Outline
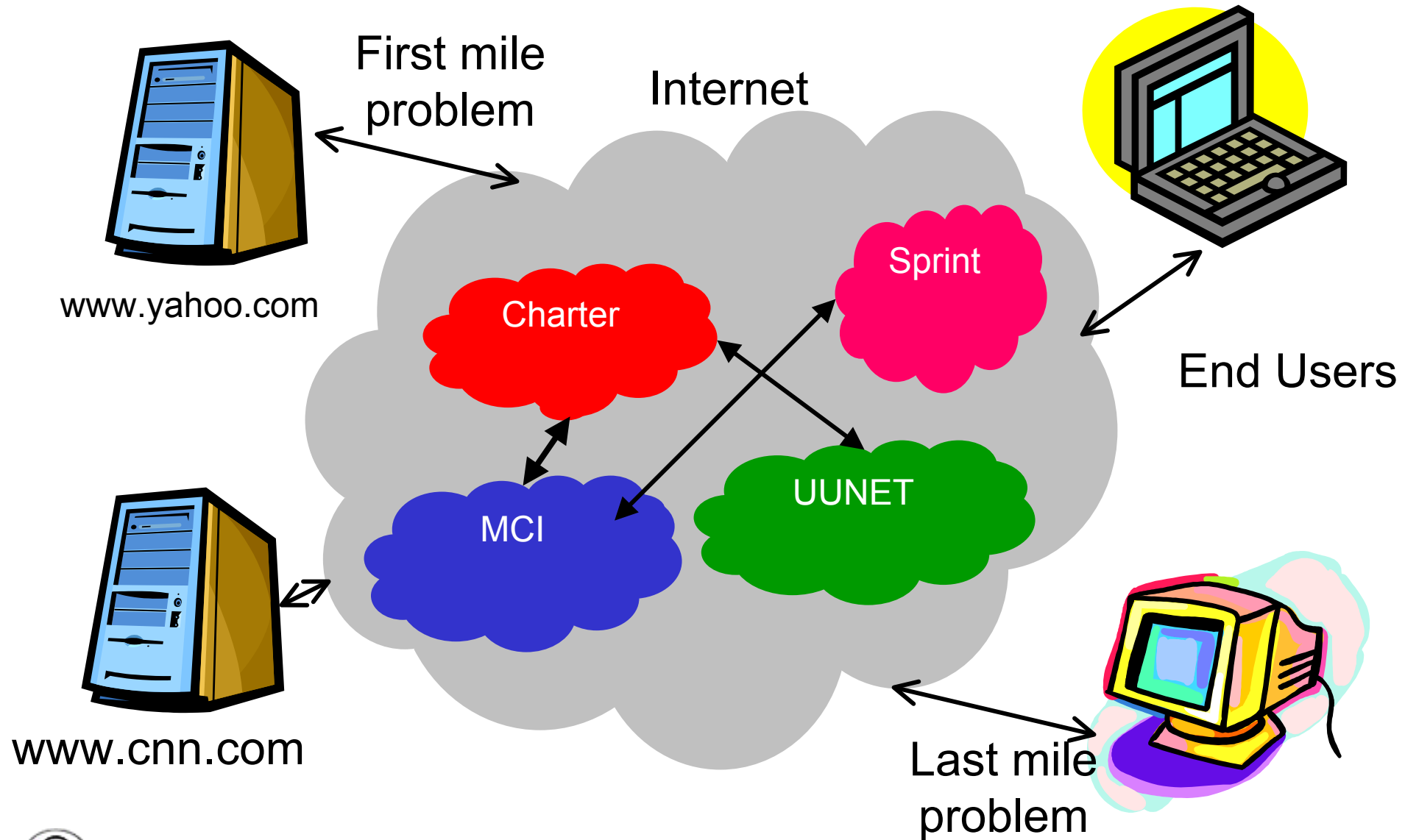
- Naming

- Applications
  - Central Server
  - Hierarchical
  - Peer-to-peer (Cont)

Internet

First mile problem

Internet

www.yahoo.com

Charter

Sprint

MCI

UUNET

End Users

www.cnn.com

Last mile problem

Performance bottlenecks

- First mile problem:
  - Server to the Internet
  - Everyone wants to access one popular service

