CS514: Intermediate Course in Computer Systems

Lecture 12: February 14, 2003

"Load Balancing Options"

Sources

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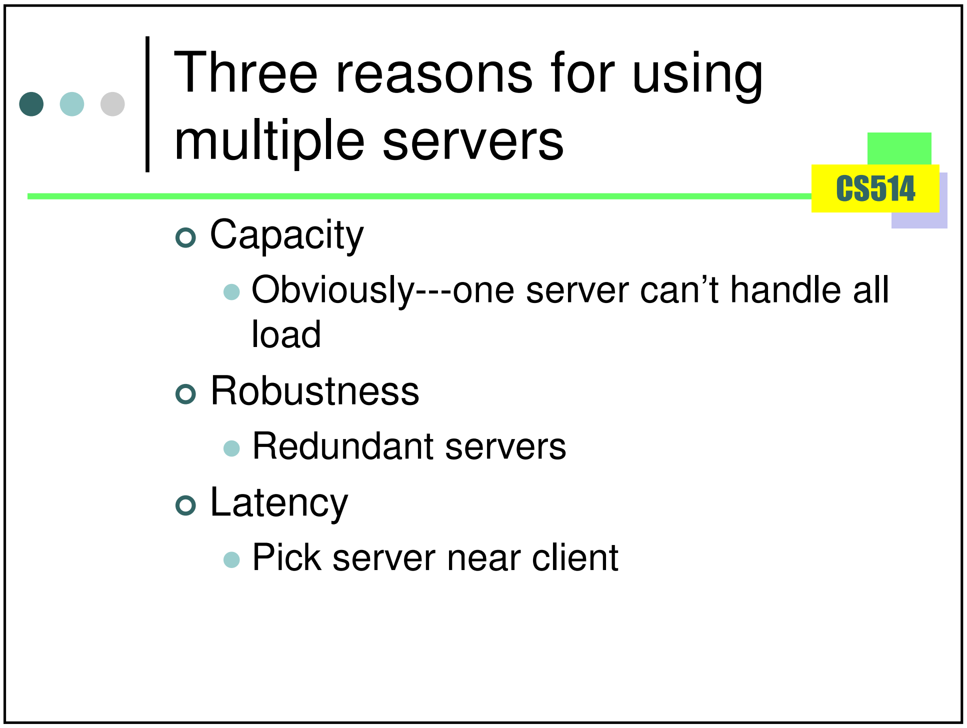
- Lots of graphics and product description courtesy F5 website (www.f5.com)
- I believe F5 is market leader in L4-L7 load balancer type products
- (No I'm not on their payroll)



Three reasons for using multiple servers

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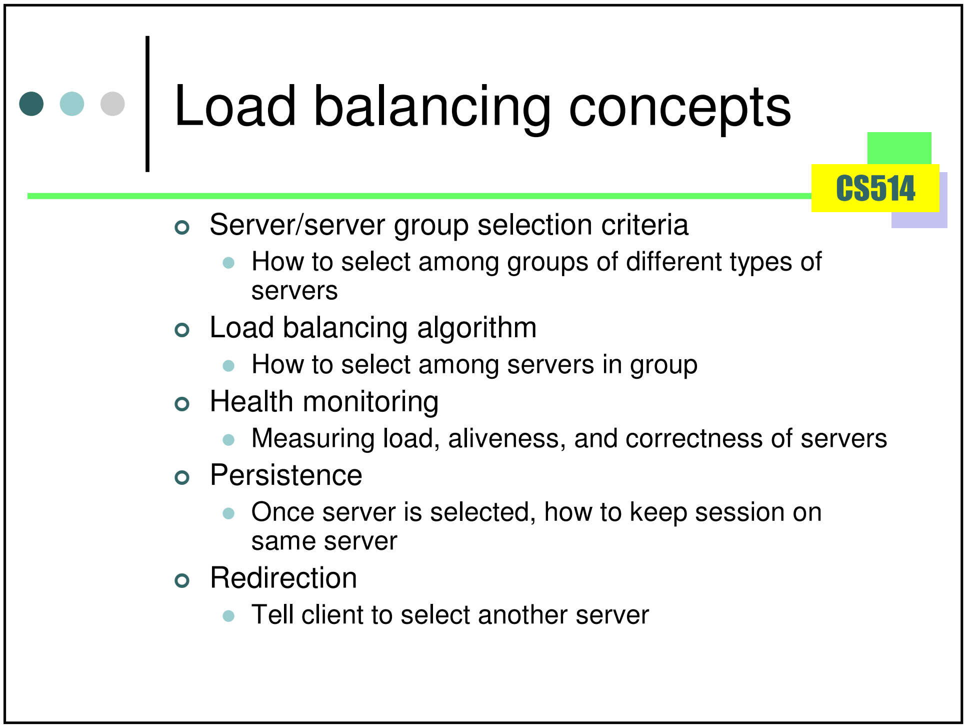
- Capacity
  - Obviously---one server can’t handle all load
- Robustness
  - Redundant servers
- Latency
  - Pick server near client



Load balancing concepts

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- Server/server group selection criteria
  - How to select among groups of different types of servers
- Load balancing algorithm
  - How to select among servers in group
- Health monitoring
  - Measuring load, aliveness, and correctness of servers
- Persistence
  - Once server is selected, how to keep session on same server
- Redirection
  - Tell client to select another server

Three levels of load balancing

- **Name-based**
  - Via URL selection
  - i.e. images placed on separate servers
- **IP-based**
  - DNS load balancer
  - Name-based and IP-based can select among geographically separated data centers
- **Local header inspection**
  - L4-L7 load balancers
  - Select among individual servers in data center
  - Sophisticated and fine-grained selection (application level)

L4-L7 Load Balancer deployment

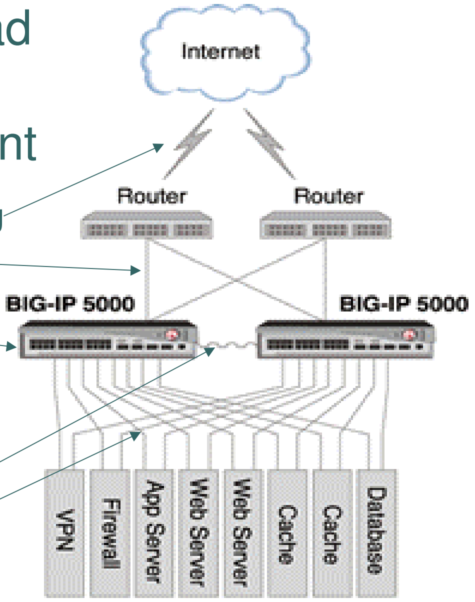
IP routing

ARP or IP routing

Standby mode (each L4-L7 load balancer advertises same IP addresses)

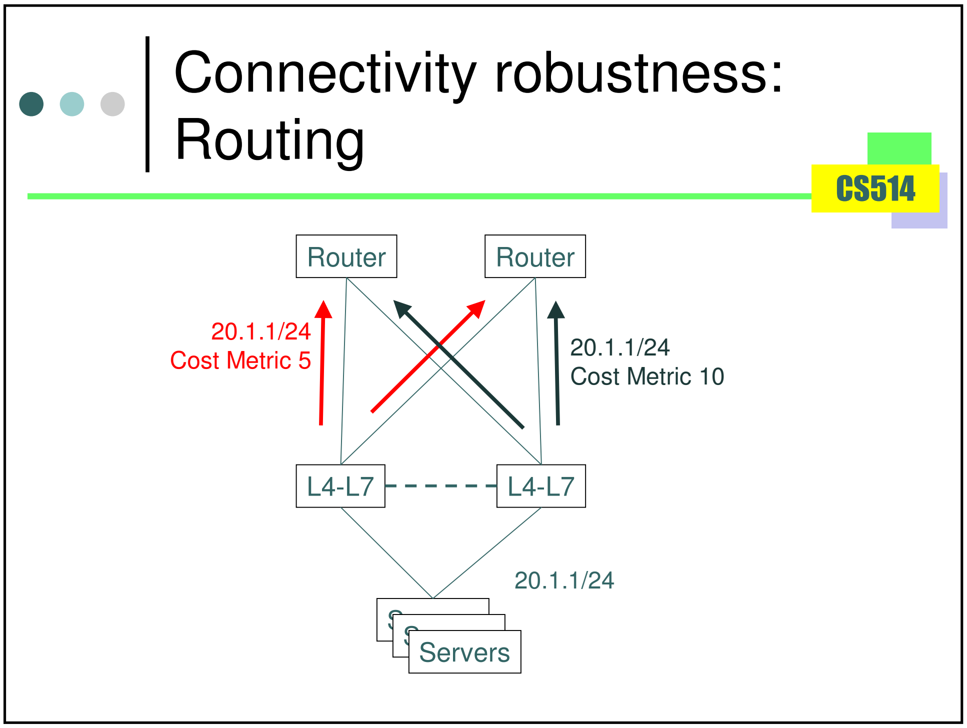
Health/session state

ARP? 802.3ad? IP routing?



Redundant BIG-IP 5000s are positioned between the router and the server array in a meshed network.

