Keeping the Balance

Load balancing Demystified

Murali Suriar
linux.conf.au 2019
Content co-written with Laura Nolan

Murali Suriar

Lapsed computer scientist, turned network engineer, turned network SRE, turned storage SRE.

Some years at Google, with some sailing in the middle.

Laura Nolan

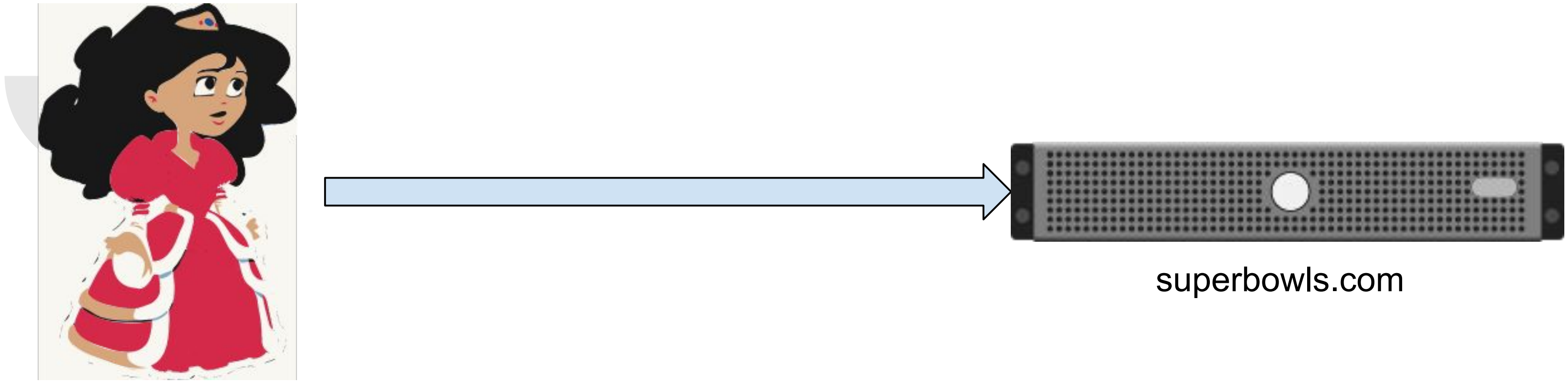
Software engineer, SRE, network SRE.

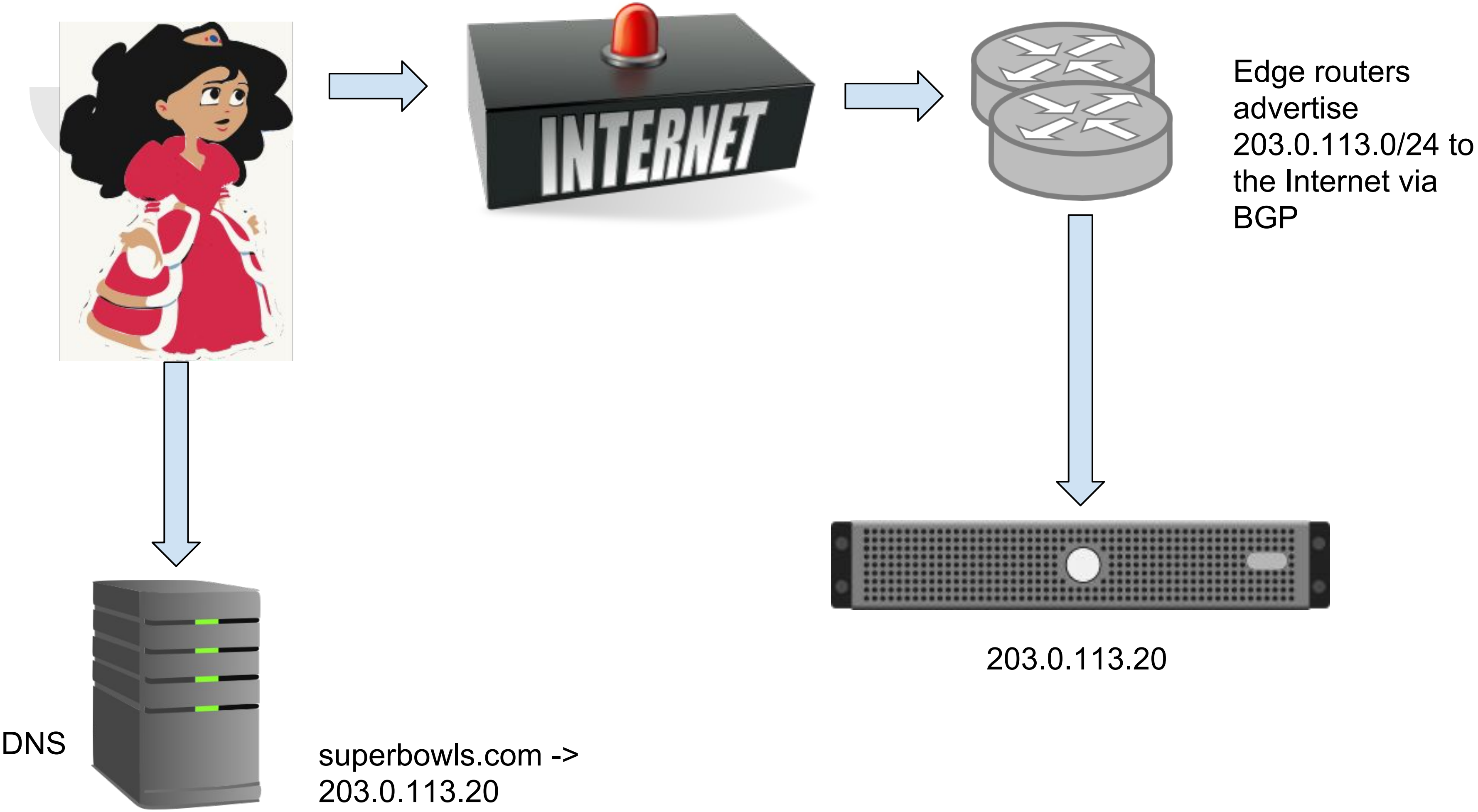
Worked on Google’s edge network.

Also some pre-Google experience in the ‘real world’.

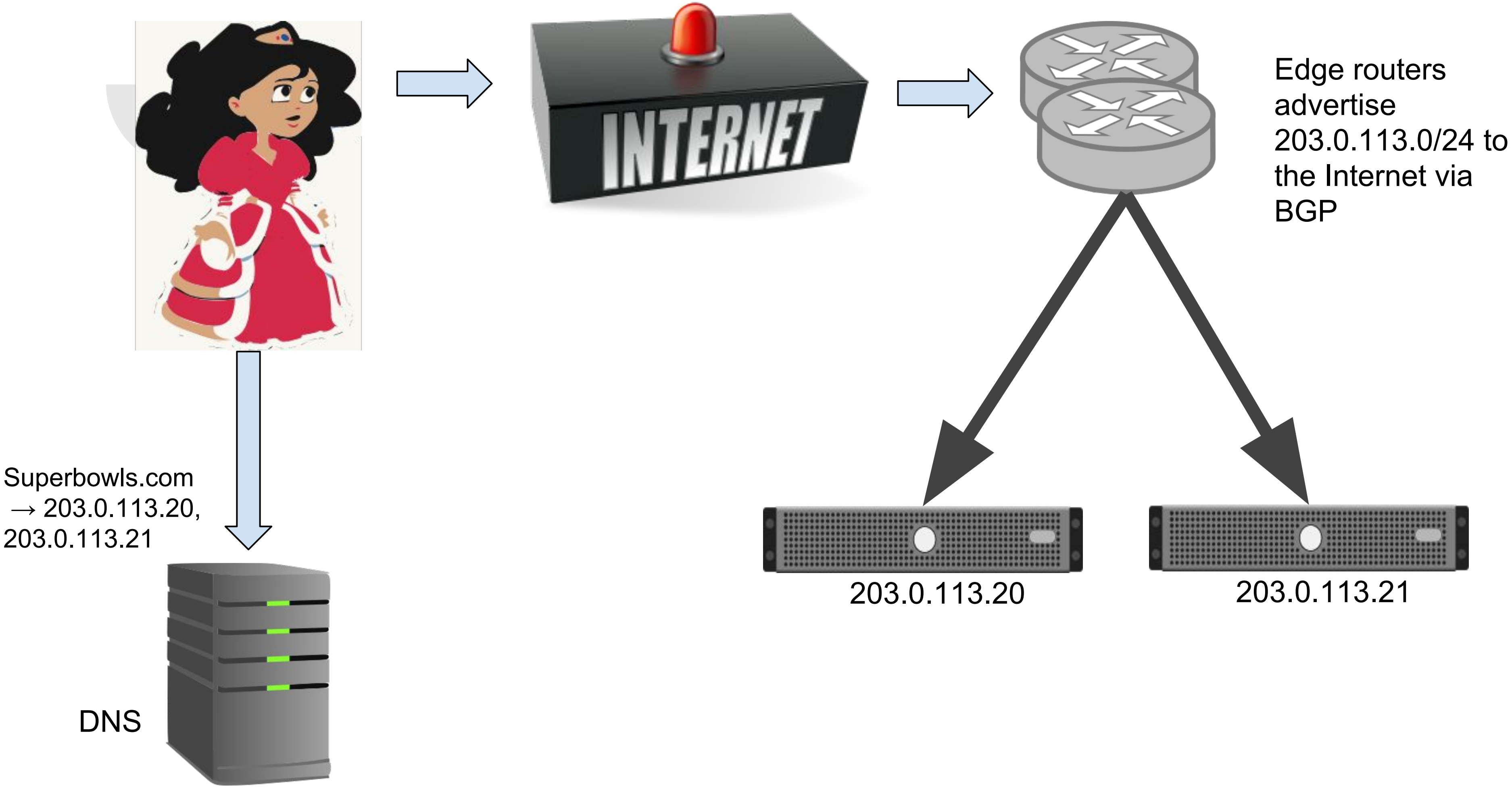
Why talk about loadbalancing?

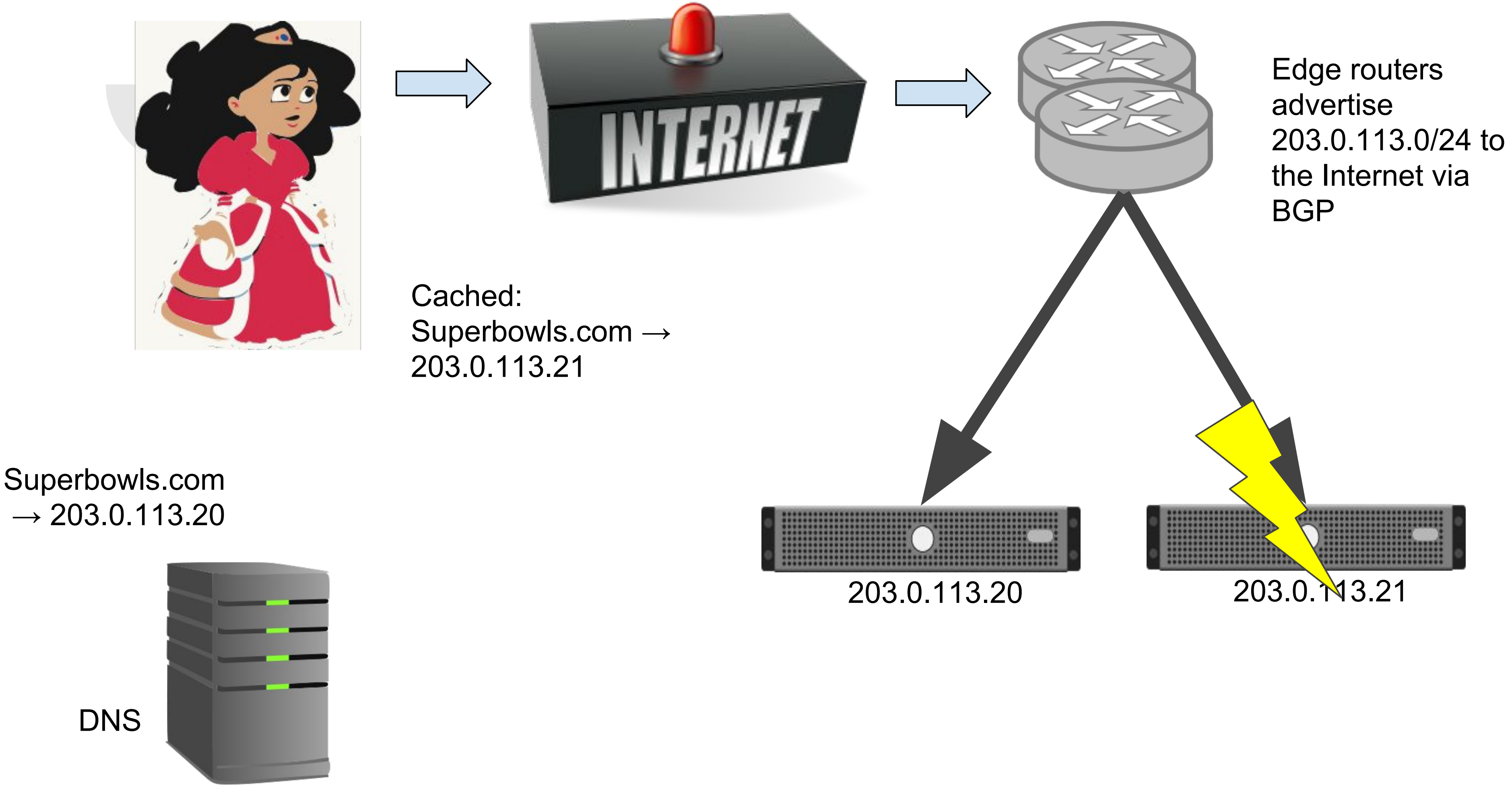
- LB failures are often dropped requests
- It’s always in your serving path
- Huge impact on the performance and resiliency of your application
    - For better or for worse


superbowls.com


INTERNET
Edge routers advertise 203.0.113.0/24 to the Internet via BGP
203.0.113.20
DNS
superbowls.com -> 203.0.113.20

