MANCHESTER LONDON NEW YORK

Using Chaos Engineering to Build Resilient Distributed Applications

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CAKESOLUTIONS

Chaos Engineering

Want to explore how these same techniques might be used to improve code development!

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- Typical Chaos Experiment
  - define views of a system (e.g. by monitoring a set of system or business metrics)
  - randomly inject faults (e.g. by killing containers or changing networking behaviour)

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  - randomly inject faults (e.g. by killing containers or changing networking behaviour)
- Infer weaknesses using deviations from expected or steady-state behaviour
- Potentially apply to production systems!

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Cloud Verification Problem

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- Cloud deployment involves dynamic environments
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  - deployment typically uses unverified processes
- Potential for unanticipated failure is highly likely
  - it doesn't matter how the code was produced!
  - embrace and test for failure!

docker-compose-testkit

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- Open-source Scala library (under development)
  - (optionally) deploys, orchestrates and instruments Docker container code
  - agnostic of deployment environment
  - composable behaviour properties
  - reusable Chaos experiments *easily* defined

templates

templates

- Specify Docker image instrumentation layers
  - injects code and resources into image
- Specify library code for using instrumentation
  - code needs to use side effects
  - maintain a functional core using extensible effects (i.e. Eff)
  - sensor events represented using Monix Observables

Demo Overview

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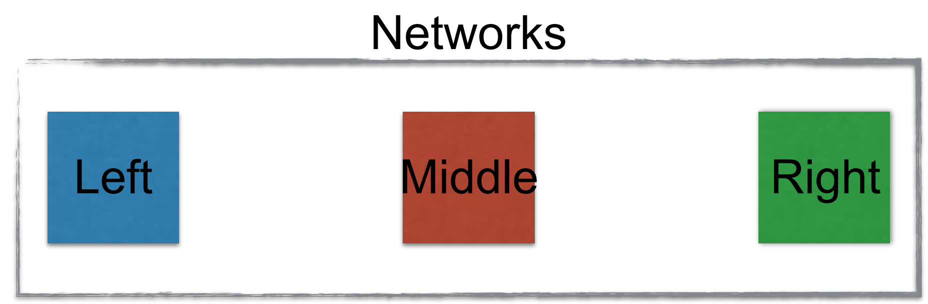

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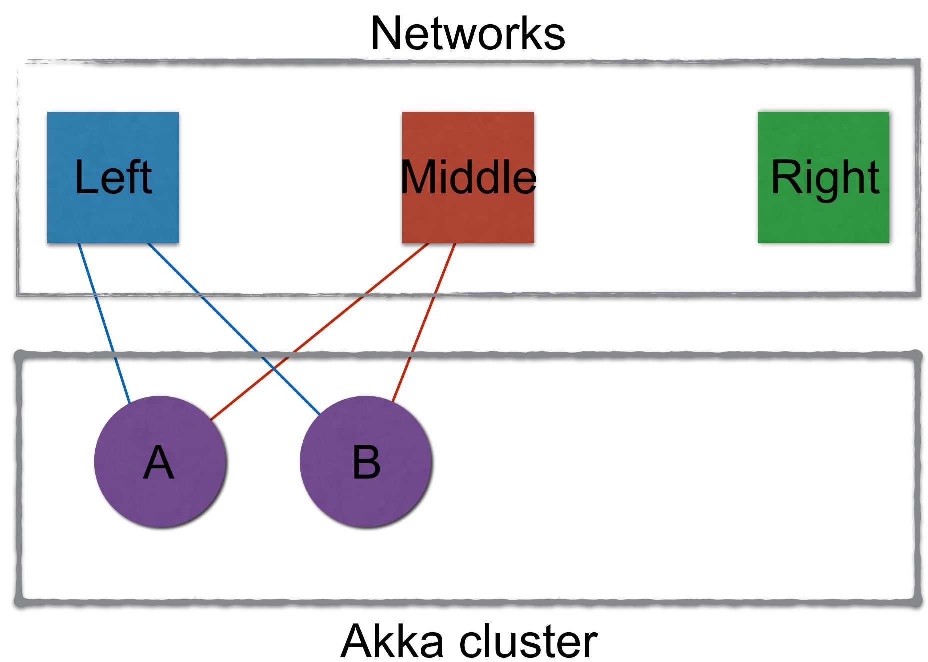