* “BIG-IP” is F5 product name



Connectivity robustness: Routing

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Router

Router

20.1.1/24
Cost Metric 5

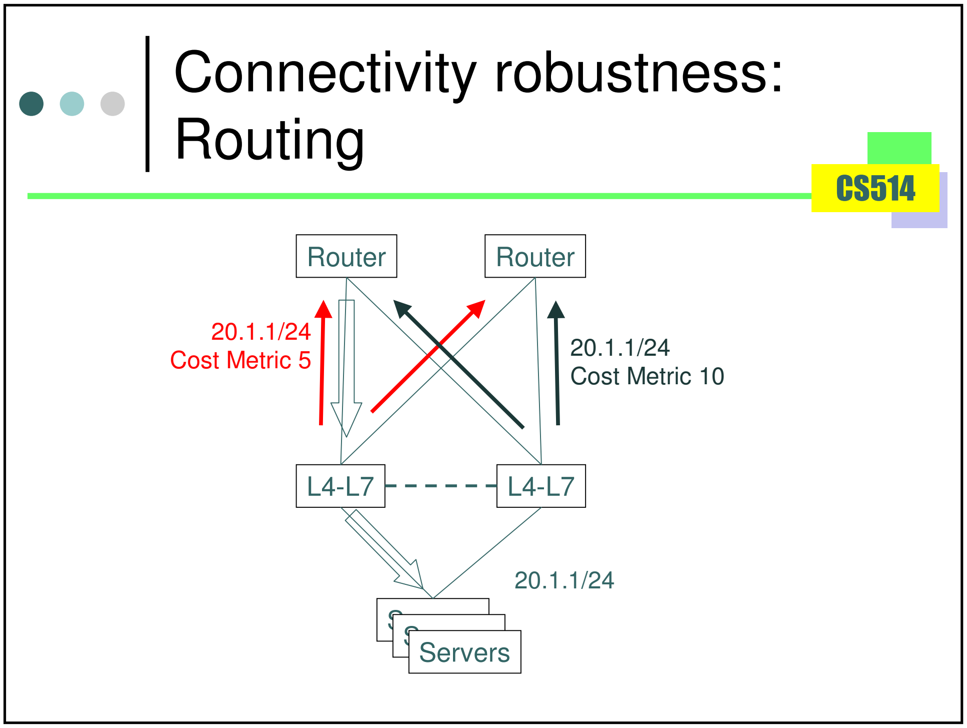
20.1.1/24
Cost Metric 10

L4-L7

L4-L7

20.1.1/24

Servers



Connectivity robustness: Routing

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Router

Router

20.1.1/24
Cost Metric 5

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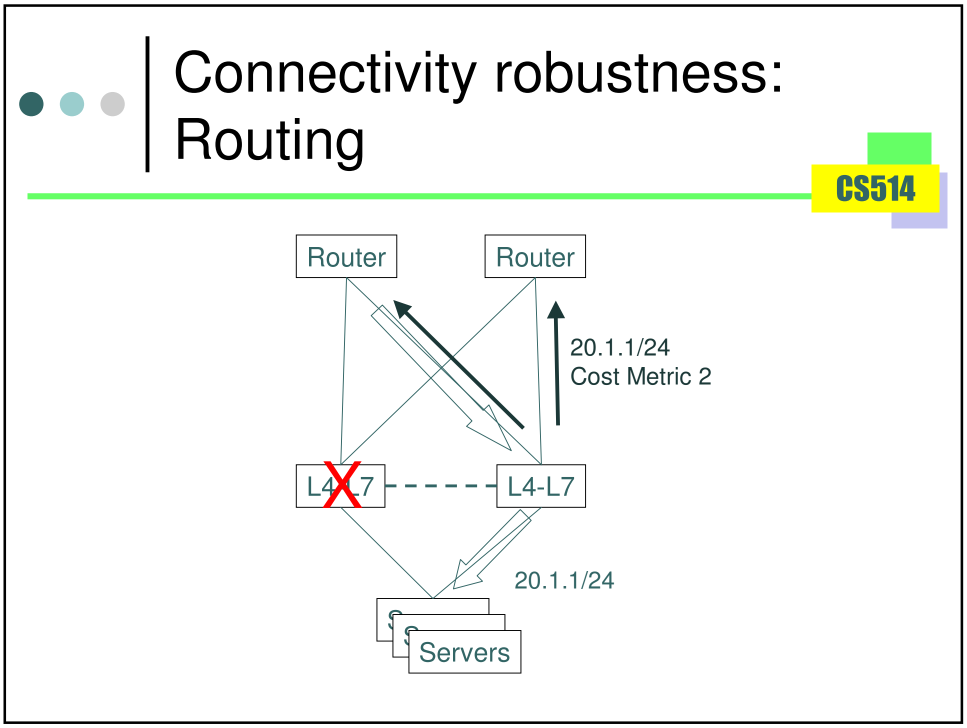
L4-L7

L4-L7

20.1.1/24

Servers



Connectivity robustness: Routing

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Router

Router

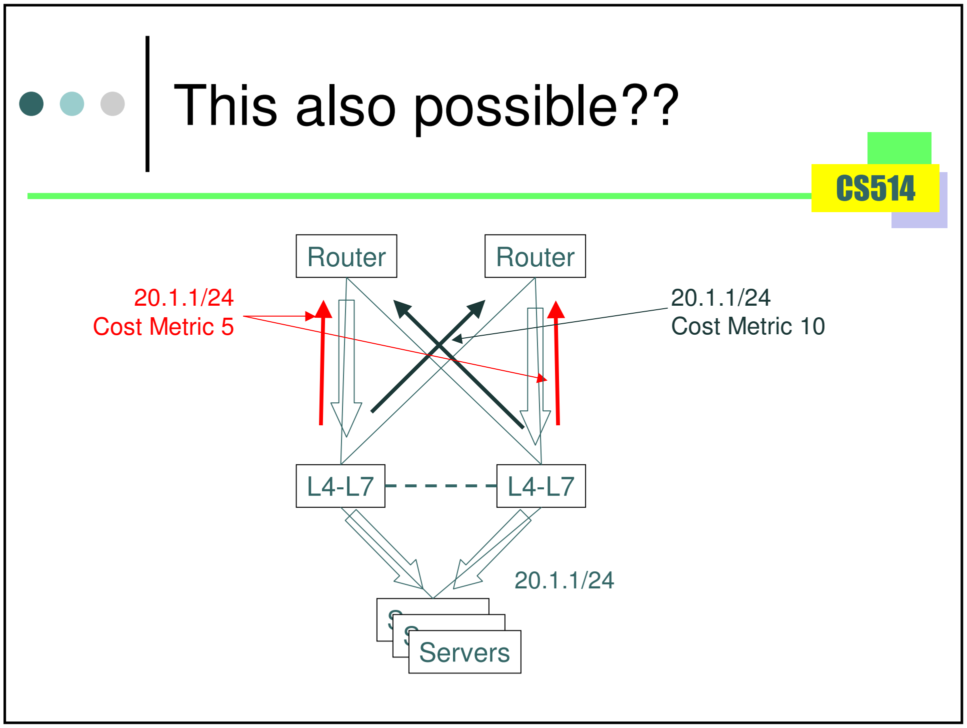
20.1.1/24
Cost Metric 2

L4-L7

L4-L7

20.1.1/24

Servers



This also possible??

