Music & the Internet
MUMT301

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Plan

- Review of last class and assignment #3
- Internet technologies (i.e., Ethernet, TCP/IP, IP Headers, TCP Header, DNS, Ports, DHCP, FTP, SSH, HTTP)
- Sound file formats
- Audio compression
- Introduction to CSS grids / JavaScript
- Assignment #4

Assignment 3

https://mumt301.github.io

Sound file formats

- **Exponential growth** of audio material on the Internet since 1995
- “**mp3**” most searched term in 1999
- Big impact of coded audio: mostly everybody is using **MPEG-1/2 Layer-3**
    - also known as MP3
- Broadly speaking, **sound content** is delivered in **two format categories**:
    - As **recorded sound**:
        - often called *waveform* sound
    - As **structured audio**:
        - Sounds are generated in a dynamic manner at runtime
        - MIDI, MODs (e.g., trackers)

Structured Audio

- Structured audio formats provide **data to support dynamic construction of sound** through hardware and software
- *Sequencers* and *trackers* control
  - the **timing of sounds**, i.e., when individual sound elements start or stop
  - **sound attributes** such as volume, pitch, and other features
- *Sound elements* can be
  - short sections of **sound samples or loops** or
  - **data elements that characterize a sound** so that a *synthesizer* can produce the actual sound

Structured Audio

- Structured audio **does not convey audio**, the sounds are generated in a dynamic manner at *runtime.* Most common formats are:
- **MIDI** (1983)
  - **technical standard** to allow the **communication between electronic music instruments** (and computers)
  - MIDI 1.0 Detailed specification
  - Organized by the MIDI association
  - MIDI message example, MIDI tutorial
  - MIDI classical archives
  - MIDI world, BitMid, Carlos' MIDI, etc, etc, etc
- **Module files or MOD**s (late 80s) are used in music *tracker* software
  - Arrangement of discrete musical notes positioned at discrete chronological positions on a timeline
  - E.g., OpenMPT, 16bitshock, BeepBox, Soundbox, Bassoon, FruityLoops, Renoise
  - http://modarchive.org/

Recorded sound

- Audio file data is stored in a **binary representation**
  - it is necessary to have a **format specification** in order to know how to read a given format's data
- Sustainability of Digital Sound Formats. Library of Congress Collections
- Comprehensive list of audio file formats
- The most common audio file formats are/were:
  - SND or AU (NeXT, Sun)
  - AIFF (Apple, SGI)
  - WAV (Microsoft)
  - MP3 (MPEG)
  - FLAC (OpenSource)
- Audio data can be stored in compressed or uncompressed formats

Uncompressed formats

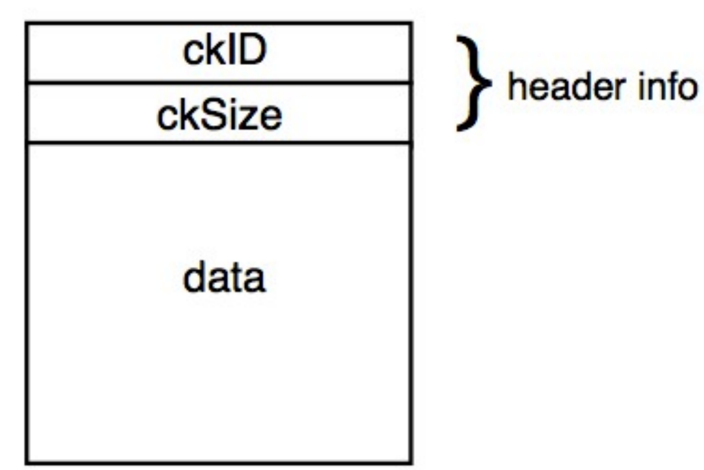
- PCM, subtype LPCM (Linear Pulse Code Modulation Audio):
  - **digital representation of analog signal**
  - **magnitude** of the signal is **sampled regularly** at uniform intervals
  - **quantized** to a series of values in binary code
  - defining characteristics:
    - **sampling rate** (44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz, 192kHz)
    - **bit depth** (8, 16, 20, 24, 32 bits per sample)
  - used for uncompressed encoding of audio data in the **Compact disc Red Book Standard** (i.e., Audio CD, 1982)

Compact Disc

- **Optical** storage of digital audio (data)
- Introduced in 1982 by Sony and Phillips (together)
- **Originally for sound** only, but later for all types of data
- 74–80 minutes of audio at 44.1KHz/16bit/stereo
- How much data?
  - 88,200 bytes/sec per channel
  - 5,292,000 bytes/minute per channel

Uncompressed formats
RIFF File formats

- RIFF (Resource Interchange File Format) is a **tagged file structure for multimedia resource files**
- Developed by Electronic Arts (the gaming company!)
- Aimed to **facilitate data transfer between different software and companies**
- Generic container file format (AIFF, WAVE, RIFF, SMF)
- RIFF is **not a file format**, but a **file structure** that defines a class of more specific file formats
- Based on **headers** pointing to “**chunks**” of data

