CS514: Intermediate Course in Operating Systems

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Today: A two-part lecture

- Part I: Some details on Web Services
  - Mostly "syntactic"
  - We'll cover this fast because it's easy
- Part II: Content distribution
  - Here look at a larger-scale problem typical of the modern web (not specific to WS)
  - Topic relates to how images are served up by big, high-volume web sites

How do Web Services really work?

- Today:
  - WSDL: The Web Services Description Language
  - UDDI: The Universal Description, Discovery and Integration standard
  - Roles for brokers in Web Services systems
  - Challenges associated with naming, discovery and translation in large systems

Discovery

- This is the problem of finding the "right" service
  - In our example, we saw one way to do it – with a URL
  - Web Services community favors what they call a URN: Uniform Resource Name
- But the more general approach is to use an intermediary: a discovery service

Example of a repository

Name	Type	Publisher	Toolkit	Language	OS
Web Services Performance and Load Tester	Application	CapeClear		N/A	Cross-Platform
Temperature Service Client	Application	cdesk	Axis	Java	Cross-Platform
Weather Buddy	Application	shmj012000	MS .NET	C#	Windows
DreamFactory Client	Application	billpeterson	DreamFactory	Javascript	Cross-Platform
Temperature Perl Client	Example Source	gfinke13		Perl	Cross-Platform
Apache SOAP Example source	Example Source	zenithcode.com	Apache SOAP	Java	Cross-Platform
ASS 4	Example Source	JWE	SOAP::Lite	N/A	Cross-Platform
PocketSOAP demo	Example Source	simonfell	PocketSOAP	C++	Windows
easyoap temperature	Example Source	jdh	EasySoap++	C++	Windows
Weather Service Client with MS Visual Basic	Example Source	eglimmer	MS SOAP	Visual Basic	Windows
TemperatureClient	Example Source	mglenn	MS .NET	C#	Windows

Roles?

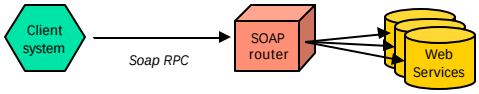
- UDDI is used to write down the information that became a "row" in the repository ("I have a temperature service…")
- WSDL documents the interfaces and data types used by the service
- But this isn't the whole story…

Discovery and naming

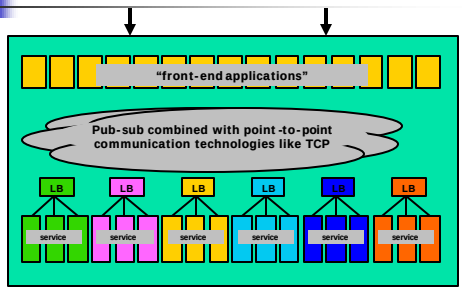
- The topic raises some tough questions
  - Many settings, like the big data centers run by large corporations, have rather standard structure. Can we automate discovery?
  - How to debug if applications might sometimes bind to the wrong service?
  - Delegation and migration are very tricky
  - Should a system automatically launch services on demand?

Client talks to eStuff.com

- One big issue: we're oversimplifying
- We think of remote method invocation and Web Services as a simple chain:



A glimpse inside eStuff.com



Discovery in eStuff.com

- Data centers are increasingly common
- And they raise hard questions!
  - How can a data center in California control decisions a client is making in Ithaca?
  - Services are clustered. How should client request be "routed" to the right member
  - Once you start talking to a server it may cache data for you. How can you be sure to get the right one next time?

CORBA approach

- CORBA had what are called
  - Ways to export specialized client stubs
    - The client stub could include server provided decision logic, like "which data center to connect with"
    - Gives data center a form of remote control
  - Factory services: manufacture certain kinds of objects as needed
    - Effect was that "discovery " can also be a "service creation" activity

CORBA is object oriented

- Seems obvious... and it is. CORBA is centered around the notion of an object
  - Objects can be passive (data)
  - ... active (programs)
  - ... persistent (data that gets saved)
  - ... volatile (state only while running)
- In CORBA the application that manages the object is inseparable from the object
  - And the stub on the client side is part of the application
  - The request per-se is an action by the object on itself and could even exploit various special protocols
  - We can't do this in Web Services

Will Web Services "help" with naming and discovery?

- Web Services tells us how
  - One client can...
  - ... find one server and
  - ... bind to that server and
  - ... send a request that will make sense
  - ... and make sense of the response
- So sure, WS will help

But Web Services won't...

