PCPP: PRACTICAL CONCURRENT & PARALLEL PROGRAMMERING

MESSAGE PASSING CONCURRENCY II / II

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AGENDA

- 3) **Broadcast:**
  - From ERLANG to JAVA+AKKA
  - Communication protocols (one-to-one ⇒ one-to-many)
- **AKKA: A proper introduction**
  - Motivations and benefits of Actors & Message Passing
  - Recommendations
- 4) **Primer:**
  - Hierarchic organization: managers supervise workers
  - Performance: MacBook Air -vs- MTLab Server
- ★ **Scatter-Gather:**
  - Prototypical AKKA Service (dynamic load balancing)
  - Extensions...

5) ABC.erl

```
-module(helloworld).
-export([start/0,
         account/1,bank/0,clerk/0]).

%% -- BASIC PROCESSING -------------------
n2s(N) -> lists:flatten( %% int2string
   io_lib:format("~p", [N])). %% HACK!

random(N) -> random:uniform(N) div 10.

%% -- ACTORS ----------------------------

account(Balance) ->
   receive
      {deposit,Amount} ->
         account(Balance+Amount) ;
      {printbalance} ->
         io:fwrite(n2s(Balance) ++ "\n")
   end.

bank() ->
   receive
      {transfer,Amount,From,To} ->
         From ! {deposit,-Amount},
         To ! {deposit,+Amount},
         bank()
   end.
```

MANDATORY HAND-IN!

a) Color ABC.erl
(according to color convention):
send, **receive**, **msgs**
actors, **spawn**, **rest.**
(try 2 B as consistent as possible)

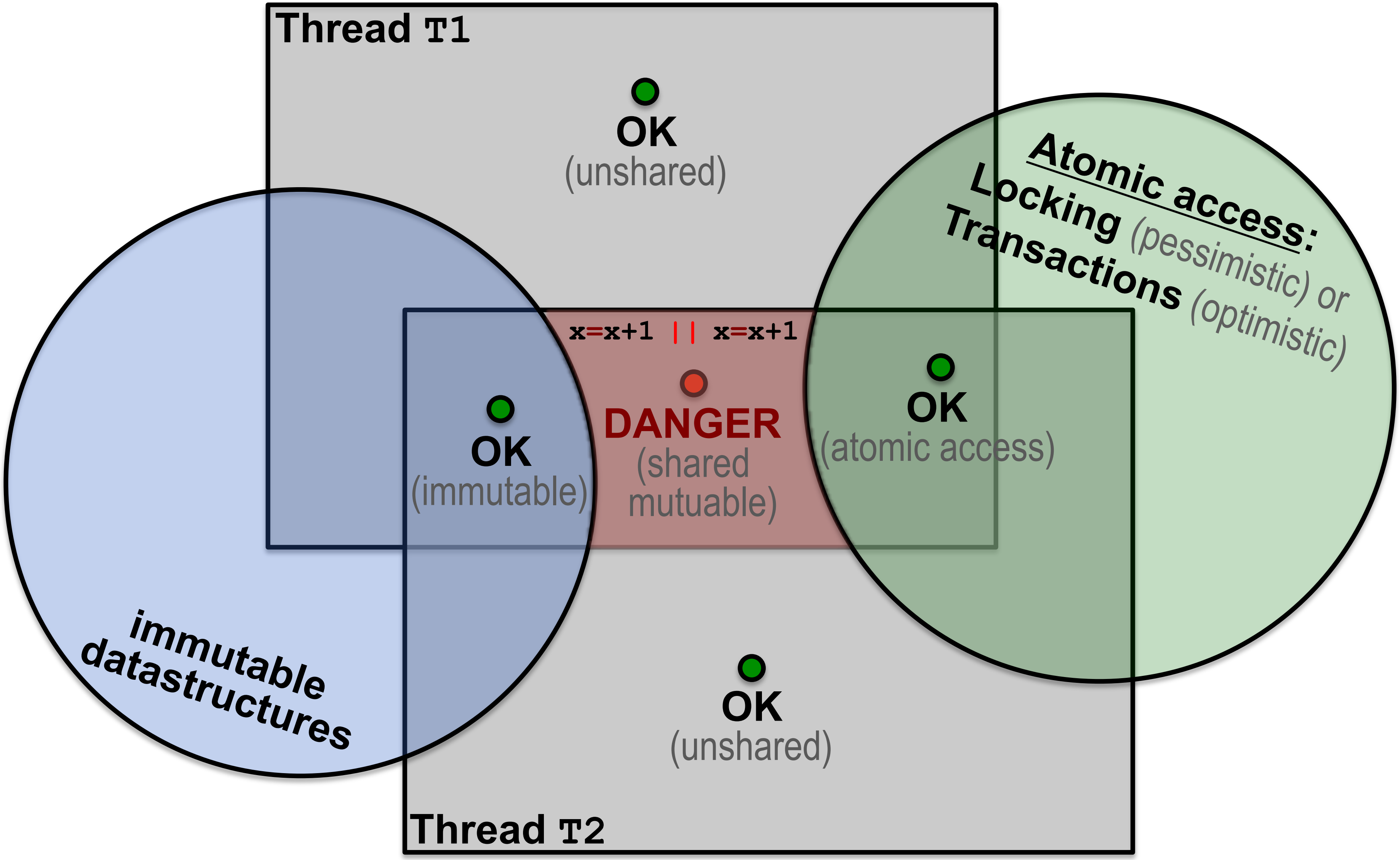
MOTIVATION:

1) Structure of ERLANG:
- **Syntax** (structure); then
- **Semantics** (meaning)

2) Discern linguistic aspects:
send, **receive**, **msgs**
actors, **spawn**, **rest.**

PROBLEMS:
Sharing && Mutability!

SOLUTIONS:
1) atomic access!
   locking or transactions
   (NB: avoid deadlock!)
2) avoid mutability!
3) avoid sharing...



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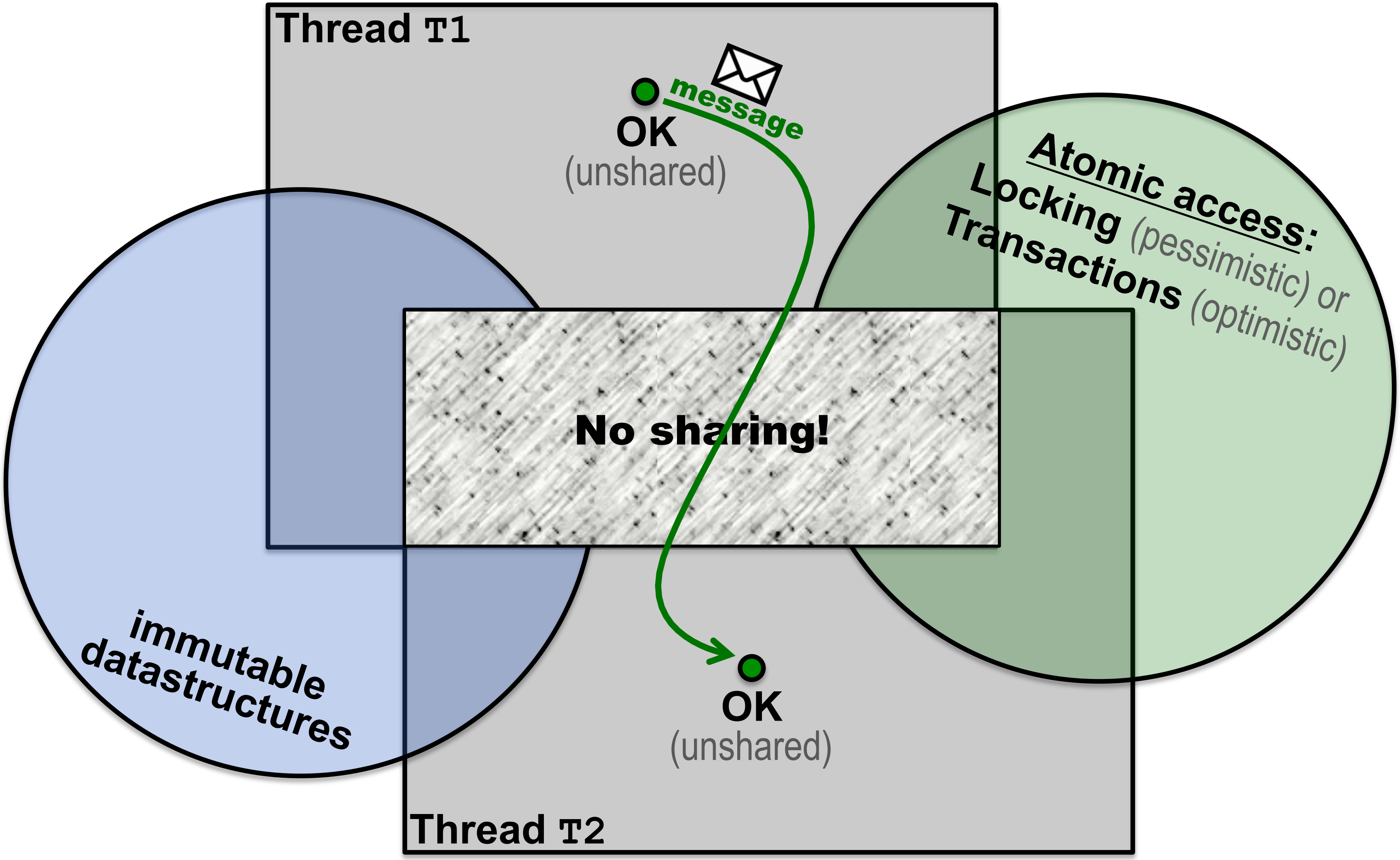
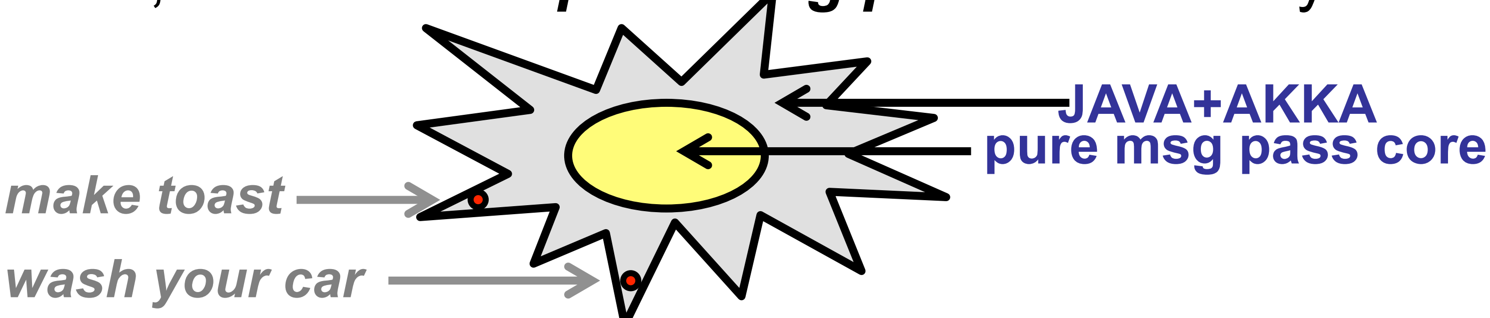


Philosophy & Expectations!

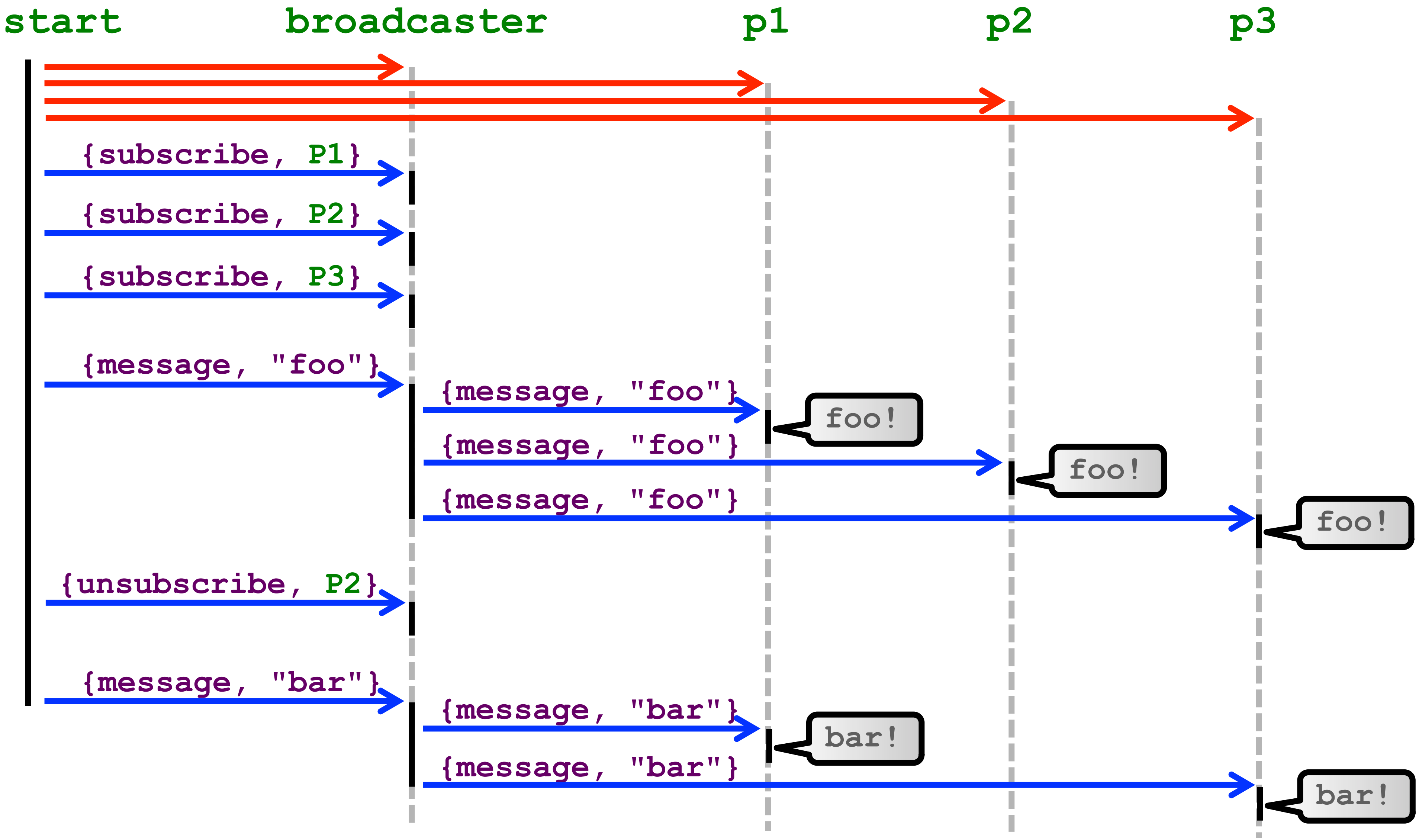
- **ERLANG:**
  - We'll use as message passing ***specification language***
  - You have to-be-able-to ***read*** simple **ERLANG** programs
    - (i.e., not ***write***, nor ***modify***)

- **JAVA+AKKA:**
  - We'll use as msg passing ***implementation language***
  - You have 2-b-a-2 ***read/write/modify*** **JAVA+AKKA** p's
  - However, we'll use its ***"pure msg pass core"*** only **!**

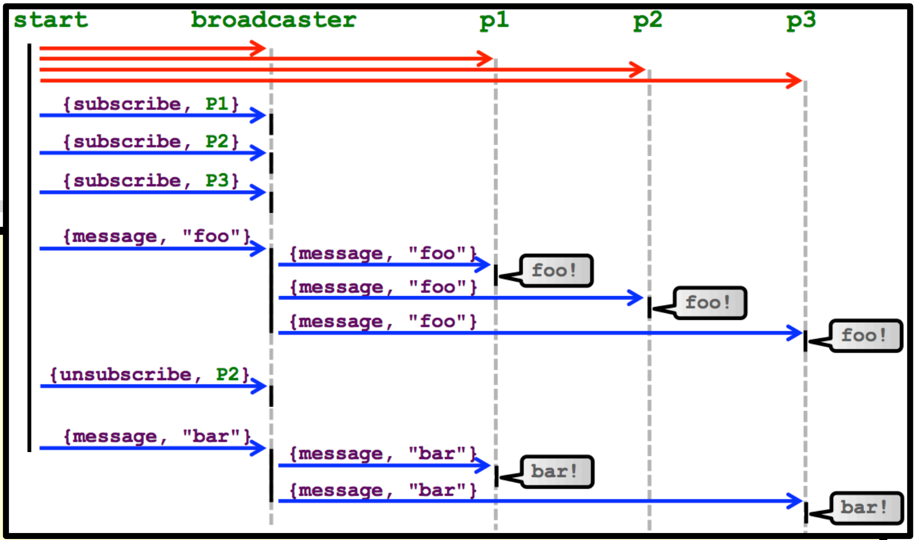
NB: we're **not** going to use all of its fantazilions of functions!