Load distribution	Distributing load across multiple pieces of infrastructure	Partial
High Availability	Avoid using unhealthy infrastructure	Partial


INTERNET
Edge routers advertise 203.0.113.0/24 to the Internet via BGP
Superbowls.com → 203.0.113.20, 203.0.113.21
DNS
203.0.113.20
203.0.113.21


INTERNET
Edge routers advertise 203.0.113.0/24 to the Internet via BGP
Cached: Superbowls.com → 203.0.113.21
Superbowls.com → 203.0.113.20
203.0.113.20
203.0.113.21
DNS

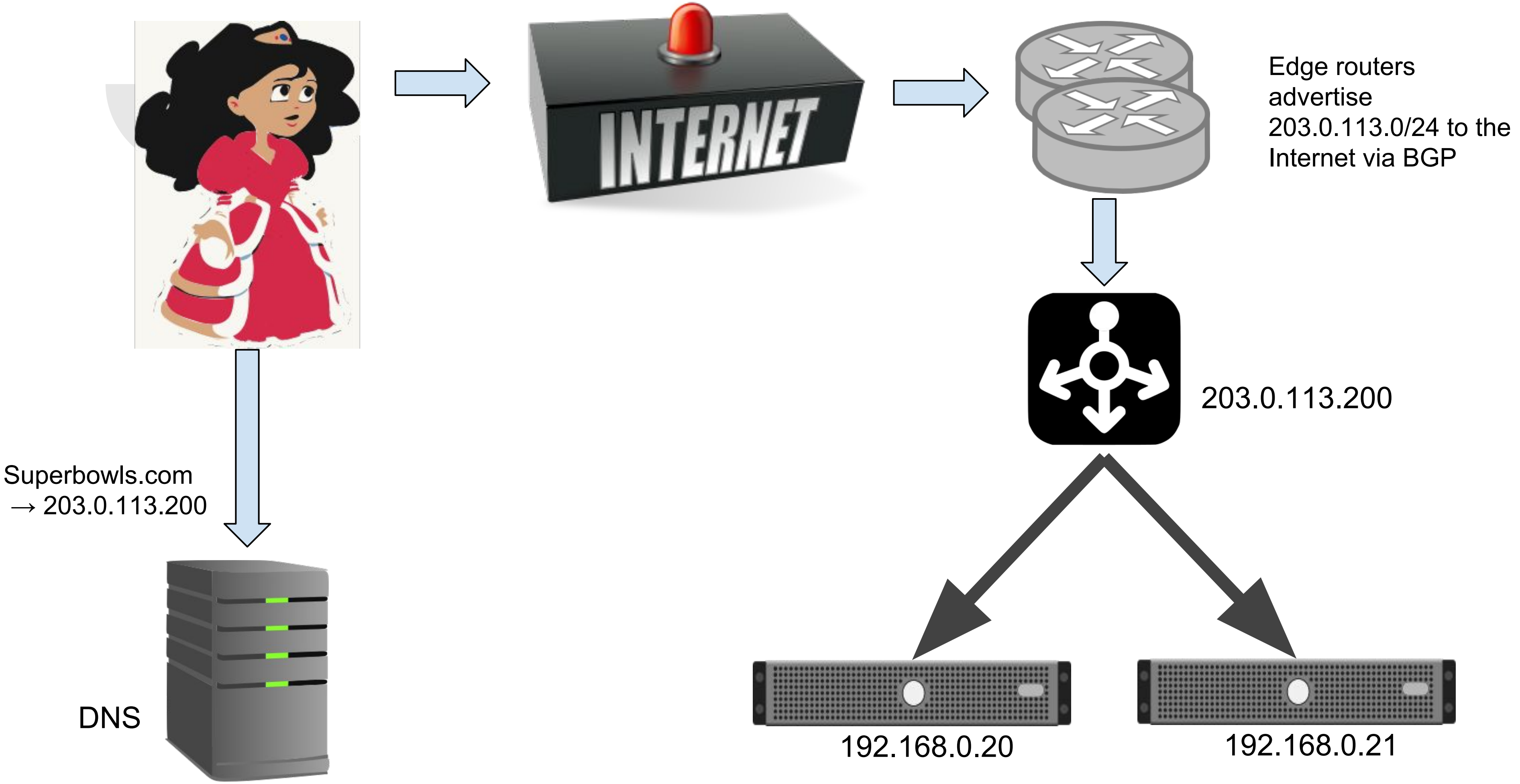
Aside: TTL tradeoffs

DNS TTL tradeoffs

- Long TTLs:
    - Many of your users will not see any change you make for a long period of time
- Very short TTLs:
    - Higher load on DNS infrastructure
    - Clients have to query DNS more often - adds latency
    - If DNS experiences any unavailability, a higher proportion of your users will be affected
    - Many clients will ignore very short TTLs anyway

Back to our story

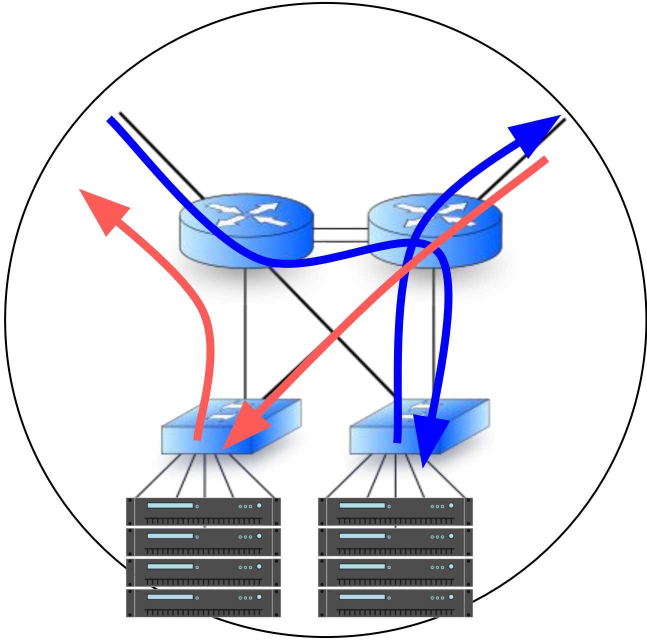
Load distribution	Distributing load across multiple pieces of infrastructure	Yes
High Availability	Avoid using unhealthy infrastructure	Poor
Flexibility	Allow operators to shift load manually or via configured policies	Delayed

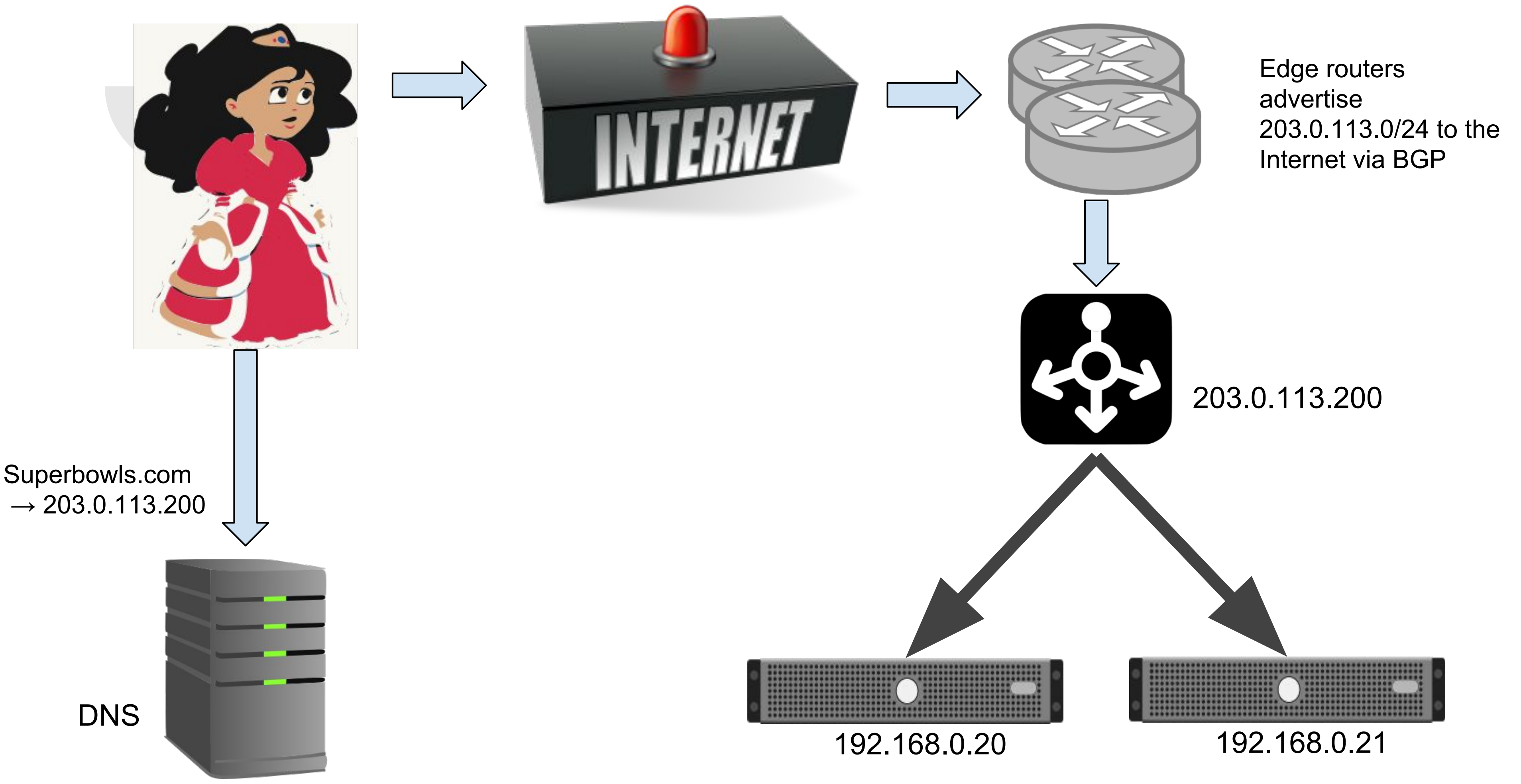

INTERNET
Edge routers advertise 203.0.113.0/24 to the Internet via BGP
203.0.113.200
Superbowls.com → 203.0.113.200
DNS
192.168.0.20
192.168.0.21

