CS 352
E-Mail

Lecture 7

http://www.cs.rutgers.edu/~sn624/352-F22

Srinivas Narayana

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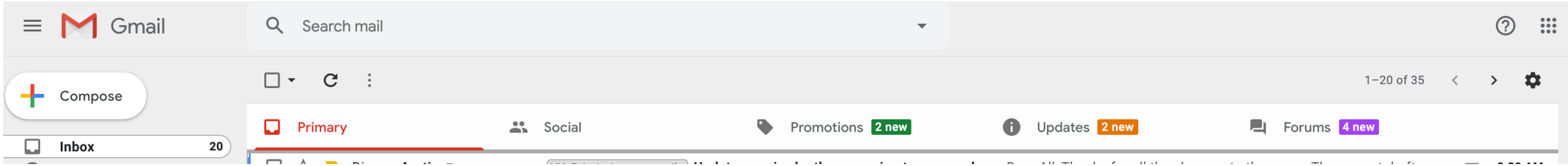
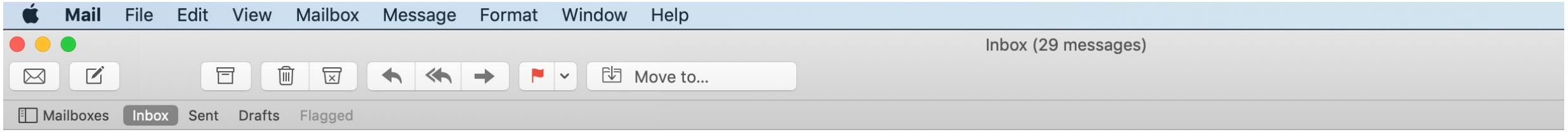
Summary of HTTP

- Request/response protocol
- ASCII-based human-readable message structures
- Enhanced stateful functionality using cookies
- Improve performance using caching, and CDN
- Simple, highly-customizable protocol
  - Just add headers
- Protocol that forms of the basis of the web we enjoy today!

Simple Mail Transfer Protocol

We’re all familiar with email. How does it work?

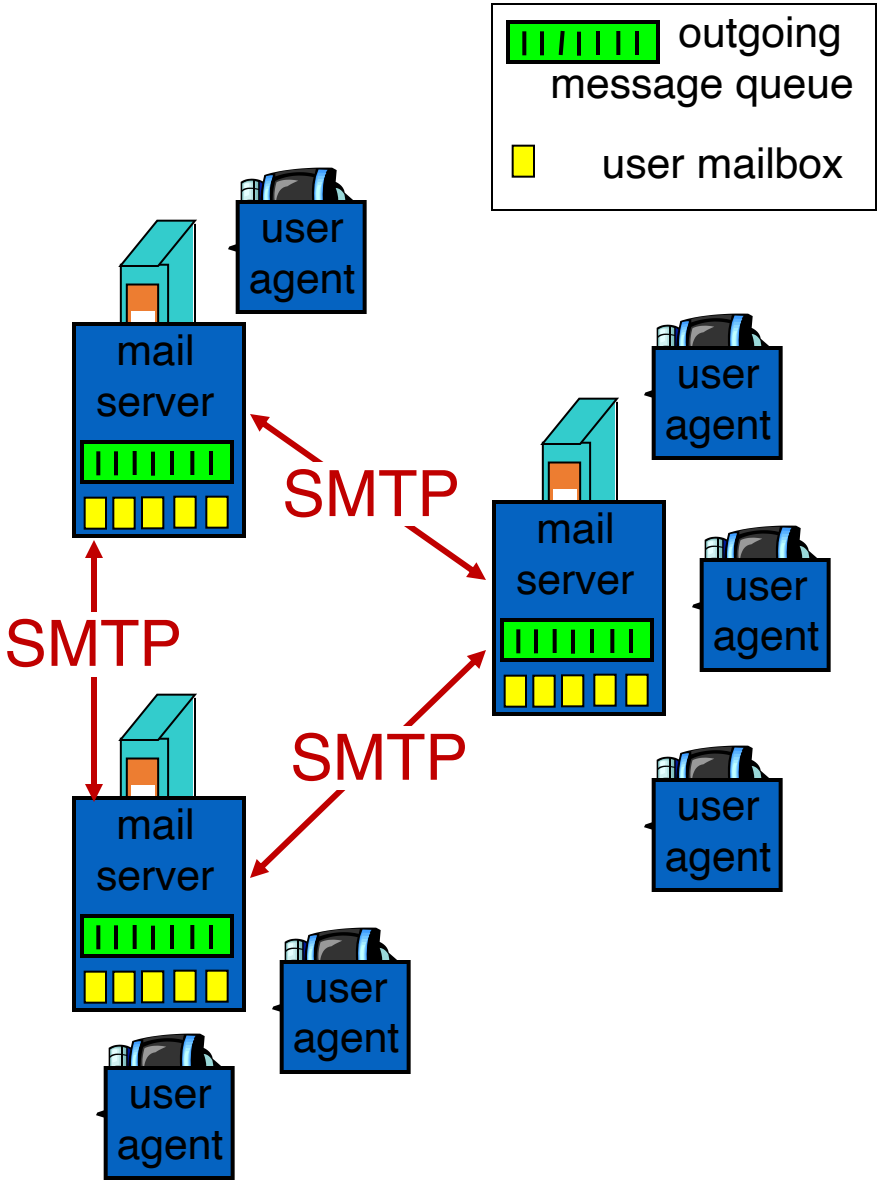




Electronic Mail

Three major components:

1. User agents
   - a.k.a. “mail reader”
   - e.g., Applemail, Outlook
   - Web-based user agents (ex: gmail)



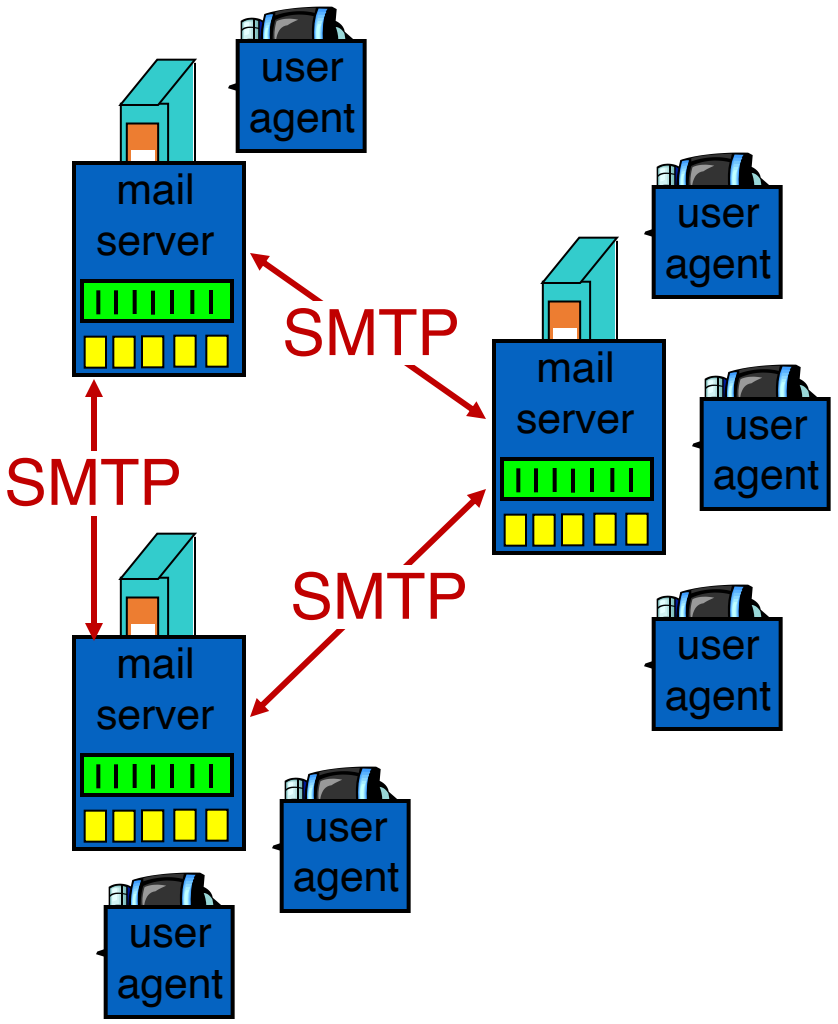
Electronic Mail: Mail servers

2. Mail Servers

- Mailbox contains incoming messages for user
- Message queue of outgoing (to be sent) mail messages
- Sender's mail server makes connection to Receiver's mail server
  - IP address, port 25

3. SMTP protocol: client/server protocol

- Used to send messages
- Client: sending user agent or sending mail server
- server: receiving mail server



Scenario: Alice sends message to Bob

1) Alice (`alice@rutgers.edu`) uses UA to compose message to `bob@nyu.edu`

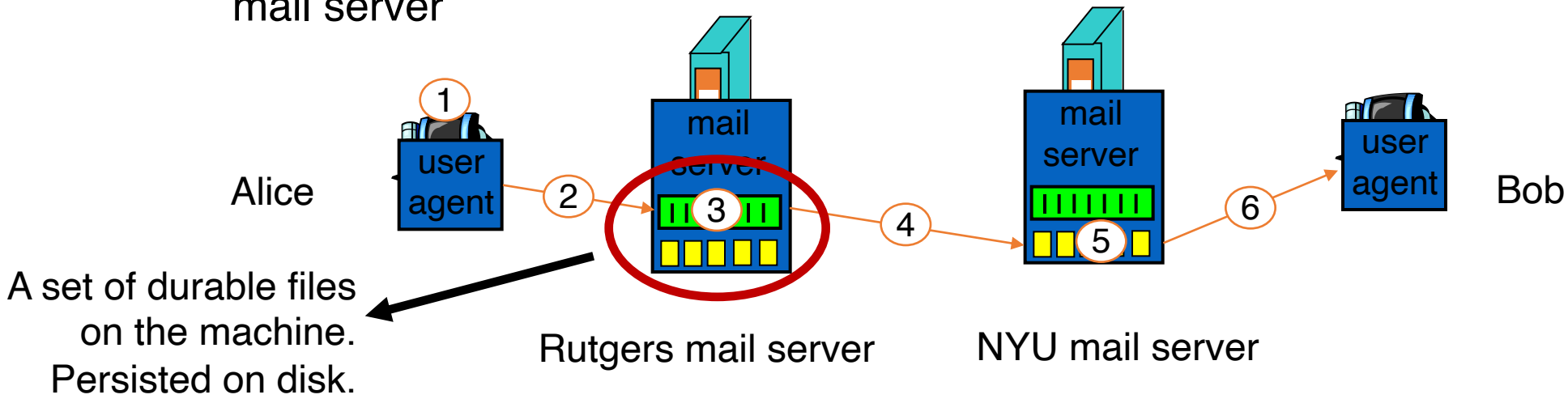
2) Alice's UA sends message to her mail server; message placed in outgoing message queue

