
AWS
re:Invent
NOV. 28 – DEC. 2, 2022 | LAS VEGAS, NV

ARC329

Operating highly available Multi-AZ applications

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AWS Resilience Infrastructure and Solutions

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Agenda

Building resilient systems using Availability Zones (AZs)

New: Route 53 Application Recovery Controller zonal shift (preview)

Real-life example

Demonstration

Best practices

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Building resilient systems using Availability Zones

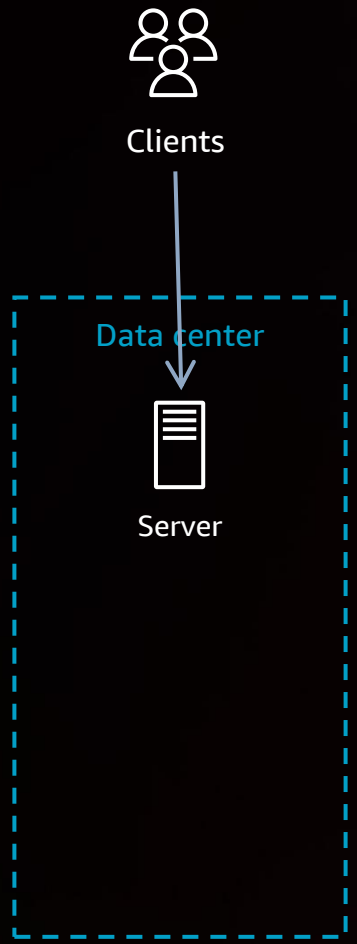
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“It’s not about how hard you hit. It’s about how hard you can get hit and keep moving forward.”

Rocky

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Building a resilient service



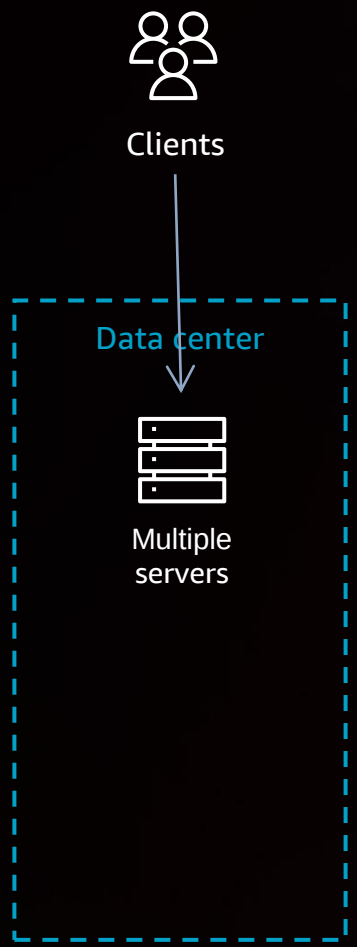
Single sources of failure:

- Single server failure

NB: “sources” not “points”

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Multiple servers

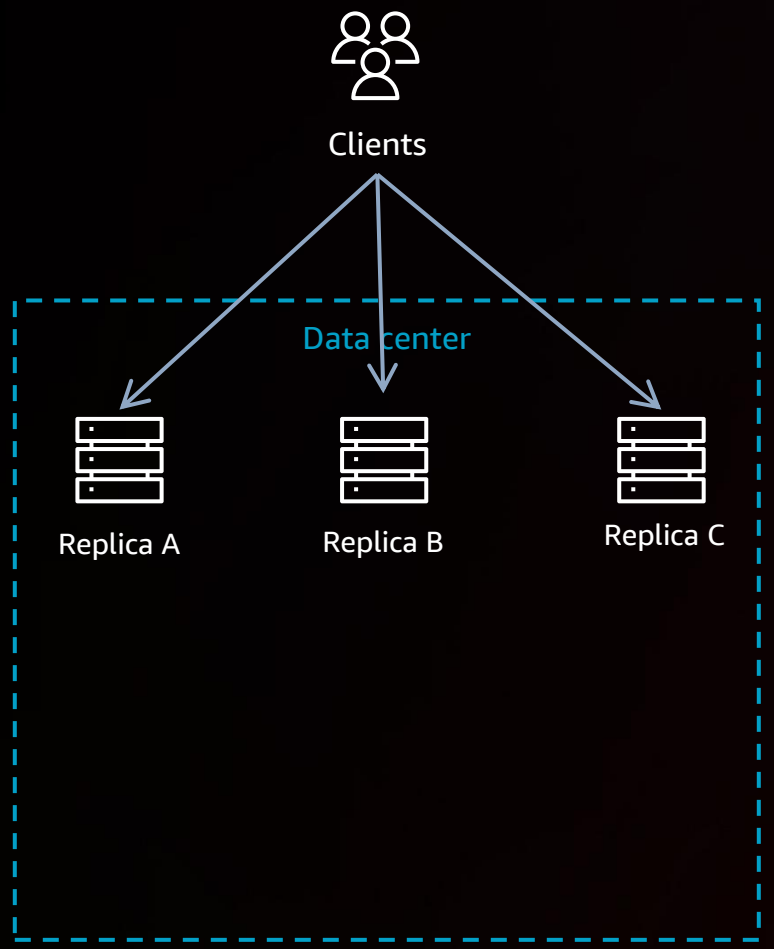


Single sources of failure:

- Single server failure ✓
- Single deployment
- Single config change

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Multiple replicas



Single sources of failure:

- Single server failure ✓
- Single deployment ✓
- Single config change ✓
- Local network issue
- Infrastructure issue
- Power failure
- Flood

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Replicas in multiple Availability Zones



Single sources of failure:

- Single server failure ✓
- Single deployment ✓
- Single config change ✓
- Local network issue ✓
- Infrastructure issue ✓
- Power failure ✓
- Flood ✓

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Diversifying replicas

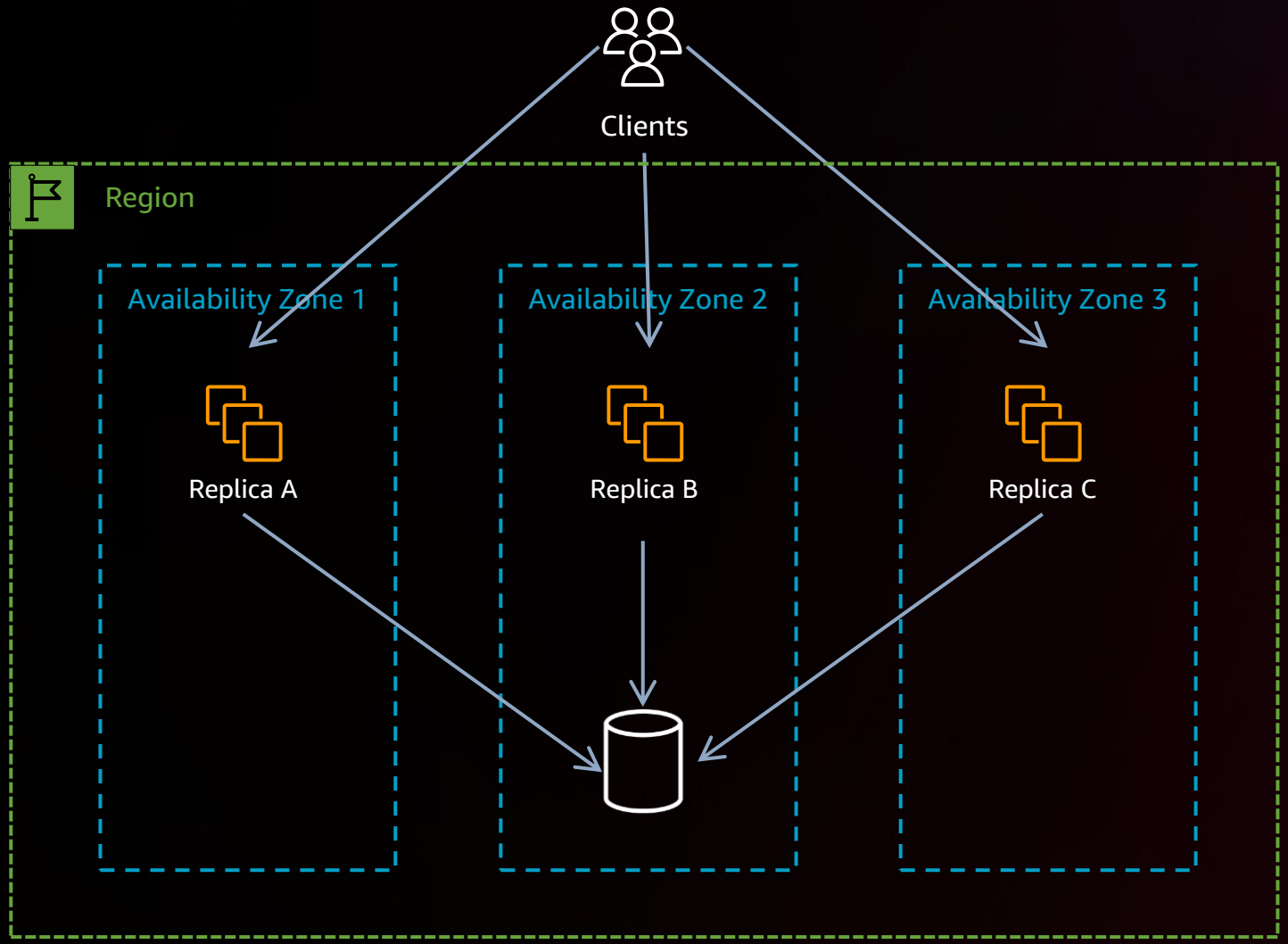


Single sources of failure:

- Single server failure ✓
- Single deployment ✓
- Single config change ✓
- Local network failure ✓
- Infrastructure failure ✓
- Power failure ✓
- Flood ✓
- Storage limits ✓
- Heap mem exceeded ✓
- TLS cert expiry ✓

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Anything left?



Single sources of failure:

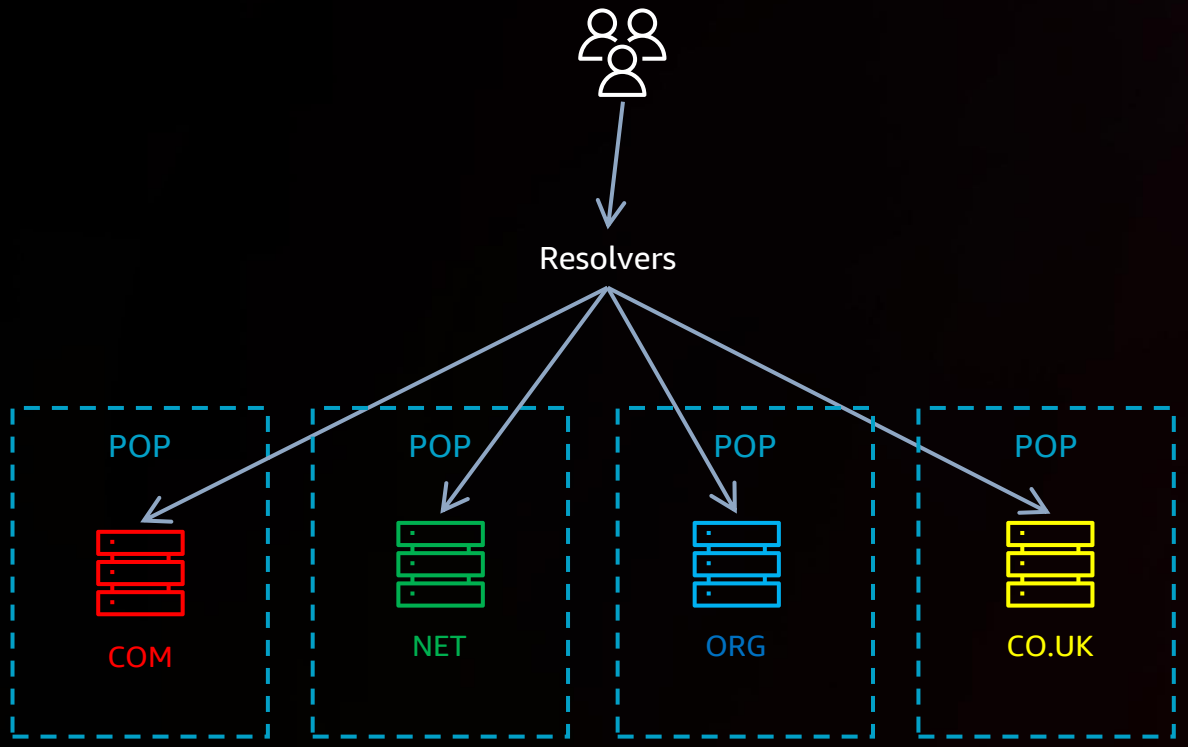
- Single server failure ✓
- Single deployment ✓
- Single config change ✓
- Local network failure ✓
- Infrastructure failure ✓
- Power failure ✓
- Flood ✓
- Storage limits ✓
- Heap mem exceeded ✓
- TLS cert expiry ✓

Others remain:

- Customer traffic/DoS
- Storage
- Dependency

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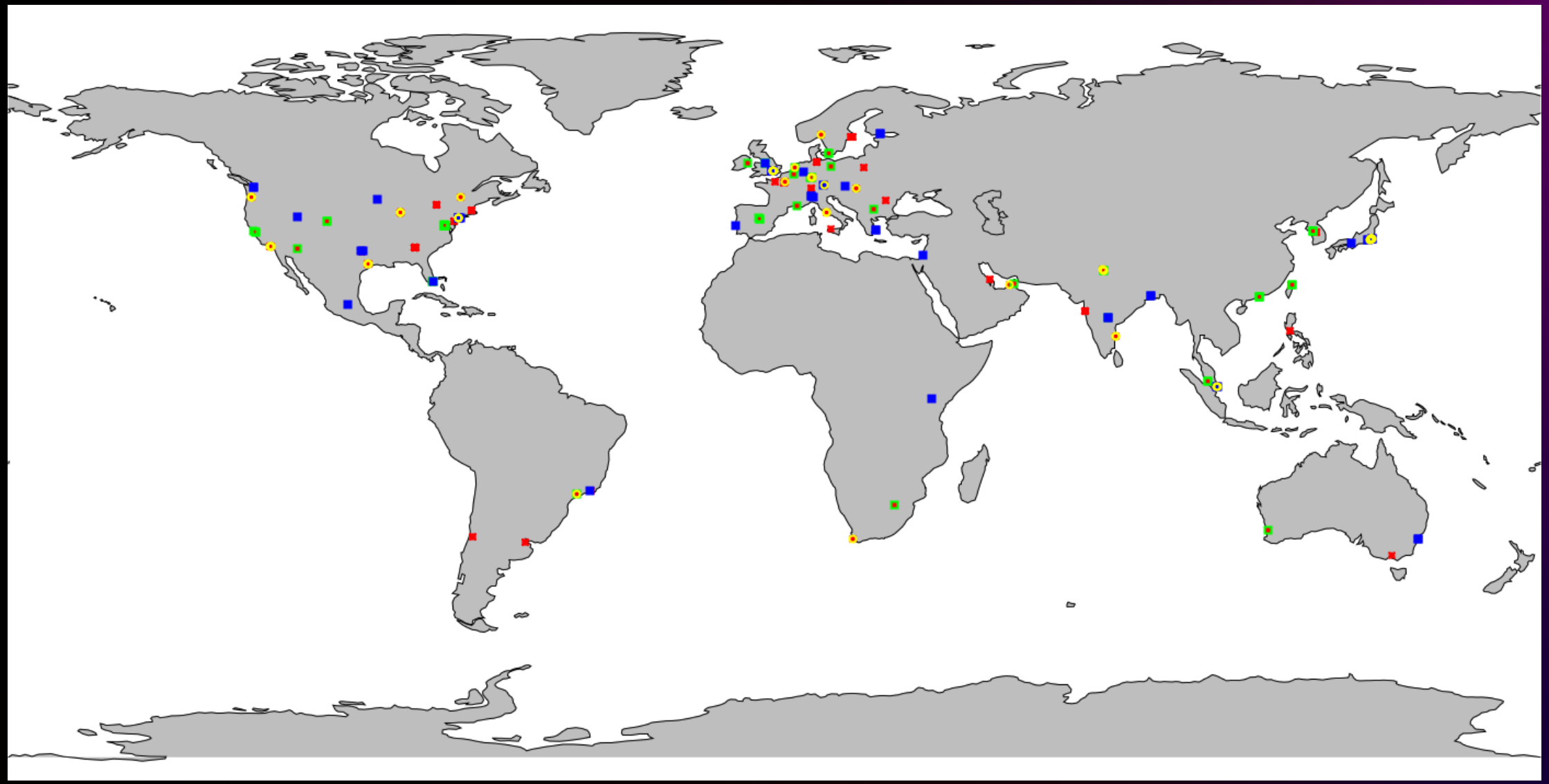
Example replica system: Route 53



- Each replica is built across 50x POPs

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Replicated resilient system: Route 53



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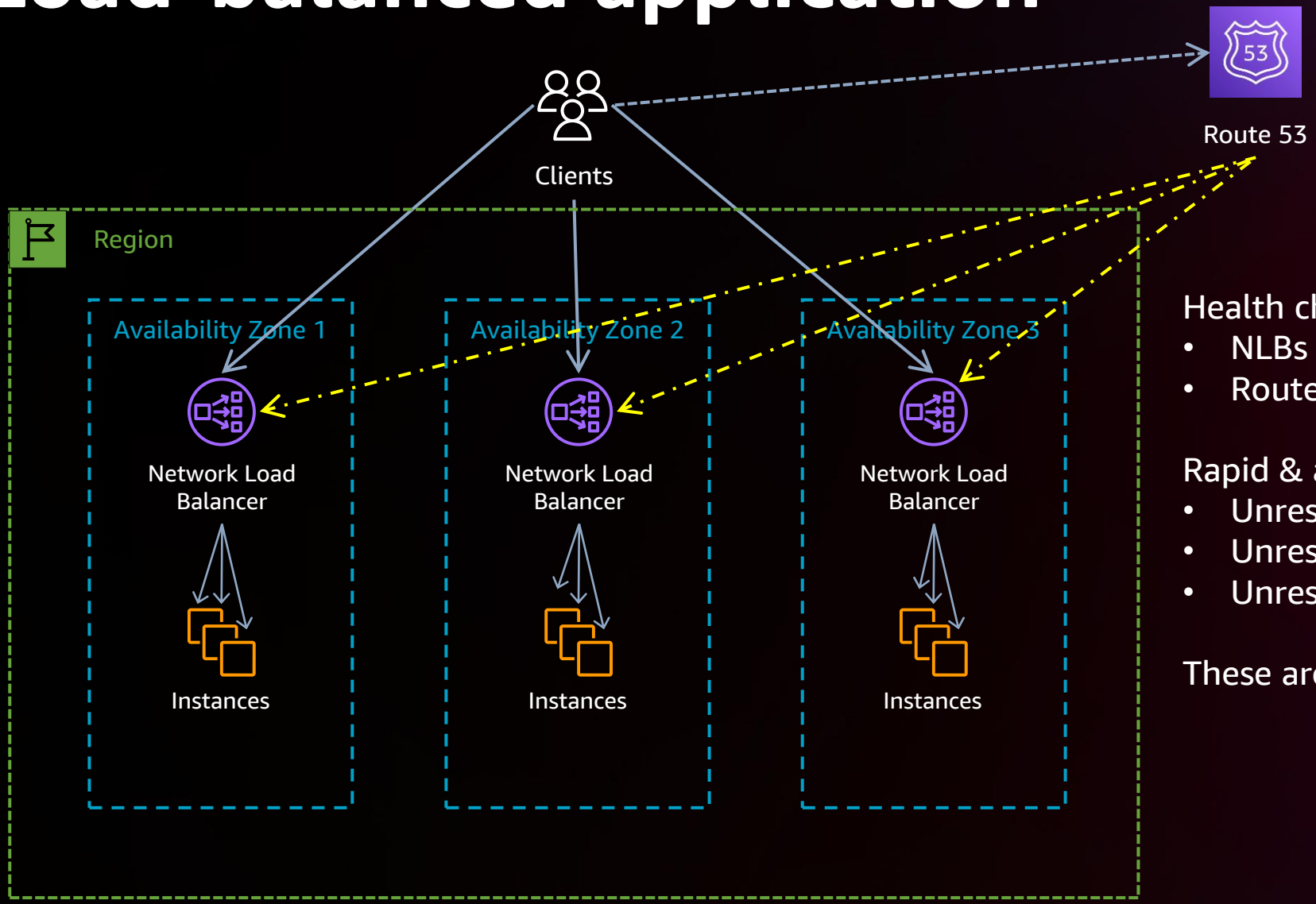
Failure handling

Redundancy is not sufficient

We need to also recover from the failure of one replica

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Load-balanced application



Health checks:

- NLBs health check target instances
- Route 53 health checks load balancers (NLBs)

Rapid & automatic recovery from:

- Unresponsive host
- Unresponsive load balancer
- Unresponsive Availability Zone

These are all “hard failures”

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Grey failures

Hard failures come to mind easily:

> "What happens when X is *down?*"

But we often forget grey failures:

> "What happens when X is up, but impaired/slow/intermittent…?"

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Grey failures

Cause of grey failures:

- Software bug causes crashing/restarting
- Bad configuration change
- Reduced capacity
- Intermittent dependency failure
- Packet loss/latency

Health may might not always detect these issues

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Grey failures

Surprisingly:

- A severe (hard) failure is impactful, but fast to detect and mitigate
- A less severe (grey) failure could be even more impactful, as it eludes detection and mitigation

Grey failures are also subjective. What level of latency can your application tolerate?

So how do we detect and mitigate grey failures?

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Turn grey failures into hard failures

Three complementary strategies:

1. Use deep health checks
2. Set ELB minimum healthy target count
3. Detect and shift away from zone

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Strategy 1: Deep health checks

Update the logic of your load balancer health check handler to more thoroughly exercise host and application health

Pros:

- Relatively cheap to do

Cons:

- Risk of overreaction and taking out capacity inappropriately
- Unlikely to detect all grey failures

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Strategy 1: Deep health checks



https://aws.amazon.com/builders-library/implementing-health-checks/

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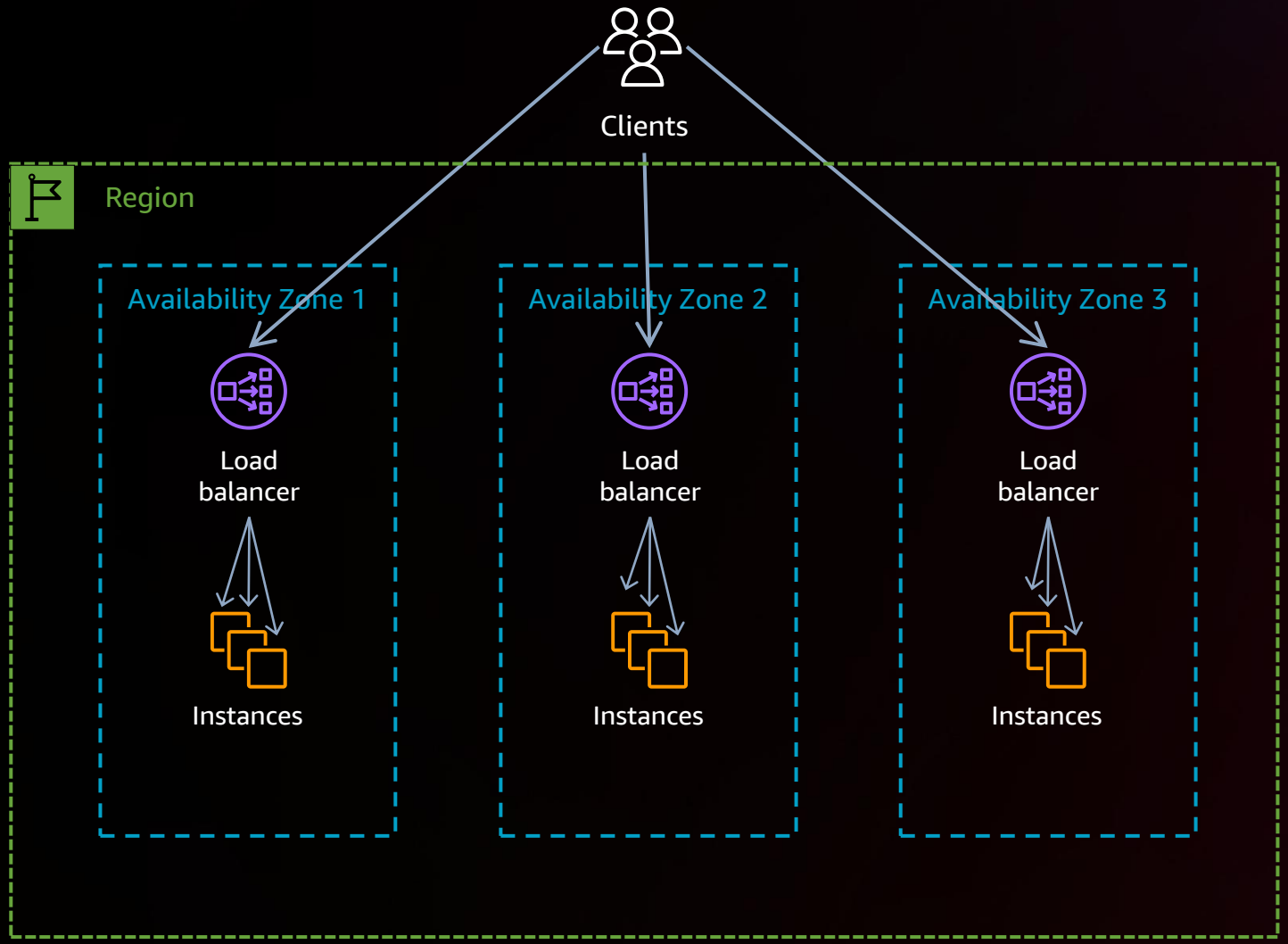
Strategy 2: ELB minimum healthy targets

