ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

HY-559
Infrastructure Technologies for Large-Scale Service-Oriented Systems

Kostas Magoutis
magoutis@csd.uoc.gr
http://www.csd.uoc.gr/~hy559

Garage innovator

- Creates new Web applications that may rocket to popular success
  - Success typically comes in the form of “flash crowds”
- Requires load-balanced system to support growth
- Does not have access to large upfront investment

Contemporary utility computing

- Low overhead during lean times
- Highly scalable
- Quickly scalable

Storage delivery networks

- Amazon S3, Nirvanix platforms
- Similar to Content Delivery Networks (CDNs)
- Large clusters of tightly coupled machines
- Handle data replication, distributed consensus, load distribution behind a static-content interface

Compute Clouds

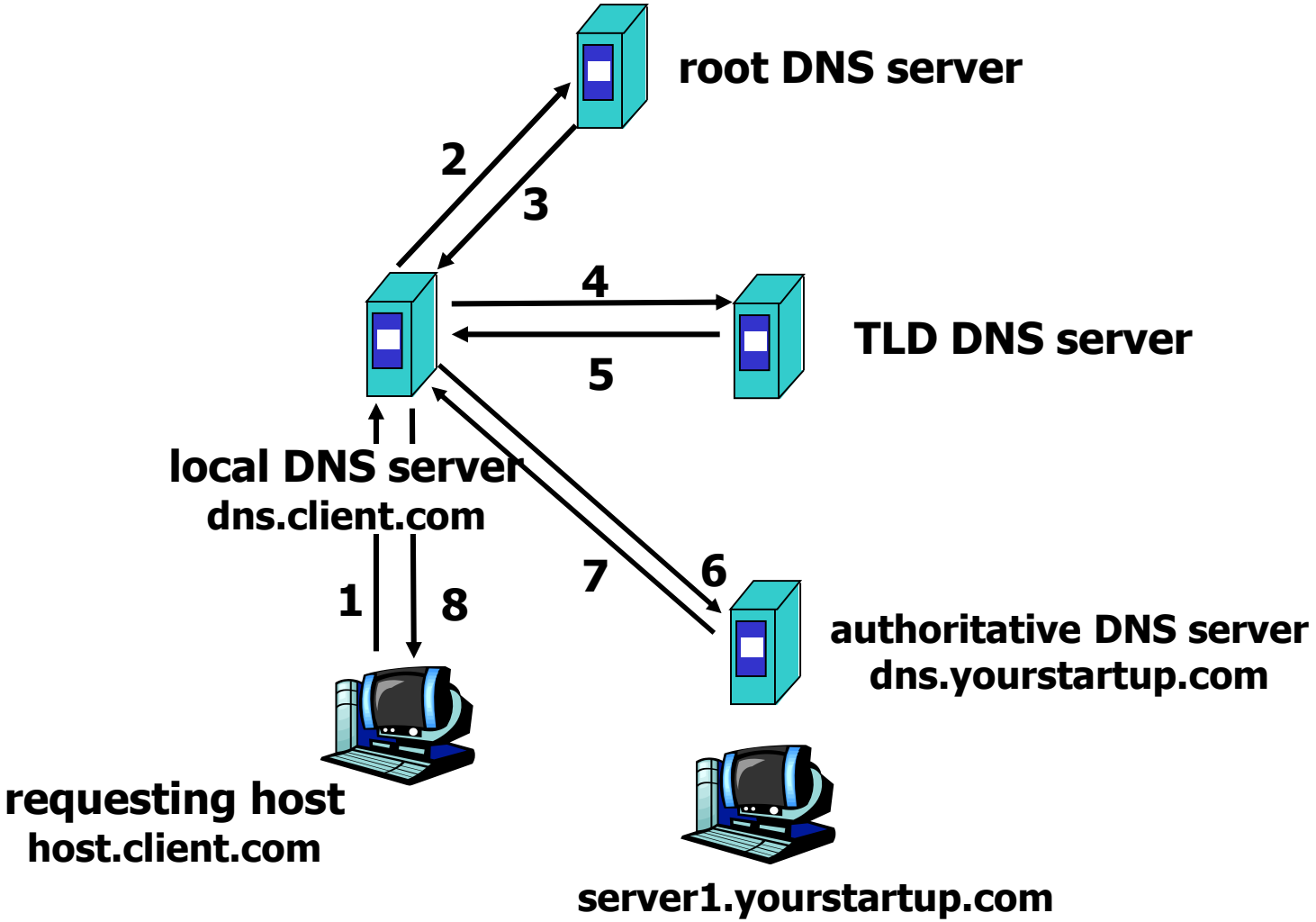
- Before Cloud computing (~2006):
  - Bandwidth to colocation facilities billed on per-use basis
  - Virtual private servers billed monthly