3) Client side of SMTP opens TCP connection with Bob's mail server

4) SMTP client sends Alice's message over the TCP connection

5) Bob's mail server places the message in Bob's incoming mailbox

6) Sometime later, Bob invokes his user agent to read message



Observations on these exchanges

- Mail servers are the “infrastructure” for email functionality
  - Receiving the email on behalf of Bob, should Bob’s machine be turned off
  - Retrying the delivery of the email to Bob on behalf of Alice, should Bob’s mail server be unavailable in the first attempt
- The same machine can act as client or server based on context
  - Rutgers’s mail server is the server when Alice sends the mail
  - It is the client when it sends mail to Bob’s mail server
- SMTP is push-based: info is pushed from client to server
  - Contrast to HTTP or DNS where info is pulled from the server

Sample SMTP interaction

- `telnet <mail-server> 25`
- `HELO <sender-domain>`
- `MAIL FROM: <name>@<sender-domain>`
- `RCPT TO: <user>@<mail-server-domain>`
- `DATA`
- Optional: Add headers
  - `From: <..>`
  - `To: <..>`
  - `Subject: <..>`
- Then your message. Then [enter].[enter] Don’t forget the “.”
- Mail headers make your email look good, help avoid junk folder

MAIL command response codes

Table 23.2 *Responses*

Code	*Description*
Positive Completion Reply	
211	System status or help reply
214	Help message
220	Service ready
221	Service closing transmission channel
250	Request command completed
251	User not local; the message will be forwarded
Positive Intermediate Reply	
354	Start mail input
Transient Negative Completion Reply	
421	Service not available
450	Mailbox not available
451	Command aborted: local error
452	Command aborted; insufficient storage
Permanent Negative Completion Reply	
500	Syntax error; unrecognized command
501	Syntax error in parameters or arguments
502	Command not implemented
503	Bad sequence of commands
504	Command temporarily not implemented
550	Command is not executed; mailbox unavailable
551	User not local
552	Requested action aborted; exceeded storage location
553	Requested action not taken; mailbox name not allowed
554	Transaction failed

220: Service ready
250: Request command complete
354: Start mail input
421: Service not available
500: Unrecognized command

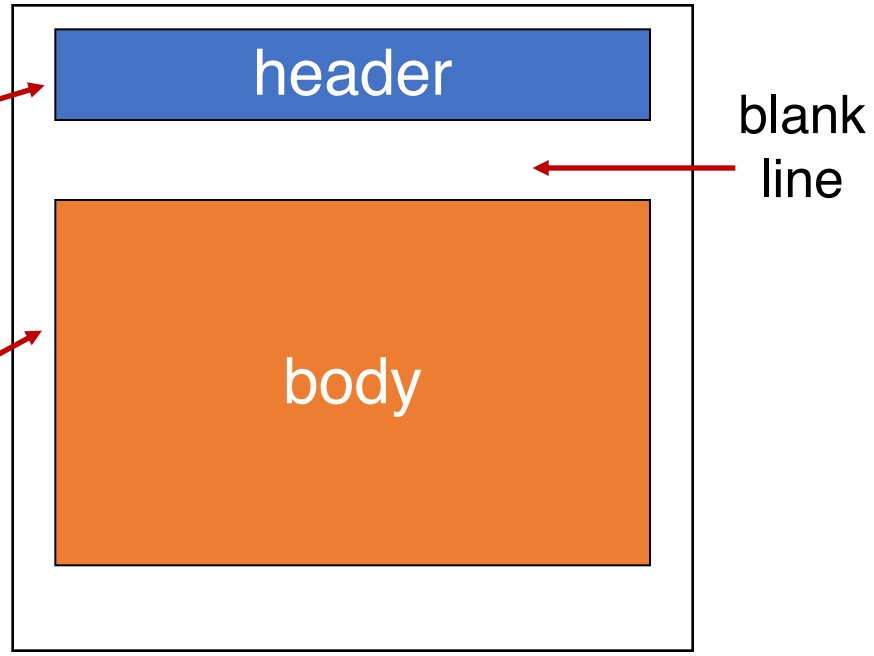
Mail message format (stored on server)

SMTP text message exchange standardized in RFC 822

- Header lines, e.g.,
  - To:
  - From:
  - Subject:

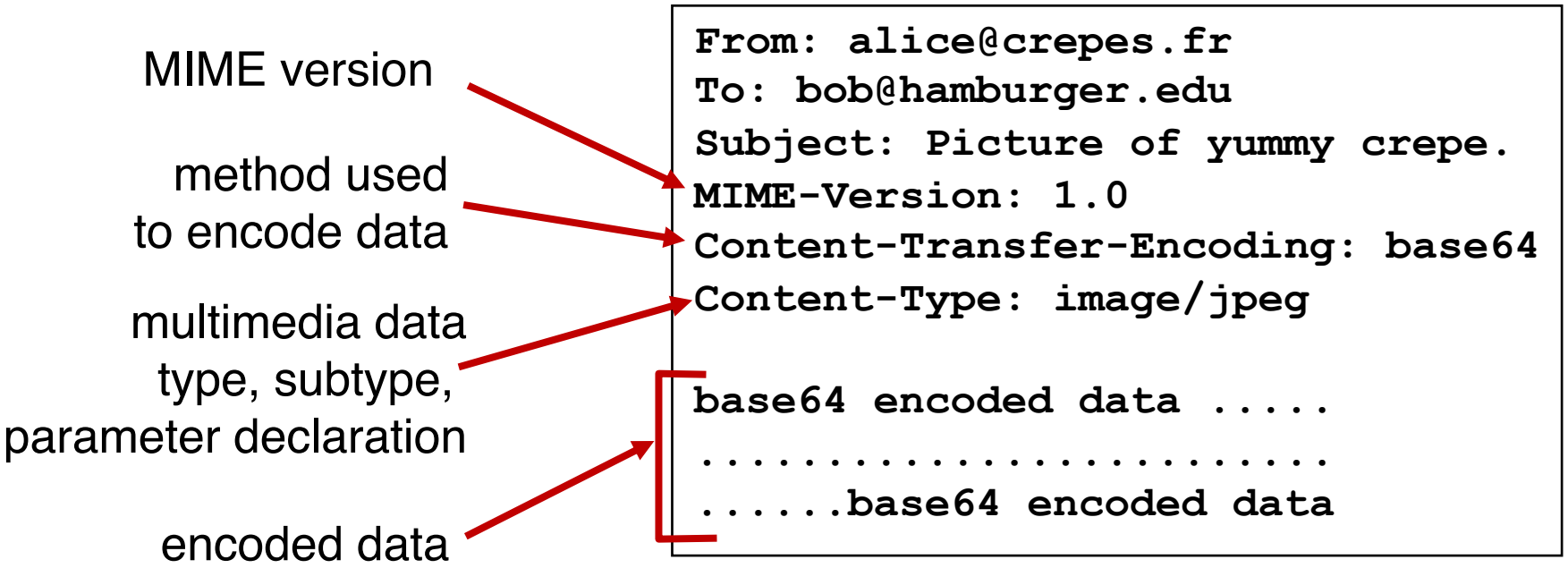
  These are different from SMTP commands!

  (these would still be under "DATA")
- body
  - the "message".
  - ASCII characters only



Message format: multimedia extensions

- MIME: multipurpose Internet mail extension, RFC 2045, 2056
- additional headers in DATA header declare MIME content type
- A message can have many parts



Vote for New Brunswick's Favorite Restaurants

Inbox ×

@NBCityCenter citymarket@newbrunswick.com via newbrunswick.ccsend.com

to me

1:17 AM (8 hours ago)

- Reply
- Forward
- Filter messages like this
- Print
- Add The Morning Paper to Contacts list
- Delete this message
- Block "The Morning Paper"
- Report spam
- Report phishing
- Show original
- Translate message
- Download message
- Mark as unread

Message-ID: <1138527284182.1100462763056.2128912358.0.1561738JL.2002@scheduler.constantcontact.com>
Date: Wed, 2 Feb 2022 17:41:43 -0500 (EST)
From: "@NBCityCenter" <citymarket@newbrunswick.com>
Reply-To: citymarket@newbrunswick.com
Sender: "@NBCityCenter" <pamela@newbrunswick.ccsend.com>
To: [redacted]
Subject: Vote for New Brunswick's Favorite Restaurants
MIME-Version: 1.0
Content-Type: multipart/alternative; boundary="----=_Part_550097535_1238800096.1643841703083"
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p=un&m=001HGjyDxPJyPKvJg5rDoRs1g%3D%3D&se=001BAprMYzSEJkLWw3FBEdL0g%3D%3D&t=001EkZLEx15CcE%3D&llr=qblcl7aab>
List-Unsubscribe-Post: List-Unsubscribe=One-Click
X-Campaign-Activity-ID: 7af9b840-b29e-4db4-8870-83aaf3a5e6a0
X-250ok-CID: 7af9b840-b29e-4db4-8870-83aaf3a5e6a0
X-Channel-ID: f1703300-eb85-11e8-8729-d4ae5275b3f6
X-Mailer: Roving Constant Contact 2012 (http://www.constantcontact.com)
X-Return-Path-Hint: Aevm4QLKeTbSIcIOq86XmoA==_1100462763056_8XAzAOuFEeiHKdSuUnWz9g==@in.constantcontact.com
X-Roving-Campaignid: 1138527284182
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------=_Part_550097535_1238800096.1643841703083
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Content-Transfer-Encoding: quoted-printable

Dine, Shop, Play & Stay... It All Happens Here! VALENTINE'S WEEKEND =EF=BB=
=BFLive music & theater entertainment, comedy shows, a variety of activitie=
s, chocolate shops, and high-end restaurants make New Brunswick an excellen=
t choice for couples on Valentine's Day! It's easy to see why this city is=
 romantic with so many fun date night options, luxurious spas, and deliciou=
s dining selections. Book Your Reservations Now Jersey's Choice Restaurant =
Poll Presented by New Brunswick's Performing Arts Center, it's your time to=
 show your support for your favorite spots in New Brunswick as NJ Monthly h=
osts their 39th Annual Restaurants of NJ Poll! New Brunswick is represented=
 strongly with many of your favorites including, Roosterspin, Stage Left St=

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 Constant Contact Data Notice Sent by citymarket@newbrunswick.com powered b=
y Try email marketing for free today!
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Content-Transfer-Encoding: quoted-printable

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 maximum-scale=3D1">
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text-indent: -1em;
padding: 0;
margin: 0;
line-height: 1.2;
}
ul, ol {
padding: 0;
margin: 0 0 0 40px;
}
p {
```