New: Elastic Load Balancing (ELB) now supports a minimum healthy target count

- Turns a grey failure into a hard failure

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Strategy 2: ELB minimum healthy targets

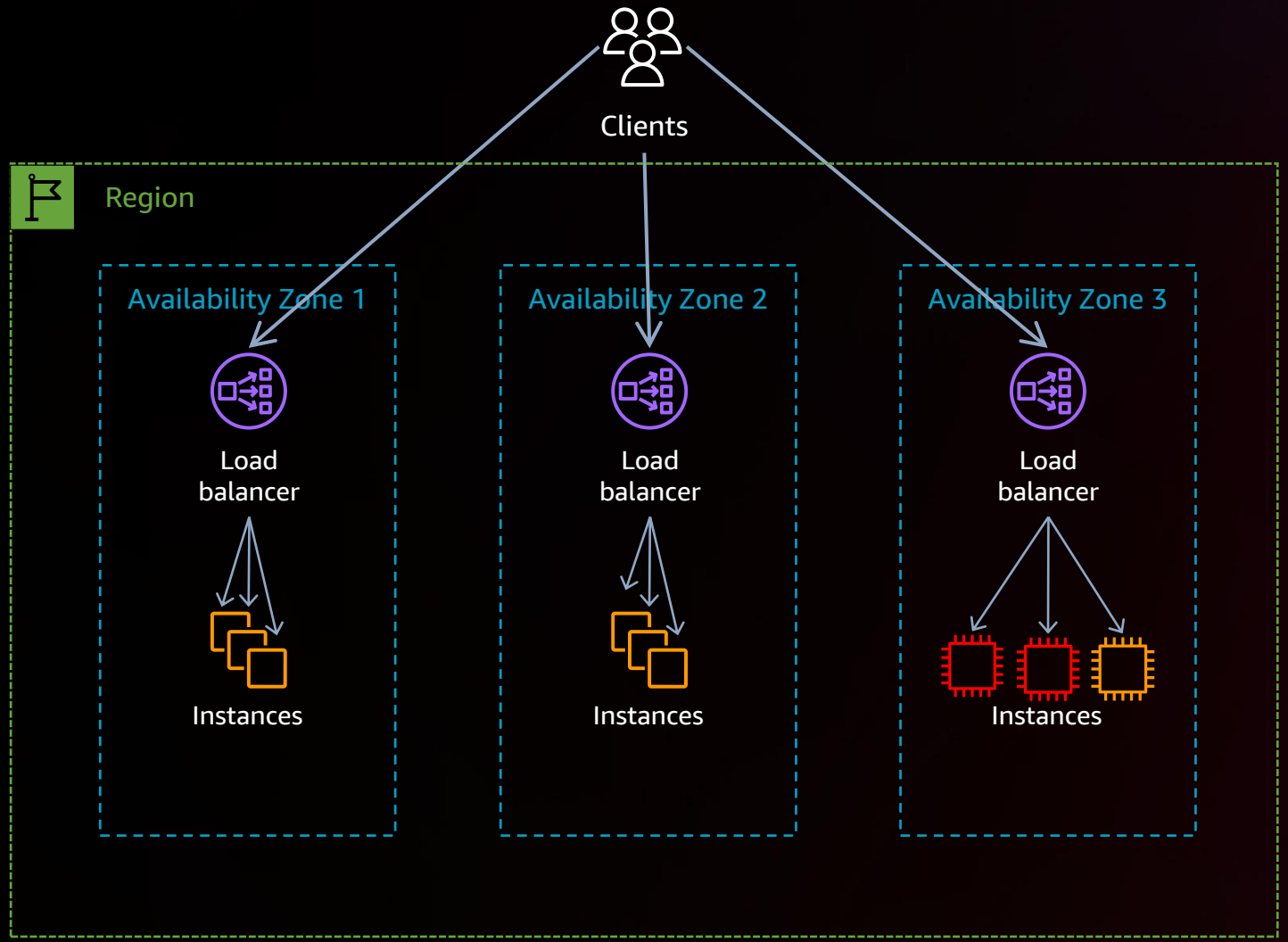


Suppose 2 of 3 hosts fail in AZ3

- Equal load continues to all 3 AZs
- AZ3 might be overwhelmed

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Strategy 2: ELB minimum healthy targets

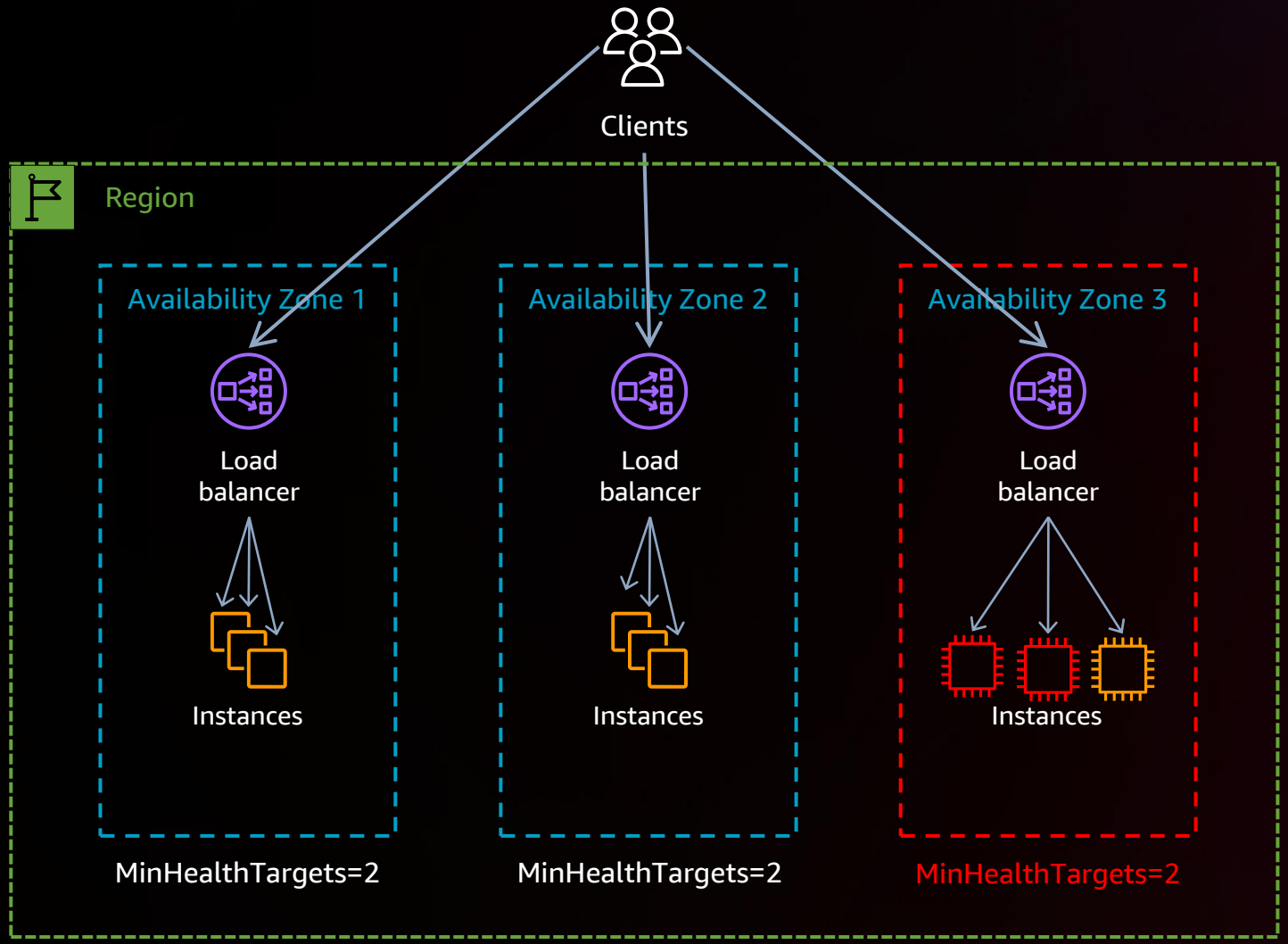


Suppose 2/3 Hosts fail in AZ3

- Equal load continues to all three AZs
- AZ3 may degrade

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Strategy 2: ELB minimum healthy targets



Suppose 2/3 Hosts fail in AZ3

- Equal load continues to all three AZs
- AZ3 may degrade

Setting MinHealthyTargets causes AZ3 to be removed

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Strategy 2: ELB minimum healthy targets

New: Elastic Load Balancing (ELB) now supports a minimum healthy target count

Turns a grey failure type into a hard failure

Especially useful with cross-zone load balancing off

You define healthy capacity in an AZ

Launched: November 17, 2022

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Strategy 3: Detect and shift away from zone

Turn a wide array of grey failures into one hard failure:

"One zonal replica is out of service"

Used widely within AWS

A. Turn off cross-zone load balancing: eases detection and reduces cross-AZ interactions

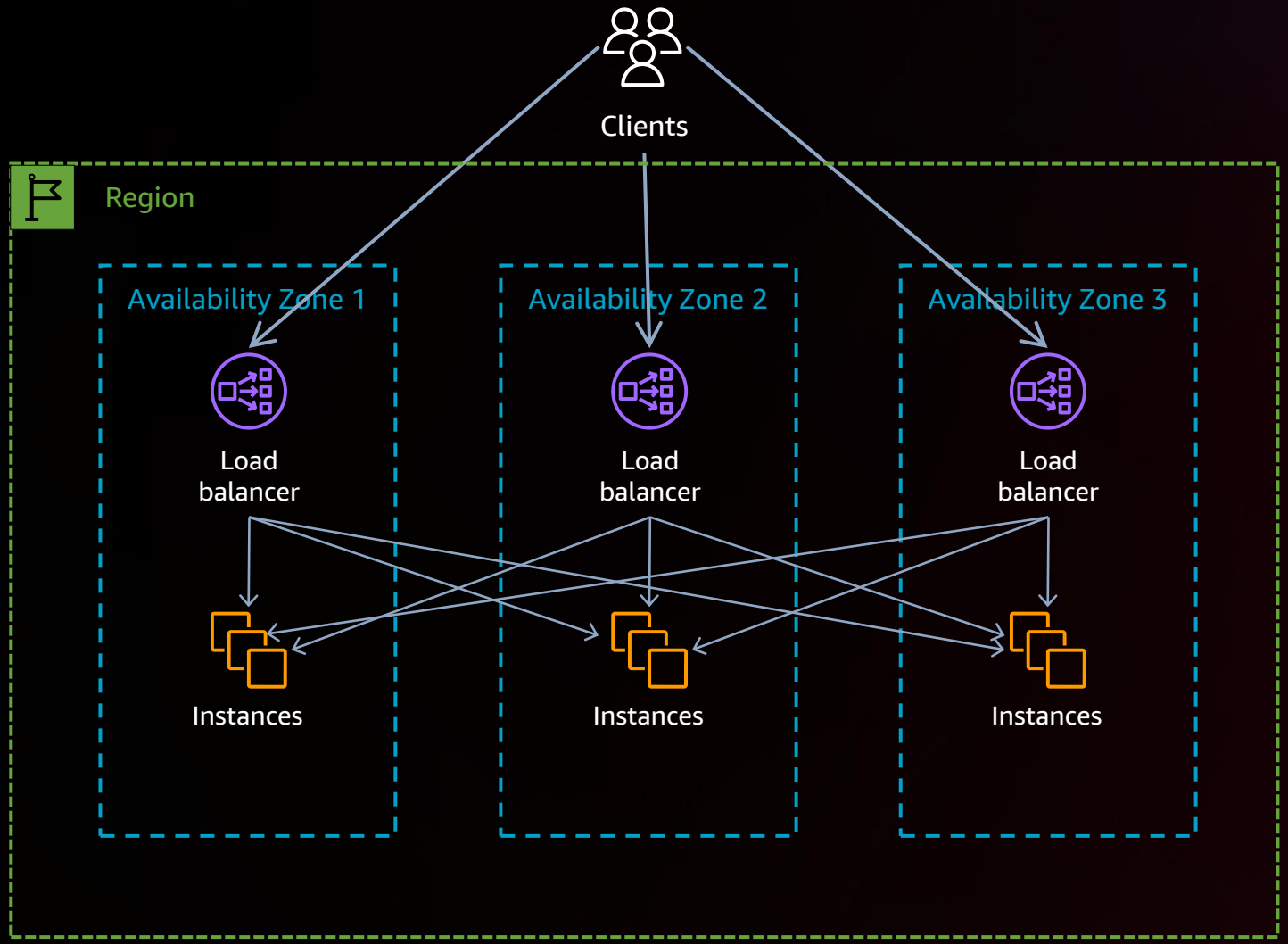
B. Monitor the per-AZ customer experience and compare

C. Detect and shift work away from a zonal replica

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3A. Cross-zone load balancing



Load balancers route requests to targets in all Availability Zones (AZs)

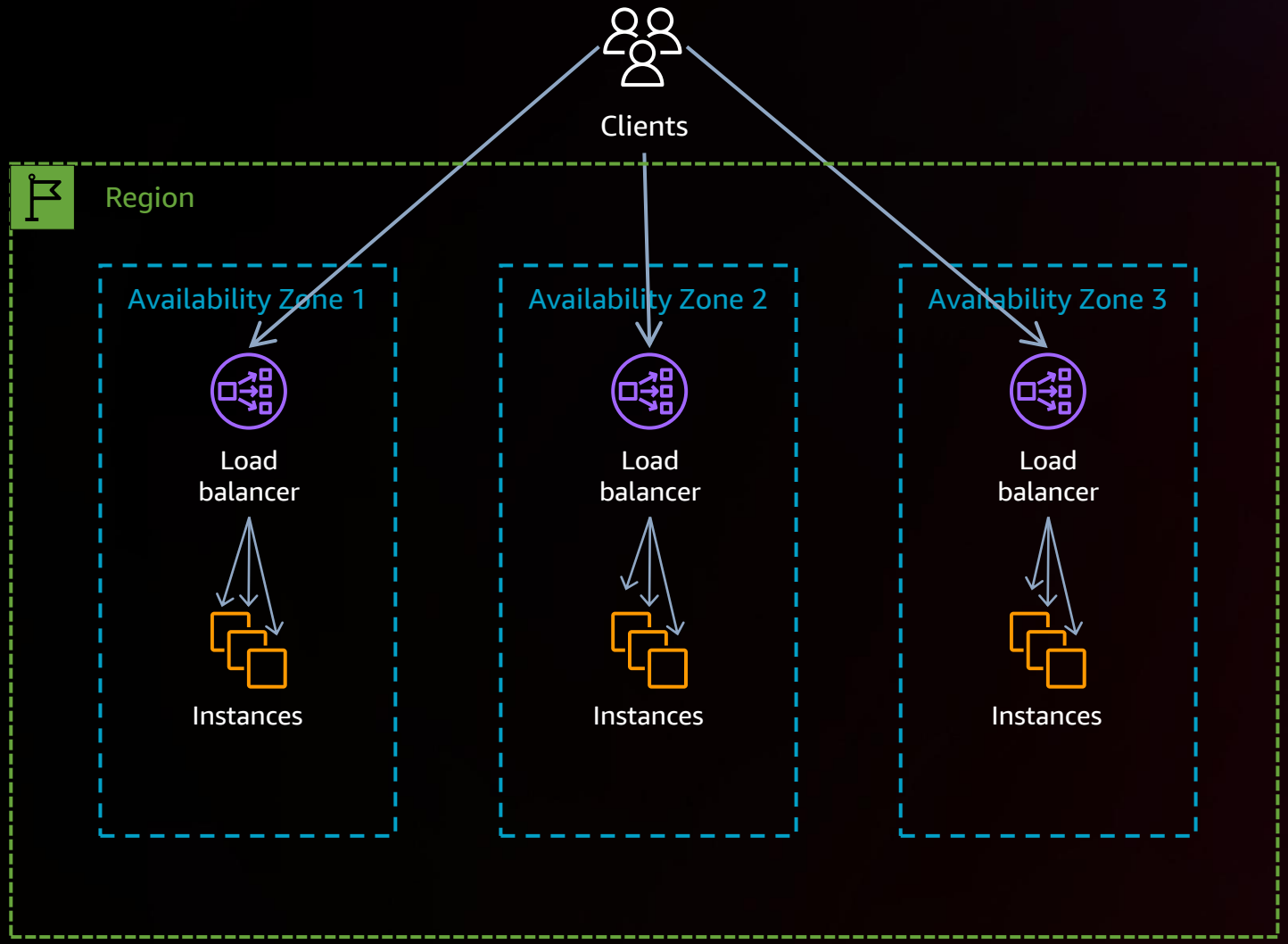
- Overall smoother load balancing
- Failure of load balancer does not reduce instance capacity

- Hard to detect a single AZ issue
- AZs interact constantly

- Default for Application Load Balancer

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3A. Cross-zone load balancing



Load balancers route requests to targets in same AZ only

- Replicas operate independently
- Easier to detect single replica issues

- Less smooth load balancing
- Failure of load balancer in AZ removes instance capacity

- Default for Network Load Balancer
- **NEW:** available also in ALB

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3A. Considerations for cross-zone off

If you've used cross-zone load balancing before, cross-zone off:

- Means DNS load balances traffic between the AZs
- Should have equal capacity in all AZs
- Not recommended for very small target groups (e.g. < 2 per AZ)
- Consider setting minimum healthy target counts
- Provision enough capacity to lose one AZ

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Strategy 3: Detect and shift away from zone

Turn a wide array of grey failures into one hard failure:

"One AZ is out of service"

Used widely within AWS

A. Turn off cross-zone load balancing: eases detection and reduces cross-AZ interactions

B. Monitor the per-AZ customer experience and compare

C. Detect and shift work away from a zonal replica

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3B. Monitoring zonal replicas

Passive monitoring per zonal replica:

- Post per-zone metrics via CloudWatch, Amazon Managed Grafana, etc.
- Fatal errors, HTTP 500s, response latency, etc.
- Compare metrics across the three zones

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3B. Monitoring zonal replicas

Active monitoring per zonal replica, e.g. CloudWatch Synthetics

ELB provides per AZ domain names that can be monitored:

test-elb-6551d31e16cb9398.elb.us-west-2.amazonaws.com

us-west-2a.test-elb-6551d31e16cb9398.elb.us-west-2.amazonaws.com

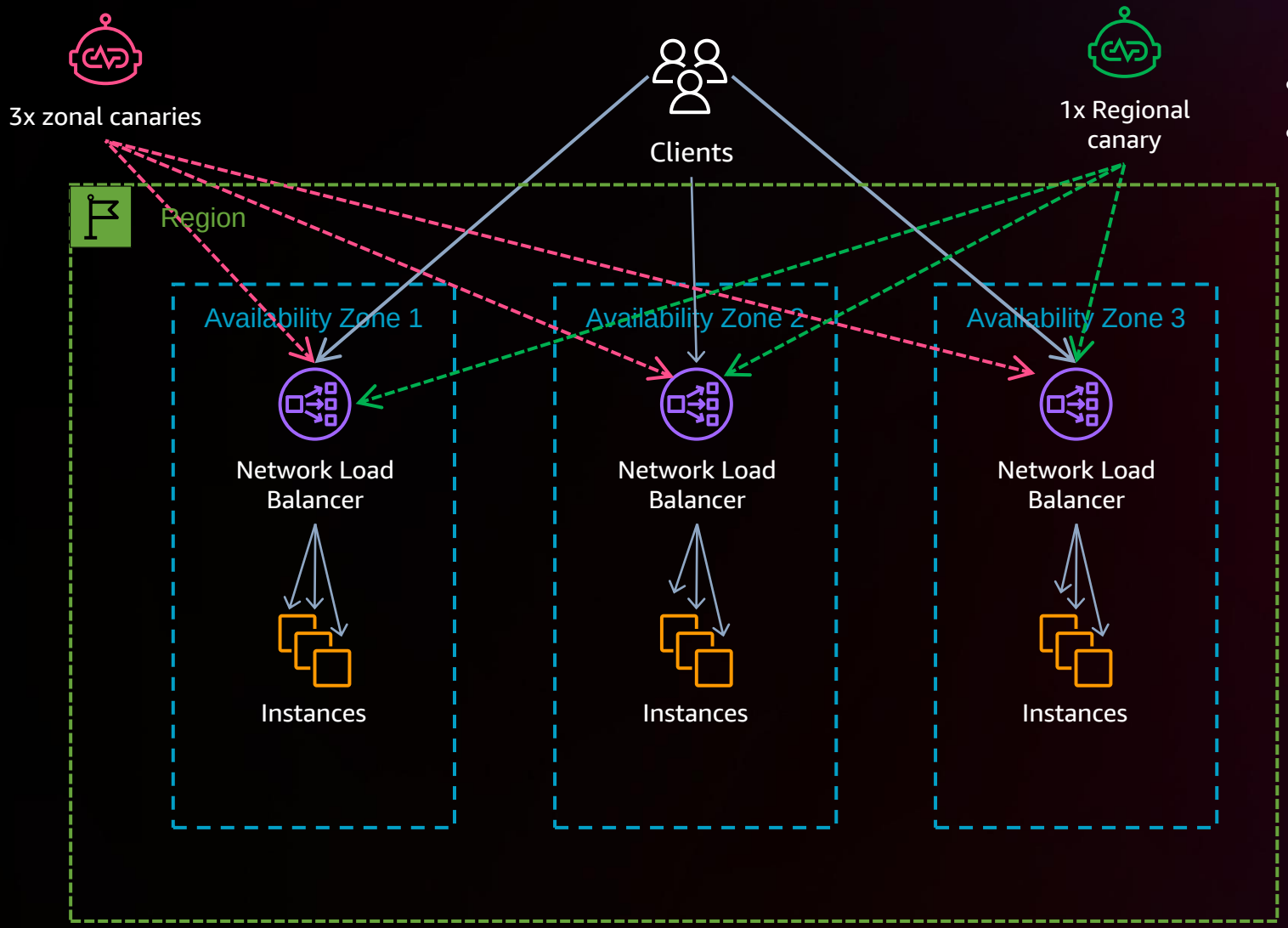
us-west-2b.test-elb-6551d31e16cb9398.elb.us-west-2.amazonaws.com

us-west-2c.test-elb-6551d31e16cb9398.elb.us-west-2.amazonaws.com

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3B. Monitoring zonal replicas



- One canary per AZ endpoint
- One canary for the Regional endpoint (customer experience)

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Sources for detecting single-AZ issues

- Passive monitoring
- Active monitoring
- AWS Service Health Dashboard: https://health.aws.amazon.com/

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3C. Shift away from a zone

Route 53 Application Recovery Controller **zonal shift**

- Allow you to shift load away from one zone temporarily
- One simple API call
- Now included for both ALB and NLB (with cross-zone turned off)
- No additional cost