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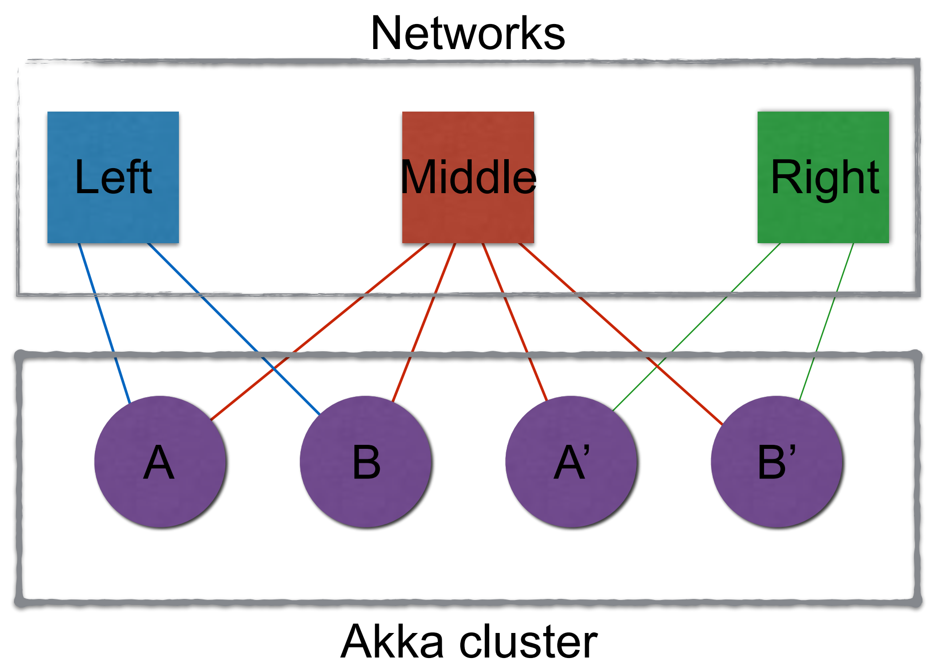

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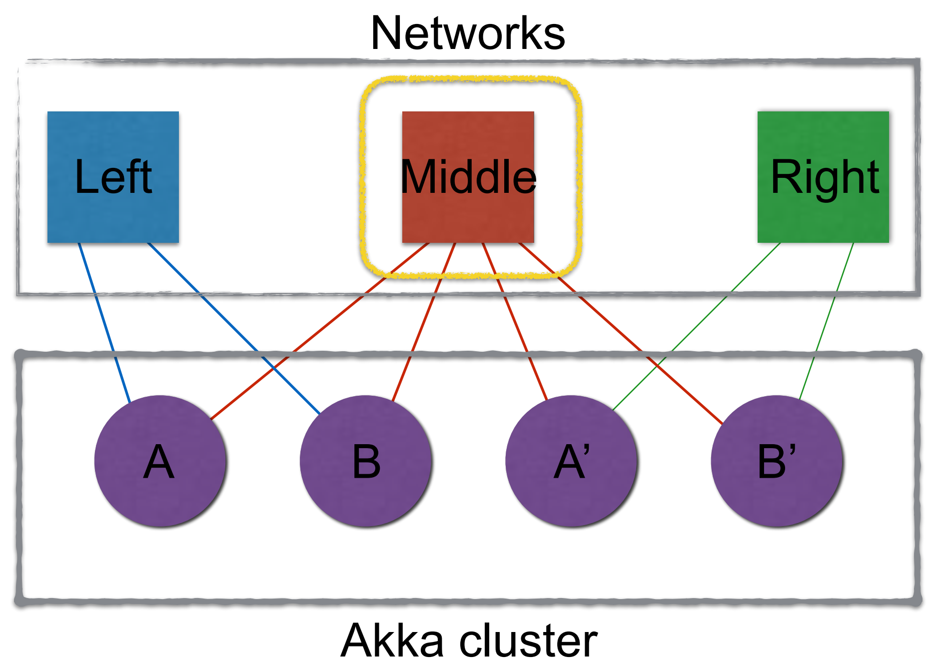

