



CS514: Intermediate Course in Computer Systems

Lecture 7: Sept. 19, 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

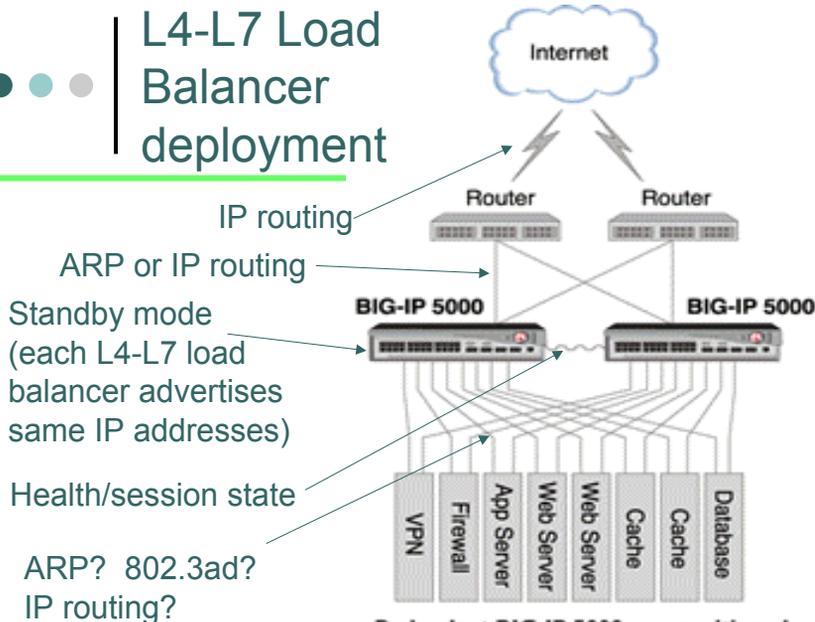
Three levels of load balancing

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- **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

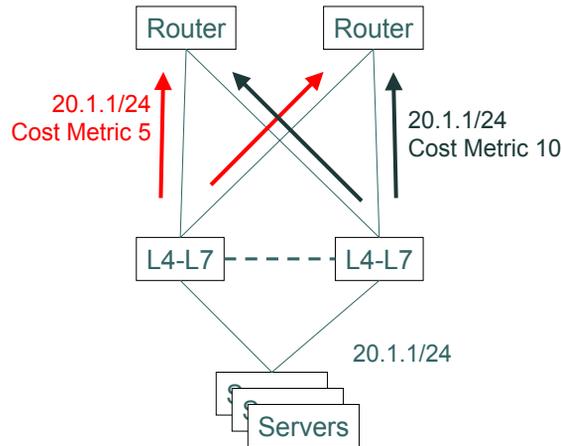
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* "BIG-IP" is F5 product name

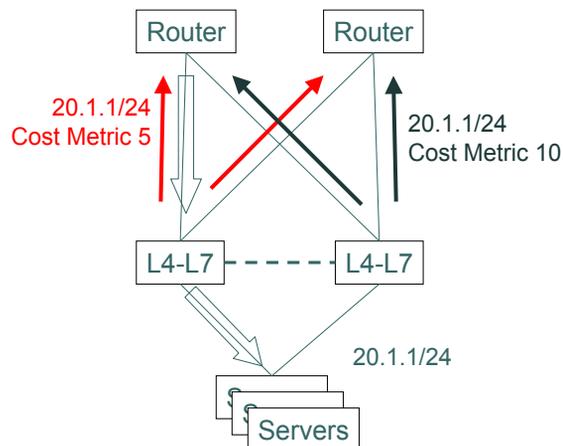
Connectivity robustness: Routing

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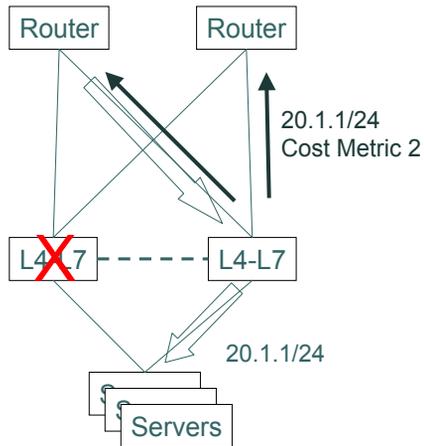
Connectivity robustness: Routing

