

Introduction to Content Delivery Networks

References

- Long Live the Web, by Tim Berners-Lee, 2010

http://www.cs.virginia.edu/~robins/Long_Live_the_Web.pdf

- History of the Internet

http://en.wikipedia.org/wiki/History_of_the_Internet

Intro

- ❑ The Early Days
- ❑ The WWW
- ❑ The Evolution of Content Networking
- ❑ The Diversity of Interests

The Early Days

- ❑ First application dedicated to content delivery:
 - The electronic distribution of documents, mainly research papers

The Early Days

- Evolution
 - FTP - File Transfer Protocol
 - Used for information retrieval

The Early Days

□ Evolution

➤ FTP - File Transfer Protocol

- Used for information retrieval

➤ Archie

- Search and catalog info available in FTP servers, by file name

The Early Days

□ Evolution

- FTP - File Transfer Protocol
 - Used for information retrieval
- Archie
 - Search and catalog info available in FTP servers, by file name
- WAIS - Wide Area Information Server
 - Search and catalog info available in FTP servers, by keywords
 - Scored responses, ranking retrieved information based on the quantity of keyword appearance
 - WAIS Inc. was the first company to commercialize technology related to content delivery

The Early Days

□ Evolution

- FTP - File Transfer Protocol
 - Used for information retrieval
- Archie
 - Search and catalog info available in FTP servers, by file name
- WAIS - Wide Area Information Server
 - Search and catalog info available in FTP servers, by keywords
 - Scored responses, ranking retrieved information based on the quantity of keyword appearance
 - WAIS Inc. was the first company to commercialize technology related to content delivery
- Gopher
 - Evolution of WAIS
 - Capable of hierarchical organization

Intro

- ❑ The Early Days of Content Delivery
- ❑ The WWW
- ❑ The Evolution of Content Networking
- ❑ The Diversity of Interests

The World Wide Web

- ❑ Internet application that links information accessible via networked computers
- ❑ Information
 - Web pages, which can contain
 - text, graphics
 - animations - audio/video
 - hyperlinks

The World Wide Web

□ Hyperlinks

- Hyperlinks are embedded in documents
- Important feature of the Web, differentiates it from early approaches
- Connect a web page to other resources, local or remote
- Enables navigation
 - browsing through information without having to know their actual location

The World Wide Web

❑ The origin of the WWW

➤ CERN, European Organization for Nuclear Research, Switzerland

- Big lab, lots of projects and experts
- Needed to support dynamic, non-centralized interaction and quick access to documents stored at secluded locations
- In 1989, Tim Berners-Lee proposes using hypertext for linking information available on individual computers

The World Wide Web

➤ CERN, Switzerland

- The hypertext concept had been proposed earlier (45, 67, 68)
 - Hypertext documents embed hyperlinks - represented as underlined texts or icons. By selecting and clicking on a hyperlink, associated information is loaded and displayed.
- Tim's proposal:
 - extend the hypertext concept to allow linking of information that can be stored on remote computers
 - create a tool which allows transparent access to remote information
- CERN approved the proposal and Tim implemented a hypertext browser/editor, finishing the 1st version at the end of 1990.

The World Wide Web

□ The origin of the WWW

➤ First browsers

- Erwise
- ViolaWWW
- MidasWWW

➤ Early 90s

- ~50 web-servers
- the WWW traffic accounted for 0.1% of the Internet traffic

The World Wide Web

❑ The origin of the WWW

➤ Real breakthrough -- Early 1993

- Mosaic - the 1st widespread graphical web browser
- Developed at NCSA by Andreessen and Bina
- User-friendly interface
 - Clickable buttons, easy navigation controls, allowed to scroll through text
- Free and easy to install
 - Allowed beginners to take advantage of the new, exciting web technology

The World Wide Web

❑ The origin of the WWW

- In 1994, Mosaic became Netscape ...
 - As Andreessen and Bina graduated and moved to Silicon Valley to commercialize their software
- ... and the Web really started to grow
 - From ~500 websites in 1994 to ~10,000 in the beginning of 1995
- Netscape quickly became the predominant browser
 - by 1996, about 75% of the Web users used Netscape

The World Wide Web

❑ The origin of the WWW

➤ Microsoft gets into the picture

- Noticing the growing importance of the Web and Netscape's enormous business success, Microsoft Corporation got into the act and started developing its own browser software - the Internet Explorer
- "The Browser War"
 - Quick innovation
 - Free browser software
 - Incompatibilities
- Microsoft crushed Netscape (and others)
 - In 2005, accounting for ~80-90% of the browsers used in the Internet

The World Wide Web

❑ The origin of the WWW

➤ Meanwhile, in "server-land"

- Apache has always dominated the server world with its open source

<http://news.netcraft.com/archives/2014/09/24/september-2014-web-server-survey.html>

➤ With Microsoft in the picture

- New trend toward an increased commercialization of the Web
- The Web has become the center for internet activity
 - with many people actually not realizing the difference between the Internet and the Web.