- Allow the data center to control decisions the client makes
- Assist us in implementing naming and discovery in scalable cluster-style services
  - How to load balance? How to replicate data? What precisely happens if a node crashes or one is launched while the service is up?
  - Help with dynamics. For example, best server for a given client can be a function of load but also affinity, recent tasks, etc

Challenge

- Web Services are expected to parallel existing web site architectures
- So to understand how load balancing could work in a web services system, start by looking at "content distribution" by big multi-datacenter content hosting systems like Akamai

Why this is a challenge

- We'll see that CDN architectures are very complex and rather specific to document caching and distribution
  - This works perfectly well for serving up, say, images from CNN.com
  - But will the *same* mechanisms also work for services that want to load balance incoming queries? Not clear!

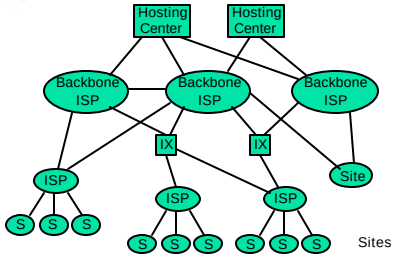
How we do it now

- Client queries directory to find the service
- Server has several options:
  - Web pages with dynamically created URLs
    - Server can point to different places, by changing host names
    - Content hosting companies remap URLs on the fly. E.g. http://www.akamai.com/www.cs.cornell.edu (reroutes requests for www.cs.cornell.edu to Akamai)
  - Server can control mapping from host to IP addr.
    - Must use short-lived DNS records; overheads are very high!
    - Can also intercept incoming requests and redirect on the fly

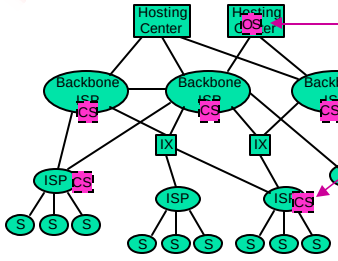
Why this isn't good enough

- The mechanisms aren't standard and are hard to implement
  - Akamai, for example, does content hosting using all sorts of proprietary tricks
- And they are costly
  - The DNS control mechanisms force DNS cache misses and hence many requests do RPC to the data center
- We lack a standard, well supported, solution!

Content Routing Principle
(a.k.a. Content Distribution Network)



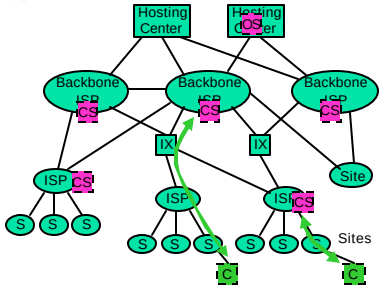
Content Routing Principle
(a.k.a. Content Distribution Network)



Content Origin here at Origin Server

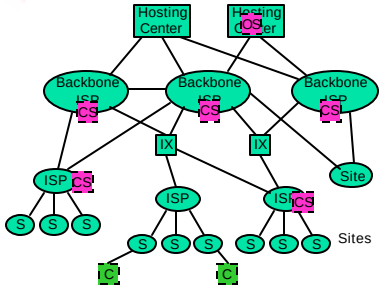
Content Servers distributed throughout the Internet

Content Routing Principle
(a.k.a. Content Distribution Network)

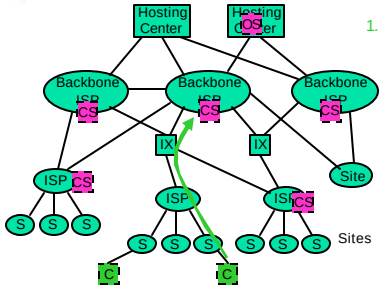


Content is served from content servers nearer to the client

Two basic types of CDN: cached and pushed

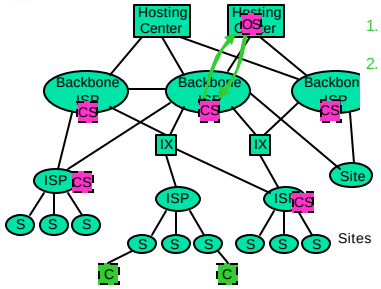


Cached CDN



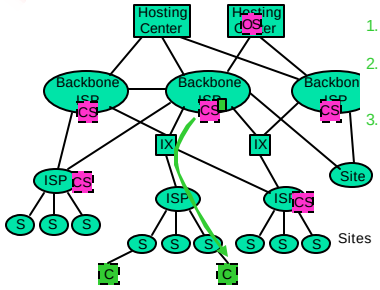
1. Client requests content.