```
free today!</a>
                      </div>
                     =20
                     =20
                    </td>
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              </td>
            </tr>
          </table>
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------=_Part_550097535_1238800096.1643841703083--
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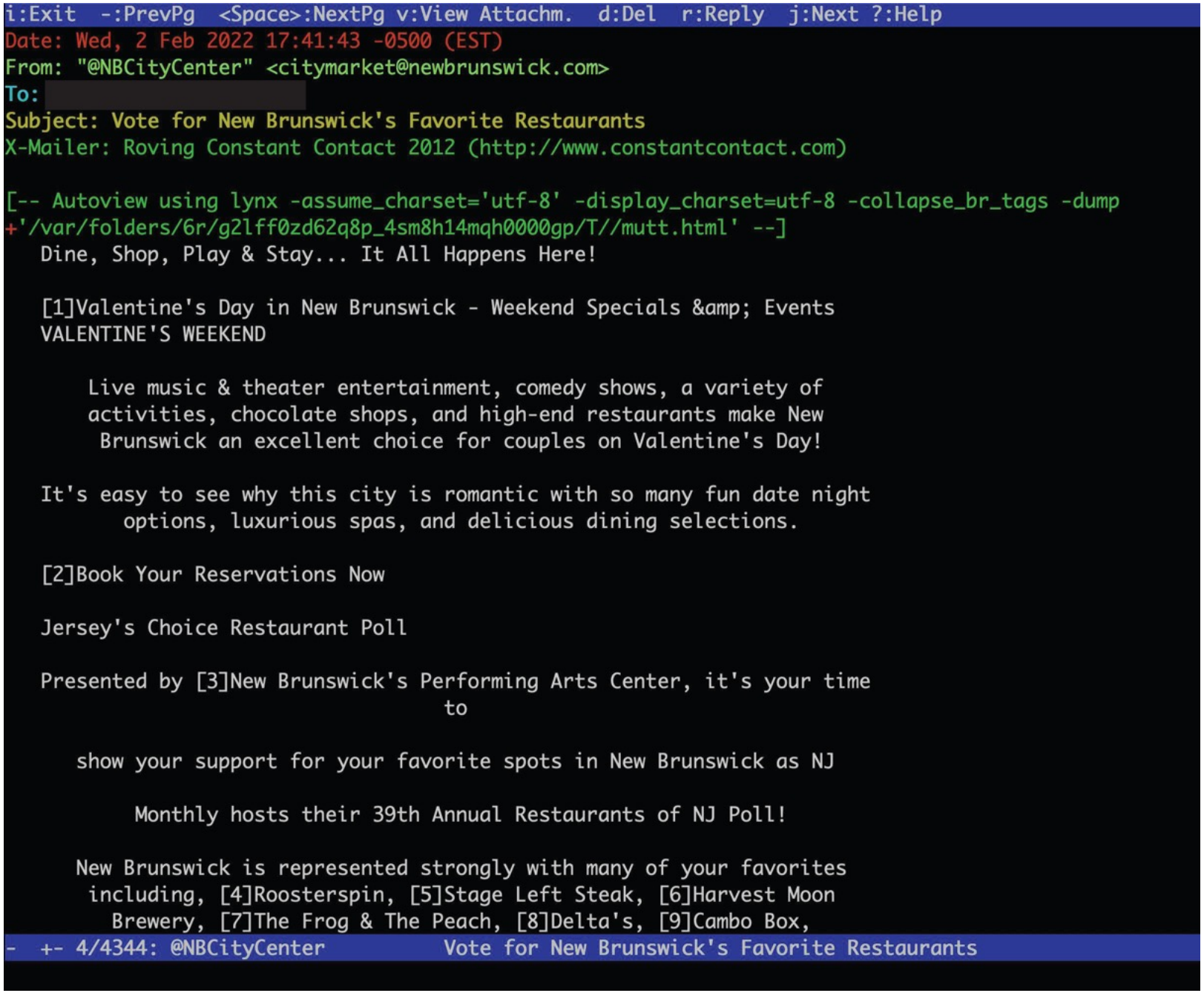
i:Exit -:PrevPg <Space>:NextPg v:View Attachm. d:Del r:Reply j:Next ?:Help
Date: Wed, 2 Feb 2022 17:41:43 -0500 (EST)
From: "@NBCityCenter" <citymarket@newbrunswick.com>
To:
Subject: Vote for New Brunswick's Favorite Restaurants
X-Mailer: Roving Constant Contact 2012 (http://www.constantcontact.com)
[-- Autoview using lynx -assume_charset='utf-8' -display_charset=utf-8 -collapse_br_tags -dump
+'/var/folders/6r/g2lff0zd62q8p_4sm8h14mqh0000gp/T//mutt.html' --]
Dine, Shop, Play & Stay... It All Happens Here!
[1]Valentine's Day in New Brunswick - Weekend Specials & Events
VALENTINE'S WEEKEND
Live music & theater entertainment, comedy shows, a variety of
activities, chocolate shops, and high-end restaurants make New
Brunswick an excellent choice for couples on Valentine's Day!
It's easy to see why this city is romantic with so many fun date night
options, luxurious spas, and delicious dining selections.
[2]Book Your Reservations Now
Jersey's Choice Restaurant Poll
Presented by [3]New Brunswick's Performing Arts Center, it's your time
to
show your support for your favorite spots in New Brunswick as NJ
Monthly hosts their 39th Annual Restaurants of NJ Poll!
New Brunswick is represented strongly with many of your favorites
including, [4]Roosterspin, [5]Stage Left Steak, [6]Harvest Moon
Brewery, [7]The Frog & The Peach, [8]Delta's, [9]Cambo Box,
- +- 4/4344: @NBCityCenter Vote for New Brunswick's Favorite Restaurants