The World Wide Web

- ❑ The origin of the WWW
 - The amount of information and services available
 - has increase at a staggering rate
 - This tremendous growth causes problems
 - Scalability
 - Reliability
 - Unpredictable service quality
 - High download delays
 - Security

The World Wide Web

□ Basic Concepts of the WWW

➤ The Web

- large universe linking information accessible via the Internet

➤ Information

- Web pages, or Web objects

➤ Web objects

- made available on computers, the Web servers

The World Wide Web

□ Basic Concepts of the WWW

- Users request Web objects from a Web server via the Internet
- Web client
 - The application initiating the request
- Request is made in two ways
 - Address typed in the browser
 - Clicking of a pre-defined link
- Homepage
 - Entry portal to a Web site

The World Wide Web

- ❑ The Web model involves 3 main concepts
 - A common representation format for hypertext documents
 - A scheme for naming and addressing Web objects
 - A standard mechanism for transmitting control and data messages between server and client

The World Wide Web

□ Representing of Web objects

➤ HTML - HyperText Markup Language

- Defines the representation for hypertext documents
- Originally specified by Tim Berners-Lee in the beginning the 1990s, has been developed and extended
- Standardization started at the IETF and is now carried out by the W3C - World Wide Web Consortium

The World Wide Web

□ Representing of Web objects

➤ HTML - HyperText Markup Language

- Defines the layout and formatting of a Web page
- Allow authors to embed hyperlink references to other resources on the Web
- Relatively simple syntax, expressed in plain ASCII format
- Tools are now available to export documents in HTML automatically
- Ease of page creation has helped to fuel the growth of the Web

➤ Possible to have Web pages in other formats, but the layout will be transparent to the browser and there will be no hyperlinks

The World Wide Web

□ Identifying Web objects

➤ Two pieces of information

- Name
- Location

➤ URI - Uniform Resource Identifier

- URN - Uniform Resource Name
- URL - Uniform Resource Location
 - <protocol>://<server>/<path>

The World Wide Web

□ Transporting Web objects

- The Web operation depends on communication
- Requires a communication protocol
 - Defines the rules, syntax, and semantics for the interaction
 - Specifies a message format and semantic rules to be applied to the various parts of the message
- HTTP - Hypertext Transport Protocol
 - Main transport mechanism on the Web
 - Application-level protocol

The World Wide Web

□ Transporting Web objects

➤ HTTP

- Request-response
- Text-based
- Stateless
 - Improves simplicity and scalability
 - Complicates the implementation of Web sites that needs to react according to previous information
 - ➔ Solution: Cookies and JavaScript

The World Wide Web

□ Applications on the WWW

- The growth and evolution of the WWW are mainly driven and heavily influenced by applications written and used by business and individuals
- Underlying Web technology
 - needs to follow the trends and developments in the application area

The World Wide Web

□ Applications on the WWW

➤ Evolution - content delivery

- Retrieving static content
- Retrieving dynamic content
- Retrieving streaming content
- Interactive collaboration

The World Wide Web

□ Model 1: Retrieving static content

- Static content comprises stored documents that reside on Web servers for retrieval by users
- Information change infrequently
- Changes require explicit modification by the author
- Typical usage
 - Accessing personal homepages
 - Fetching research papers
- Limited interaction with the user
- Not suitable for frequently changing data

The World Wide Web

- **Model 2: Retrieving dynamic content**
 - Dynamic content made new levels of interaction possible
 - Dynamic content is created only at the time it is requested
 - Final form is not stored
 - It is created with information created or gathered at the time of the request
 - Contents are typically generated by a program run at the server
 - **Pages can be customized**
 - According to information given by the requesting user
 - According to the capability of the user's end device or network connection
 - Resulting page looks may look different for different users
 - **Typical usage**
 - Content portals: news, stock quotes, weather forecasts
 - Examples: My Yahoo! and eBay

The World Wide Web

□ Model 3: Retrieving streaming content

- Deliver of continuously flowing media such as audio and video
 - Streaming technology establishes a steady data flow from the server to the client
- Different from playback!
 - No need to wait for the download
- Two main categories
 - On-demand streaming - deliver of pre-recorded content to many users at different times
 - Live streaming - broadcast of live content to many users at the same time

The World Wide Web

□ Model 4: Interactive collaboration

- Allows two or more users to interact in real-time
 - Users typically react to previous actions of other users in real time
- Examples:
 - Videoconferencing
 - Networked gaming
 - Instant messaging
- Challenges
 - Need to transfer data synchronously with low delay, in real time, for a potentially large number of users

