Transactors

Simpler Concurrency

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R&D DIRECTOR

The Short Story

- Developer since 1998
- Started on C
- Been on the JVM since 2001
- Background in business software
- Pragmatist
- OSS Enthusiast
- Concurrency Maniac

About Akka

Akka is the platform for the next generation event-driven, scalable and fault-tolerant architectures on the Java Virtual Machine

Before we start

- This will be JVM-focused
- There is no general optimal solution
- Problems, tools and the problem with tools
- I expect a continuous flow of questions!

This presentation will hurt

But it **will** be worth it

What is Concurrency?

What about Parallelism?

Computer programs
are lifeless collections
of instructions

Processes

A Process is

- An instance of a computer program
- Has its own timeline
- Call Stack
- Address space (Heap)
- Security attributes and more...

Process gotchas

- OS Processes can be expensive to create (win32)
- Inter-Process Communication has overhead
- Context switching costs
- Hangs onto resources when idling
- Error management and recovery is hard

Threads

A Thread is

- An standalone execution path within a process
- Has its own timeline
- Call Stack
- Shares Address space (Heap) with other Threads within the same process

Thread gotchas

- Expensive to create
- Context switching costs
- Suffers from diminishing returns
- Hangs onto resources when idling
- Lifecycle is hard to control from the outside
- Error handling and recovery is hard

Others

- Actors
- Fibers
- Executor services
- Dataflow concurrency
- Parallel collections
- Agents
- and more...

Schedulers

- The job of the OS scheduler is to allocate available CPU time between processes
- The JVM has it's own scheduler to distribute its share of CPU time between threads

Some

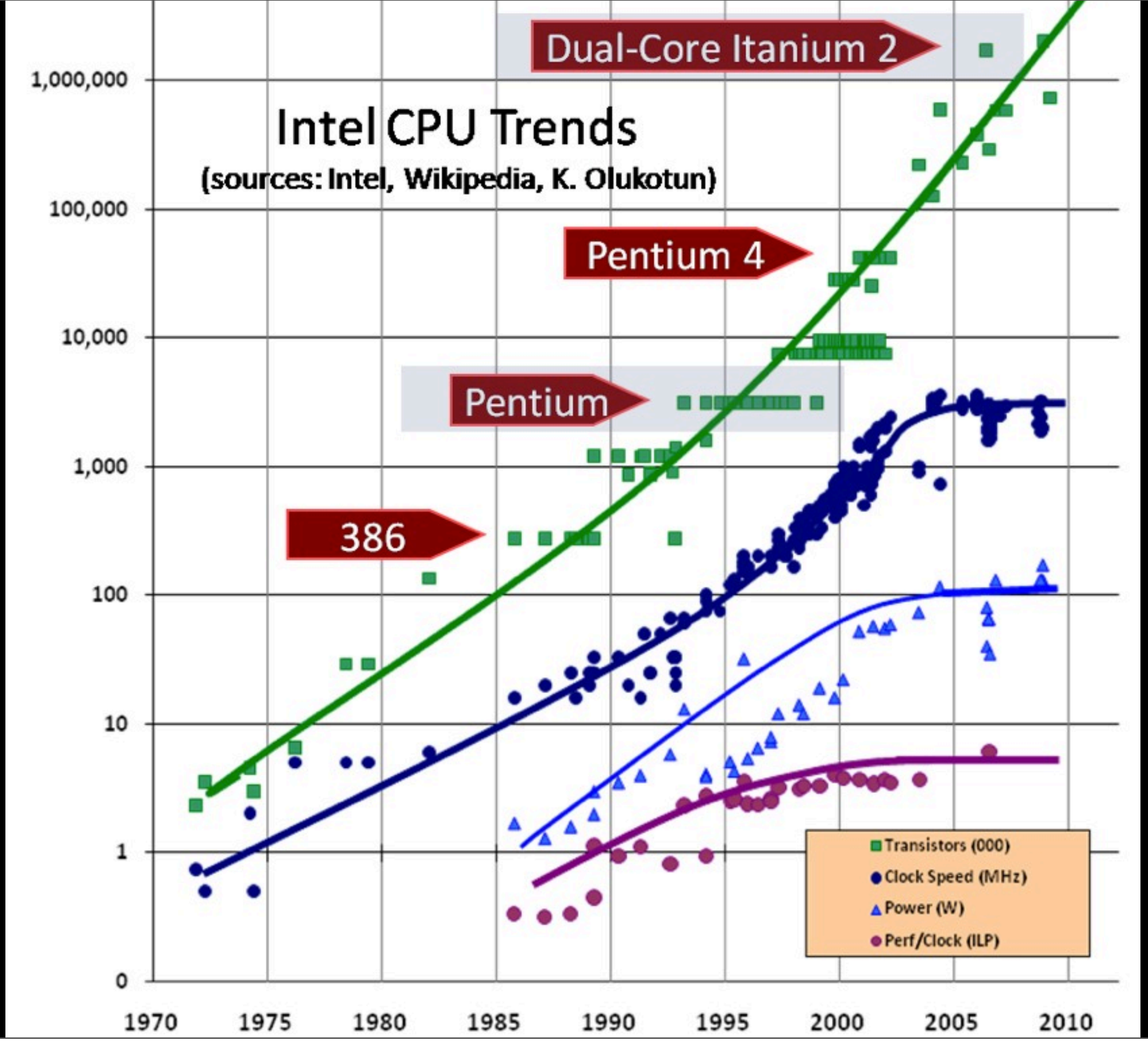
bad news guys...

The free lunch is over

Herb Sutter 2005 http://www.gotw.ca/publications/concurrency-ddj.htm

Intel CPU Trends

(sources: Intel, Wikipedia, K. Olukotun)



Chip manufacturers will

focus on multicore technology

as the way to

improve performance

As a result -

Software developers will be forced to write massively multithreaded software

Some

good news...

Multicore

gives us

parallelism

Sync

vs

Async

The SLA

- 4 Services
  1. 3 seconds
  2. 4 seconds
  3. 1 second
  4. 6 seconds
- The services are unrelated
- Results need to be joined and returned
- Your budget is 7 seconds

The SLA: Sync

```
def callServices = {
  val first     = callService1  //3 seconds
  val second = callService2 //4 seconds
  val third    = callService3 //1 seconds
  val fourth  = callService4 //6 seconds
  return first + second + third + fourth
}
```

The SLA: Async

```
def callServices = {
  val first     = callService1  //3 seconds
  val second = callService2 //4 seconds
  val third    = callService3 //1 seconds
  val fourth  = callService4 //6 seconds
  return first.await + second.await +
            third.await + fourth.await
}
```

Result: The SLA

- Synchronous calls

14 seconds

- Asynchronous calls

6 seconds

The Store

Rules!

- Current stock is non-negative
- Must not allow overselling
- Must not miscommunicate to the customer
- More than 1 customer needs to be able to simultaneously use the shop

It's a minefield out there!

Example pitfalls

- Race-conditions
- Deadlocks
- Lock Convoys
- Starvation
  - Livelocks
- Data corruption
- Visibility and ordering issues

Race-conditions

REPL time!

Deadlocks

ThreadA:
lockA.lock
lockB.lock

ThreadB:
lockB.lock
lockA.lock

REPL time!

Lock Convoys

Starvation & Livelocks

Data corruption

REPL time!

Visibility and ordering

REPL time!

```
class SomeClass {
  var first = 0
  var second = 0

  def foo() {
    first = 1
    second = 1
  }

  def bar() {
    if (second == 1 && first == 0)
      println("can't happen")
  }
}
```

The usual suspects

- Mutable shared state
- Side effects
- Wrong use of concurrency control structures/techniques

```
class Counter {
  private val count: Long = 1000000

  def increment(): Long = count += 1

  def decrement(): Long = count -= 1

  def set(newCount: Long) {
    count = newCount
  }

  def value(): Long = count
}
```

Concurrency Control:
Encoding correct behavior

Concurrency primitives

Compare-And-Swap

- Atomic
- Conditional modification
- Low level construct
- **Very** useful

CTS example

```
class MyClass {
  private var isActive = false

  def start() {
    if (!isActive) {
      isActive = true
      //Code to be run on start
    }
  }

  def shutdown() {
    if (isActive) {
      isActive = false
      //Code to be run on shutdown
    }
  }
}
```

CAS example

```
class MyClass {
  val isActive = new AtomicBoolean(false)

  def start() {
    if (isActive.compareAndSet(false,true)) {
      //Code to be run on start
    }
  }

  def shutdown() {
    if (isActive.compareAndSet(true,false)) {
      //Code to be run on shutdown
    }
  }
}
```

Volatile variables

- Makes sure that reads and writes of the variable are against main memory
- Access synchronizes all cached copies of variables with main memory
- Reads and writes are atomic, but NOT lockable.

Monitor

- A thread safe? object
- Serializes execution of its methods
- Employs the use of wait and notify
- java.lang.Object is a Monitor but requires the use of the synchronized keyword to mark methods that needs mutual exclusion
- Access synchronizes all cached copies of variables with main memory

Locks

- Controls access to a common resource
- May support reentrancy
- May support readers/writer

The loo

Semaphore

- Controls access to a common resource
- Binary (MUTual EXclusion) or Counting

The Restaurant

Latches

- A condition starting out as false
- When set to true remains true forever
- Enables Threads to wait for it to become true

Barrier

- Any thread must stop at the barrier
- Cannot proceed until enough threads have arrived
- Can be viewed as a threshold

Threads... well...

The "**Threads & locks**"-combination is still taught as The Way to Do It

The problem is

Knowing up front which locks need to be locked Breaks encapsulation

All locks need to be taken before modification - in the correct order

All locks must be unlocked

Thread are expensive and their lifecycle management is error prone

"Threads are to Concurrency as Witchcraft is to Physics"

"Hanging by a thread is the punishment for Shared State Concurrency"

- Gilad Bracha

Java Language architect and maintainer and co-author of the Java Language Specification.

Software Transactional Memory (STM)

Transaction?

- A list of operations
- Atomic: All or nothing
- Usually
  - Atomic
  - Consistent
  - Isolated
  - Durable
- Example: Database transaction

STM Overview

- View the memory (heap and stack) as a transactional dataset
- Similar to a database
  - begin
  - commit
  - abort/rollback
- Transactions are retried automatically upon collision
- Rolls back changes on abort

STM Overview

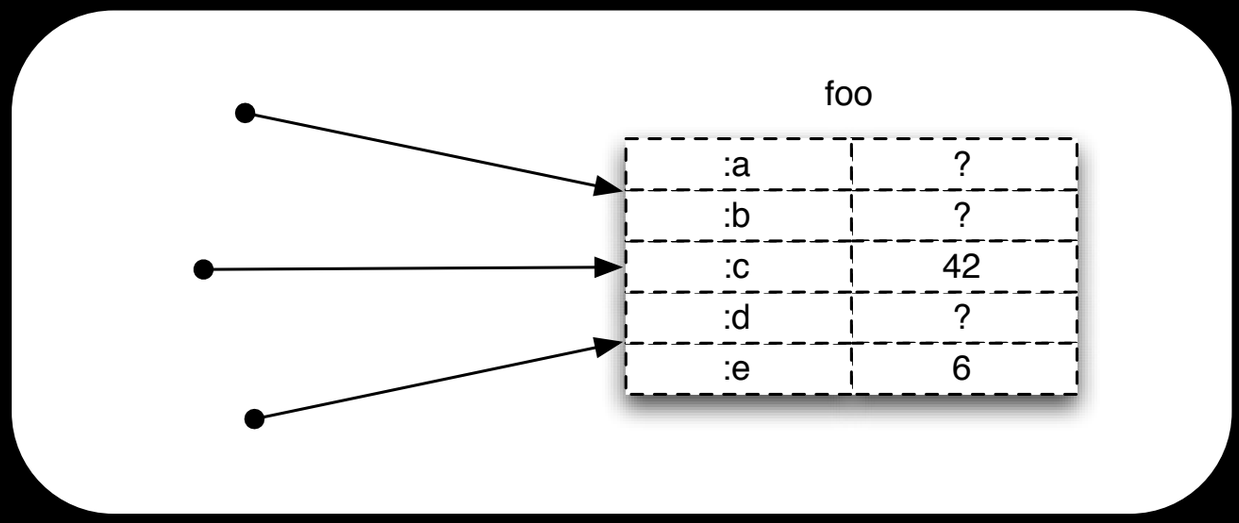
- Atomic
- Consistent
- Isolated
- Transactions can nest
- Transactions can compose!

STM restrictions

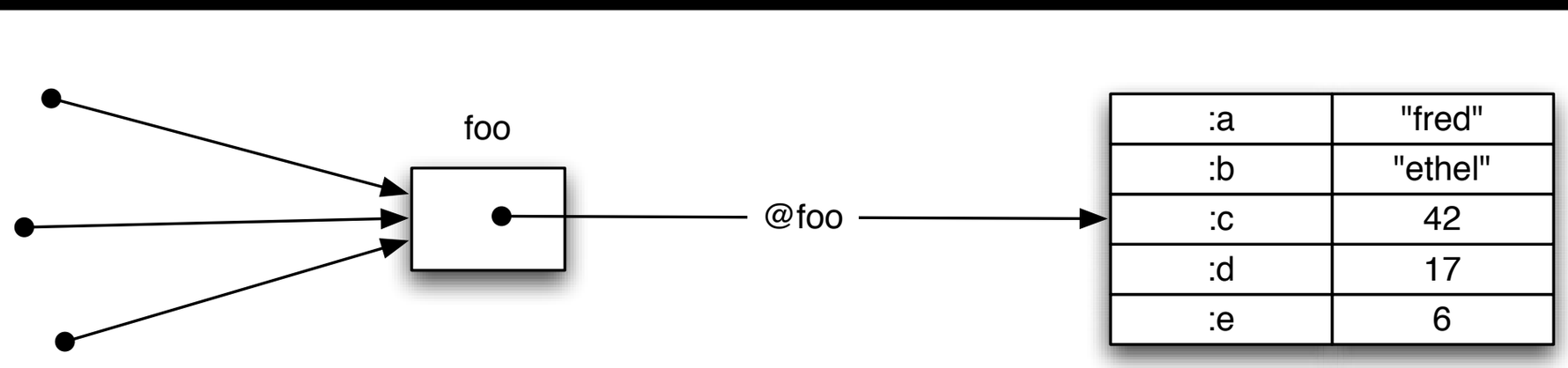
- Operations within the scope of a transaction
  - need to be idempotent
  - can't have side-effects

Managed References

Typical OO: direct access to mutable objects



Managed Reference: separates Identity & Value



Managed References

Separates Identity from Value

- Values are immutable
- Identity (Ref) holds Values

Change is a function

Compare-and-swap (CAS)

Abstraction of time

Must be used within a transaction

Transactional Reference

Creation:

```
val number = Ref(0)
```

Usage:

```
atomic {
  number.alter( _ + 5 )
  number.swap(10)
  val result = number.get
}
```

Transactional Map

Creation:

```
val beers = TransactionalMap[String,Float]( )
```

Usage:

```
atomic {
  beers.put("Heineken",5.0f)
  val alcoholPct = beers("Heineken")
}
```