Source address
Source port
Destination address
Destination port
Protocol

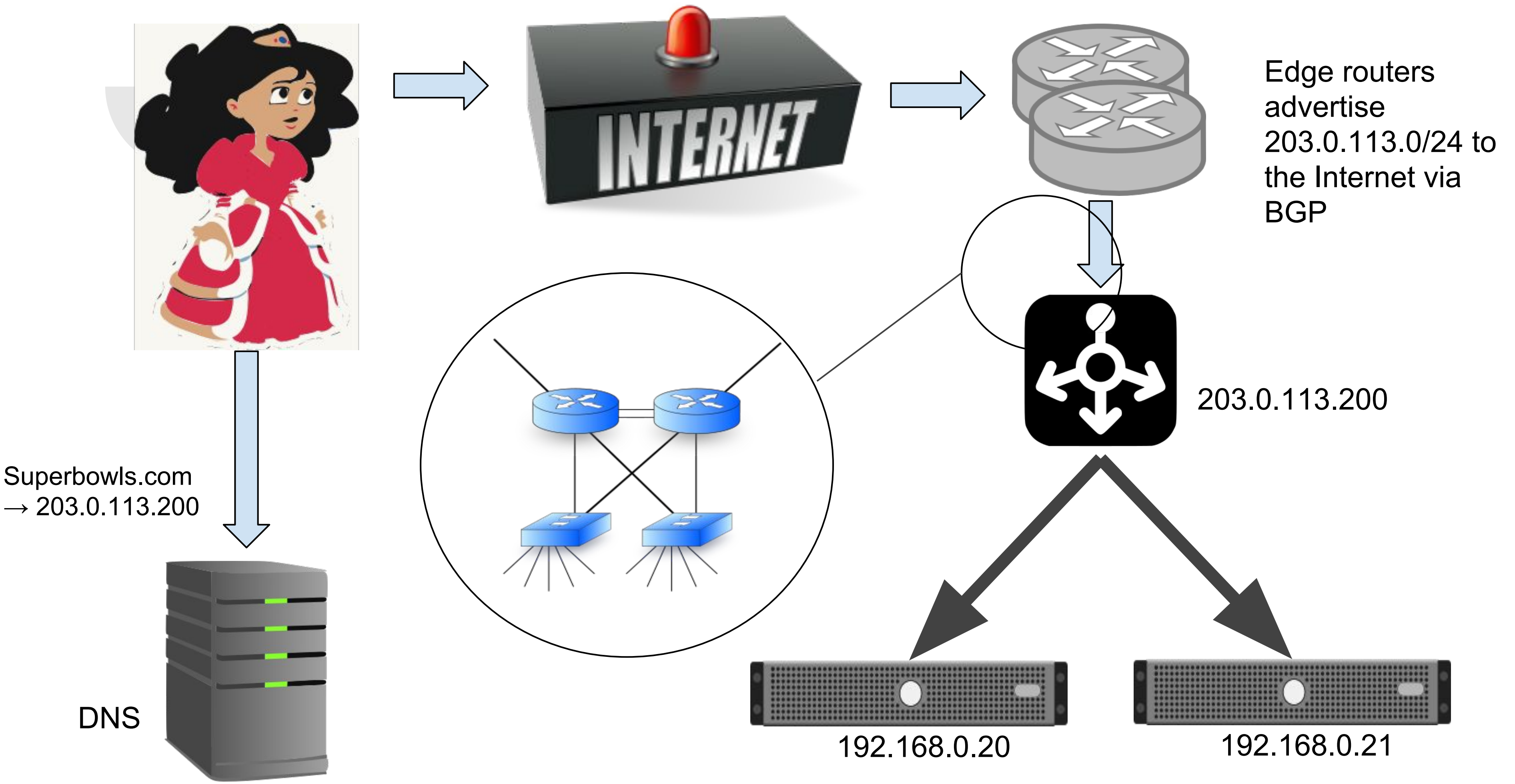
Hash of
5-tuple

Selected
backend




INTERNET
Edge routers advertise 203.0.113.0/24 to the Internet via BGP
203.0.113.200
Superbowls.com
→ 203.0.113.200
DNS
192.168.0.20
192.168.0.21

Load distribution	Distributing load across multiple pieces of infrastructure	Yes
High Availability	Avoid using unhealthy infrastructure	Yes
Flexibility	Allow operators to shift load manually or via configured policies	Yes



INTERNET
Edge routers advertise 203.0.113.0/24 to the Internet via BGP
203.0.113.200
Superbowls.com → 203.0.113.200
DNS
192.168.0.20
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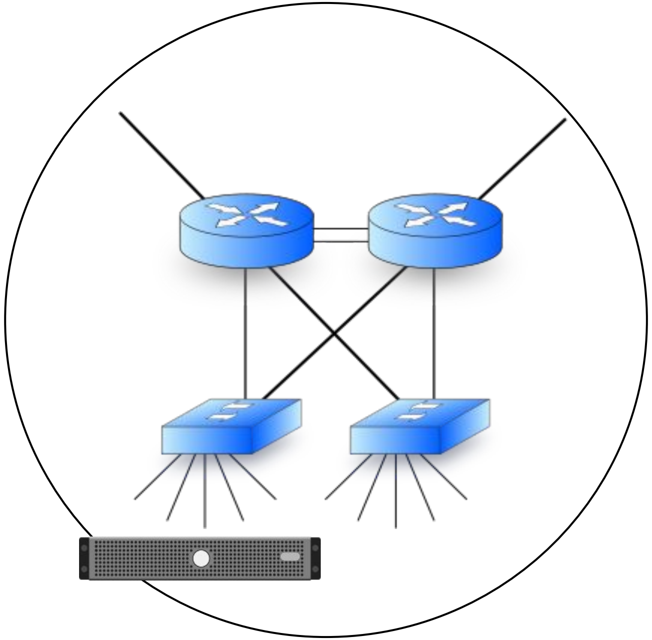
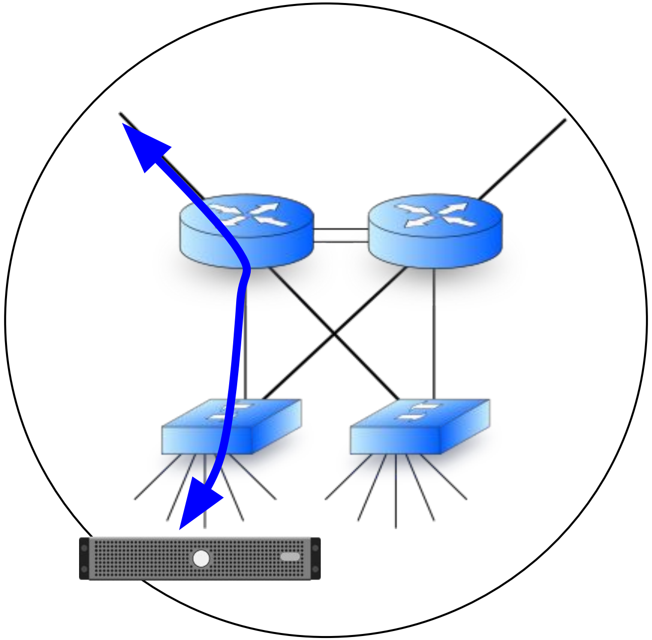
Aside: network load balancing