The World Wide Web

□ Applications on the WWW

➤ Evolution -- content

- Web 1.0
 - Read or write
- Web 2.0
 - Read and write
- Web 3.0 -- Semantic Web
 - Read, write, and request

The World Wide Web

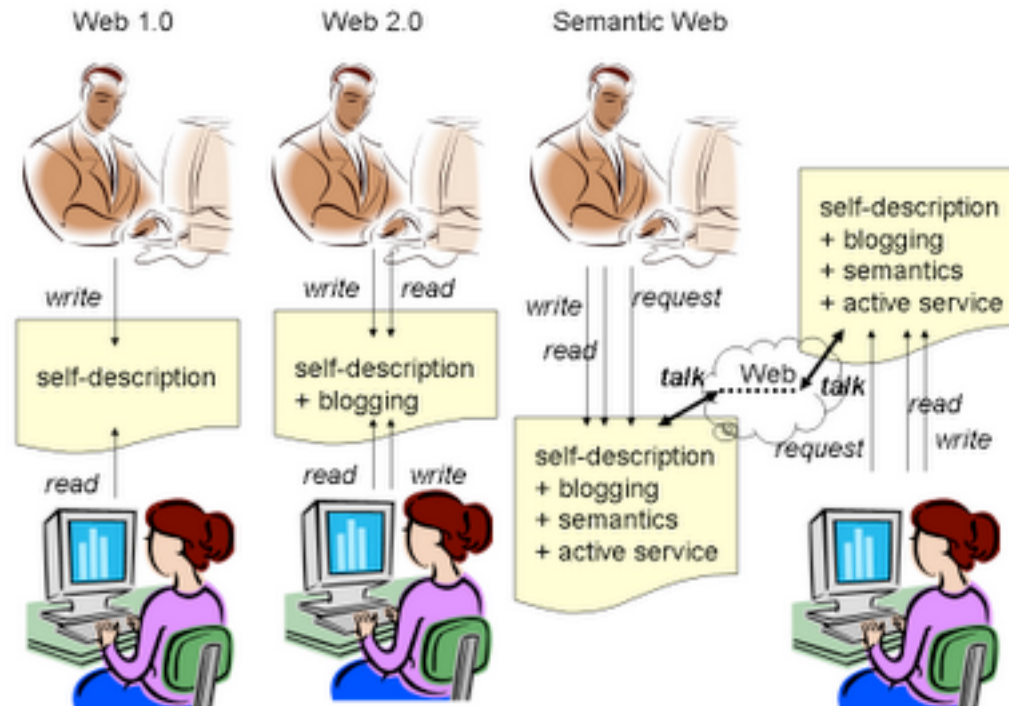


Image from Thinking Space by Yihong Ding

<http://www.zdnet.com/blog/web2explorer/a-simple-picture-of-web-evolution/408>

The World Wide Web

□ Applications on the WWW

➤ The evolution

- The way in which the Web is used has exposed some shortcomings of the traditional internet/web model

➤ Consequence

- Content Network
 - ➔ Enhanced network technology overlaying the Internet

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- ❑ The Diversity of Interests

The Evolution of Content Networking

□ Web evolution

- Fast growth in number of users
- Enormous growth in network traffic
- Decrease in service quality
 - Delay
 - Unavailability
- Users abandon slow-response sites
 - Lost sales and dissatisfied customers

The Evolution of Content Networking

□ Web evolution

- Web-based e-commerce represents significant business
- Important to invest in improving service quality
- Important to invest in the Content Network
 - Technologies that aim to improve content delivery and service provisioning

The Evolution of Content Networking

□ The Traditional Web Model

- The Web is highly decentralized and distributed
 - Decentralization helped the growth and propagation
- The simplicity of Web site creation
 - results in an ever-increasing variety of content offered over the web

The Evolution of Content Networking

□ The Traditional Web Model

➤ A small number of pages accounts for the majority of user requests

- Enable content portals to cover a large percentage of requests
- Provides the opportunities for performance improvements

The Evolution of Content Networking

□ The Traditional Web Model

➤ The service model is centralized

- Consequences

- Bottlenecks at popular servers and/or Internet links to popular servers
- Scalability Issues

- Worse yet

- Extreme traffic peaks

The Evolution of Content Networking

□ The Traditional Web Model

➤ The service model is centralized

■ Another problem

- Distance between server and clients leads to delays
 - » Plain delay
 - » Packet loss
 - » Geographic distance
 - ★ Network distance (in number of routers)
- Need to minimize network distance

The Evolution of Content Networking

❑ The Traditional Web Model

➤ High-speed always-on Internet access

- Big problem - getting worse with smart phones!
- more use → more sites → more traffic

➤ Result

- Low-service quality, due to high delay
- Unstable throughput
- Loss of packets

The Evolution of Content Networking

□ Evolutionary Steps

➤ Adding more ...