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Router

Router

20.1.1/24
Cost Metric 5

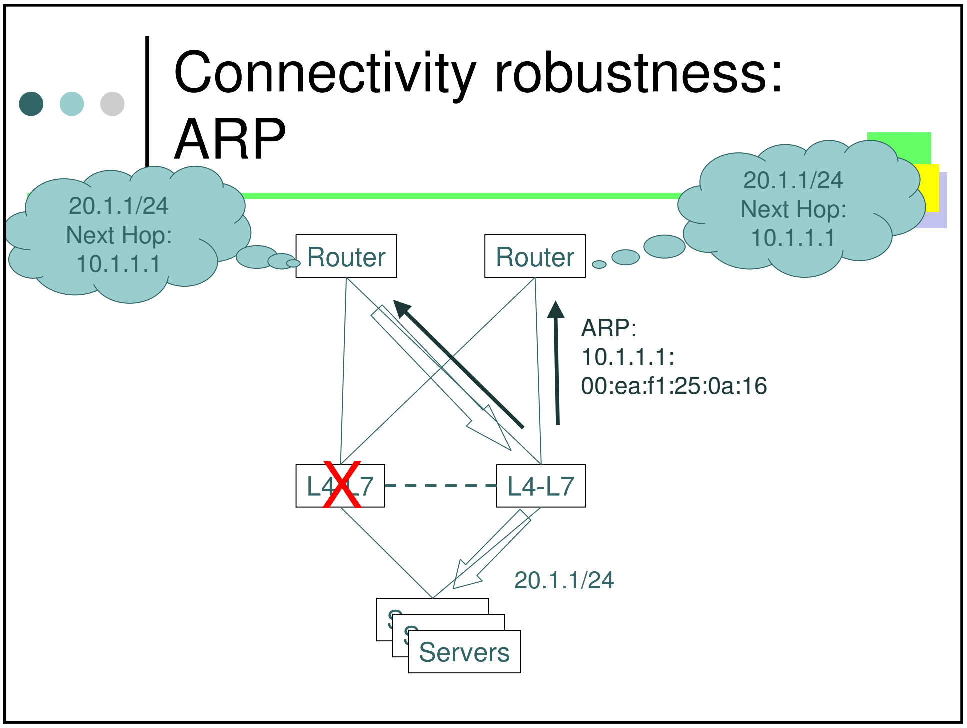
20.1.1/24
Cost Metric 10

L4-L7

L4-L7

20.1.1/24

Servers



Connectivity robustness: ARP

20.1.1/24
Next Hop:
10.1.1.1

20.1.1/24
Next Hop:
10.1.1.1

Router

Router

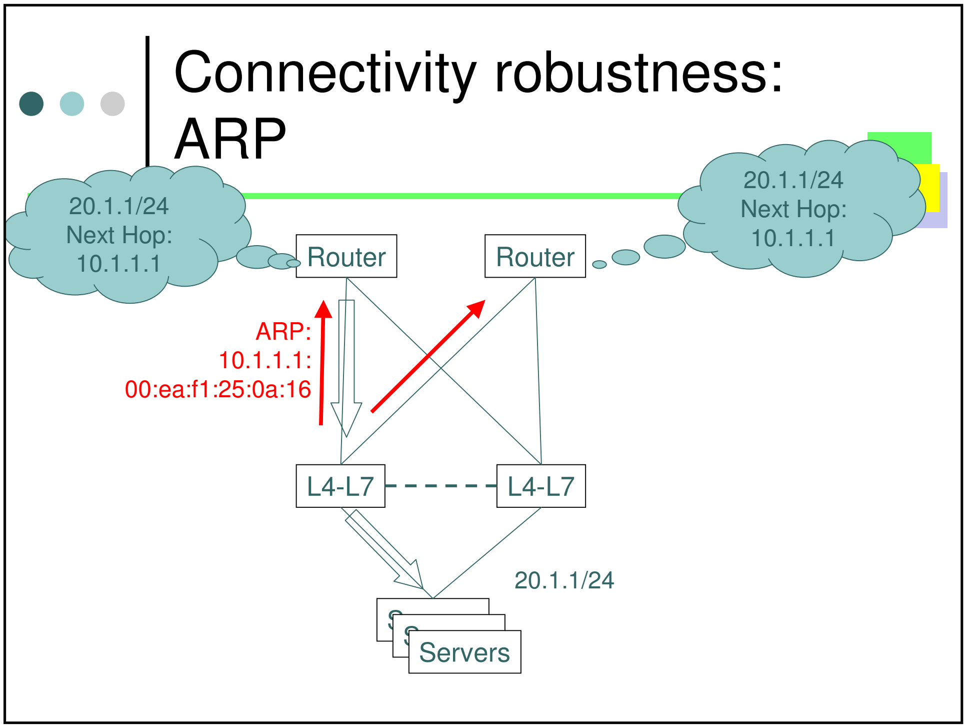
ARP:
10.1.1.1:
00:ea:f1:25:0a:16

L4-L7

L4-L7

20.1.1/24

Servers



Connectivity robustness: ARP

20.1.1/24
Next Hop:
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20.1.1/24
Next Hop:
10.1.1.1

Router

Router

ARP:
10.1.1.1:
00:ea:f1:25:0a:16

L4-L7

L4-L7

20.1.1/24

Servers

BIG-IP Input-Output

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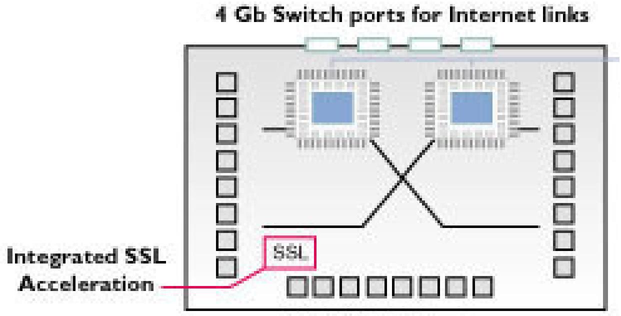
4 Gb Switch ports for Internet links
SSL
Integrated SSL Acceleration
24 FE Switch ports

(Fast Ethernet)

16 Gbps (8 each way)
800 SSL Trans/Sec
(claimed)

Tahoe Networks router architecture

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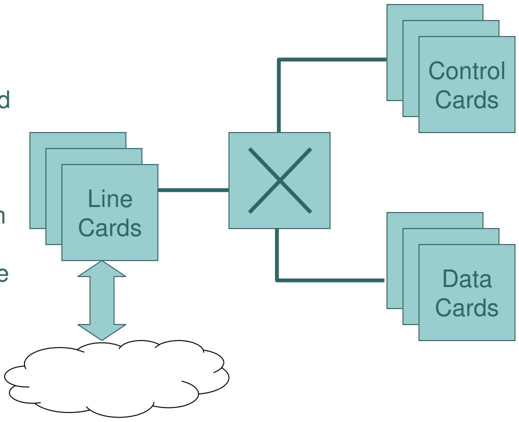
- Redundant state everywhere
- Initially line cards selects control card for new session
- Control card selects data card for data packets (and program line cards with selection)
- Control cards periodically update line cards with their own load.
- Line cards periodically update control cards with their load.



Control Cards

Line Cards

Data Cards

Load balancing concepts

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- Server/server group selection criteria
  - How to select among groups of different types of servers
- Load balancing algorithm
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- Health monitoring
  - Measuring load, aliveness, and correctness of servers
- Persistence
  - Once server is selected, how to keep session on same server
- Redirection
  - Tell client to select another server

Health Monitoring

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- Same techniques apply to all three load balance levels (name, IP, local)
- “Keep alive” messages
  - Must be application level, not IP ping
    - i.e., if web services, send actual web request, check response for correctness
- Agent operating on server itself (less common)
  - Measures load indicators (CPU, I/O, etc.) and health
  - Reports back to load balancer
  - (Note that load balancer itself can monitor load)
- Note that snooping real traffic, or monitoring absence of traffic, does not scale well
  - MUST minimize per data packet processing

Load balancing concepts

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Groups of servers

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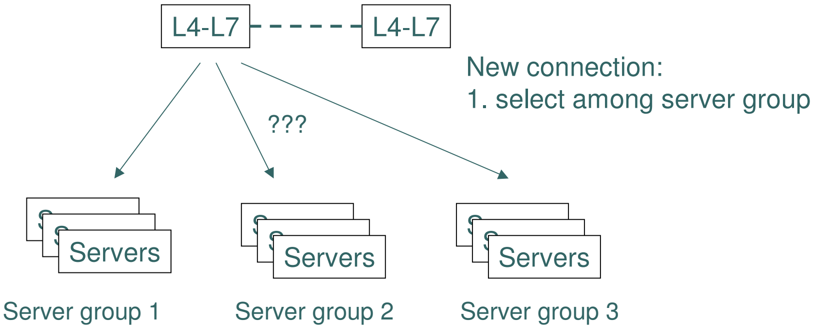
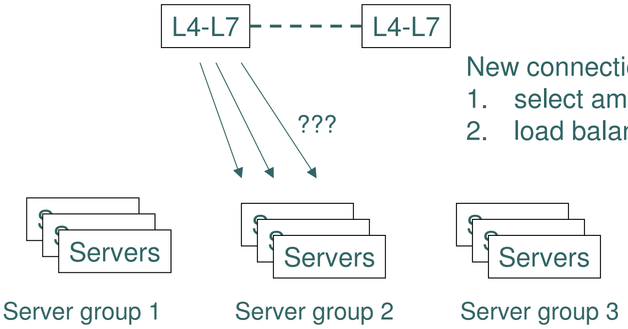


New connection:
1. select among server group

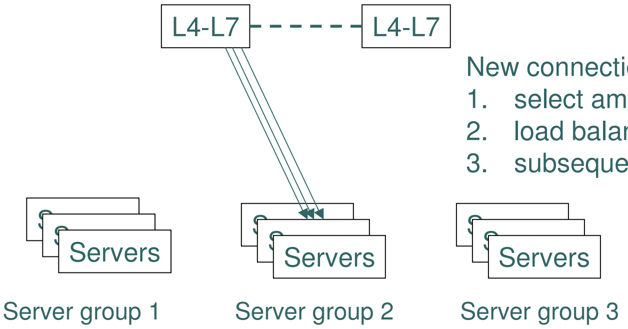
Groups of servers



New connection:

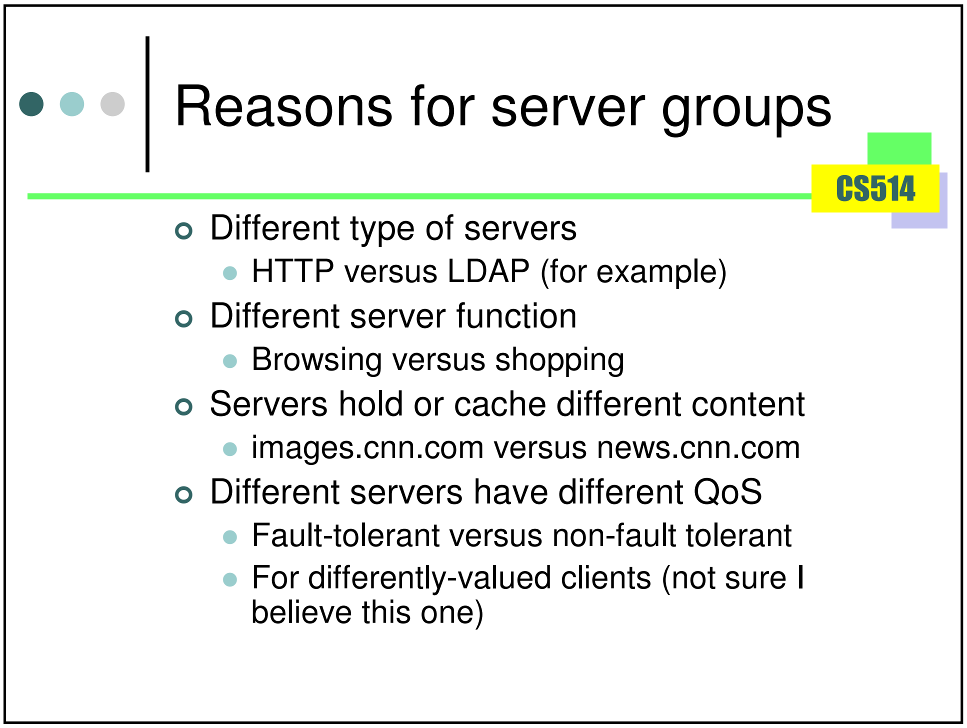
1. select among server group
2. load balance among group