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Content-Disposition: attachment;
        filename="screenshot.png"
Content-Transfer-Encoding: base64
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Content-ID: <f_kz66ba9k0>

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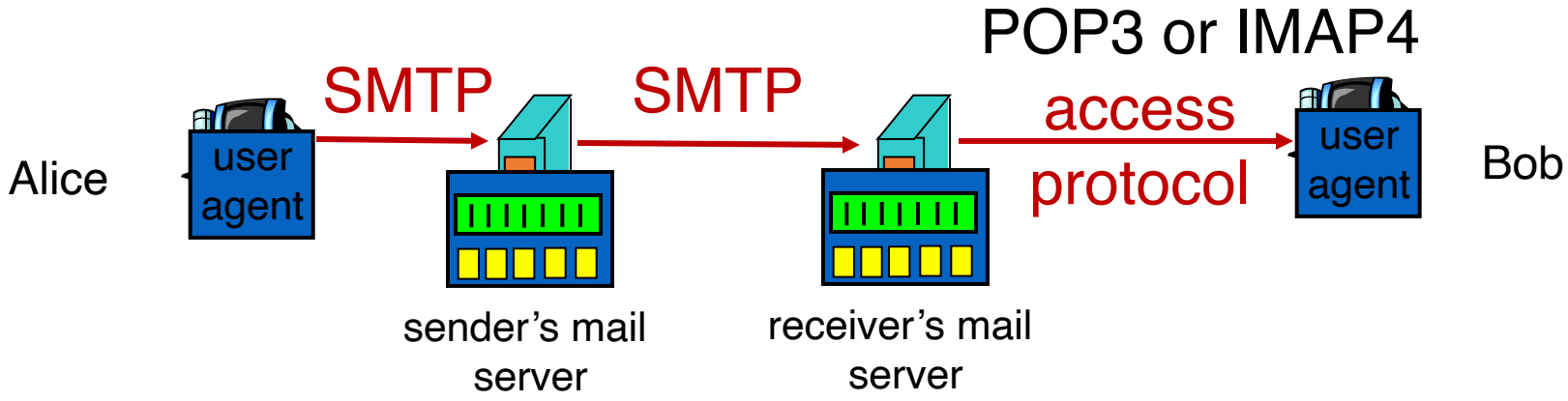
Mail Access Protocols

Mail access protocols



- SMTP: delivery/storage to receiver's server. Focused on push
- Mail access protocol: pull from server
  - POP: Post Office Protocol [RFC 1939]
    - Client connects to POP3 server on TCP port 110
  - IMAP: Internet Mail Access Protocol [RFC 1730]
    - Client connects to TCP port 143. Many desktop mail clients use IMAP.
  - HTTP: gmail, outlook, etc.

Web-based email

- Connect to mail servers via web browser
  - Ex: gmail, scarletmail, etc.

- Browsers speak HTTP
- Email servers speak SMTP
- Need to bridge these two

Web based email

HTTP

Application process on the web server machine uses SMTP to push mail

A

a@scarletmail.rutgers.edu

HTTP server
scarletmail.rutgers.edu

May run on the same or different machines (owned by your webmail provider)

SMTP Client/Server
aspmx4.googlemail.com

A's mail provider's server(s)

Internet

HTTP server
outlook.com

HTTP

B

App process on the web server uses access protocol to pull email

SMTP server
outlook-com.olc.protection.outlook.com

B's mail provider's server(s)

IMAP

B
b@outlook.com

Comparing SMTP with HTTP

- HTTP: pull
- SMTP: push

- Both have ASCII command/response interaction, status codes

- HTTP: each object encapsulated in its own response msg
- SMTP: multiple objects sent in multipart msg

- HTTP: can put non-ASCII data directly in response (dedicated entity body for binary data)
- SMTP: need ASCII-based encoding (base64)

More themes from app-layer protocols

- Keep it simple until you really need complexity
  - Start with ASCII-based design. Stateless servers. Then introduce:
  - Cookies for HTTP state
  - Multimedia extensions (MIME) in e-mail
- Performance optimizations often after-thought: e.g., caching
- Security extensions too! (e.g., HTTPS, IMAPS, SMTPS, …)
- Use headers to evolve without breaking old functionality
- Partition functions based on what's best at each place. Examples:
  - Content rendering (browser, UA) vs. protocol operations (mail server)
  - Mail UAs can be unavailable. Rely on mail server for reliable delivery (an "infrastructure" concern). UA will use access protocol later

Multimedia:
Data Representations

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Multimedia networking

- Many applications on the Internet use audio or video
- IP video traffic will be 82 percent of all IP traffic […] by 2022, up from 75 percent in 2017
- CCTV traffic over the Internet will increase sevenfold between 2017 to 2022
- Internet video to TV will increase threefold between 2017 to 2022.
- Consumer Video-on-Demand (VoD) traffic will nearly double by 2022

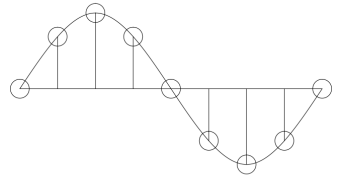
Source: Cisco visual networking index 2017--22

What's different about these applications?