Stateless network load distribution



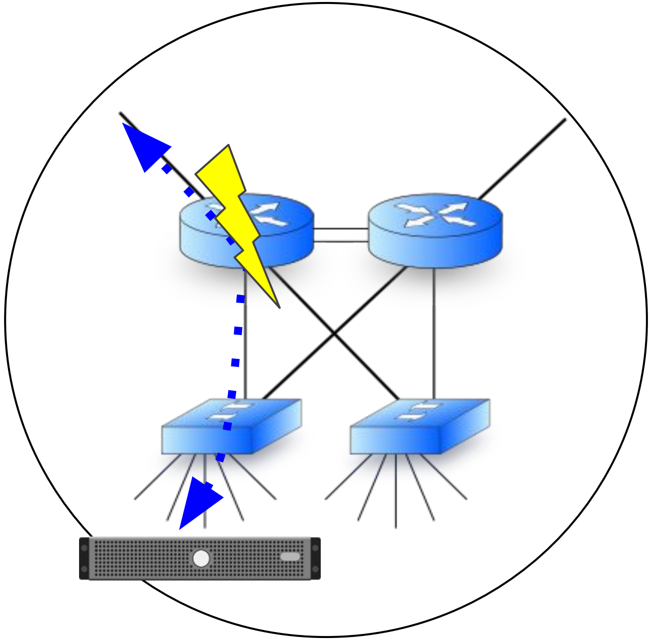
Stateless network load distribution

- Availability



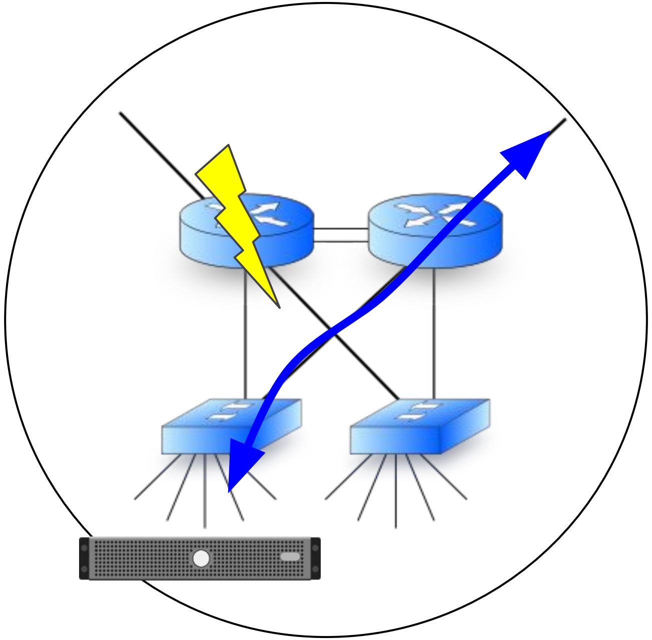
Stateless network load distribution

- Availability

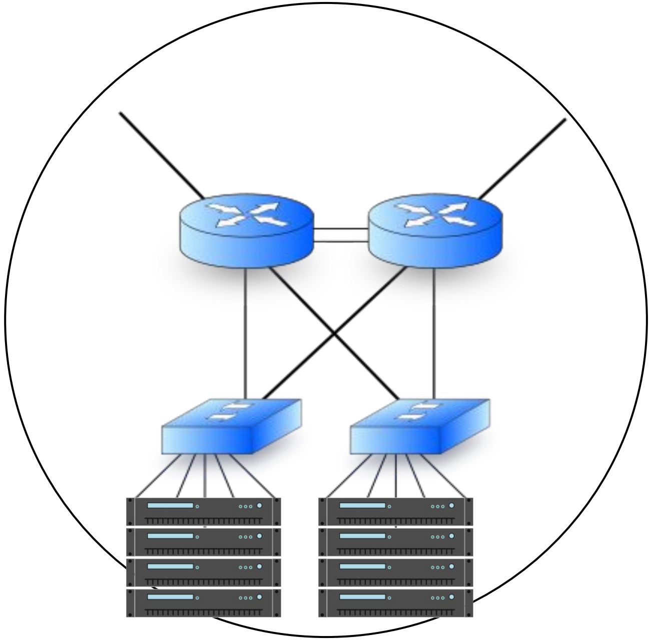


Stateless network load distribution

- Availability

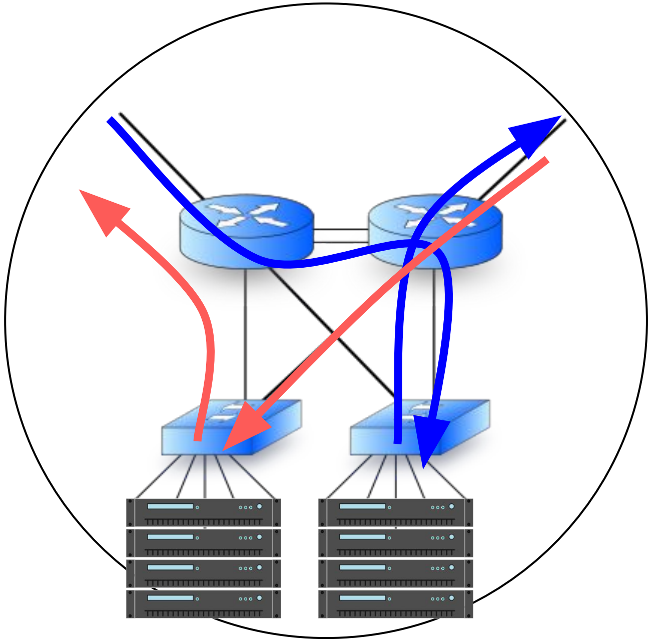


Stateless network load distribution



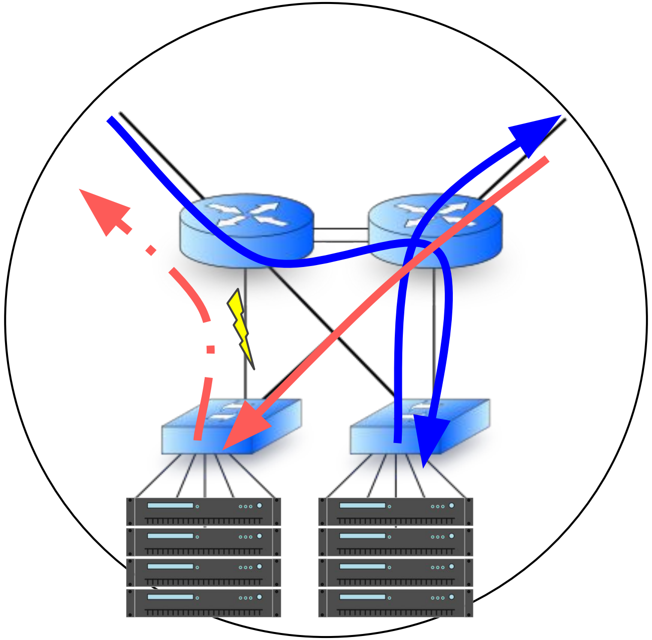
Stateless network load distribution

- Capacity

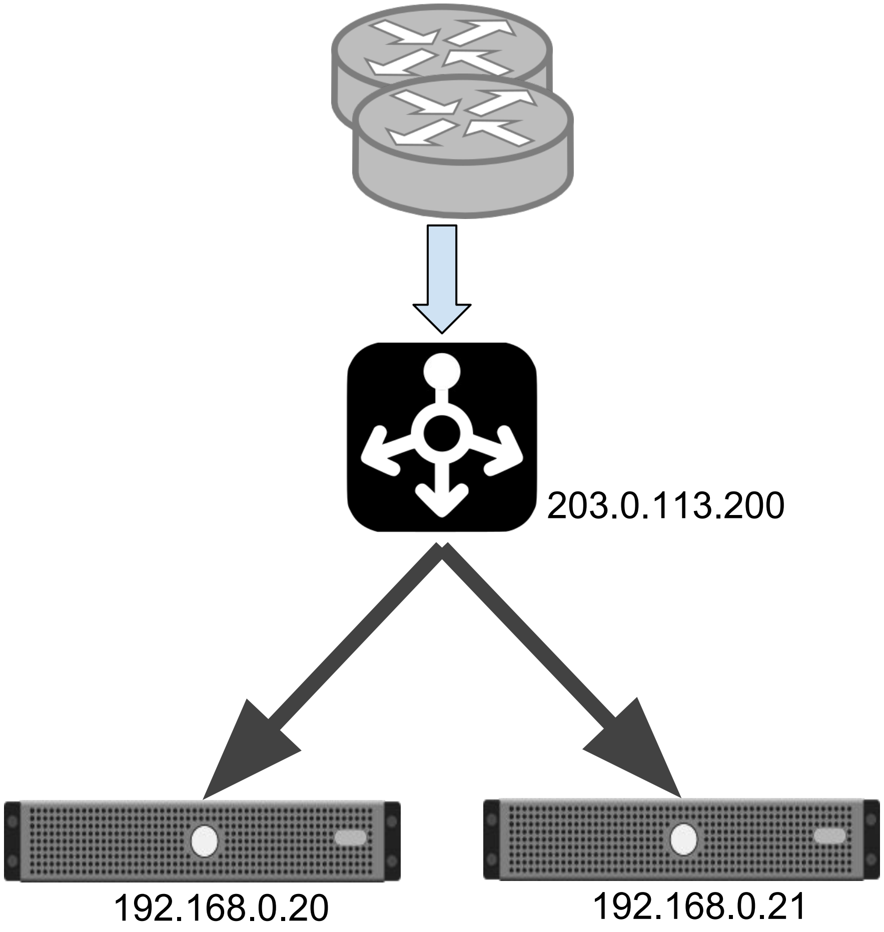


Stateless network load distribution

- Capacity

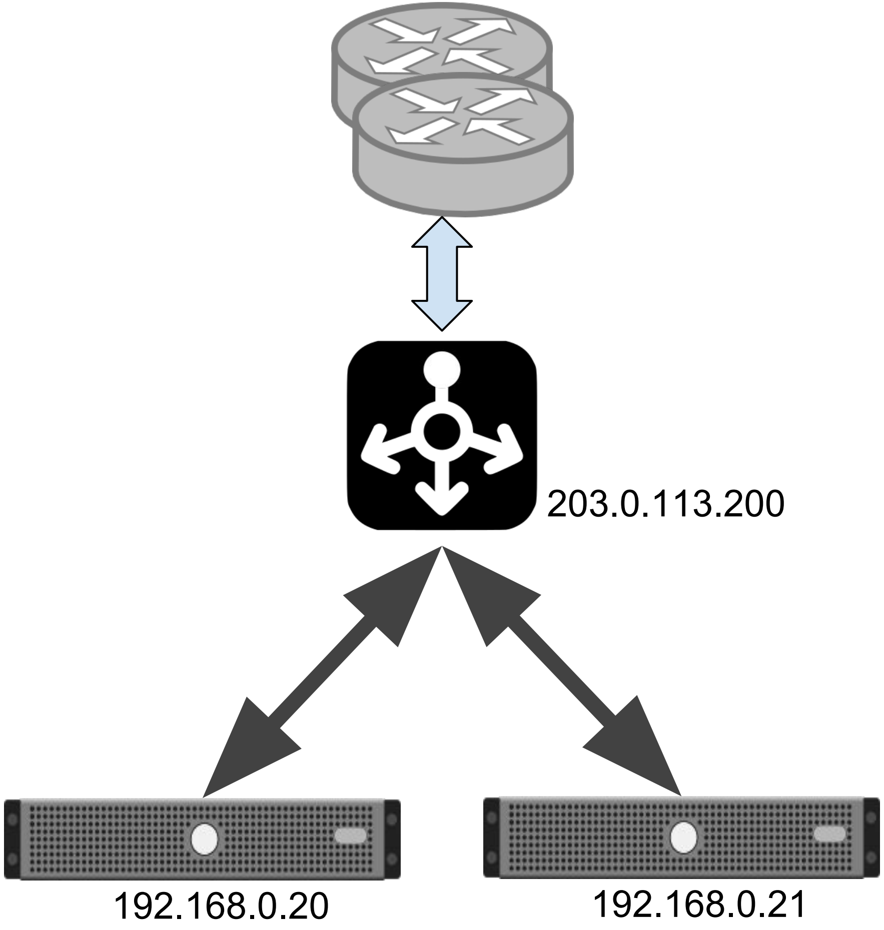


Network Load Balancing



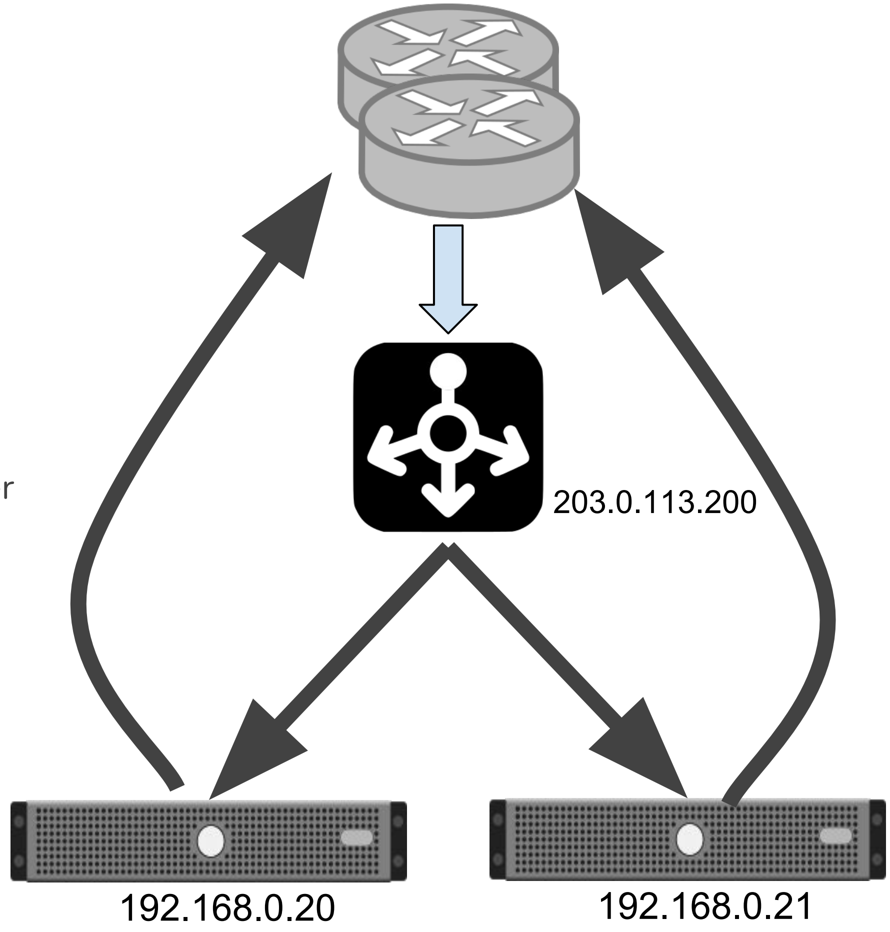
Network Load Balancing - Proxy

- Inbound and outbound traffic through load balancer.
- Requires state in loadbalancer
- LB backends can be anywhere in your network.



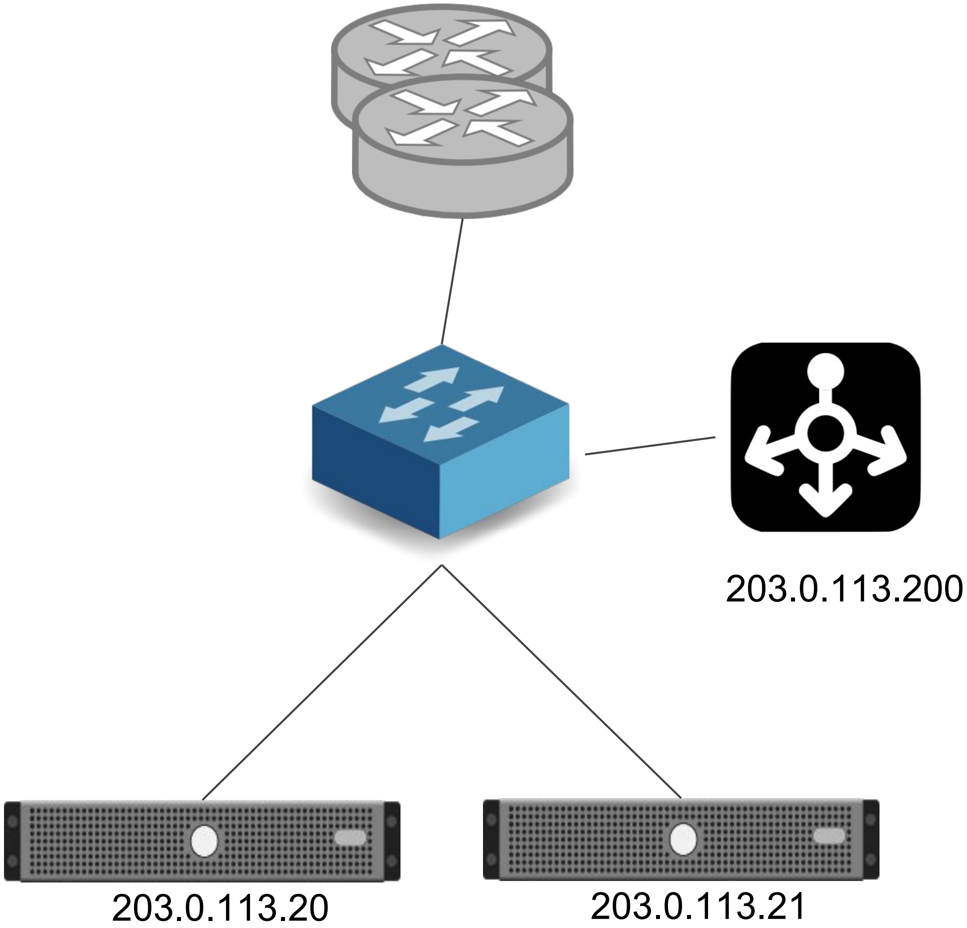
Network Load Balancing - DSR

- Direct serv{ice, er} return
- Inbound path through load balancer
- Outbound path direct, bypassing load balancer



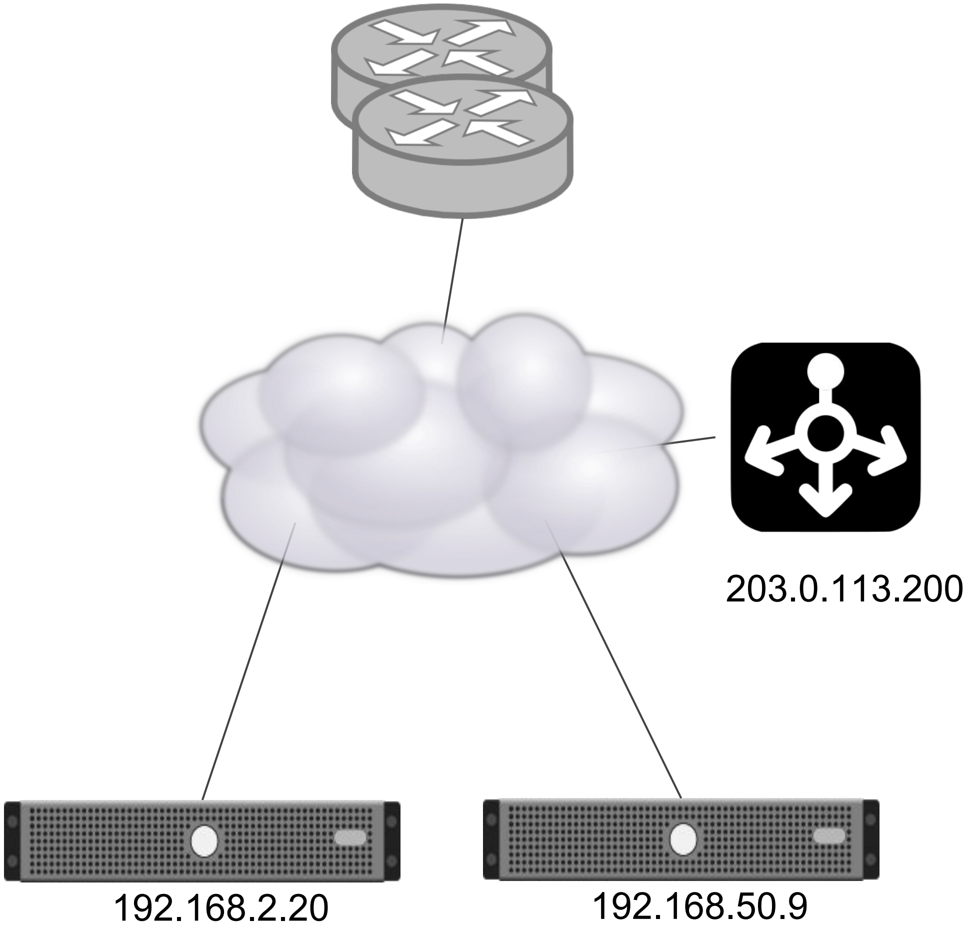
Network Load Balancing - L2DSR

- Load balancer and all backends on the same (layer 2, Ethernet) network.
- Service VIP is still .200.



