Outline

• Applications
  – Central Server
  – Hierarchical
  – Peer-to-peer
Networked distributed system architectures

Central Server based
   Web servers

Hierarchical Services
   Domain Name System – DNS

Peer-to-Peer Systems
   Napster, gnutella
Central Server based

• A central server provides service
  – Reliability and fault tolerance
    • If server shuts down, then no service
  – Scalability
    • Performance bottle neck
    • E.g. if everyone accesses Microsoft.com from the east coast (new release of web browser), accesses to Yahoo.com in California might be slow because we share the same link from east coast till Utah (say)
  – Easy to deploy, administer
Domain Name Service (DNS)

- Provides Internet domain name to IP address translation
  - Domain name translation (uga.edu)
  - Hostname translation (greenhouse.cs.uga.edu)
  - Service location (MX records, mail service for UGA)

$ nslookup –query=mx home.com
home.com preference = 100, mail exchanger = mx-d-rwc.mail.home.com
home.com preference = 150, mail exchanger = mx-a-rwc.mail.home.com
home.com preference = 100, mail exchanger = mx-c-tx.mail.home.com
home.com preference = 150, mail exchanger = mx-a-tx.mail.home.com
home.com preference = 175, mail exchanger = mx-a-va.mail.home.com
home.com preference = 50, mail exchanger = mx-rr.home.com

- Hierarchical
  - Decentralized administration of name space
  - Hierarchy of authority and trust
Domain Naming System Hierarchy

- edu
  - princeton
  - mit
  - cs
  - ee
  - physics
  - ux01
  - ux04

- com
  - cisco
  - yahoo

- gov
  - nasa
  - nsf

- mil
  - arpa
  - navy

- org
  - acm
  - ieee

- net
  - uk
  - fr

- gov
  - mil
  - org

- edu
  - com
  - gov
  - mil
  - org
  - net
  - uk
  - fr
DNS name space is *hierarchical*:
- fully qualified names are “little endian”
- scalability
- decentralized administration
- domains are naming *contexts*

Source: Jeff Chase
DNS Protocol

- UDP-based client/server
  - client-side resolvers
    - typically in a library
    - `gethostbyname`, `gethostbyaddr`
  - cooperating servers
    - query-answer-referral model
    - forward queries among servers
    - server-to-server may use TCP ("zone transfers")

Source: Jeff Chase
DNS servers are organized into a hierarchy that mirrors the name space.

Specific servers are designated as *authoritative* for portions of the name space.

Servers may delegate management of *subdomains* to child name servers.

Parents refer subdomain queries to their children.

Resolvers are bootstrapped with pointers to one or more local servers; they issue *recursive* queries.

Source: Jeff Chase
Server selection problem

- Avoid the scalability problems of central servers by "distributing" load

Which network site?

Which server?

“Contact the weather service.”

Source: Jeff Chase
DNS round robin

DNS server for nhc.noaa.gov

“www.nhc.noaa.gov is IP address a” (or \{b,c,d\})

“lookup www.nhc.noaa.gov”

local DNS server

DNS server returns one of multiple addresses based on load
e.g. www1.aol.com
www2.aol.com

Source: Jeff Chase
## DNS record for www.yahoo.com

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<th>TTL</th>
<th>Type</th>
<th>CNAME</th>
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<td>292</td>
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<td>A 64.58.76.223</td>
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</table>

`;; AUTHORITY SECTION:`

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<th>Type</th>
<th>Name</th>
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<td>984</td>
<td>IN</td>
<td>NS ZG.akadns.net.</td>
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<td>IN</td>
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<td>IN</td>
<td>NS ZD.akadns.net.</td>
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<tr>
<td>akadns.net.</td>
<td>984</td>
<td>IN</td>
<td>NS ZE.akadns.net.</td>
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Internet

First mile problem

Internet

Last mile problem

End Users

www.yahoo.com

Charter

Sprint

www.cnn.com

MCI

UUNET
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

MCI

UUNET

www.cnn.com

Sprint

End Users
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.

DNS server for nhc.noaa.gov

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

lookup a128.g.akamai.net

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

Akamai servers store/cache secondary content for “Akamaized” services.

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 propagate 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