- Traditional applications (HTTP(S), SMTP)
  - Delay tolerant but not loss tolerant
  - Data used *after* transfer complete
- Multimedia applications are often real time
  - Data delivery time *during transfer* matters for user experience
- Video/audio streaming
  - Delay-sensitive
- Real-time audio and video
  - Delays > 400 ms for audio is a bad user experience
  - Somewhat loss tolerant

Digital representation of audio and video

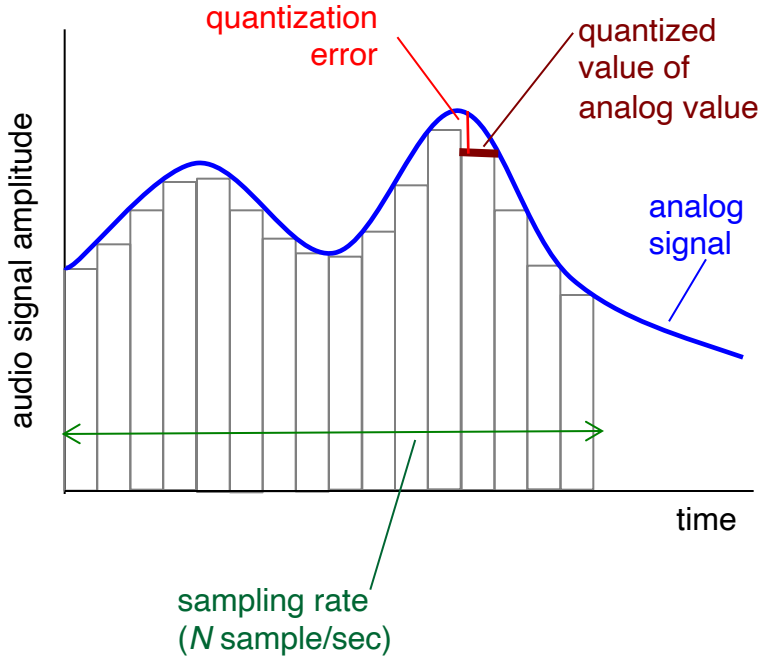
Digital representation of audio



- Must convert analog signal to digital representation
- Sample
  - How many times (twice the max frequency in the signal)
- Quantize
  - How many levels or bits to represent each sample
  - More levels ➔ more accurate representation of signal
  - More levels ➔ more bits to store & need more bandwidth to transmit
- Compress
  - Compact representation of quantized values

Audio representation

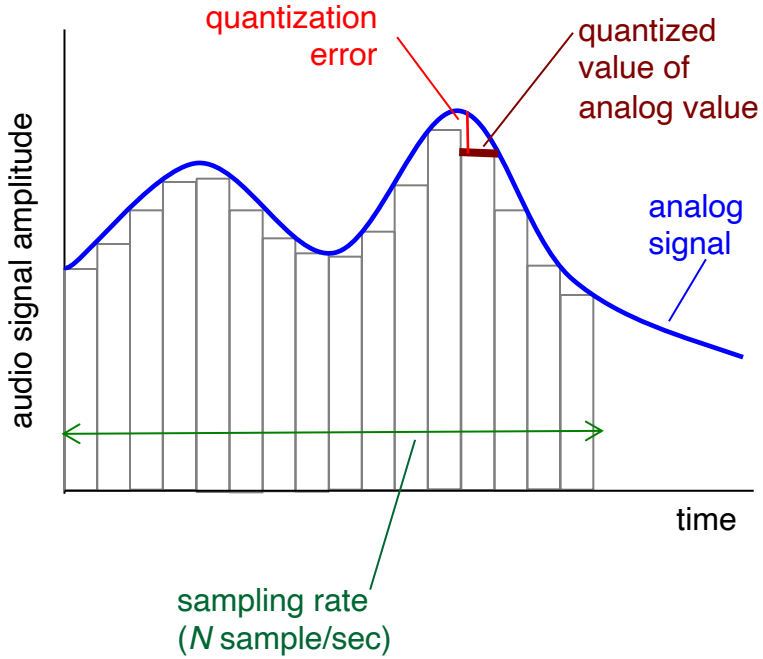
- analog audio signal sampled at constant rate
  - telephone: 8,000 samples/sec
  - CD music: 44,100 samples/sec
- each sample quantized, i.e., rounded
  - e.g., 2^8=256 possible quantized values
  - each quantized value represented by bits, e.g., 8 bits for 256 values



Audio representation

- example: 8,000 samples/sec, 256 quantized values
- Bandwidth needed: 64,000 bps