Transactional Vector

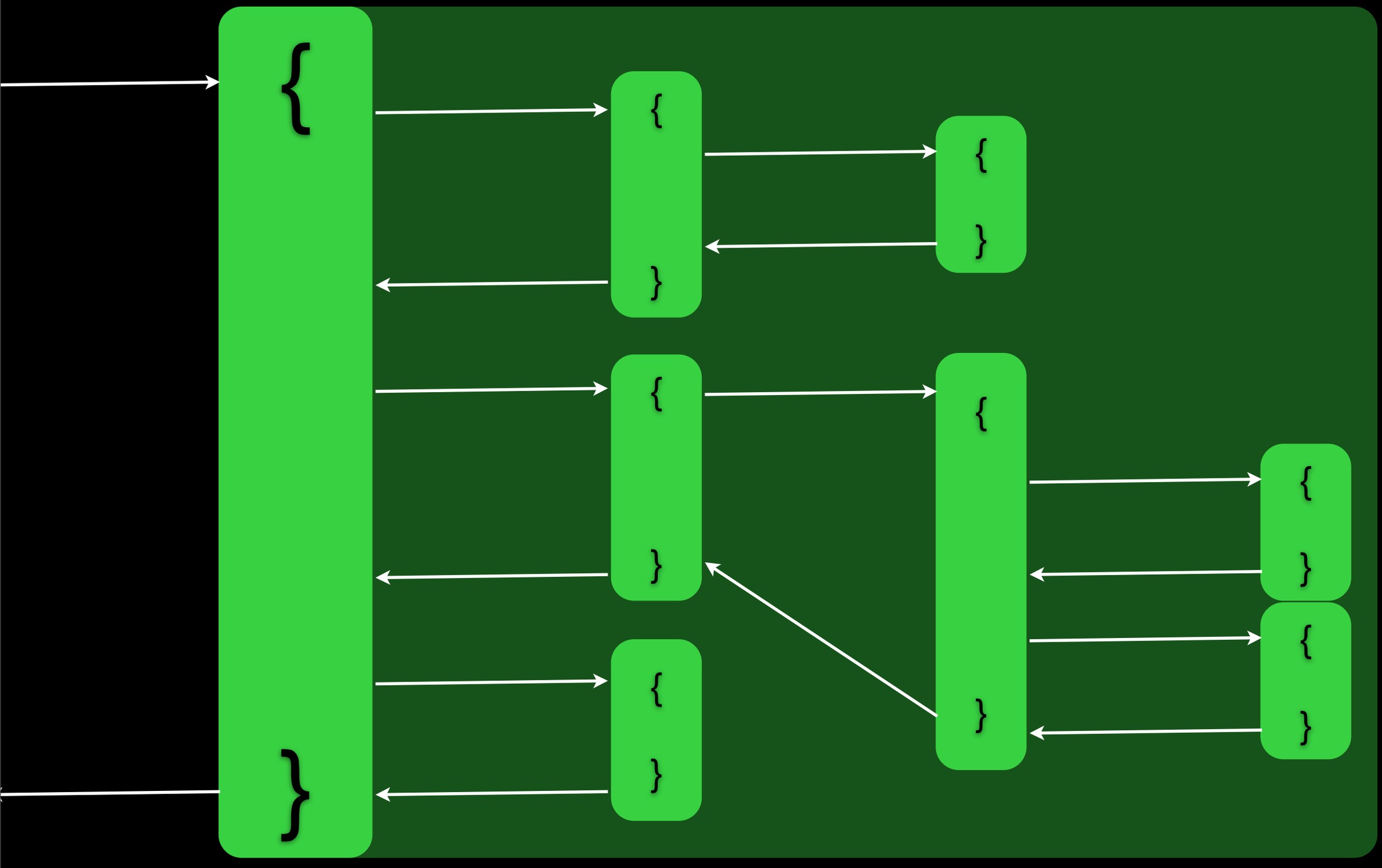
Creation:

```
val users = TransactionalVector(new User(“”))
```

Usage:

```
atomic {
  users.add(new User(“Jonas”))
  users.update(0, new User(“Viktor”))
  val first = users.get(0)
}
```

Transaction composition

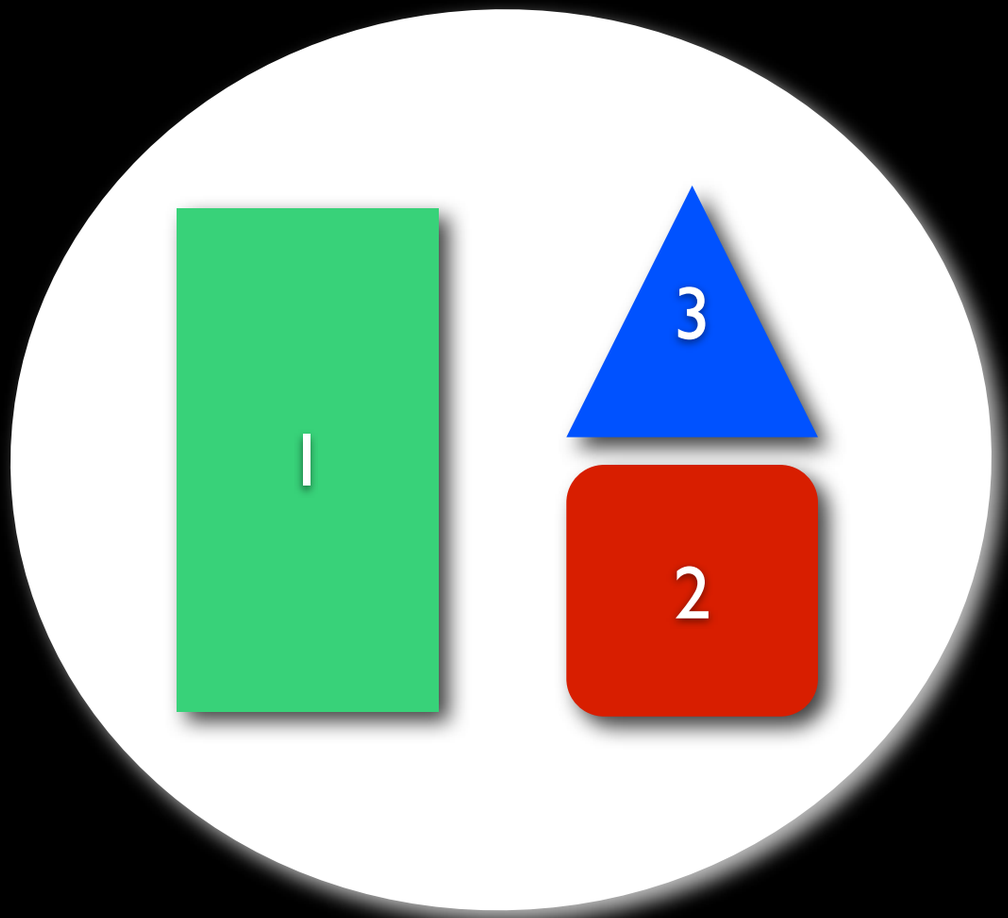


REPL time!

Actors

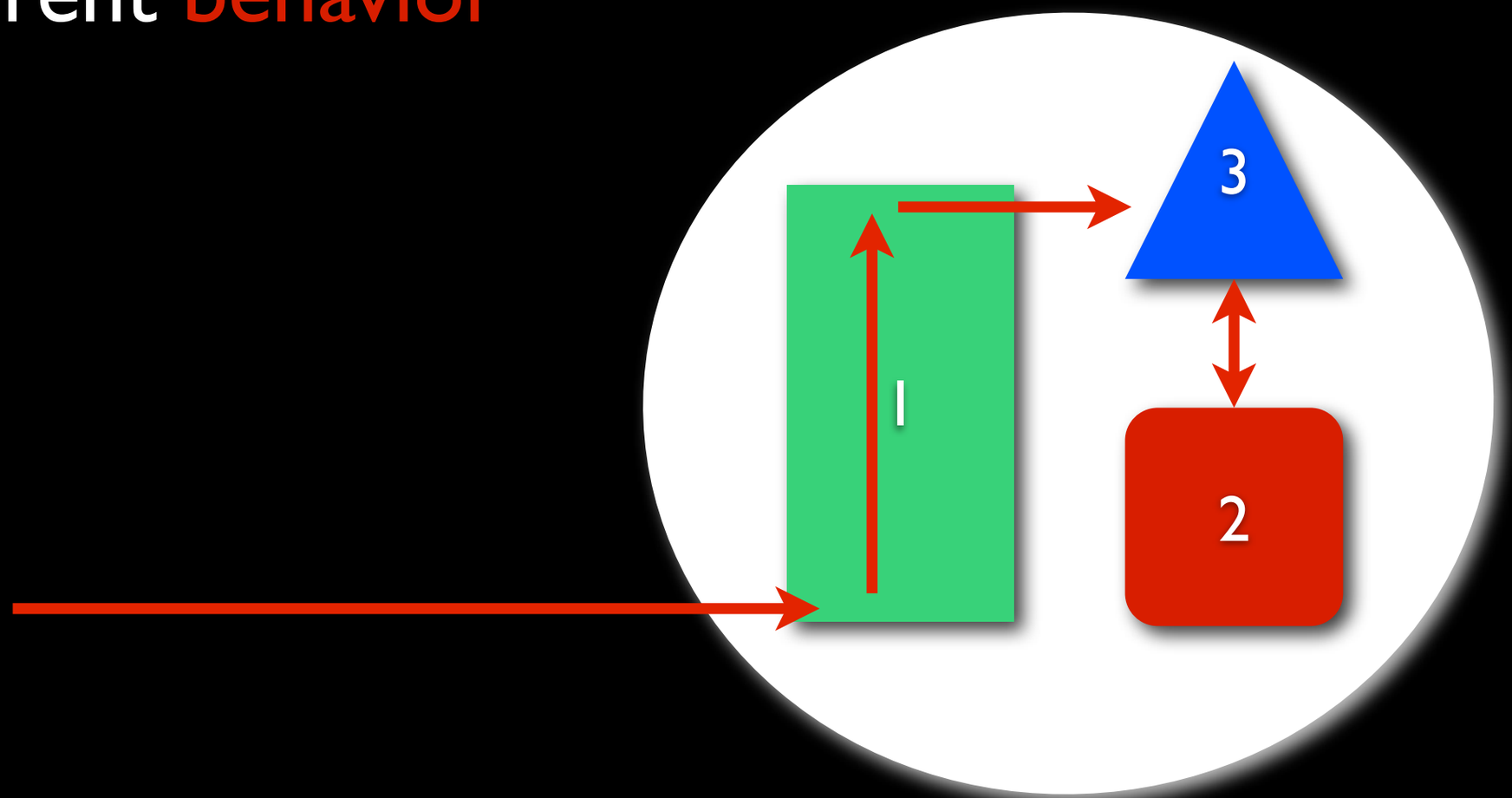
An Actor is

1. A mailbox
2. State (Optional)
3. Current behavior



Message flow

1. The mailbox
2. The State (Optional)
3. The Current behavior



Benefits of Actors

- One message at a time = no locks
- Inherently asynchronous
- Cheap!
- Literally MILLIONS at the same time

Actor Essentials

- An actor can send messages to other actors
- Can create new actors
- Can change behavior towards the next message
- Processes one message at a time

Lifecycle

- Unstarted
- Running
  - BeingRestarted
- Shutdown

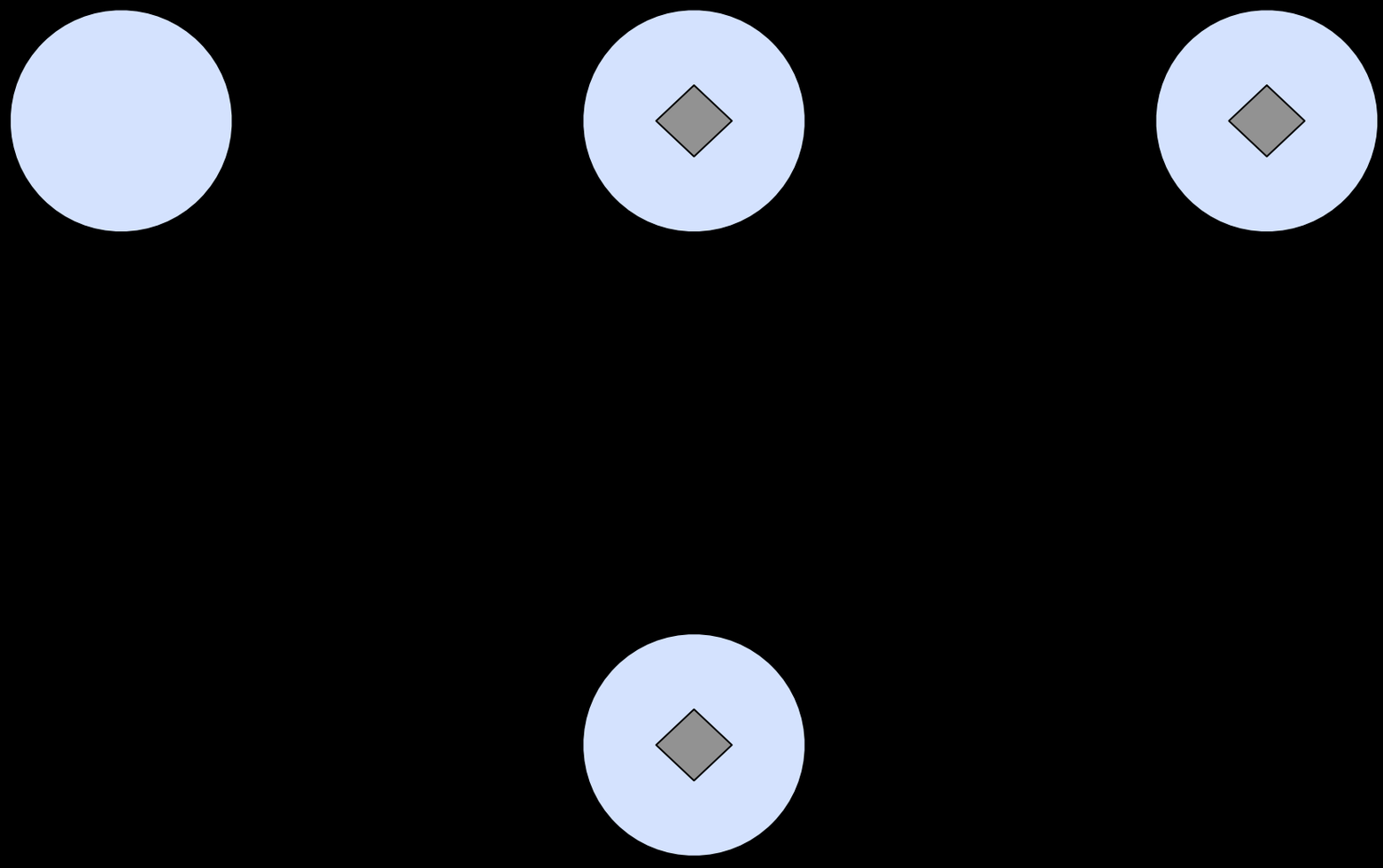
Defining an Actor

```
class MyActor extends Actor {
  def receive = {
    case “hello world” => reply(“This is getting old man!”)
    case 5 => reply(“I really don’t like 5”)
    case i: Int => reply(i * i)
    case _ => //I ignore other messages
  }
}
```

Sending messages

Method	Scala	Java
Send message	actor ! message	actor.sendOneWay(message)
Send reply within	actor !! message	actor.sendRequestReply(message)
Send reply eventually	actor !!! message	actor.sendRequestReplyFuture(message)