Cached CDN



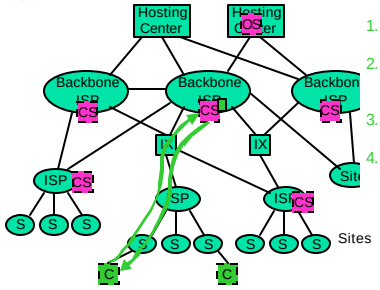
1. Client requests content.
2. CS checks cache, if miss gets content from origin server.

Cached CDN



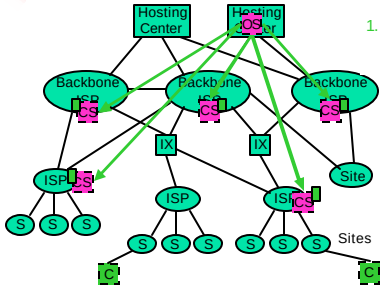
1. Client requests content.
2. CS checks cache, if miss gets content from origin server.
3. CS caches content, delivers to client.

Cached CDN



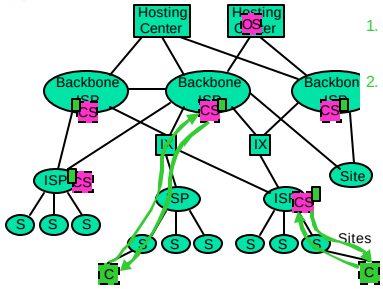
1. Client requests content.
2. CS checks cache, if miss gets content from origin server.
3. CS caches content, delivers to client.
4. Delivers content out of cache on subsequent requests.

Pushed CDN



1. Origin Server pushes content out to all CSs.

Pushed CDN



1. Origin Server pushes content out to all CSs.
2. Request served from CSs.

CDN benefits

- Content served closer to client
  - Less latency, better performance
- Load spread over multiple distributed CSs
  - More robust (to ISP failure as well as other failures)
  - Handle flashes better (load spread over ISPs)
  - *But well-connected, replicated Hosting Centers can do this too*

CDN costs and limitations

- Cached CDNs can't deal with dynamic/personalized content
  - More and more content is dynamic
  - "Classic" CDNs limited to images
- Managing content distribution is non-trivial
  - Tension between content lifetimes and cache performance
  - Dynamic cache invalidation
  - Keeping pushed content synchronized and current

CDN example: Akamai

- Won huge market share of CDN business late 90's
- Cached approach
- Now offers full web hosting services in addition to caching services
  - Called edgesuite

Akamai caching services
ARL: Akamai Resource Locator

http://a620.g.akamai.net/7/620/16/259fdbf4ed29de/www.cnn.com/i/22.gif

Host Part | Akamai Control Part | Content URL

/7/620/16/259fdbf4ed29de/

a620.g.akamai.net/ /www.cnn.com/i/22.gif

Thanks to ratul@cs.washington.edu, "How Akamai Works"

ARL: Akamai Resource Locator

http://a620.g.akamai.net/7/620/16/259fdbf4ed29de/www.cnn.com/i/22.gif

Content Provider (CP) selects which content will be hosted by Akamai. Akamai provides a tool that transforms *this CP URL* into *this ARL*

a620.g.akamai.net/ /www.cnn.com/i/22.gif

ARL: Akamai Resource Locator

http://a620.g.akamai.net/7/620/16/259fdbf4ed29de/www.cnn.com/i/22.gif

This in turn causes the client to access *Akamai's content server* instead of the *origin server*.

a620.g.akamai.net/ /www.cnn.com/i/22.gif

ARL: Akamai Resource Locator

http://a620.g.akamai.net/7/620/16/259fdbf4ed29de/www.cnn.com/i/22.gif

If Akamai's content server doesn't have the content in its cache, it retrieves it using *this URL*.

a620.g.akamai.net/ /www.cnn.com/i/22.gif

ARL Control Part

Type Code (different types will have different contents)

Customer Number (I.e. CNN, Yahoo…)

???

Content Checksum (May be used for identifying changed content. May also validate content???)