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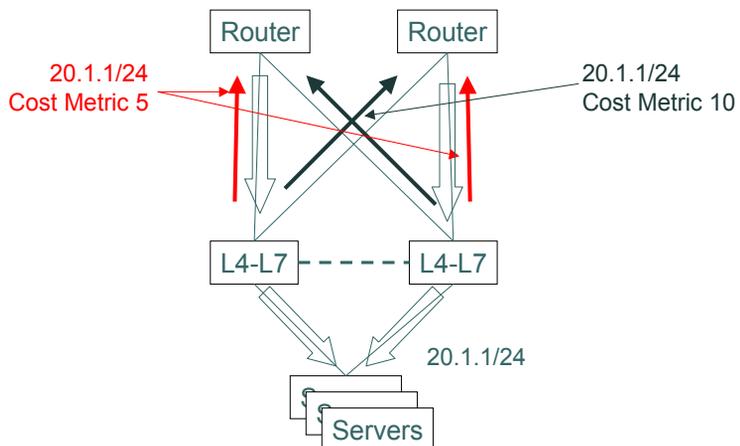
Connectivity robustness: Routing

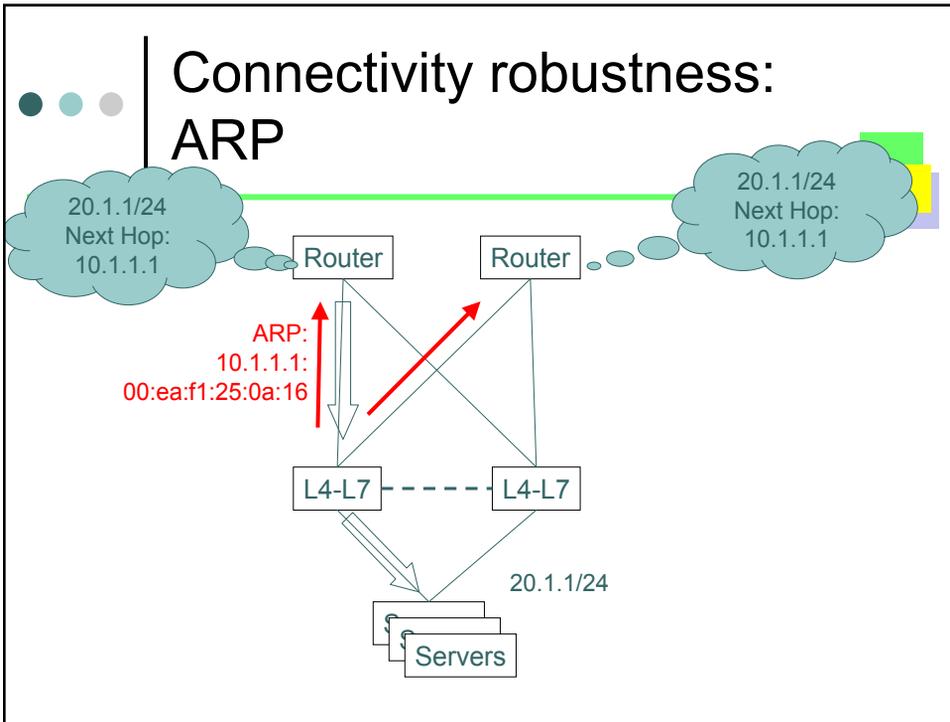
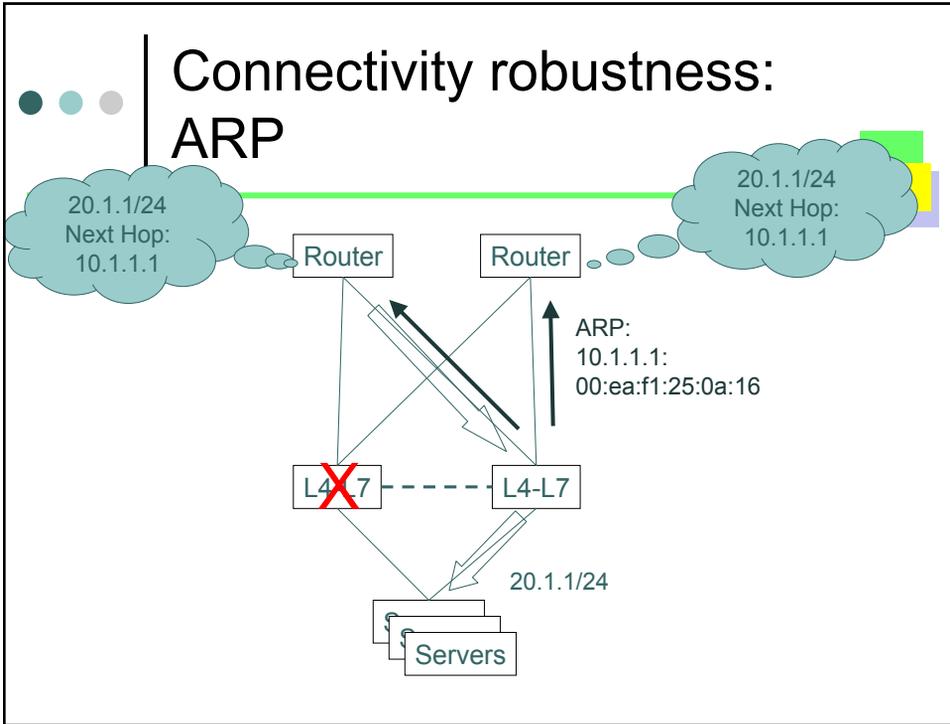
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This also possible??