Groups of servers: “Switch and Persist”



New connection:

1. select among server group
2. load balance among group
3. subsequent persistence



Reasons for server groups

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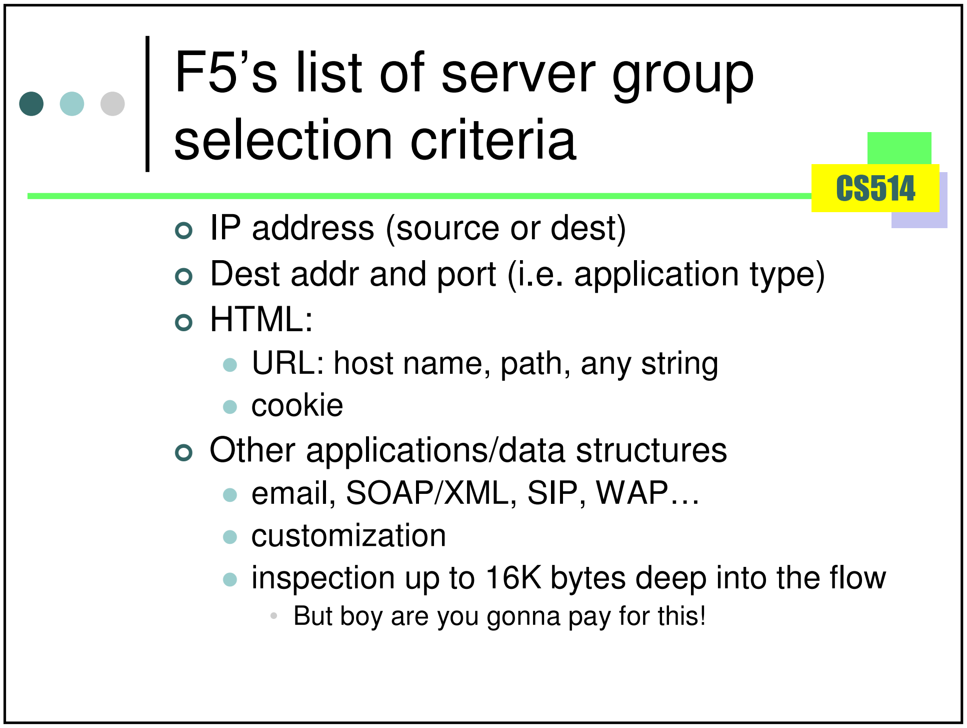
- Different type of servers
  - HTTP versus LDAP (for example)
- Different server function
  - Browsing versus shopping
- Servers hold or cache different content
  - images.cnn.com versus news.cnn.com
- Different servers have different QoS
  - Fault-tolerant versus non-fault tolerant
  - For differently-valued clients (not sure I believe this one)



F5’s list of server group selection criteria

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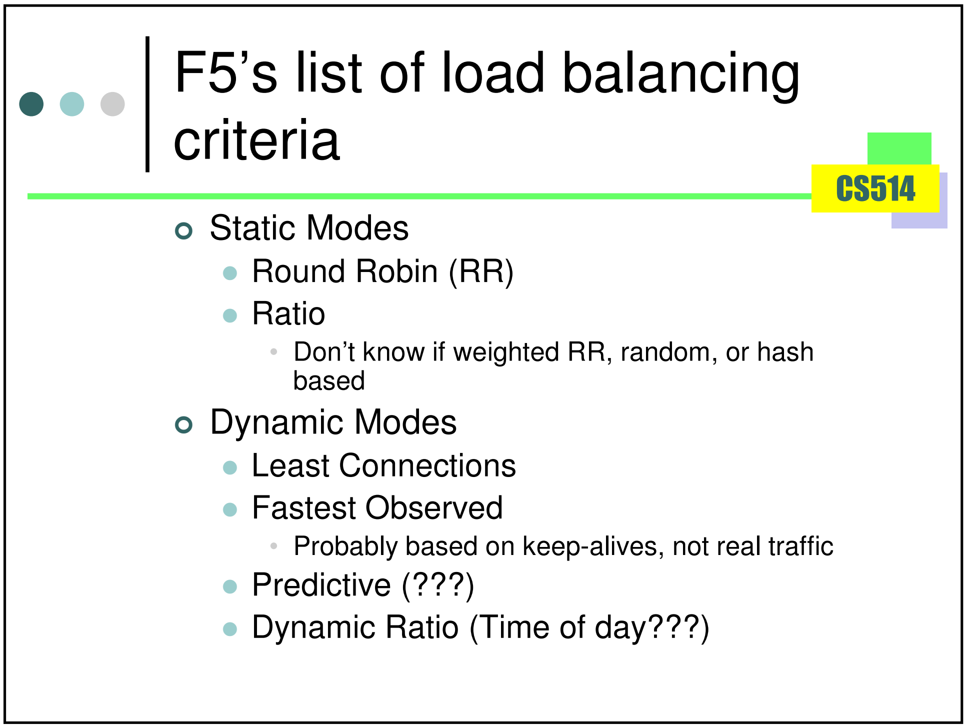
- IP address (source or dest)
- Dest addr and port (i.e. application type)
- HTML:
  - URL: host name, path, any string
  - cookie
- Other applications/data structures
  - email, SOAP/XML, SIP, WAP…
  - customization
  - inspection up to 16K bytes deep into the flow
    - But boy are you gonna pay for this!



F5’s list of load balancing criteria

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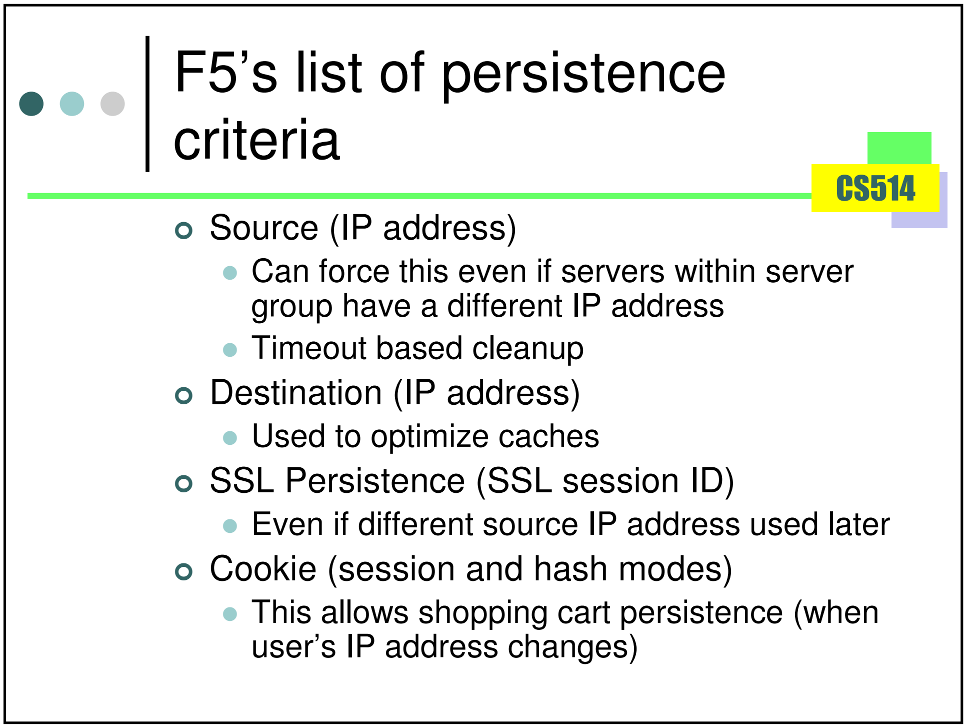
- Static Modes
  - Round Robin (RR)
  - Ratio
    - Don’t know if weighted RR, random, or hash based
- Dynamic Modes
  - Least Connections
  - Fastest Observed
    - Probably based on keep-alives, not real traffic
  - Predictive (???)
  - Dynamic Ratio (Time of day???)



F5’s list of persistence criteria

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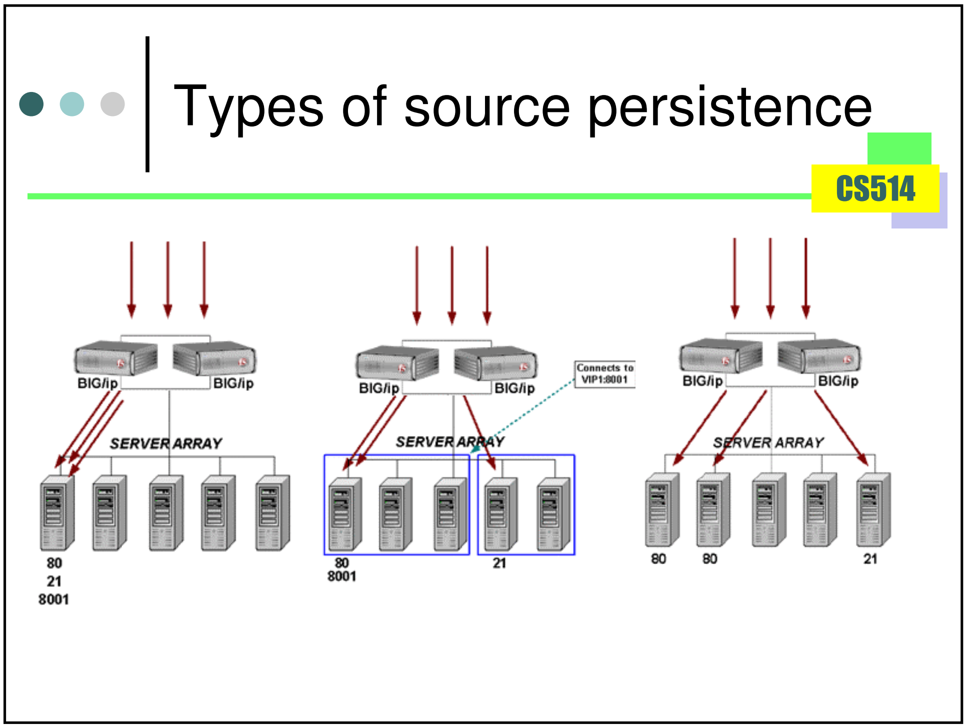
- Source (IP address)
  - Can force this even if servers within server group have a different IP address
  - Timeout based cleanup
- Destination (IP address)
  - Used to optimize caches
- SSL Persistence (SSL session ID)
  - Even if different source IP address used later
- Cookie (session and hash modes)
  - This allows shopping cart persistence (when user’s IP address changes)



