn how to
  - Transmit multimedia over Internet and wireless network

Recall: Challenges in Multimedia Communications

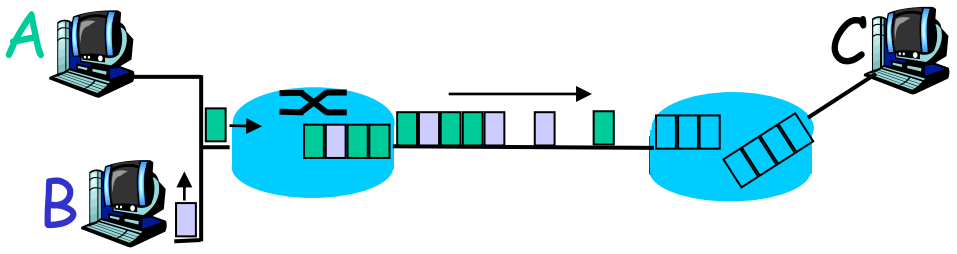
- Real-time communications
  - Delay < 0.4 sec in video conference
- Sequencing within the media
- Synchronization (e.g., between video & audio)
- Robustness to transmission error



Can we achieve these requirements through the Internet?

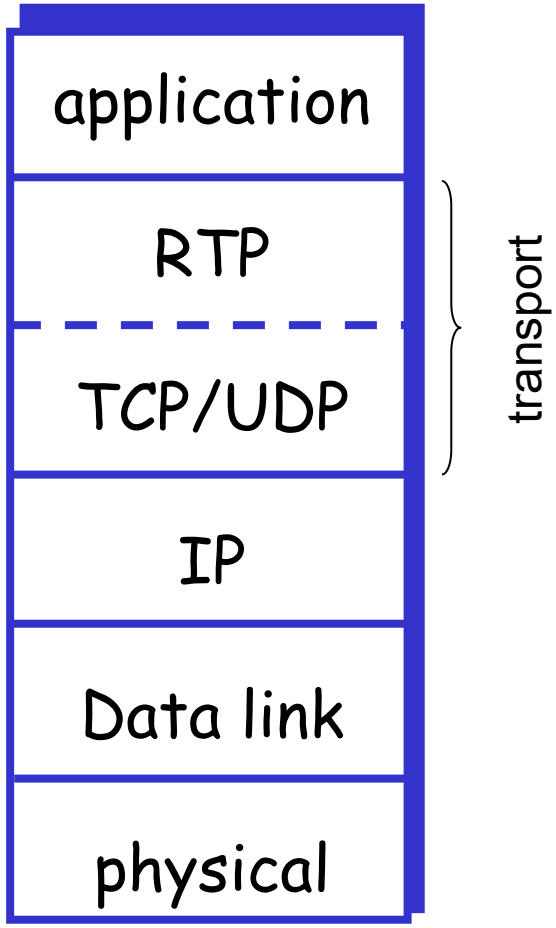
Internet

- Packet-switched network
- Network resources are shared
- Each packet is handled by a series of routers before being received
- Packets can be discarded if the buffer of a router is full
- All packets are treated the same way in congestion



Internet Protocol Stack

- IP: Internet Protocol
  - Best effort (unreliable)!
- TCP: Transmission Control Protocol
  - Provides reliable (but slow) service
- UDP: User Datagram Protocol
  - Provides unreliable (but fast) service
  - Suitable for real-time application
- RTP: Real-time Transport Protocol
  - packet format for multimedia streams
- RTCP: RTP control protocol
  - Monitor/report service quality
- RTSP: Real-time streaming protocol
  - "Internet VCR remote control"



Quality of Service (QoS) Parameters

- End-to-end Delay
  - time required for the end-to-end transmission of a single data element
- Jitter
  - variation in delay
- Packet loss rate
  - the proportion of data elements that are dropped
- Bandwidth: bits / second (bps)
  - rate of flow of multimedia data

QoS Control

- Algorithms to improve the QoS of Multimedia applications
- Policing
  - Control the input rate to network (leak bucket model)
- Scheduling
  - Divide buffers into logic queue
  - Decide which queue to service next

Error Resilience

Improve the decoded quality in the presence of lost data
- often occurs in wireless networks (and also Internet)

- Add redundancy at encoder:
  - Error correction code
  - Layered coding
  - Multiple description coding
- Post-processing at decoder to hide the error
  - Error concealment