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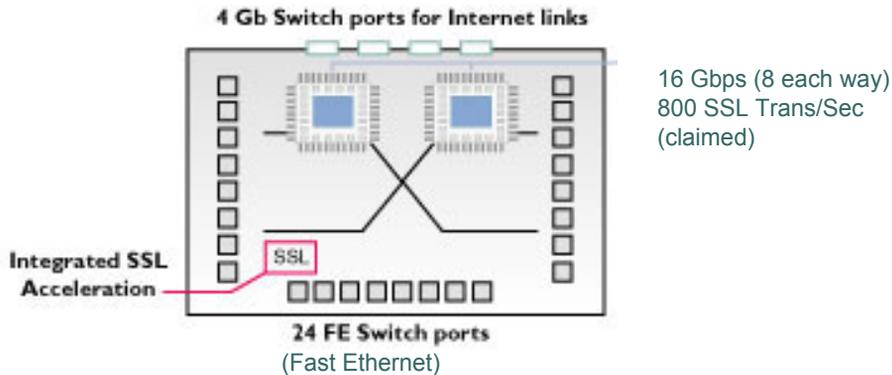






BIG-IP Input-Output

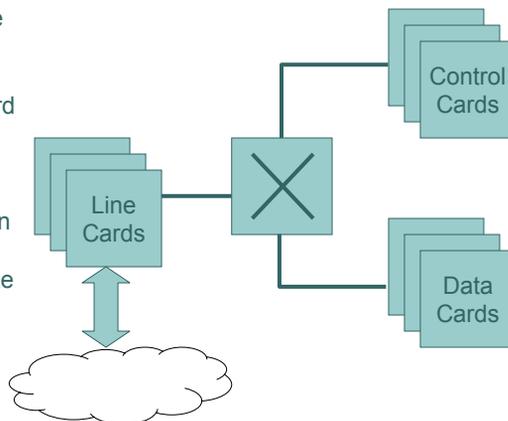
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Tahoe Networks router architecture

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- Redundant state everywhere
- Initially line cards select 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.





Load balancing concepts

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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

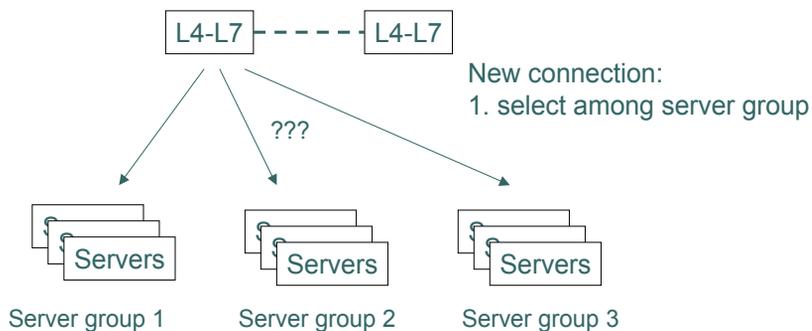
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Groups of servers