Types of source persistence

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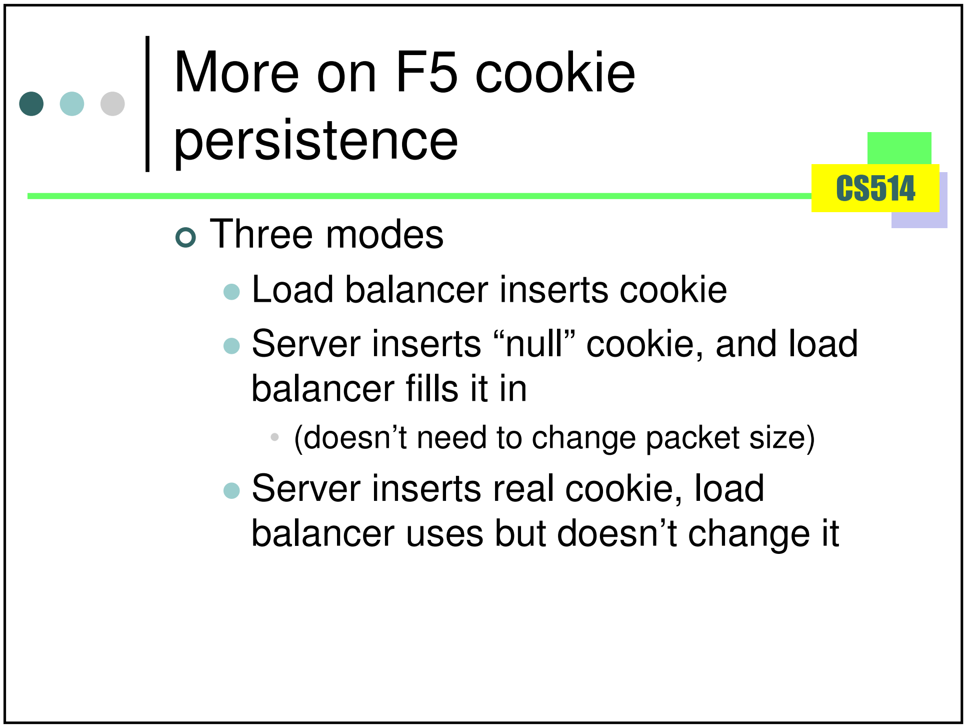

More on F5 cookie persistence

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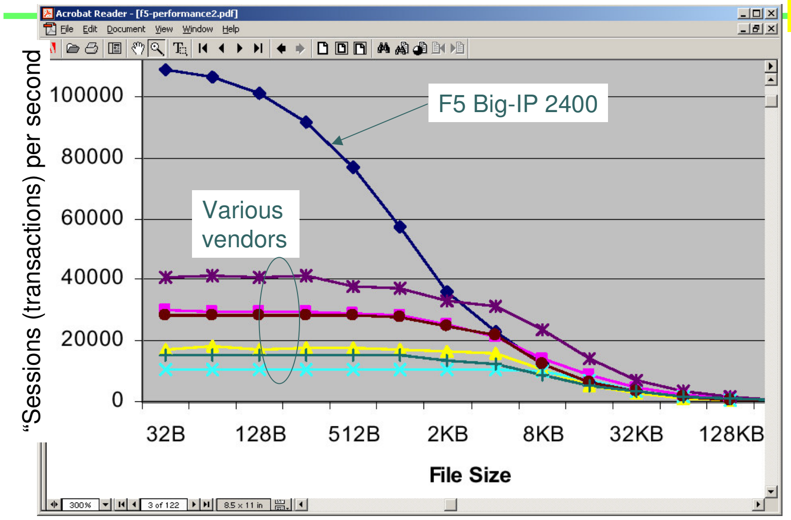
- Three modes
  - Load balancer inserts cookie
  - Server inserts “null” cookie, and load balancer fills it in
    - (doesn’t need to change packet size)
  - Server inserts real cookie, load balancer uses but doesn’t change it

Session or hash-based cookies

- If load balancer creates cookie, then cookie can be simple identifier of server
  - different sources can be given same cookie
  - simplifies everything
- If server creates cookie, then there is one per source
  - can keep per session state
  - or load balancer can use (definable) portion of cookie as hash ID
    - don't need per session state
    - this is only mention of hashing I found though???

L4 inspection performance

(Veritest "F5 Networks Layer 4/Layer 7 Performance Comparison")



L4 inspection performance

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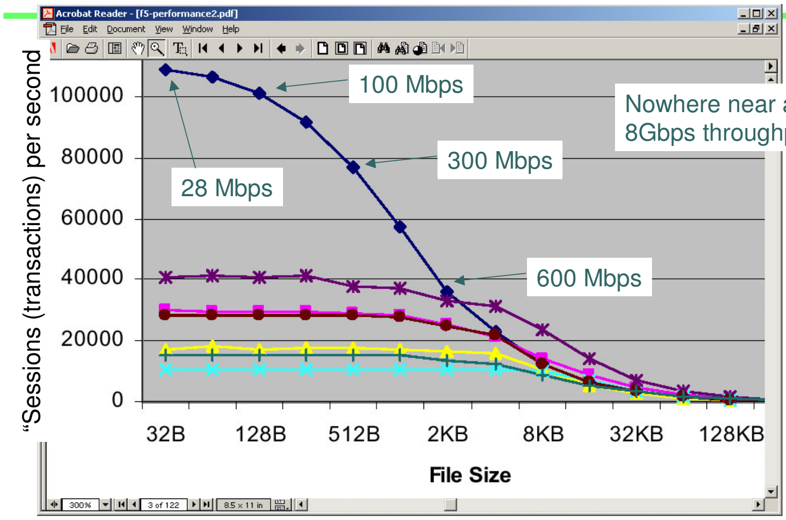

100 Mbps

28 Mbps

300 Mbps

600 Mbps

Nowhere near advertised 8Gbps throughput!!!

L7 inspection performance

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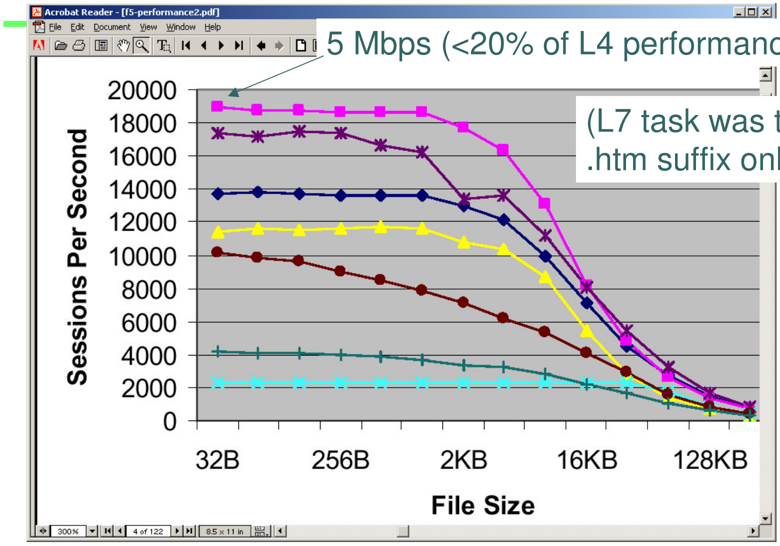
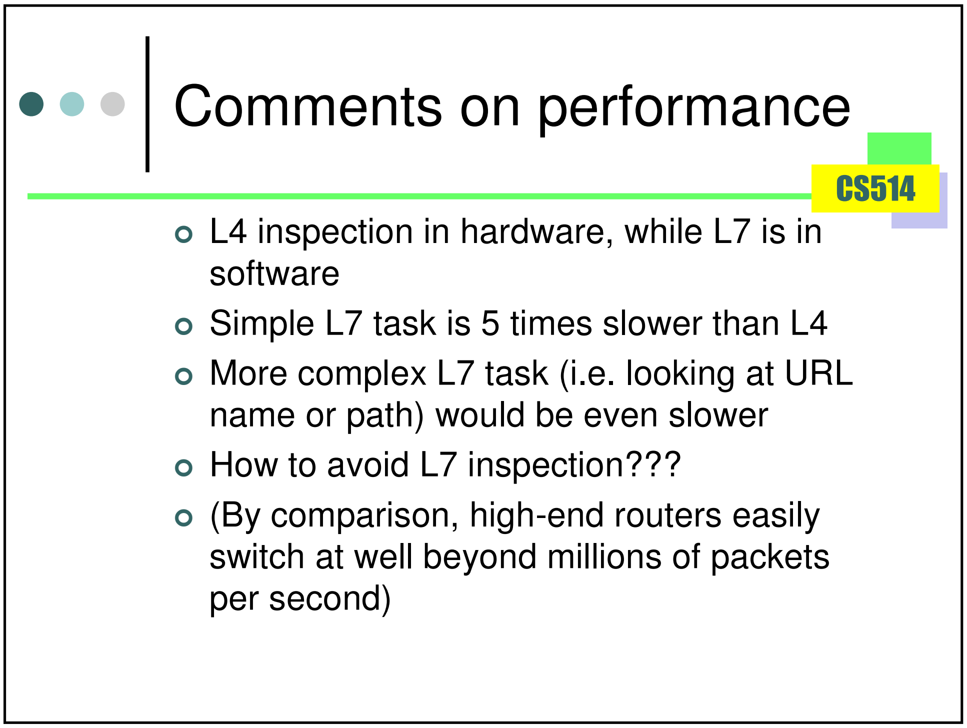