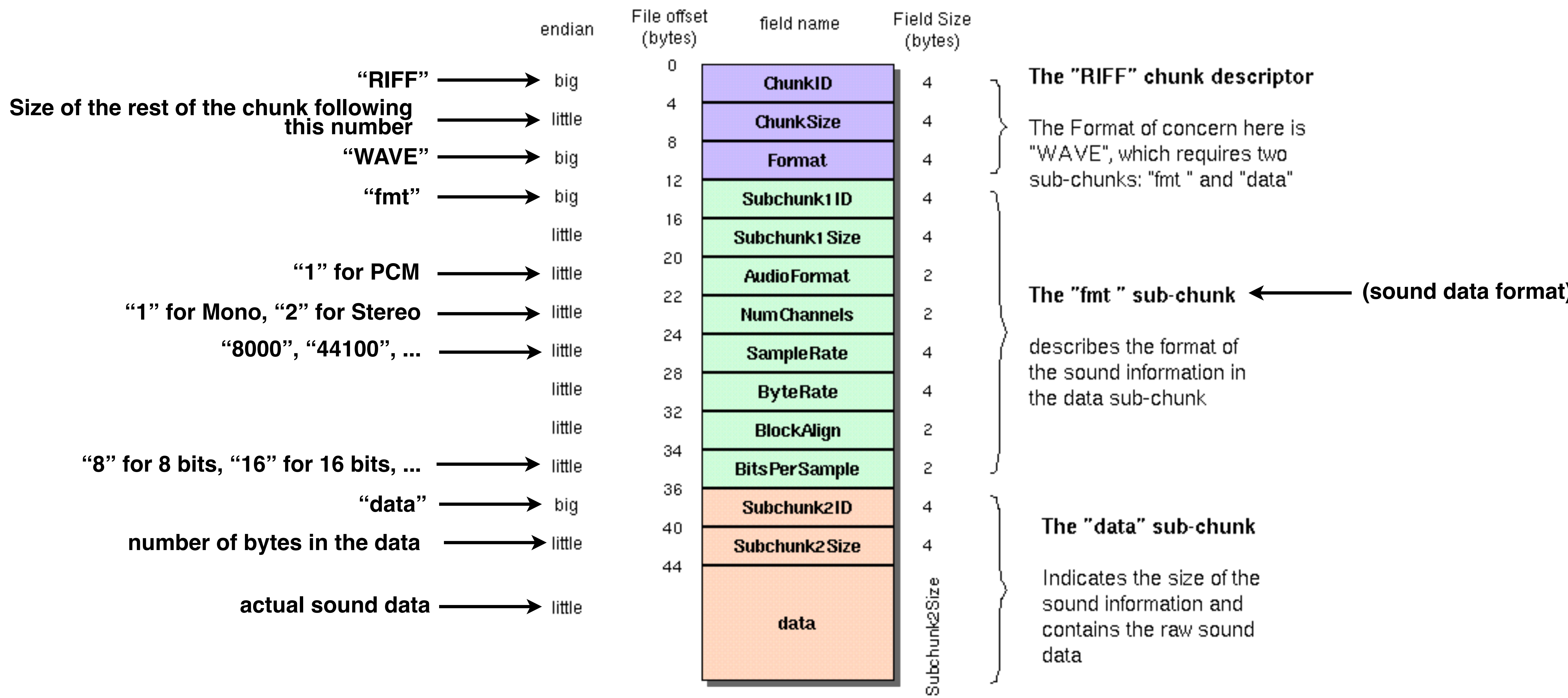


A chunk.