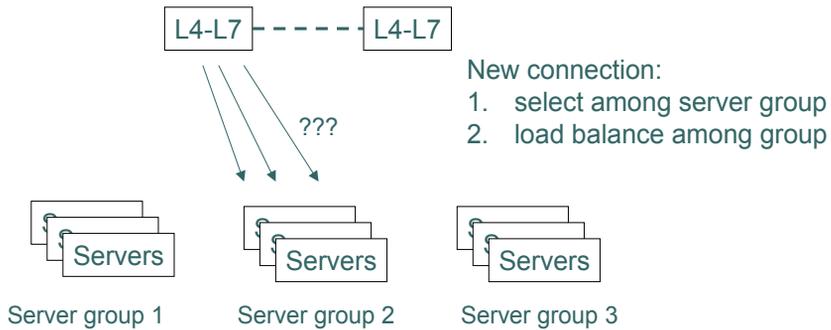
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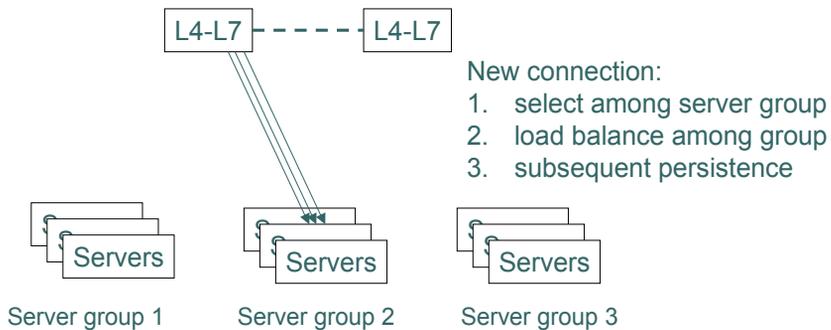
Groups of servers

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Groups of servers: “Switch and Persist”

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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

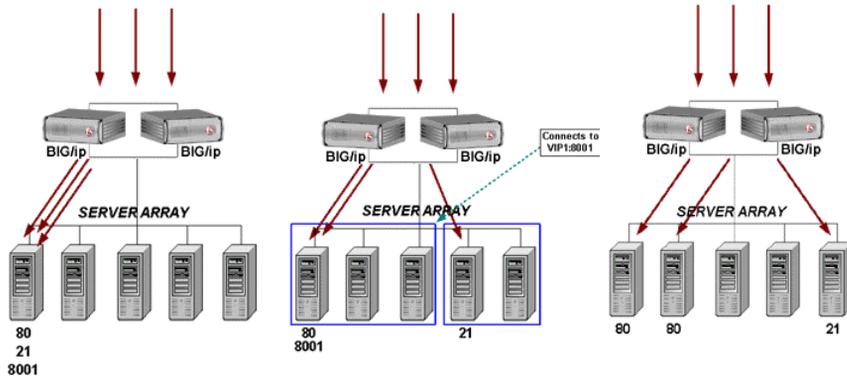
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- Source (IP address)
 - Can force this even if servers within server group have a different IP address
 - Timeout based cleanup
- Destination (IP address)
 - Used to optimize caches
- SSL Persistence (SSL session ID)
 - Even if different source IP 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
 - (doesn't need to change packet size)
 - Server inserts real cookie, load balancer uses but doesn't change it

Session or hash-based cookies

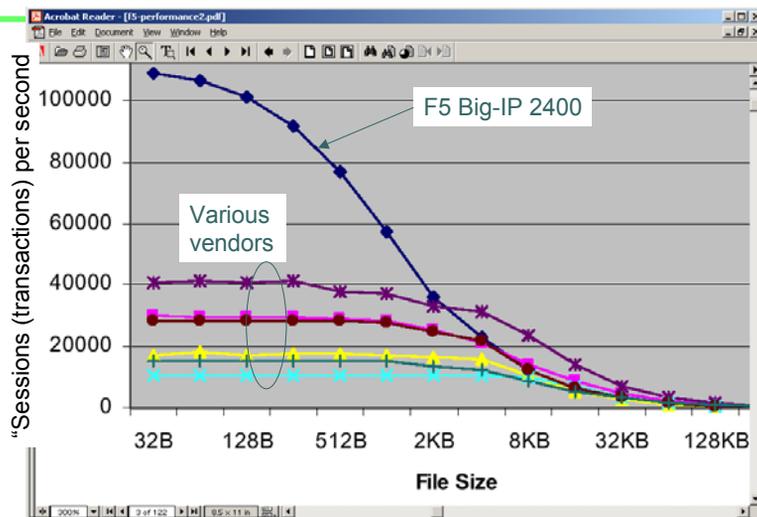
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- If load balancer creates cookie, then cookie can be simple identifier of server
 - different sources can be given same cookie
 - simplifies everything
- If server creates cookie, then there is one per source
 - can keep per session state
 - or load 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