- receiver converts bits back to analog signal:
  - some quality reduction

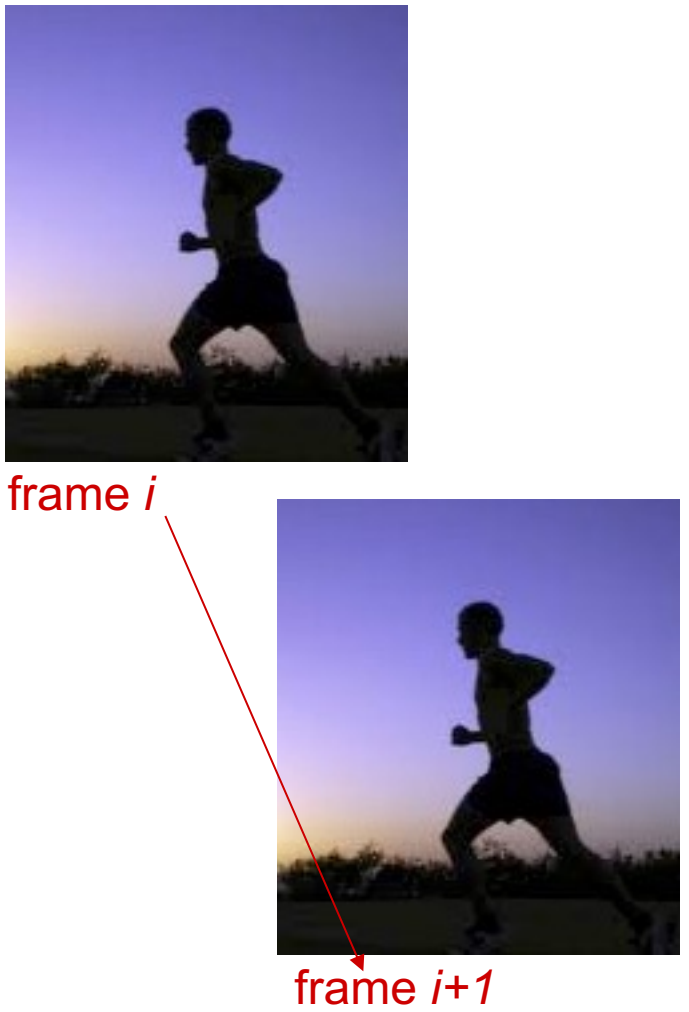


Example rates

- CD: 1.411 Mbps
- MP3: 96, 128, 160 Kbps
- Internet telephony: 5.3 Kbps and up

Video representation

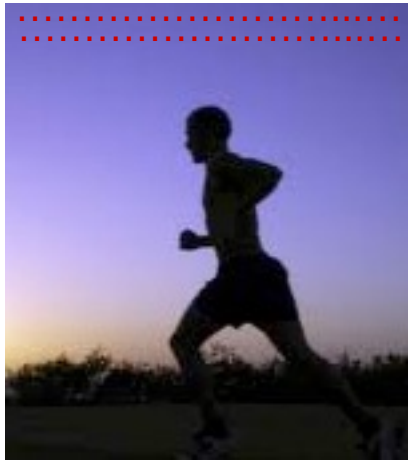
- Video: sequence of images displayed at constant rate
  - e.g., 30 images/sec
  - Appear continuous due to the stroboscopic effect



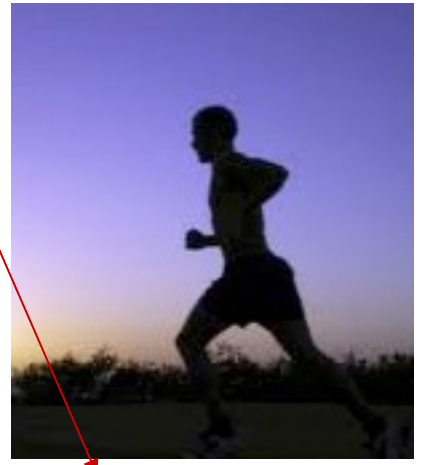
Video representation

- Digital image: array of pixels
  - each pixel represented by bits
  - Encode luminance and color
  - Number of pixels: resolution
- Coding: use redundancy *within* and *between* images to decrease # bits used to encode image
  - spatial (within image)
  - temporal (from one image to next)
- Coding/decoding algorithm often called a codec

spatial coding example: instead of sending *N* values of same color (all purple), send only two values: color value (*purple*) *and number of repeated values* (N)



frame *i*



frame *i+1*

temporal coding example: instead of sending complete frame at i+1, send only differences from frame i (motion vectors)

Video codecs: terminology

- Video *bit rate*: effective number of bits per second of the video after encoding
- It depends on many factors
  - Resolution of each image: more pixels = more bits
  - Detail per pixel: better luminance & color detail = more bits
  - Amount of movement in the video. More movement = more bits
  - Quality of overall compression in the codec
- Video bit rate is typically correlated with quality of perception.
  - Higher bit rate == better to perceive

Bit-rates: terminology

- Bit-rate of a video changes over the duration of the video
- CBR: (constant bit rate): fixed bit-rate video
- VBR: (variable bit rate): different parts of the video have different bit rates, e.g., changes in color, motion, etc.
  - For VBR, we talk about average bit-rate over video's duration
- Examples of average video bit-rates
  - MPEG 1 (CD-ROM) 1.5 Mbps. MPEG2 (DVD) 3-6 Mbps
  - MPEG4 (often used in Internet, < 1 Mbps)
  - In general, one Internet video stream takes up a few Mbit/s (unless HD)

https://blog.video.ibm.com/streaming-video-tips/what-is-video-encoding-codecs-compression-techniques/

Networking multimedia: 3 types

- On-demand streamed video/audio
  - Can begin playout before downloading the entire file
  - Ful video/audio stored at the server: able to transmit faster than audio/video will be rendered (with storing/buffering at client)
  - e.g., Spotify, YouTube, Netflix
- Conversational voice or video over IP
  - interactive human-to-human communication limits delay tolerance
  - e.g., Zoom, Google Stadia
- Live streamed audio, video
  - e.g, sporting event on sky sports
  - Can buffer a little, but must be close to the “live edge” of content