Uncompressed formats
RIFF File formats

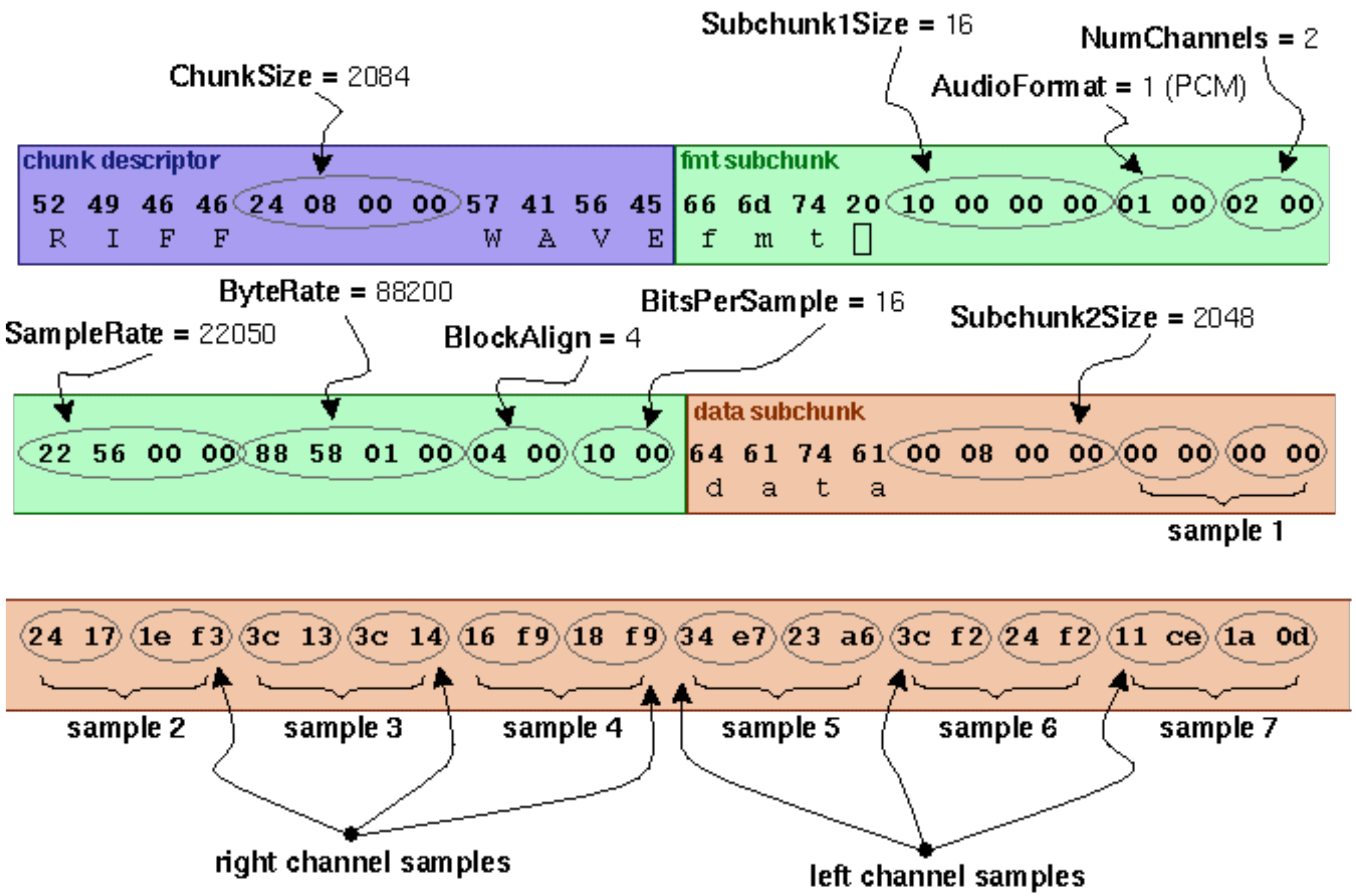
- AIFF (Audio Interchange File Format, 1989)
- WAVE (Waveform Audio File Format, 1991)

Uncompressed formats
The Canonical WAVE file format



Taken from http://soundfile.sapp.org/doc/WaveFormat/

Uncompressed formats
The Canonical WAVE file format



Taken from http://soundfile.sapp.org/doc/WaveFormat/

Compressed sound file formats

- Lossy and Lossless
- **Lossy compression**:
  - only **an approximation of the original data can be reconstructed after decompression**,
  - How well it approximates the original data **depends on the compression rate**
  - Common lossy formats
    - MP3 (patented!)
    - Vorbis (aka Ogg Vorbis), xiph.org webpage (free and open source) (V1.0 2002)
    - WMA
- **Lossless compression**:
  - **data can be perfectly reconstructed after decompression**
  - Lossless formats
    - Monkey's Audio, WavPack, Apple Lossless, ...
    - FLAC, xiph.org webpage
      - non-proprietary
      - no patent restricted
      - open-source

Audio compression

- Basic task of audio compression?
  - to compress the digital audio data in a way that
    - compression as efficient as possible, i.e., file **size as small as possible**
    - the decoded audio should be **as close as possible to the original** audio before compression
- **Perceptual audio coding** is the technique used to accomplish this
  - research topic since the late 70's, exploded since 1986
  - uses **knowledge from psychoacoustics** to reach the target of efficient, but inaudible, compression
  - is a *lossy* compression technique
    - the decoded file **is not a bit-exact replica of the original** digital audio data

MPEG-1 Layer-3 perceptual model

- PCM digitally reproduces the waveform of an incoming signal as accurately as possible

- **Human aural perception works different**, our ears and brain are imperfect and biased

- **Sounds can be masked in frequency and/or time**

- The theory behind perceptual coding uses the idea that **our aural perception** doesn't need the actual bit-to-bit waveform representation, but only the **properties of the waveform that are most important for the listener**, and prioritize the recording of these properties

- In other words, **PCM attempts to capture a waveform *as it is*, an MP3 attempts to capture *as it sounds*** (as we perceive it)