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Start a zonal shift

```
% aws arc-zonal-shift start-zonal-shift \
              --away-from apse2-az1 \
              --expires-in 30m \
              --resource-identifier "arn:aws:elasticloadbalancing:ap-southeast-
2:231838188243:loadbalancer/net/zonal-shift-demo/4e60cc05ac46be60" \
              --comment "shift away from AZ B"
{
    "status": "ACTIVE",
    "comment": "shift away from AZ B",
    "awayFrom": "apse2-az1",
    "zonalShiftId": "e0c2348b-c043-b9fb-f1cd-fe7245ff063f",
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aws

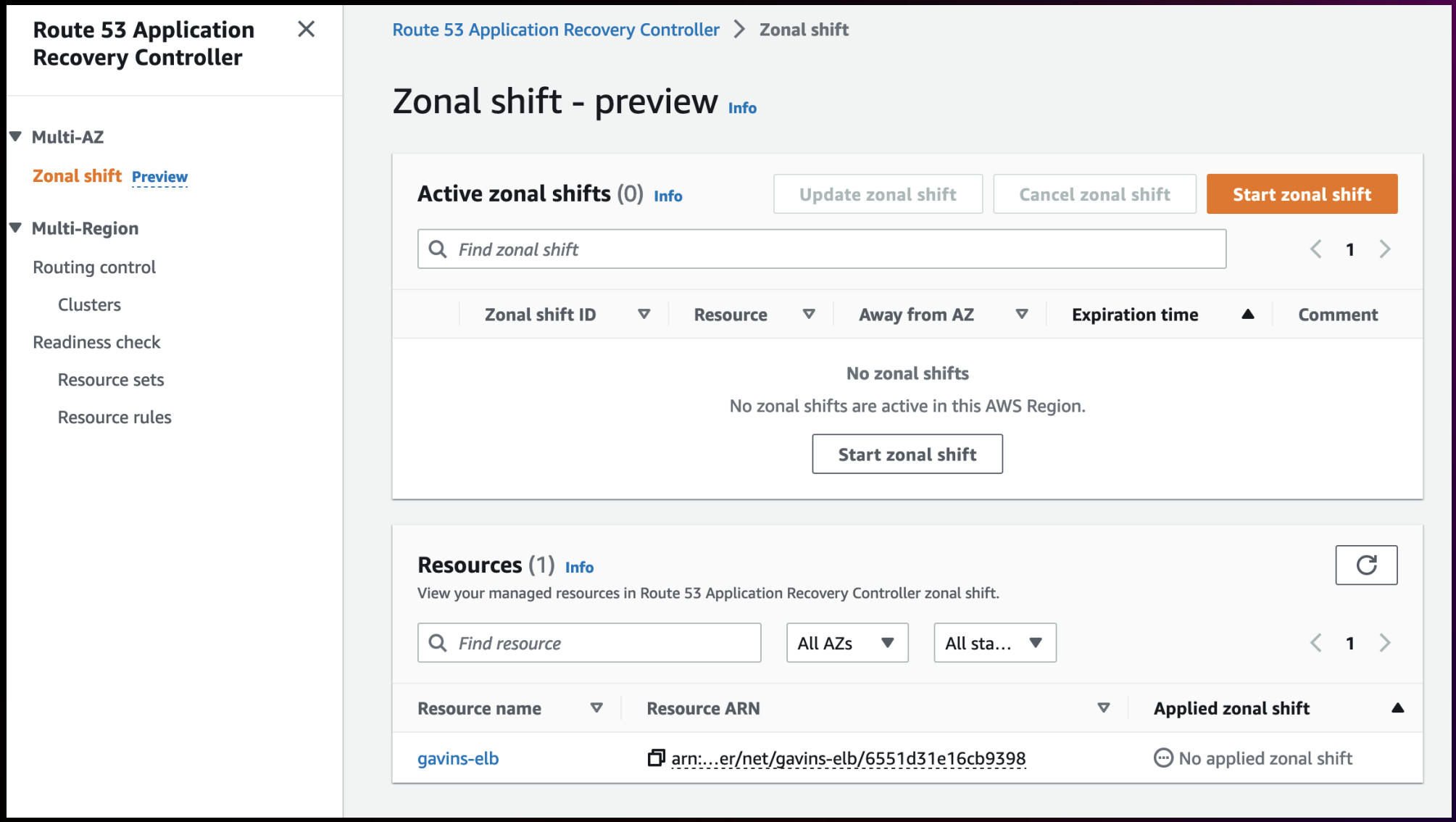
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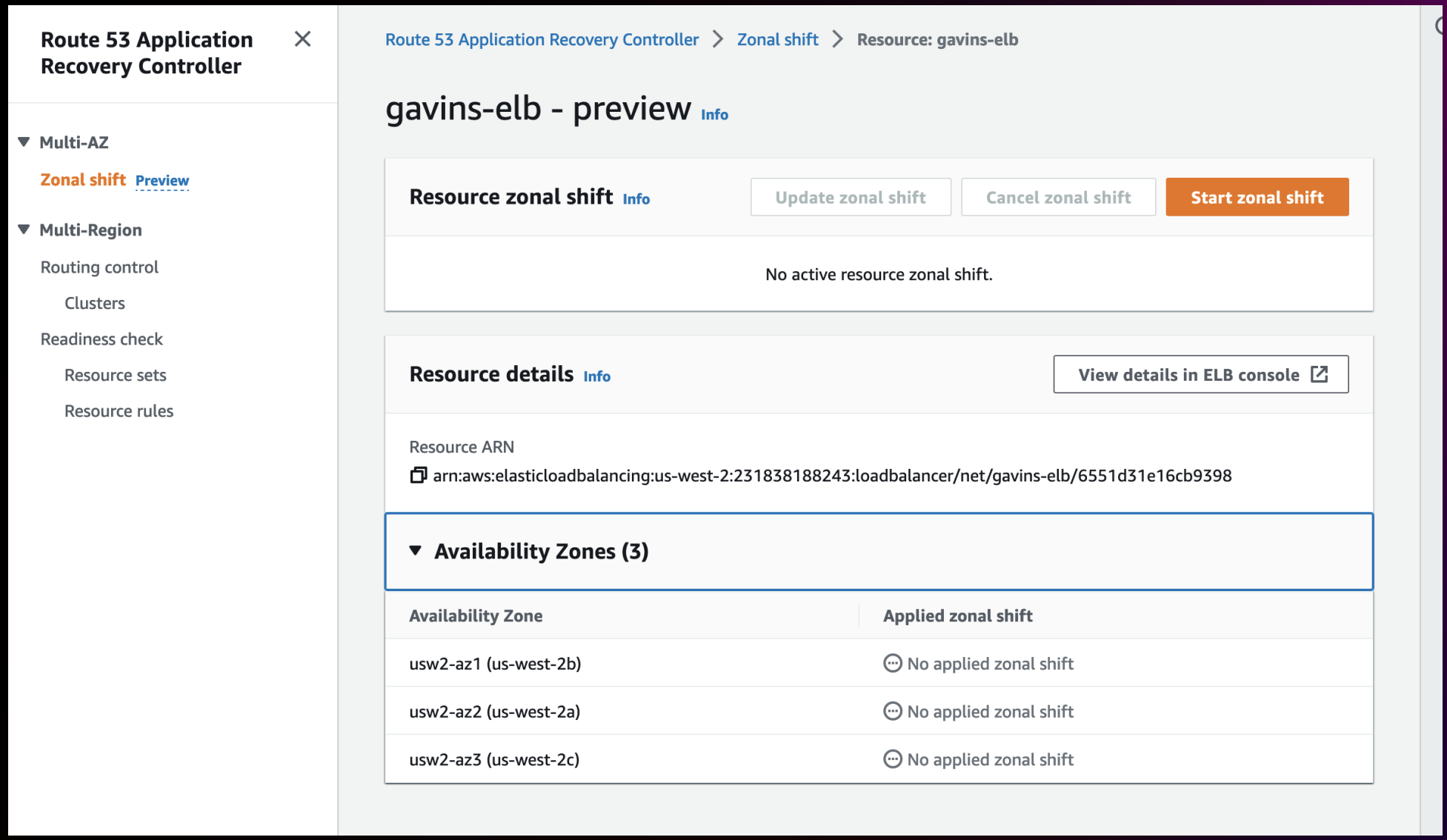
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Start a zonal shift – Console



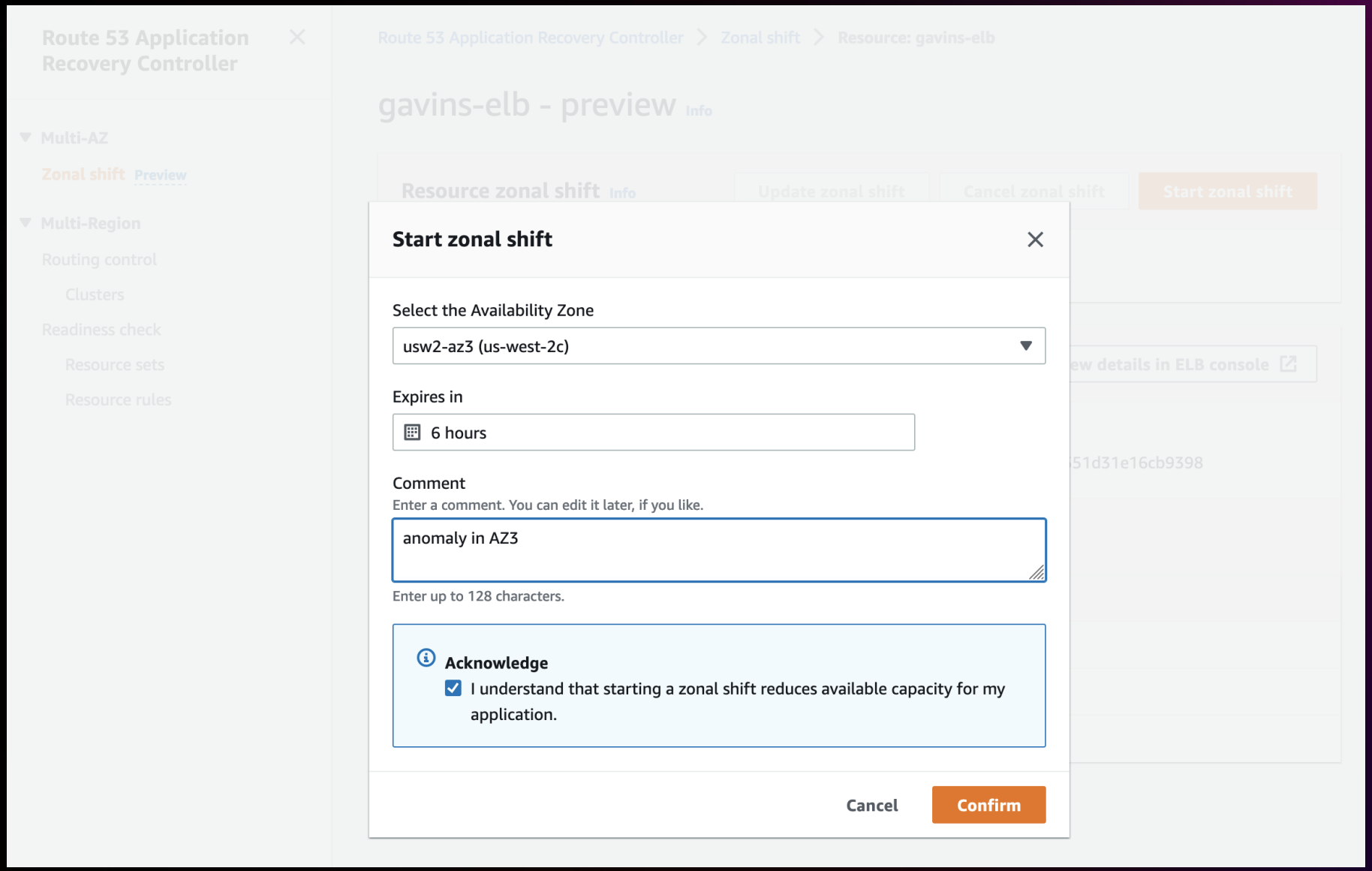
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Start a zonal shift – Console



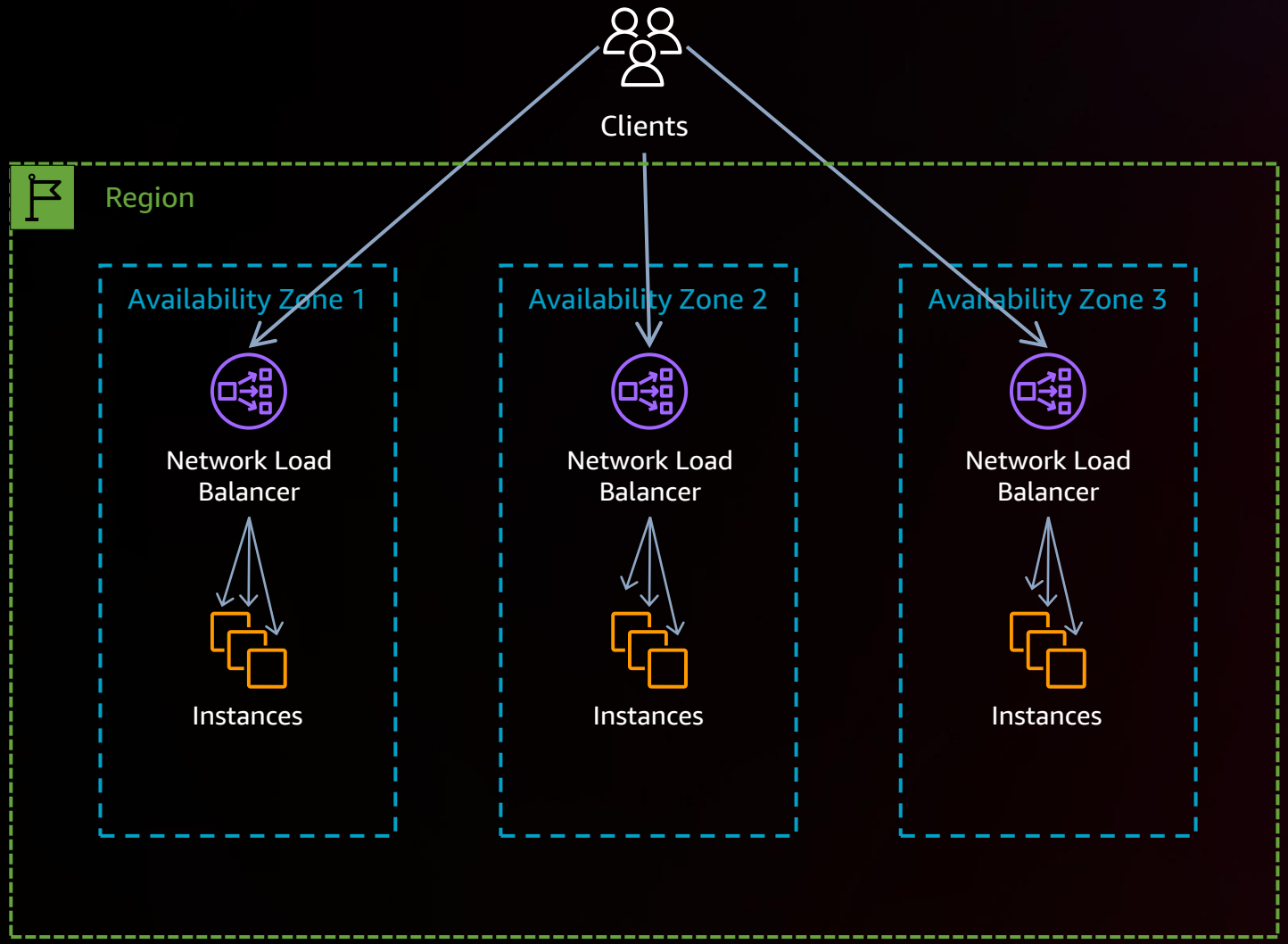
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Start a zonal shift – Console



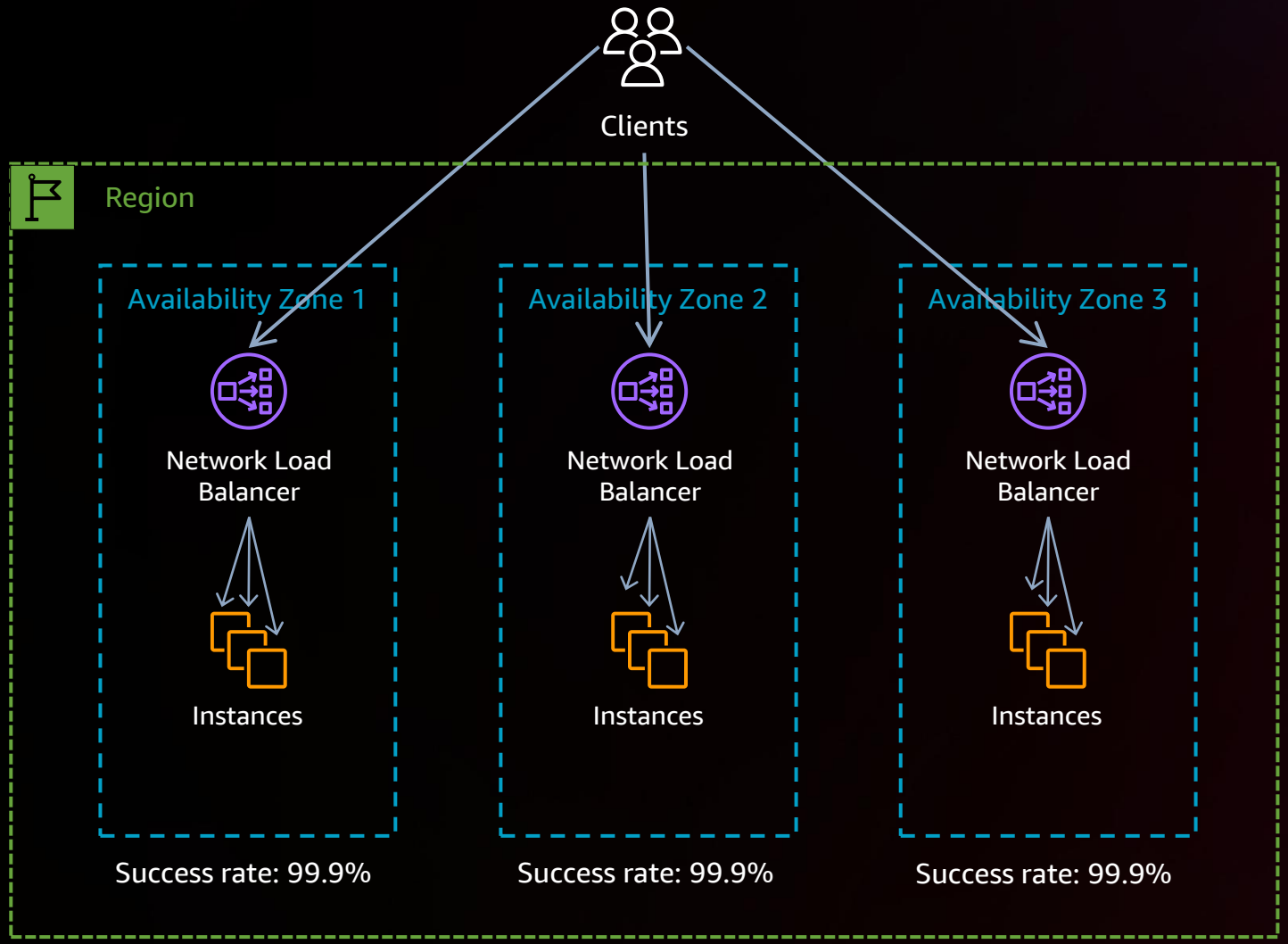
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Load-balanced application



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AZ redundant



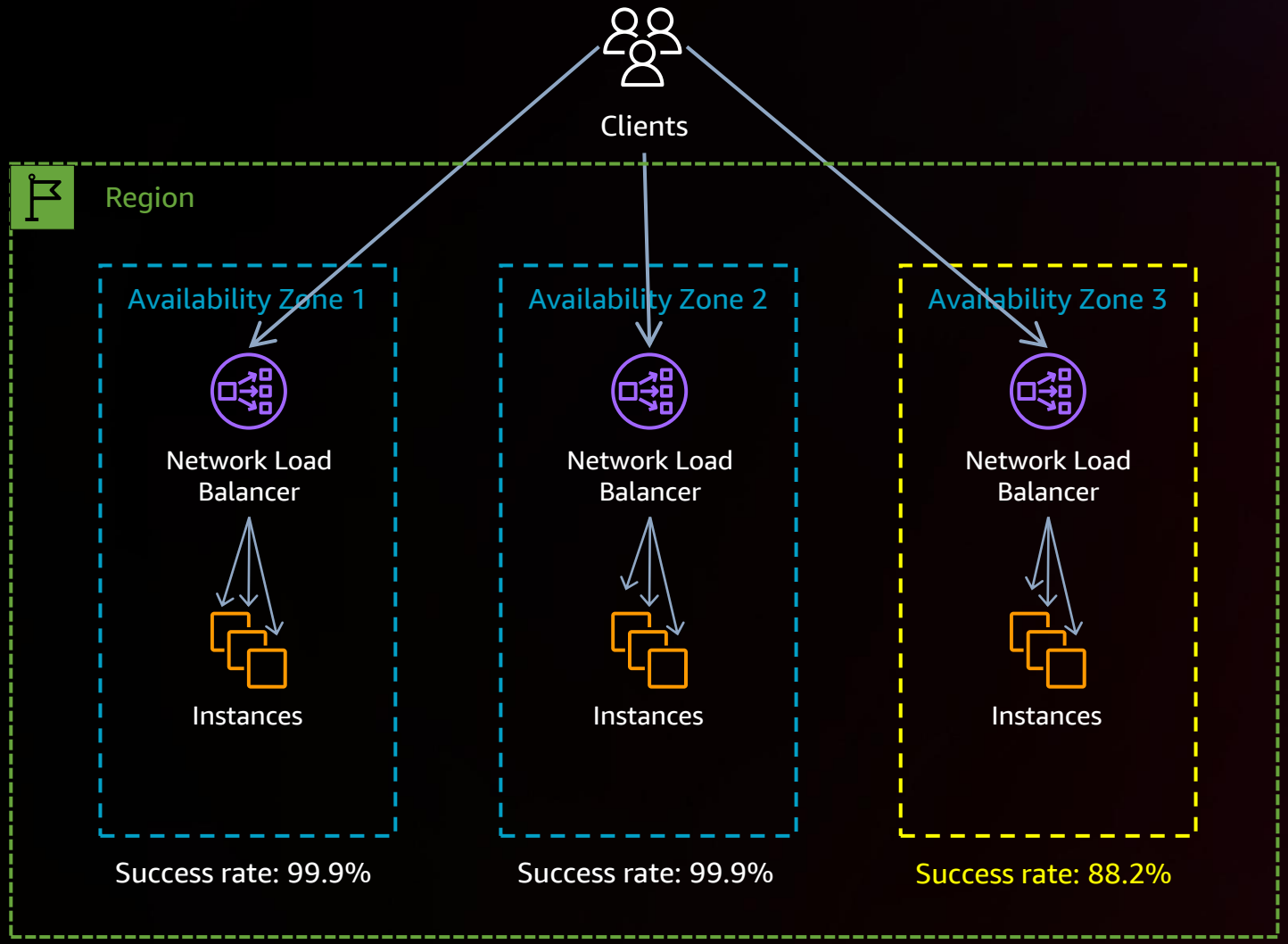
AZ redundant:

- Each AZ is **pre-scaled** with 50% capacity headroom
- All AZs are healthy and taking traffic
- Cross-zone load balancing is disabled
- Monitor the per-AZ success rate

Aggregate success rate: 99.9%

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Failure detected in AZ3



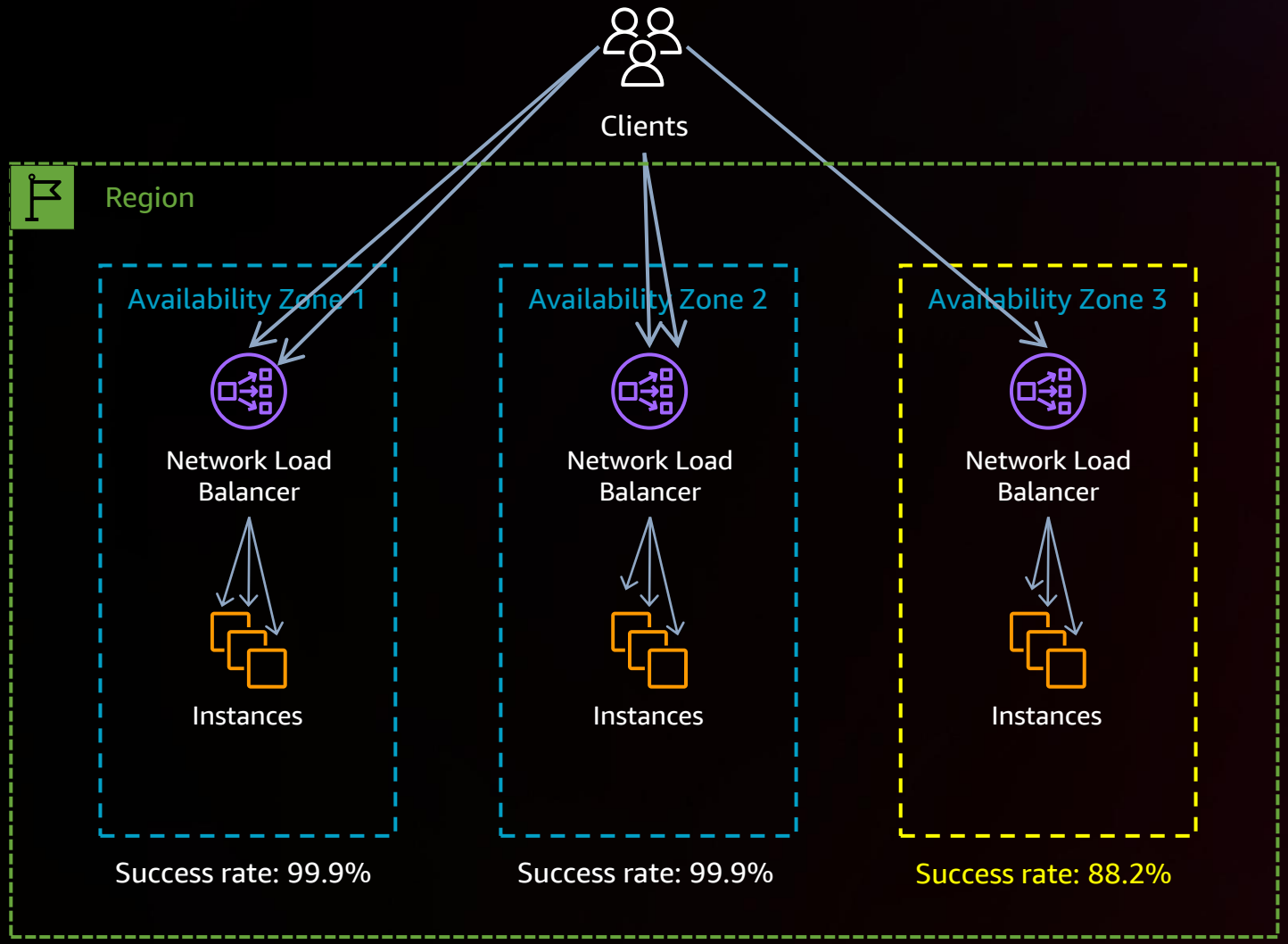
Start a zonal shift