3) Broadcast


start
broadcaster
p1
p2
p3
{subscribe, P1}
{subscribe, P2}
{subscribe, P3}
{message, "foo"}
{message, "foo"}
foo!
{message, "foo"}
foo!
{message, "foo"}
foo!
{unsubscribe, P2}
{message, "bar"}
{message, "bar"}
bar!
{message, "bar"}
bar!

3) Broadcast.erl




```
-module(helloworld).
-export([start/0,person/0,broadcaster/1]).

person() ->
  receive
    {message,M} ->
       io:fwrite(M ++ "\n"),
       person()
  end.

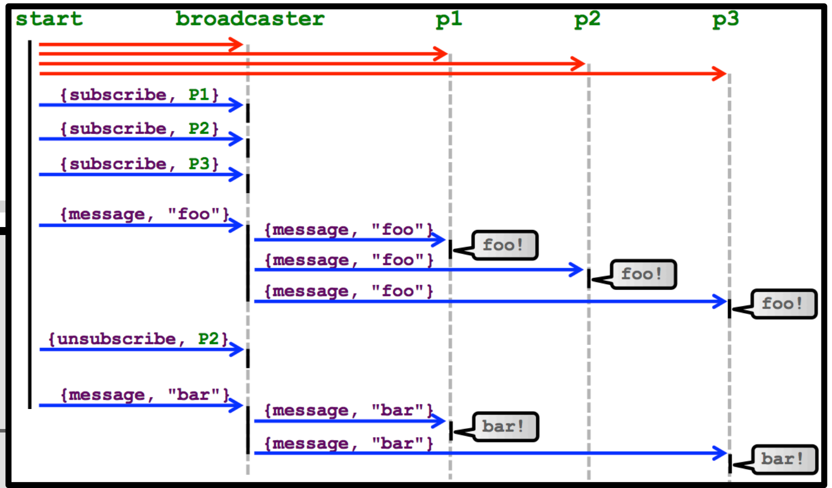
broadcast([],_) -> true;
broadcast([Pid|L],M) ->
   Pid ! {message,M},
   broadcast(L,M).

broadcaster(L) ->
   receive
      {subscribe,Pid} ->
         broadcaster([Pid|L]) ;
      {unsubscribe,Pid} ->
         broadcaster(lists:delete(Pid,L)) ;
      {message,M} ->
         broadcast(L,M),
         broadcaster(L)
   end.
```

```
start() ->
  Broadcaster = spawn(helloworld,broadcaster,[[]]),
  P1 = spawn(helloworld,person,[]),
  P2 = spawn(helloworld,person,[]),
  P3 = spawn(helloworld,person,[]),
  Broadcaster ! {subscribe,P1},
  Broadcaster ! {subscribe,P2},
  Broadcaster ! {subscribe,P3},
  Broadcaster ! {message,"Purses half price!"},
  Broadcaster ! {unsubscribe,P2},
  Broadcaster ! {message,"Shoes half price!!"}.
```

```
purses half price!
purses half price!
purses half price!
shoes half price!!
shoes half price!!
```

3) Broadcast.java




```
import java.util.*;
import java.io.*;
import akka.actor.*;

// -- MESSAGES -----------------------------------

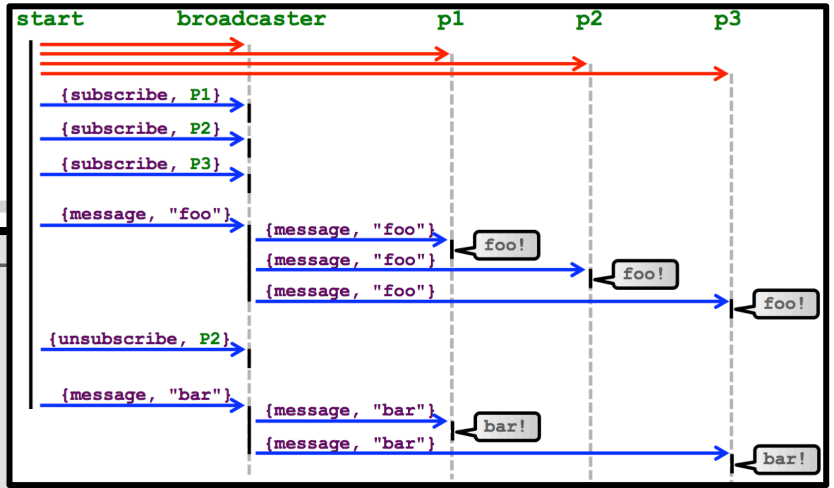
class SubscribeMessage implements Serializable {
    public final ActorRef subscriber;
    public SubscribeMessage(ActorRef subscriber) {
        this.subscriber = subscriber;
    }
}

class UnsubscribeMessage implements Serializable {
    public final ActorRef unsubscriber;
    public UnsubscribeMessage(ActorRef unsubscriber) {
        this.unsubscriber = unsubscriber;
    }
}

class Message implements Serializable {
    public final String s;
    public Message(String s) {
        this.s = s;
    }
}
```

```
purses half price!
purses half price!
purses half price!
shoes half price!!
shoes half price!!
```

3) Broadcast.java




```
// -- MAIN ----------------------------------

public class Broadcast {
    public static void main(String[] args) {
        final ActorSystem system =
            ActorSystem.create("BroadcastSystem");
        final ActorRef broadcaster =
            system.actorOf(Props.create(BroadcastActor.class), "broadcaster");
        final ActorRef p1 = system.actorOf(Props.create(PersonActor.class), "p1");
        final ActorRef p2 = system.actorOf(Props.create(PersonActor.class), "p2");
        final ActorRef p3 = system.actorOf(Props.create(PersonActor.class), "p3");
        broadcaster.tell(new SubscribeMessage(p1), ActorRef.noSender());
        broadcaster.tell(new SubscribeMessage(p2), ActorRef.noSender());
        broadcaster.tell(new SubscribeMessage(p3), ActorRef.noSender());
        broadcaster.tell(new Message("purses half price!"), ActorRef.noSender());
        broadcaster.tell(new UnsubscribeMessage(p2), ActorRef.noSender());
        broadcaster.tell(new Message("shoes half price!!"), ActorRef.noSender());
        try {
            System.out.println("Press retur
            System.in.read();
        } catch(IOException e) {
            e.printStackTrace();
        } finally {
            system.shutdown();
        }
    }
}
```

```
start() ->
  Broadcaster = spawn(helloworld,broadcaster,[[]]),
  P1 = spawn(helloworld,person,[]),
  P2 = spawn(helloworld,person,[]),
  P3 = spawn(helloworld,person,[]),
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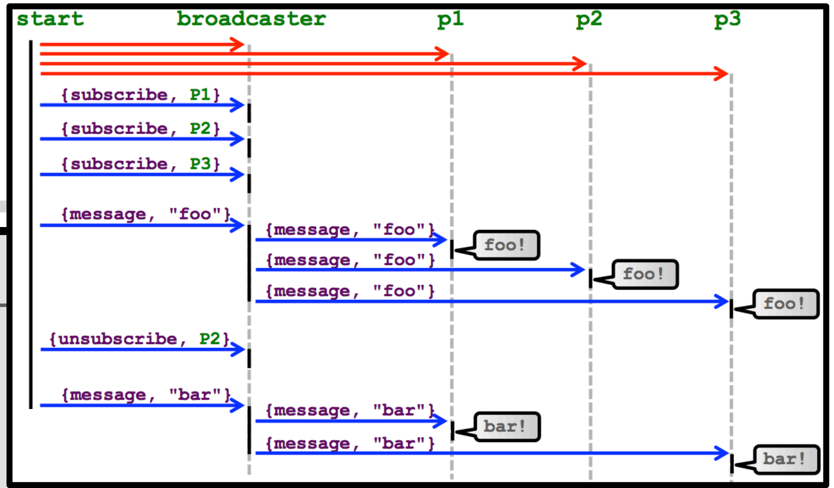


```
// -- ACTORS ---------------------------------

class PersonActor extends UntypedActor {
   public void onReceive(Object o) throws Exc' {
      if (o instanceof Message) {
         System.out.println(((Message) o).s);
      }
   }
}

class BroadcastActor extends UntypedActor {
   private List<ActorRef> list =
      new ArrayList<ActorRef>();

   public void onReceive(Object o) throws Exception {
      if (o instanceof SubscribeMessage) {
         list.add(((SubscribeMessage) o).subscriber);
      } else if (o instanceof UnsubscribeMessage) {
         list.remove(((UnsubscribeMessage) o).unsubscriber);
      } else if (o instanceof Message) {
         for (ActorRef person : list) {
            person.tell(o, getSelf());
         }
      }
   }
}
```

```
person() ->
  receive
    {message,M} ->
      io:fwrite(M ++ "\n"),
      person()
  end.
```

```
broadcast([],_) -> true;
broadcast([Pid|L],M) ->
  Pid ! {message,M},
  broadcast(L,M).

broadcaster(L) ->
  receive
    {subscribe,Pid} ->
      broadcaster([Pid|L]) ;
    {unsubscribe,Pid} ->
      broadcaster( L \ Pid ) ;
    {message,M} ->
      broadcast(L,M),
      broadcaster(L)
  end.
```

3) Broadcast.java

- Compile:

```
javac -cp scala.jar:akka-actor.jar Broadcast.java
```

- Run:

```
java -cp scala.jar:akka-actor.jar:akka-config.jar:. Broadcast
```

- Output:

```
purses half price!
purses half price!
purses half price!
shoes half price!!
shoes half price!!
```

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AKKA

- **Mountain in Sweden:**
  - Northern Sweden
  - (Close to Norway)

- **Nordic Goddesses: "Àhkkas"**
  - From Nordic/Arctic/Saami Mythology
  - The Àhkkas: daughters of Mother Sun
  - Ancient creator goddesses of the past

- **Software runtime middleware:**
  - For **Java Virtual Machine** (made in Scala)

akka

TDC
Telefonica
CSC
htc quietly brilliant
hp
BLIZZARD ENTERTAINMENT
UBS
SIEMENS
amazon.com
KLOUT
W3C®
HSBC
CISCO
HUAWEI
banksimple
svt
Autodesk
CREDIT SUISSE
IGN
AtoS
O2
vmware
dialog Smart Stream Platform
SEVEN Networks
xerox
UNIBET
DRW TRADING GROUP
OOYALA
novus
BBC
navirec
T8 Webware
CARTOMAPIC
moshi monsters
JUNIPER NETWORKS
ngmoco:)
Maritime Poker
Answers.com The world's leading Q&A site
azavea
zeebox The best thing to happen to TV since TV

Why the Sudden Popularity?!?

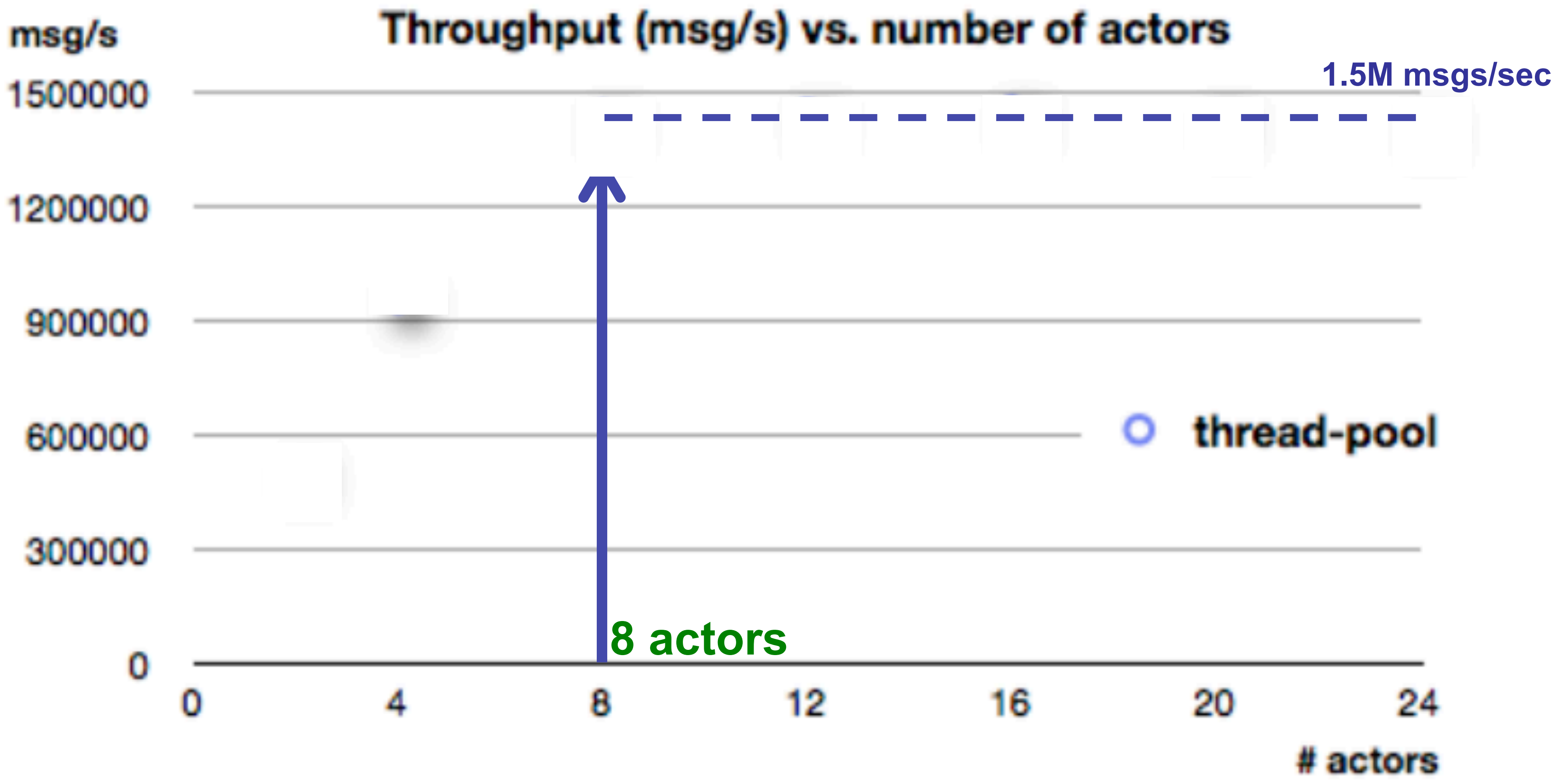
- Recently, processor speed "hit the wall":
  - Speed of light: $c = 3 \cdot 10^8$ m/s (meters per sec)
  - Processor speed: $s = 3 \cdot 10^9$ x/s (instructions per sec)
    - $c/s = (3 \cdot 10^8 \text{m/s} / 3 \cdot 10^9 \text{x/s}) = 0.1$ m/x (meters per instruction)
    - *i.e.*, ***"light travels 10cm per instruction"***
- **Before** (more speed)**:**
  - **Moore's Law:** #Transistors-per-CPU double**s** every 1.8 years
  - **Dennard Scaling:** Performance-per-Watt doubled every 1.57 years
- **Now** (more speed)**:**
  - We have to ***increase parallelism !***
  - Recent developments: ***"Work Stealing Queue"***

used for: managing the actors effectively

Chase and Lev: ***"Dynamic Circular Work-Stealing Queue"***, SPAA **2005**
Michael, Vechev, Saraswat: ***"Idempotent Work Stealing"***, PPoPP **2009**

Scalability? :-(

- Using a conventional "Thread Pool Executor":



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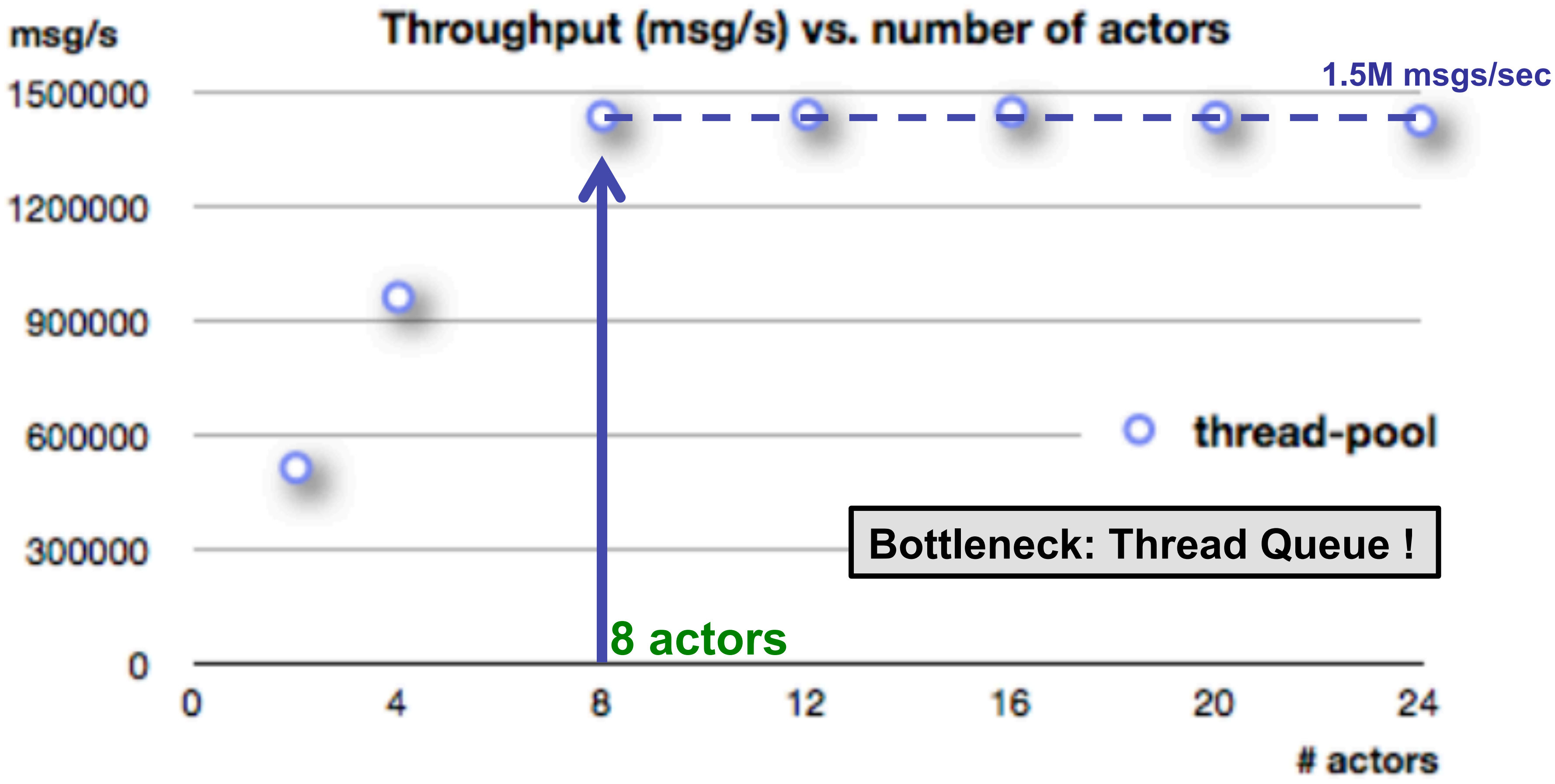

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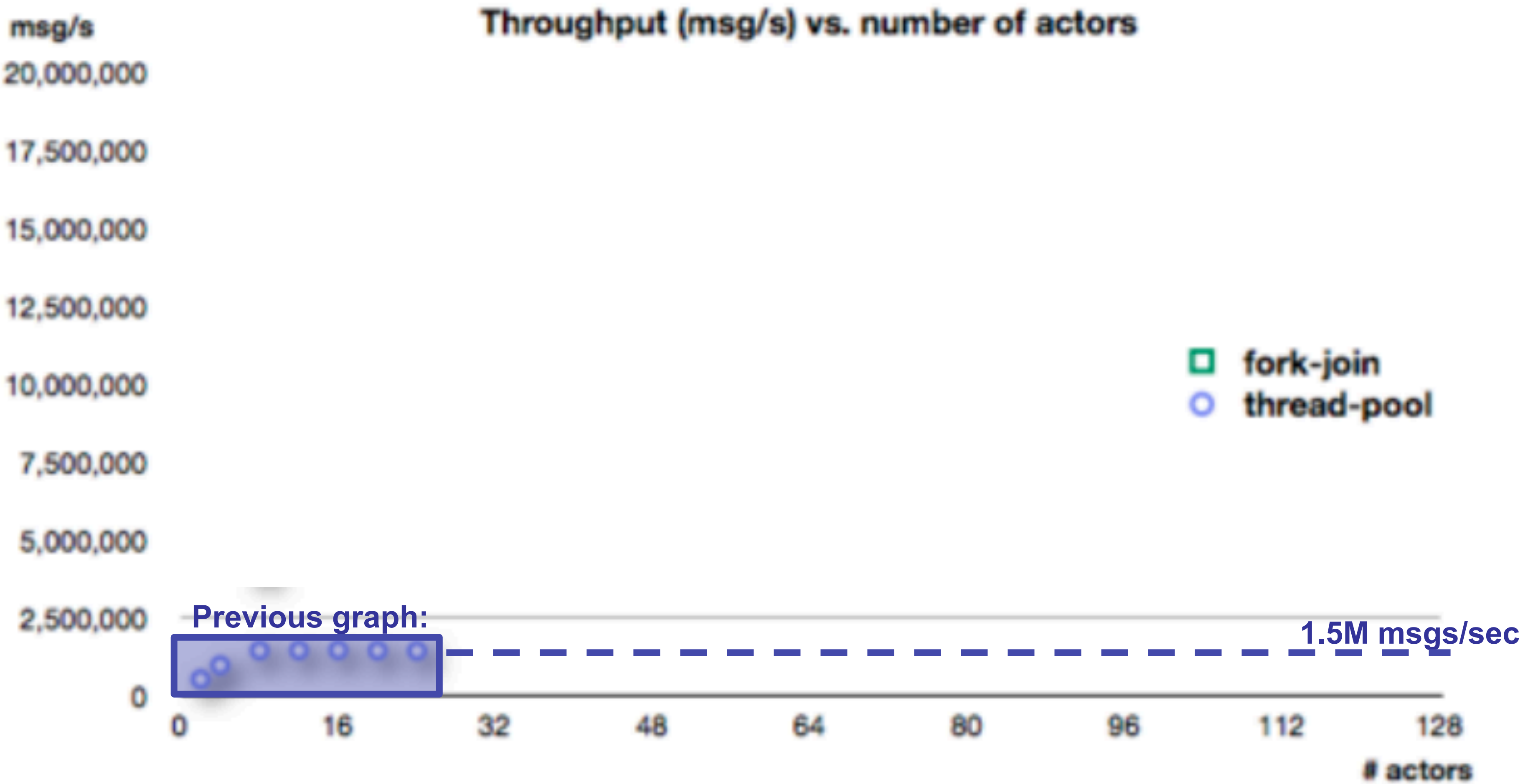
Scalability!

- Java 8's New Fork Join Pool (Work Stealing):



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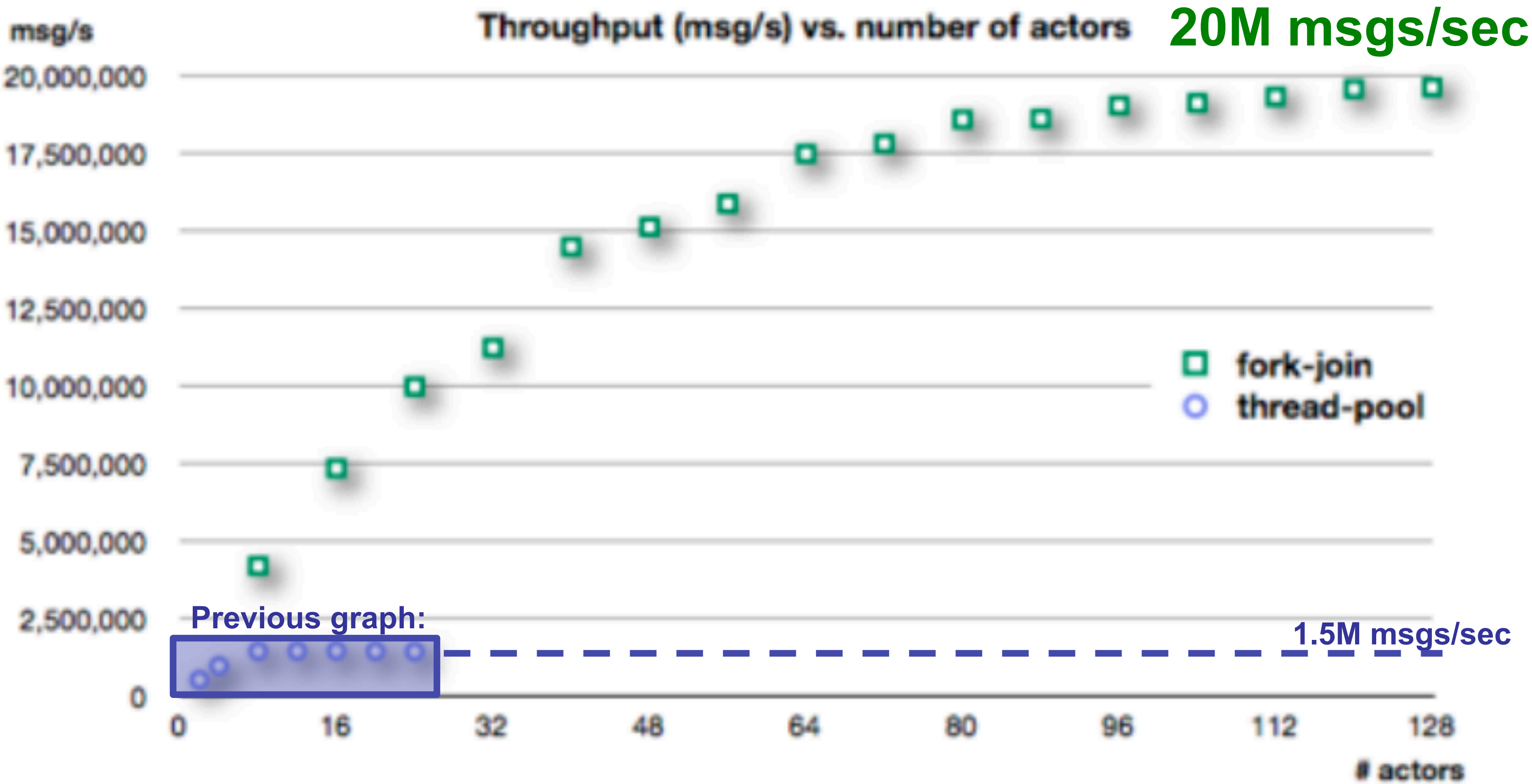

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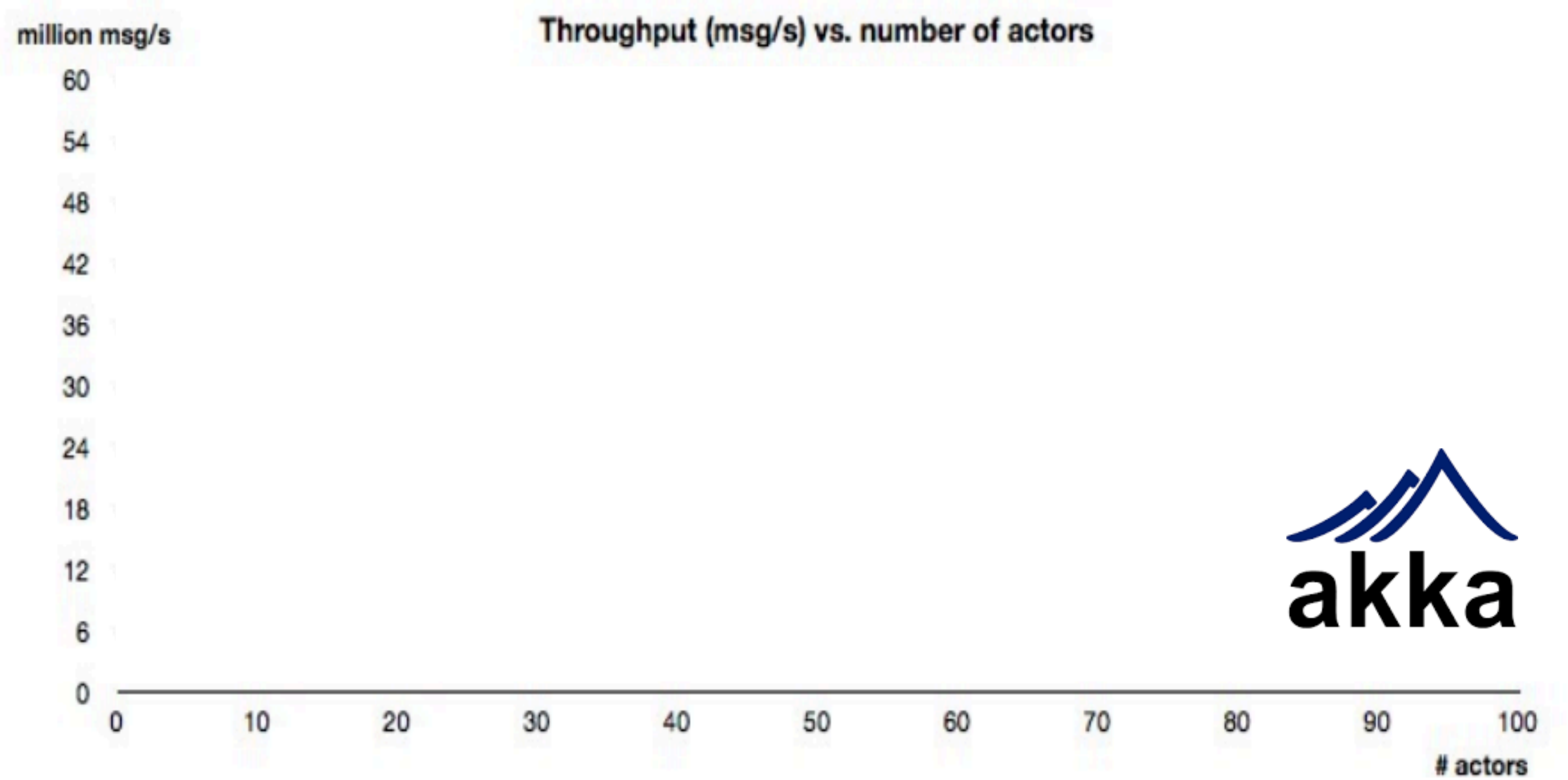
Scalability! :-)

- ...and after optimizing for throughput:



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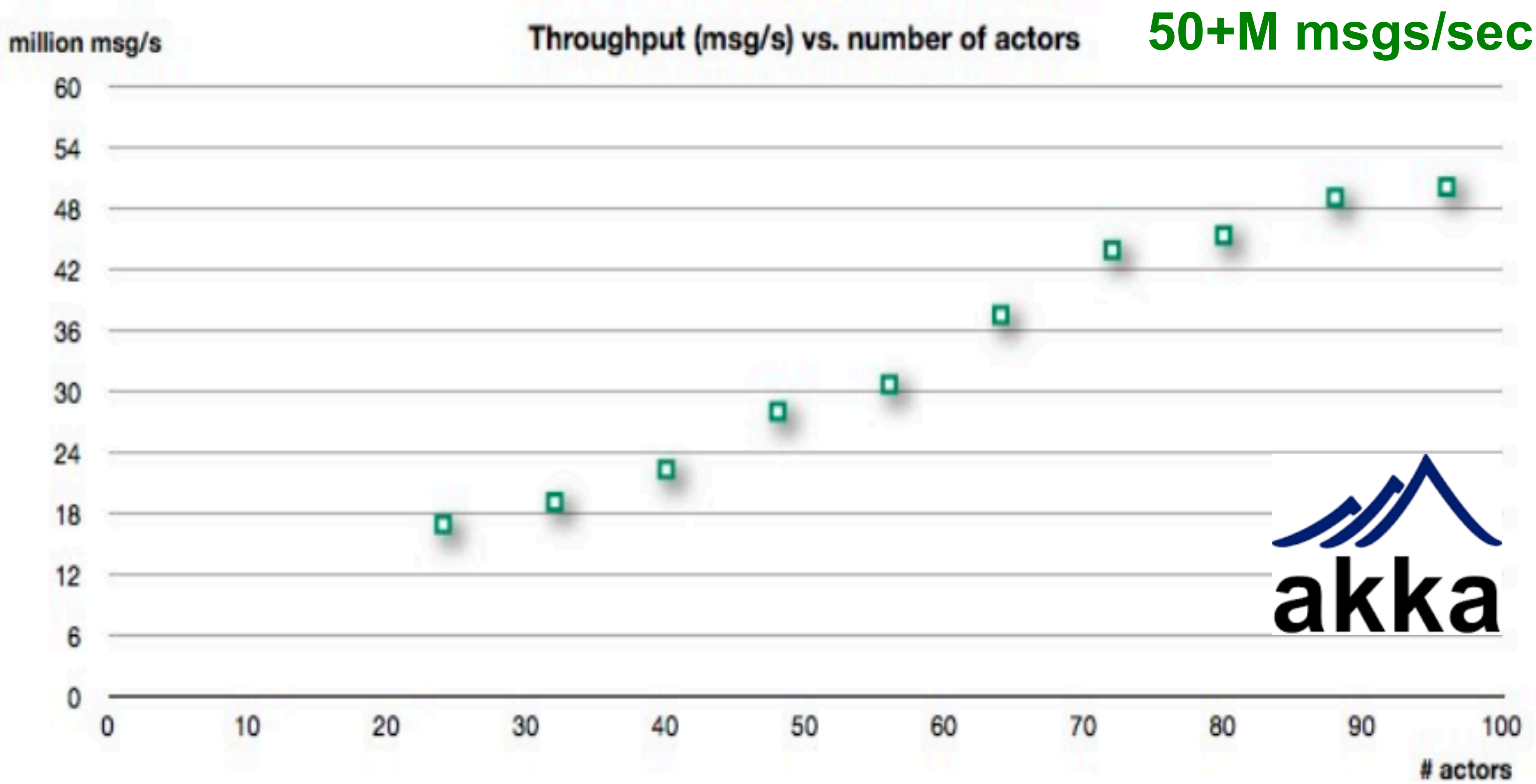

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An Actor is...:

- A fundamental ***unit of computation*** that embodies:
  - 1) **Processing**
  - 2) **State**
  - 3) **Communication**

- **In particular: no shared && mutable state!**

- When an actor receives a message, it can...:
  - 1) **perform computation**
  - 2) **change state**
  - 3) **send messages to actors it knows**
  - 4) **spawn new actors**

Actors & Msg Passing: Benefits

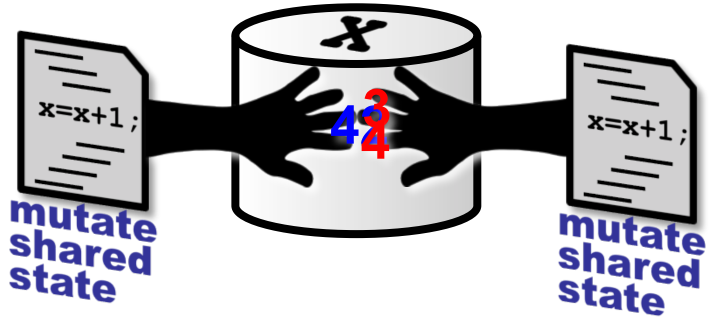
- **Correct highly concurrent systems:**
  - Higher level abstraction (via message passing)
    - coordination (declarative/what) ≠ business logic (imperative/how)
  - No low-level locking (no shared && mutable state)
- **Truly scalable systems:**
  - Actors are extremely lightweight entities
  - Actors are location transparent
  - Distributable-by-design
  - Transparently map MP programs onto given hardware:
    - "Scale up" (more processors), "Scale out" (more machines)
- **Self-healing, fault-tolerant systems:**
  - Adaptive load balancing and actor migration
  - "Let it crash" model (deal w/ failure, great succes in telecom industry)
  - Manage system overload (graceful service degradation)

Actors & Msg Passing: Drawbacks

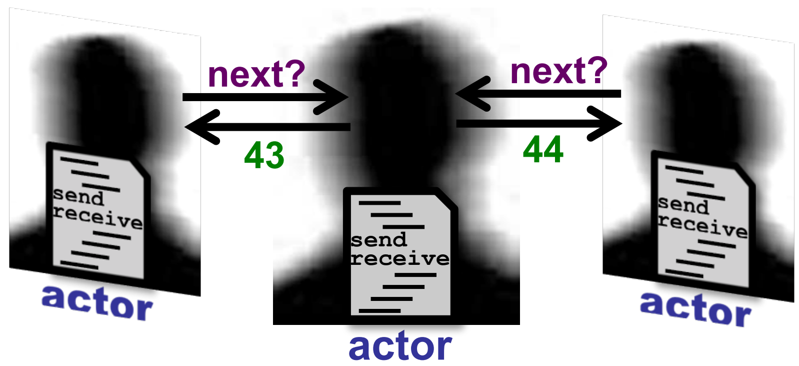
- **New/different paradigm:**
  - Many programmers unfamiliar with message passing
- **Overhead of (high level) message passing:**
  - Overhead of sending messages:
    - Less efficient than shared && mutable state
  - (analogy: expl memory allocation vs garbage collection)
- **The Correlation problem:** [exemplified...]**:**
  - A --favorite-fruit?--> B ; A --favorite-color?--> B;
  - B --orange!--> A (correlate response with request?!?)
- **Hard to identify global state properties:**
  - i.e., computing: `f(global-state)`:
    - e.g., termination condition of a distributed algorithm

The People Metaphor

- **Shared Mutable state:**
  - Concurrency problems!
    - **Shared && mutable !**
  - Hard to (later) distribute!



- **Actors** **(with encapulated state):**
  - Can't "look inside head" of a living person (actor) !
  - Instead: **ask questions ?**
  - ...and **get responses !**
  - **...one at a time !**



The People Metaphor (cont'd)

- **Programming Metaphor:**
  - "The People Analogy"

- Think of it as **"coordinating lots of people"**:
  - Each can do simple tasks
  - Consider workflow (of orders/messages in your system)

The People Metaphor (cont'd)

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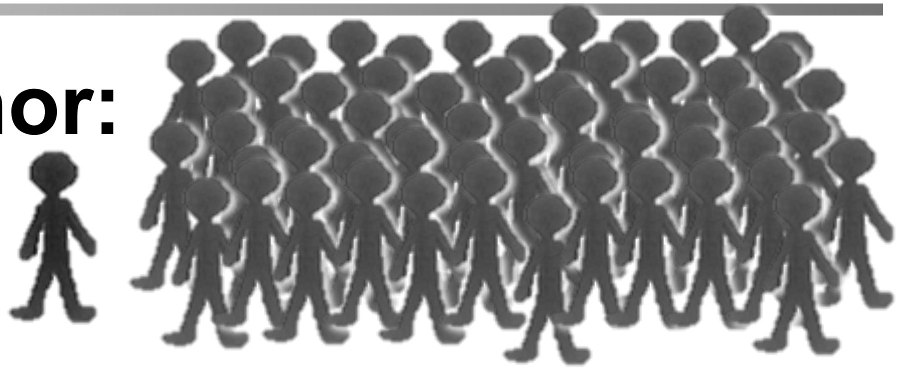

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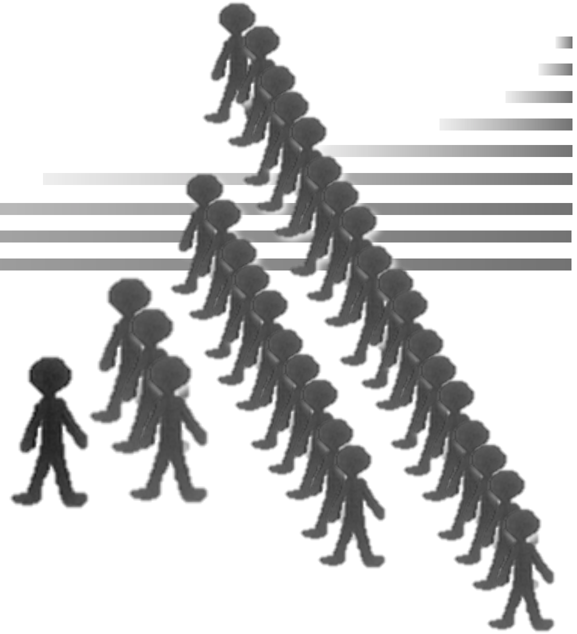

- **Programming Metaphor:**
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- Think of it as **"coordinating lots of people":**
  - Each can do simple tasks
  - Consider workflow (of orders/messages in your system)
  - Need more work ⇒ hire more people **(spawn more actors)**
  - Hierarchic organization: managers supervise workers
  - Fault tolerance (expect failures and deal with them)

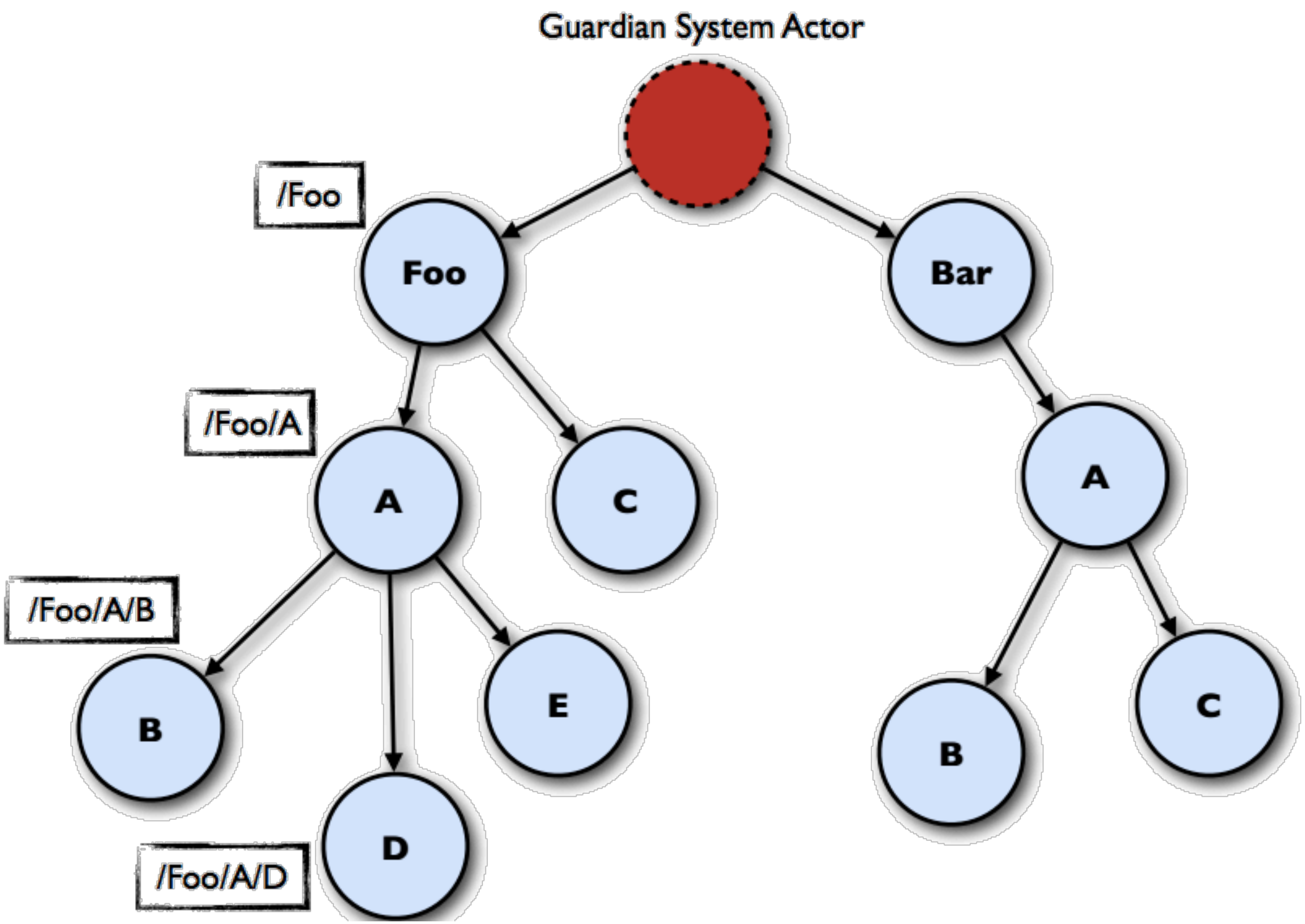
Recommendations

- 1) **Actors should be like nice co-workers:**
  - do their job effectively w/o bothering others needlessly
  - should not roll thumbs (idle or blocking operations)
- 2) **Actors should not send mutable objects:**
  - O/w we're back to "shared && mutable" ⇒ problems !
- 3) **Actors should send data, not programs:**
  - O/w we're back to "shared && mutable" ⇒ problems !
  - (Note: ERLANG does not have higher-order functions)
- 4) **Create few top-level actors:**
  - If these crash, your whole system will crash
  - If their workers die, they just hire (spawn) new ones

Recommendations

- 5) **Managers should supervise Workers:**
  - organization as a hierarchy
  - pass on and schedule tasks for workers
  - "hire" (spawn) more workers by need
  - deal with failure (of your workers)
- 6) **Actors should spawn workers for "dangerous operations"** (Qatar 2022 ?)**:**
  - avoid crashing with important data
  - spawn workers for "dangerous operations"
  - deal with failure (of your workers)

A Hierarchy of Actors



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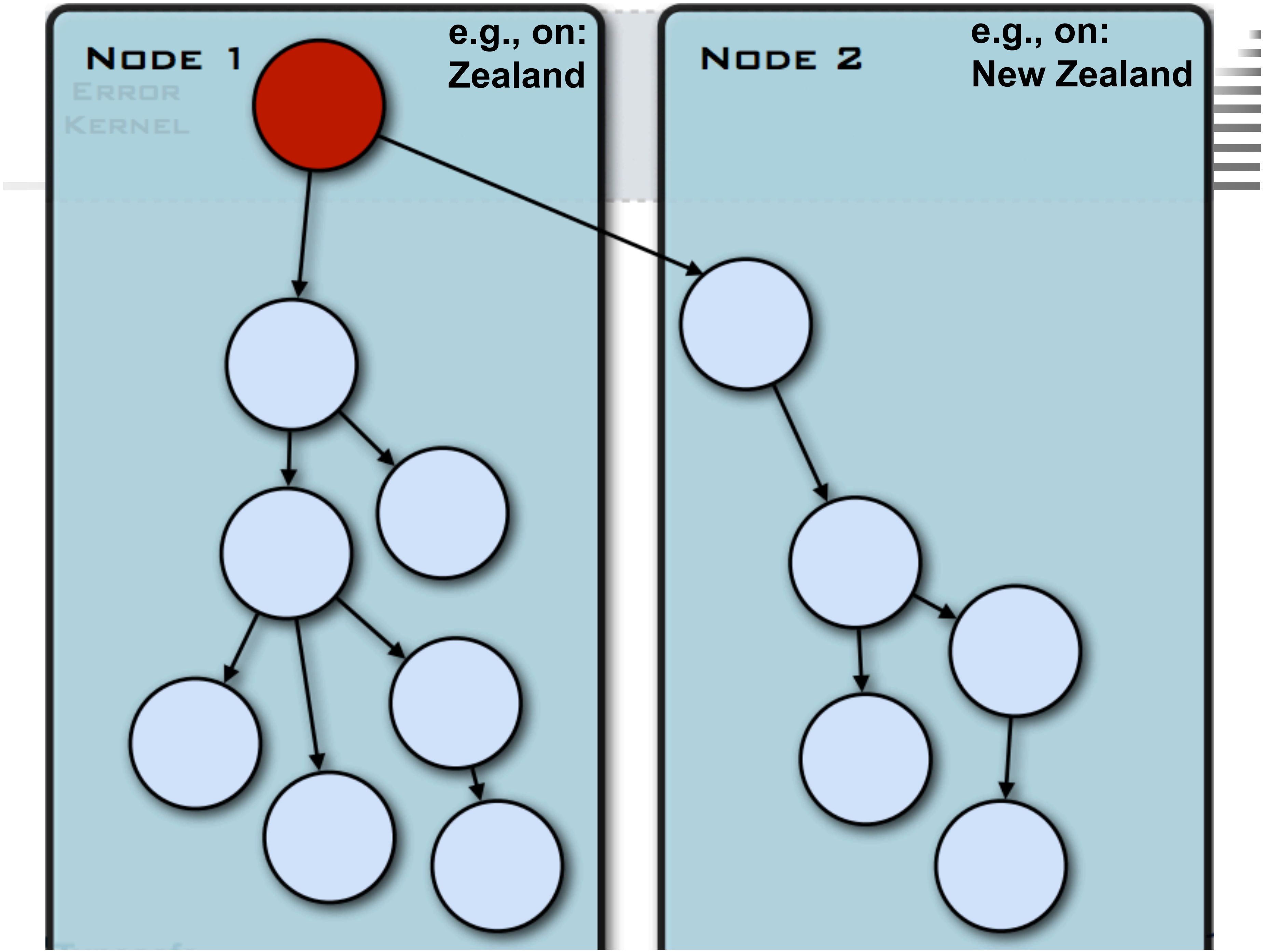

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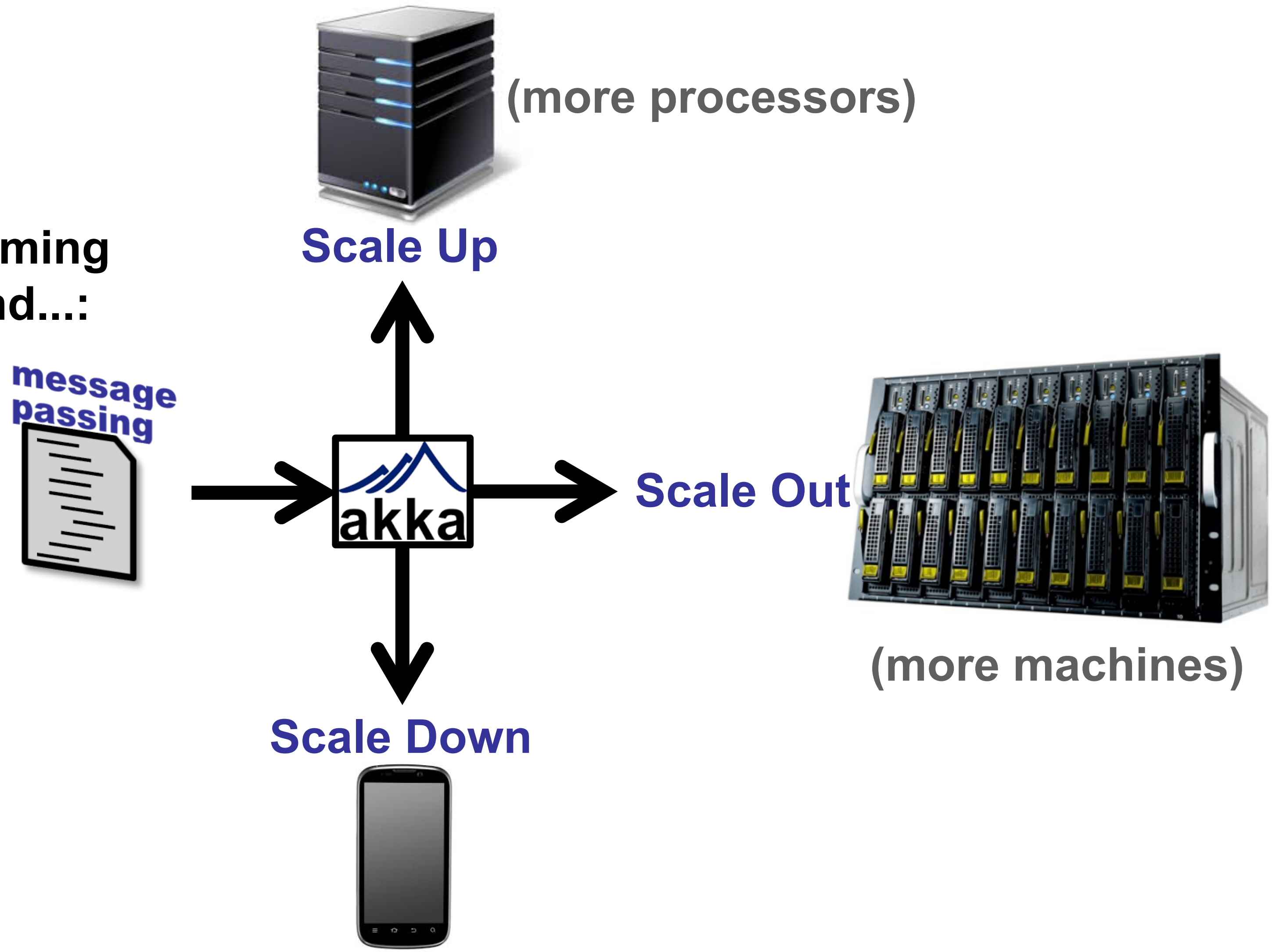
Scale Down, Scale Up, Scale Out

When programming with actors and...:



Fault Tolerance

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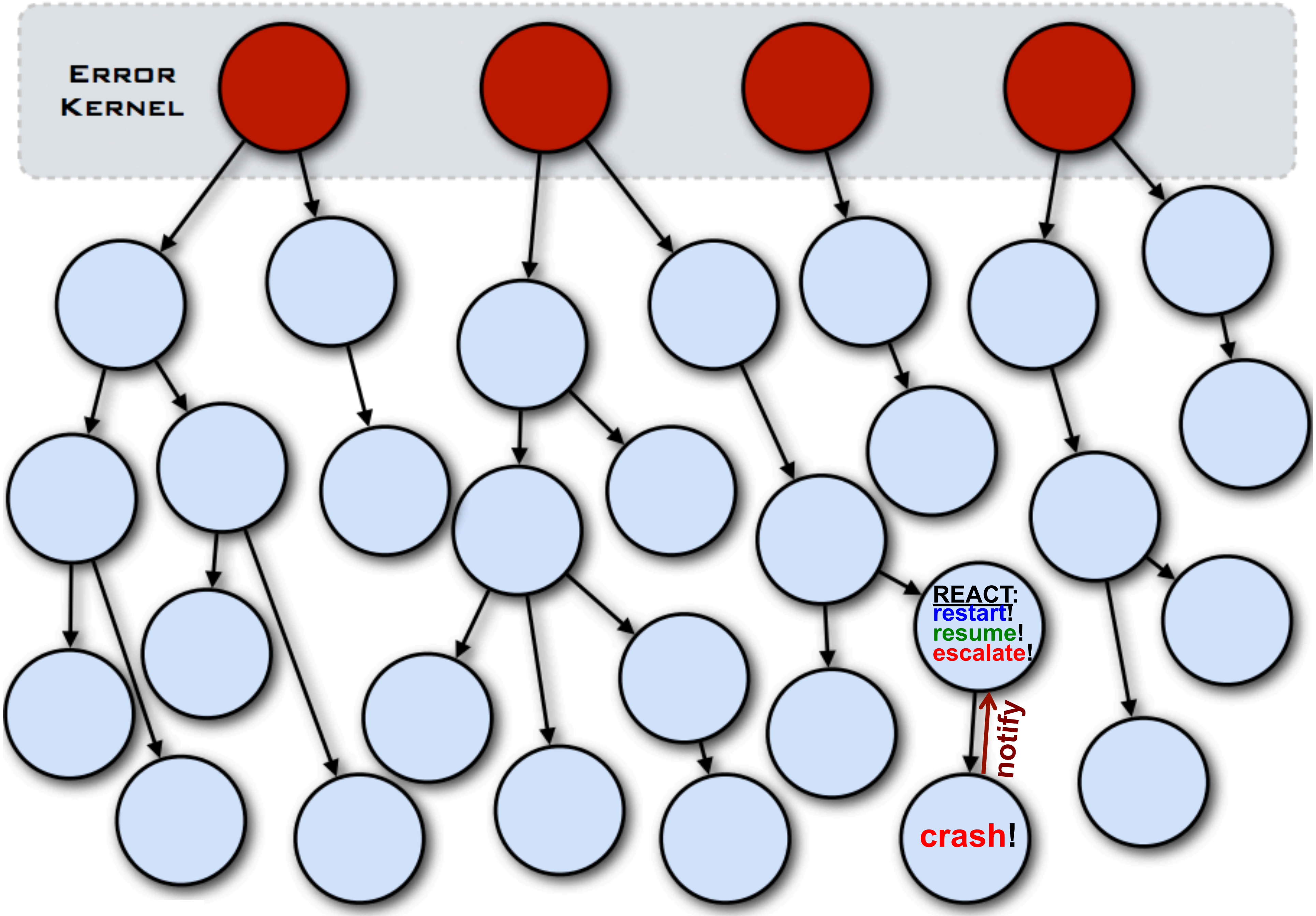

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4) Primer

Let's assume...:
FAST message passing,
SLOW i/o and CPU
Q: Which ## output order ??

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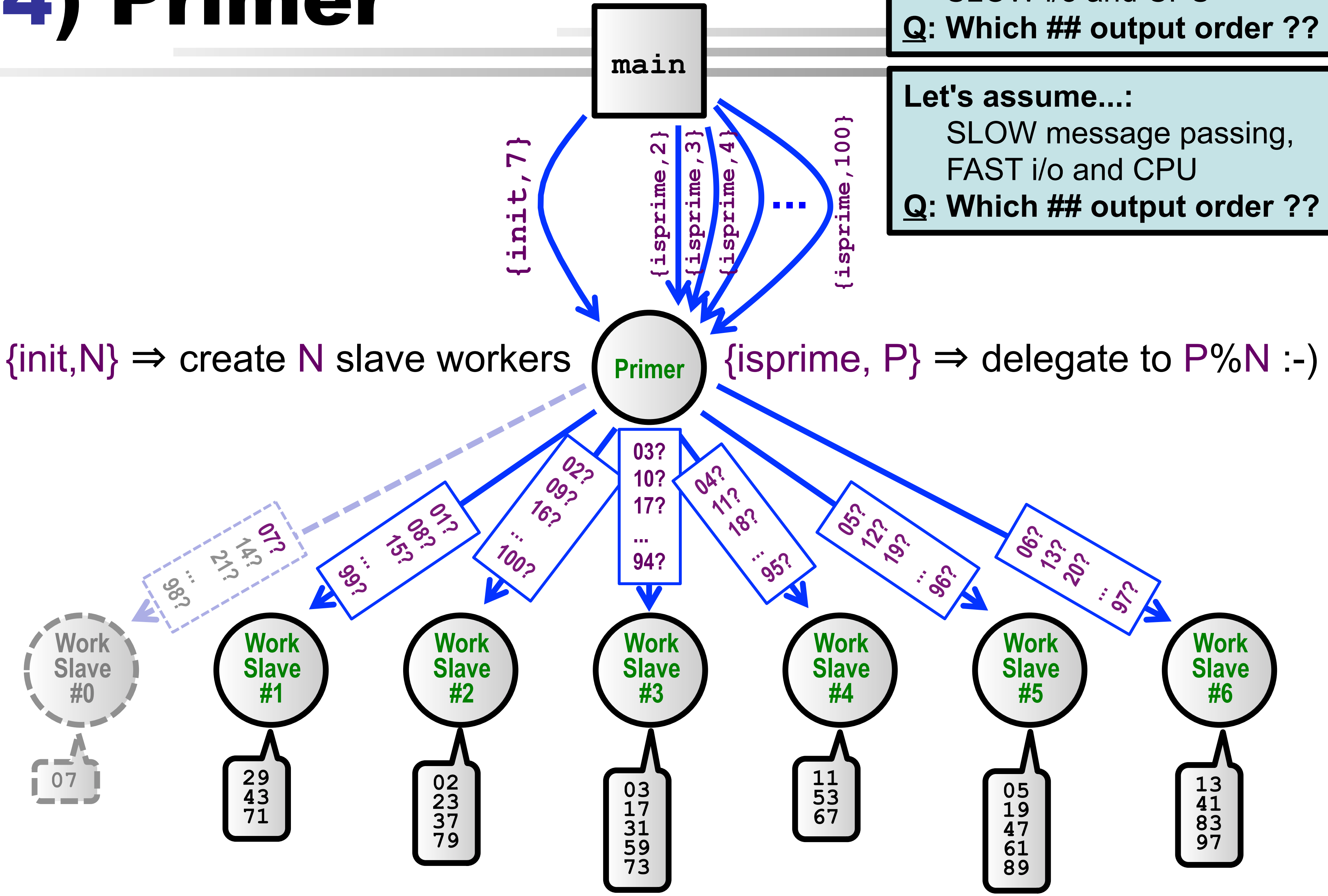


4) Primer.erl

Slave