5 Mbps (<20% of L4 performance)

(L7 task was to find .htm suffix only)



Comments on performance

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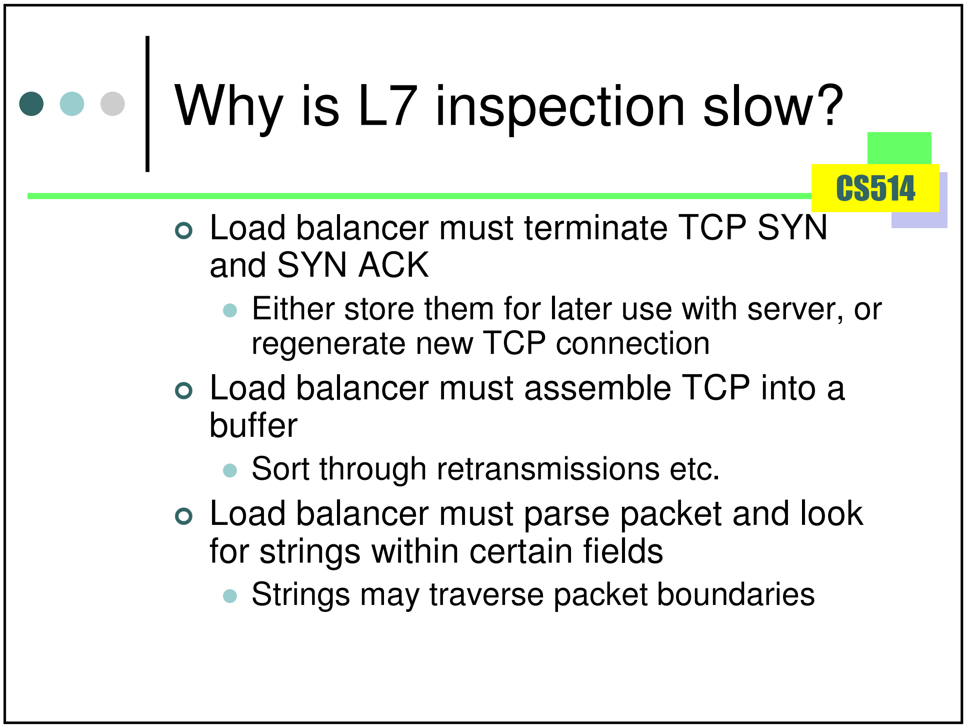
- L4 inspection in hardware, while L7 is in software
- Simple L7 task is 5 times slower than L4
- More complex L7 task (i.e. looking at URL name or path) would be even slower
- How to avoid L7 inspection???
- (By comparison, high-end routers easily switch at well beyond millions of packets per second)



Why is L7 inspection slow?

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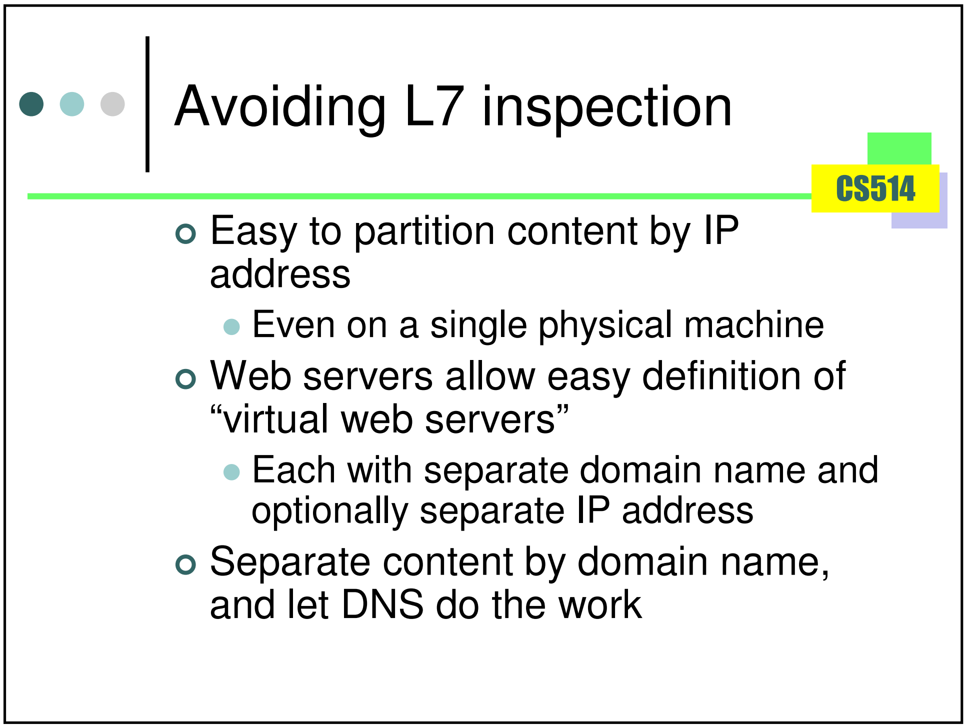
- Load balancer must terminate TCP SYN and SYN ACK
  - Either store them for later use with server, or regenerate new TCP connection
- Load balancer must assemble TCP into a buffer
  - Sort through retransmissions etc.
- Load balancer must parse packet and look for strings within certain fields
  - Strings may traverse packet boundaries



Avoiding L7 inspection

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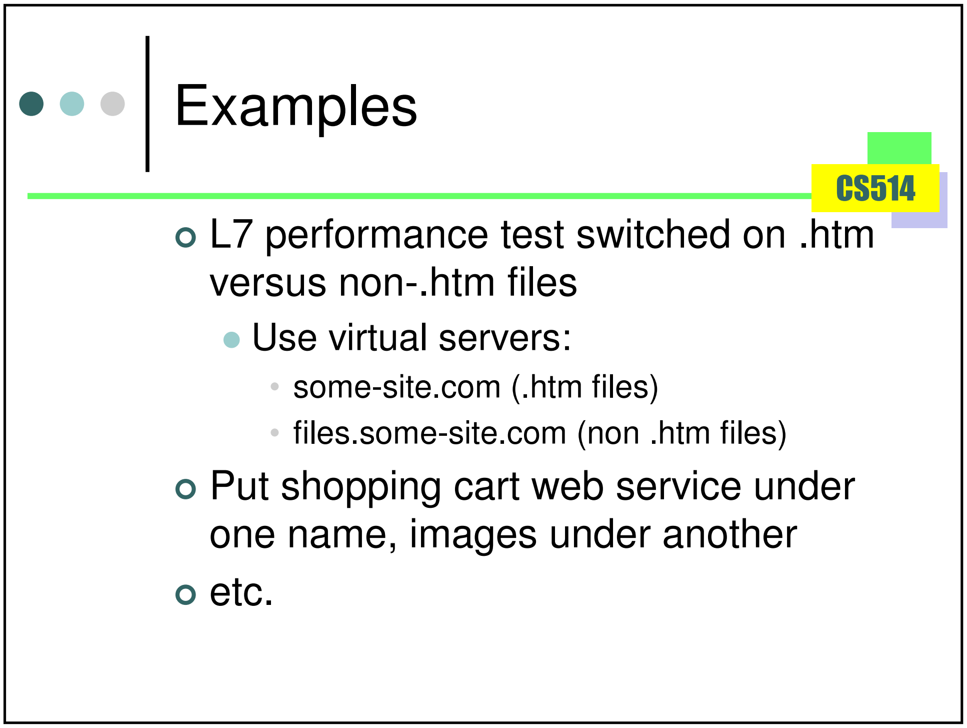
- Easy to partition content by IP address
  - Even on a single physical machine
- Web servers allow easy definition of “virtual web servers”
  - Each with separate domain name and optionally separate IP address
- Separate content by domain name, and let DNS do the work



Examples

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- L7 performance test switched on .htm versus non-.htm files
  - Use virtual servers:
    - some-site.com (.htm files)
    - files.some-site.com (non .htm files)
- Put shopping cart web service under one name, images under another
- etc.

Other local load balancer features

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- Terminates SSL (Secure Socket Layer) to offload server
- Server can dynamically modify load balancing parameters
- Can do HTTP redirect if some or all servers fail
- Consolidate multiple user’s requests into a single TCP to the server
- Return traffic may bypass load balancer (i.e. streaming media)

What if one (pair of) load balancers is not enough?