- Current utility computing providers offer VM instances billed per hour

Other building blocks

- Missing piece: relational databases
- DNS outsourcing
  - Avoids DNS becoming single point of failure

DNS example


root DNS server
2
3
4
5
TLD DNS server
local DNS server
dns.client.com
1
8
7
6
authoritative DNS server
dns.yourstartup.com
requesting host
host.client.com
server1.yourstartup.com

DNS: caching and updating records

- Once any name server learns mapping, it caches it
  - Cache entries timeout after some time (TTL)
  - TLD servers cached in local name servers
    - Thus root name servers are not visited often

- update/notify mechanisms under design by IETF
  - RFC 2136
  - http://www.ietf.org/html.charters/dnsind-charter.html

DNS records

RR format: (name, value, type, TTL)

- Type=A
  - name is hostname
  - value is IP address

- Type=NS
  - **name** is domain (e.g. foo.com)
  - **value** is hostname of authoritative name server for this domain

- Type=CNAME
  - name is alias for some "canonical" (real) name
    www.ibm.com is really servereast.backup2.ibm.com
  - value is canonical name

- Type=MX
  - value is name of mail server associated with name

Inserting records into DNS

- Example: just created startup "Network Utopia"

- Register name networkuptopia.com at a registrar (e.g., Network Solutions)
  - Need to provide registrar with names and IP addresses of your authoritative name server (primary and secondary)
  - Registrar inserts two RRs into the com TLD server:
    - (networkutopia.com, dns1.networkutopia.com, NS)
    - (dns1.networkutopia.com, 212.212.212.1, A)

Inserting records into DNS (2)

- Put in authoritative server Type A record for www.networkuptopia.com

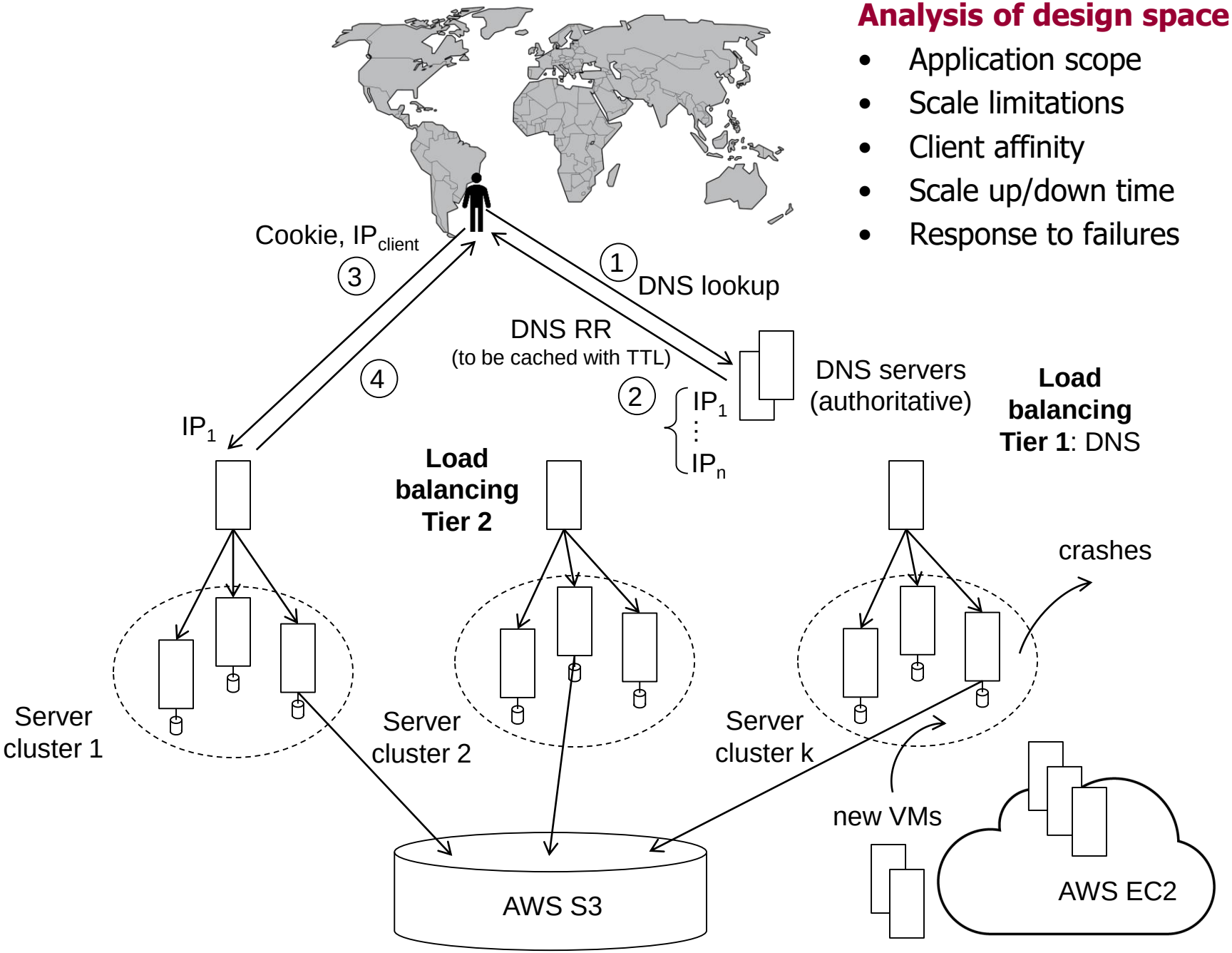
- Put Type MX record for networkutopia.com