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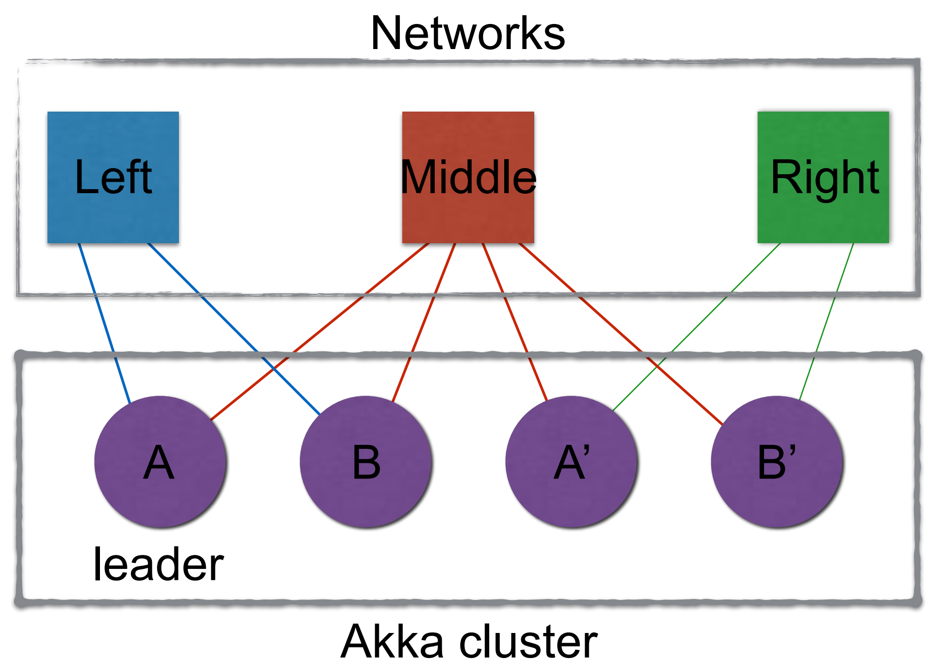

Auto-downing Enabled!!