Actors



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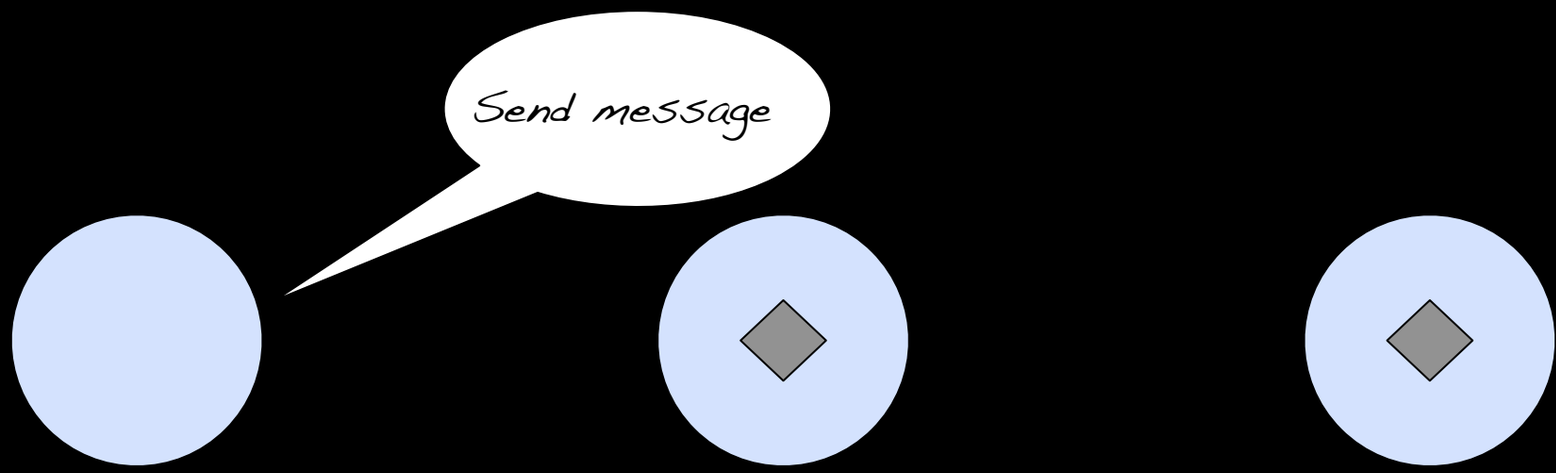

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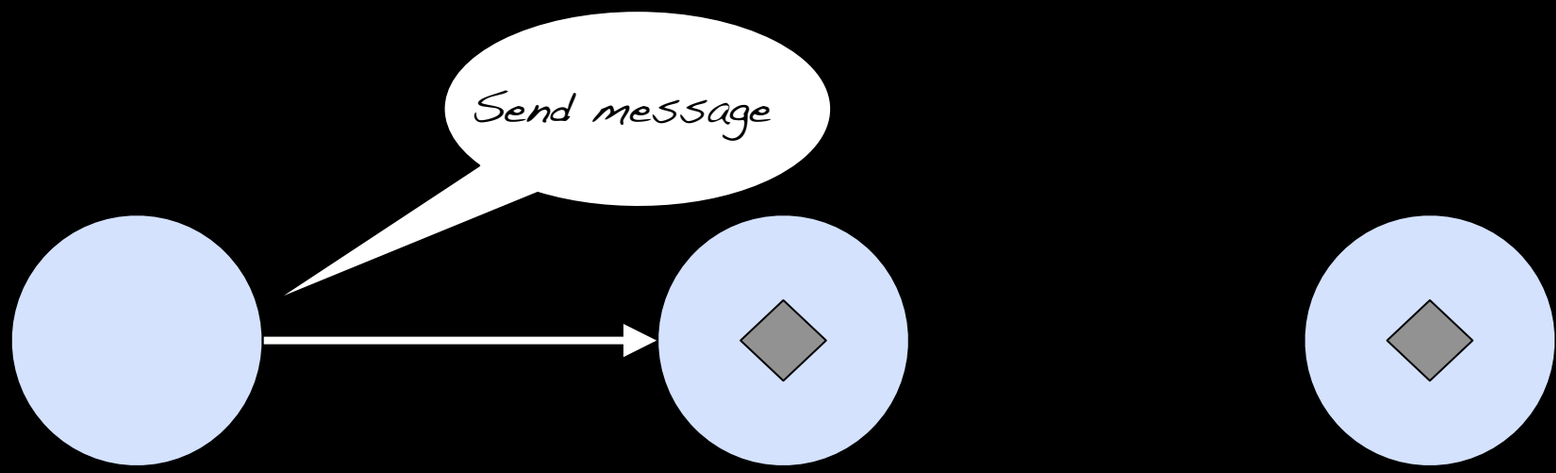

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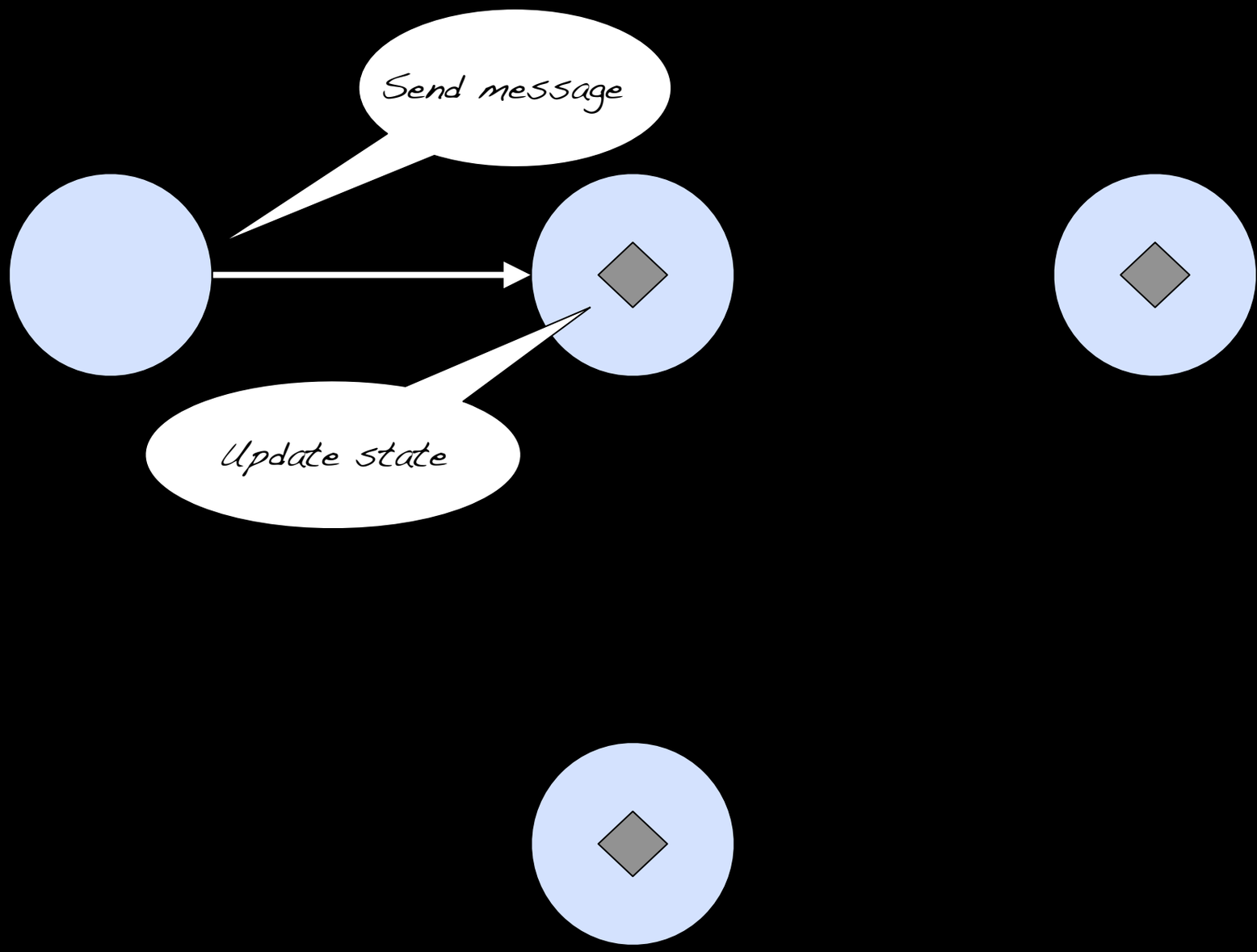

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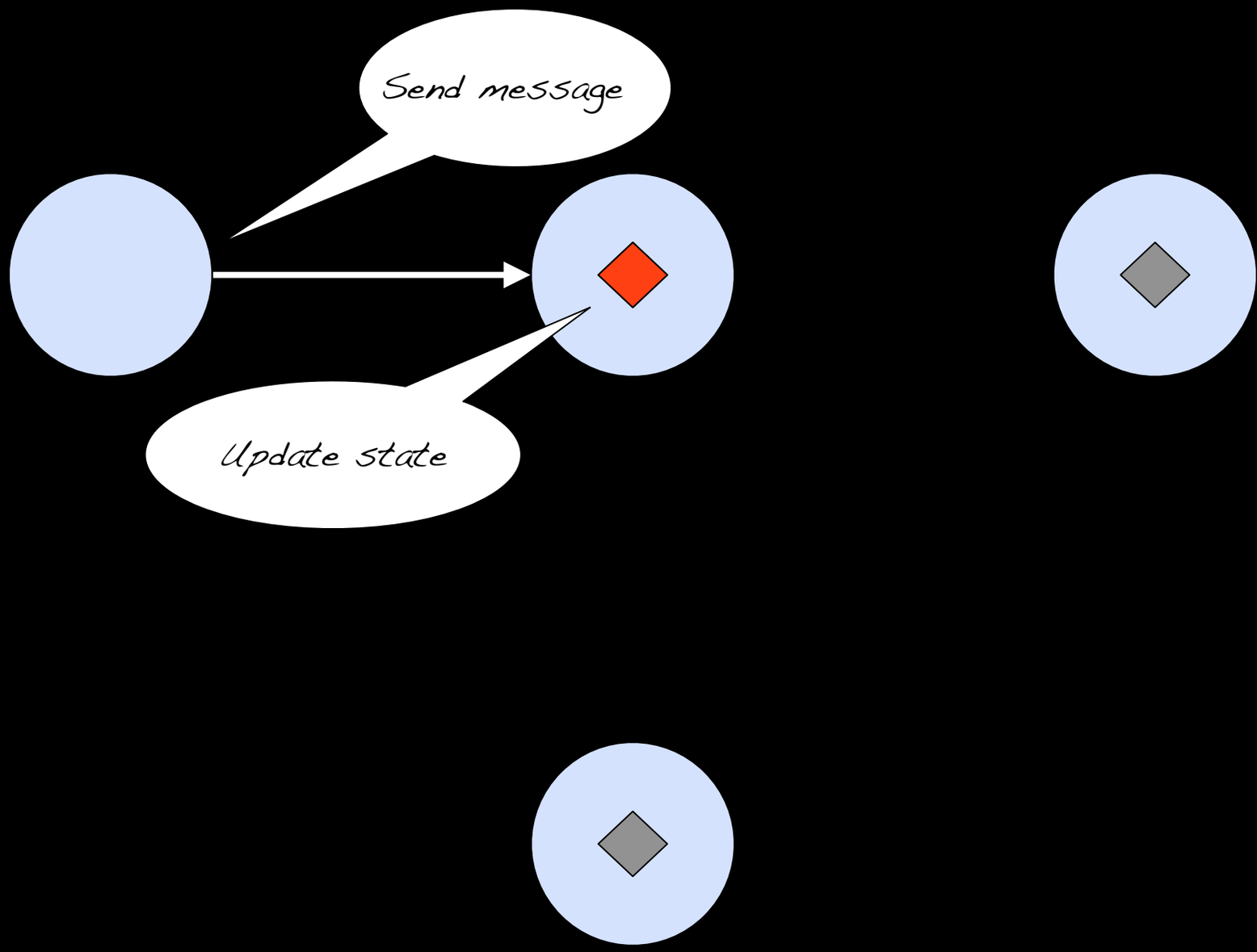

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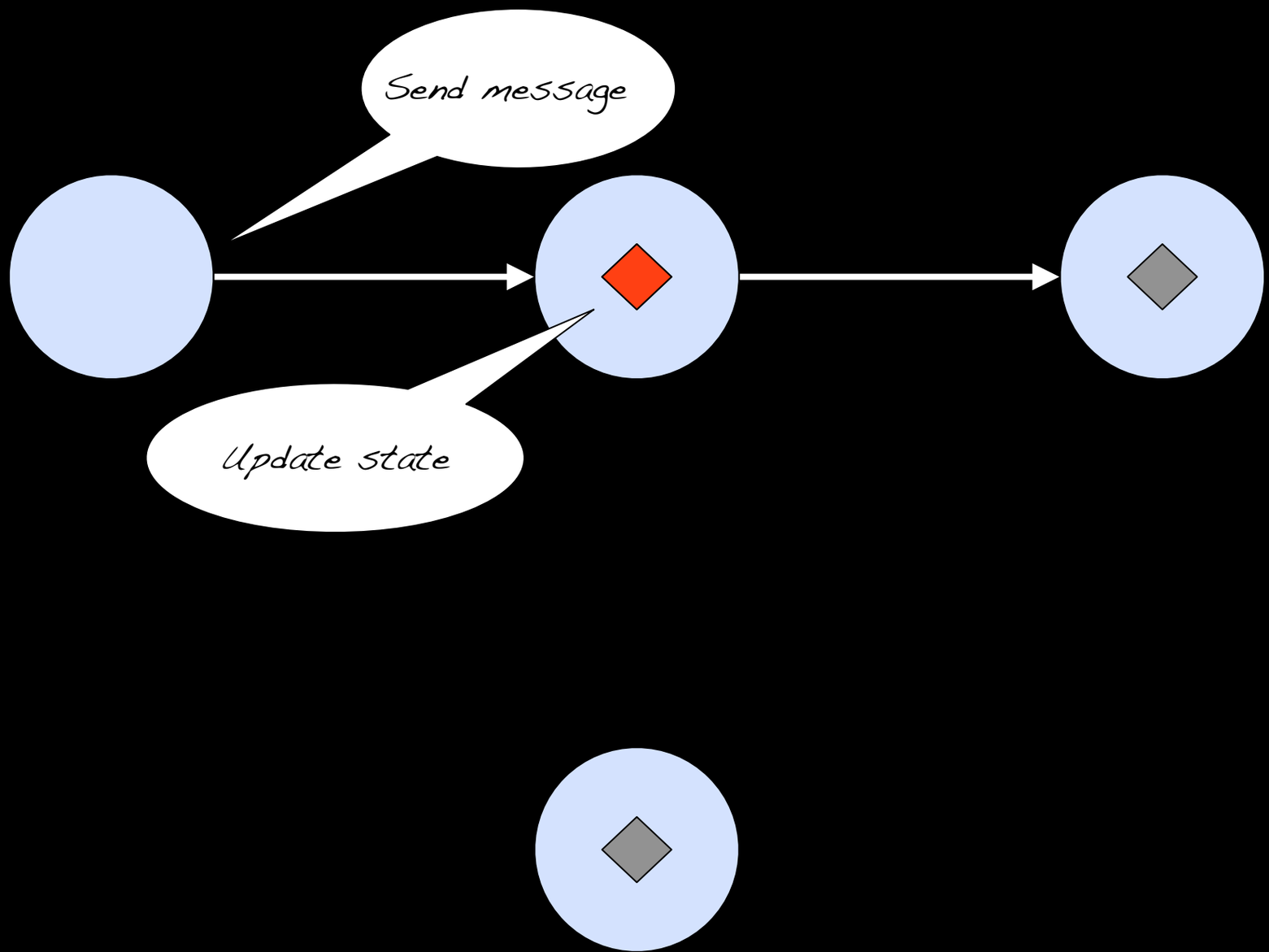