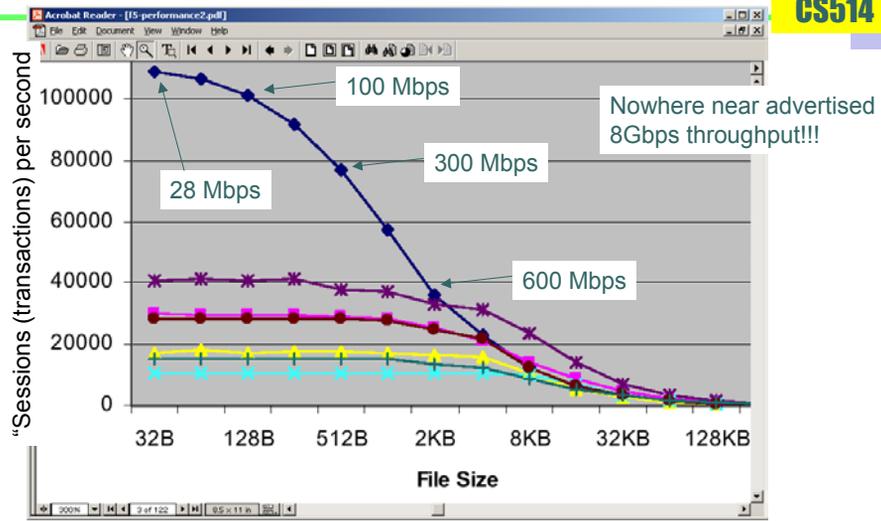
(Veritest "F5 Networks Layer 4/Layer 7 Performance Comparison")

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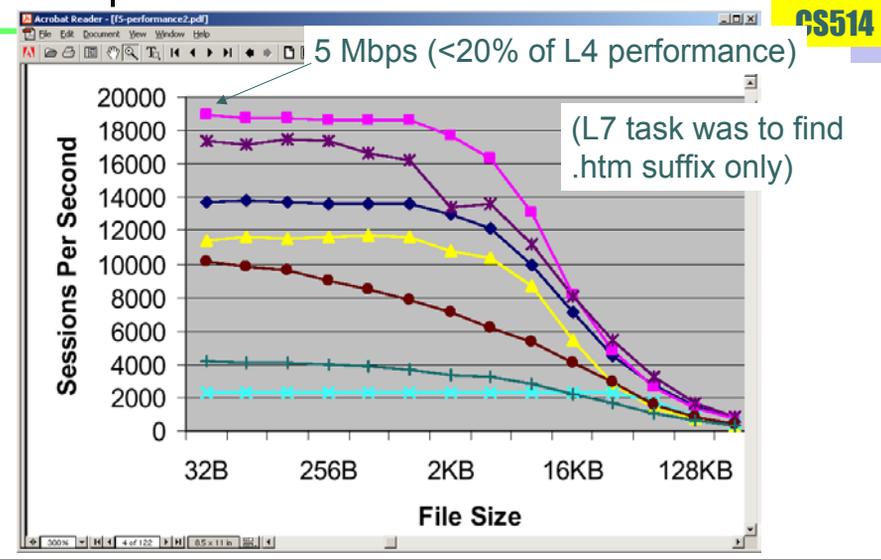
L4 inspection performance

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L7 inspection performance

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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)