Scaling architectures

- Using the bare SDN
- DNS load-balanced cluster
- HTTP redirection
- L4 or L7 load balancing
- Hybrid approaches

Analysis of design space

- Application scope
- Scale limitations
- Client affinity
- Scale up/down time
- Response to failures



Application scope

- Bare SDN suitable for static content only
- HTTP redirector works with HTTP
- L7 load balancers constrained by application protocol
- DNS and L4 load balancers work across applications

Scale limitation

- SDNs are designed to be scalable
- HTTP redirection involved only in session setup
- L4/L7 load balancer limited by forwarder's ability to handle entire traffic
- DNS load balancing has virtually no scalability limit

Client affinity

- SDN fulfills client request regardless of where it arrives
- HTTP redirection provides strong client affinity
  - Use client session identifier
- L4 balancers cannot provide affinity
- L7 balancers can provide affinity
- DNS clients cannot be relied upon to provide affinity

Scale up and down time

- Bare SDN designed for instantaneous scale up/down
- HTTP redirectors and L4/L7 balancers have identical behavior
  - Scale down time is trickier, need to consider worst-case session length
- DNS is most problematic

Effects of front-end failure

- SDN has multiple redundant hot-spare load balancers
- L4 and L7 balancers are highly susceptive
  - A solution is to split traffic across *m* balancers, use redundant hot spares (DNS load-balanced)
- HTTP redirectors same as above, except that there is no impact on existing sessions
- DNS load balancing affected by failure when
  - Using single DNS server (no replication)
  - Short TTLs so as to handle scale-up/down and backend node failure

Effects of back-end failure

- "Back-end" are servers that are running service code
- SDN managed by service provider (~1% writes fail)
- HTTP redirector and L4/L7 balancer
  - Newly arriving sessions see no degradation at all
  - Existing sessions see only transient failures
- DNS load balancing suffers worst performance