MPEG-1 Layer-3 perceptual model

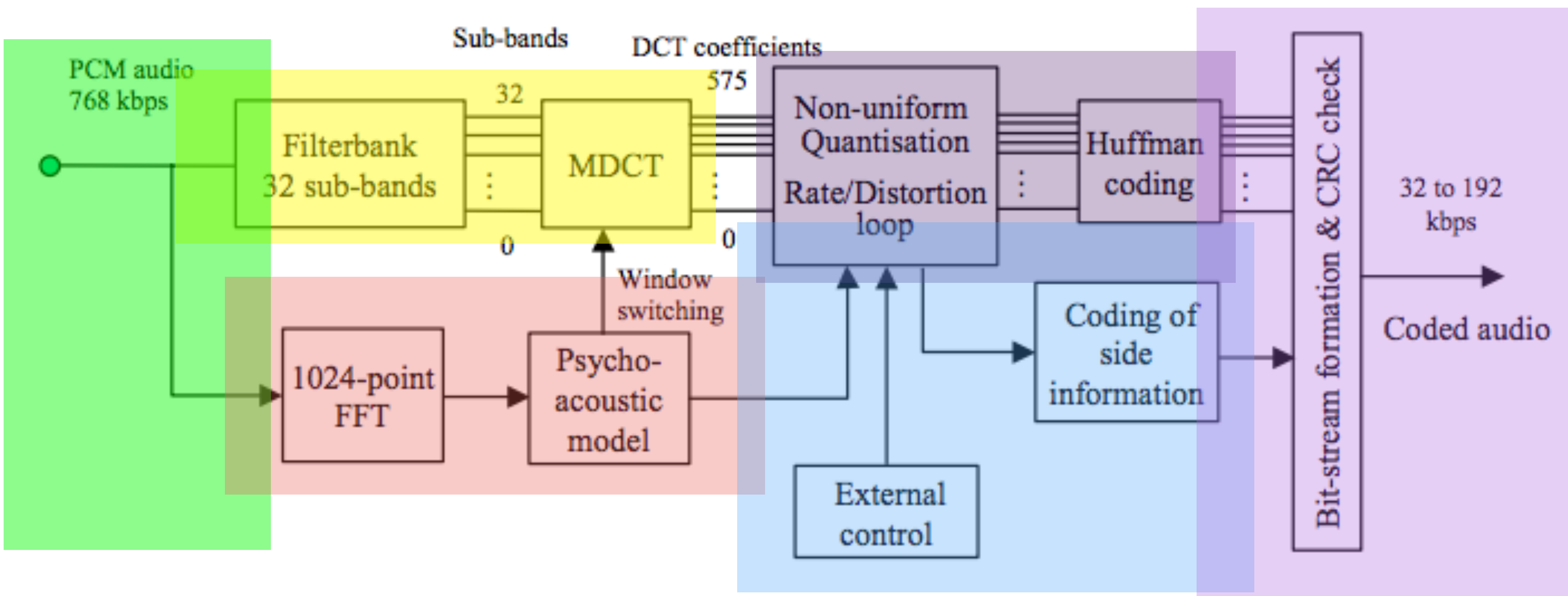
- Perceptual coding basic concept: **irrelevancy**
  - Certain properties of any given waveform will be not perceived by a human listener, and so it will be **meaningless to store them**
- Perceptual model depends on peculiarity of human auditory perception: **auditory masking**
  - in the temporal domain it is called **temporal masking**: a sudden stimulus makes inaudible other sounds immediately preceding or following the stimulus
  - in the frequency domain, it is called **frequency masking**: the threshold of hearing for one sound is raised by the presence of another sound
- Masking enables perceptual coding to get away much of the data that conventional waveform coding (e.g., PCM) stores
- **Not all irrelevant data is discarded, but fewer bits are assigned to the masked elements than to relevant ones**
- This process introduces distortion, but it will be hopefully confined to the masked zone, and hopefully will be imperceptible on playback.

MPEG-1 Layer-3 audio standard

- MPEG audio standard is **informative instead of normative**
  - minimum amount of **normative elements**:
    - the **data representation** (i.e., format of the compressed audio)
    - the **decoder** (however there is freedom in how to implement it)
- **Encoding** of MPEG audio is **left to the implementer**
  - the standard only gives description of example encoders
  - MPEG audio **encoders can vary in quality**