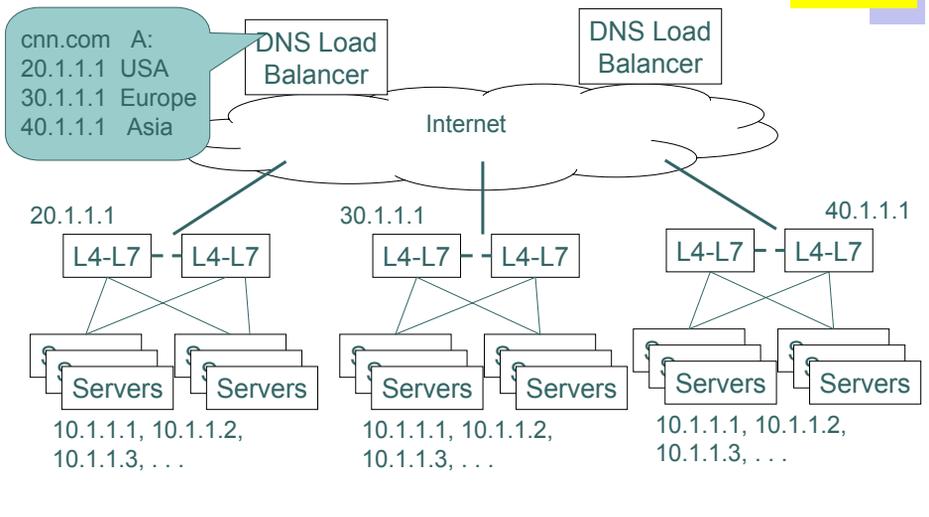
What if one (pair of) load balancers is not enough?

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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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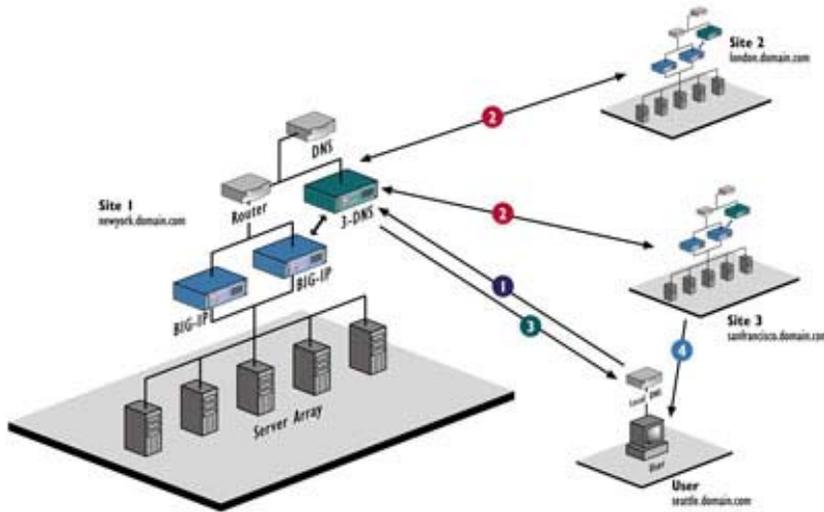
DNS Load balancer

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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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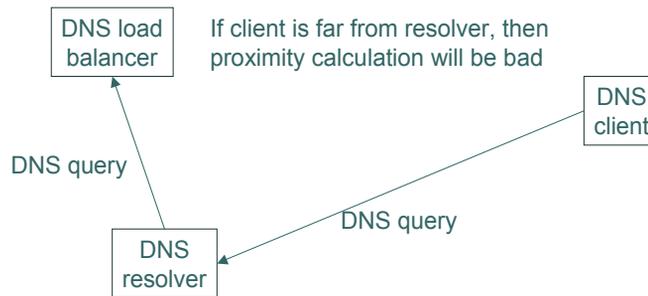


DNS-based geographical selection rough at best

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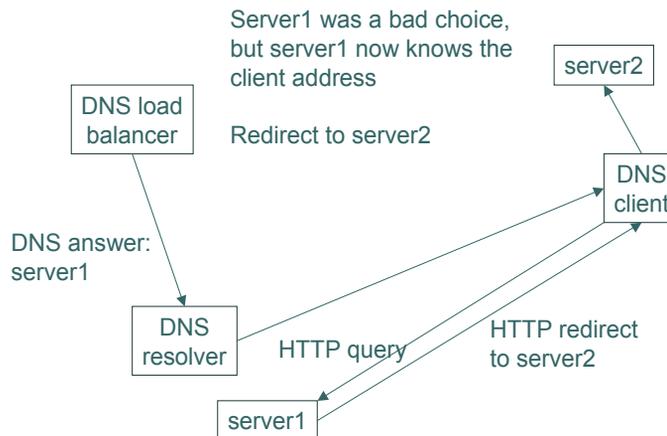
DNS load balancer knows IP address of resolver, but not of actual client