Demo Overview

```
def clusterNode(name: String, network1: String, network2: String): String =
  s"""$name:
     |    template:
     |      resources:
     |        - cakesolutions.docker.jmx.akka
     |        - cakesolutions.docker.network.default.linux
     |      image: docker-compose-testkit-tests:$version
     |    environment:
     |      AKKA_HOST: $name
     |      AKKA_PORT: 2552
     |      CLUSTER_SEED_NODE: "akka.tcp://TestCluster@A:2552"
     |    expose:
     |      - 2552
     |    networks:
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val yaml = DockerComposeString(
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      |
      |services:
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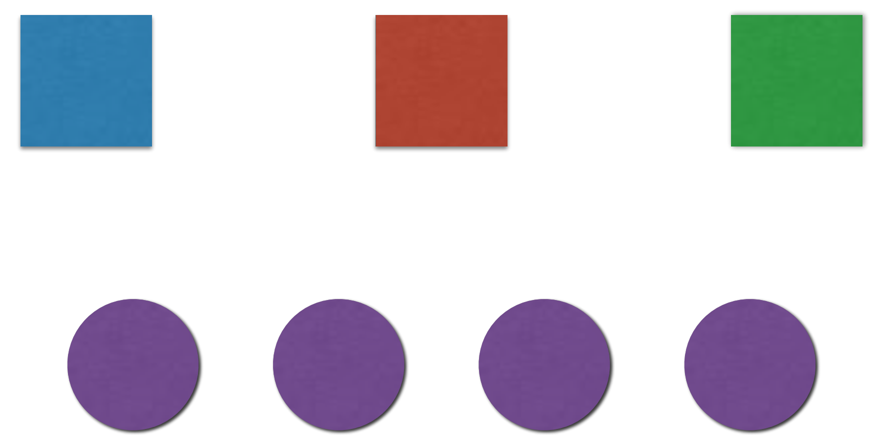
immutable container

Demo Overview



Point out our framework is capable of far more fault injection than this!
Necessary to perform some coding to define this instrumentation layer.