```
aws arc-zonal-shift start-zonal-shift
  --resource-identifier
  arn:aws:elasticloadbalancing:us-west-2:...
  --away-from apse2-az3
  --comment “possible problem in AZ3”
  --expires-in 12h
```

Aggregate success rate: 96.0%

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AZ3 removed from DNS

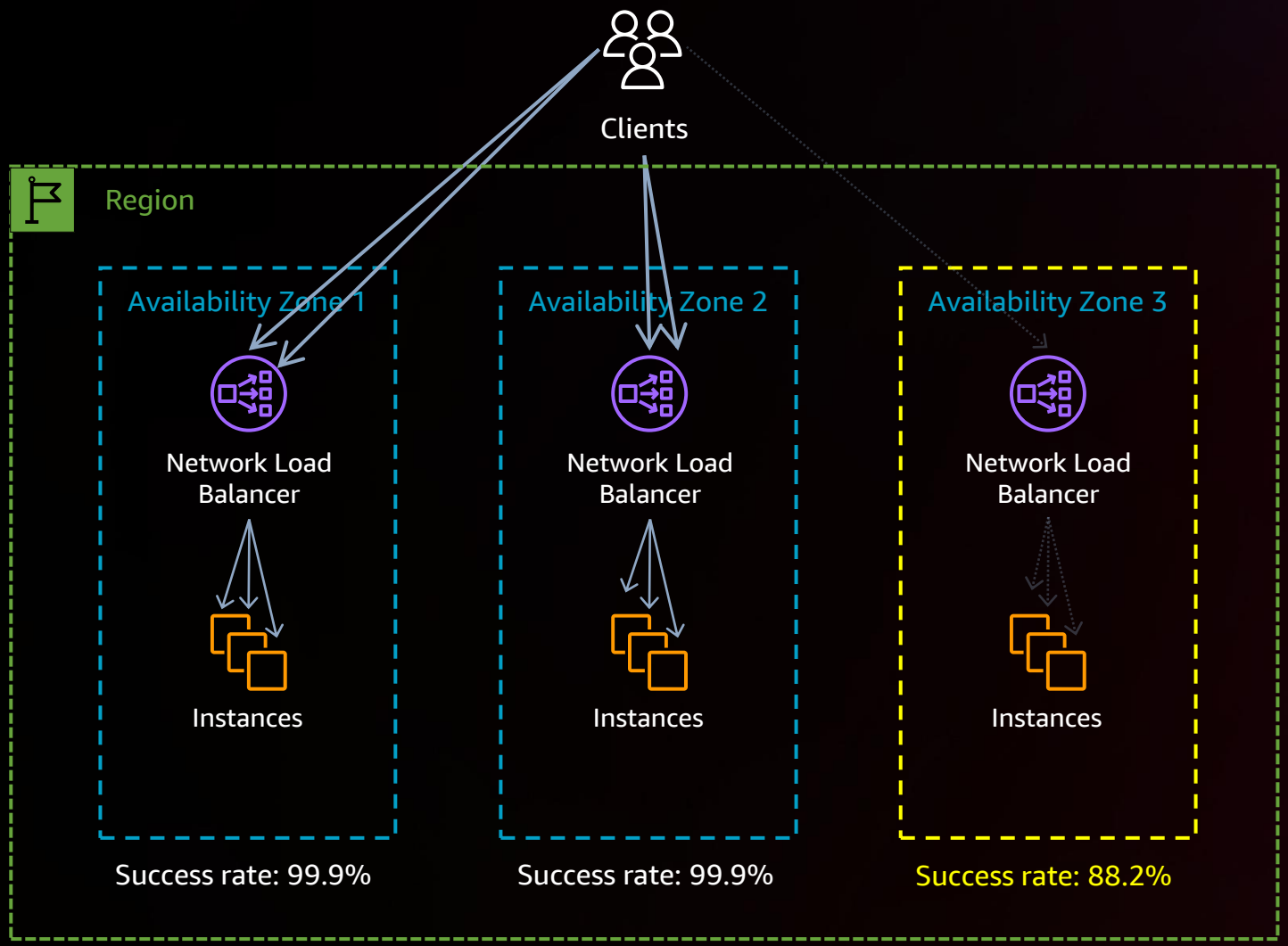


Zonal shift in progress

Aggregate success rate: 98.0%

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Load shifted away from AZ3

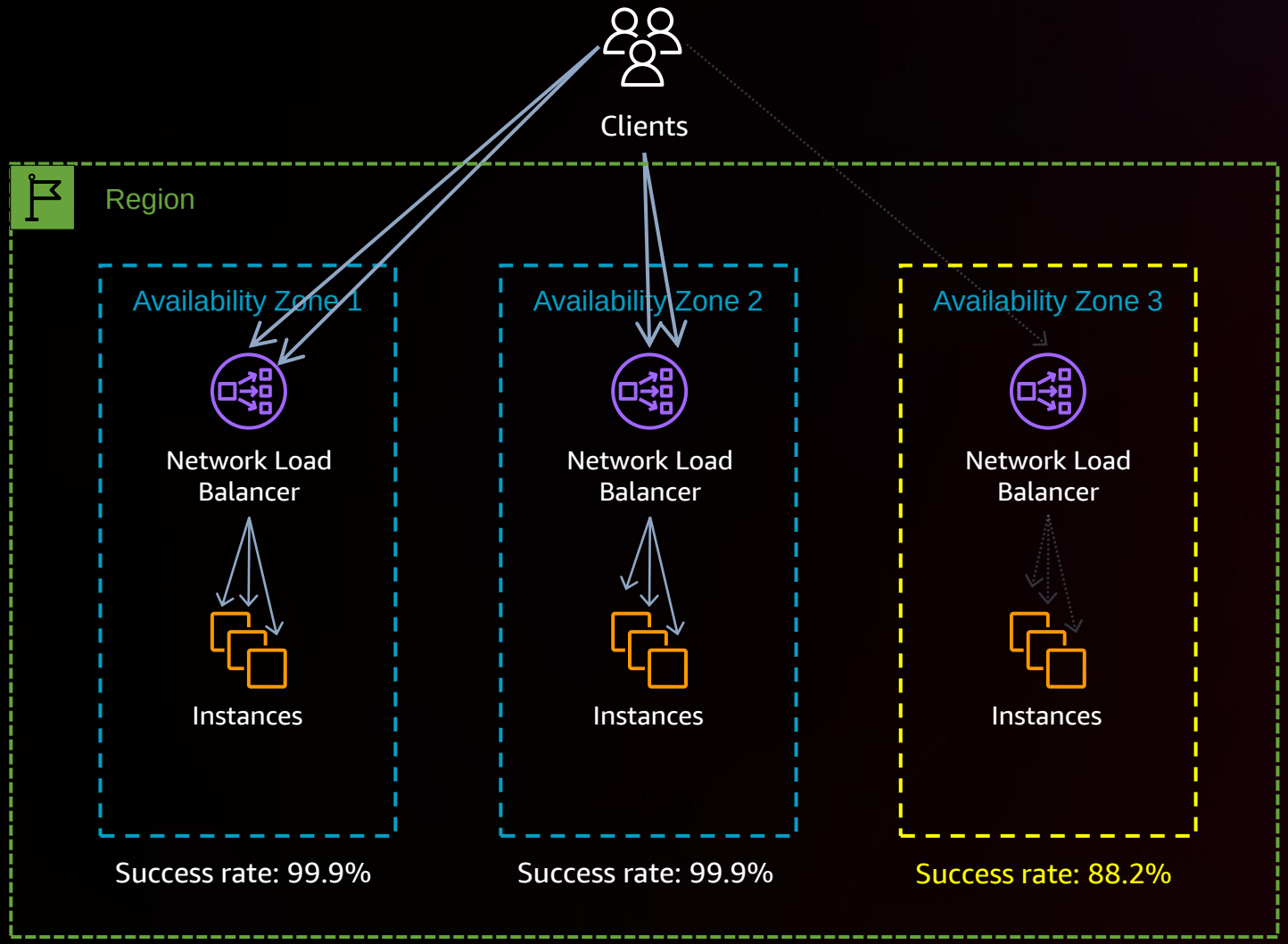


Recovery for customers

Aggregate success rate: 99.9%

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Extend the zonal shift



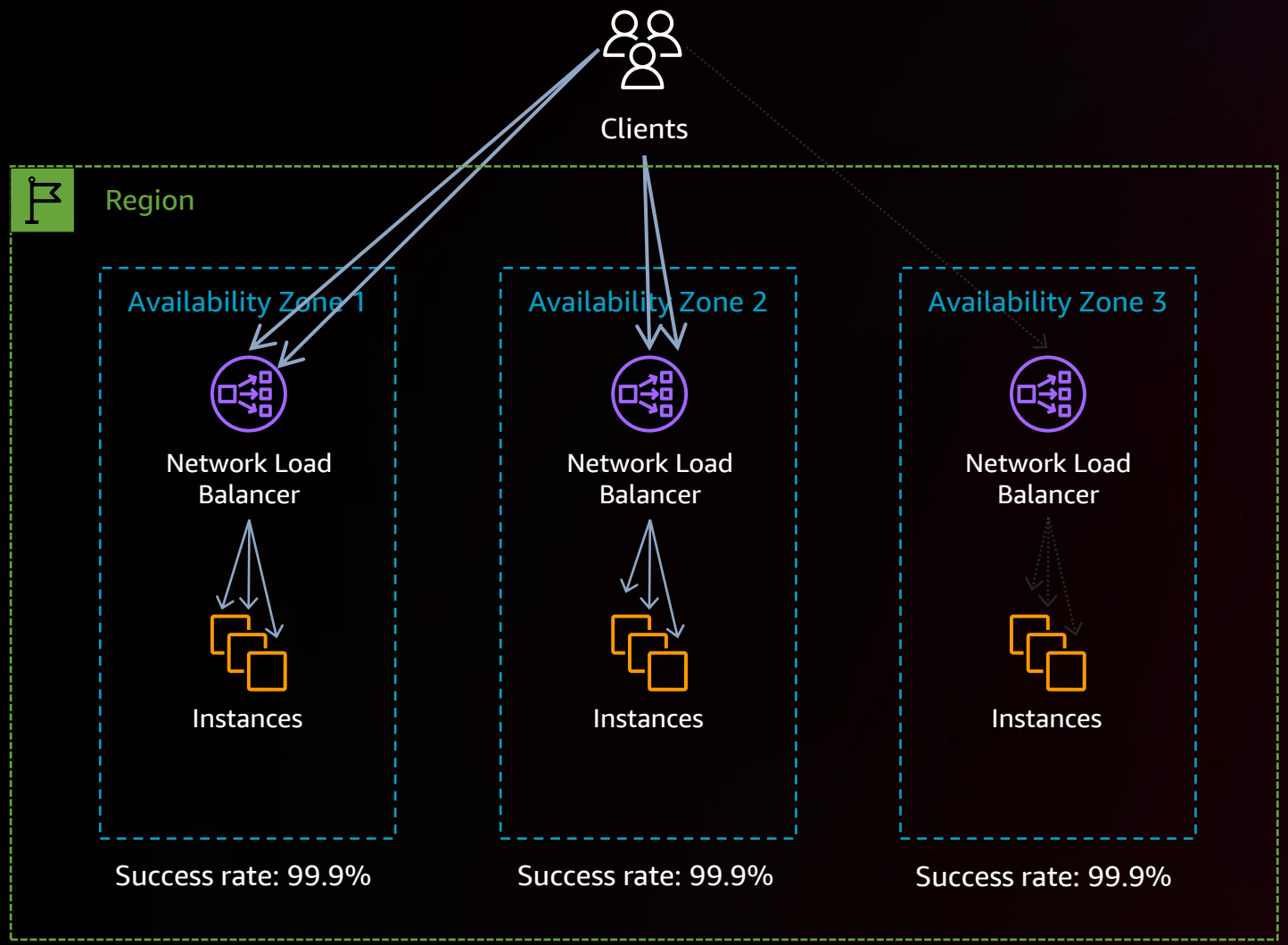
Extend the zonal shift

```
aws arc-zonal-shift update-zonal-shift \
  --zonal-shift-id e0c2348b-c043-b9fb-f1cd-
fe7245ff063f \
  --expires-in 6hr
```

Aggregate success rate: 99.9%

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Repair and return to AZ3



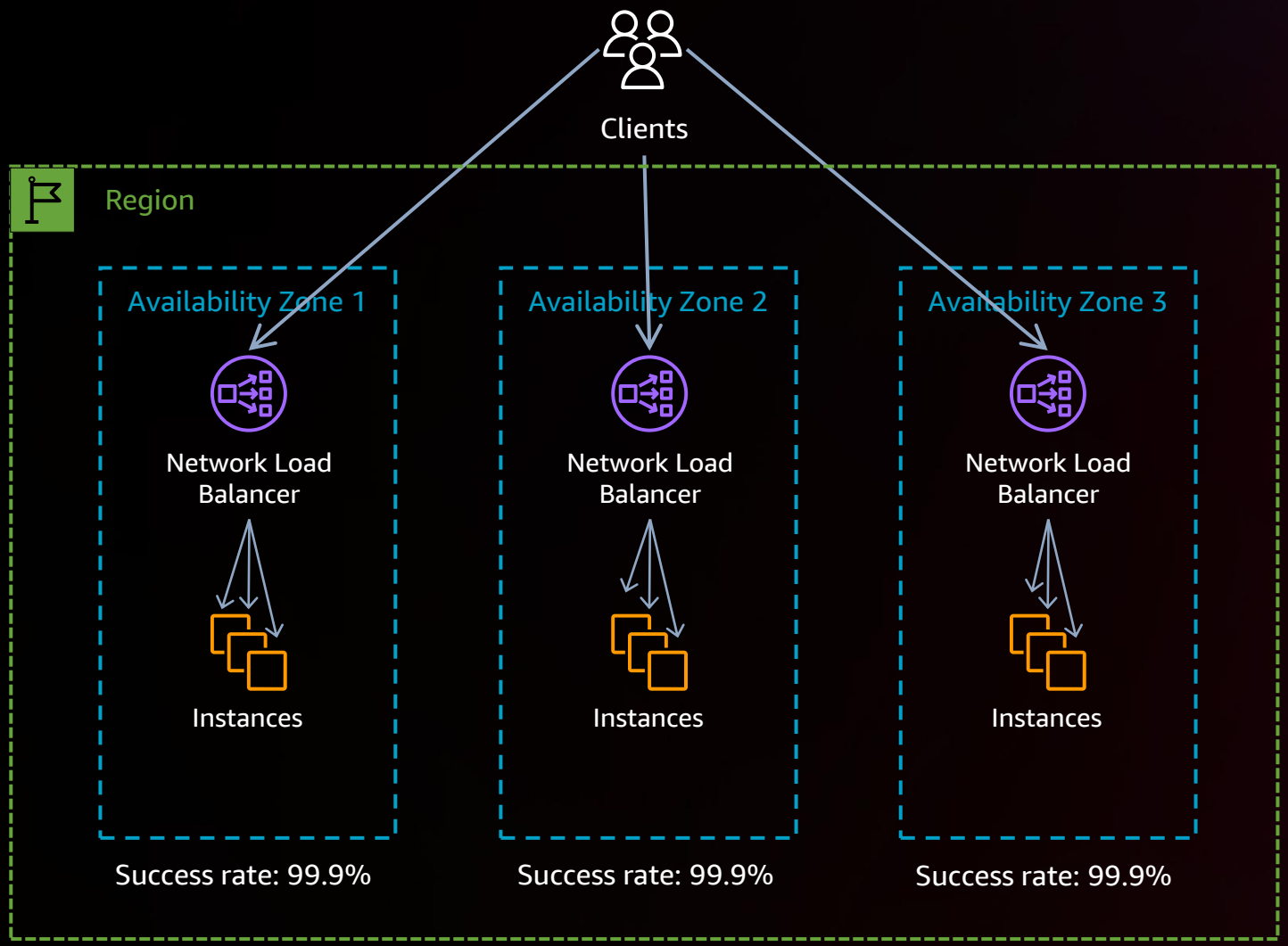
End the zonal shift to return to AZ3