```
-module(helloworld).
-export([start/0,slave/1,primer/1]).

is_prime_loop(N,K) ->
   K2 = K * K, R = N rem K,
   case (K2 =< N) and (R /= 0) of
      true  -> is_prime_loop(N, K+1);
      false -> K
   end.

is_prime(N) ->
K = is_prime_loop(N,2),
   (N >= 2) and (K*K > N).

n2s(N) ->
   lists:flatten(io_lib:format("~p",[N])).

slave(Id) ->
   receive
      {isprime, N} ->
         case is_prime(N) of
           true -> io:fwrite("(" ++
n2s(Id) ++ ") " ++ n2s(N) ++ "\n");
           false -> []
         end,
         slave(Id)
   end.
```

Primer

```
create_slaves(Max,Max) -> [];
create_slaves(Id,Max) ->
   Slave = spawn(helloworld,slave,[Id]),
   [Slave|create_slaves(Id+1,Max)].

primer(Slaves) ->
   receive
      {init, N} when N=<0 ->
         throw({nonpositive,N}) ;
      {init, N} ->
         primer(create_slaves(0,N)) ;
      {isprime, _} when Slaves == [] ->
         throw({uninitialized}) ;
      {isprime, N} when N=<0 ->
         throw({nonpositive,N}) ;
      {isprime, N} ->
         SlaveId = N rem length(Slaves),
         lists:nth(SlaveId+1, Slaves)
            ! {isprime,N},
         primer(Slaves)
   end.

spam(_, N, Max) when N>=Max -> true;
spam(Primer, N, Max) ->
   Primer ! {isprime, N},
   spam(Primer, N+1, Max).

start() ->
   Primer =
      spawn(helloworld, primer, [[]]),
   Primer ! {init,7},
   spam(Primer, 2, 100).
```

4) Primer.java

```
import java.util.*;
import java.io.*;
import akka.actor.*;

// -- MESSAGES --------------------------------------------------

class InitializeMessage implements Serializable {
    public final int number_of_slaves;
    public InitializeMessage(int number_of_slaves) {
        this.number_of_slaves = number_of_slaves;
    }
}

class IsPrimeMessage implements Serializable {
    public final int number;
    public IsPrimeMessage(int number) {
        this.number = number;
    }
}
```

4) Primer.java

```
// -- SLAVE ACTOR ----------------------------------------------------

class SlaveActor extends UntypedActor {
    private boolean isPrime(int n) {
        int k = 2;
        while (k * k <= n && n % k != 0) k++;
        return n >= 2 && k * k > n;
    }

    public void onReceive(Object o) throws Exception {
        if (o instanceof IsPrimeMessage) {
            int p = ((IsPrimeMessage) o).number;
            if (isPrime(p)) System.out.println("(" + p % Primer.P + ") " + p); // HACK
        }
    }
}
```

4) Primer.java

```java
// -- PRIME ACTOR ------------------------------------------------------------
class PrimeActor extends UntypedActor {
    List<ActorRef> slaves;

    private List<ActorRef> createSlaves(int n) {
        List<ActorRef> slaves = new ArrayList<ActorRef>();
        for (int i=0; i<n; i++) {
            ActorRef slave =
                getContext().actorOf(Props.create(SlaveActor.class), "p" + i);
                slaves.add(slave);
        }
        return slaves;
    }

    public void onReceive(Object o) throws Exception {
        if (o instanceof InitializeMessage) {
            InitializeMessage init = (InitializeMessage) o;
            int n = init.number_of_slaves;
            if (n<=0) throw new RuntimeException("*** non-positive number!");
            slaves = createSlaves(n);
            System.out.println("initialized (" + n + " slaves ready to work)!");
        } else if (o instanceof IsPrimeMessage) {
            if (slaves==null) throw new RuntimeException("*** uninitialized!");
            int n = ((IsPrimeMessage) o).number;
            if (n<=0) throw new RuntimeException("*** non-positive number!");
            int slave_id = n % slaves.size();
            slaves.get(slave_id).tell(o, getSelf());
        }
    }
}
```

4) Primer.java

```
// -- MAIN -----------------------------------------------

public class Primer {
    private static void spam(ActorRef primer, int min, int max) {
        for (int i=min; i<max; i++) {
            primer.tell(new IsPrimeMessage(i), ActorRef.noSender());
        }
    }

    public static void main(String[] args) {
        final ActorSystem system = ActorSystem.create("PrimerSystem");
        final ActorRef primer =
            system.actorOf(Props.create(PrimeActor.class), "primer");
        primer.tell(new InitializeMessage(7), ActorRef.noSender());
        try {
            System.out.println("Press return to initiate...");
            System.in.read();
            spam(primer, 2, 100);
            System.out.println("Press return to terminate...");
            System.in.read();
        } catch(IOException e) {
            e.printStackTrace();
        } finally {
            system.shutdown();
        }
    }
}
```

4) Primer.java

- **Compile:**

```
javac -cp scala.jar:akka-actor.jar Primer.java
```

- **Run:**

```
java -cp scala.jar:akka-actor.jar:akka-config.jar:. Primer
```

- **Output:**

```
press return to initiate...
initialized (7 slaves ready to work)!

(2) 2
(3) 3
Press return to terminate...
(0) 7
(5) 5
(4) 11
(6) 13
(3) 17
(5) 19
(2) 23
(1) 29
(3) 31
```