/7/620/16/259fdbf4ed29de/

a620.g.akamai.net/ /www.cnn.com/i/22.gif

http://a620.g.akamai.net/7/620/16/259fdbf4ed29de/www.cnn.com/i/22.gif

ARL Host Part

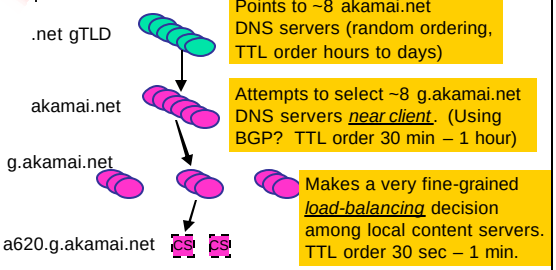
But why such a complex domain name????

/7/620/16/259fdbf4ed29de/

a620.g.akamai.net/ /www.cnn.com/i/22.gif

http://a620.g.akamai.net/7/620/16/259fdbf4ed29de/www.cnn.com/i/22.gif

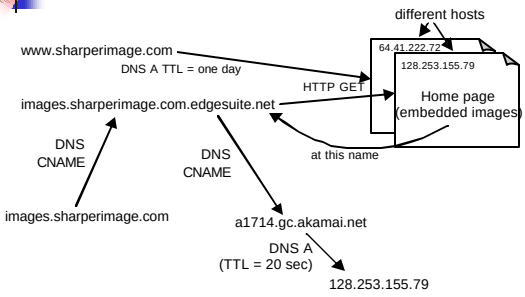
ARL Host Part



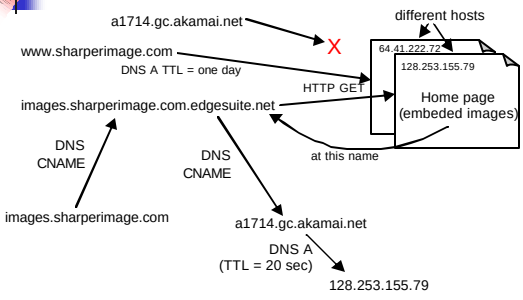
Akamai Edgesuite

- Appears that both DNS and web service handled by akamai
- Also may be that content may be pushed out to edge servers---no caching!

Sharper Image and Edgesuite



Sharper Image and Edgesuite



What may be happening...

- images.sharperimage.com.edgesuite.net returns same pages as www.sharperimage.com
  - But the shopping basket doesn't work!!
- Perhaps akamai cache blindly maps foo.bar.com.edgesuite.net into bar.com to retrieve web page
  - No more sophisticated akamaization
  - Easier to maintain origin web server??
  - Simpler akamai web caches??

Akamai isn't the only story

- We looked at the Akamai architecture
- But they don't have a "lock" on multi-datacenter content distribution…
- Are there other models to consider?

Other content routing mechanisms

- Dynamic HTML URL re-writing
  - URLs in HTML pages re-written to point at nearby and non-overloaded content server
  - In theory, finer-grained proximity decision
    - Because know true client, not clients DNS resolver
    - In practice very hard to be fine-grained
  - Clearway and Fasttide did this
  - Could in theory put IP address in re-written URL, save a DNS lookup
    - But problem if user bookmarks page

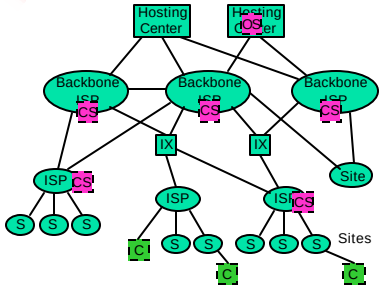
Other content routing mechanisms

- Dynamic .smil file modification
  - .smil used for multi-media applications (Synchronized Multimedia Integration Language)
    - Contains URLs pointing to media
  - Different tradeoffs from HTML URL re-writing
    - Proximity not as important
    - DNS lookup amortized over larger downloads
  - Also works for Real (.rm), Apple QuickTime (.qt), and Windows Media (.asf) descriptor files

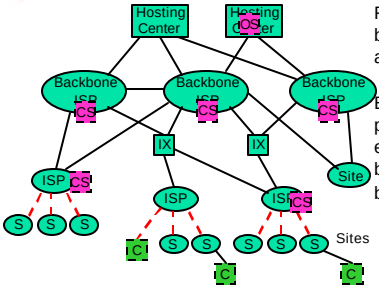
Other content routing mechanisms

- HTTP 302 Redirect
  - Directs client to another (closer, load balanced) server
  - For instance, redirect image requests to distributed server, but handle dynamic home page from origin server
- See *draft-cain-known-request-routing-00.txt* for good description of these issues
  - But expired, so use Google to find archived copy

How well do CDNs work?