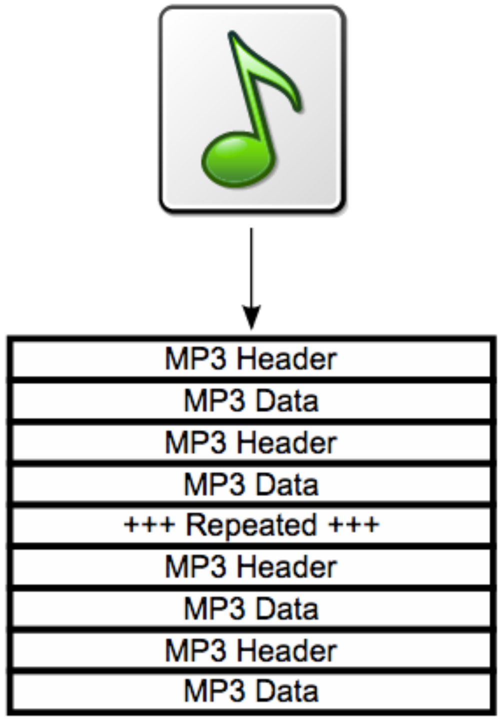
MPEG-1 Layer-3 characteristics

- **Flexibility**
  - **Different operating modes**:
    - **Single channel**
    - **Dual channel** (two independent channels, e.g., two different language versions of an audio piece)
    - **Stereo** (no joint stereo coding, the two channels are encoded independently)
    - **Joint stereo** (information about differences from each channel is stored in one channel, whilst identical information is stored in the other. Help to reduce bit-rate)
- **Sampling frequency**
  - **MPEG-1**: **32kHz, 44.1kHz, 48kHz**
  - MPEG-2: extends MPEG-1 to half rates: 16kHz, 22.05kHz, 24kHz
  - MPEG-2.5: Fraunhofer-proprietary: 8kHz, 11.05kHz, 12kHz
- **Bit-rate**
  - the MPEG-1 standard defined a range of **bit-rates from 32 kbits/s up to 320k bits/s**
  - MPEG-2 standard extends the bit-rate to 8 kbits/s
  - **selection of bit-rate left to the operator of the audio coder**



Taken from Brandeburg, K. 1999. MP3 and AAC explained. In Proceedings of the AES 17th International Conference on High Quality Audio Coding

MP3 header



Bits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Binary	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0
Hex	F				F				F				B				A			
Meaning	MP3 Sync Word												Version	Layer		Error Protection	Bit Rate			
Value	Sync Word												1 = MPEG	01 = Layer 3		1 = No	1010 = 160			

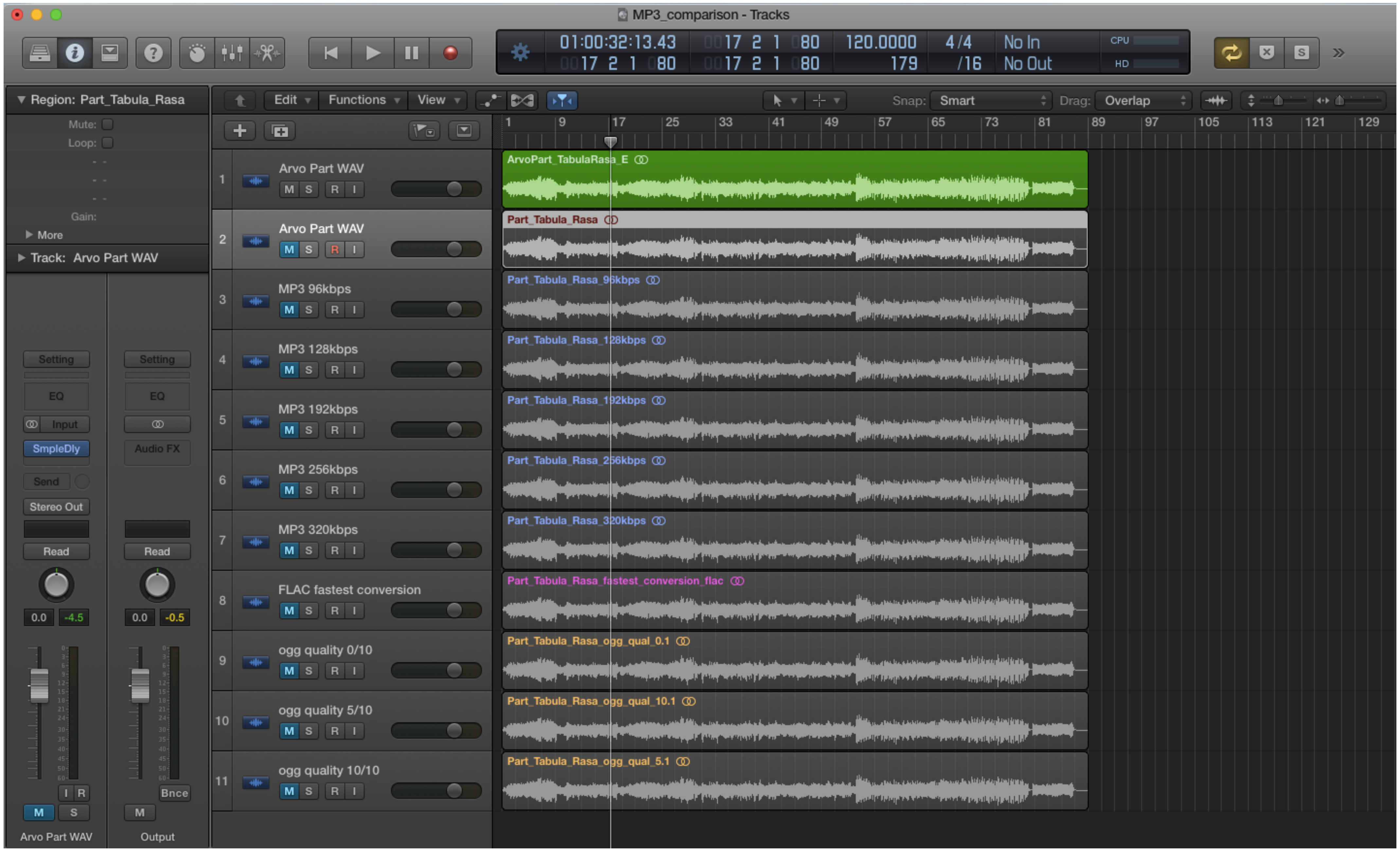
21	22	23	24	25	26	27	28	29	30	31	32
0	0	0	0	0	1	0	0	0	0	0	0
0				4				0			
Frequency		Pad. Bit	Priv. Bit	Mode		Mode Extension (Used With Joint Stereo)		Copy	Original	Emphasis	
00 = 44100 Hz		0 = Frame is not padded	Unknown	01 = Joint Stereo		0 = Intensity Stereo Off	0 = MS Stereo Off	0 = Not Copy-righted	0 = Copy Of Original Media	00 = None	