```
aws arc-zonal-shift cancel-zonal-shift
 --zonal-shift-id e0c2348b-c043-b9fb-f1cd-
fe7245ff063f
```

Aggregate success rate: 99.9%

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Full redundancy restored



Aggregate success rate: 99.9%

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Route 53 ARC zonal shift (preview)

Allows a temporary shift away from an AZ so you can recover, then investigate and repair

Reduces mean time to recovery

Preview now available for all ALBs and NLBs with cross-zone load balancing off (in 9x Regions)

Blog post: Rapidly recover from application failures in a single AZ – https://go.aws/3AVM2Yt

aws

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Real-life events

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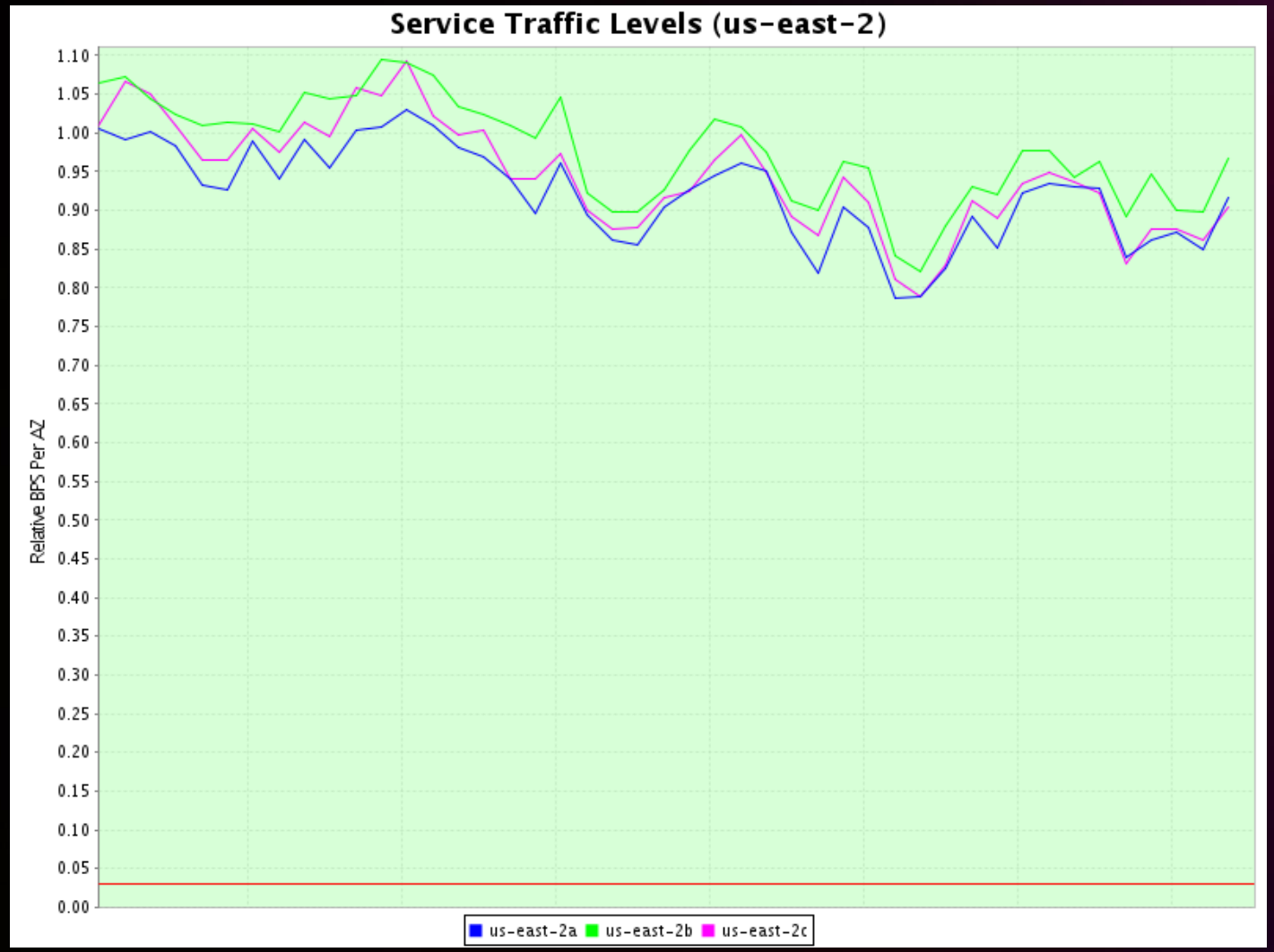
A real-life event

Route 53 ARC zonal shift (preview) is a new public feature

However, shifting away from AZs has a long history in AWS

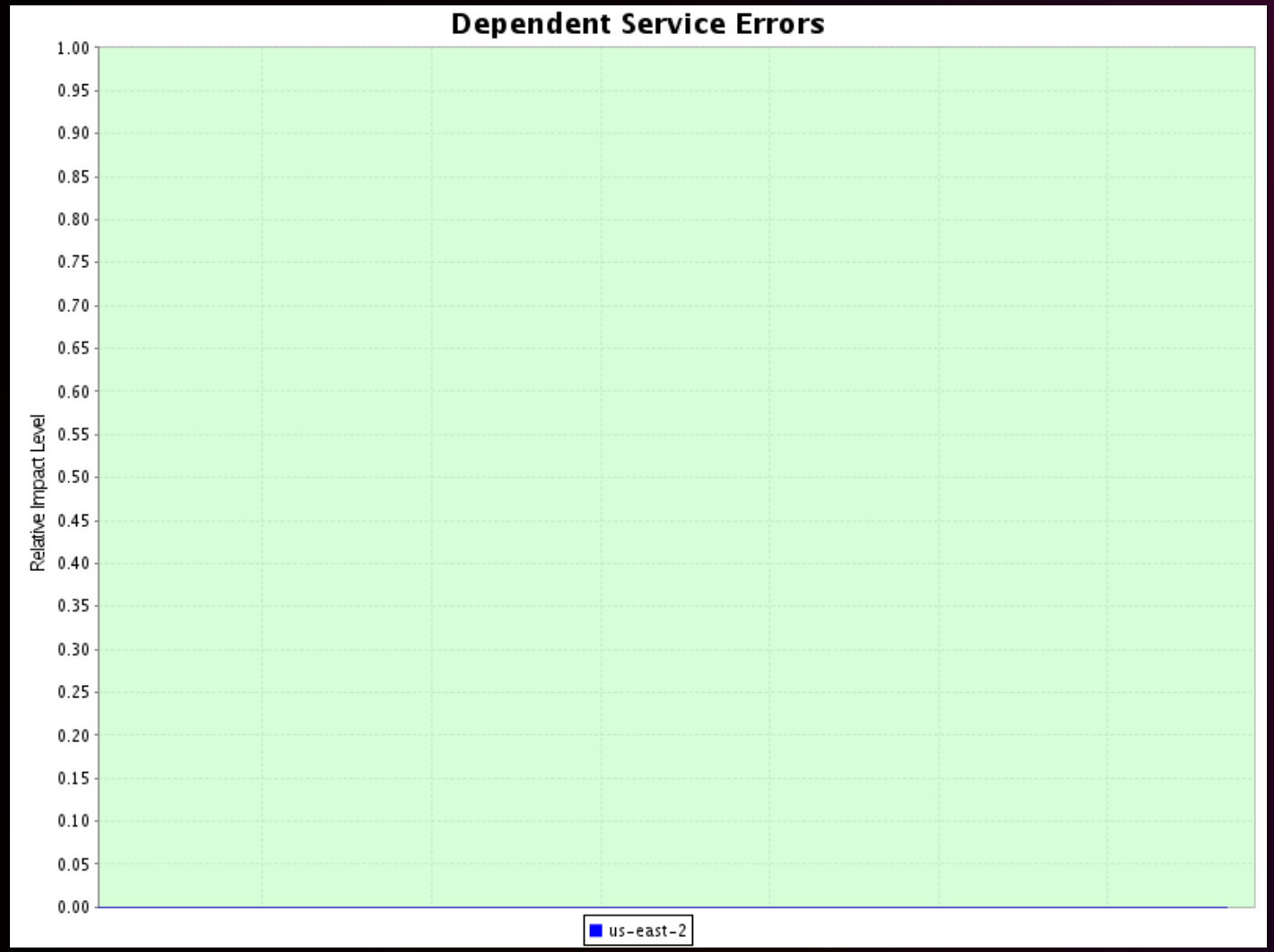
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Real-life event: Traffic levels



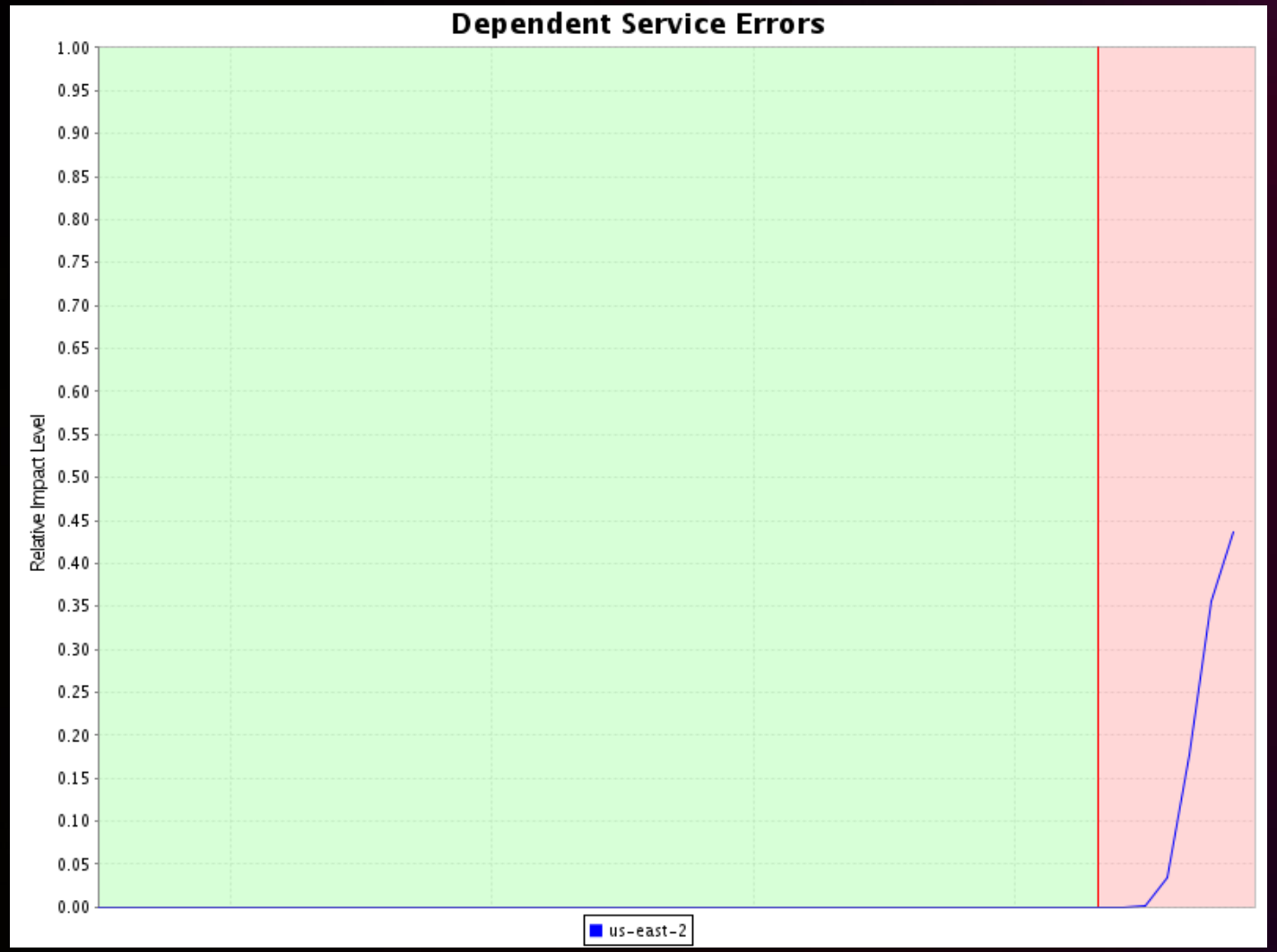
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Real-life event: Customer error rate



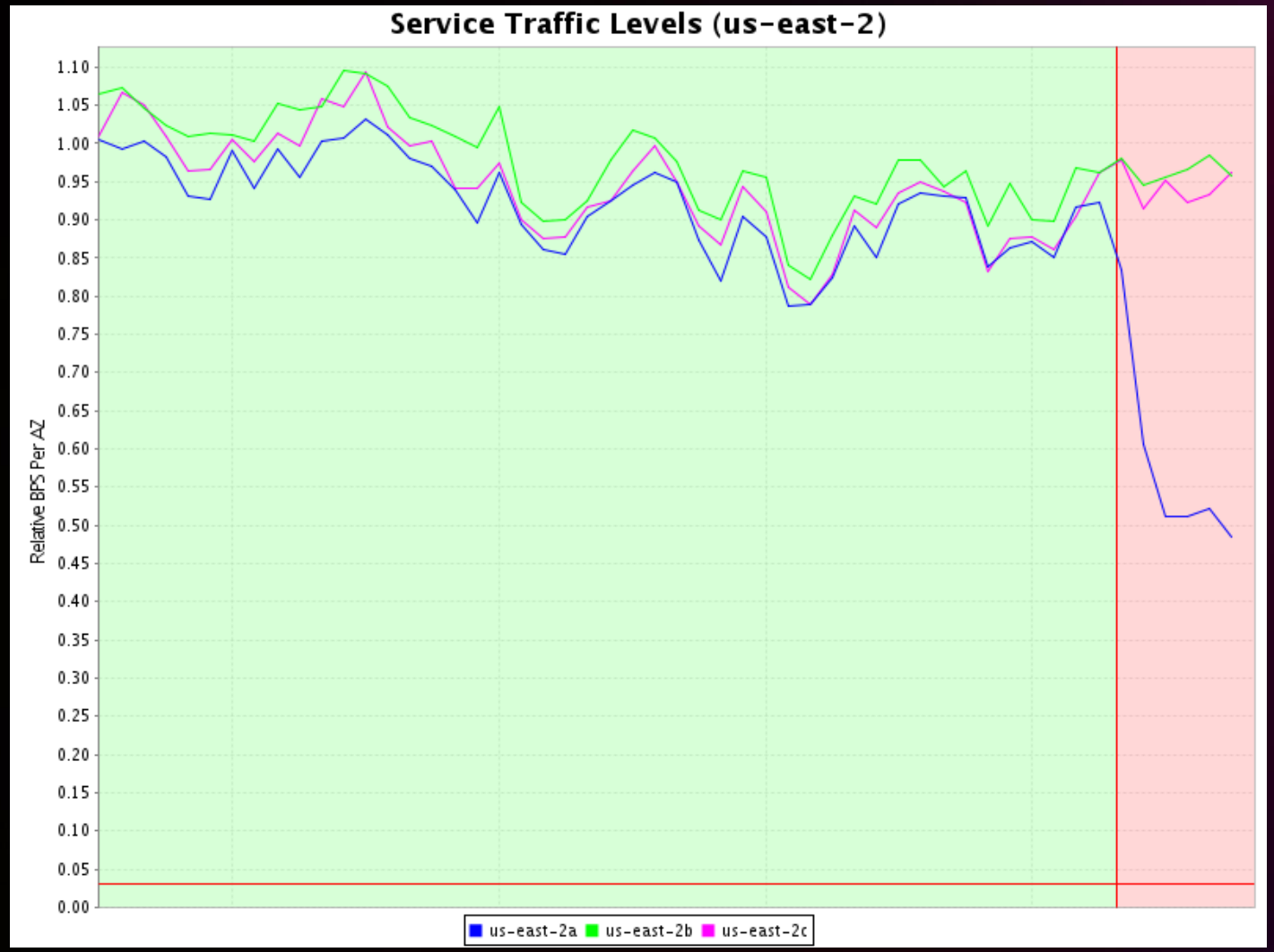
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Increased errors



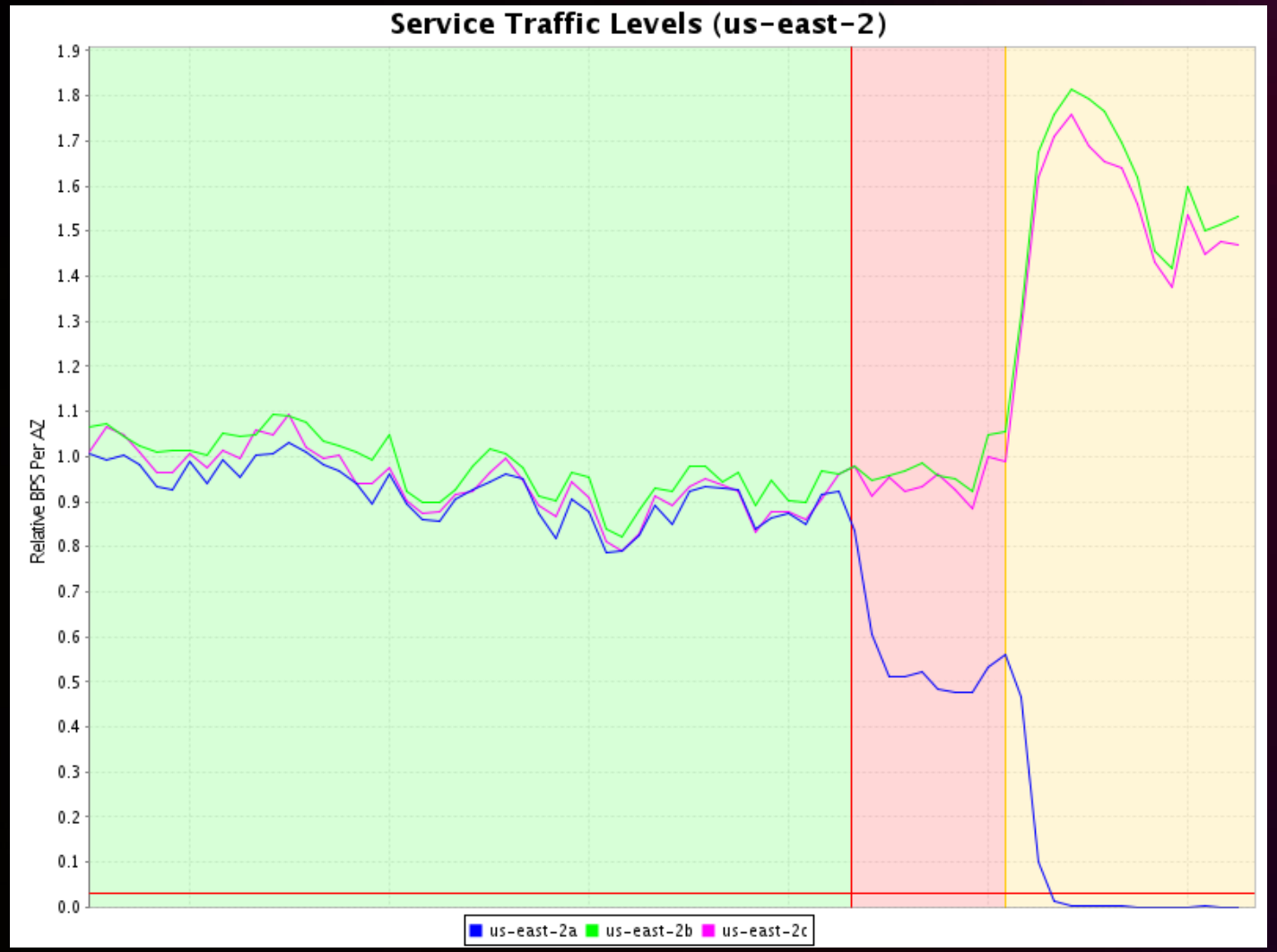
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Traffic levels: us-east-2a anomalous (?)



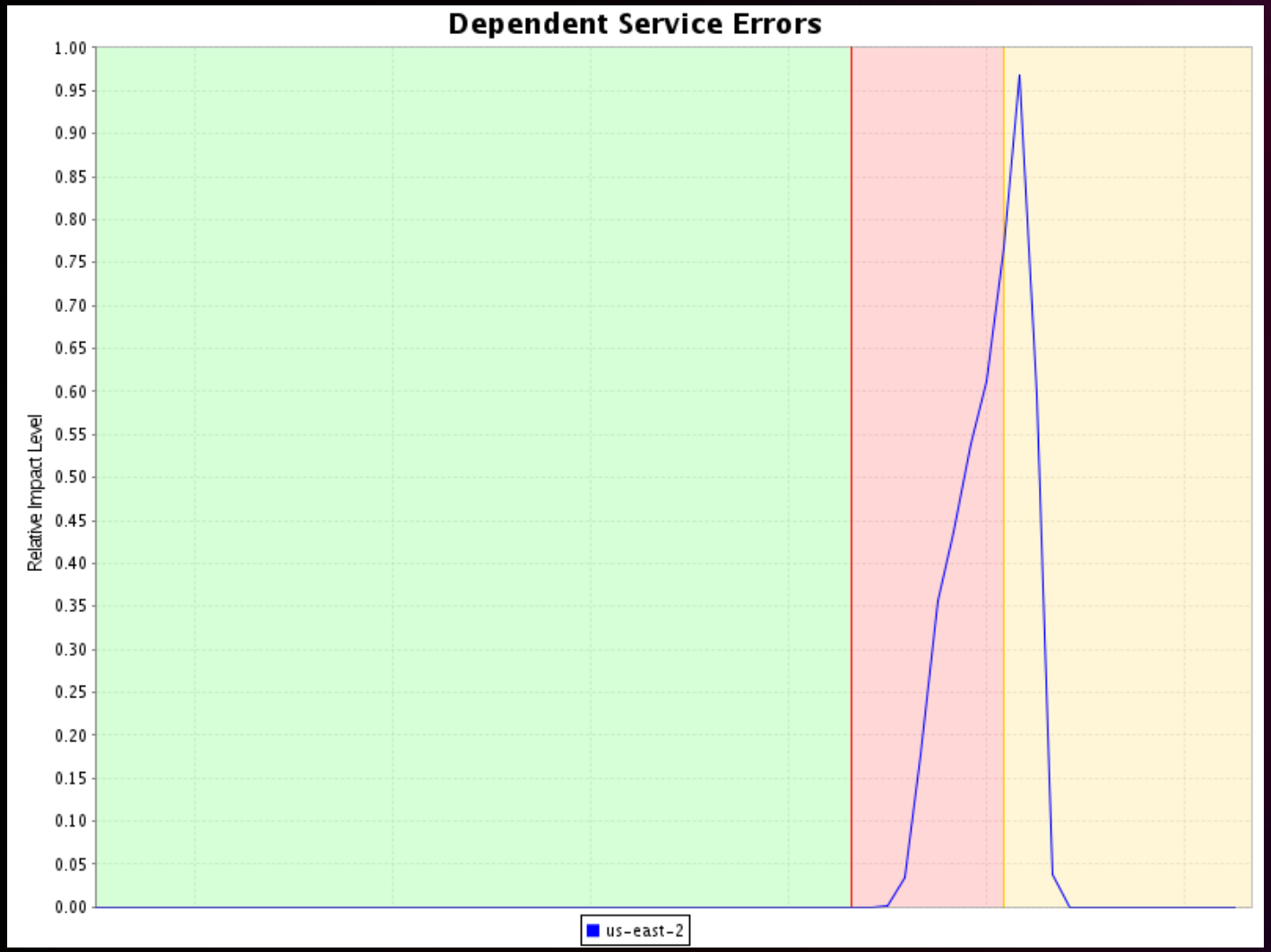
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Shift away from us-east-2a



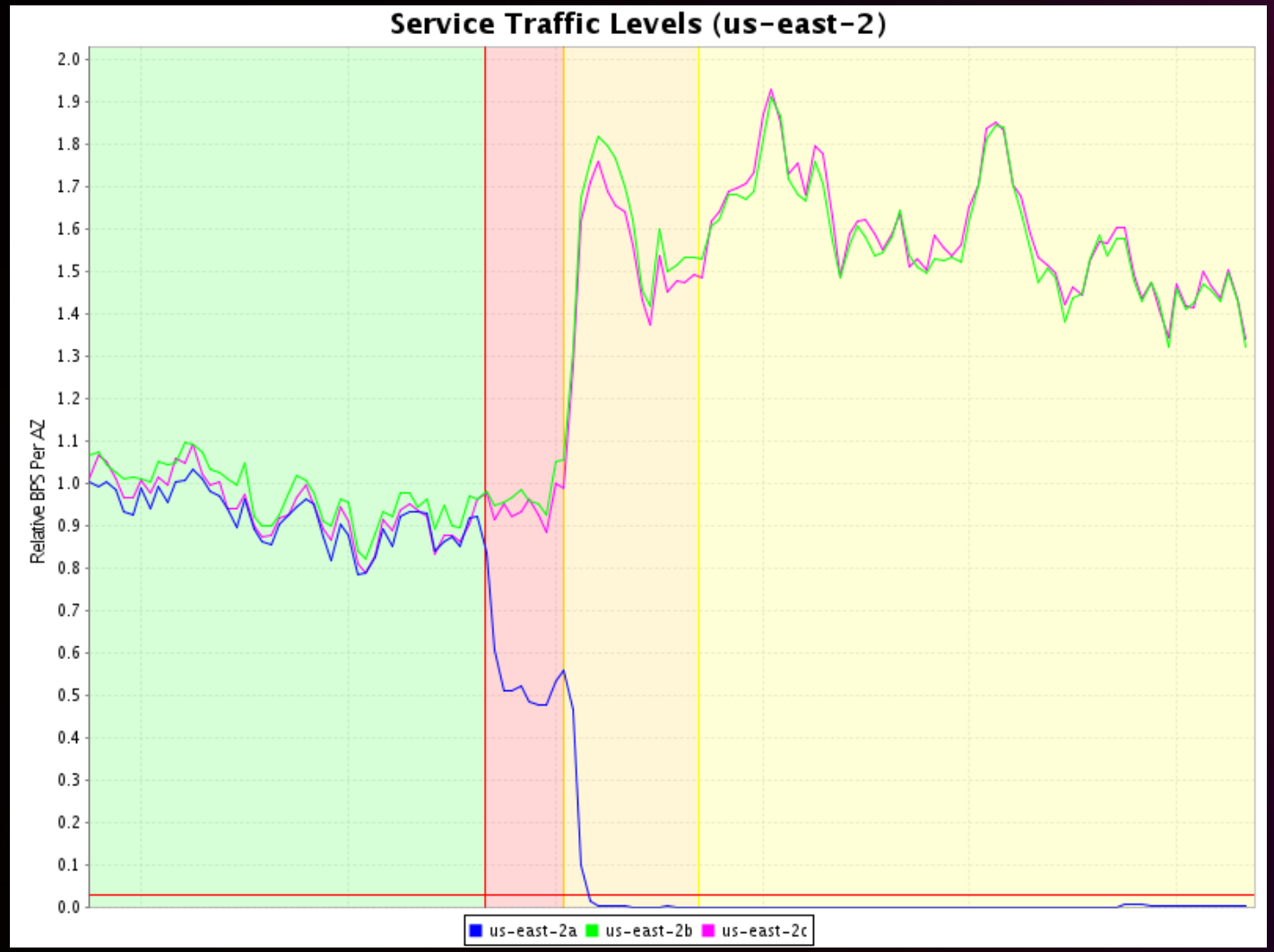
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Customers recover



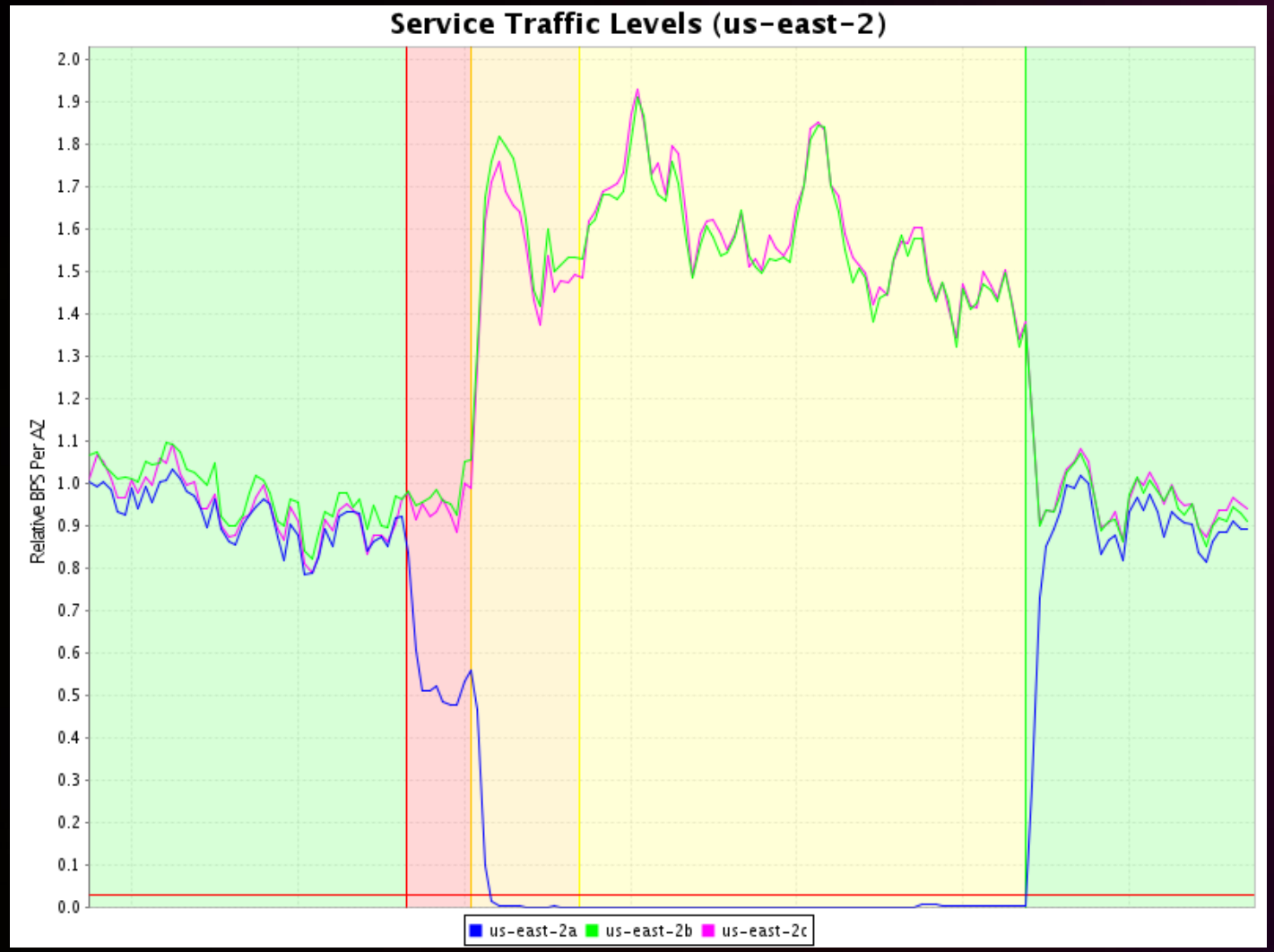
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Root cause, repair



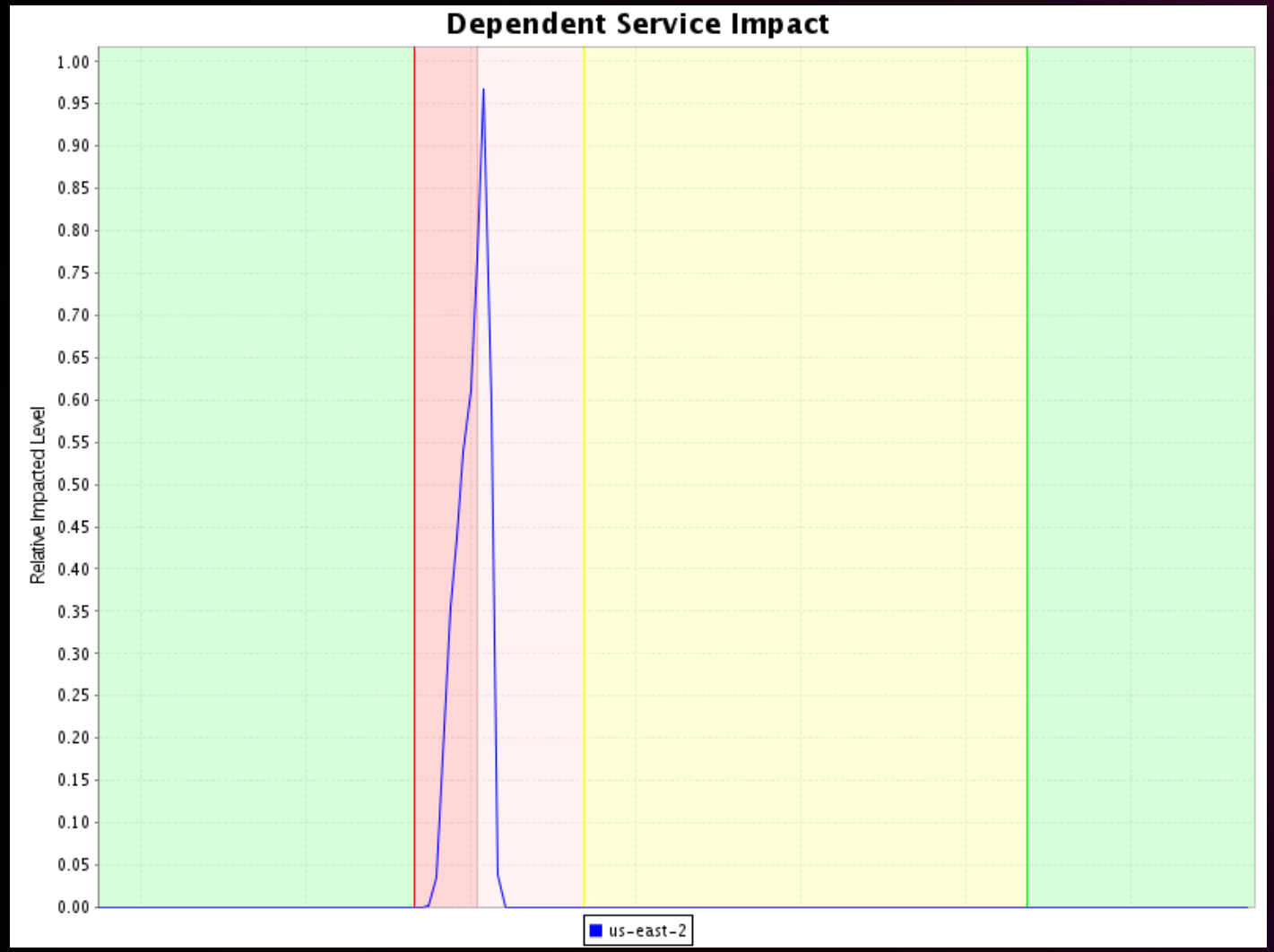
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Restore us-east-2a



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Impact time reduced by 90%



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Results

Root cause was the deployment of one service component

Deployment was to a single AZ only

Shifting service away from that one AZ reduced MTTR by 90%

Full recovery before root cause was known

Repairs carried out safely and carefully, not urgently

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Demonstration

CloudFormation stack includes:

- 3-AZ NLB with cross-zone load balancing off
- Auto Scaling group with 6 instances running Apache, serving 1MB file
- CloudWatch Synthetics canaries (3x AZ, 1x Region) and alarms
- CloudWatch dashboard
- Fault injection simulator experiments (chaos testing)

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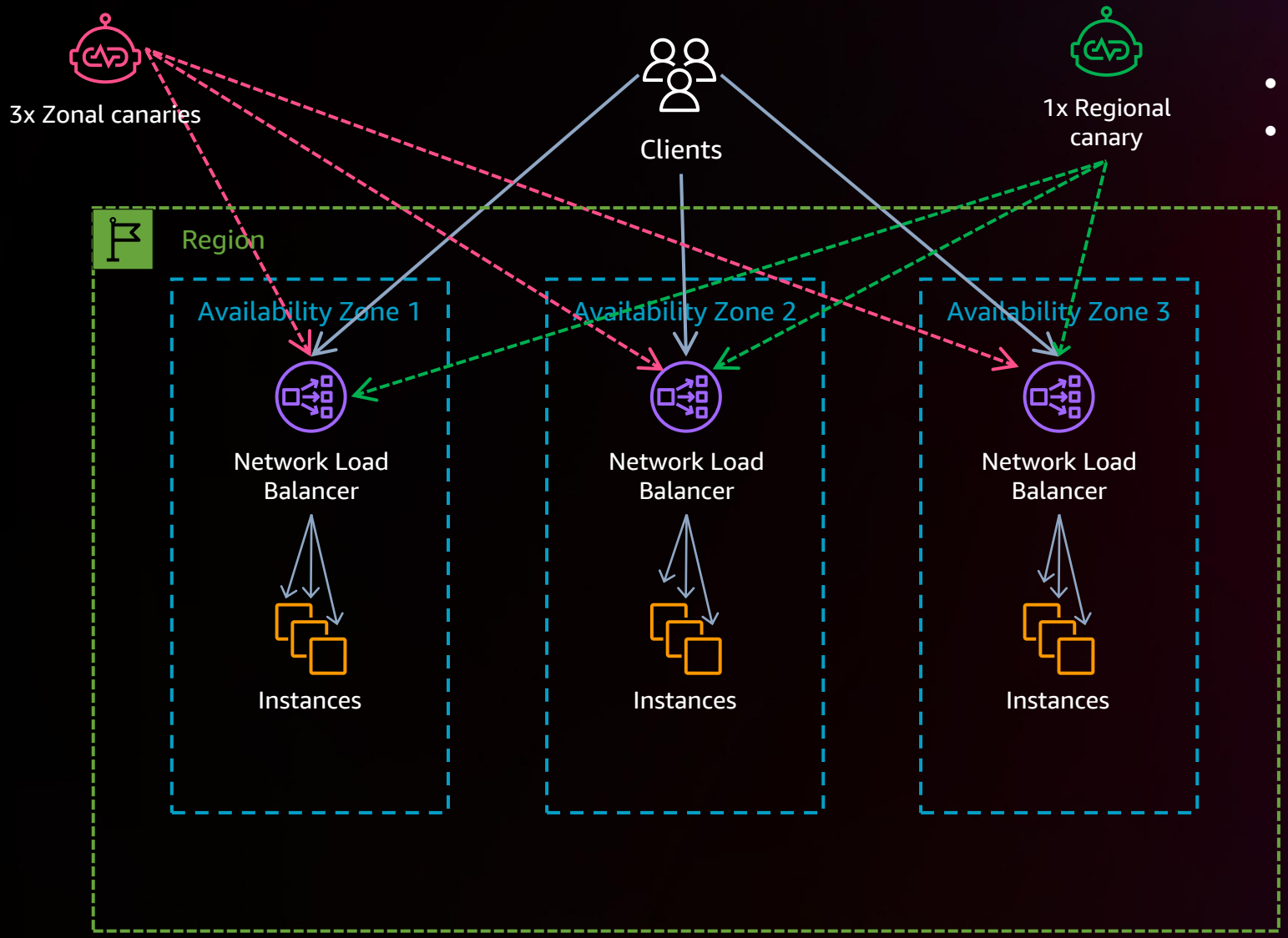
Demo setup