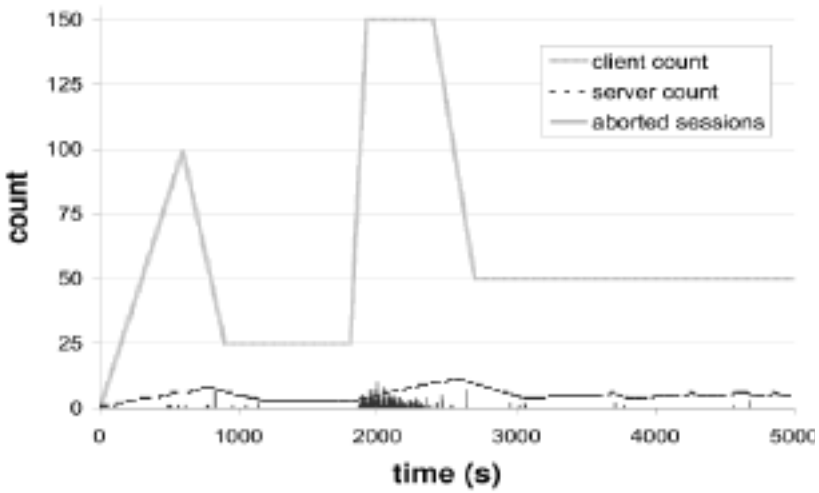
Summary

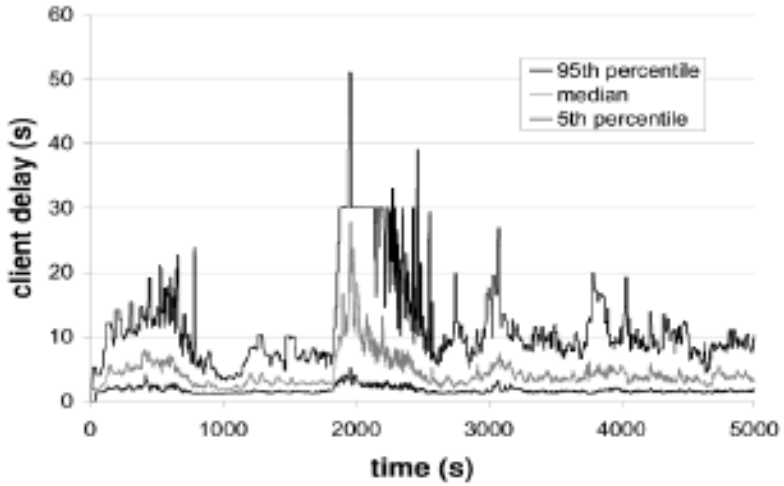
Criterion	Design			
	Bare SDN	HTTP Redir.	L4/L7 Load Bal.	DNS Load Bal.
§3.1: Application Scope	Static HTTP	HTTP	All	All
§3.2: Scale Limitation	Very large	Client arrival rate	Total traffic rate	Unlimited
§3.3: Client affinity	N/A	Consistent	Consistent	Inconsistent
§3.4: Scale-Up Time	Immediate	VM Startup Time (about a minute)	VM Startup Time (about a minute)	VM Startup + DNS TTL (5-10 minutes)
§3.4: Scale-Down Time	Immediate	Session Length	Session Length	Days
§3.5: Front-End Node Failure: Effect on New Sessions	N/A	Total Failure	Total Failure	Major Failure
§3.5: Front-End Node Failure: Effect on Estab. Sessions	N/A	No effect	Total Failure	Rare effect
§3.5: Front-End Node Failure: Effect on New Sessions (m redundant front-ends)	Unlikely	long delay for $1/m$th sessions?	long delay for $1/m$th sessions?	Short delay (§4.2)
§3.5: Front-End Node Failure: Effect on Estab. Sessions (m redundant front-ends)	Unlikely	No effect	$1/m$th sessions fail	A few sessions see short delay
§3.6: Back-End Node Failure: Effect on New Sessions	Unlikely	No effect	No effect	long delay for $1/n$th of sessions
§3.6: Back-End Node Failure: Effect on Estab. Sessions	Unlikely	User-recoverable failure	Transient failure	long delay for $1/n$th of sessions