- Bandwidth
- Capacity power
- Quality-of-service support

... not enough

The Evolution of Content Networking

□ Evolutionary Steps

➤ More dynamic content network

- Load-balanced server farms
- Replication of contents
- Web caches
- Content and Web Services

The Evolution of Content Networking

❑ Evolutionary Steps

➤ Distributing load at a centralized server

- Web server: potential bottleneck
- Simple solution: more powerful servers
- Scalable and flexible solution: server farms
 - In the same location, connected to the same subnet
 - Can be connected to multiple ISPs for extra performance gains
 - Requests pass through a front-end load balancer
 - Devices: Web Switch, Content Switch
 - Extra feature: fault tolerance

The Evolution of Content Networking

❑ Evolutionary Steps

➤ Distributing content and centralized services

- Distributing and moving content closer to the user
 - Decrease delay and load on the network
- Server replication
- Web caches
 - Browser caching → Stores requested Web objects locally
 - Proxy caching → Stores requested Web objects in an intermediate location between server and client, preferably close to client
- Web caches - evolution
 - Hierarchical caching
 - Cooperative caching

The Evolution of Content Networking

❑ Evolutionary Steps

➤ Distributing content and services

- New architectures and systems move server-side services out of the edge of the network, closer to the user
- Enables customization
 - Dynamic assembly of personalized Web pages
 - Content adaptation for wireless devices
- Trend ➔ framework for distributed Web applications
 - Web services architecture
 - Web services are interoperable building blocks for constructing complex Web applications

The Evolution of Content Networking

❑ Evolutionary Steps

- Simple → Complex

- Centralized model

 - Helped the Web to grow, but did not scale well

- Distributed content provisioning and applications

 - Increased complexity and higher initial costs

 - But scales better and provides better performance and reliability

- Example

 - Deploying server-side load balancing and web caching

The Evolution of Content Networking

□ Content Networking Defined

➤ Buzz terms

- Content Distribution
- Content Delivery
- Caching Overlays
- Proxy Networks

The Evolution of Content Networking

□ Content Networking Defined

➤ Terms

- Content

- Information that is made available to other users on the Internet

The Evolution of Content Networking

□ Content Networking Defined

➤ Terms

■ Content Networks

- Provides the **infrastructure** to better support delivery of relevant content over the Internet
- **Communication network** that deploys infrastructure components operating at protocols Layers 4-7.
 - » These components interconnect with one another, creating a virtual network layered on top of an existing packet network infrastructure

The Evolution of Content Networking

□ Content Networking Defined

➤ Terms

- Intermediaries

- Application-level **devices** that are part of Web transaction, but are neither the originating nor the terminating device in the transaction.
- Example: Web caches

The Evolution of Content Networking

□ Content Networking Defined

- Functional components of content networks
 - Content Distribution
 - Request-routing
 - Content processing
 - Authorization, authentication, and accounting
- Not all 4 are always available

The Evolution of Content Networking

□ Content Networking Defined

➤ Functional components of content networks

- Content Distribution

- Services (mechanisms and protocols) for moving content from source to users

- Request-routing

- Services for navigating user requests to a location best suited for retrieving the requested content

The Evolution of Content Networking

□ Content Networking Defined

➤ Functional components of content networks

- Content processing
 - Services for creating or adapting content to suit user preferences and device capabilities
- Authorization, authentication, and accounting
 - Services that enable monitoring, logging, accounting, and billing of content usage.

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The Diversity of Interests

- ❑ Every party has a different stake and incentive in the Internet business
- ❑ Disparity of interests
 - Cable companies and telephone providers
 - Want to provide access
 - ISPs
 - Want to provide access
 - Backbone service providers
 - Pressure to cope with traffic growth
 - E-commerce companies
 - Concerned about security, reliability, and performance

The Diversity of Interests

- Understanding this diversity
 - Important in the design and deployment of content networks
- Addressing the content-network beneficiaries
 - Value chain
 - Content provider
 - Content network provider
 - Content consumer

The Diversity of Interests

□ Value chain

➤ Content provider

- Typically, content creator \neq content host
- Challenge: response time and availability
- Trend: Hire a third party for providing
- Need some control
 - For example, to obtain feedback on usage

The Diversity of Interests

❑ Value chain

➤ Content network provider

- Provides
 - delivery,
 - caching,
 - replication,
 - request-routing,
 - possibly content processing
- Need to provide usage feedback to content providers
- Dilemma:
 - Aim to attract as many requests as possible, but needs to reduce the aggregate load on resources and network links

The Diversity of Interests

□ Value chain

➤ Content consumer

- High expectations for low delay and high throughput
- Needs tailored service (e.g., for wireless devices)

END