- Last mile problem:
  - End user to the Internet
  - Broadband (cable, DSL), T1, T3, dialup, 2G cellular (slow)

- Peering problem:
  - Data goes through multiple networks and service providers at peering points

- Backbone problem:
  - The information highway for data traffic

Content delivery network

- Move server replicas to the edge

Internet

www.yahoo.com

Charter

Sprint
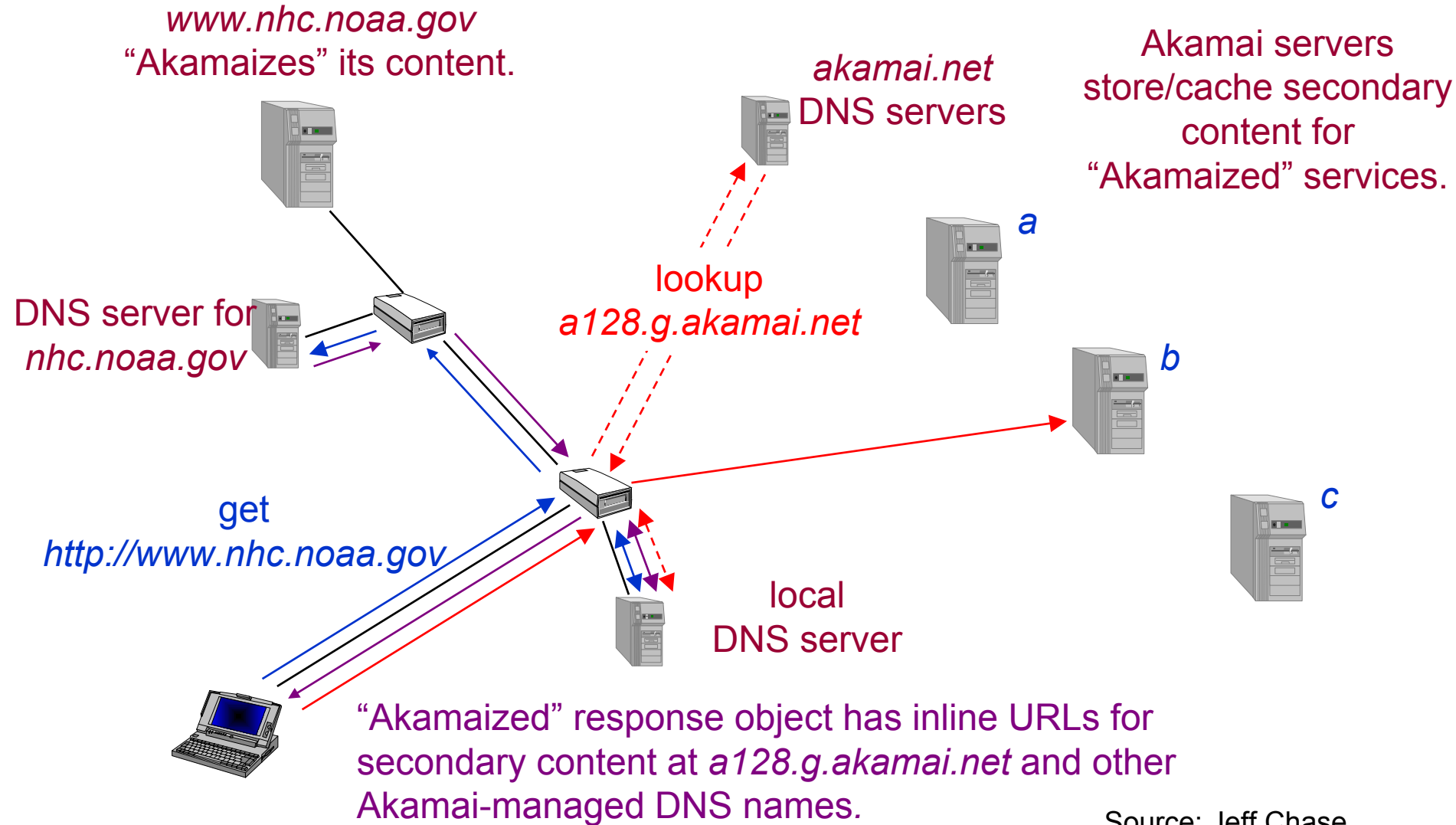
End Users

MCI

UUNET

www.cnn.com
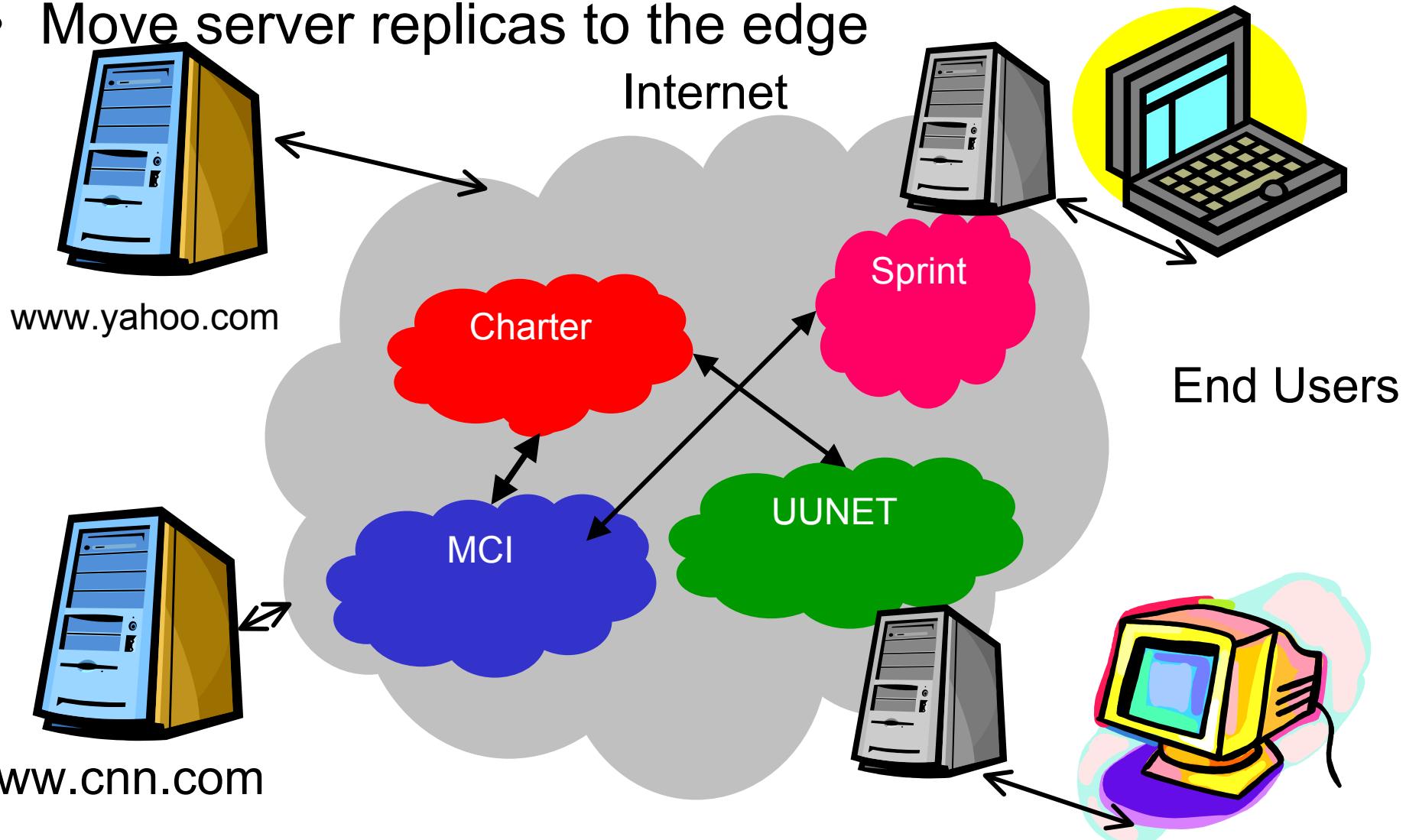
Content Delivery Network

– CDN (e.g., Akamai) creates new domain names for each client content provider.

- e.g., *a128.g.akamai.net*

– The CDN's DNS servers are authoritative for the new domains.

– The client content provider modifies its content so that embedded URLs reference the new domains.