Taken from http://en.wikipedia.org/wiki/MP3

MPEG-2 AAC

- Same paradigm as MPEG-1 Layer-3, but
  - **higher frequency resolution** (1024 instead of 576 frequency lines)
  - improved joint stereo coding
  - improved Huffman coding
- AAC reaches the same quality as Layer-3 at 70% of the bit-rate
- Do not confuse MPEG-2 with MP2 (MPEG-1 Layer-2). MPEG-2 is standard for video (and associated audio), whose audio can be in a number of formats, including AC3 and AAC

MP3 comparison



BREAK

Introduction to CSS grids & JavaScript

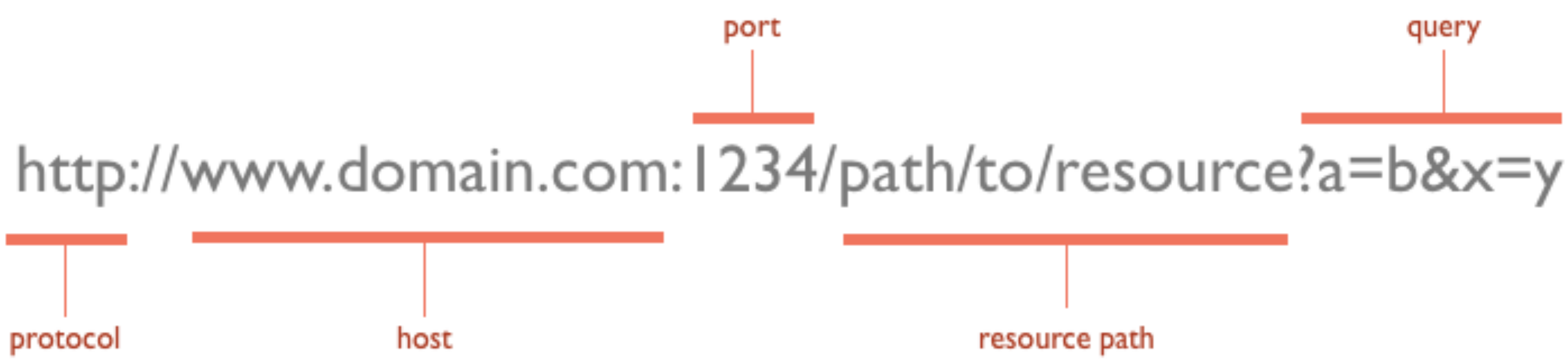
https://mumt301.github.io

Today's class

- Review of last class and assignment #3
- Sound file formats
- Audio compression
- Introduction to JavaScript
- Assignment #4

HTTP requests

- Request messages are at the heart of web communications using HTTP
- These messages are sent using URLs (Uniform Resource Locators)