Docker-compose templating is used here!

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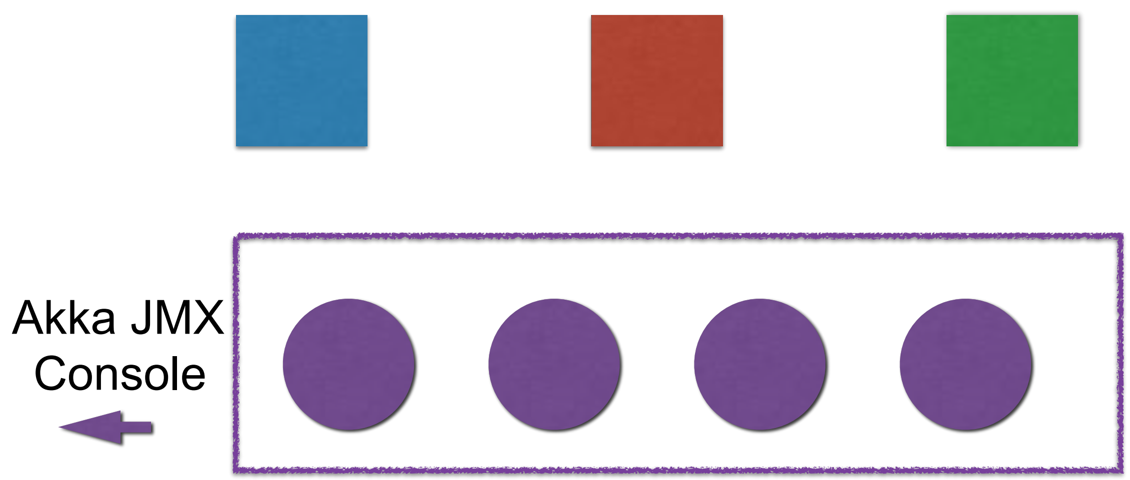

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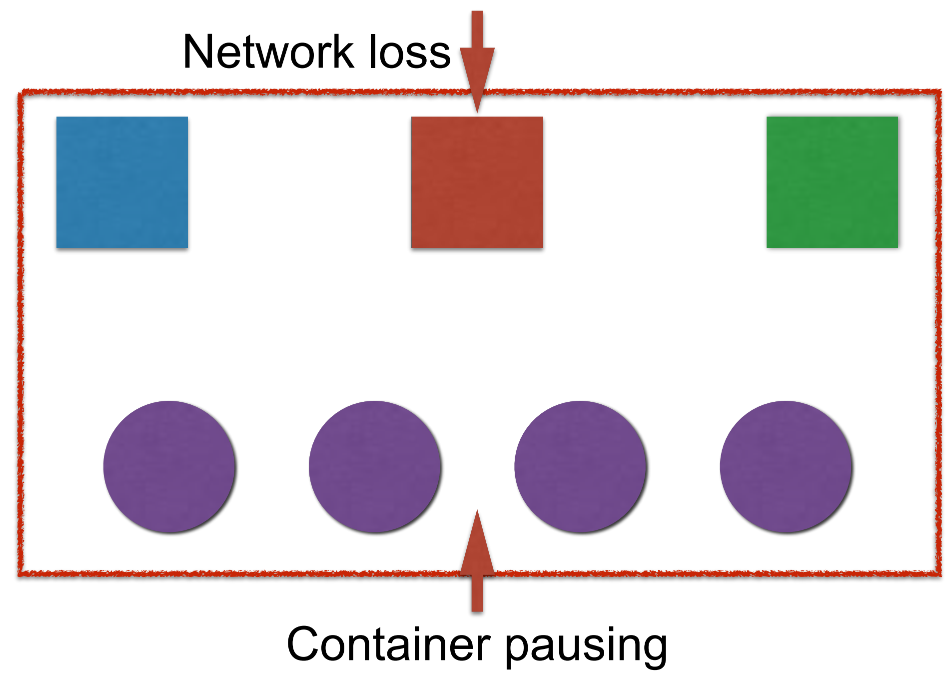

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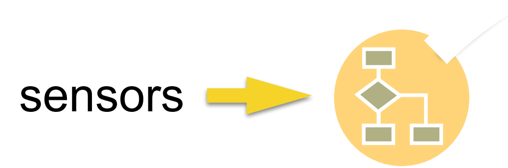

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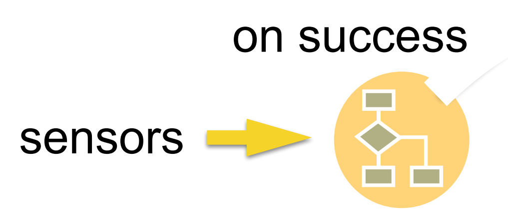

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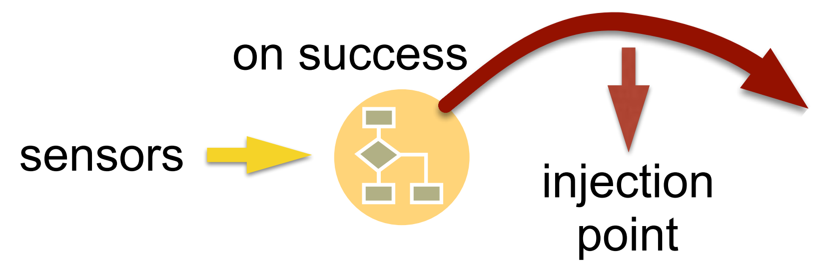

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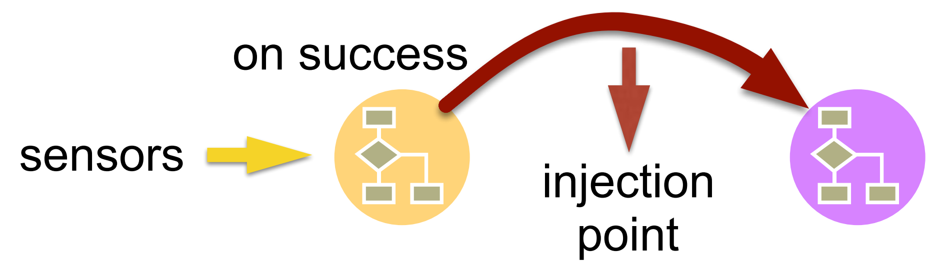

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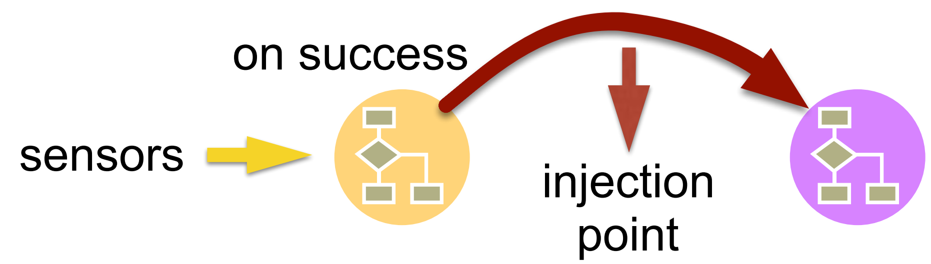

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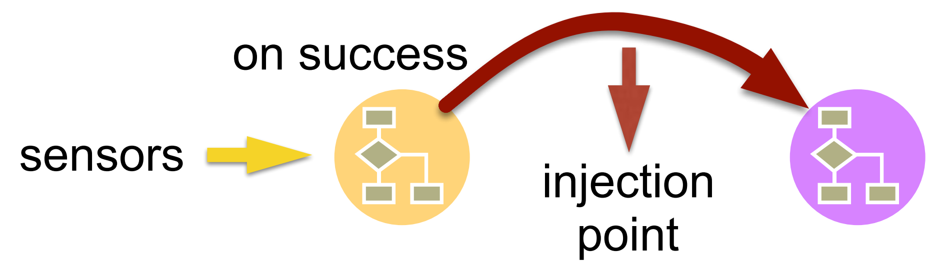

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```
def experiment[M: _jvm: _network: ..](implicit ..): Eff[M, Notify] =
  for {









  } yield Accept()
```