- "Akamaize" content

- e.g.: http://www.cnn.com/image-of-the-day.gif becomes

  http://a128.g.akamai.net/image-of-the-day.gif

– Using multiple domain names for each client allows the CDN to further subdivide the content into groups.

- DNS sees only the requested domain name, but it can route requests for different domains independently.

Source: Jeff Chase

Akamai with DNS hooks

www.nhc.noaa.gov
"Akamaizes" its content.

akamai.net
DNS servers

Akamai servers
store/cache secondary
content for
"Akamaized" services.

a

DNS server for
nhc.noaa.gov

lookup
a128.g.akamai.net

b

get
http://www.nhc.noaa.gov

c

local
DNS server

"Akamaized" response object has inline URLs for
secondary content at *a128.g.akamai.net* and other
Akamai-managed DNS names.

Source: Jeff Chase

Peer-to-peer systems

- Decentralized, no "server"
- Robust – no single point of failure
- "Will perform work for others since they will work for us" computing
- Can scale up

- Locating resources harder
- E.g. napster (has a central directory server)
      gnutella

Gnutella

- Queries issued by a servant at a given node propagate out to neighbor nodes

- The neighbors propage the query to their neighbors, and so on, for a given number of hops.

- Depending on where a user's query is first issued, it may or may not reach a node that has the file sought by the user.