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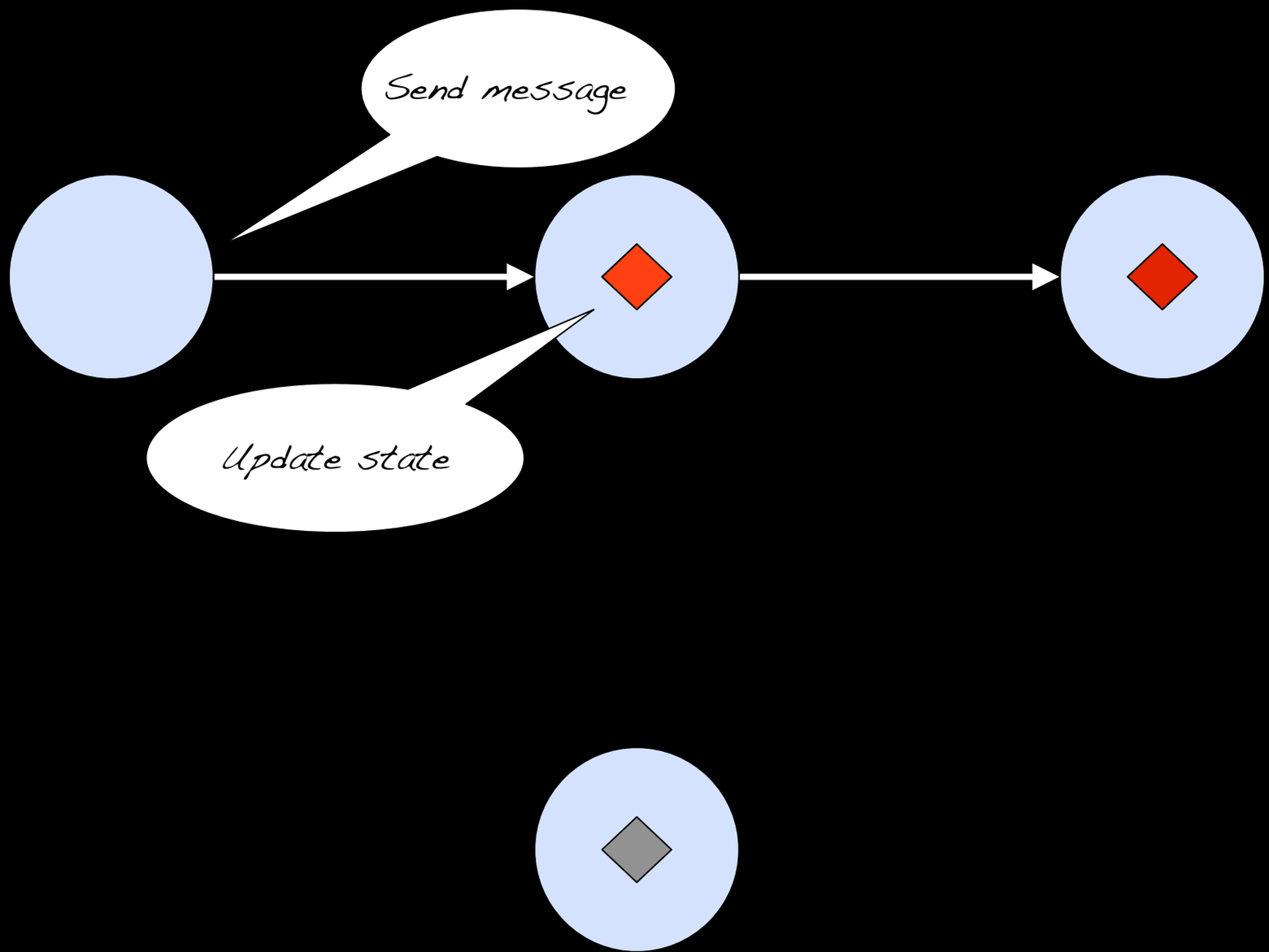

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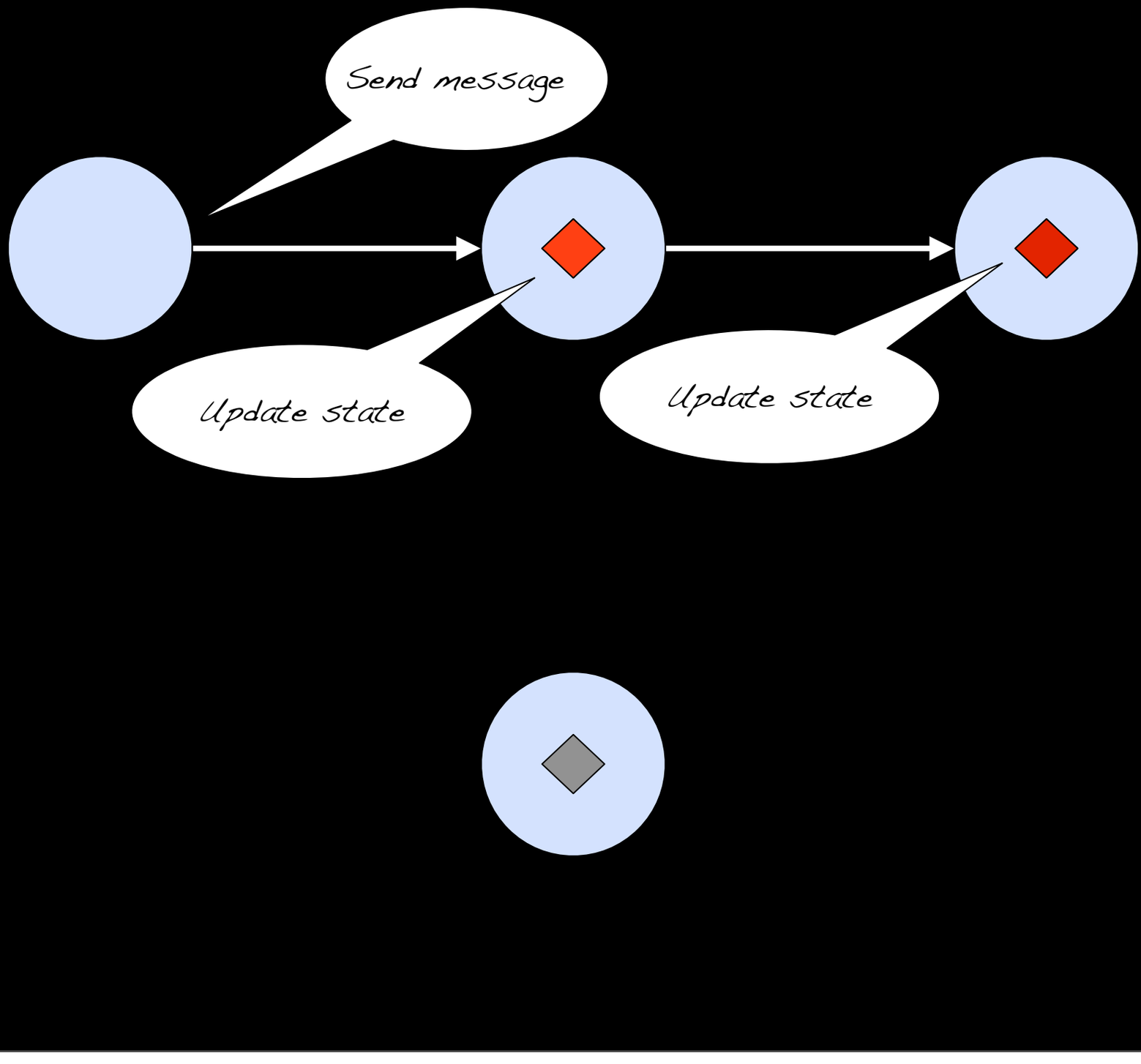

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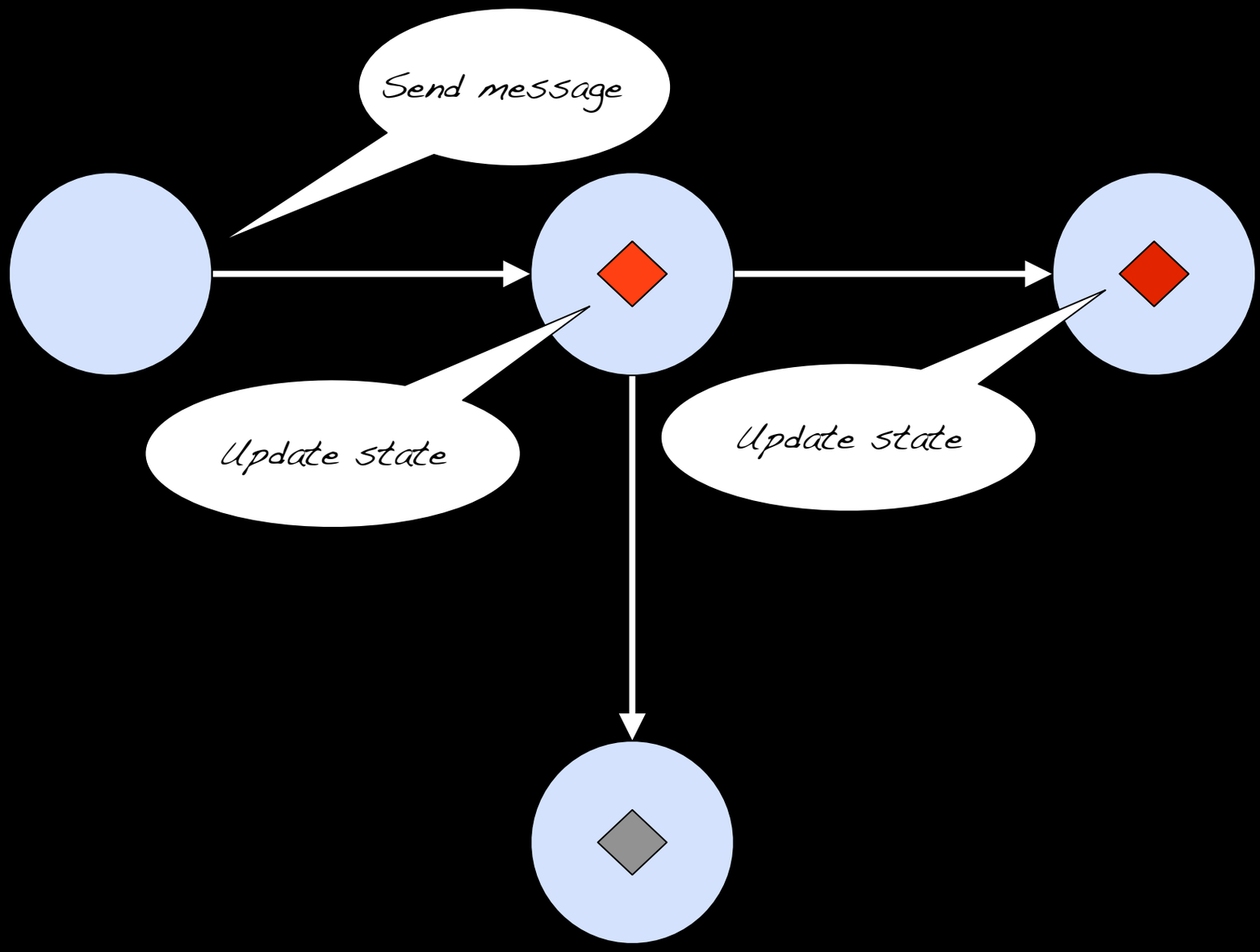

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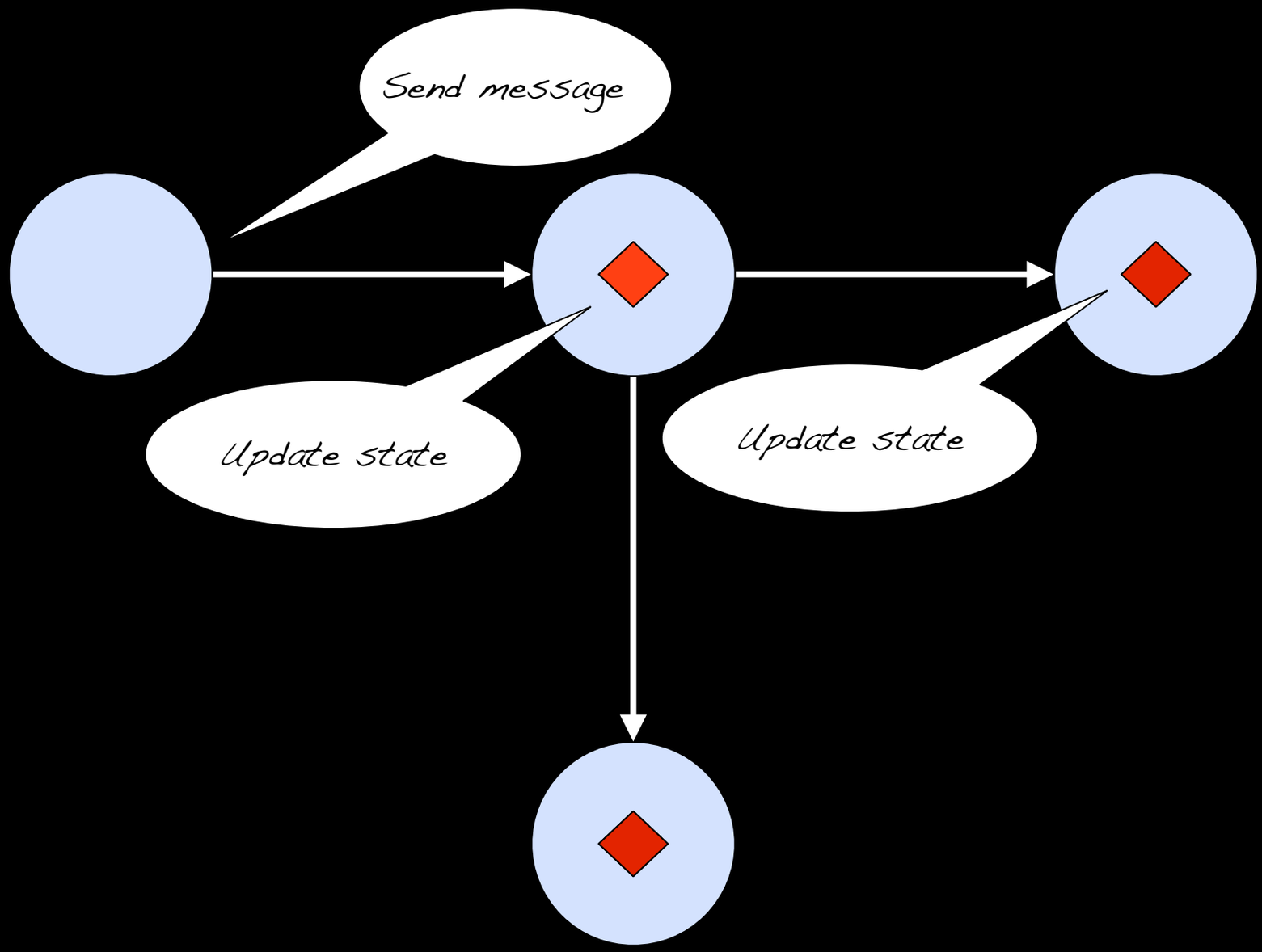