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



Redirection can improve geographical selection

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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

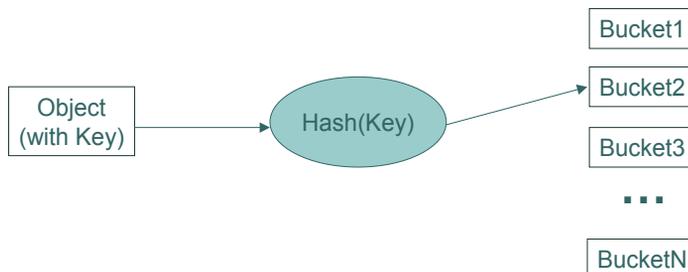
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- Perfect stateless persistence is impossible
 - That's why F5 is stateful
- But stateless “pretty good persistence” is possible
 - May be used for “content affinity”: directing requests to web caches
- Using “consistent hashing”
 - (Could just have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



Hashing rehash

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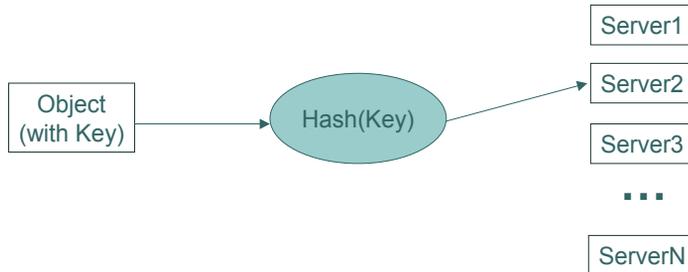


With regular hashing, you can control the number of buckets and get good performance as a result.



Hashing rehash

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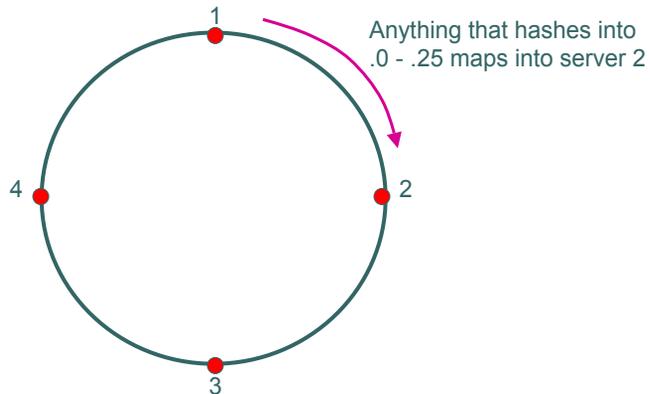


With regular hashing, you can control the number of buckets and get good performance as a result. But with load balancing, the buckets are the servers.....



Spread servers over unit circle, hash onto circle

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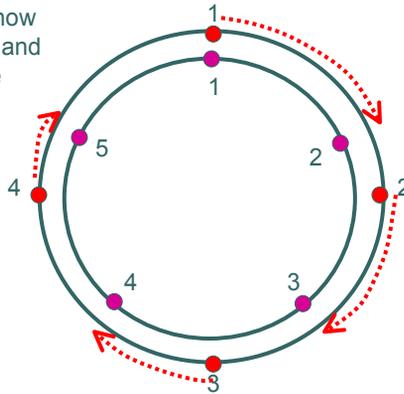


If server added, many mappings change

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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

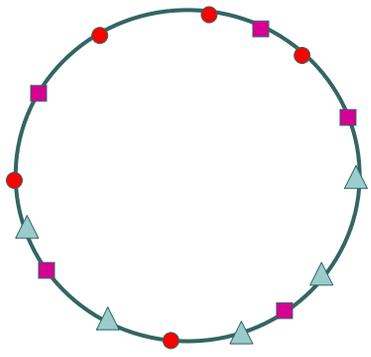
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- Rather than evenly spread servers over unit circle:
- Replicate servers many times, and randomly place servers on unit circle