Partial Map of Gnutella Network – 7/27/00

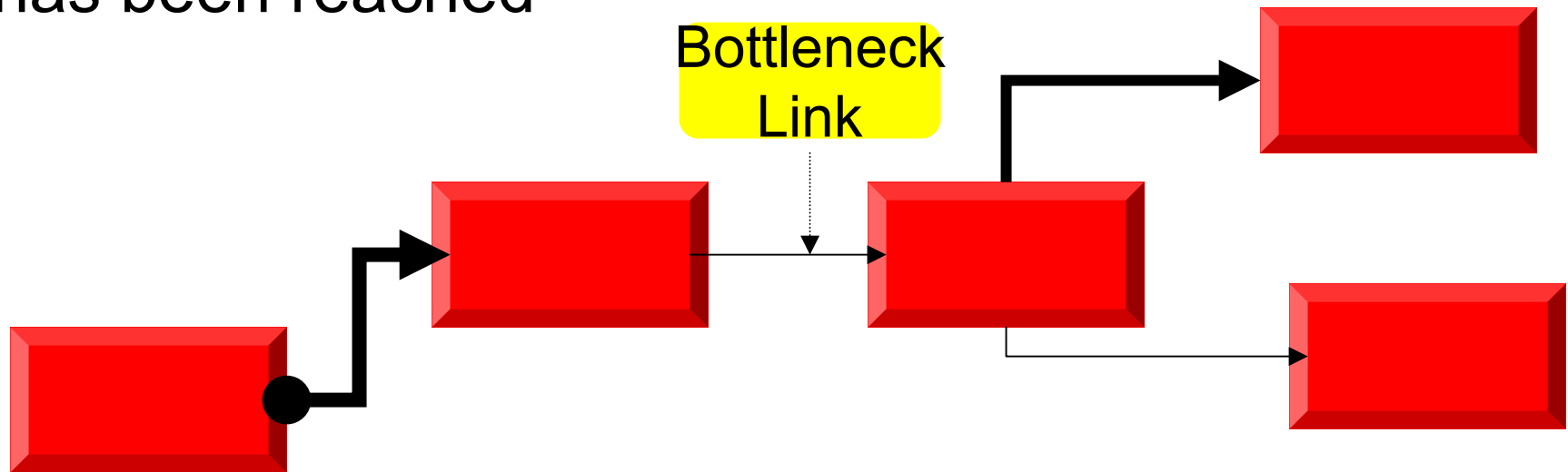Clip2 Distributed Search Services

http://dss.clip2.com
(c)2000 Clip2.com, Inc.
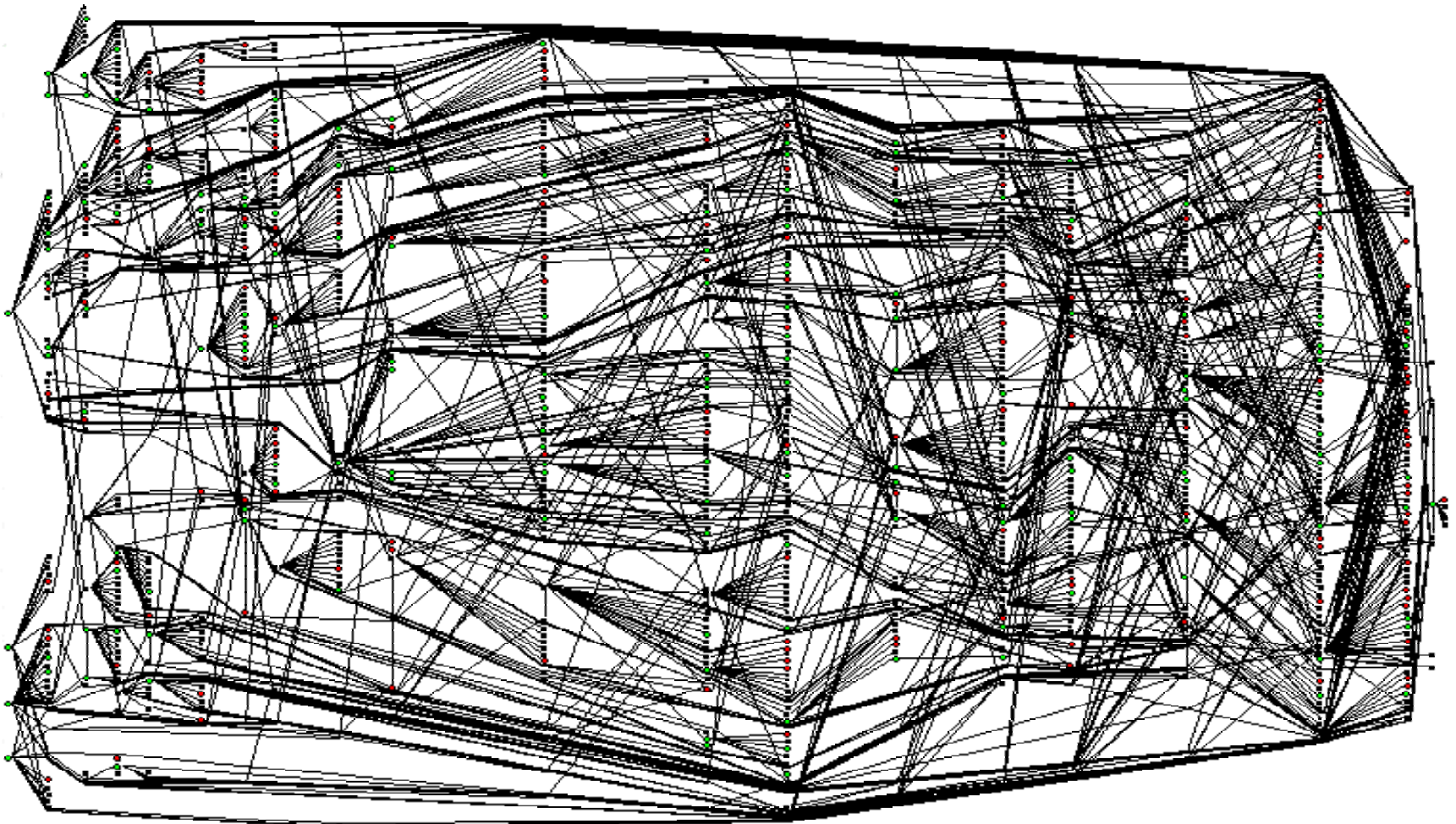
Scalability

- The scalability of a Gnutella network to accommodate more users performing more searches is limited by the lowest bandwidth links prevalent within the network

- For dial-up users it is 10 requests per second and has been reached

Bottleneck Link

Internet RFC

- Request for comment (RFC) (started in 1969)
  - In informal way to publish new ideas/protocols
  - First publish Internet Drafts before publishing as RFC
  - RFC can be obsoleted by newer RFCs, not modified
  - Some of them become standards