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def experiment[M: _jvm: _network: ..](implicit ..): Eff[M, Notify] =
  for {
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    ..




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Demo Overview

```
def experiment[M: _jvm: _network: ..](implicit ..): Eff[M, Notify] =
  for {
    obs1 <- ???
    ..
    _ <- jvmGC(JvmGCStart)(rightA)
    _ = note("A' JVM GC pause starts")
    obs2 <- ???
    ..







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```

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    _ = note("A' JVM GC pause ends")
    obs3 <- ???
    ..



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    ..
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    _ = note("A' JVM GC pause ends")
    obs3 <- ???
    ..
    _ <- impair(Loss("100%"))("middle")
    _ = note("partition into left and right networks")
    obs4 <- ???
    ..
  } yield Accept()
```

Demo Overview

```scala
def inCluster(nodes: Address*): Monitor[Boolean, AkkaClusterState] = {
  Monitor(false) {
    case false => {
      case Observe(AkkaClusterState(_, members, unreachable))
        if unreachable.isEmpty && nodes.forall(node => members.filter(_.status == Up).exists(_.address == node)) =>
        Goto(true, 3.seconds)
    }

    case true => {
      case Observe(AkkaClusterState(_, _, unreachable)) if unreachable.nonEmpty =>
        Stop(Fail())
      case Observe(AkkaClusterState(_, members, _))
        if nodes.exists(node => members.filter(_.status == Up).forall(_.address != node)) =>
        Stop(Fail())
      case StateTimeout =>
        Stop(Accept())
    }
  }
}
```

Demo Overview

Monitor State

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def inCluster(nodes: Address*): Monitor[Boolean, AkkaClusterState] = {
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        if nodes.exists(node => members.filter(_.status == Up).forall(_.address !=
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        Stop(Fail())
      case StateTimeout =>
        Stop(Accept())
    }
  }
}
```

Initial State

Demo Overview

Observed Event

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```

Timeout Event

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  for {











  } yield Accept()
```

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Demo Overview

```
def experiment[M: _jvm: _network: ..](implicit ..): Eff[M, Notify] =
  for {
    obs1 <- jmx(inCluster(leftA, leftB, rightA, rightB))(leftA)
    _ <- check(isAccepting(obs1))
    _ = note("cluster formed, is stable and A an available leader")
    ..
  } yield Accept()
```