```
git clone https://github.com/aws-samples/arc-zonal-shift-demo.git

aws cloudformation create-stack \
       --stack-name arc-zonal-shift-demo \
       --template-body file://ZonalShiftExample/ARC-Zonal-Shift-Demo.json  \
       --capabilities CAPABILITY_NAMED_IAM \
       --parameters 'ParameterKey=OperatorEMail,ParameterValue=[EMAIL]'
```

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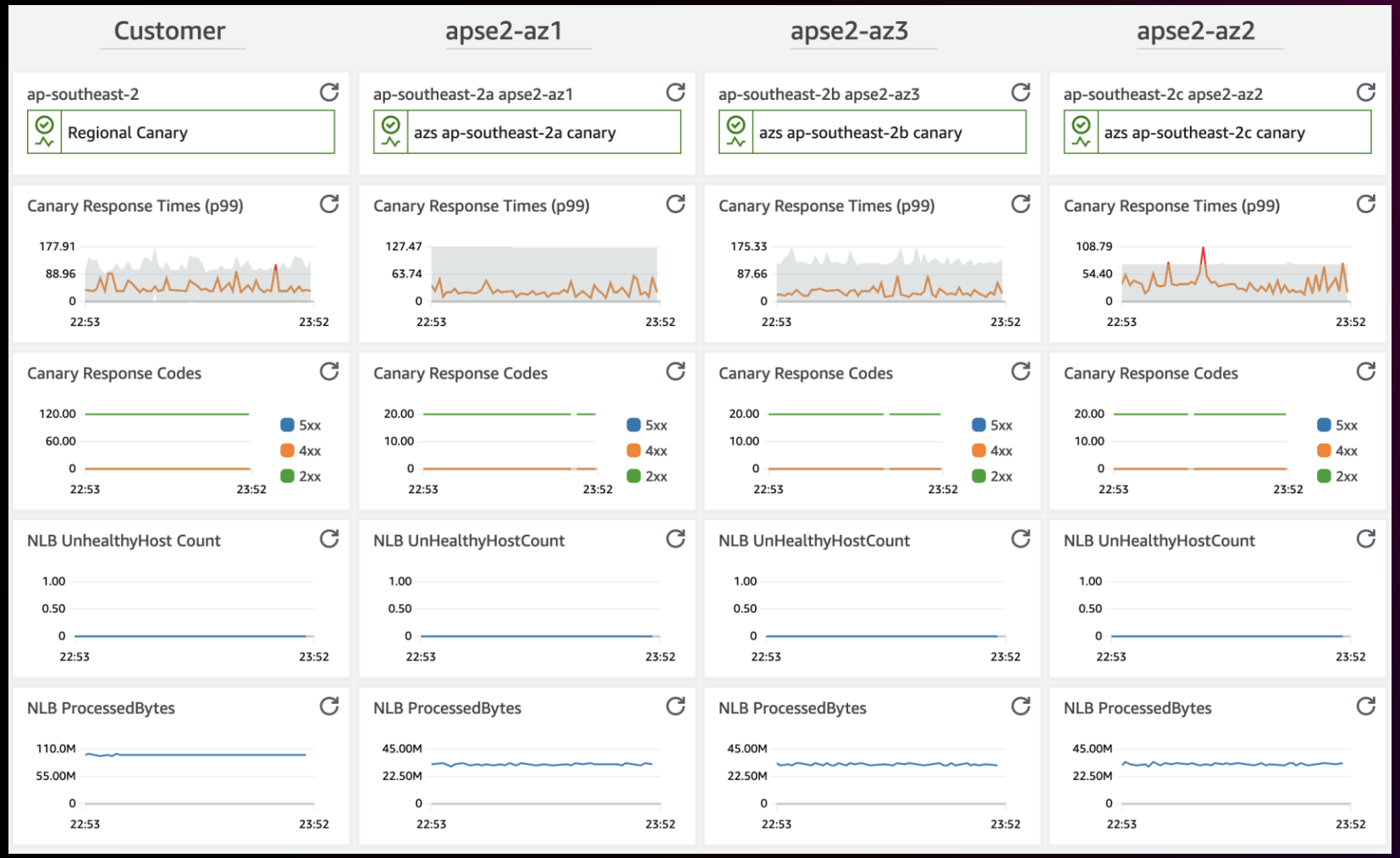
Demo architecture



- One canary per AZ endpoint
- One canary for the Regional endpoint (customer experience)

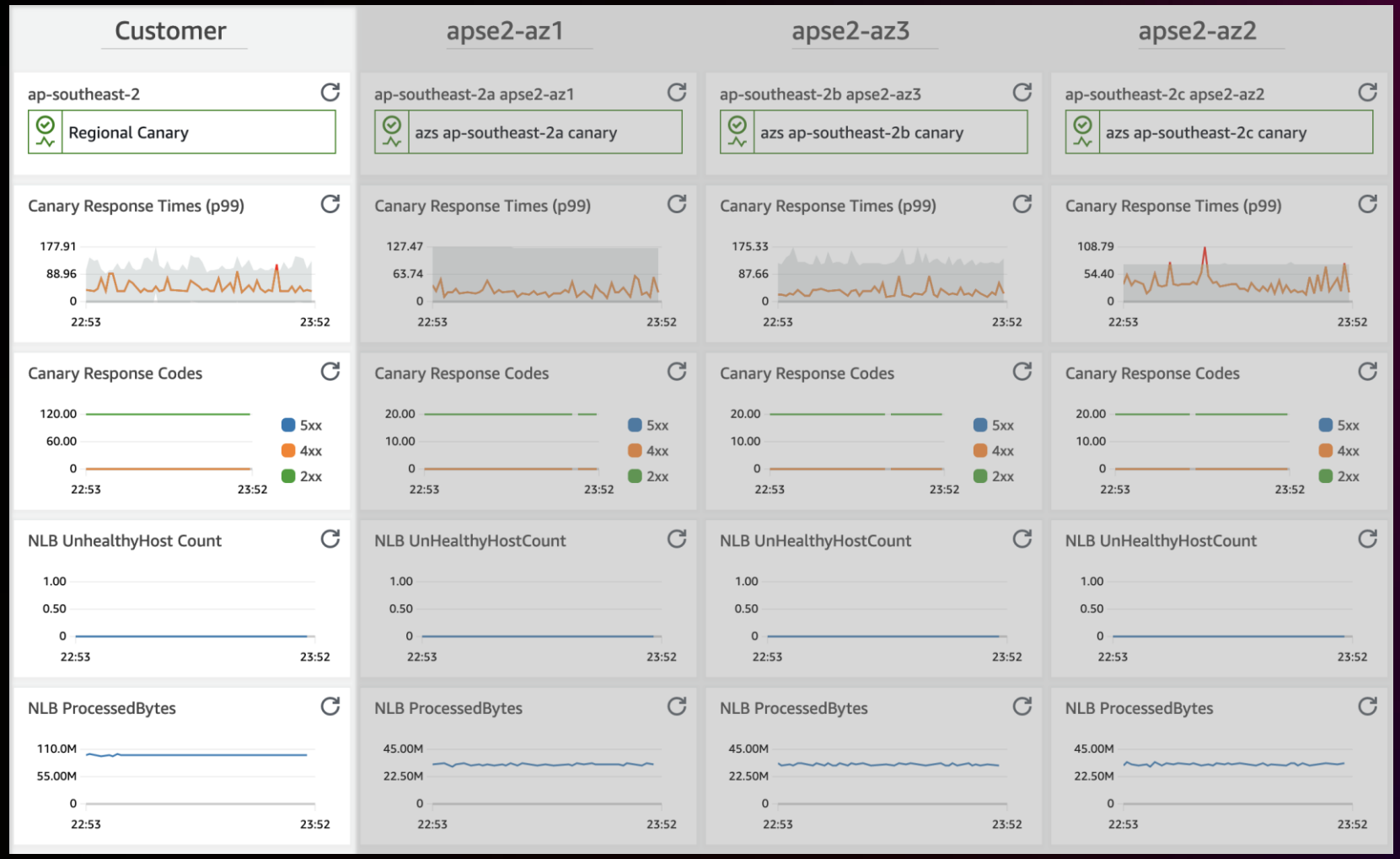
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AZ operations dashboard



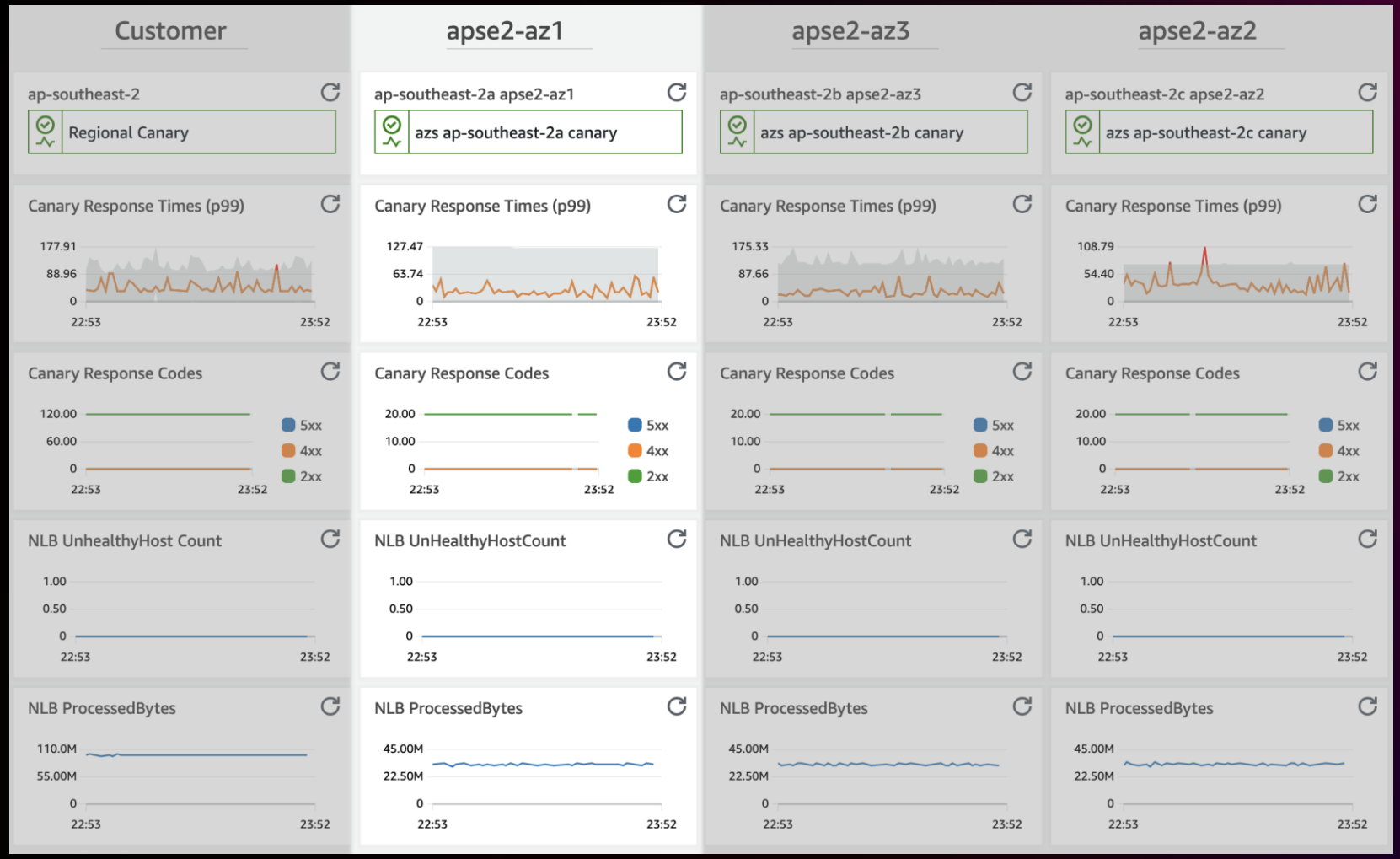
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AZ operations dashboard



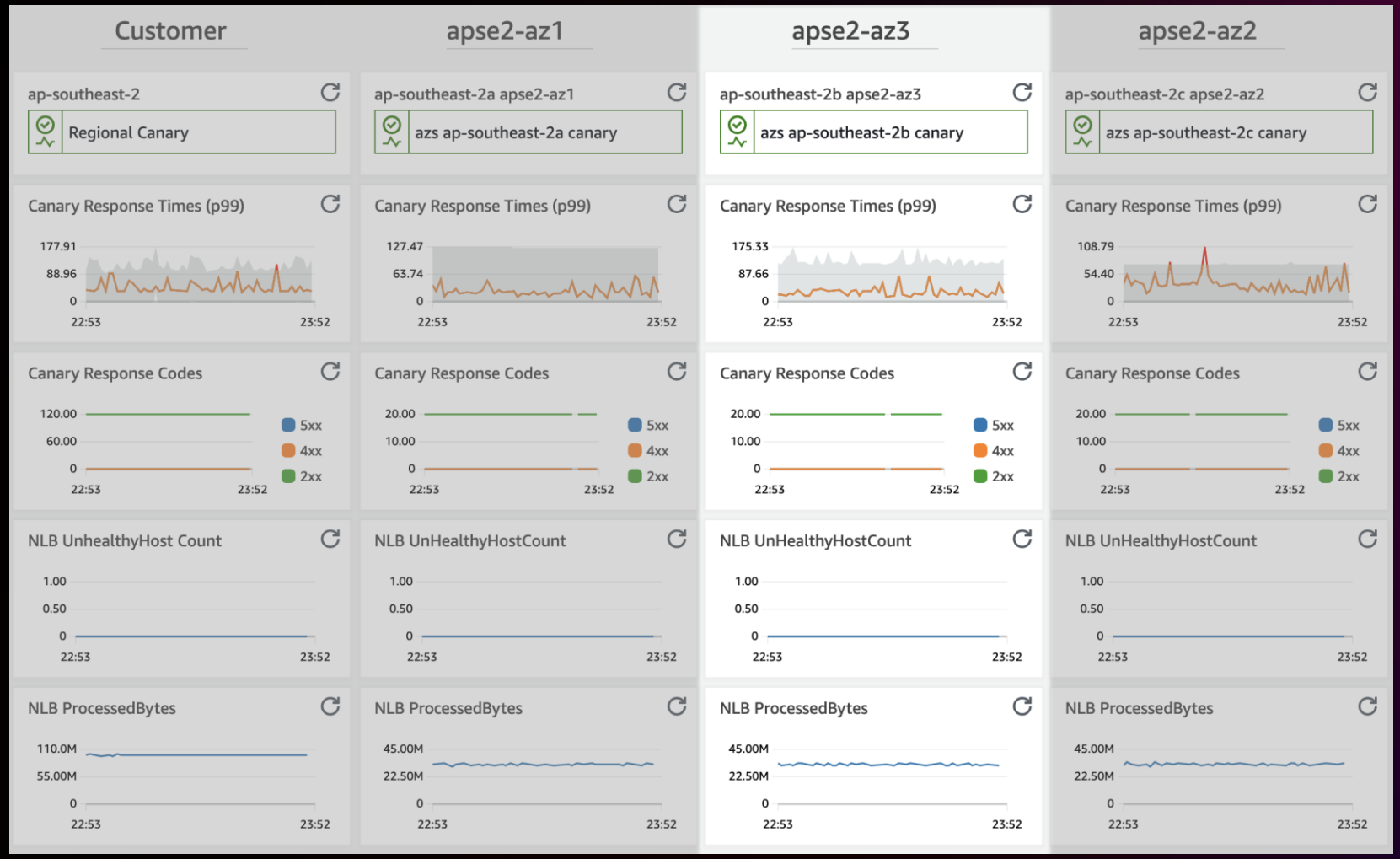
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AZ operations dashboard



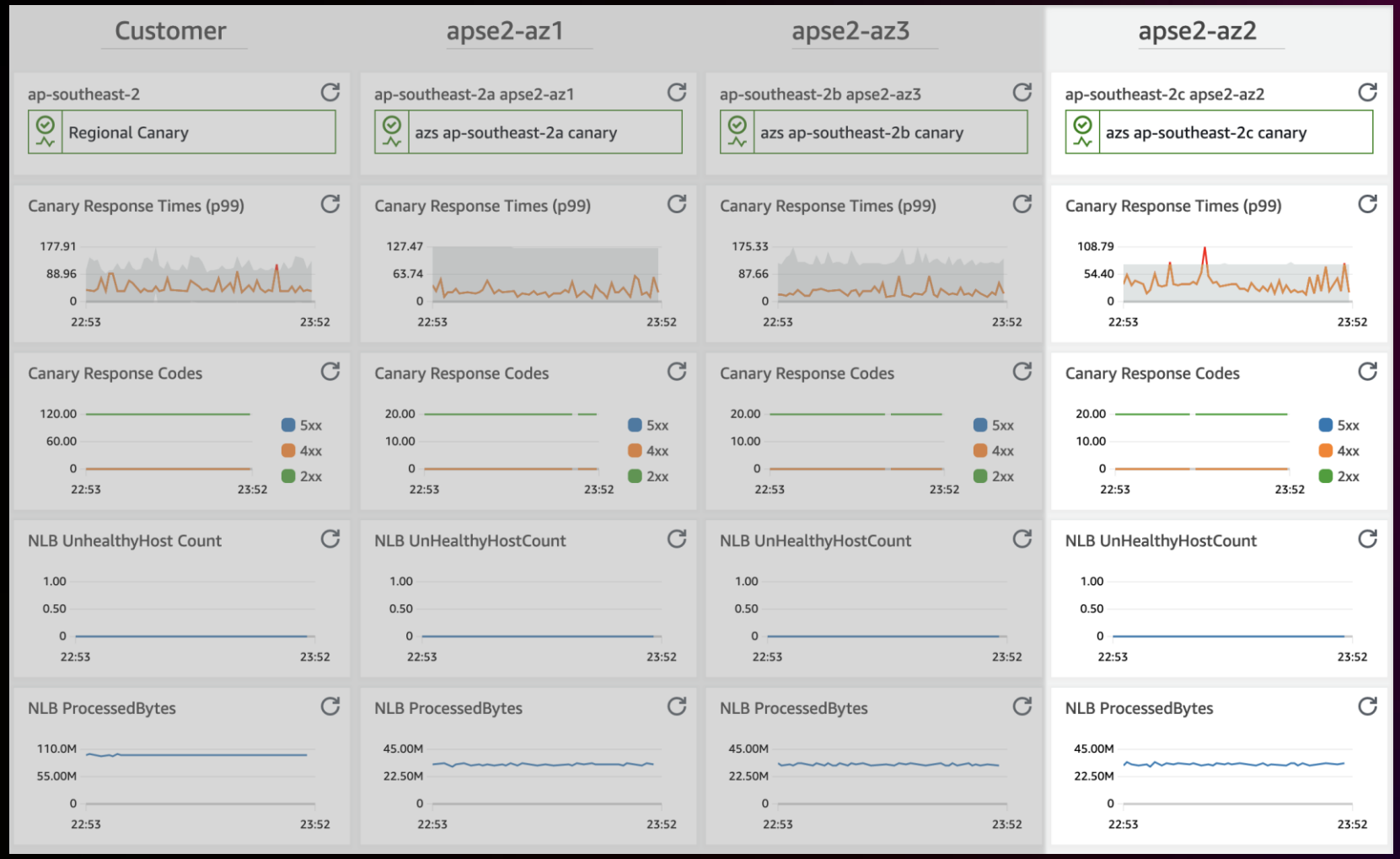
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AZ operations dashboard



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Test a hard failure

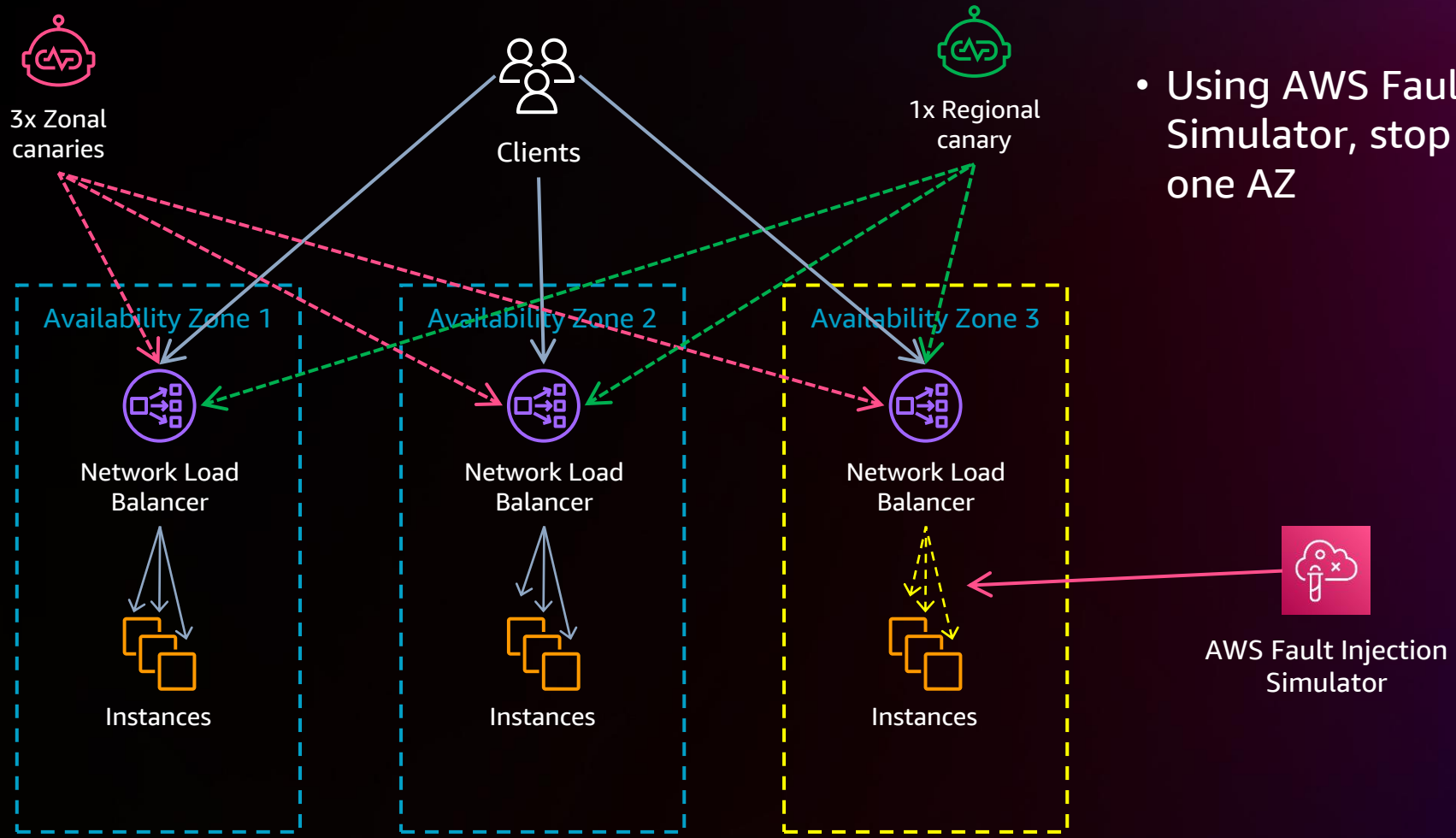
Use the FIS experiment, AWSFIS-Run-Kill-Process

Stop the web server in one AZ

Test that health checks recover

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CloudWatch Synthetics canary



- Using AWS Fault Injection Simulator, stop web server in one AZ

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AZ operations dashboard

```
(base) 147ddace0ce4:~ gavinmc$ aws fis list-experiment-templates
{
    "experimentTemplates": [
        {
            "id": "EXT3mtfZyMyXhetY",
            "description": "Stop Apache in AZ B",
            "creationTime": "2022-11-15T19:40:01.904000-08:00",
            "lastUpdateTime": "2022-11-15T19:43:13.880000-08:00",
            "tags": {
                "Name": "StopApache-AZ-B"
            }
        },
        {
            "id": "EXTC1XsyQQ5vfcL",
            "description": "Inject packet loss an instances in AZ B",
            "creationTime": "2022-11-15T19:40:05.559000-08:00",
            "lastUpdateTime": "2022-11-15T19:40:05.559000-08:00",
            "tags": {
                "Name": "PacketLossOnInstancesIn-AZ-B"
            }
        }
    ]
}
(base) 147ddace0ce4:~ gavinmc$
```

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AZ operations dashboard