EC2-integrated HTTP redirector

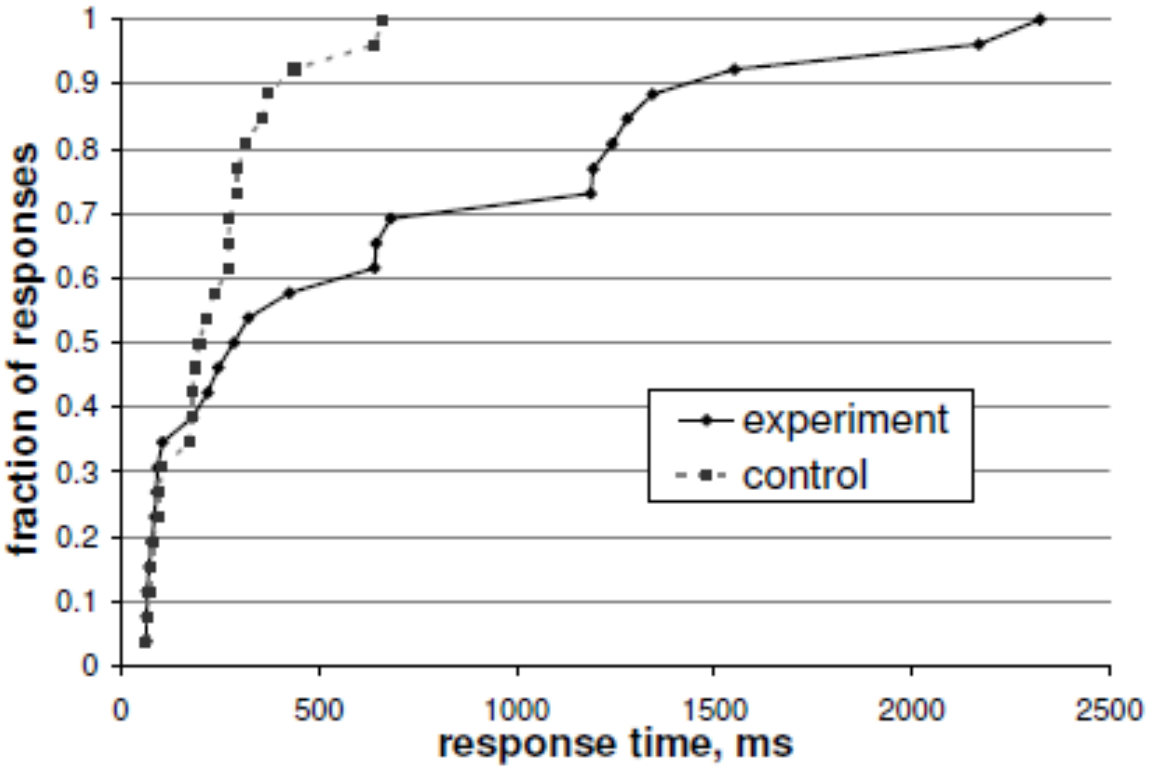
- Monitors load on each running service instance
  - Servers send periodic heartbeats with load statistics
  - Redirector uses heartbeats to evaluate server liveness
- Resizes server farm in response to client load
  - When total free CPU capacity on servers with short run queues are less than 50%, start new server
  - When more than 150%, terminate server with stale sessions
- Routes new sessions probabilistically to lightly loaded servers

HTTP redirect experiment





DNS server failover behavior



Other microbenchmarks

- Web client DNS failover behavior
  - Clients experience delays from 3 to 190 seconds
- Badly-behaved resolvers
- Maximum size of DNS replies
- Client affinity observations

MapCruncher

- Interactive map generated by client (AJAX) code
- Service instance responds to HTTP GET bringing an image off of stable storage
- Initially used 25GB of images on a single server's disk
- Flash crowd service peaked at 100 files / sec
- Moving to Amazon S3 solved I/O bottleneck

Asirra

- CAPTCHA Web service
- Asirra session consists of
  - Client retrieves challenge
  - Submits user response for scoring
  - Produce service ticket to present to webmaster
  - Webmaster independently verifies service ticket
- Deployed in EC2
  - 100GB of images (S3)
  - Metadata (MySQL) reduced into simple database loaded on each server's local disk

Asirra (2)