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- Performance of a single load balancer is limited…
- Load balance among load balancers using DNS

DNS Load Balancer (F5 etc. makes this too)

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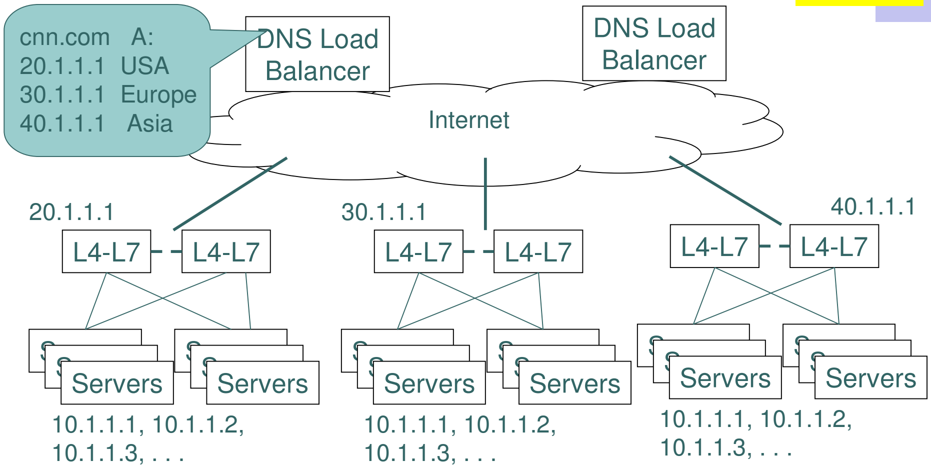

DNS Load balancer

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- Has similar load balancing and health monitoring as L4-L7 load balancer
- Does not have "switch and persist"
- May have ability to select based on geographical location of client
  - F5 claims to be able to detect country of origin
    - This can typically be done just looking at IP prefix assignments
  - Note that DNS load balancer does not see client address, only that of the client's DNS server

F5's picture of DNS load balancer

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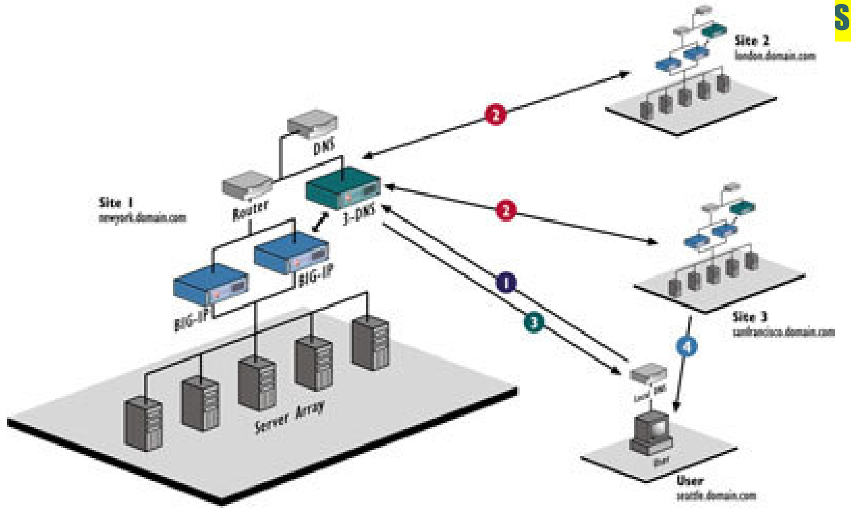

DNS-based geographical selection rough at best

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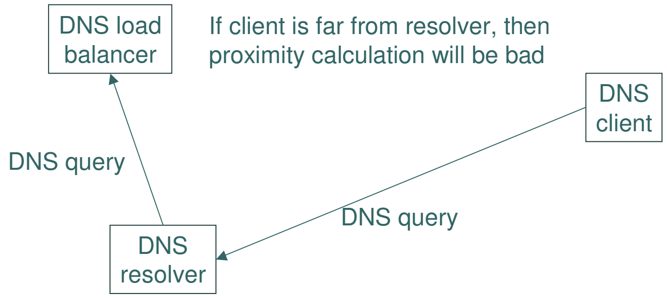
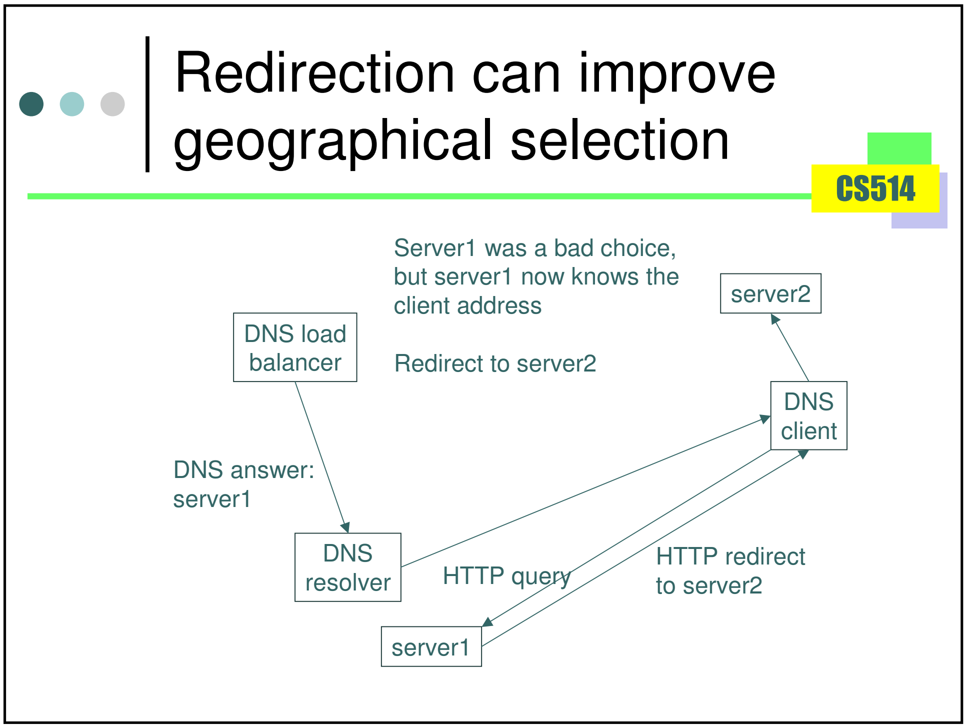
DNS load balancer knows IP address of resolver, but not of actual client

If client is far from resolver, then proximity calculation will be bad





Redirection can improve geographical selection

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Server1 was a bad choice, but server1 now knows the client address

Redirect to server2

DNS load balancer

server2

DNS client

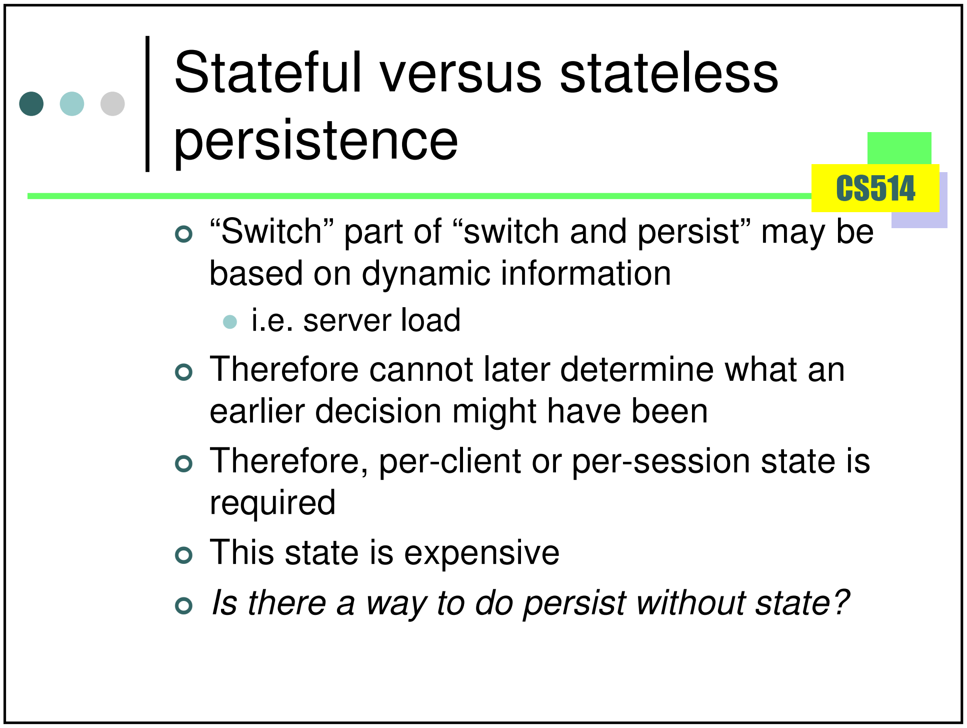
DNS answer: server1

DNS resolver

HTTP query

HTTP redirect to server2

server1



Stateful versus stateless persistence

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- “Switch” part of “switch and persist” may be based on dynamic information
  - i.e. server load
- Therefore cannot later determine what an earlier decision might have been
- Therefore, per-client or per-session state is required
- This state is expensive
- *Is there a way to do persist without state?*

Not really

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- Perfect stateless persistence is impossible
  - That’s why F5 is stateful
- But stateless “pretty good persistence” is possible
  - May be used for “content affinity”: directing requests to web caches
- Using “consistent hashing”
  - (Could just have well been called persistent hashing!)