How well do CDNs work?



Recall that the bottleneck links are at the edges.

Even if CSs are pushed towards the edge, they are still behind the bottleneck link!

Reduced latency can improve TCP performance

- DNS round trip
- TCP handshake (2 round trips)
- Slow -start
  - ~8 round trips to fill DSL pipe
  - total 128K bytes
    - Compare to 56 Kbytes for cnn.com home page
    - Download finished before slow-start completes
- Total 11 round trips
- Coast-to-coast propagation delay is about 15 ms
  - Measured RTT last night was 50ms
    - No difference between west coast and Cornell!
- 30 ms improvement in RTT means 330 ms total improvement
  - Certainly noticeable

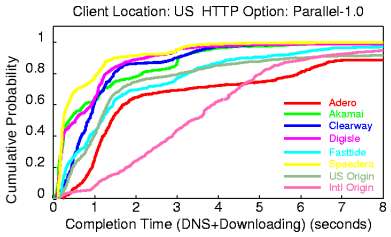
Lets look at a study

- Zhang, Krishnamurthy and Wills
  - AT&T Labs
- Traces taken in Sept. 2000 and Jan. 2001
- Compared CDNs with each other
- Compared CDNs against non-CDN

Methodology

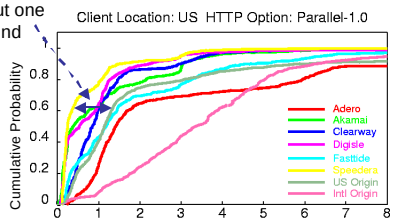
- Selected a bunch of CDNs
  - Akamai, Speedera, Digital Island
    - Note, most of these gone now!
- Selected a number of non-CDN sites for which good performance could be expected
  - U.S. and international origin
  - U.S.: Amazon, Bloomberg, CNN, ESPN, MTV, NASA, Playboy, Sony, Yahoo
- Selected a set of images of comparable size for each CDN and non-CDN site
  - Compare apples to apples
- Downloaded images from 24 NIMI machines

Response Time Results (II) Including DNS Lookup Time



Response Time Results (II) Including DNS Lookup Time

About one second

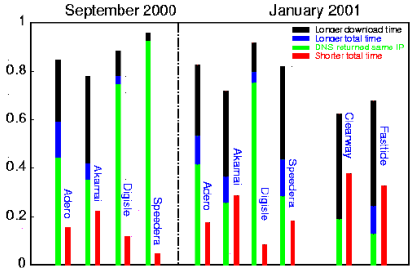


Author conclusion: CDNs generally provide much shorter download time.

CDNs out-performed non-CDNs

- Why is this?
- Lets consider ability to pick good content servers…
- They compared time to download with a fixed IP address versus the IP address dynamically selected by the CDN for each download
  - Recall: short DNS TTLs

Effectiveness of DNS load balancing



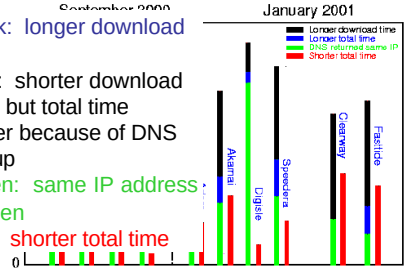
Effectiveness of DNS load balancing

Black: longer download time

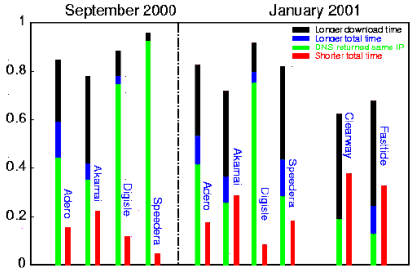
Blue: shorter download time, but total time longer because of DNS lookup