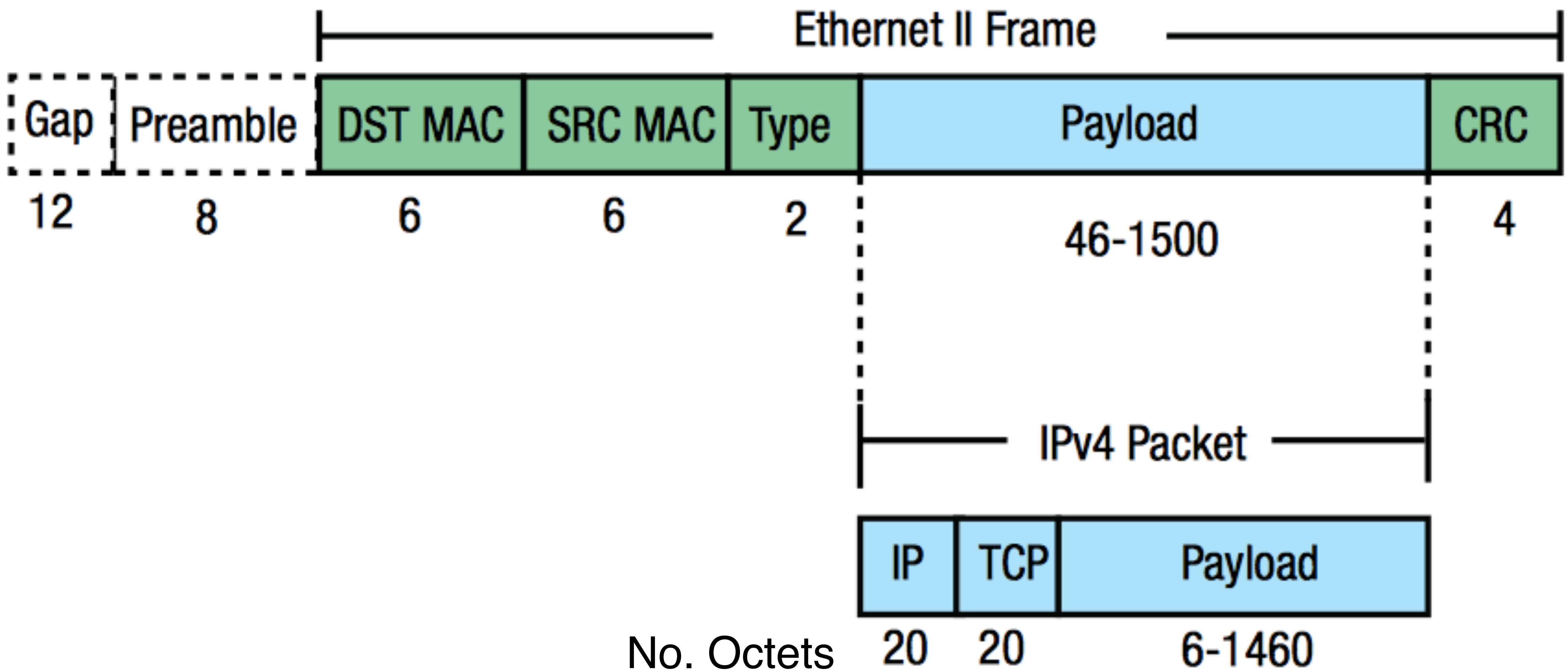


Taken from http://code.tutsplus.com/

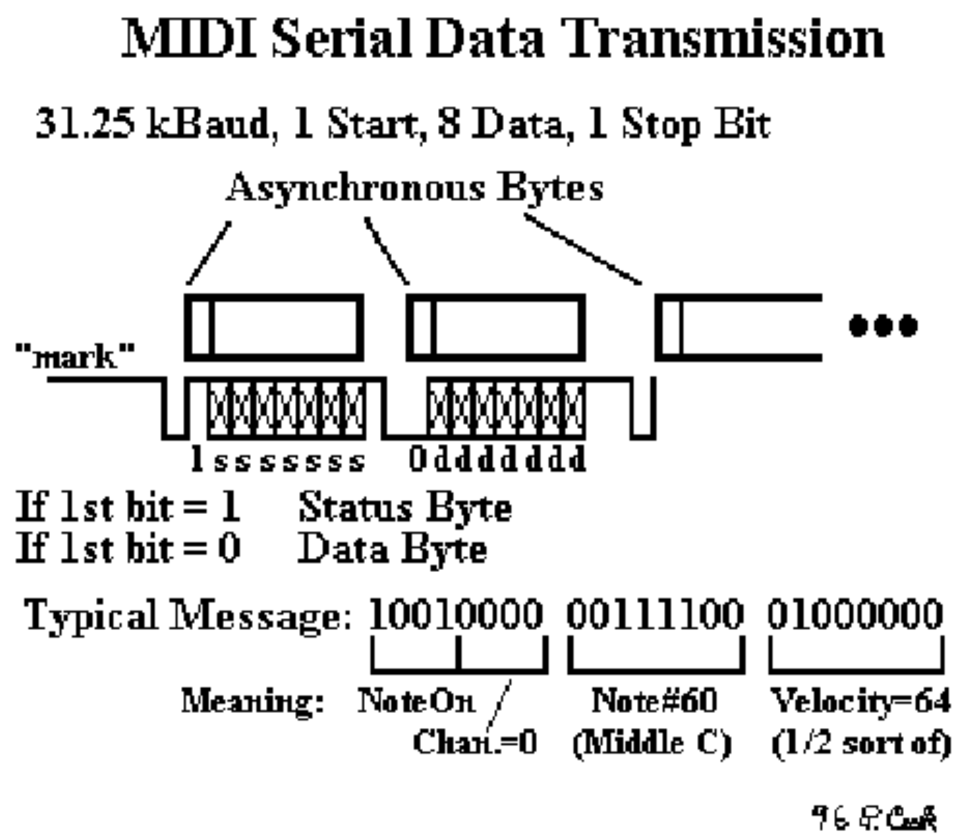
https://soundcloud.com/search/people?q=jonah+orbach