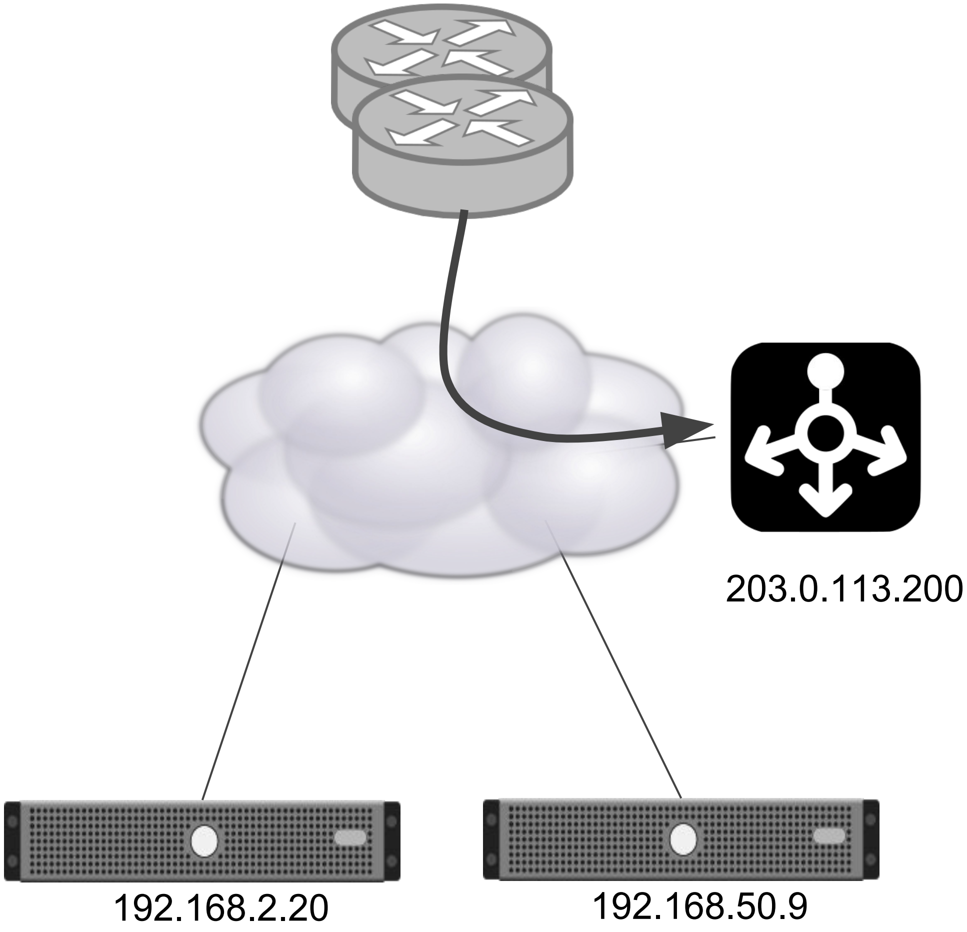
Network Load Balancing - L3DSR

- Load balancer and all backends on the **different** networks.
- Service VIP is still .200.



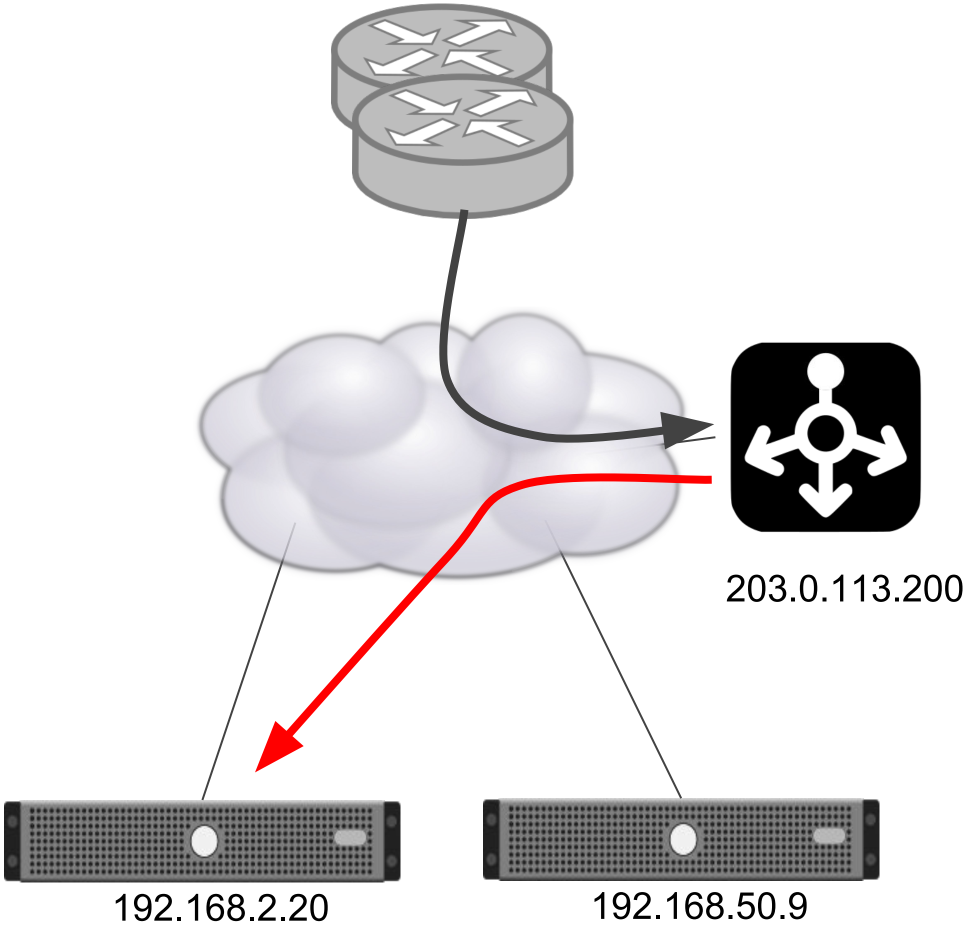
Network Load Balancing - L3DSR

- Internet → loadbalancer (**black**)
  - Src IP: <user public IP>
  - Dst IP 203.0.113.200 (VIP)
- (MAC addresses not relevant this time)



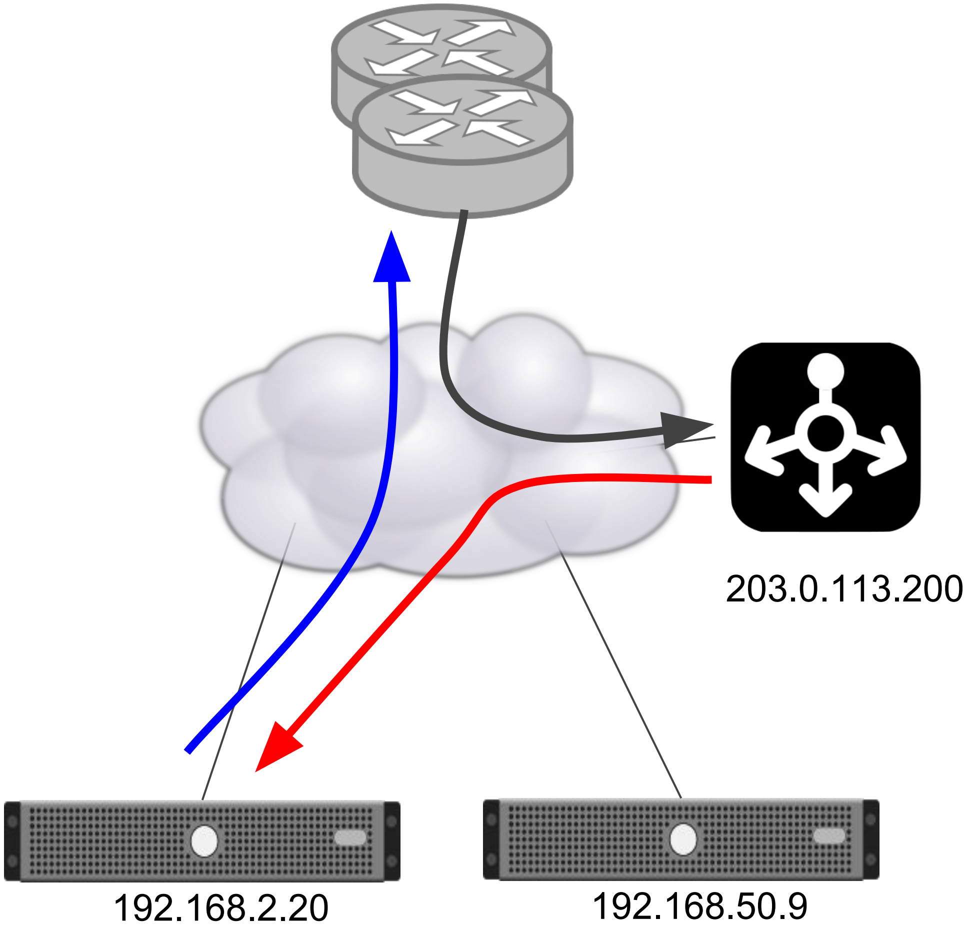
Network Load Balancing - L3DSR

- Loadbalancer → backend (**red**)
  - Src IP: <load balancer private IP>
  - Dst IP: **192.168.2.20**
  - **<Encap header> (GRE/IP-IP)**
  - Src IP: <user public IP>
  - Dst IP 203.0.113.200 (VIP)
- Request IP header preserved.
- Backends need to be able to decapsulate.
- Careful about MTU!

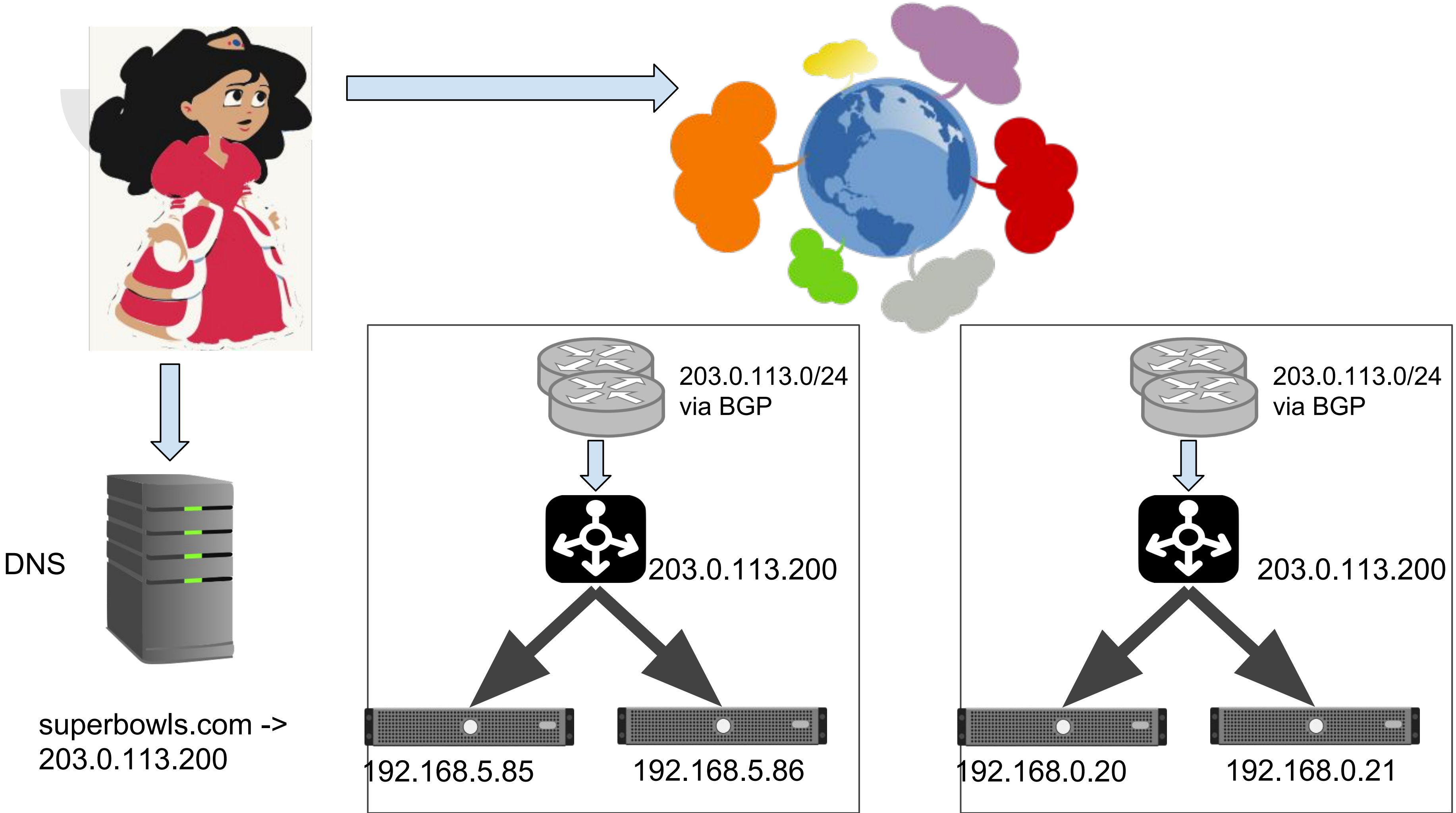


Network Load Balancing - L2DSR

- Loadbalancer → backend (**blue**)
  - Src IP 203.0.113.200 (VIP)
  - Dst IP: <user public IP>