```
(base) 147ddace0ce4:~ gavinmc$ aws fis start-experiment --experiment-template-id EXT3mtfZyMyXhetY | cat
{
    "experiment": {
        "id": "EXPhVqVsyQsdsfoP5t",
        "experimentTemplateId": "EXT3mtfZyMyXhetY",
        "roleArn": "arn:aws:iam::231838188243:role/gavinmc-test-FISRole-1SXSJZIEIJ5HY",
        "state": {
            "status": "initiating",
            "reason": "Experiment is initiating."
        },
        "targets": {
            "AZ-B-Instances": {
                "resourceType": "aws:ec2:instance",
                "resourceTags": {
                    "Stack": "ZoneShiftExperiment"
                },
                "filters": [
                    {
                        "path": "Placement.AvailabilityZone",
                        "values": [
                            "ap-southeast-2b"
                        ]
                    },
                    {
                        "path": "State.Name",
                        "values": [
                            "running"
```

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ELB DNS: Three IP addresses (AZs)

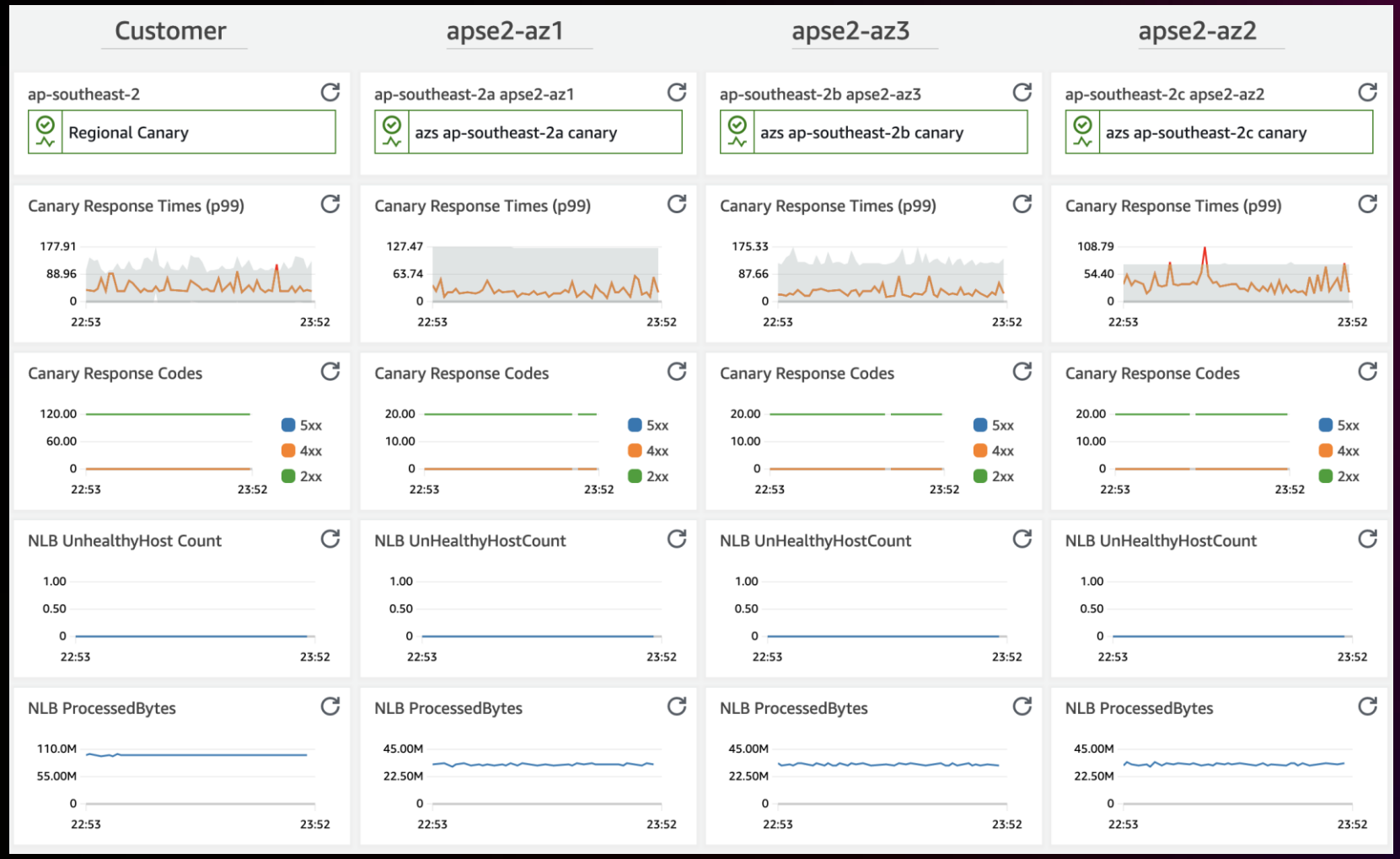
```
(22-11-10 5:31:37) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 % dig zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans

; <<>> DiG 9.11.4-P2-RedHat-9.11.4-26.P2.amzn2.5.2 <<>> zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans
;; global options: +cmd
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 54.253.188.240
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 13.236.132.126
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 3.105.114.106

(22-11-10 5:31:48) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 %
```

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AZ operations dashboard



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~3 minutes later

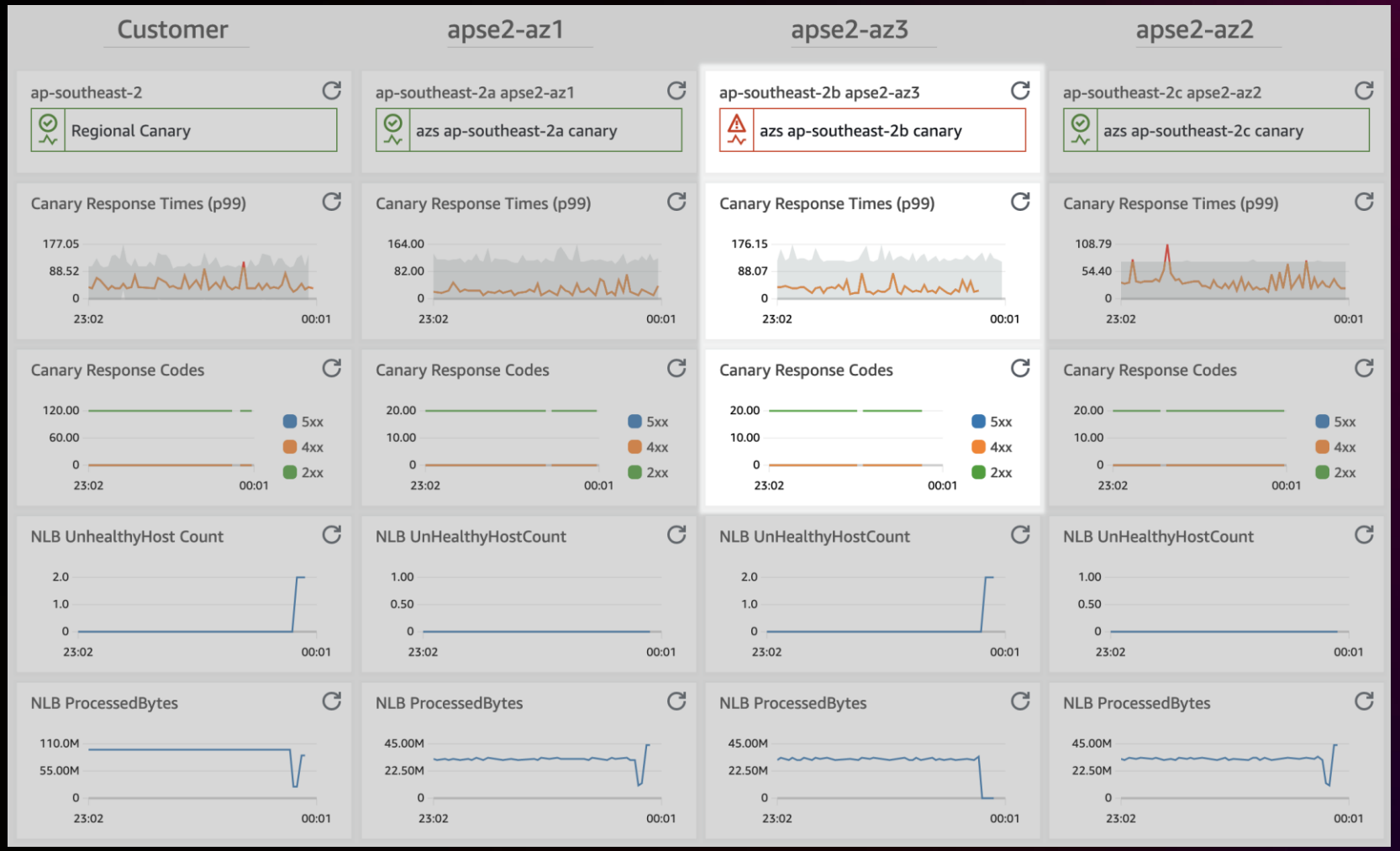
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AZ operations dashboard



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One IP gone from DNS

```
(base) 147ddace0ce4:~ gavinmc$  dig zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans

; <<>> DiG 9.10.6 <<>> zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans
;; global options: +cmd
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 13.236.132.126
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 54.253.188.240
```

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AZ operations dashboard



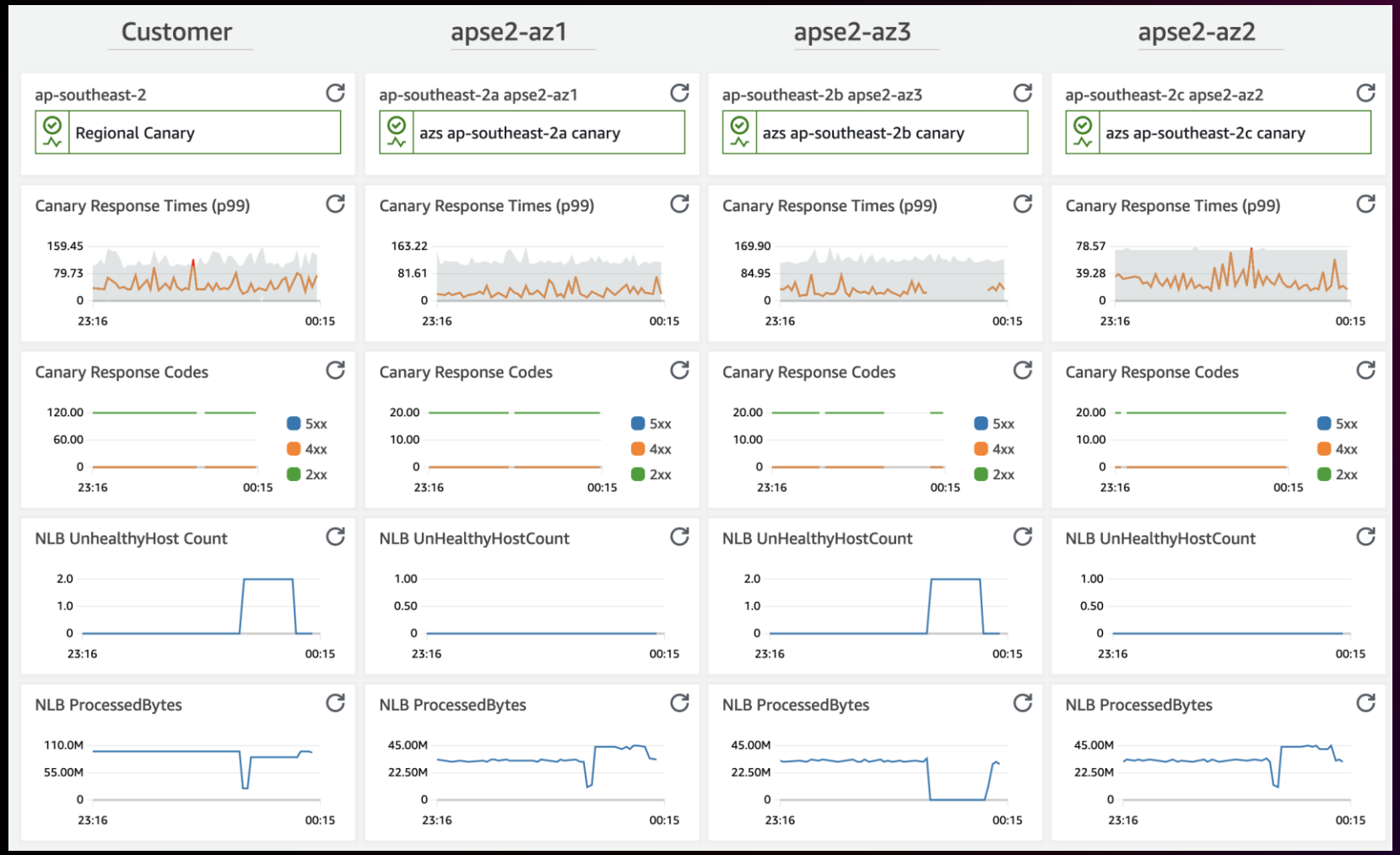
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AZ operations dashboard



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AZ operations dashboard



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Test a grey failure

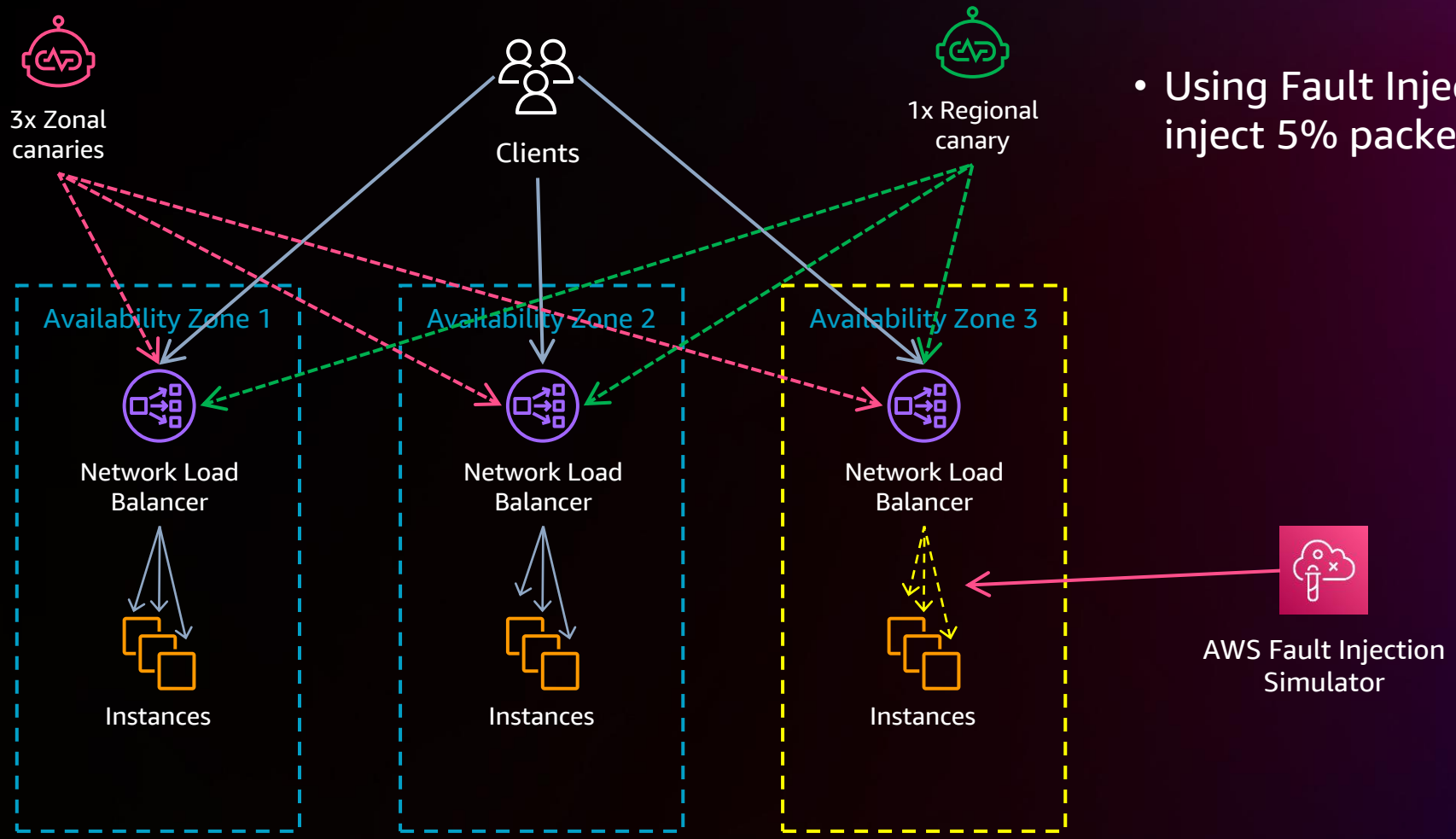
Inject a subtle grey failure which will not fail health checks

Use the FIS experiment, AWSFIS-Run-Network-Packet-Loss

Inject 5% packet loss in one AZ

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CloudWatch Synthetics canary



- Using Fault Injection Simulator, inject 5% packet loss

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ELB DNS: Three IP addresses (AZs)

```
(22-11-10 5:31:37) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 % dig zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans

; <<>> DiG 9.11.4-P2-RedHat-9.11.4-26.P2.amzn2.5.2 <<>> zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans
;; global options: +cmd
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 54.253.188.240
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 13.236.132.126
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 3.105.114.106

(22-11-10 5:31:48) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 %
```

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Inject a fault: 5% packet loss in one AZ

```
(base) 147ddace0ce4:~ gavinmc$ aws fis start-experiment --region ap-southeast-2 --experiment-template-id EXTBHFVYgnDsAcs1r
```

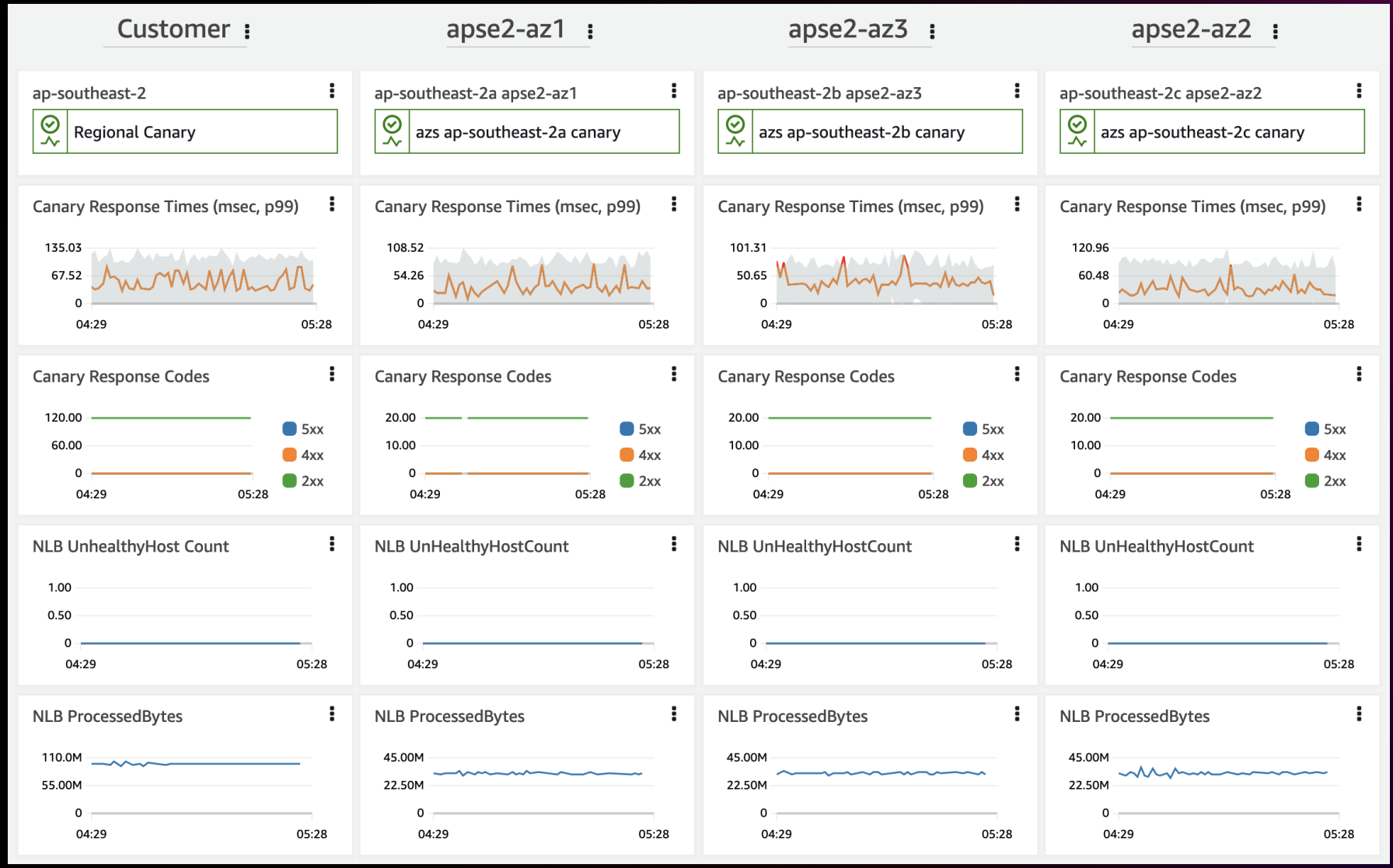
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Inject a fault: 5% packet loss in one AZ