Consistent hashing

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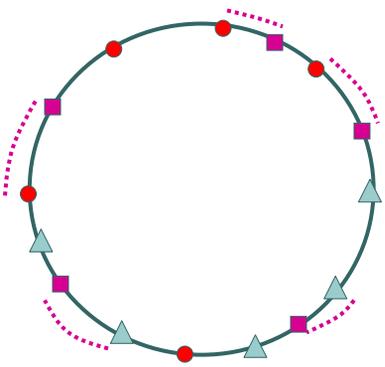


- 1
- 2
- ▲ 3



Consistent hashing

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- 1
- 2
- ▲ 3

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



Poor man's load balancing

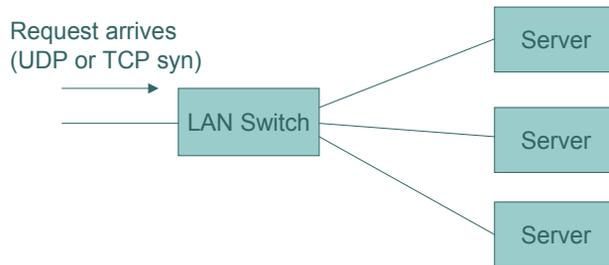
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- Microsoft has a load balancing feature (Network Load Balancing, NLB)
 - Across a cluster of up to 32 servers
- Three types of affinity (TCP and UDP)
 - Source IP addr and source port (so-called "none")
 - Single source IP addr
 - Class C block of source IP addr



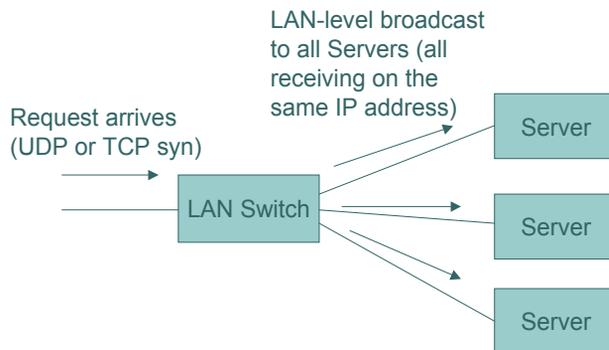
Operation

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Operation

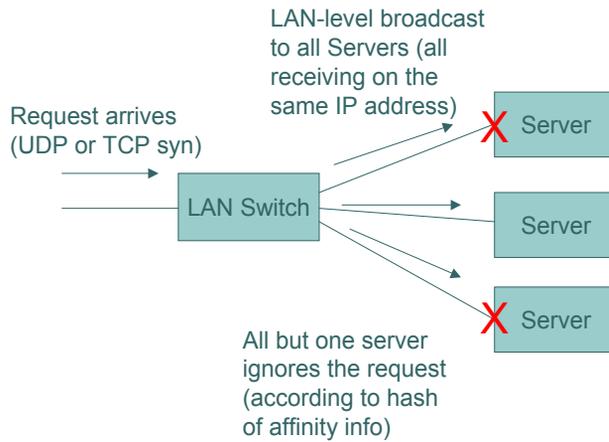
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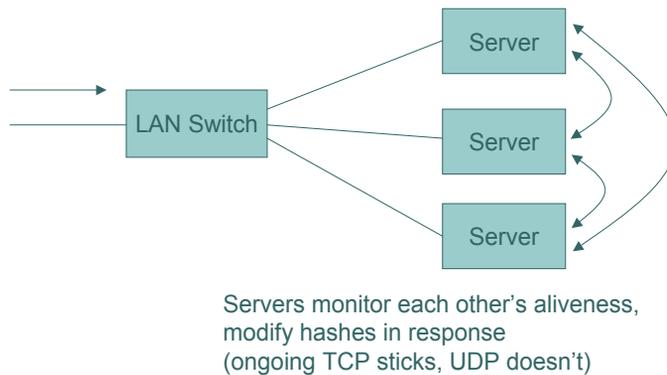
Operation

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Operation

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Why poor man's?

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- You don't have to buy an L4-L7 load balancer
- But significantly less flexibility than L4-L7 load balancer
- And, every server gets every packet and does L3-L4 inspection, so clearly some extra load
 - Don't know if this is done in CPU or off-board...