Complete Ethernet Packet

Taken from openmicrolab.com



MIDI Message example



The **NOTE ON** message is structured as follows:

- Status byte : 1001 CCCC
- Data byte 1 : 0PPP PPPP
- Data byte 2 : 0VVV VVVV

Pitch value: 60

The **NOTE OFF** message is structured as follows

- Status byte : 1000 CCCC
- Data byte 1 : 0PPP PPPP
- Data byte 2 : 0VVV VVVV

where:

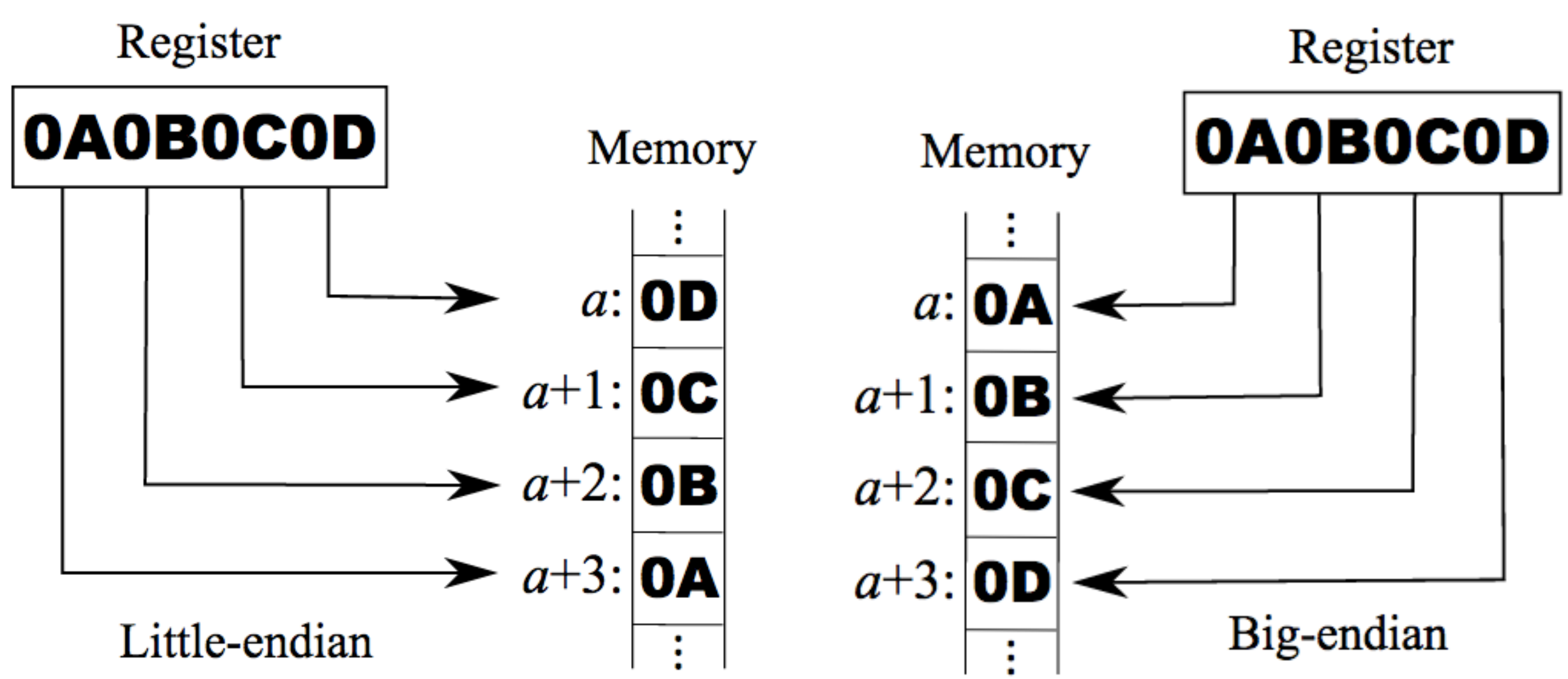
CCCC is the MIDI channel (from 0 to 15)

PPP PPPP is the pitch value (from 0 to 127)

VVV VVVV is the velocity value (from 0 to 127)

Endianness

- In WAVE files, data bytes are “little endian” ordered, When looking at multiple bytes, the first byte is smallest.
- In AIFF files, data bytes are “big endian” ordered. When looking at multiple bytes, the first byte (lowest address) is the biggest.



Taken from http://en.wikipedia.org/wiki/Endianness