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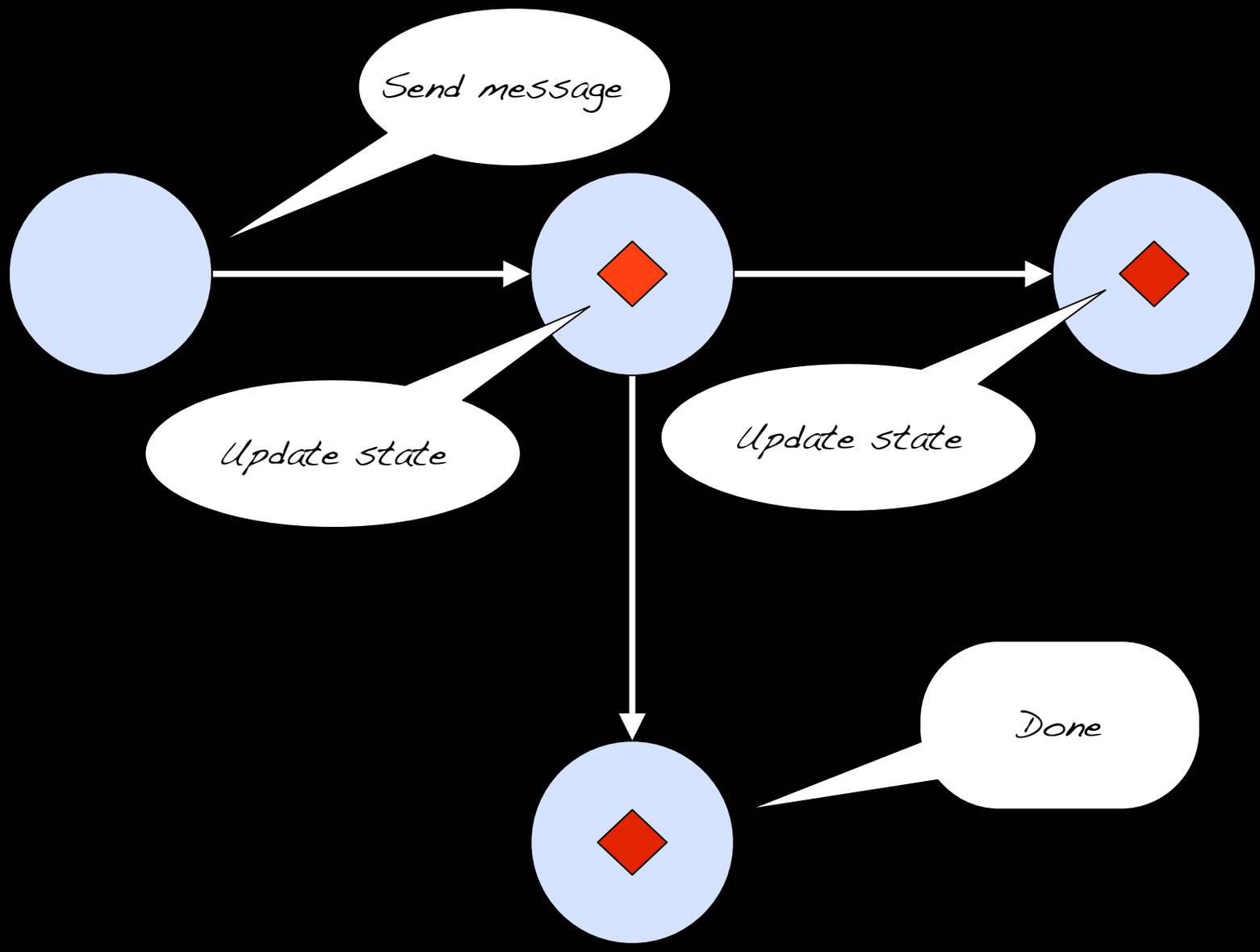


REPL time!

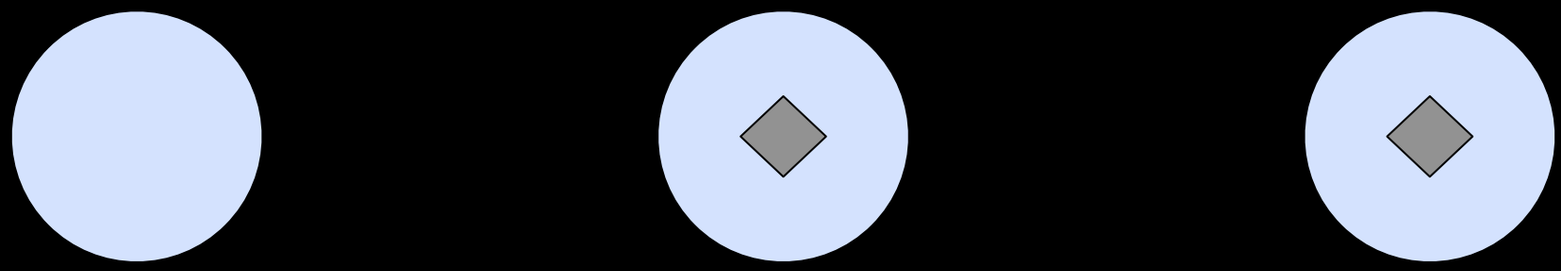
Actor gotchas

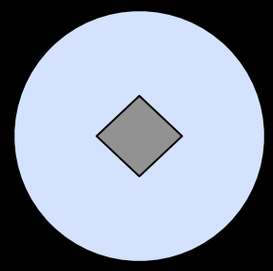
- Messages should be immutable
- References to mutable internal state must not escape the Actor
- Coordinating state changes between multiple actors is hard
- Actors are reactive, not proactive

Actors + STM =

Transactors

Transactors





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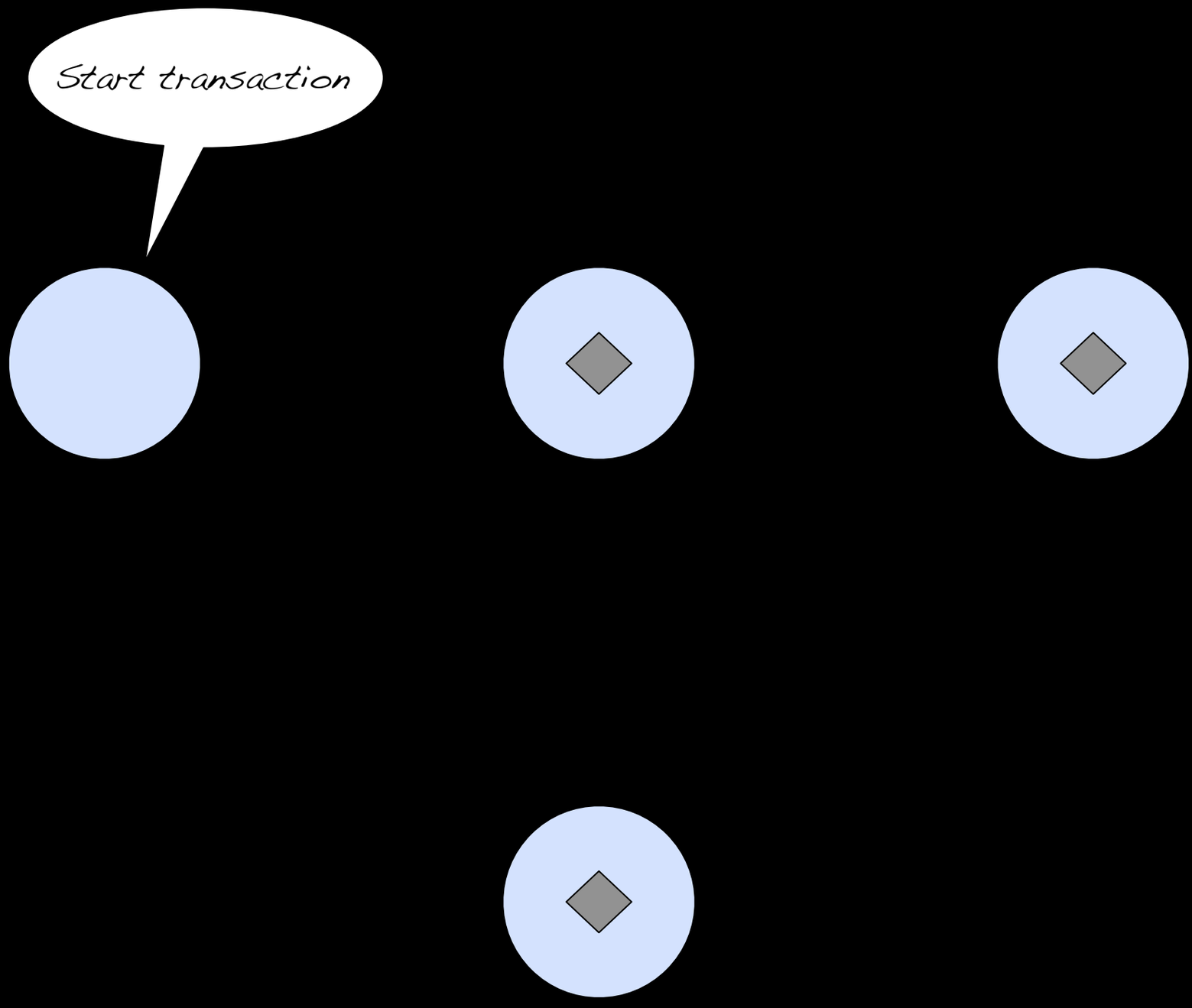

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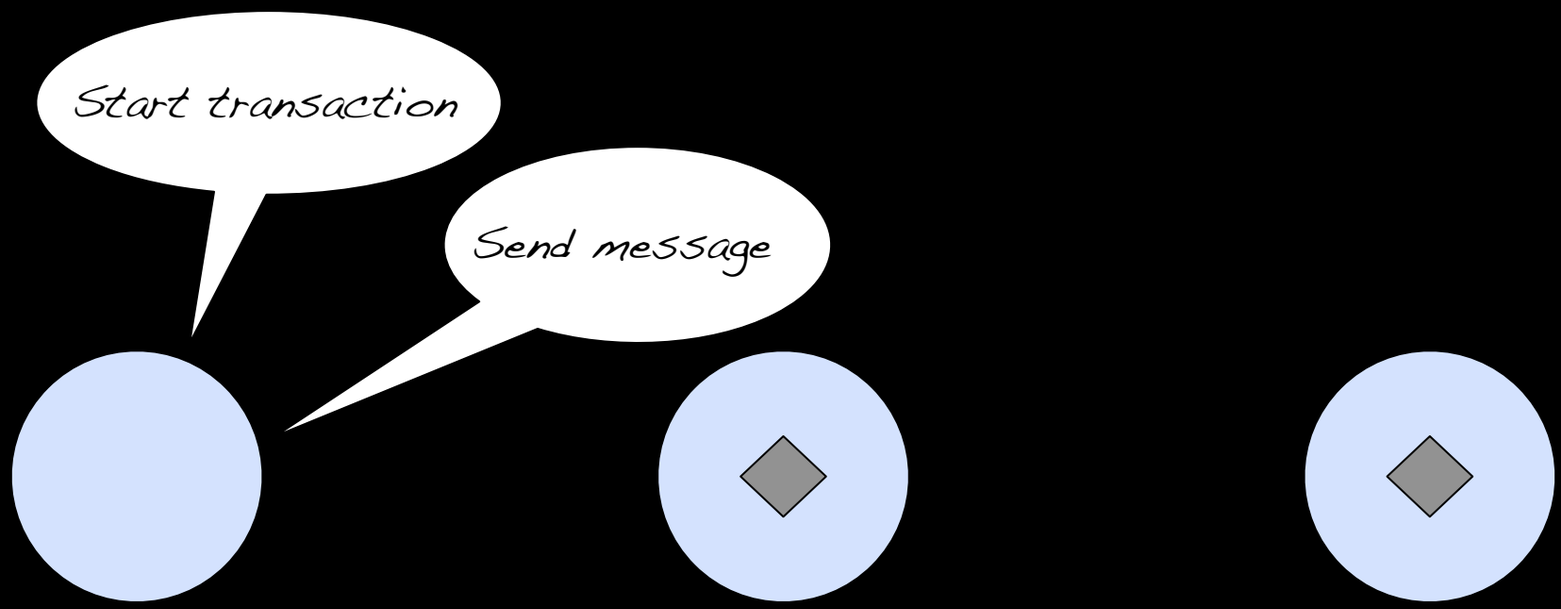

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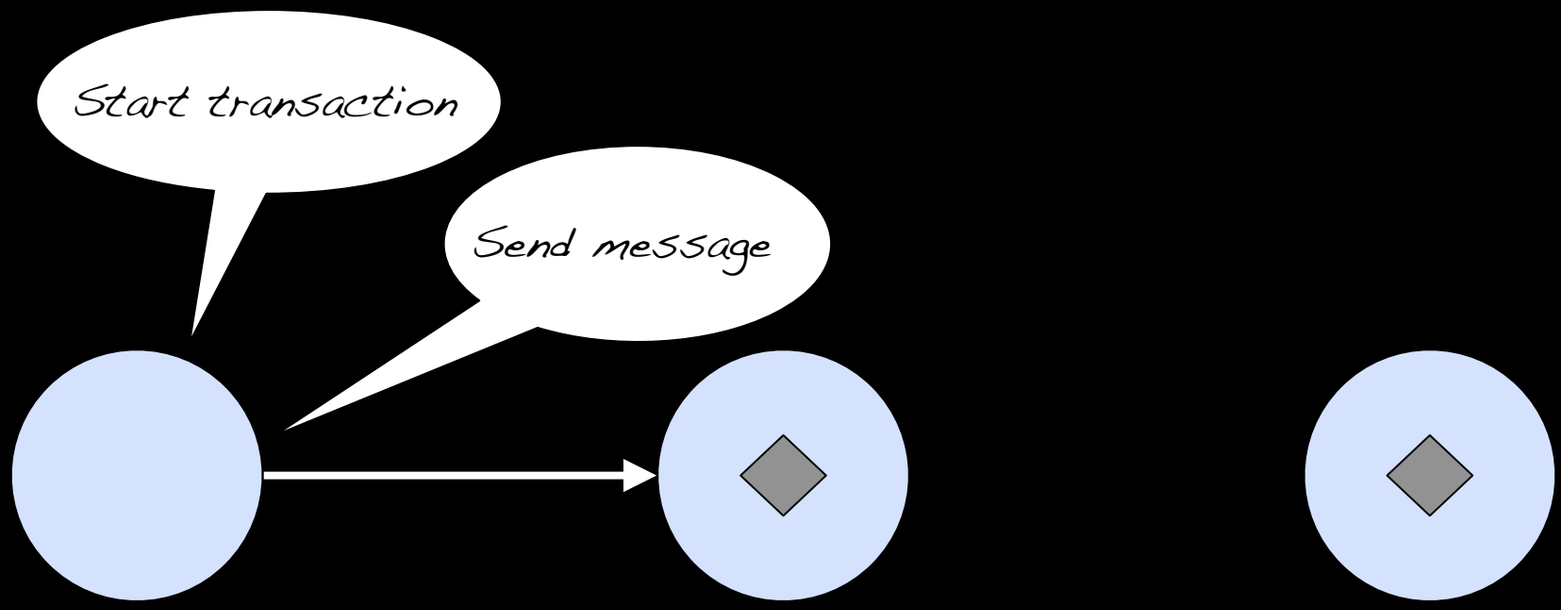