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    obs2 <- jmx(unreachable(rightA))(leftA)
    _ <- check(isAccepting(obs2))
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    _ = note("A' is unreachable")
    ..
    obs3 <- jmx(inCluster(leftA, leftB, rightA, rightB))(leftA)
    _ <- check(isAccepting(obs3))
    _ = note("cluster stabilised with A' as a member")
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    obs3 <- jmx(inCluster(leftA, leftB, rightA, rightB))(leftA)
    _ <- check(isAccepting(obs3))
    _ = note("cluster stabilised with A' as a member")
    ..
    obs4 <- jmx(inCluster(leftA, leftB))(leftA)
              && jmx(inCluster(leftA, leftB))(leftB)
              && jmx(inCluster(rightA))(rightA)
              && jmx(inCluster(rightB))(rightB)
    _ <- check(isAccepting(obs4))
    _ = note("cluster split brains into 3 clusters: A & B; A'; B'")
  } yield Accept()
```

Demo Overview

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```
type Model = Fx.fx5[JmxAction, NetworkAction, ..]
```

Demo Overview

```
val cluster = Map(
  leftA -> compose.service(leftA).docker.head,
  leftB -> compose.service(leftB).docker.head,
  rightA -> compose.service(rightA).docker.head,
  rightB -> compose.service(rightB).docker.head
)
```

Demo Overview

```
experiment[Model].runJvm(cluster).runNetwork…
```

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Demo Overview

```
experiment[Model].runJvm(cluster).runNetwork…
```

Demo Time!

docker events --filter type=container
sbt clean “dockerComposeTests/testOnly *AutoDownSplitBrainDockerTest”

Development Use Cases

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- Can we use instrumentation to investigate *difficult to observe* issues?

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- For example:
  - directly observe and extract networking evidence
  - observe impact of resource starved Docker containers
    - e.g. low memory or small thread pools

Development Use Case: Networking

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- Networking issues
  - instrument container with *iptables*
  - use runtime monitors to validate received/sent network traffic expectations
    - capture PCAP data as a side effect of monitoring for offline examination

Development Use Case: Container Resource Stress

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- Use *LIB_PRELOAD* “trick” to load application code via *libfiu*

Development Use Case: Container Resource Stress

- Use *LIB_PRELOAD* “trick” to load application code via *libfiu*
- libfiu - Fault Injection in Userspace
  - DSL allows system calls to return with an error code
    - every time or randomly specified
  - reliably simulate container memory, CPU or thread resourcing issues
    - often very difficult to detect!

Development Use Case: JVM

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- Modify JVM class loaders to instrument runtime application code

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- Modify JVM class loaders to instrument runtime application code
- Byteman
  - rule based instrumentation DSL
    - event-condition-action (ECA) rules
  - operates at the the Java (not bytecode) level
  - enables principled experiments to guide investigation into difficult to observe issues
    - exceptions that get *swallowed*
    - validate expected data and control flows
    - etc.

Next Steps

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- Failure control plane
  - sidecar failure control node per Docker container
  - failure agent within each container
  - lower Dockerfile impact

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- Failure control plane
  - sidecar failure control node per Docker container
  - failure agent within each container
  - lower Dockerfile impact
- Describe how we may automatically generate Chaos experiments from models
  - observational models
  - models based on static analysis
  - models built using domain expertise

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  - by relating data injection traces to observed system behaviour

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Conclusion

- Taken steady state behavioural specifications and developed a composable DSL for experiments
  - by relating data injection traces to observed system behaviour
- Applied techniques to a range of fault-injection scenarios
- Shown how these techniques can be used within debugging scenarios

References

- https://github.com/carlpulley/ docker-compose-testkit /tree/ scala-sphere-2017
- *Chaos Engineering* by A.Basiri, N.Behnam, R.de Rooij, L.Hochstein, L.Kosewski, J.Reynolds and C.Rosenthal
- *Freer monads, more extensible effects* by O.Kiselyov and H.Ishii
- *eff* - https://github.com/atnos-org/eff
- *libfiu* - https://blitiri.com.ar/p/libfiu/
- *Byteman* - http://byteman.jboss.org/

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