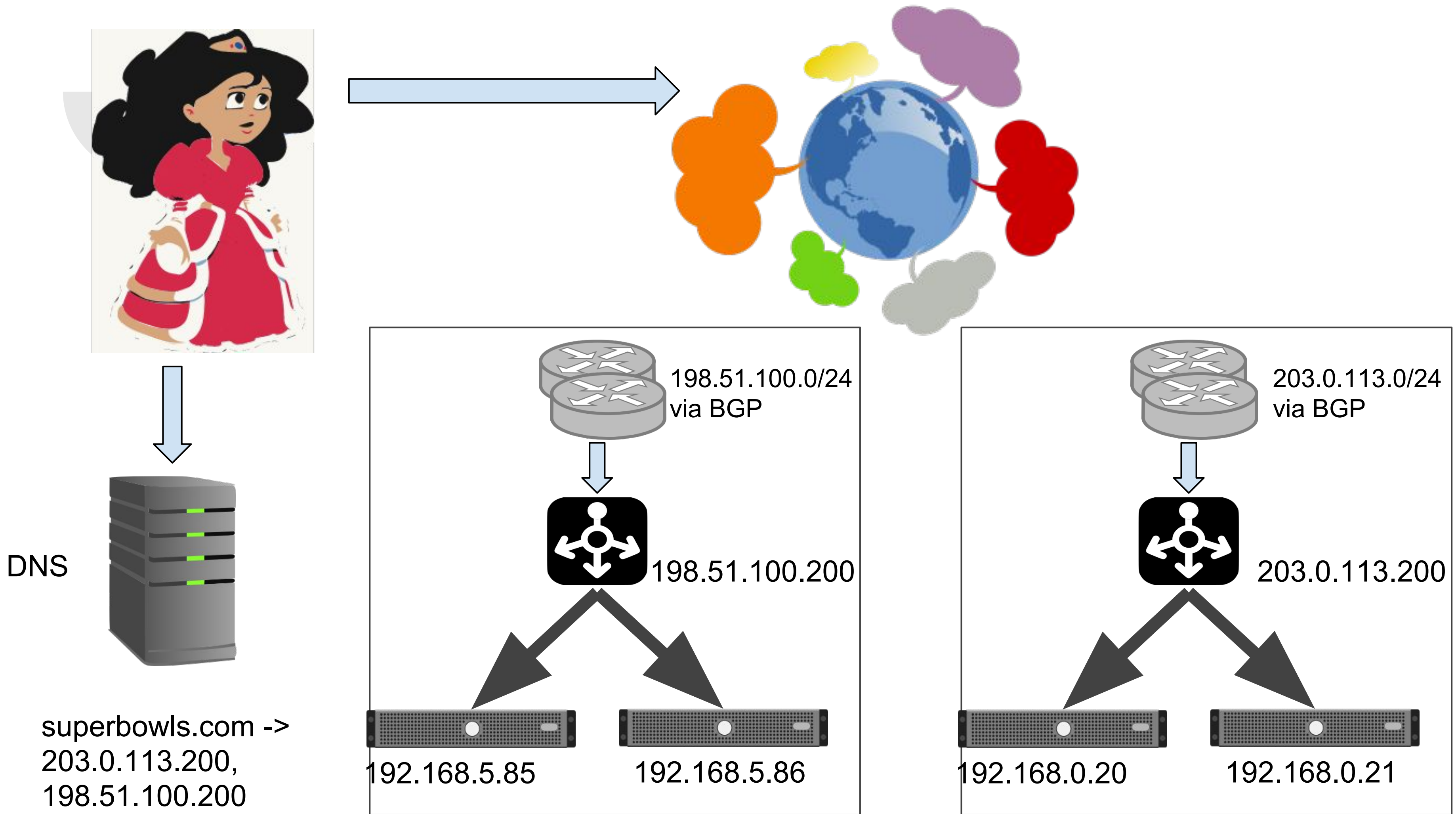
Back to our story

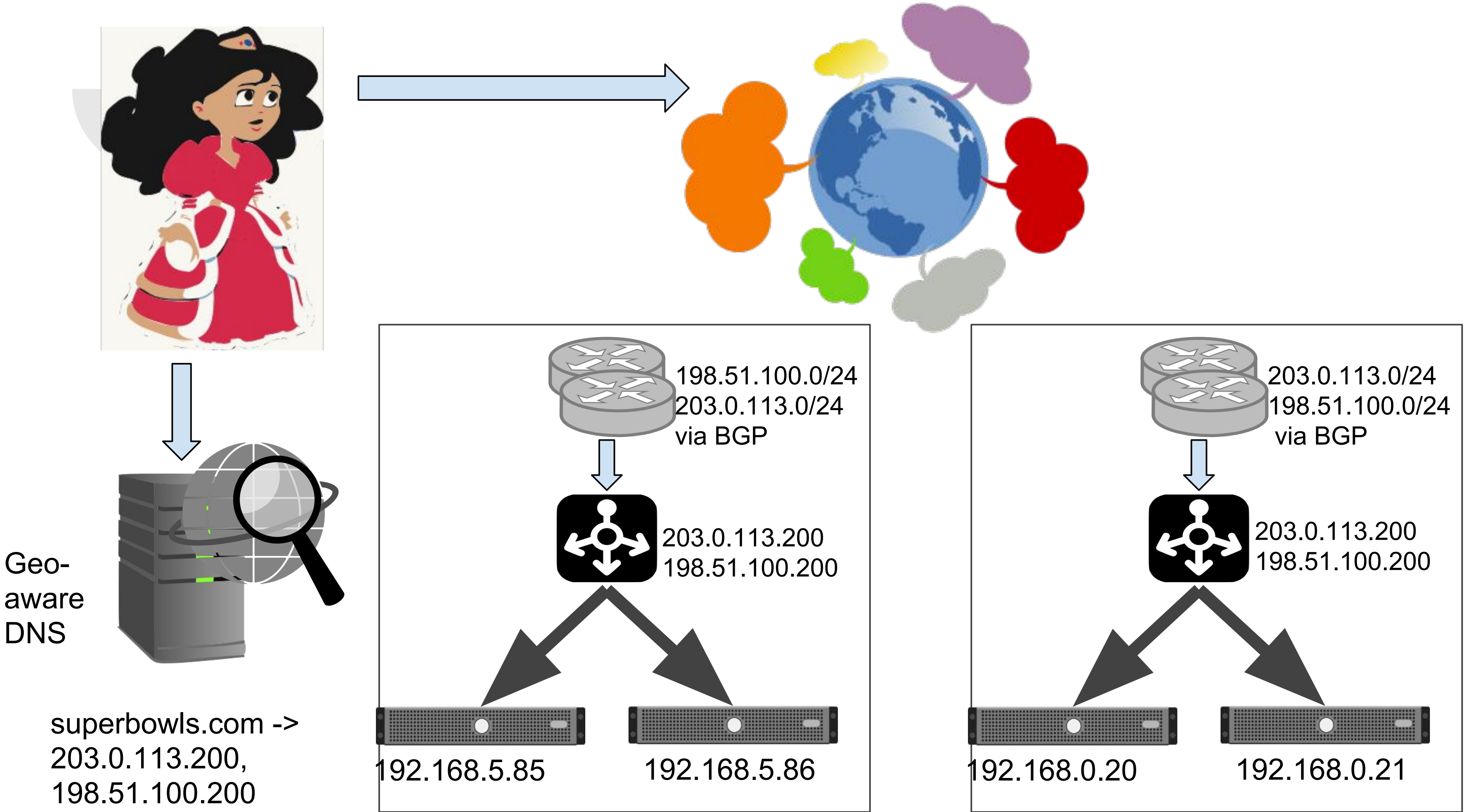


DNS
superbowls.com -> 203.0.113.200
203.0.113.0/24 via BGP
203.0.113.200
192.168.5.85
192.168.5.86
203.0.113.0/24 via BGP
203.0.113.200
192.168.0.20
192.168.0.21

Anycast

- It’s not loadbalancing.
- What is it?
  - Same address, multiple locations.
  - Network decides where to route each packet.
  - No concept of balancing; still just load distribution
- Caveats
  - Monitoring is hard
  - Capacity planning is hard
  - Cascading failure is easy.
- See Murali’s previous talk at SRECon EMEA 2017


198.51.100.0/24
via BGP
203.0.113.0/24
via BGP
DNS
198.51.100.200
203.0.113.200
192.168.5.85
192.168.5.86
192.168.0.20
192.168.0.21
superbowls.com ->
203.0.113.200,
198.51.100.200


198.51.100.0/24
203.0.113.0/24
via BGP
203.0.113.200
198.51.100.200
203.0.113.0/24
198.51.100.0/24
via BGP
203.0.113.200
198.51.100.200
Geo-
aware
DNS
superbowls.com ->
203.0.113.200,
198.51.100.200
192.168.5.85
192.168.5.86
192.168.0.20
192.168.0.21

Aside: the perils of DNS geo loadbalancing

Problems with geographic balancing

- Internet addressing scheme wasn't designed to support this
- Blocks of addresses move
- Recursive resolution: the source IP that your DNS sees may not be close to the end user
- Inevitably involves a lot of messing about configuring exceptions or cleaning data - toil

EDNS0 extension: client subnet

- Extends DNS with information about the network that originated a query
- Also lets the authoritative nameserver specify the network that the response is intended for
- Implemented by OpenDNS and Google Public DNS

Back to our story

Load distribution	Distributing load across multiple pieces of infrastructure	Yes
High Availability	Avoid using unhealthy infrastructure	Yes
Flexibility	Allow operators to shift load manually or via configured policies	Yes
Geo awareness	Systems serve from the best location for users (less latency)	Yes
Load aware	**Can balance lightweight and heavyweight loads effectively**	**No**

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Load aware	Can balance lightweight and heavyweight loads effectively	No
Content-based	**Can perform load distribution based on the content of the request (e.g. cookies)**	**No**

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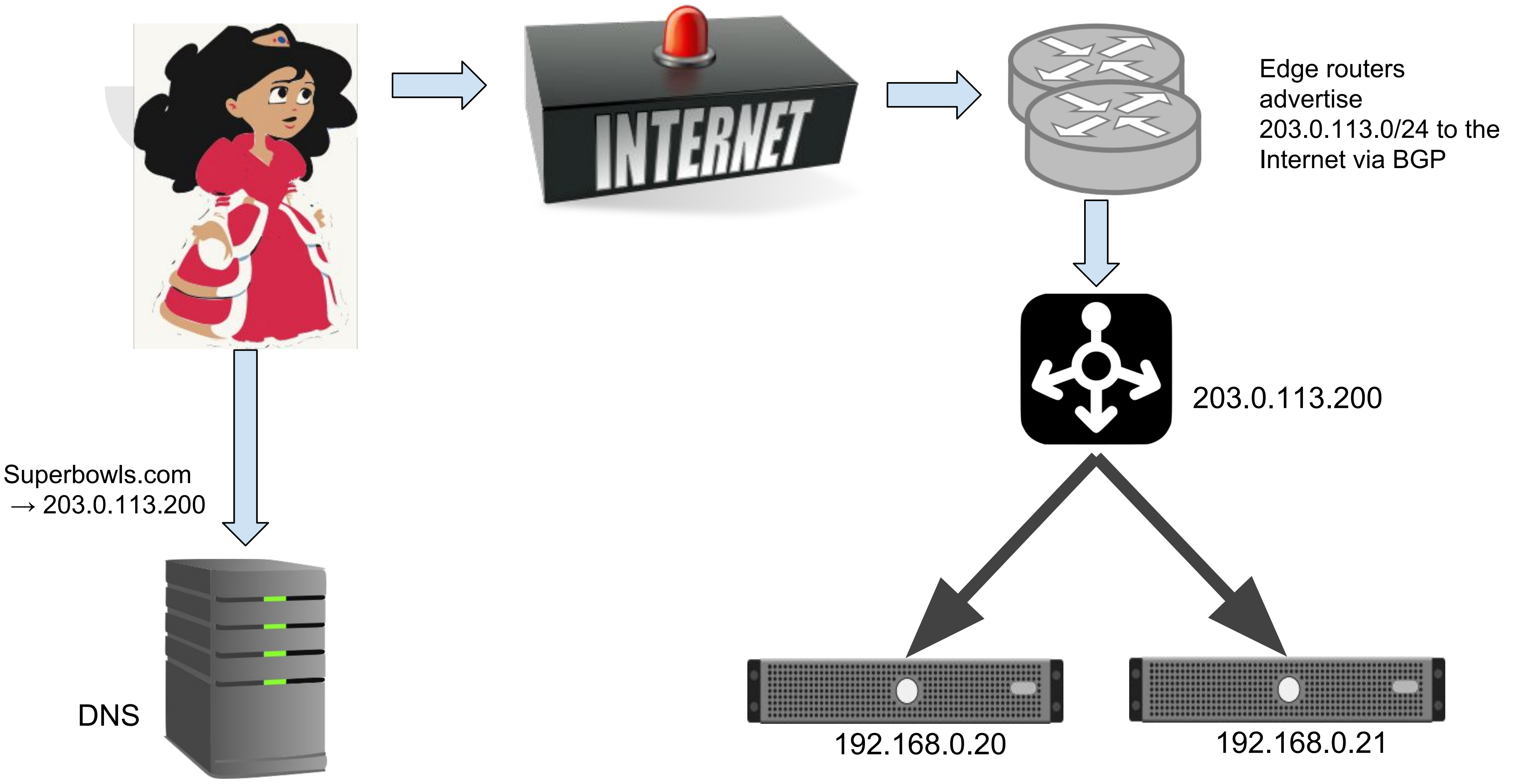
Load aware	Can balance lightweight and heavyweight loads effectively	No
Content-based	Can perform load distribution based on the content of the request (e.g. cookies)	No
Policy enforcement	**Point to apply DDoS protection, rate limiting and load-shedding**	**No**