```
(2) 37
(6) 41
(1) 43
(5) 47
(4) 53
(3) 59
(5) 61
(4) 67
(1) 71
(3) 73
(2) 79
(6) 83
(5) 89
(6) 97
```

ERLANG -vs- JAVA+AKKA

ERLANG:

SLOW message passing*
=predicted=effect=>
You would get numbers in ***slave-worker order:***
- 07, 29, 02, 03, 11, 05, ...

[observed in ERLANG]

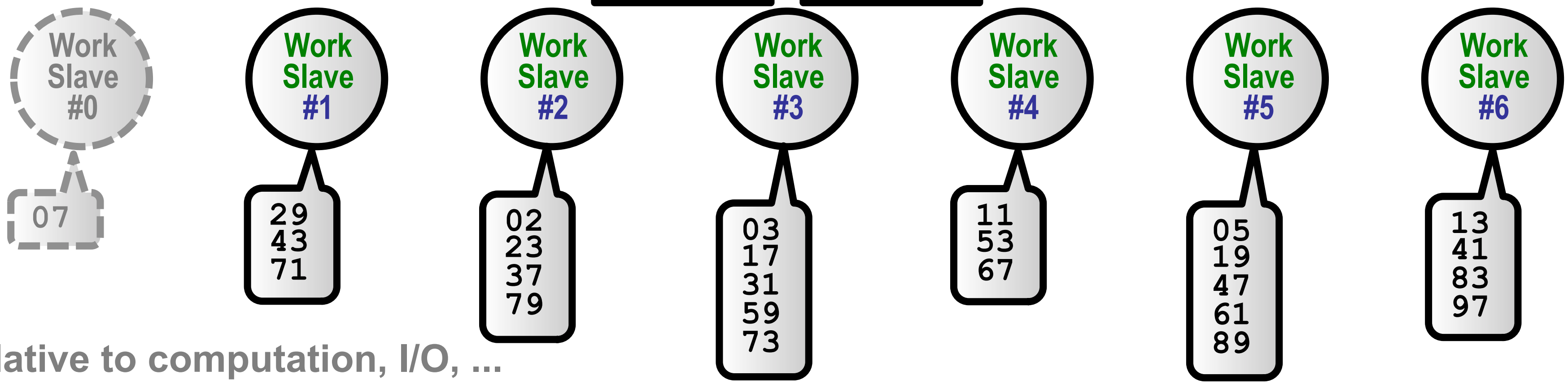
#0:	07
#1:	29
#2:	02
#3:	03
#4:	11
#5:	05
#6:	13
#1:	43
#2:	23
#3:	17
#4:	53
#5:	19
#6:	41

#2:	02
#3:	03
#5:	05
#0:	07
#4:	11
#6:	13
#3:	17
#5:	19
#2:	23
#1:	29
#3:	31
#2:	37
#6:	41

JAVA+AKKA:

FAST message passing*
=predicted=effect=>
You would get numbers in ***numerical order:***
- 02, 03, 05, 07, 11, 13, ...

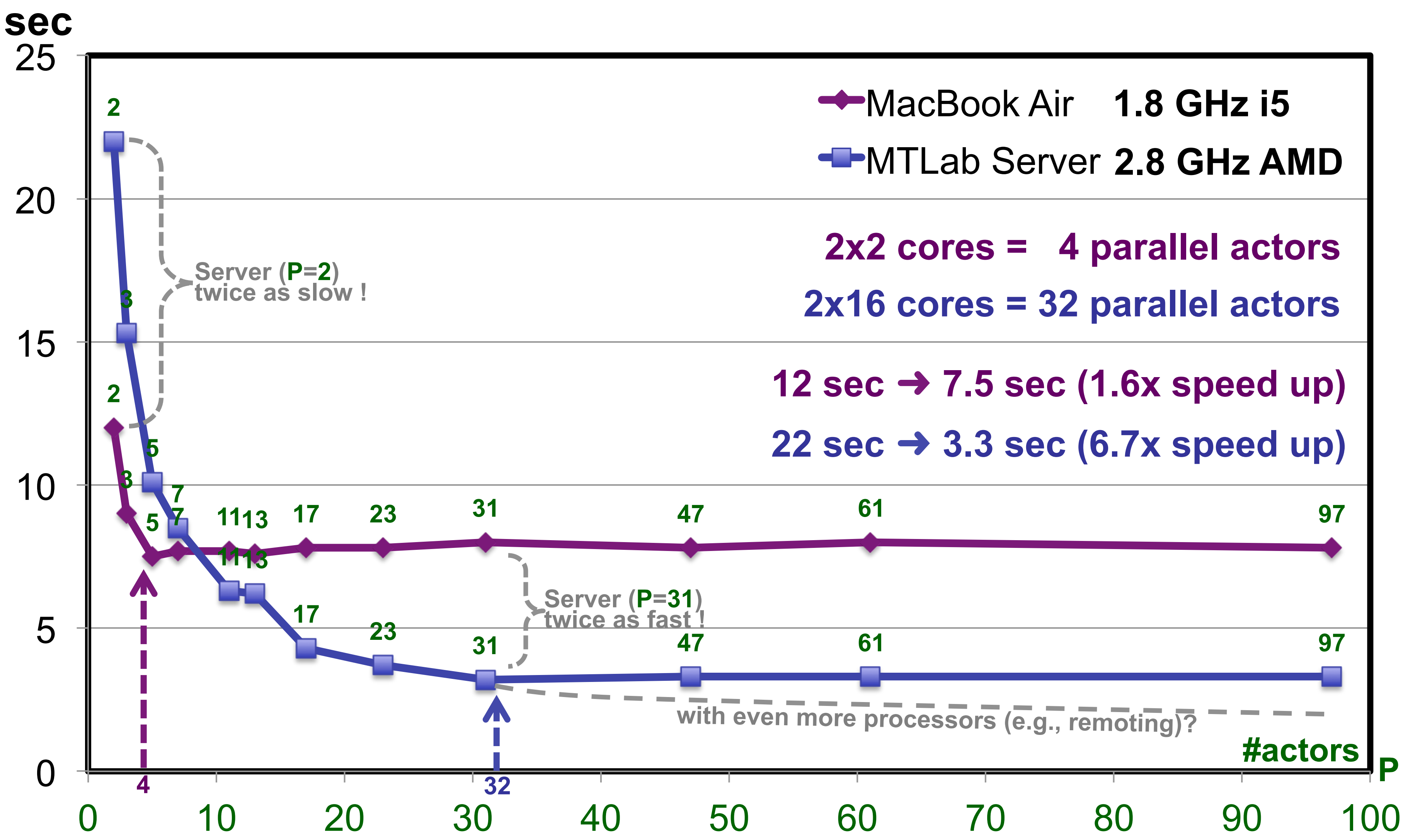
[observed in JAVA+AKKA]



*) relative to computation, I/O, ...

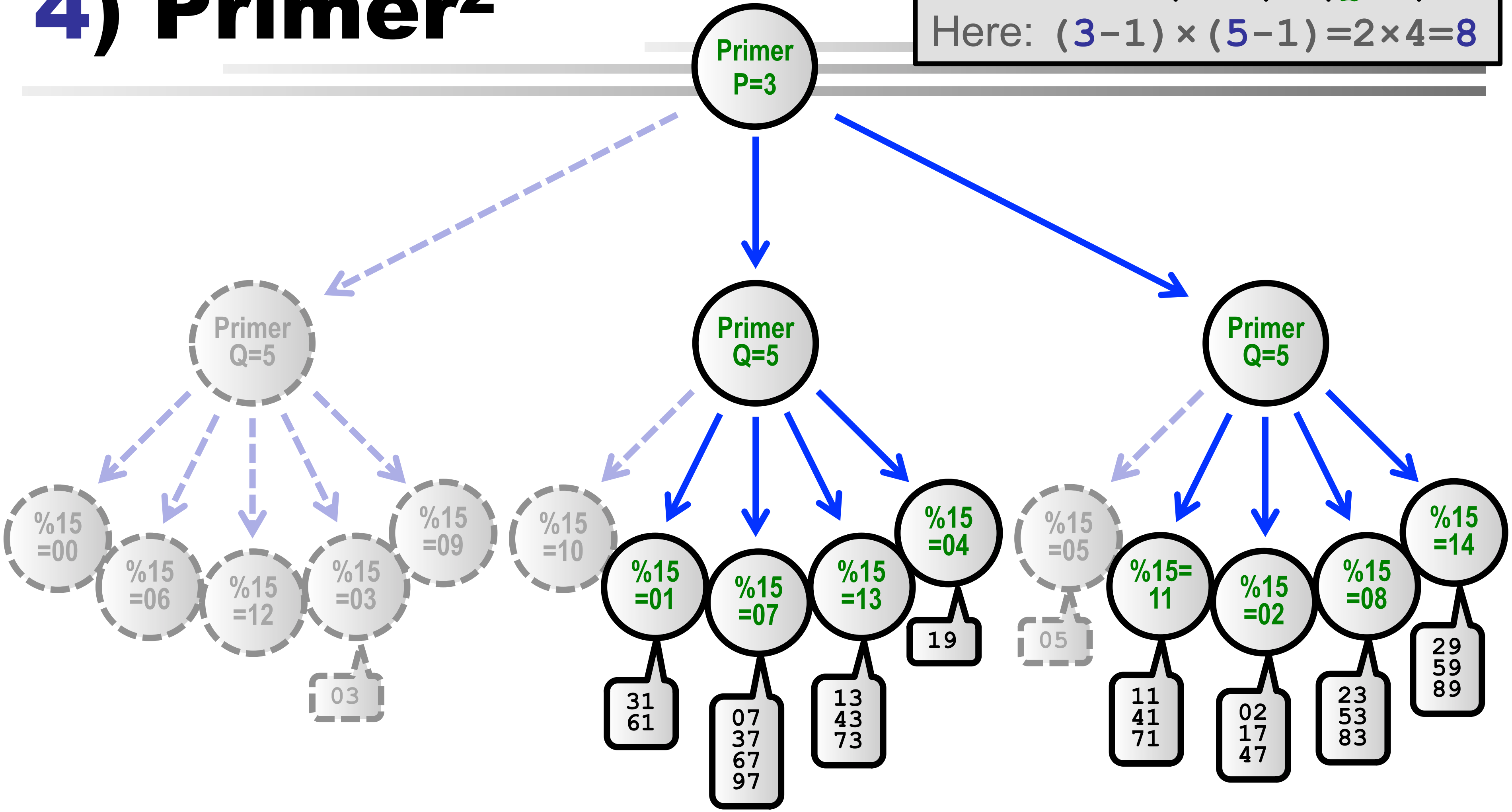
Note: added silly time-consuming computation to every `isPrime()` method call !

Low -vs- High Parallelization !



4) Primer²

#Workers: `P×Q`
#Effective: `(P-1)×(Q-1)`
Here: `(3-1)×(5-1)=2×4=8`

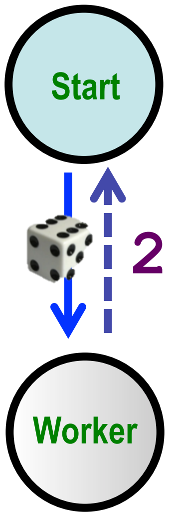


Note: Two primers with P=3 x Q=5 is equivalent to one primer with P=15.
BTW: This is why you should always use a prime number in a hash function!

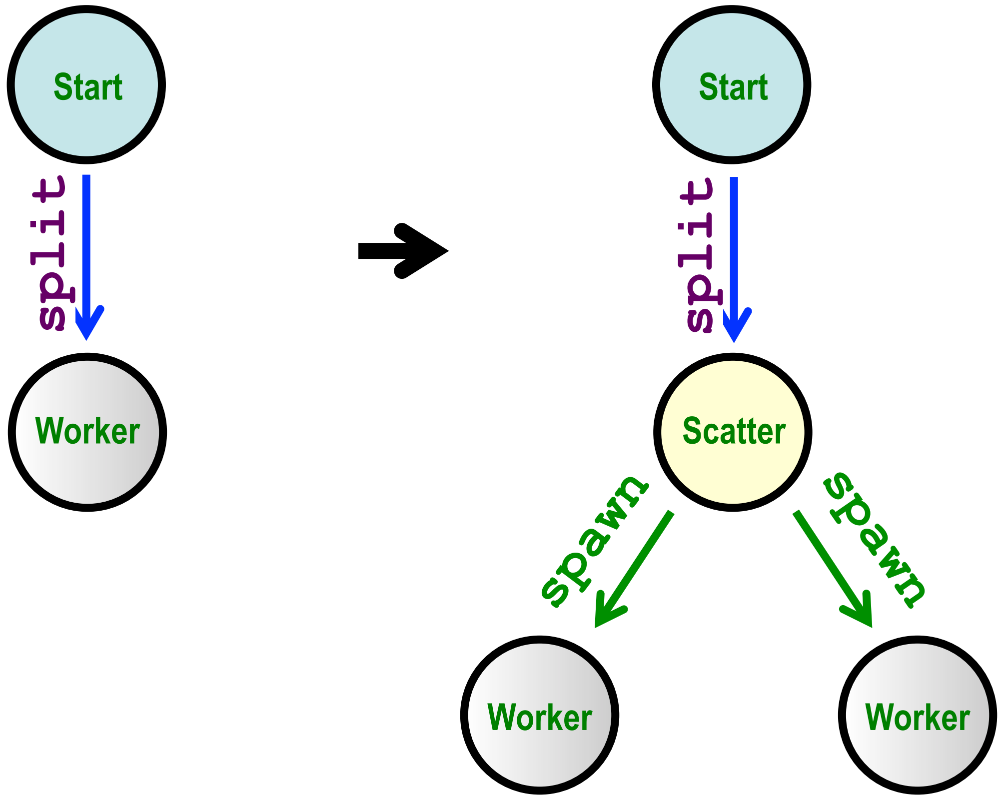
AGENDA

- 3) **Broadcast:**
  - From ERLANG to JAVA+AKKA
  - Communication protocols (one-to-one ⇒ one-to-many)
- **AKKA: A proper introduction**
  - Motivations and benefits of Actors & Message Passing
  - Recommendations
- 4) **Primer:**
  - Hierarchic organization: managers supervise workers
  - Performance: MacBook Air -vs- MTLab Server
- ★ **Scatter-Gather:**
  - Prototypical AKKA Service (dynamic load balancing)
  - Extensions

6) Scatter-Gather

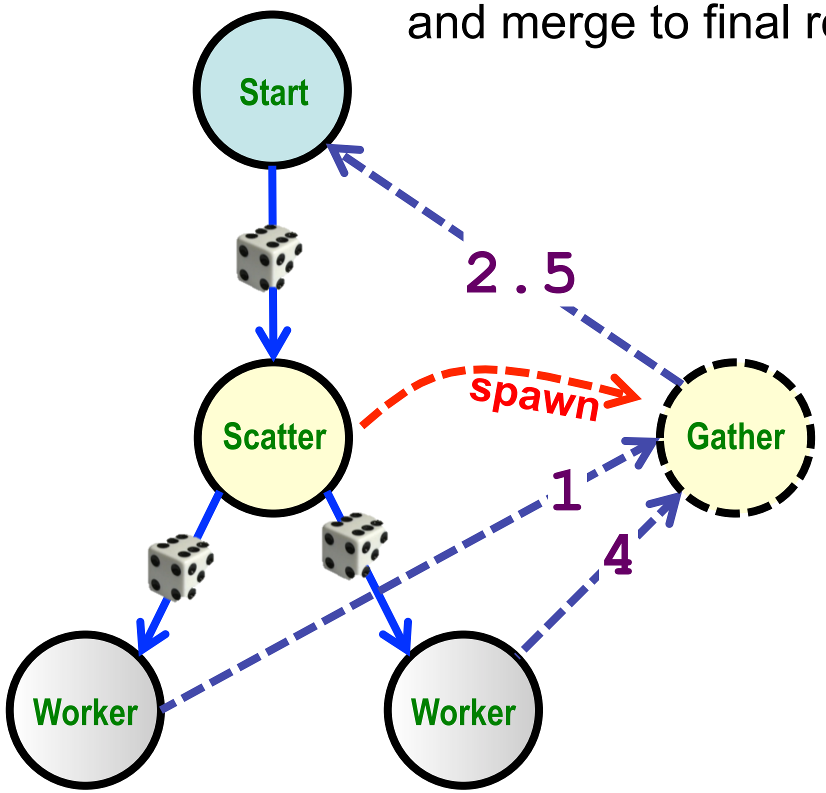


6) Scatter-Gather



6) Scatter-Gather

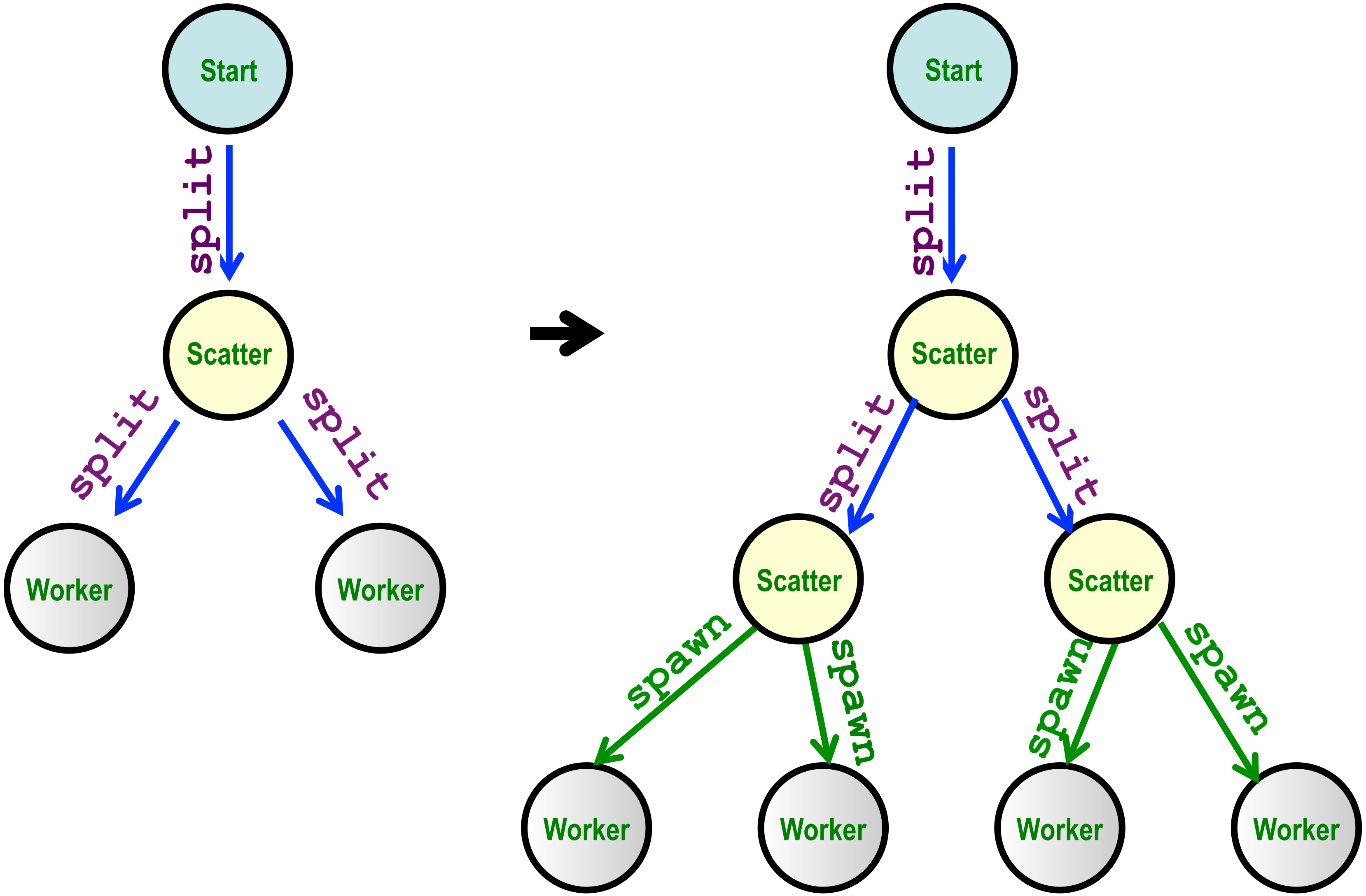
Gatherer:
collect incoming responses
and merge to final result inform its parent




```
-- OUTPUT --
1
4
result = 2.5
```

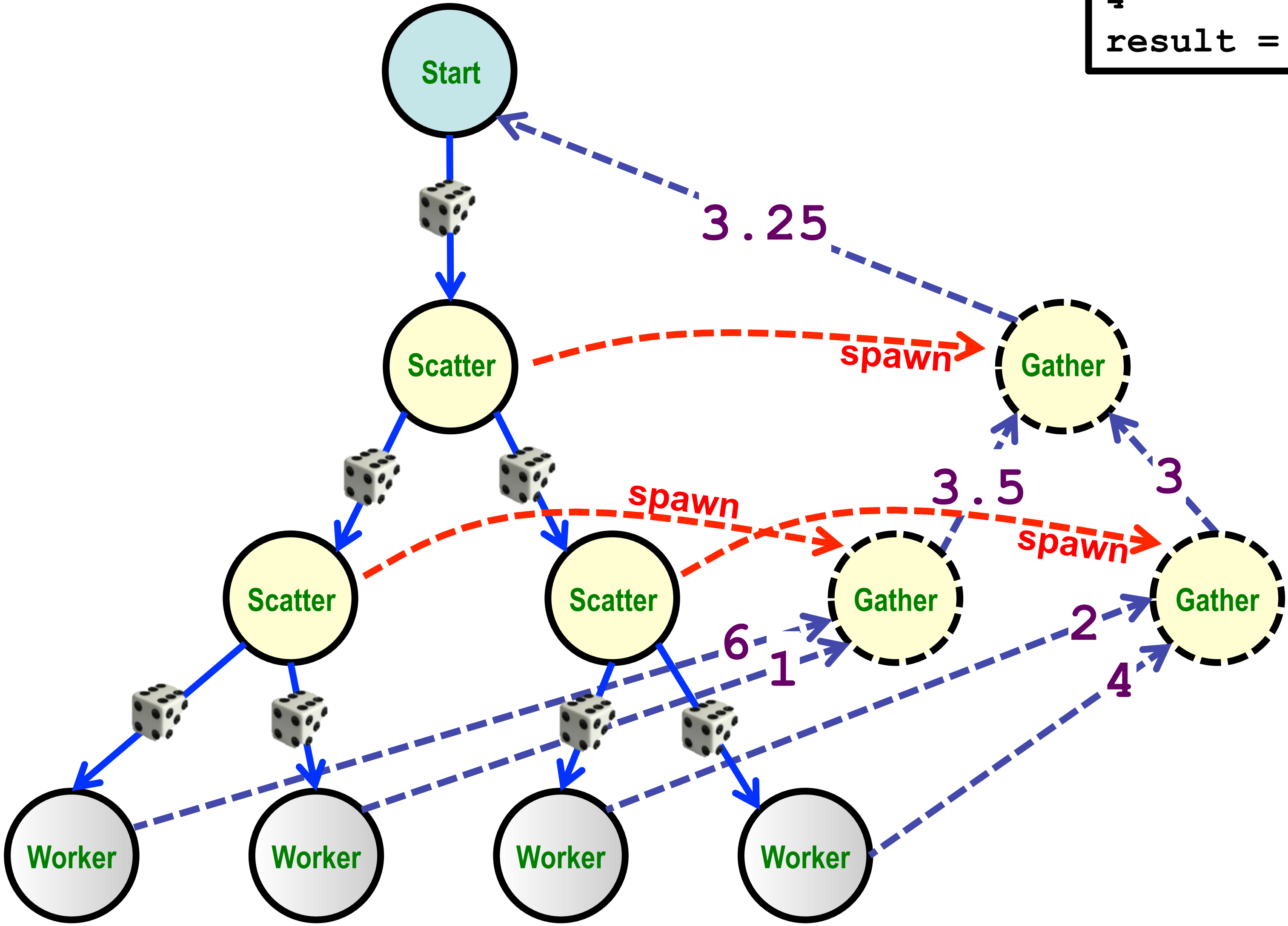
Scatter:
I don't want the result,
send it to my gatherer:
- I'm too busy processing new incoming requests
- besides, it's hard to correlate requests-responses (aka, "the correlation problem")

6) Scatter-Gather

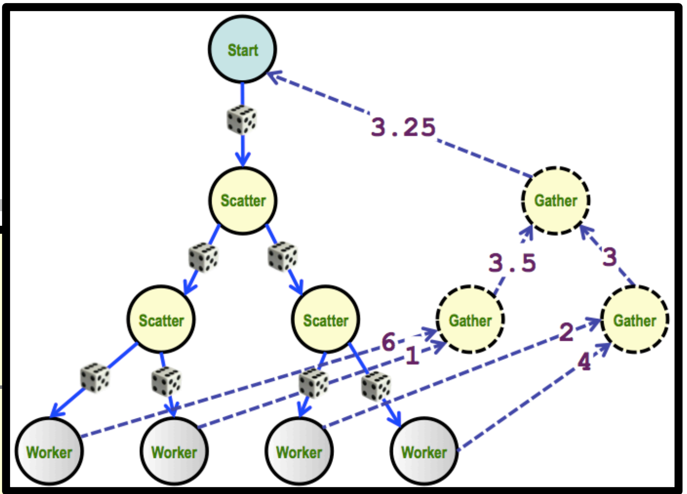


6) Scatter-Gather