Hashing rehash

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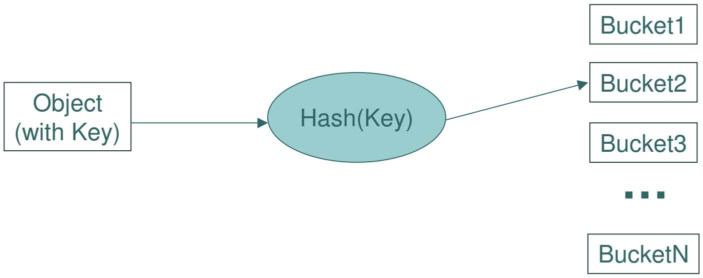
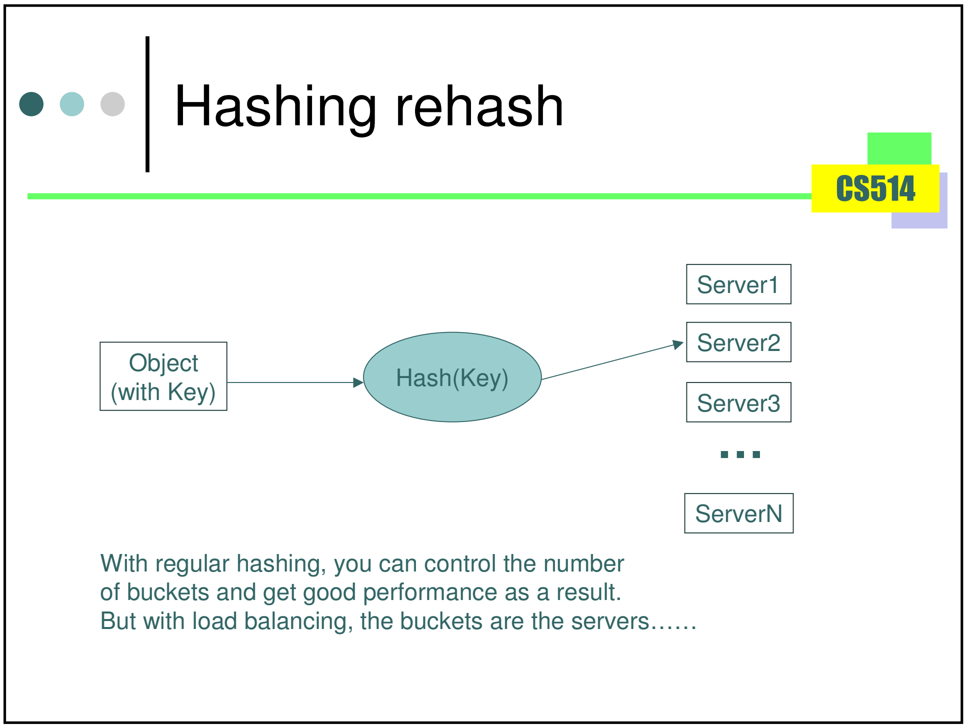


With regular hashing, you can control the number of buckets and get good performance as a result.



Hashing rehash

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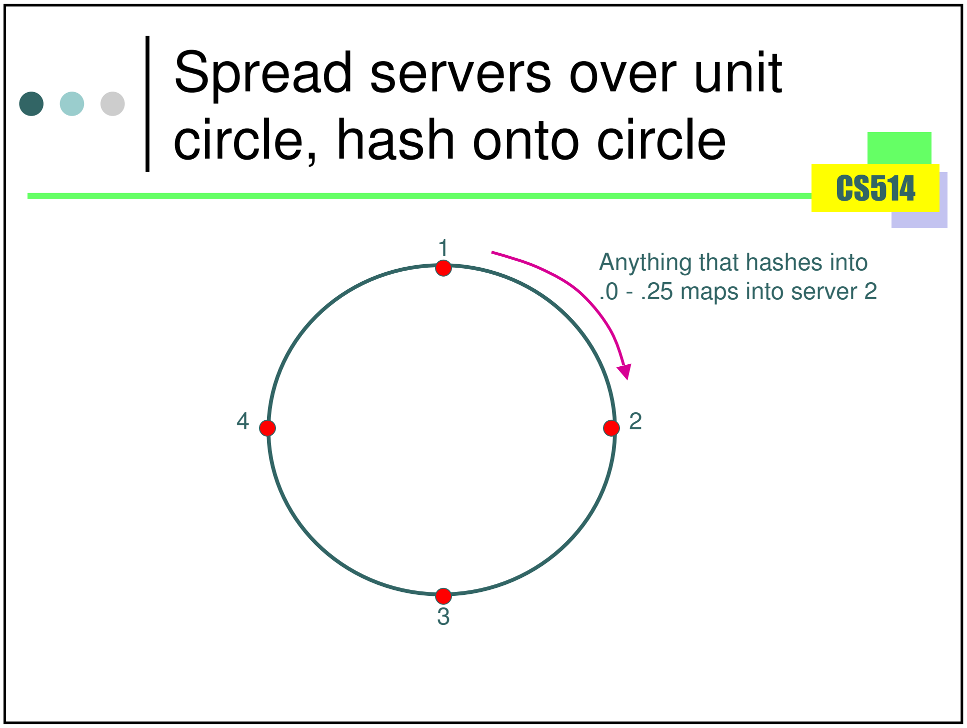
With regular hashing, you can control the number of buckets and get good performance as a result. But with load balancing, the buckets are the servers……



Spread servers over unit circle, hash onto circle

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Anything that hashes into .0 - .25 maps into server 2

If server added, many mappings change

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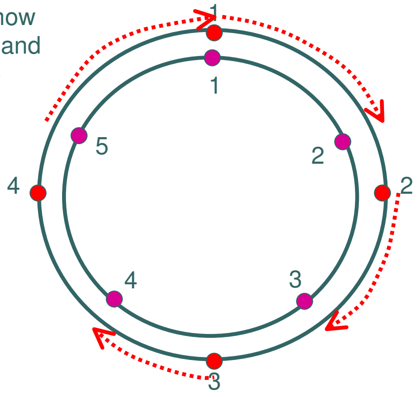
Dotted red lines show regions where old and new mappings are the same.

Everywhere else, old mappings no longer point to the same server.



Consistent hashing

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- Rather than evenly spread servers over unit circle:
- Replicate servers many times, and randomly place servers on unit circle

Consistent hashing

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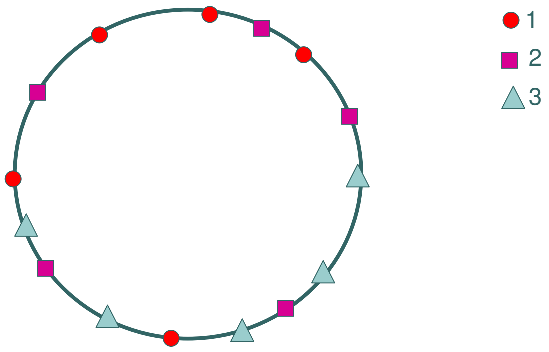

Consistent hashing

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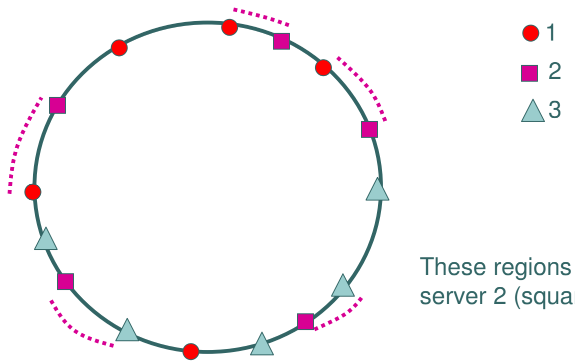
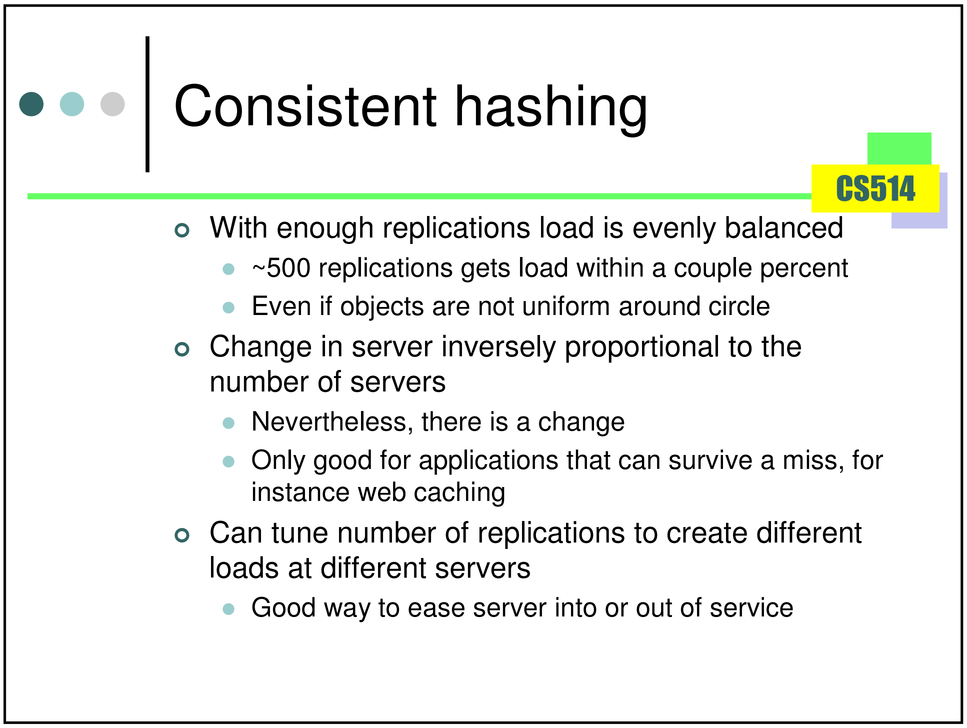


These regions map into server 2 (square)



Consistent hashing

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- With enough replications load is evenly balanced
  - ~500 replications gets load within a couple percent
  - Even if objects are not uniform around circle
- Change in server inversely proportional to the number of servers
  - Nevertheless, there is a change
  - Only good for applications that can survive a miss, for instance web caching
- Can tune number of replications to create different loads at different servers
  - Good way to ease server into or out of service