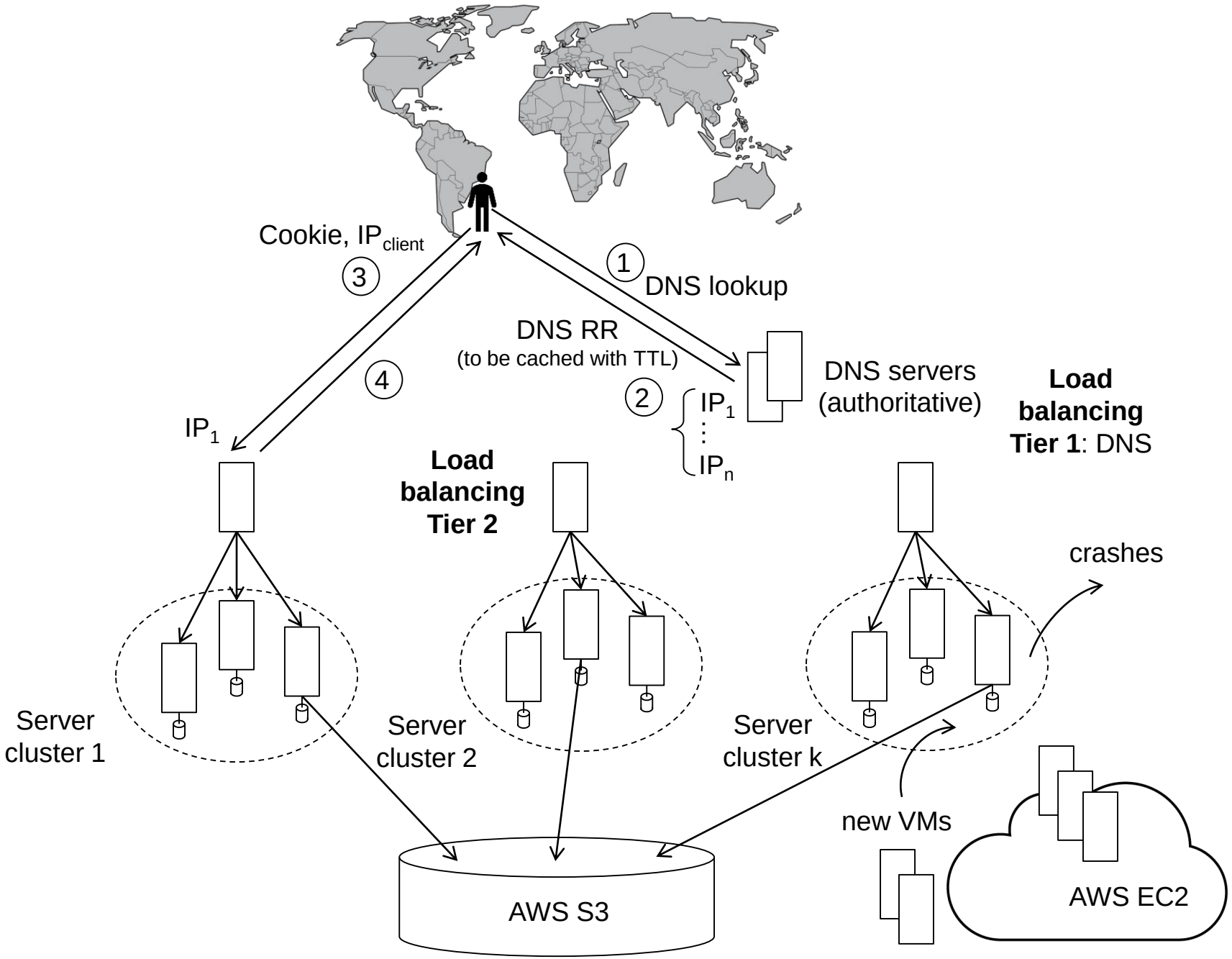
- Session state kept locally within each server
  - S3 option considered inadequate (write performance)
- Client affinity becomes important
  - DNS load balancing does not guarantee affinity
- Servers forward session to its home
  - Rate of affinity failures about 10%
- Flash crowd
  - 75,000 challenges plus 30,000 DoS requests over 24 hours

Asirra lessons learned

- Poor client-to-server affinity due to DNS load balancing was not a big problem
- EC2 lost IP reservation after failure (fixed)
- Denial of service attack easily dealt with with Cloud resources
  - Further lesson: No need to optimize code before on-going popularity materializes

Inkblot

- Website to generate images as password reminders
  - Must store dynamically created information (images) durably
- Coded simply but inefficiently in Python
- Store both persistent and ephemeral state in S3
- Initial cluster consistent of two servers, load balanced through DNS
  - Updating DNS required interacting with human operator


Cookie, IP client
3
1
DNS lookup
DNS RR
(to be cached with TTL)
4
2
DNS servers
(authoritative)
IP 1
IP n
IP 1
Load balancing Tier 1: DNS
Load balancing Tier 2
crashes
Server cluster 1
Server cluster 2
Server cluster k
new VMs
AWS S3
AWS EC2

Inkblot (2)

- Flash crowd resulted into run-queue length of 137
  - Should be below 1
- Added 12 more servers, DNS update, within half hour
- New server saw load immediately, original servers recovered in about 20 minutes
- 14 servers averaged run queue lengths b/w 0.5-0.9
- After peak, removed 10 servers from DNS, waited an extra day for rogue DNS caches to empty