- Check out www.rfc-editor.org
  - RFC 0133 **File Transfer and Recovery** R.L. Sundberg [Apr 1971]
  - RFC 1889 **RTP: A Transport Protocol for Real-Time Applications** Audio-Video Transport Working Group, H. Schulzrinne, S. Casner, R. Frederick, V. Jacobson [January 1996]
  - RFC 1945 **Hypertext Transfer Protocol -- HTTP/1.0** T. Berners-Lee, R. Fielding, H. Frystyk [May 1996]
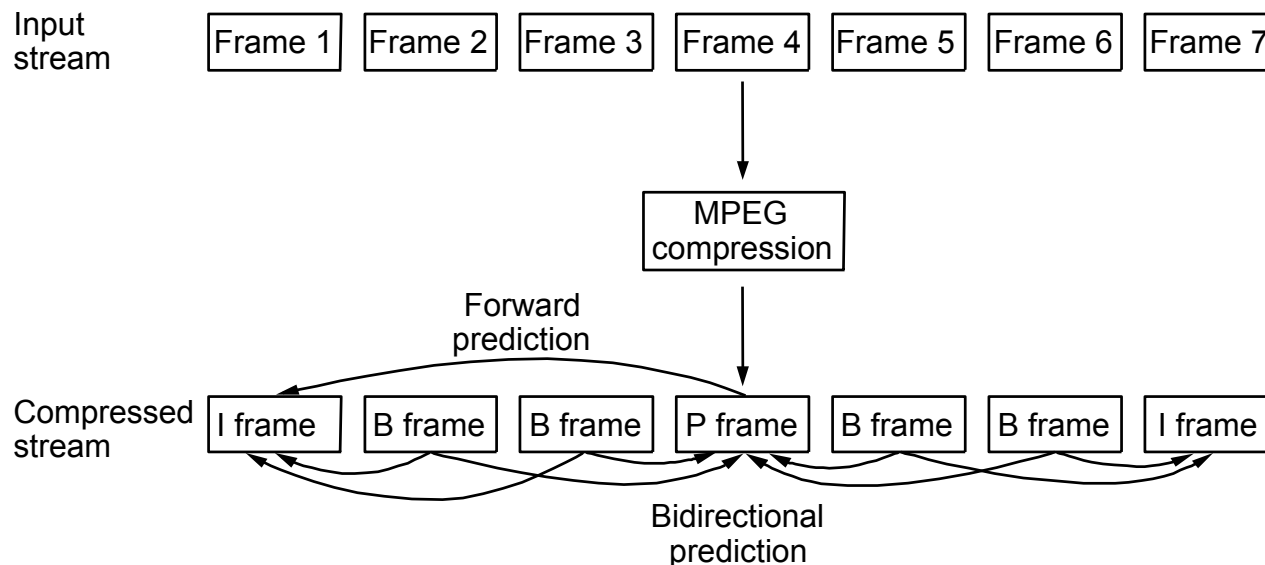
Multimedia streams

- Variable bit rate requirements
  - The data rate requirements changes with time

- Real time requirements to avoid jitter (packet not arriving on time)

- Need to efficiently transmit lots of data to many clients (multicasting)

MPEG

- Motion Picture Expert Group
- Lossy compression of video
- First approximation: JPEG on each frame
- Also remove inter-frame redundancy

MPEG (cont)

- Frame types
  - I frames: intrapicture
  - P frames: predicted picture
  - B frames: bidirectional predicted picture

Input stream

Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7

MPEG compression

Forward prediction

Compressed stream

I frame	B frame	B frame	P frame	B frame	B frame	I frame

Bidirectional prediction

- Example sequence transmitted as I P B B I B B

MPEG (cont)

- B and P frames
  - coordinate for the macroblock in the frame
  - motion vector relative to previous reference frame (B, P)
  - motion vector relative to subsequent reference frame (B)
  - delta for each pixel in the macro block

- Effectiveness
  - typically 90-to-1
  - as high as 150-to-1
  - 30-to-1 for I frames
  - P and B frames get another 3 to 5x

RTP

- Application-Level Framing

- Data Packets
  - sequence number
  - timestamp (app defines "tick")

- Control Packets (send periodically)
  - loss rate (fraction of packets received since last report)
  - measured jitter

Real-Time Scheduling

- Priority

- Earliest Deadline First (EDF)

- Rate Monotonic (RM)

- Proportional Share
  - with feedback
  - with adjustments for deadlines