Green: same IP address chosen

Red: shorter total time



DNS load balancing not very effective



Other findings of study

- Each CDN performed best for at least one (NIMI) client
  - Why? Because of proximity?
- The best origin sites were better than the worst CDNs
- CDNs with more servers don't necessarily perform better
  - Note that they don't know load on servers..
- HTTP 1.1 improvements (parallel download, pipelined download) help a lot
  - Even more so for origin (non-CDN) cases
  - Note not all origin sites implement pipelining

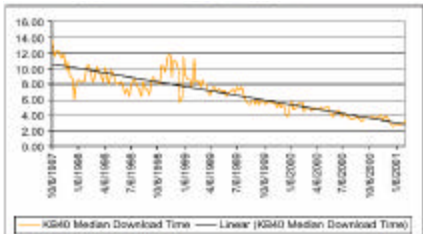
Ultimately a frustrating study

- Never actually says *why* CDNs perform better, only that they do
- For all we know, maybe it is because CDNs threw more money at the problem
  - More server capacity and bandwidth relative to load

Another study

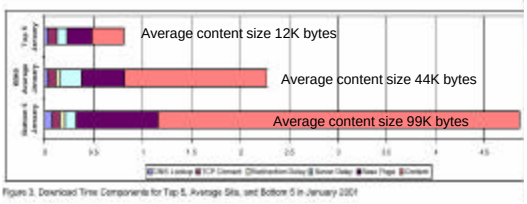
- Keynote Systems
  - "A Performance Analysis of 40 e-Business Web Sites"
- Doing measurements since 1997
  - (All from one location, near as I can tell)
- Latest measurement January 2001

Historical trend: Clear improvement

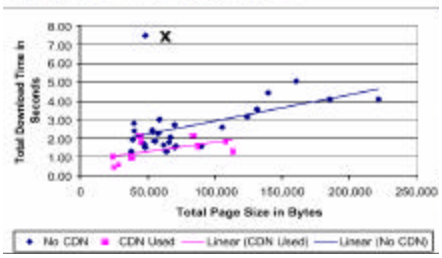


Performance breakdown

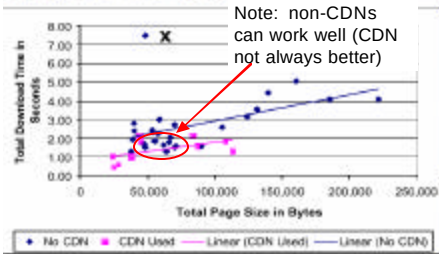
Basically says that smaller content leads to shorter download times (duh!)



Effect of CDN: Positive (but again, we don't know why)



Most web sites not using CDN (4-1)



To wrap things up

- As late as 2001, CDNs still used and still performing well
  - On a par or better than best non-CDN web sites
- CDN usage not a huge difference
- We don't know why CDNs perform well
  - But could very well simply be server capacity
- Knowledge of client location valuable more for customized advertising than for latency
  - Advertisements in right language

Back to web services

- Our goal was to think about how web services might distribute client-server work within a complex of data centers with replication of the service in each
- Could these same mechanisms be "generalized" to solve the client-server version of the problem?

Aside: Why do this?

- A comment
  - In fact this is definitely ***not*** the very best way to solve the problem
  - But recall that web services are intended to leverage the standards of the world of web sites as much as possible
  - Hence vendors are highly motivated to generalize a document-sharing solution if at all possible rather than invent something new from scratch!

Layered Naming

- Recent proposal for discovery: naming requires four distinct layers:
  1. User-level descriptor (ULD) lookup (e.g. email address, search string, etc)
  2. Service-ID descriptor (SID): a sort of index naming the service and valid over the duration of this interaction
  3. SID to Endpoint-ID (EID) mapping: client-side protocol (e.g. HTTP) maps from SID to EID
  4. EID to IP address "routing": server side control over the decision of which "delegate" will handle the request
- Today we tend to blur the middle two layers and lack standards for this process, forcing developers to innovate
- See: "A Layered Naming Infrastructure for the Internet", Balikrishnan *et. al.*, ACM SIGCOMM Aug. 2004, Portland.

Research challenges

- Naming and discovery are examples of research challenges we're now facing in the Web Services arena
- There are many others, we'll see them as we get more technical in the coming lectures
- CS514 won't tackle naming but we will look hard at issues bearing on "trust"

Homework (not to hand in)

- Continue to read Parts I and II of the book
- Visit the semantic web repository at www.w3.org
- What does that community consider to be a potential "home run" for the semantic web?