```
-- OUTPUT --
6
1
2
4
result = 3.25
```



6) ScatterGather.erl

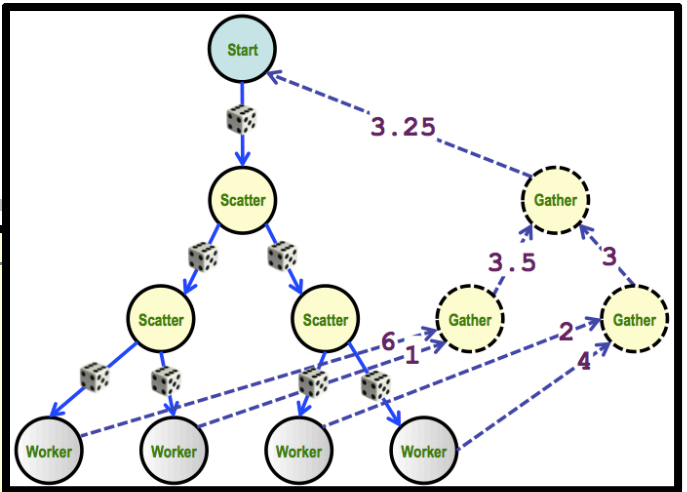



```
-module(helloworld).
-export([start/0,worker/0,scatter/2,gather/1]).

%% -- COMPUTE ----------------------------------------

seed() -> {_, A2, A3} = now(), %% Seed wrt Time & Pid !
          random:seed(erlang:phash(node(), 100000),erlang:phash(A2, A3),A3).

n2s(N) -> lists:flatten(io_lib:format("~p", [N])). %% HACK: num to string conversion!

random(N) -> random:uniform(N).

compute(X) -> random(X).

average(X,Y) -> (X + Y) / 2.
```

```
%% -- START -----------------------------------------

start() ->
   Worker = spawn(helloworld,worker,[]),
   Worker ! split,
   Worker ! split,
   Worker ! {compute,6,self()},
   receive
      {result,R} ->
         io:fwrite("result = " ++ n2s(R) ++ "\n")
   end.
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

6) ScatterGather.erl

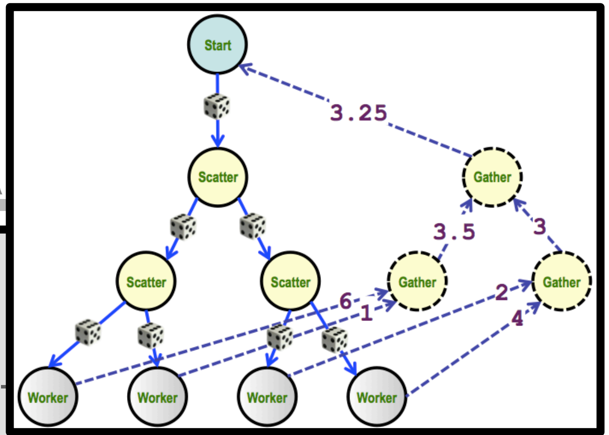



```
%% -- WORKER ----------------------------------------
worker() ->
    seed(),
    receive
        split ->
            Left  = spawn(helloworld,worker,[]),
            Right = spawn(helloworld,worker,[]),
            scatter(Left, Right) ;
       {compute,X,Caller} ->
            Res = compute(X),
            io:fwrite(n2s(Res) ++ "\n"),
            Caller ! {result,Res},
            worker()
    end.

%% -- SCATTER ---------------------------------------
scatter(Left, Right) ->
    receive
        split ->
            Left  ! split,
            Right ! split ;
        {compute,X,Caller} ->
            Gather = spawn(helloworld,gather,[Caller]),
            Left  ! {compute,X,Gather},
            Right ! {compute,X,Gather}
    end,
    scatter(Left, Right).
```

```
%% -- GATHER ----------------------------------
gather(Caller) ->
    receive
        {result,Res1} ->
            receive
                {result,Res2} ->
                    Res = average(Res1,Res2),
                    Caller ! {result, Res} % die!
            end
    end.
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

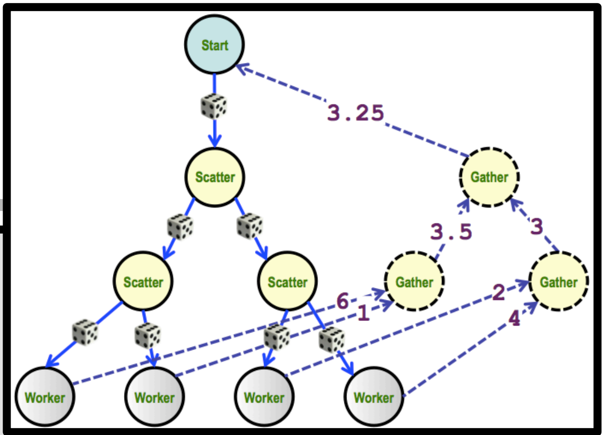
6) ScatterGather.java




```
import java.util.Random;   import java.io.*;
import akka.actor.*;

// -- MESSAGES ----------------------------------------

class StartMessage implements Serializable { public StartMessage() { } }

class SplitMessage implements Serializable { public SplitMessage() { } }

class CallerMessage implements Serializable {
    public final ActorRef caller;
    public CallerMessage(ActorRef caller) { this.caller = caller; }
}

class ComputeMessage implements Serializable {
    public final int number;
    public final ActorRef caller;
    public ComputeMessage(int number, ActorRef caller) {
         this.number = number;
         this.caller = caller;
    }
}

class ResultMessage implements Serializable {
    public final double result;
    public ResultMessage(double result) { this.result = result; }
}
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

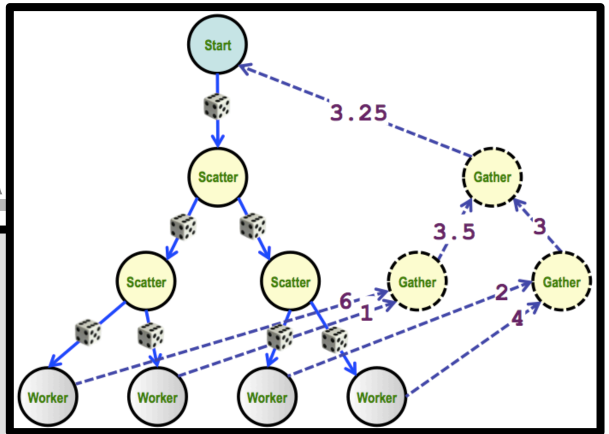
6) ScatterGather.java




```java
class WorkerScatterActor extends UntypedActor {
   // null => worker , non-null => scatter:
   private ActorRef left, right;
   private final Random rnd = new Random();
   private int random(int n) { return rnd.nextInt(n); }
   private int compute(int n) { return random(n) + 1; }

   private void worker(Object o) throws Exception {
      if (o instanceof SplitMessage) {
         left = getContext().actorOf(Props.create(WorkerScatterActor.class), "left");
         right = getContext().actorOf(Props.create(WorkerScatterActor.class), "right");
      } else if (o instanceof ComputeMessage) {
         ComputeMessage m = (ComputeMessage) o;
         int result = compute(m.number);
         System.out.println(result);
         m.caller.tell(new ResultMessage(result), ActorRef.noSender());
      }
   }

   private void scatter(Object o) throws Exception { [...] }

   public void onReceive(Object o) throws Exception {
      // dispatch according to actor role: 'worker' or 'scatter'
      if (left == null) worker(o);
      else scatter(o);
   }
}
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

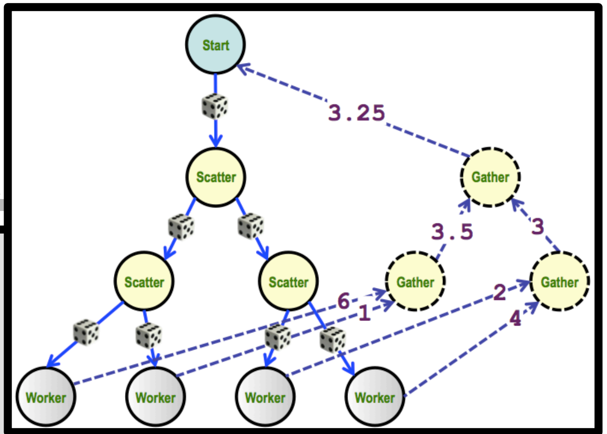
6) ScatterGather.java




```
class WorkerScatterActor extends UntypedActor {
   // null => worker , non-null => scatter:
   private ActorRef left, right;
   [...]

   private void worker(Object o) throws Exception { [...] }

   private void scatter(Object o) throws Exception {
      if (o instanceof SplitMessage) {
         left.forward(o, getContext());
         right.forward(o, getContext());
      } else if (o instanceof ComputeMessage) {
         ComputeMessage m = (ComputeMessage) o;
         ActorRef gather = getContext().actorOf(Props.create(GatherActor.class), "g");
         // send message with callter, instead of arguments to gather constructor:
         gather.tell(new CallerMessage(m.caller), ActorRef.noSender());
         left.tell(new ComputeMessage(m.number, gather), ActorRef.noSender());
         right.tell(new ComputeMessage(m.number, gather), ActorRef.noSender());
      }
   }

   public void onReceive(Object o) throws Exception {
      // dispatch according to actor role: 'worker' or 'scatter'
      if (left == null) worker(o);
      else scatter(o);
   }
}
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

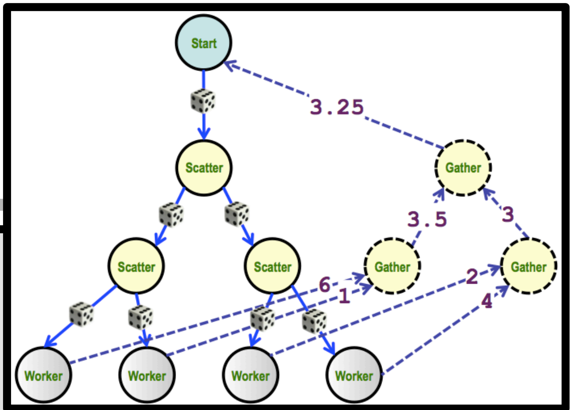
6) ScatterGather.java




```
class GatherActor extends UntypedActor {
   double res1;
   ActorRef caller;

   private double average(double x, double y) {
      return (x + y) / 2;
   }

   public void onReceive(Object o) throws Exception {
      if (o instanceof CallerMessage) {
         caller = ((CallerMessage) o).caller;
      } else if (o instanceof ResultMessage) {
         if (caller == null) throw new Exception("no caller address!!!");
         if (res1 == 0) {
            res1 = ((ResultMessage) o).result;
         } else {
            double res2 = ((ResultMessage) o).result;
            double res = average(res1, res2);
            caller.tell(new ResultMessage(res), ActorRef.noSender());
            getContext().stop(getSelf()); // die!
         }
      }
   }
}
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

6) ScatterGather.java




```
class StartActor extends UntypedActor {
   public void onReceive(Object o) throws Exception {
      if (o instanceof StartMessage) {
         ActorRef worker =
            getContext().actorOf(Props.create(WorkerScatterActor.class), "worker");
         worker.tell(new SplitMessage(), ActorRef.noSender());
         worker.tell(new SplitMessage(), ActorRef.noSender());
         worker.tell(new ComputeMessage(6, getSelf()), ActorRef.noSender());
      } else if (o instanceof ResultMessage) {
         double result = ((ResultMessage) o).result;
         System.out.println("result = "  + result);
      }
   }
}

public class ScatterGather {
   public static void main(String[] args) {
      final ActorSystem system = ActorSystem.create("HelloWorldSystem");
      final ActorRef starter =
         system.actorOf(Props.create(StartActor.class), "starter");
      starter.tell(new StartMessage(), ActorRef.noSender());
      try { System.out.println("Press return to terminate..."); System.in.read();
      } catch(IOException e) { e.printStackTrace();
      } finally { system.shutdown();
      }
   }
}
```

```
-- OUTPUT --
6
1
2
4
result = 3.25
```

Scatter-Gather + ...

- **Adaptive Load balancing:**
  - Monitor system to extract up-to-date statistics
  - Based on statistics, adjust system capacity (cf. our split) or Quality-of-Service (ak^{2}a, "graceful degradation")
    - Note: this may be done on ***all*** nodes in the hierarchy!
- **Memoization/Caching:**
  - Often, memoization is used to "cache" already-performed-computations `// Map<Key,Val> cache;`
    - Note: this may be done on ***all*** nodes in the hierarchy!
- **Fault Tolerance:**
  - Supervisors react if workers don't respond or crash
  - Then: resume(), subtree.restart(), parent.escalate()

More information...

- ERLANG:
  - [http://www.erlang.org/download/erlang-book-part1.pdf]

- AKKA Video Talks:
  - [https://www.youtube.com/watch?v=GBvtE61Wrto]
  - [https://www.youtube.com/watch?v=t4KxWDqGfcs] // Slides
    - http://gotocon.com/dl/goto-aar-2012/slides/JonasBonr_UpUpAndOutScalingSoftwareWithAkka.pdf

- JAVA+AKKA Documentation:
  - [http://doc.akka.io/docs/akka/snapshot/java/untyped-actors.html]
  - [http://doc.akka.io/docs/akka/2.3.7/AkkaJava.pdf]

- JAVA+AKKA API:
  - [http://doc.akka.io/japi/akka/2.3.7/]

Thx!

Questions?

Reception (ERLANG vs AKKA)

- **In ERLANG:**
  - Locally nested receives (depending on local state)
- **In JAVA+AKKA:**
  - You only have one top-level receive:
- **Example ⇒ refactored (ready) for JAVA+AKKA:**

```
%% -- GATHER -----------------------------
gather(Pid) ->
   receive  // State #0 ('Res1' not set)
      {result,Res1} ->
         receive   // State #1 ('Res1' set)
            {result,Res2} ->
               Res = average(Res1,Res2),
               Pid ! {result, Res} % die.
         end
   end.
```

```
%% -- GATHER' -----------------------------
gather(Pid, Res1) ->
   receive
      {result,Res1} when Res1 = undef ->
         gather(Pid, Res1)
   ;
      {result,Res2} ->
         Res = average(Res1, Res2),
         Pid ! {result, Res} % die.
   end.
```

[See also ERLANG Book, program 5.3]