Layer 7 load balancing

- AKA application loadbalancing, or a reverse proxy
- Terminates the connection from the user, make requests to one or more backend servers, and then returns responses to the user
- Understands the structure of the request -> only kind of balancers that can distribute load based on a cookie, or a parameter or similar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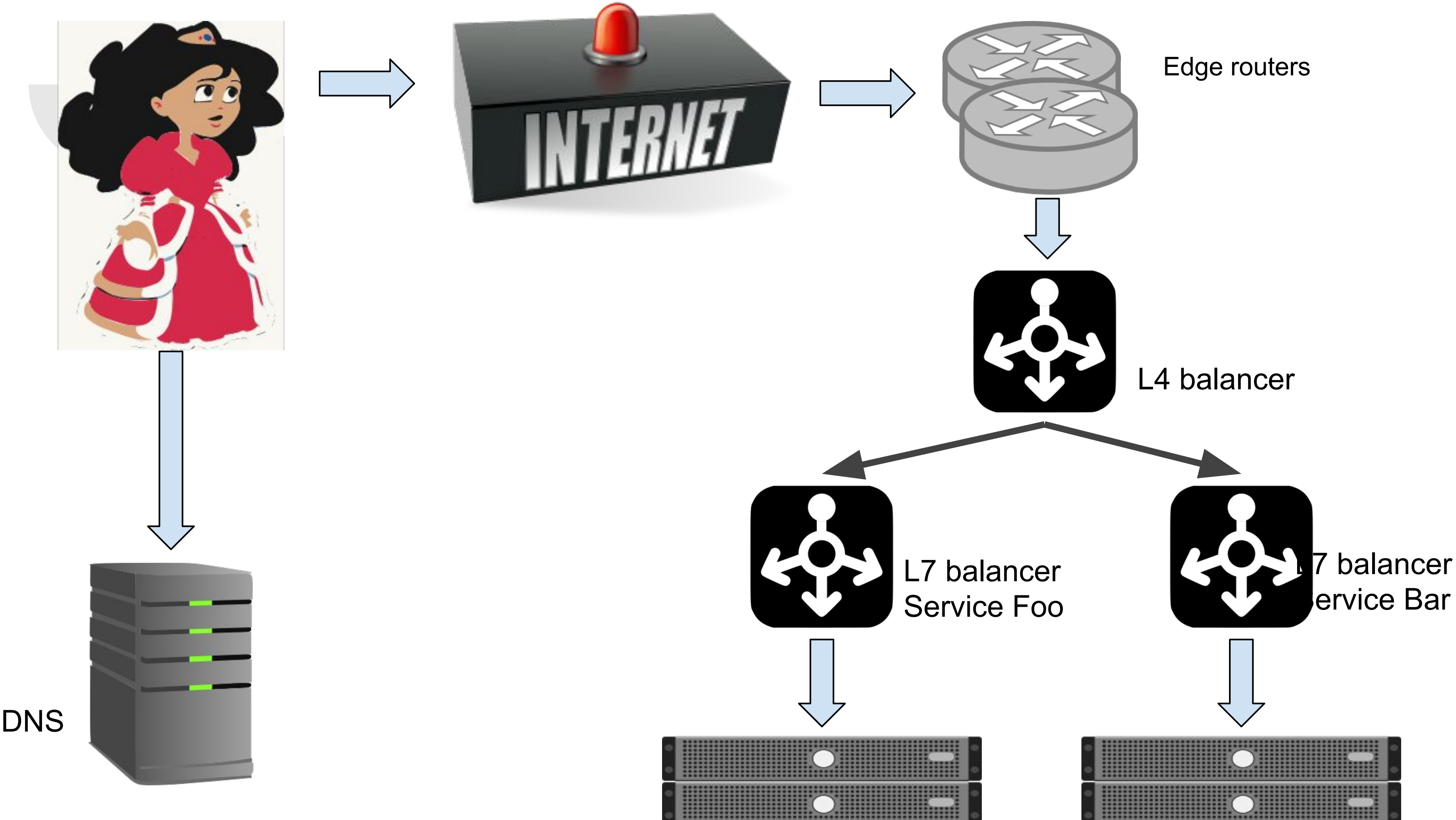
INTERNET
203.0.113.200
Superbowls.com
→ 203.0.113.200
DNS
192.168.0.20
192.168.0.21


INTERNET
Edge routers
L4 balancer
L7 balancer
Service Foo
DNS

Layer 7 load balancing - scalability

- Resources will be held on the LBs for the duration of user requests
- A L7 balancer crashing will be seen by users
  - L4 can often fail transparently
- L7 balancers can retry a request that failed on one of its backends
- Will add more latency to a request than L4 balancers

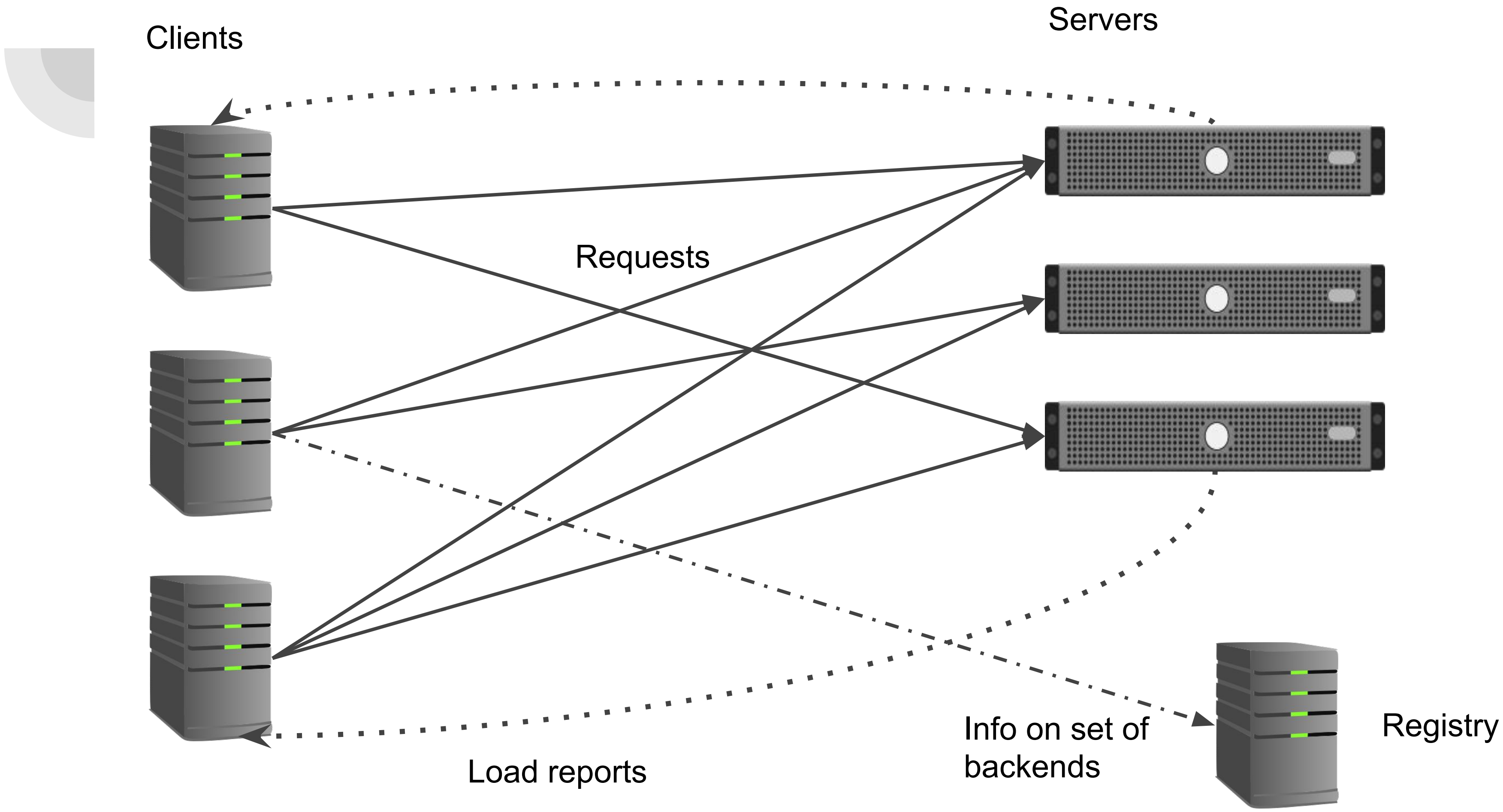
Layer 7 load balancing - reliability

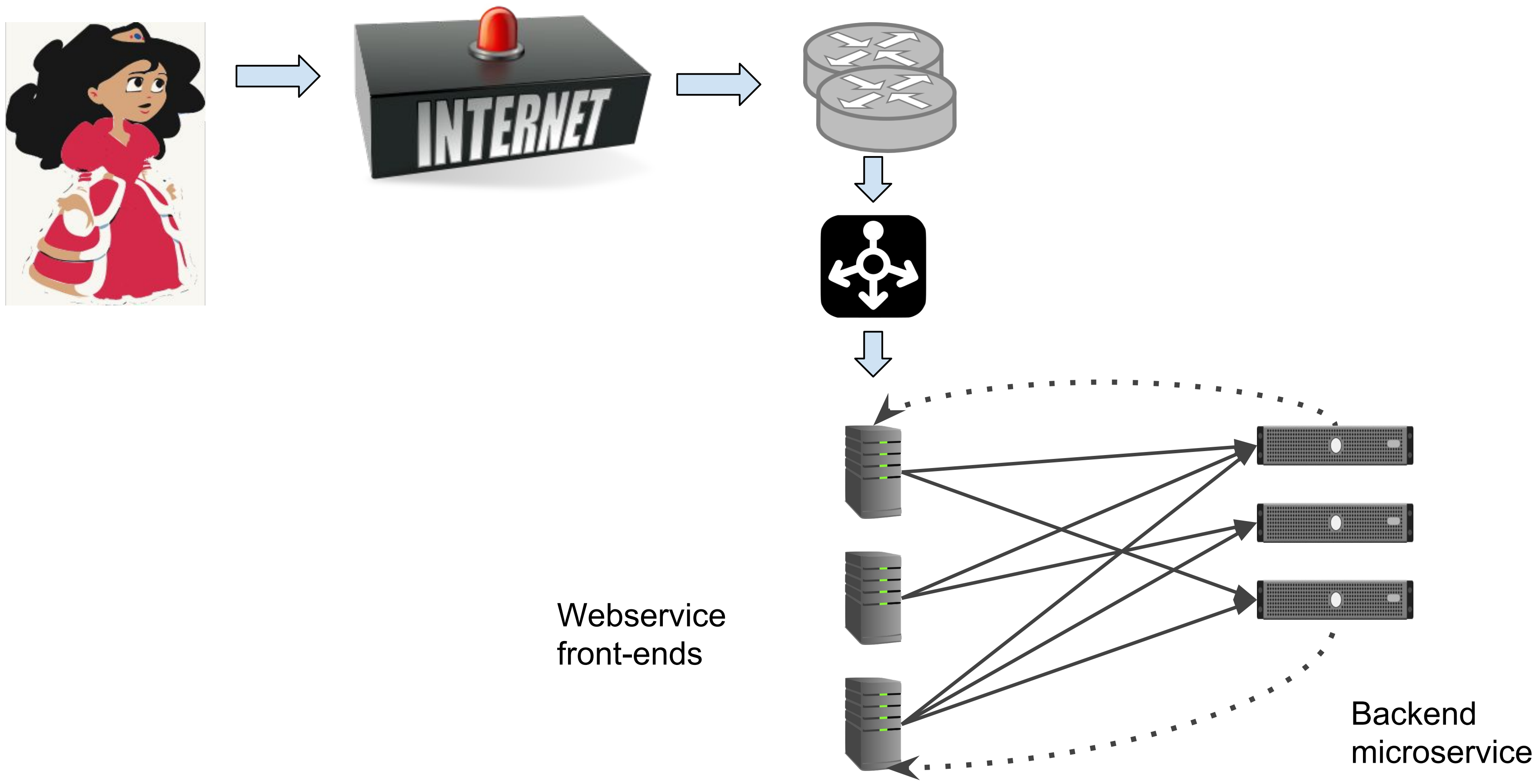
- Can be load aware
- Rate limiting and loadshedding
- Line of defence against application-layer DoS attacks
- Produces much better telemetry than a L4 balancer can