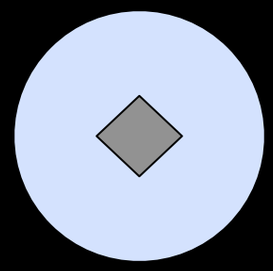

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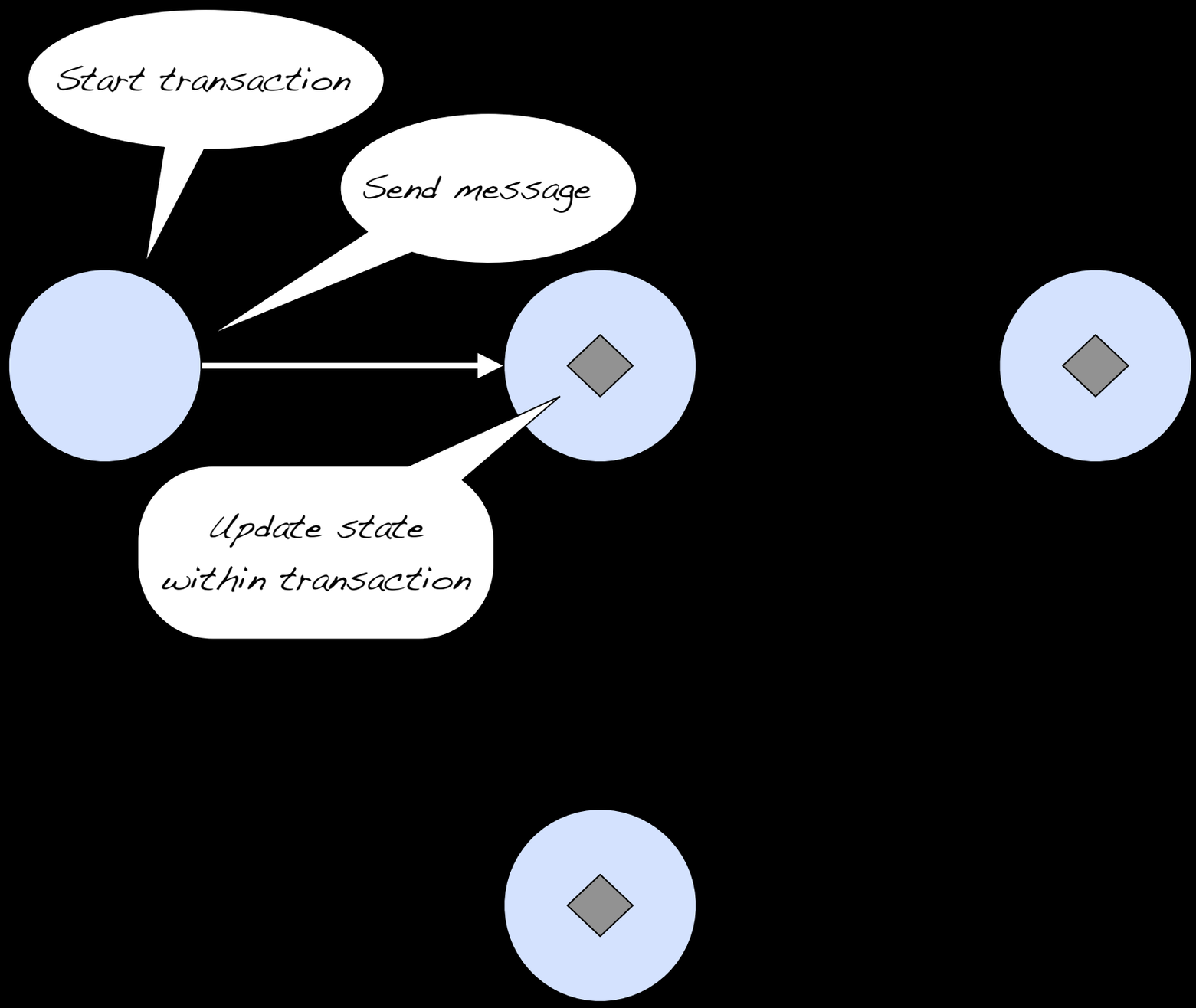

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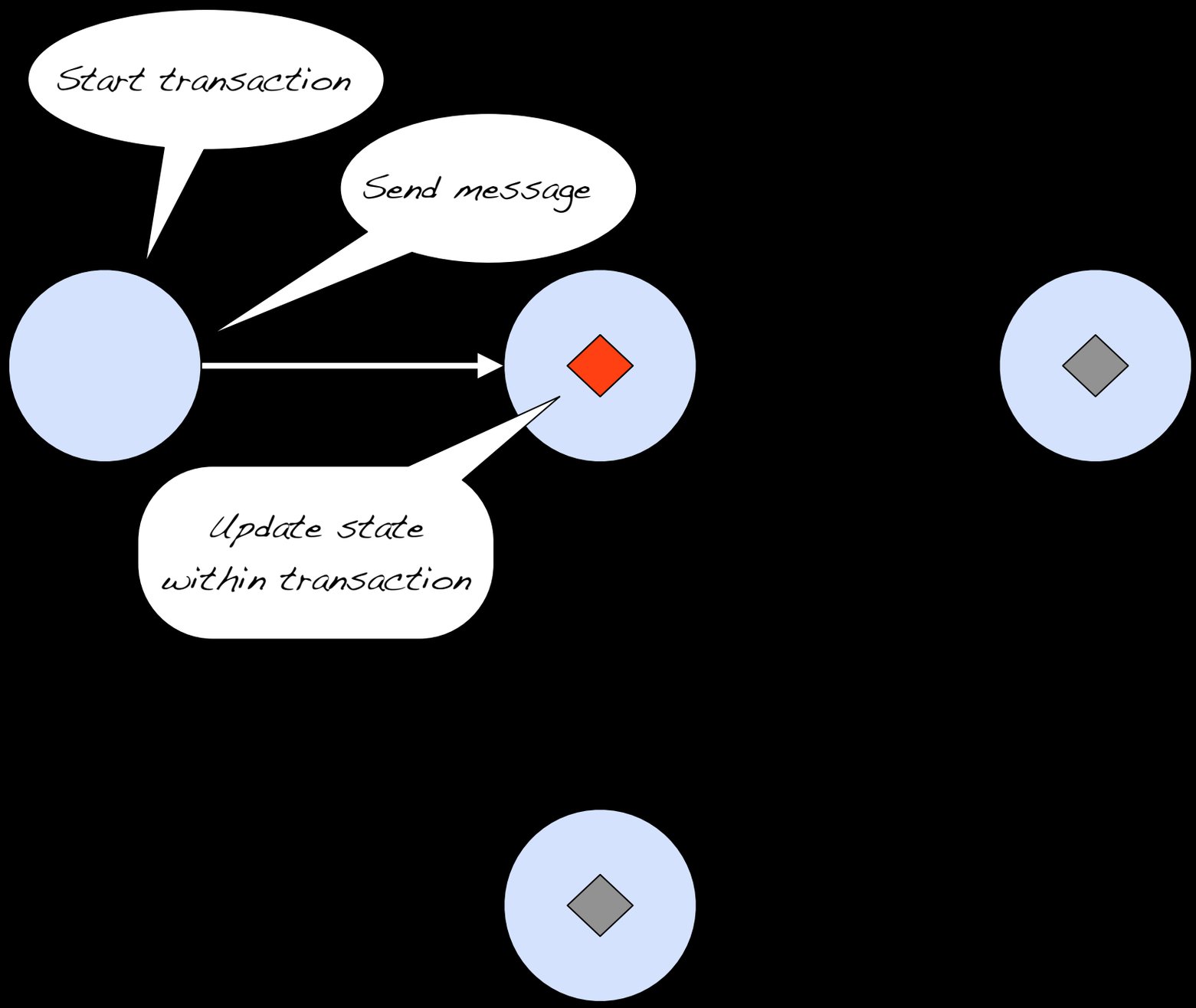

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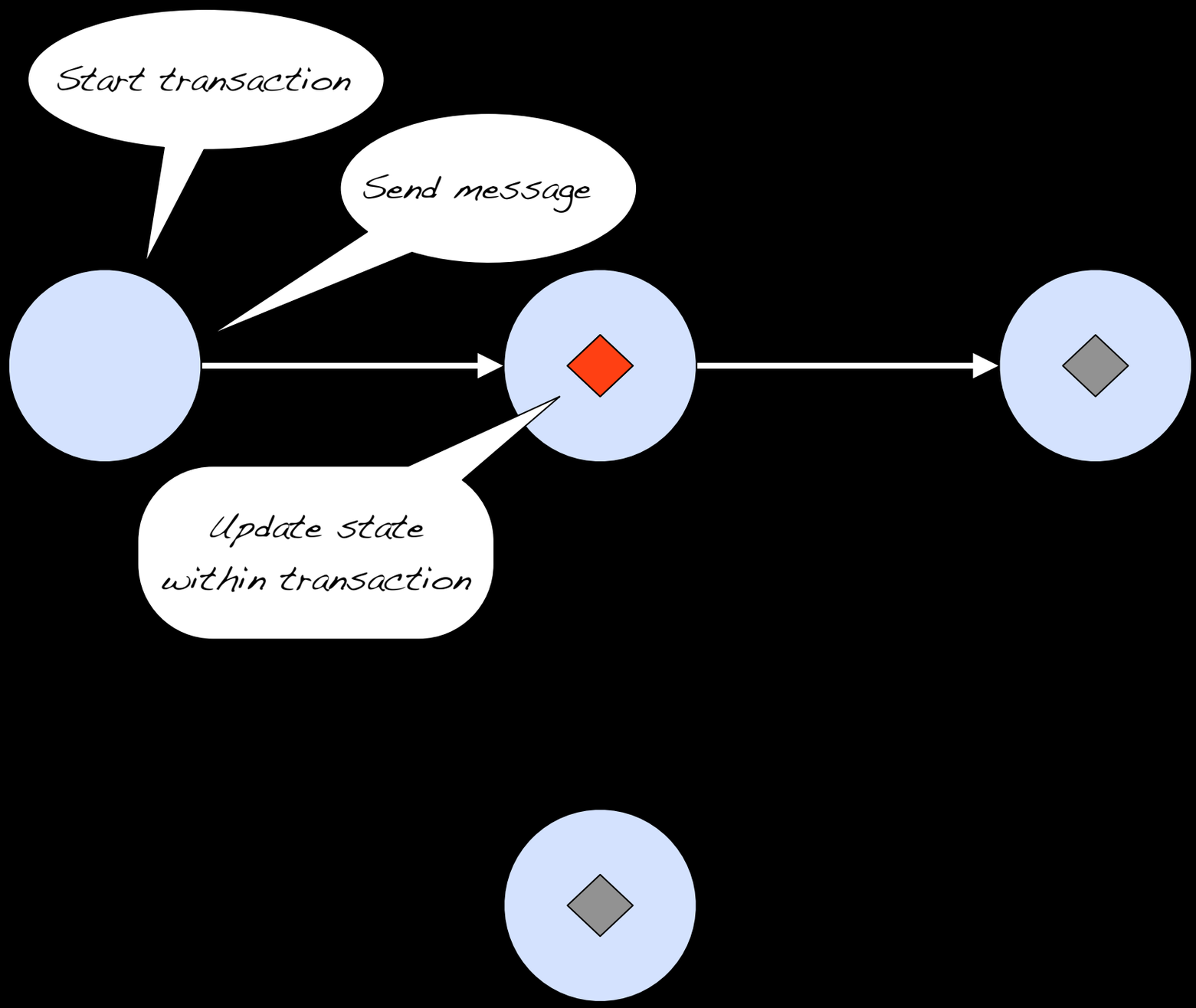

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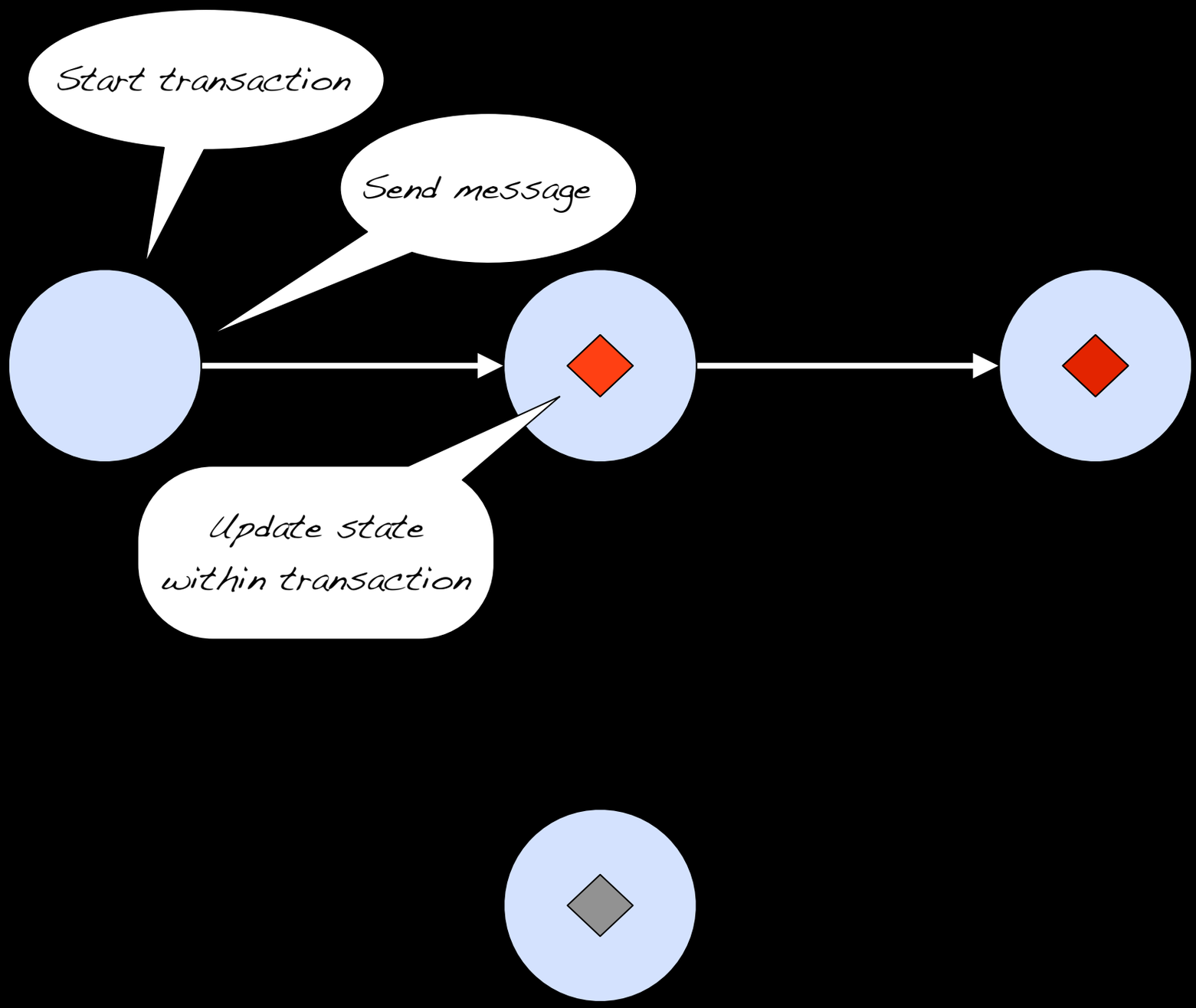

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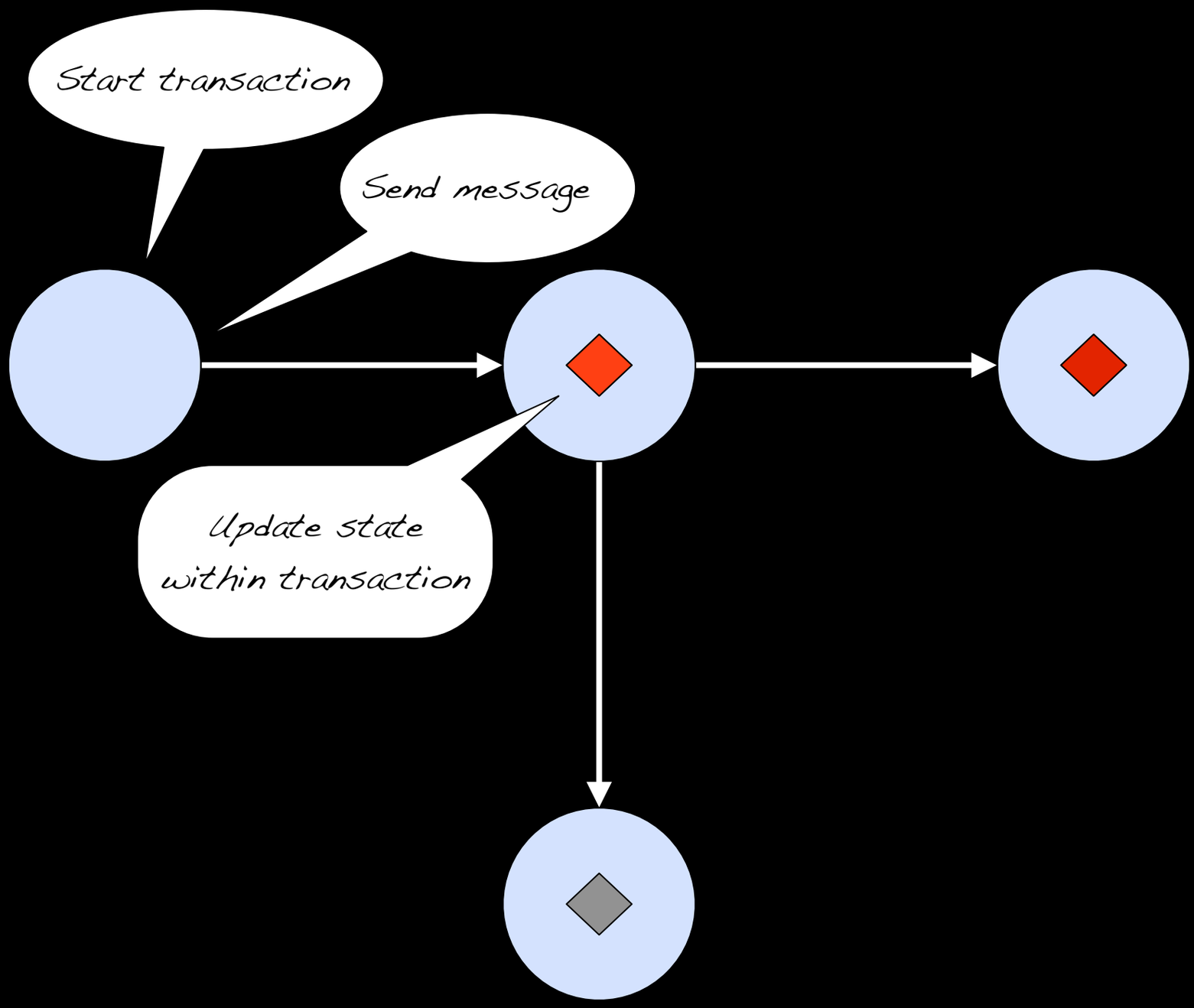