```
{
    "experiment": {
        "id": "EXPbaKd4Fj62UrDyMC",
        "experimentTemplateId": "EXTBHFVYgnDsAcs1r",
        "roleArn": "arn:aws:iam::231838188243:role/gavinmc-test-FISRole-1SXSJZIEIJ5HY",
        "state": {
            "status": "initiating",
            "reason": "Experiment is initiating."
        },
        "targets": {
            "AZ-B-Instances": {
                "resourceType": "aws:ec2:instance",
                "resourceTags": {
                    "Stack": "ZoneShiftExperiment"
                },
                "filters": [
                    {
                        "path": "Placement.AvailabilityZone",
                        "values": [
                            "ap-southeast-2b"
                        ]
                    },
                    {
                        "path": "State.Name",
                        "values": [
:
```

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Initial dashboard

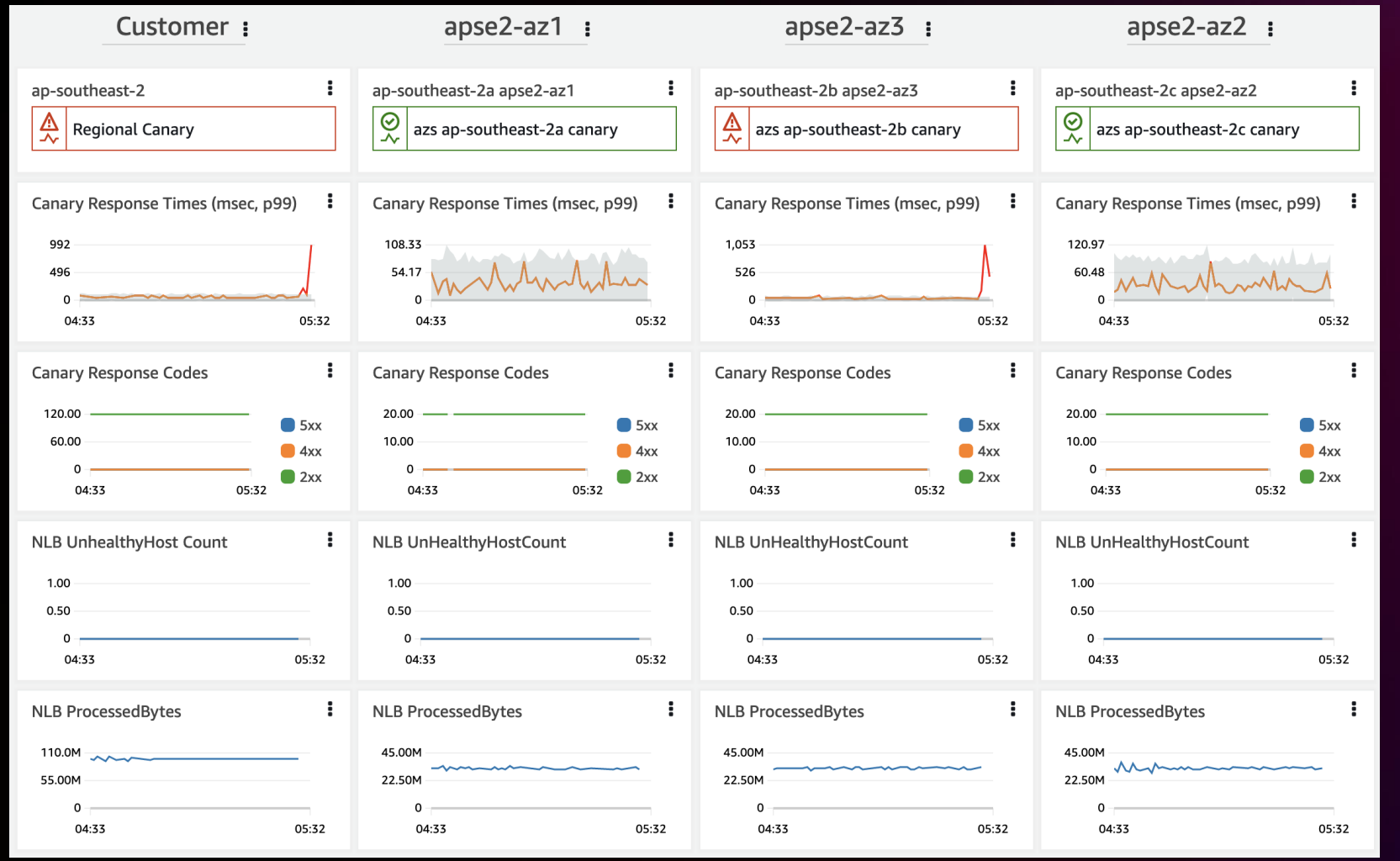


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~3 minutes later

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Impact has begun



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AZ3 is an outlier



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Requests still succeeding



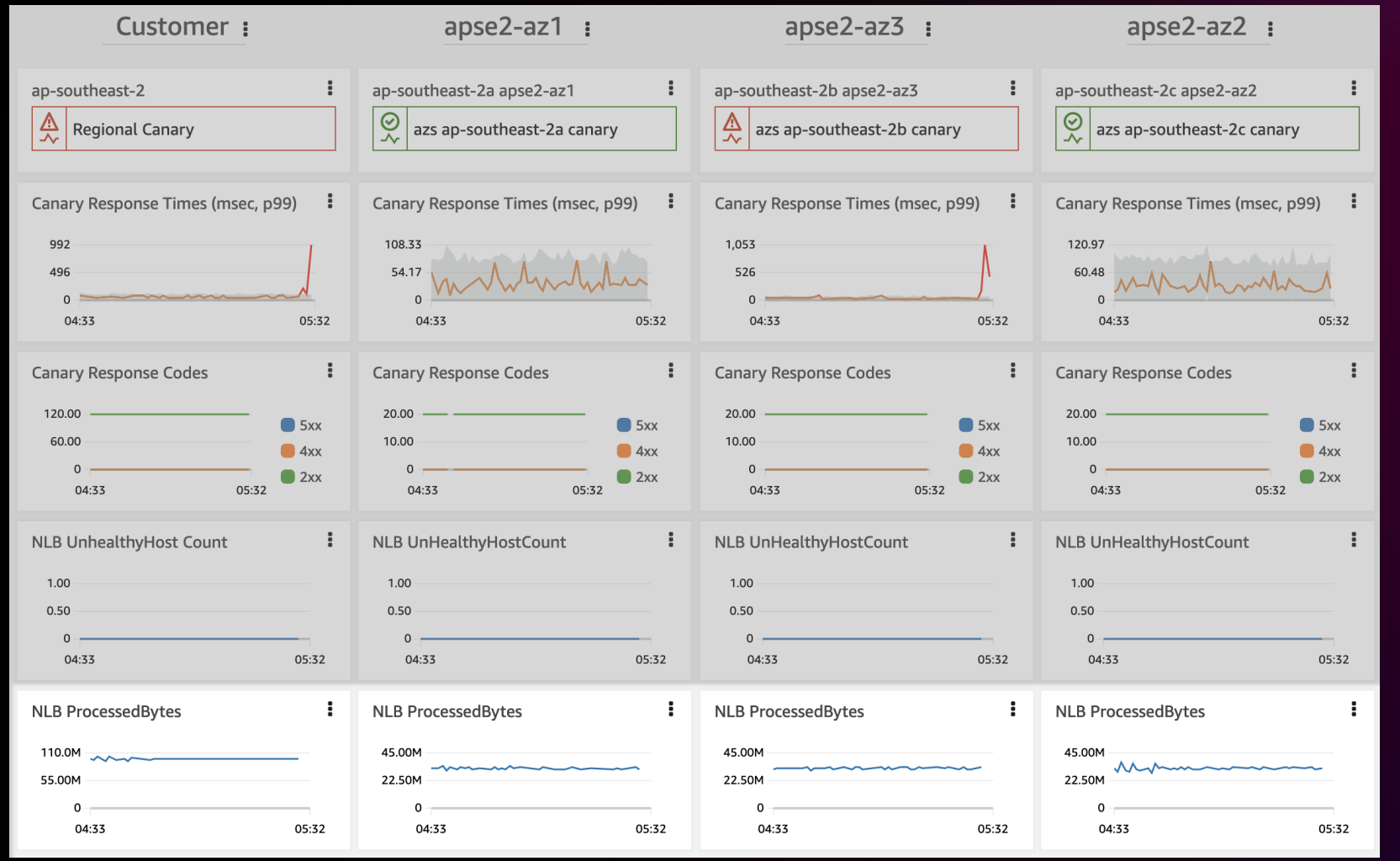
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Health checks passing



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Traffic levels even



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Shift away from AZ3

```
(22-11-10 5:34:05) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 % aws arc-zonal-shift --region ap-southeast-2 --endpoint "https://ap-southeast-2-prod.api.perc.aws.dev" start-zo
nal-shift --away-from apse2-az3 --expires-in 30m --resource-identifier "arn:aws:elasticloadbalancing:ap-southeast-2:231838188243:loadbalance
r/net/zonal-shift-demo/4e60cc05ac46be60" --comment "shift away from AZ B"
{
    "status": "ACTIVE",
    "comment": "shift away from AZ B",
    "awayFrom": "apse2-az3",
    "zonalShiftId": "0cc23004-0416-0070-7a1a-636513d90f05",
    "expiryTime": 1668060249.0,
    "resourceIdentifier": "arn:aws:elasticloadbalancing:ap-southeast-2:231838188243:loadbalancer/net/zonal-shift-demo/4e60cc05ac46be60",
    "startTime": 1668058449.0
}

(22-11-10 5:34:10) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 %
```

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~2 minutes later

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DNS now shows only 2 IPs

```
(22-11-10 5:39:03) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 % dig zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans

; <<>> DiG 9.11.4-P2-RedHat-9.11.4-26.P2.amzn2.5.2 <<>> zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com +noall +ans
;; global options: +cmd
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 54.253.188.240
zonal-shift-demo-4e60cc05ac46be60.elb.ap-southeast-2.amazonaws.com. 60 IN A 13.236.132.126

(22-11-10 5:39:03) <0> [~]
dev-dsk-gavinmc-2b-4a81c998 %
```

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First sign of recovery



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Recovery



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Recovery



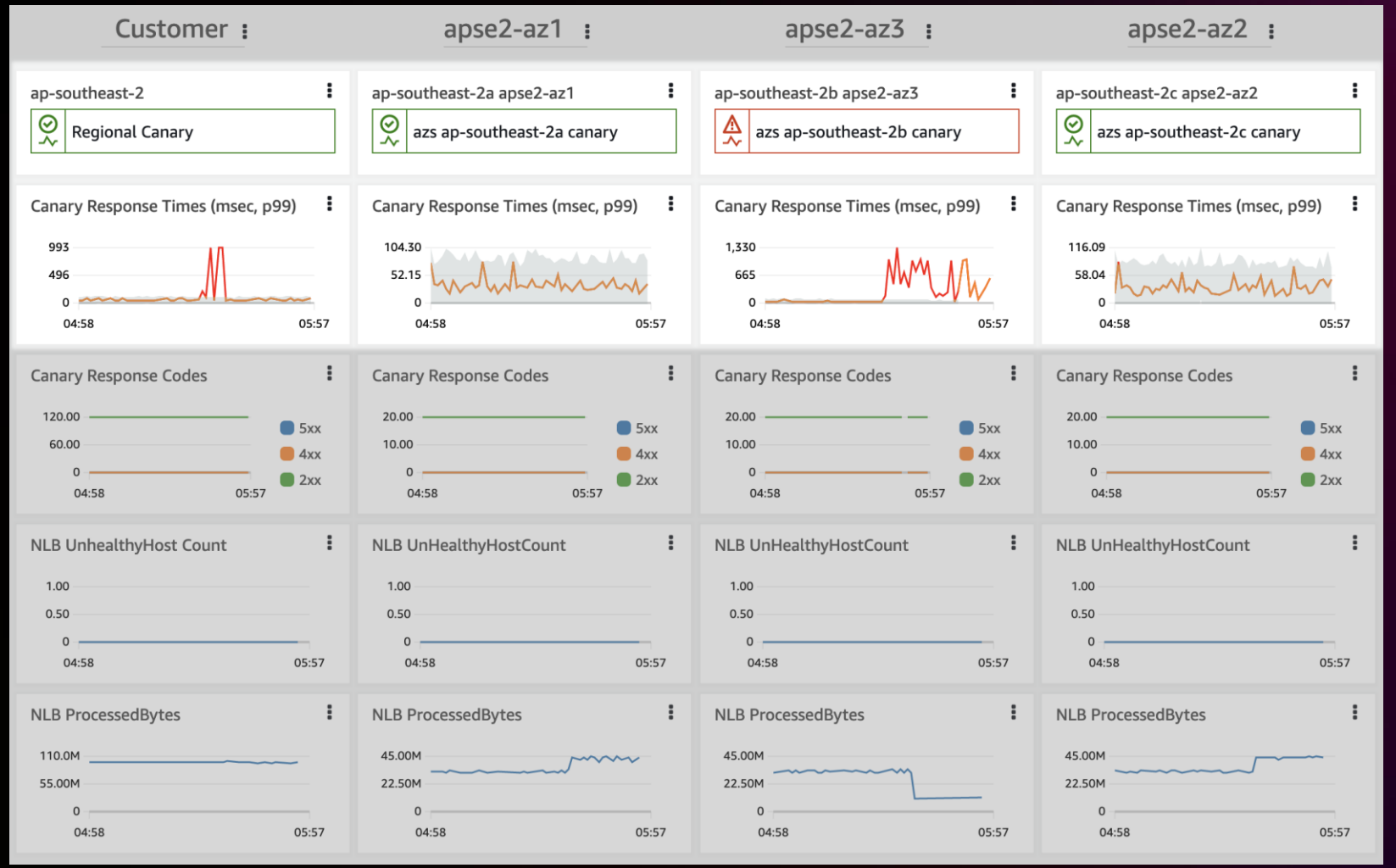
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Recovery



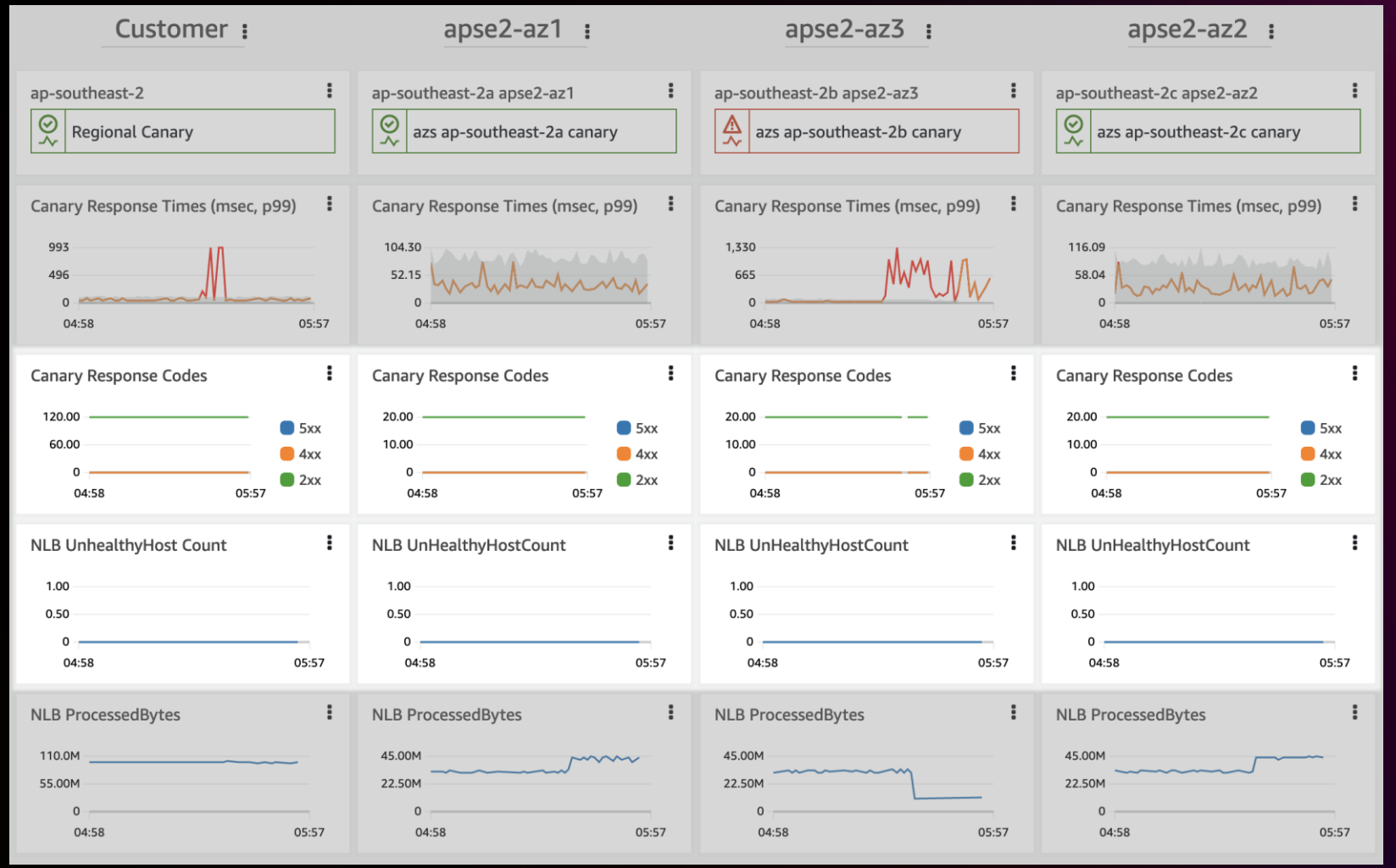
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Recovery



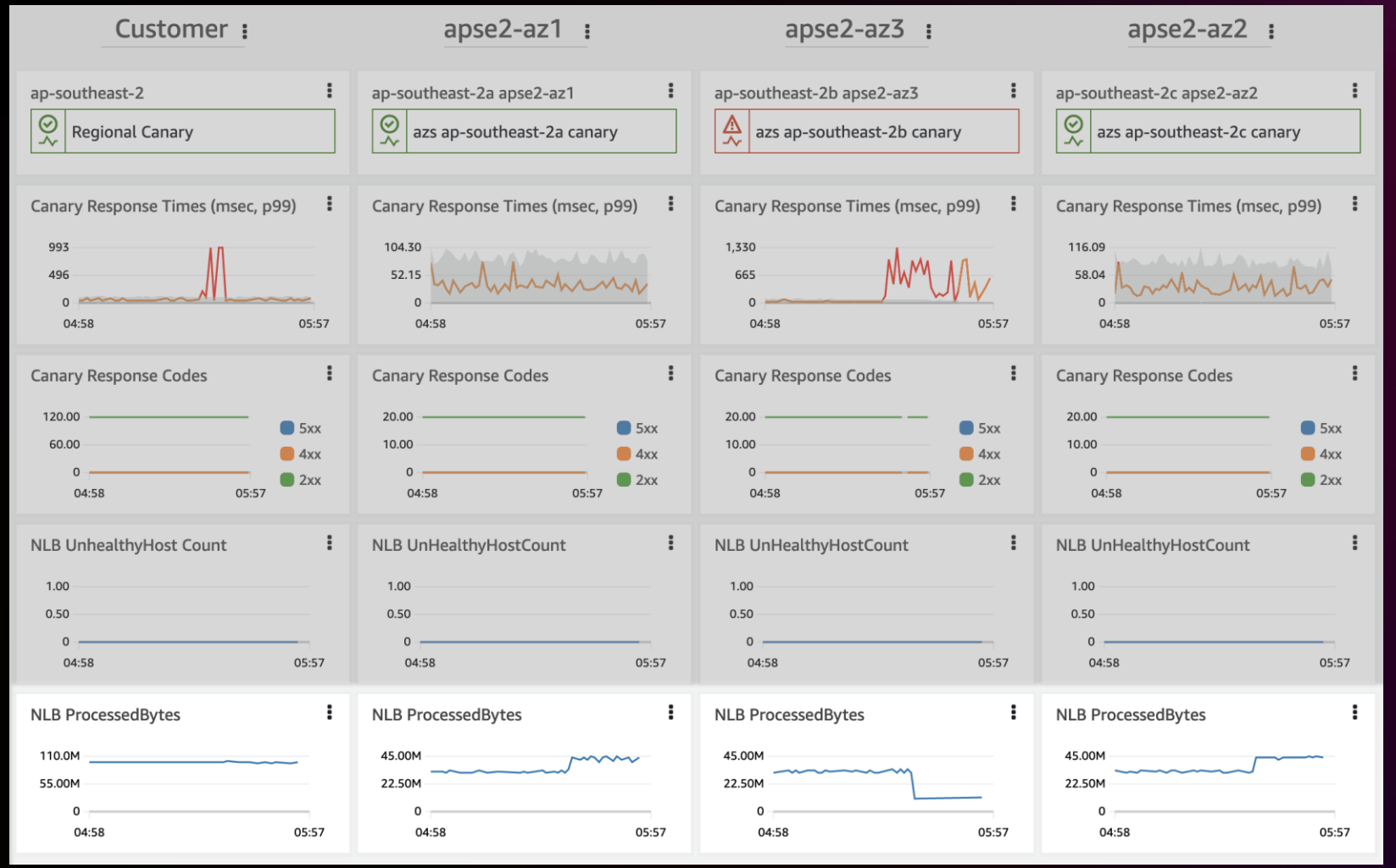
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Recovery



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Recovery



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FIS experiment (impact) ends



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Cancel zonal shift

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(22-11-10 6:06:27) <0> [~]
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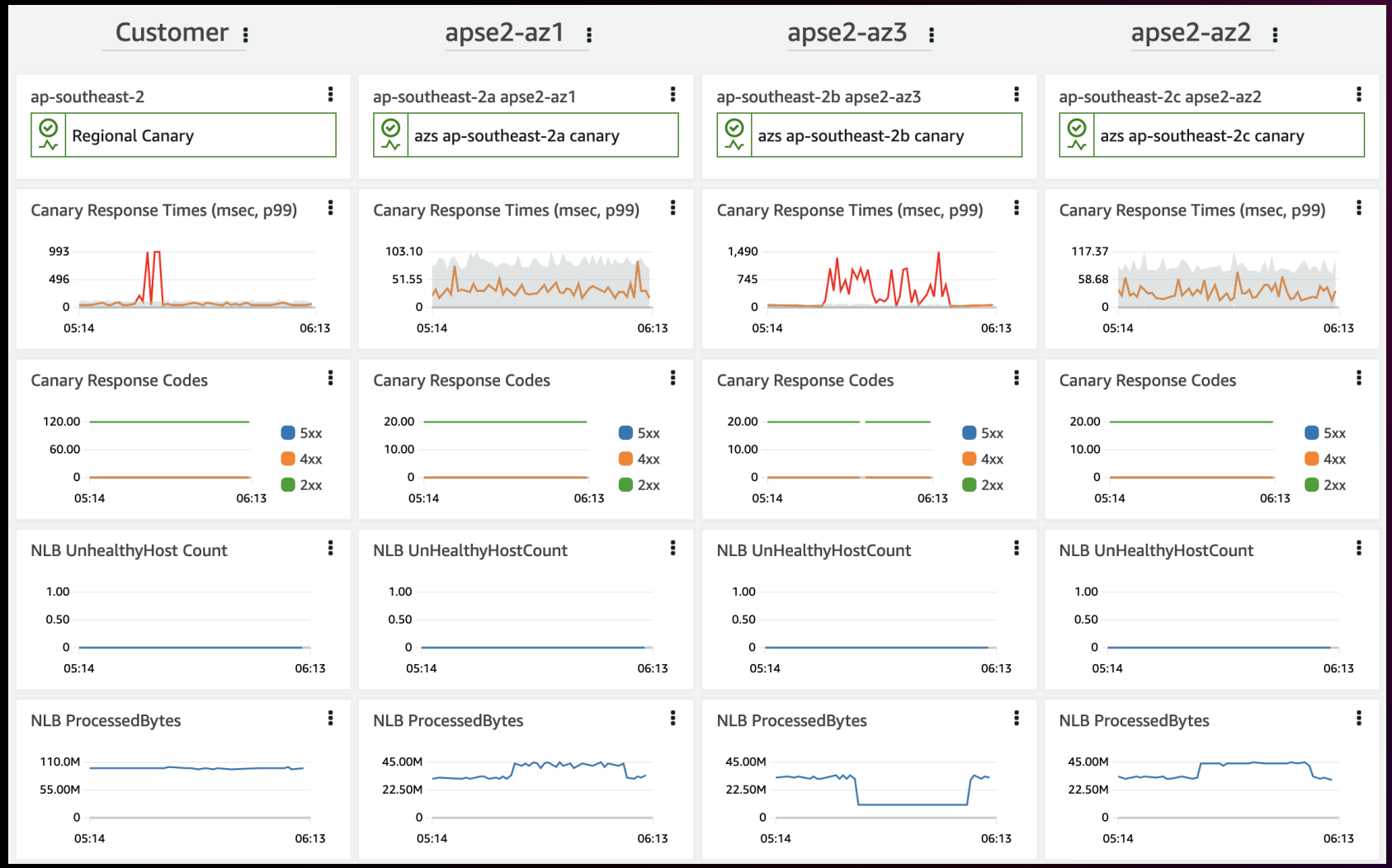
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aws

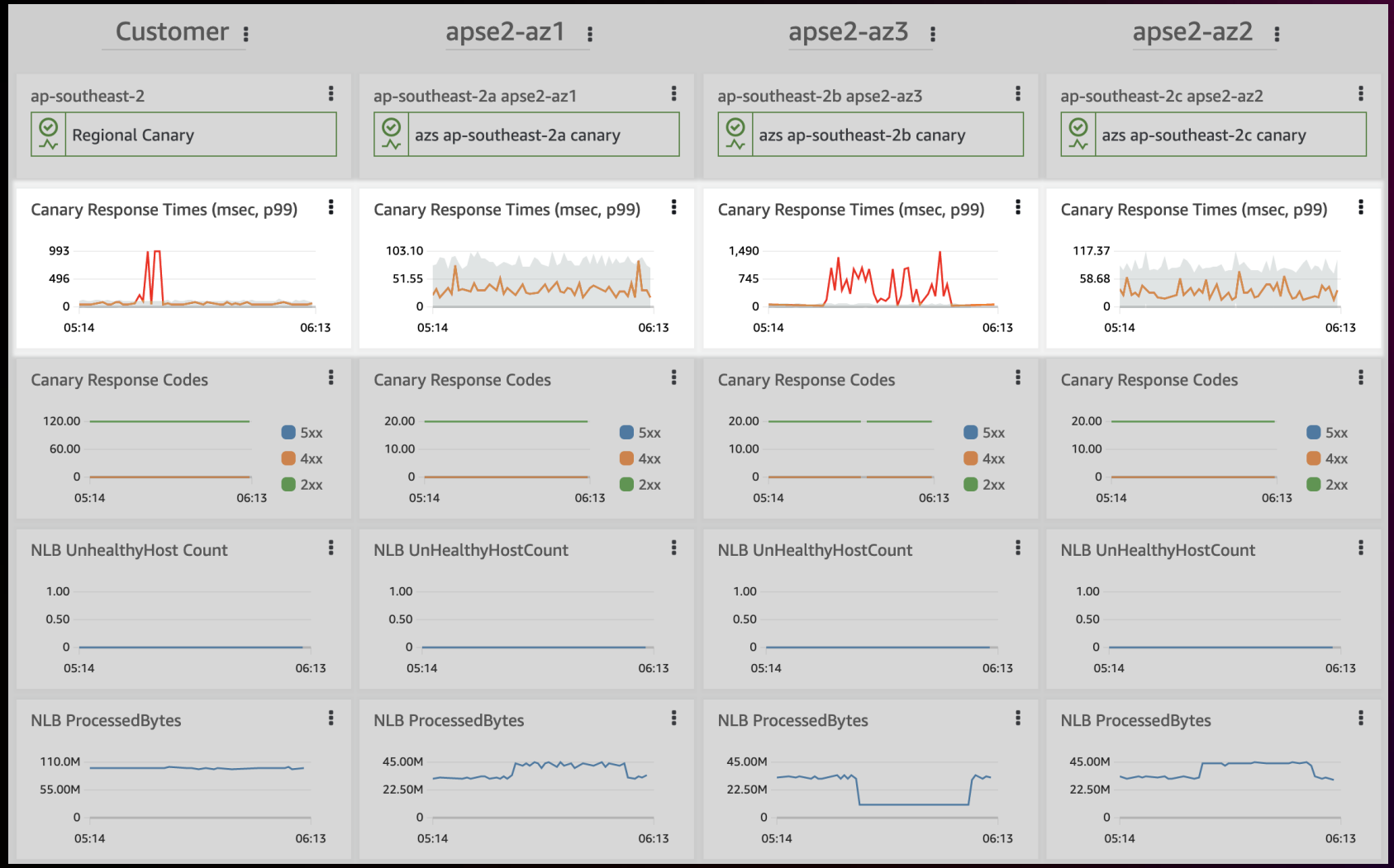
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Impact mitigated without root cause



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Impact reduced by 75%



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Best practices

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Best practices for zonal shift

1. Pre-scale capacity
2. Ensure zonal replicas are healthy and taking traffic
3. Test zonal shift in advance
4. Practice using the API/CLI

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Best practices for zonal shift

5. Use zonal shift as a temporary action
6. Automate carefully
7. Actively monitor from another Region

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Summary

Independent replicas allow rapid recovery

- Deploy per replica, configure per replica
- AZ per replica
- Vary limits per replica

ELB Health Checks automatically mitigate hard failures

ARC zonal shift turns a grey failure into a hard AZ failure

aws

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Summary

For more on zonal shift:

- Amazon Route 53 Application Recovery Controller – https://aws.amazon.com/route53/application-recovery-controller/
- Blog post: Rapidly recover from application failures in a single AZ – https://go.aws/3AVM2Yt

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Thank you!



Please complete the session survey in the **mobile app**

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