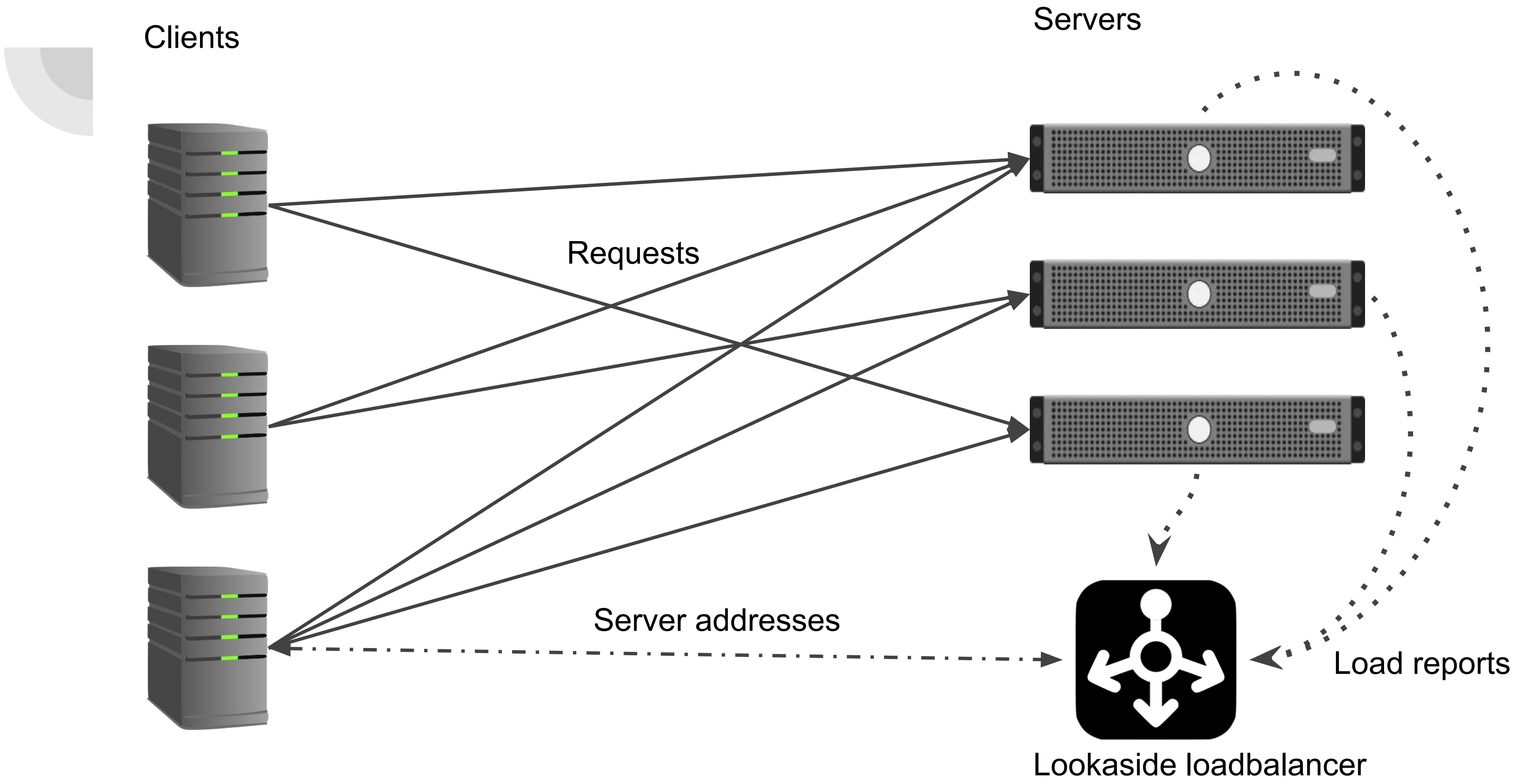
Aside: the cloud

Loadbalancing algorithms

- Balancing in a single pool of backends
  - Stateless hashing
  - Round robin
  - Least-loaded, shortest queue and similar
  - Weighted round robin
  - Probation
  - Choice of 2
- Multiple pools of backends
  - Priority/failover
  - Nearest by location

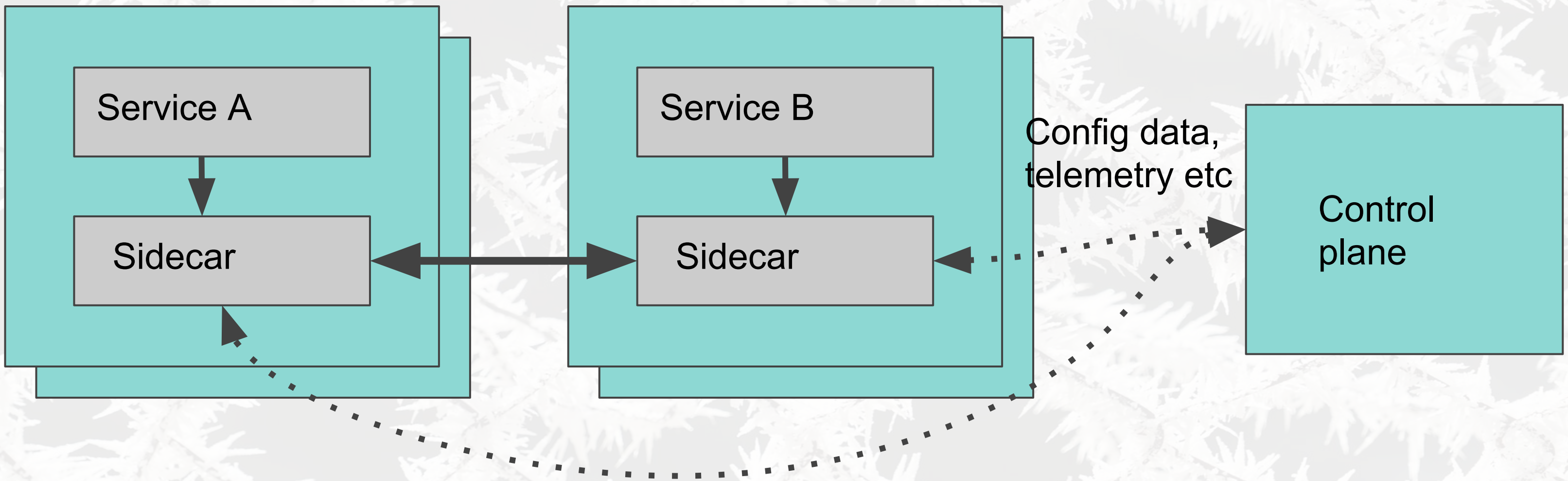

Clients
Servers
Requests
Load reports
Info on set of backends
Registry

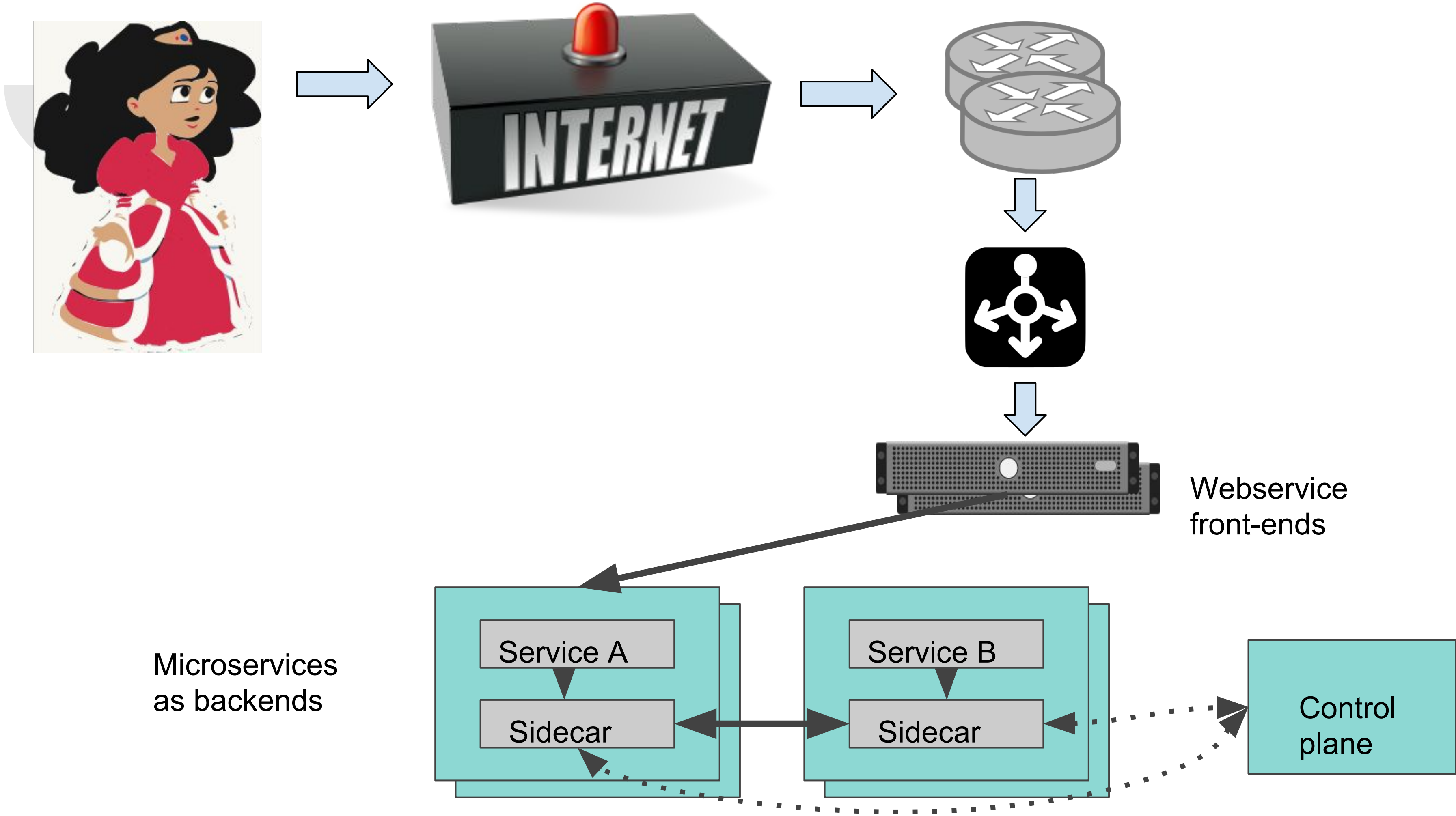

INTERNET
Webservice
front-ends
Backend
microservice


Clients
Servers
Requests
Server addresses
Load reports
Lookaside loadbalancer

Service Mesh

- Infrastructure layer for service to service communication
- Linkerd, Envoy, Istio, Conduit
- Goal of a service mesh is to make service communication a first-class citizen
    - Service discovery
    - Configurable routing policies
    - Authentication and authorization
    - Monitoring and management of service to service communications, distributed tracing, fault injection etc
    - Consistent point to apply policies on retrying, deadlines etc


Service A
Sidecar
Service B
Sidecar
Config data,
telemetry etc
Control
plane



INTERNET
Webservice
front-ends
Microservices
as backends
Service A
Sidecar
Service B
Sidecar
Control
plane

The big idea: consistency

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High Availability	Avoid using unhealthy infrastructure	Yes
Flexibility	Allow operators to shift load manually or via configured policies	Yes
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Policy enforcement	Point to apply DDoS protection, rate limiting and load-shedding	Yes

Takeaways

- What do you want from your systems?
  - More capacity? Higher availability? Higher utilisation?
  - Finer grained control?
  - More instrumentation and monitoring?
- What constraints do you have?
  - Do you trust your clients?
  - Do you control your whole stack?


ASK

Links

- Google's maglev paper
- Facebook Katran
- HAProxy
- ucarp
- Google SRE Book loadbalancing chapter
- EDNS0 client subnet RFC
- Summary of Facebook's Billion User Loadbalancing talk
- Google's GFS and Bigtable papers
- gRPC load balancing
- Istio, Linkerd
  - Monzo talk on using Linkerd + Kubernetes in production

Keeping the balance: loadbalancing demystified

Murali Suriar (Google) and Laura Nolan

- Loadbalancing has evolved hugely in the last decade.
- What do you want from your systems?
  - More capacity? Higher availability? Higher utilisation?
  - Finer grained control? More instrumentation and monitoring?
- What constraints do you have?
  - Do you trust your clients?
  - Do you control all layers of your stack?

See the talk slides for more.