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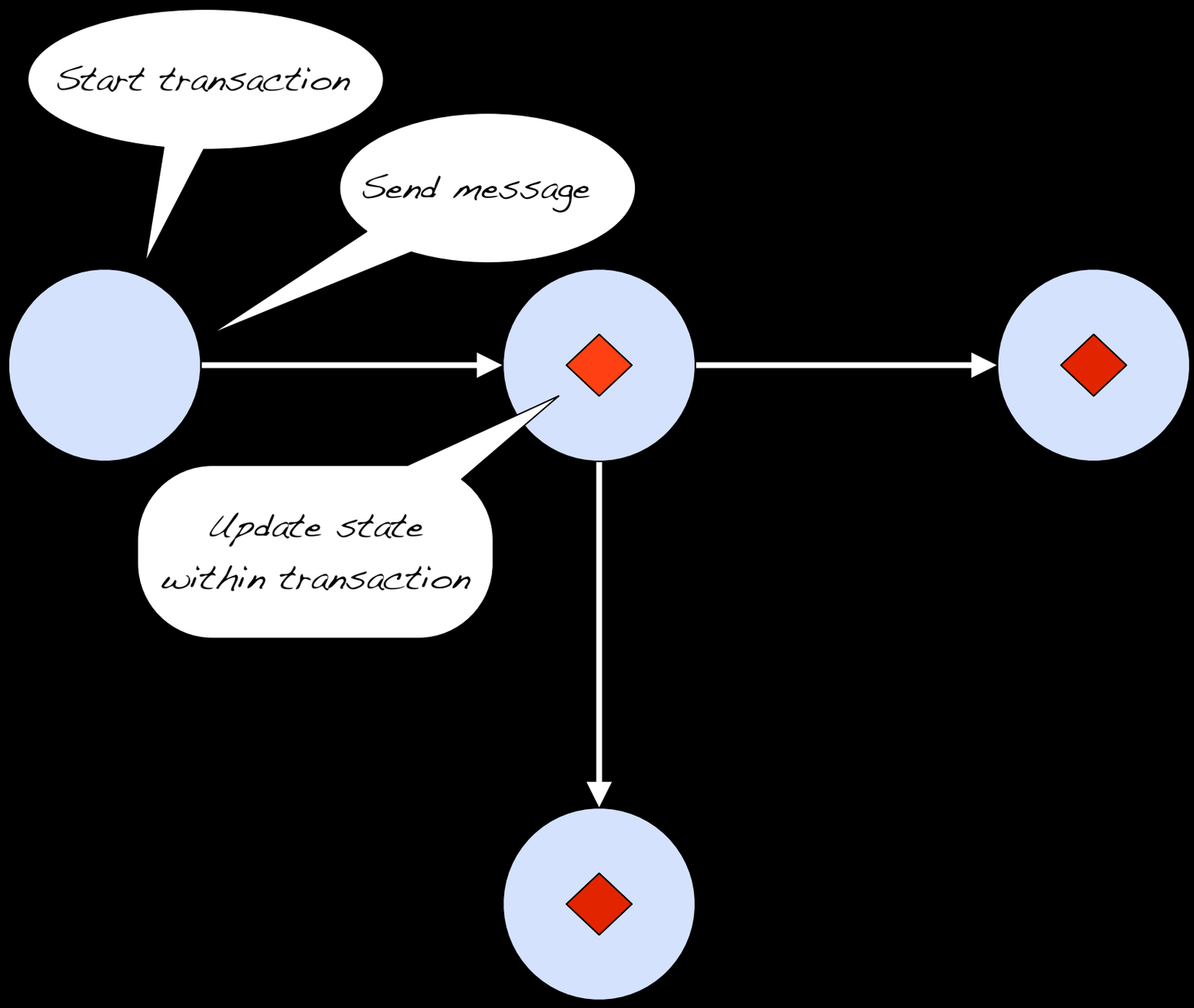

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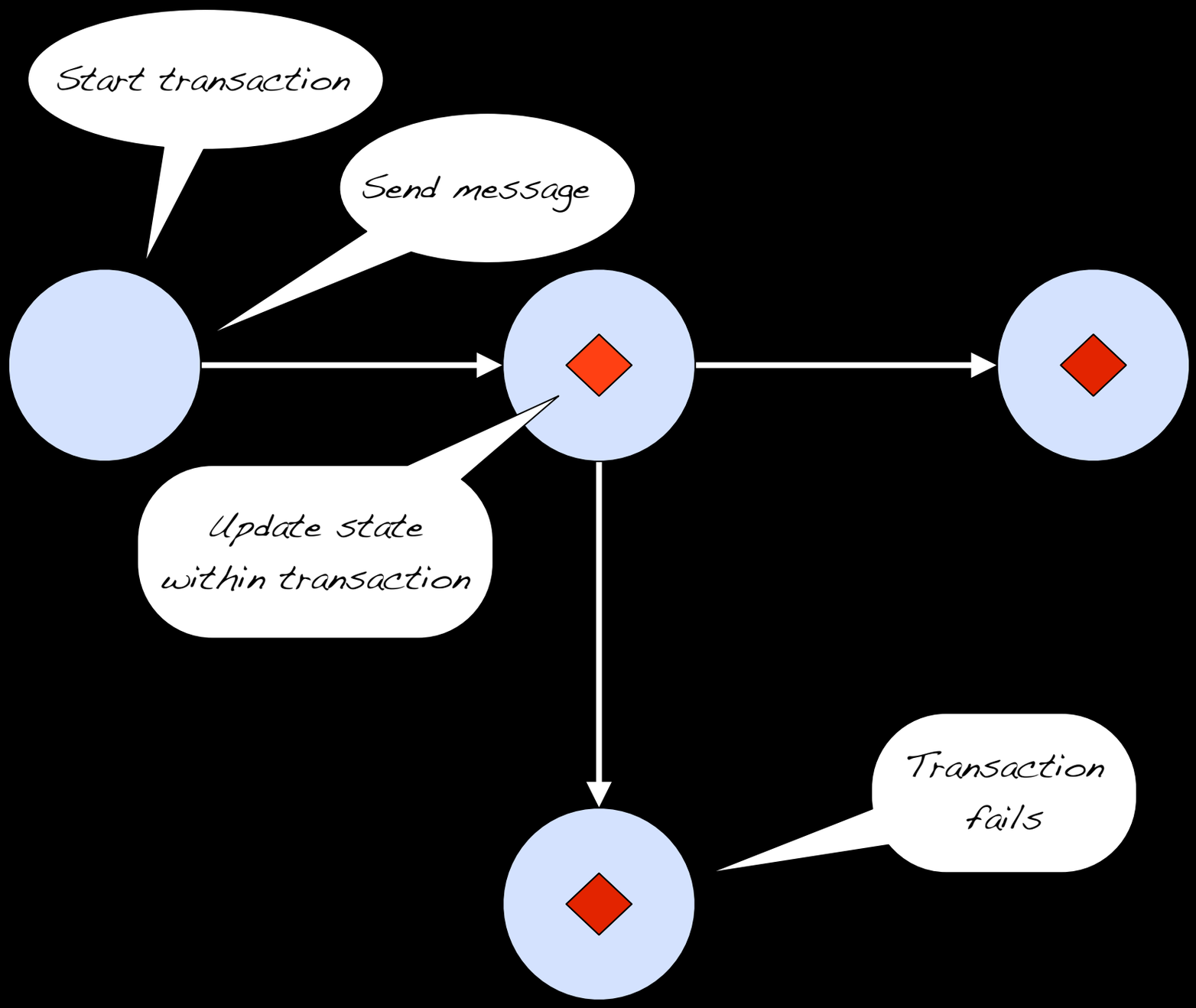

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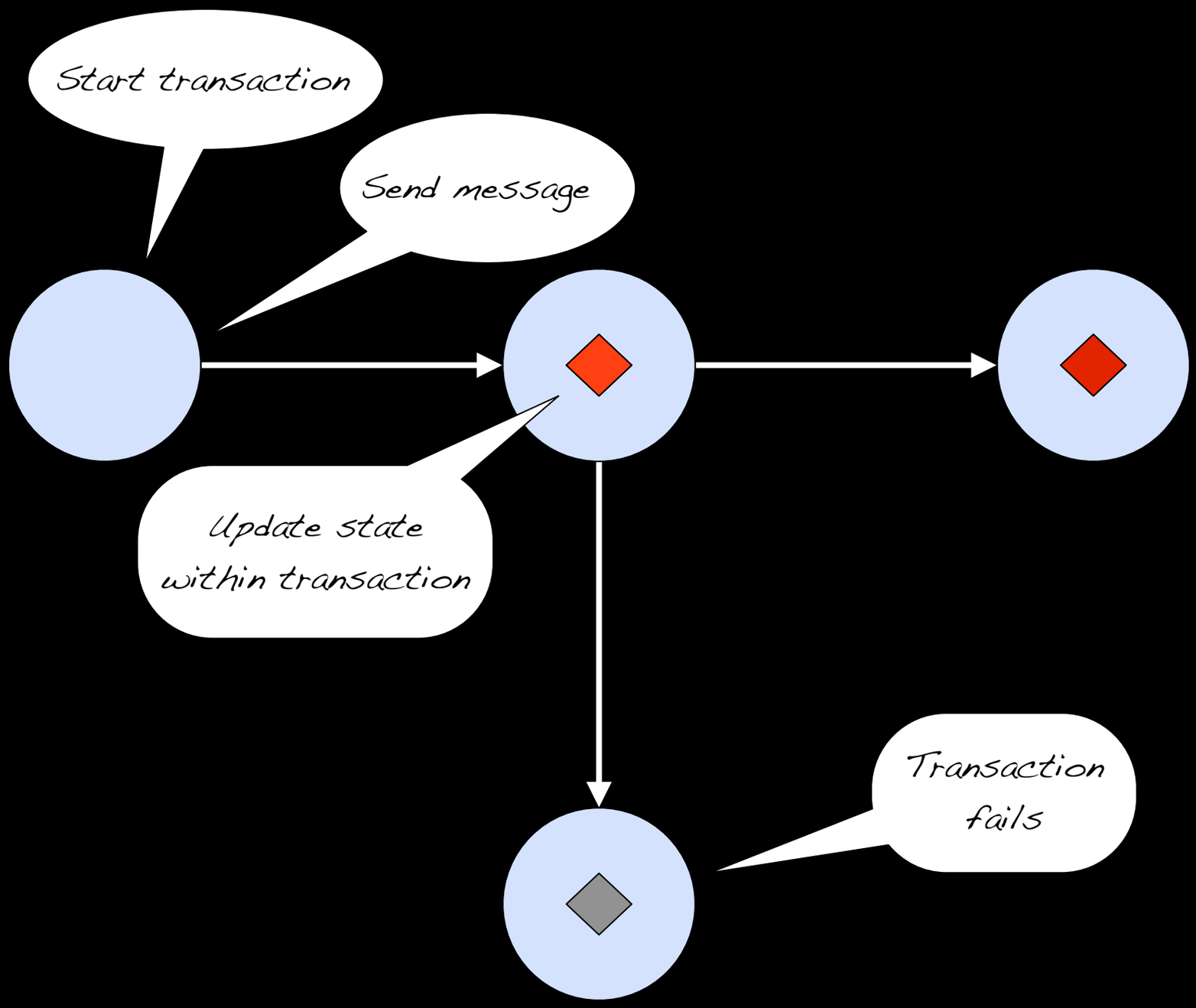

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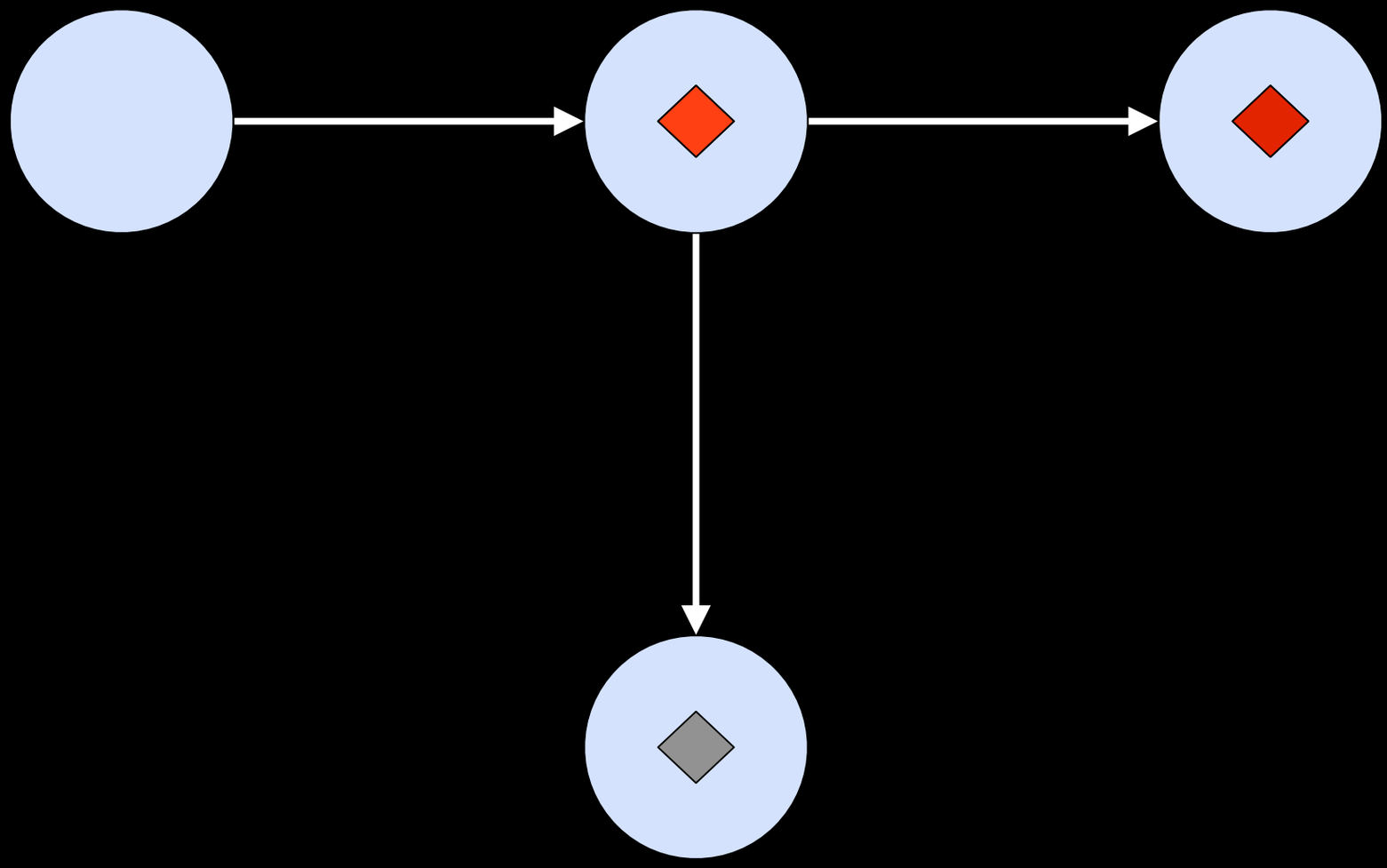

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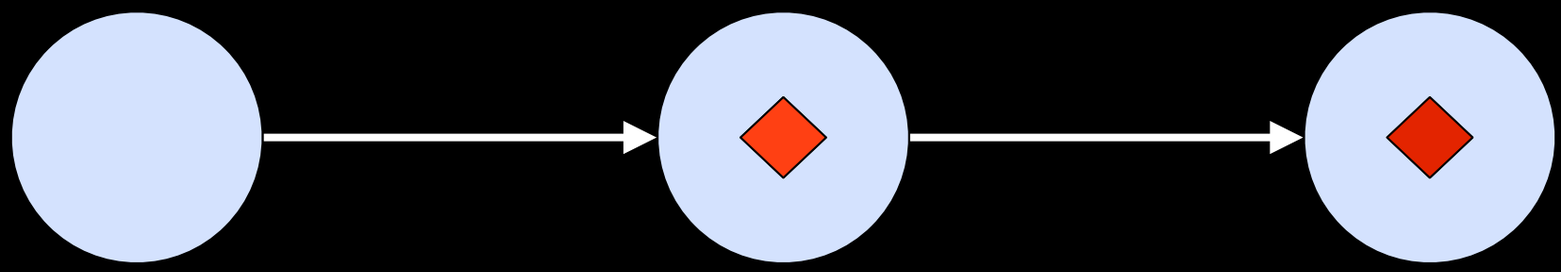

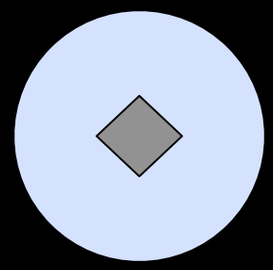

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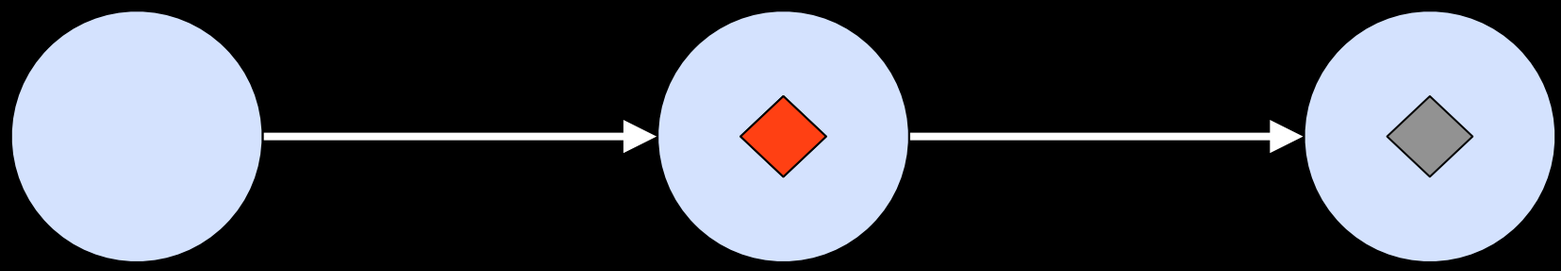

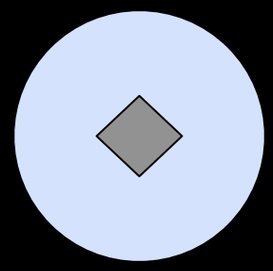

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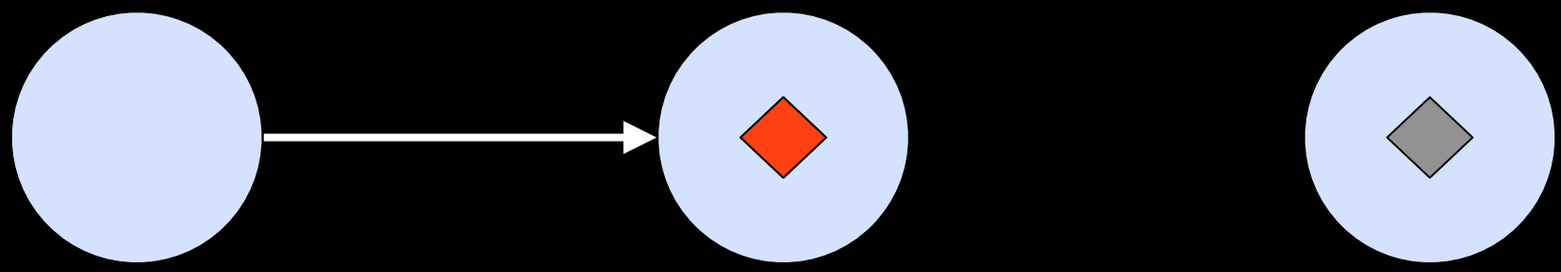

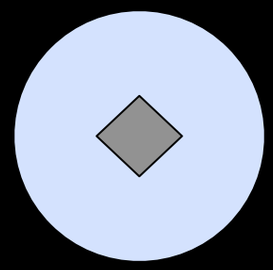

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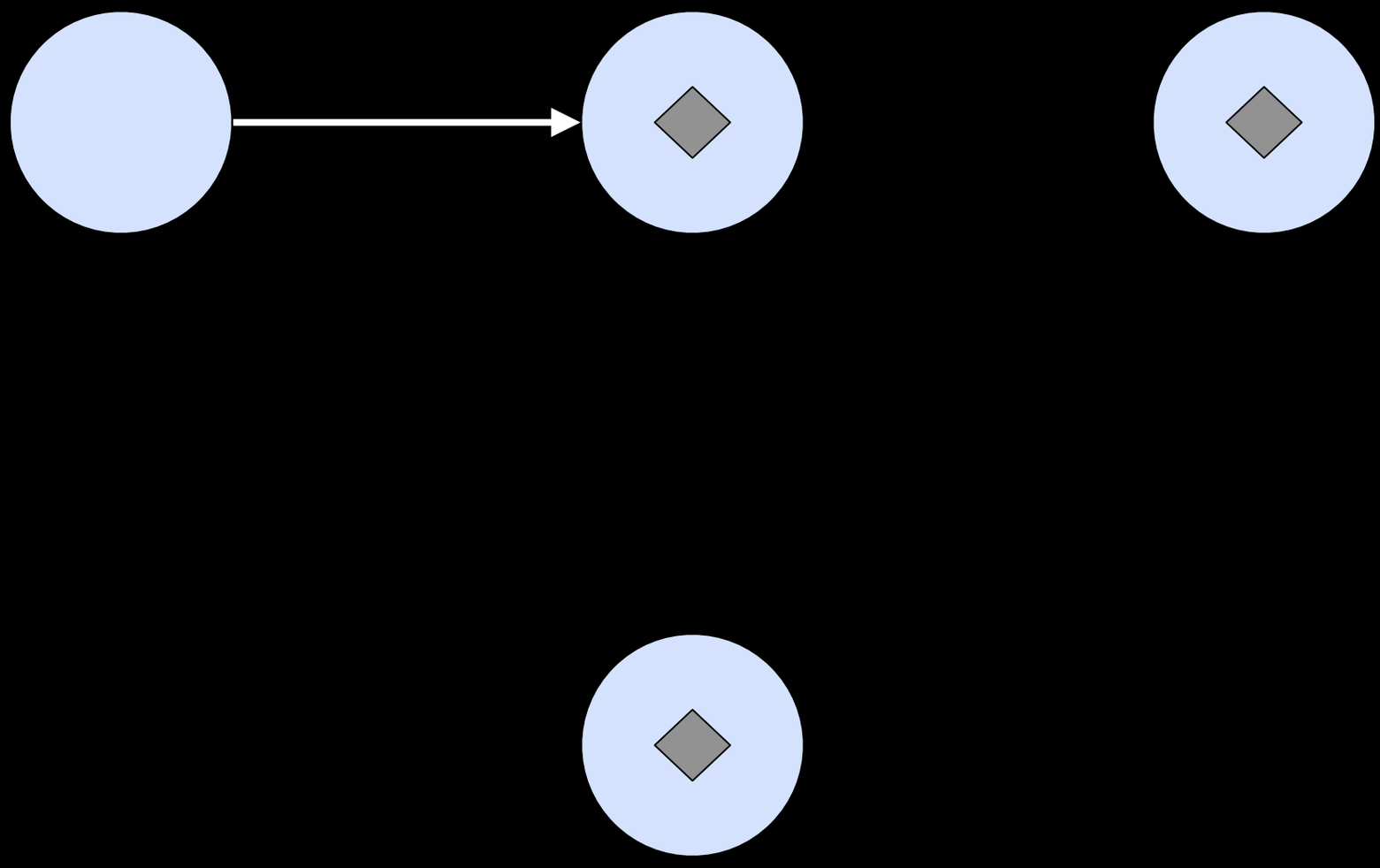

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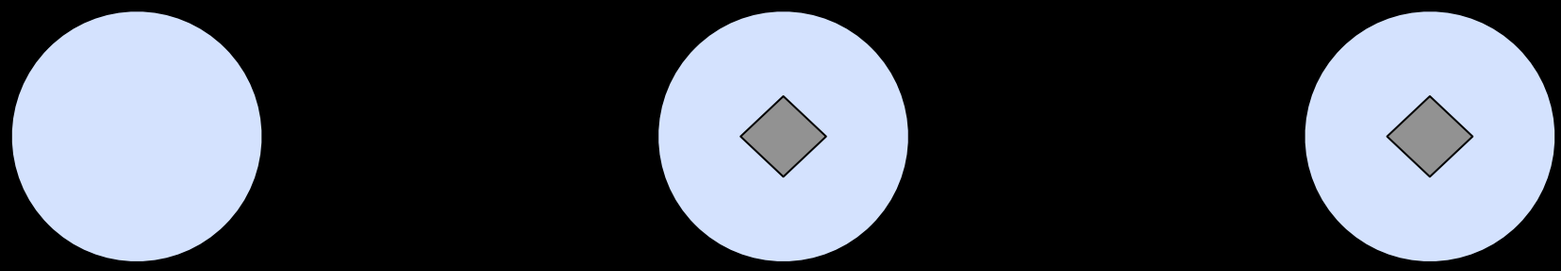
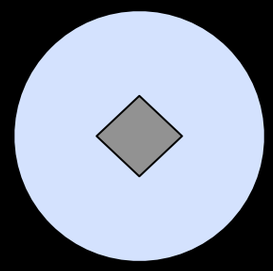
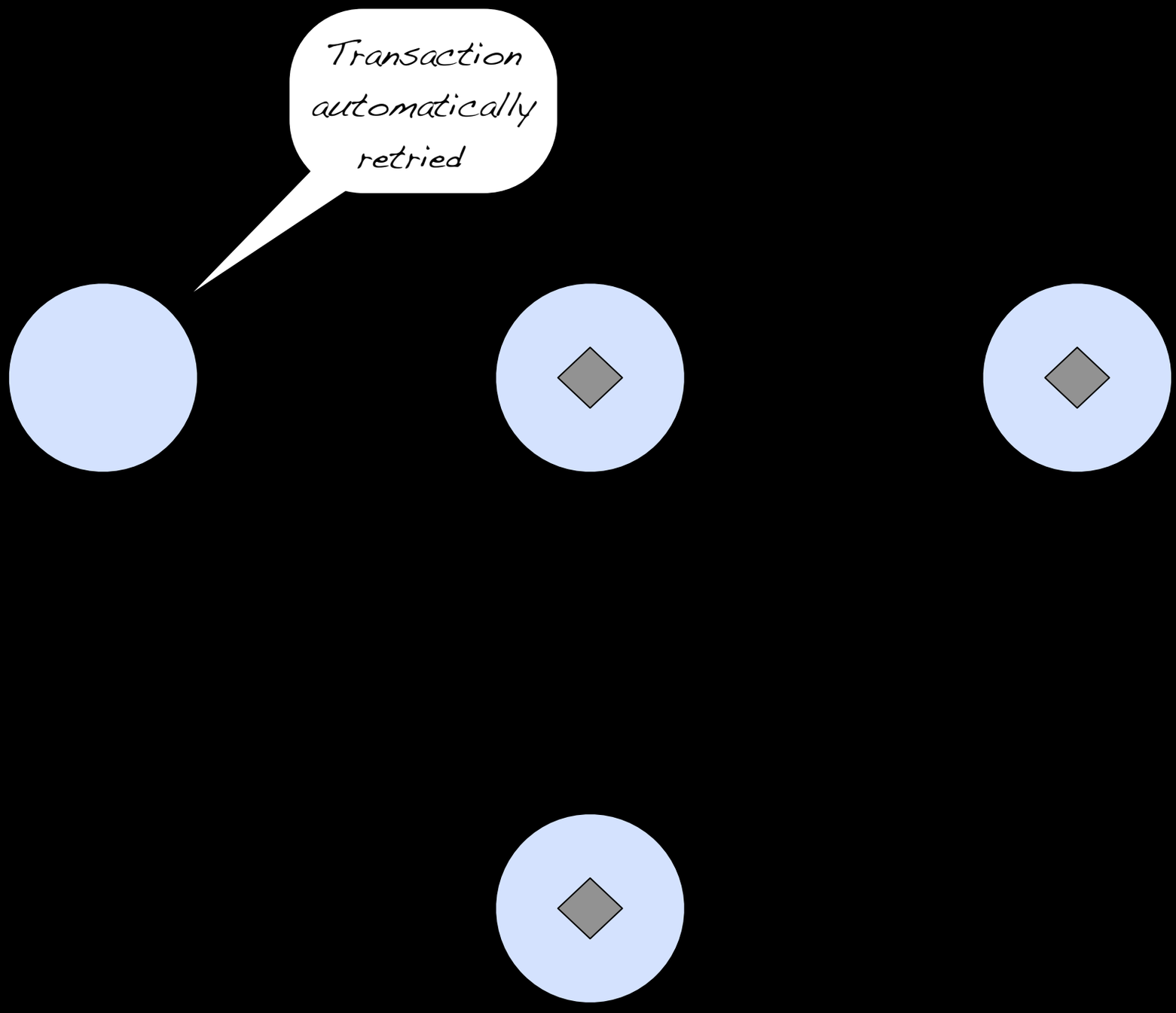




Transactors



REPL time!

Transactor Overview

- All the good from Actors
- All the good from STM
- Removes state update coordination issues from Actors
- Replaces Threads as the concurrency mechanism for STM

Transactor gotchas

- Non-transactional changes may occur if such code is called within a transaction
-

Summary

Threads and locks

are...

...sometimes

plain evil

It doesn't have to be like this

We need to raise the abstraction level

...but always the

wrong default

Introducing

STM Actors Agents

Dataflow Distributed Open Source

RESTful Secure Persistent

www.akkasource.com

http://github.com/viktorklang/transactors