CAF 2.0 Phasers

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Scale of Computation

http://www.scl.ameslab.gov/Projects/parallel_computing/cluster_examples.html

http://www.olcf.ornl.gov/titan/

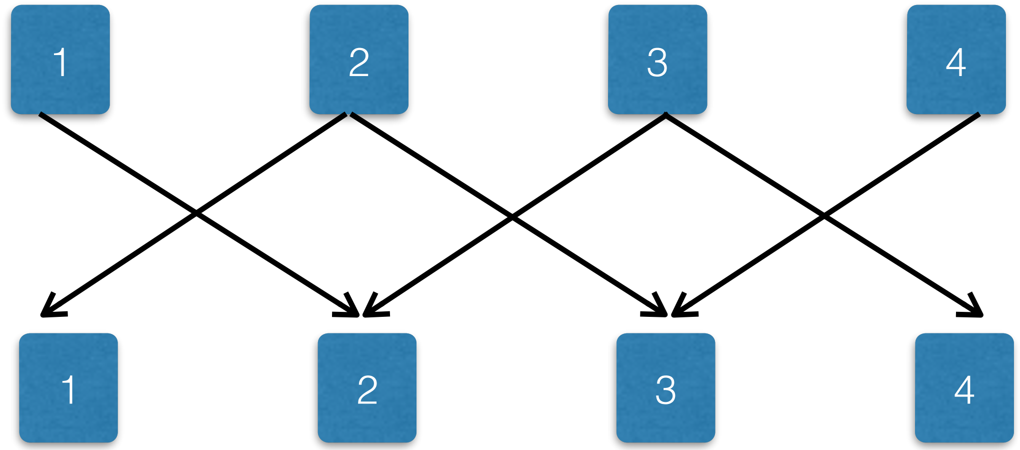
- Data Movement
- Synchronization ★
- Load Balancing
- Power Consumption

CHAOS

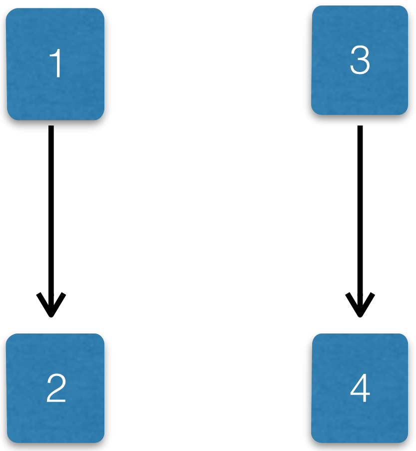
http://nepaliaustralian.com/2012/09/07/traffic-chaos-around-the-world/

Patterns of Synchronization

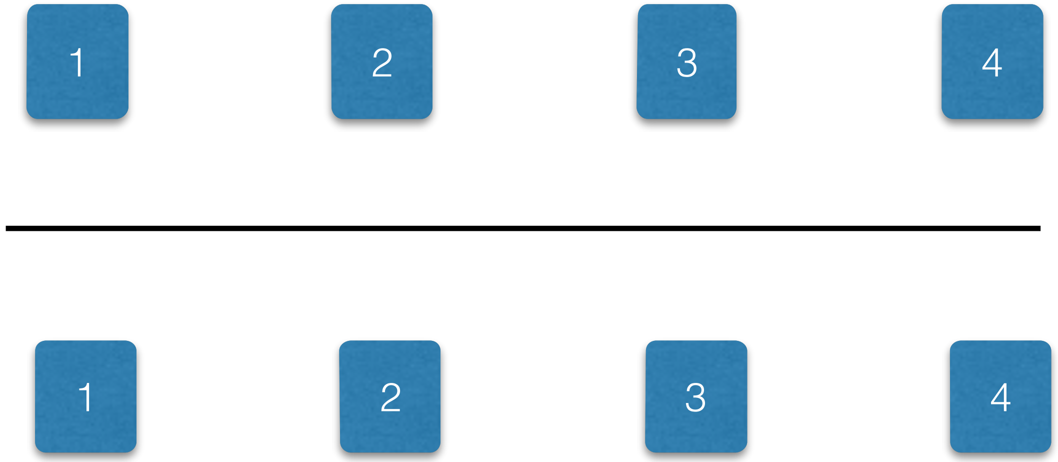
- **Point-to-Point**



- **Producer-Consumer**

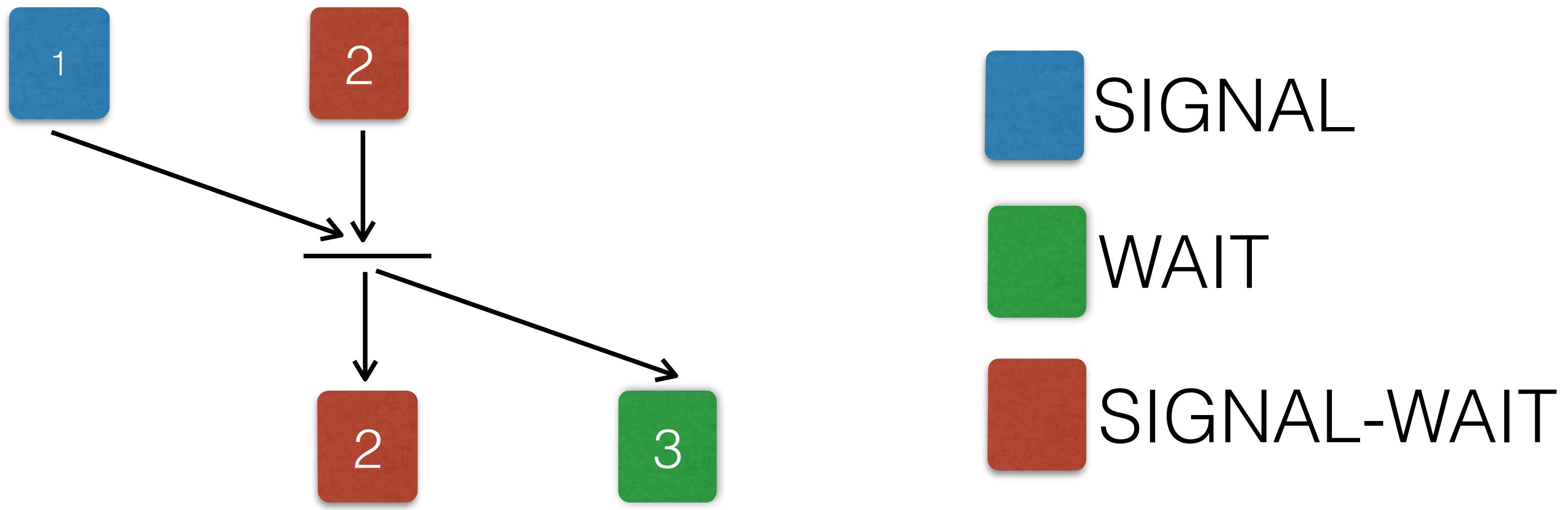


- **Barrier**



Phaser

- Unifies barrier and point-to-point synchronization
- Allows dynamic addition/deletion of processes
- Flexible participation modes for each process involved

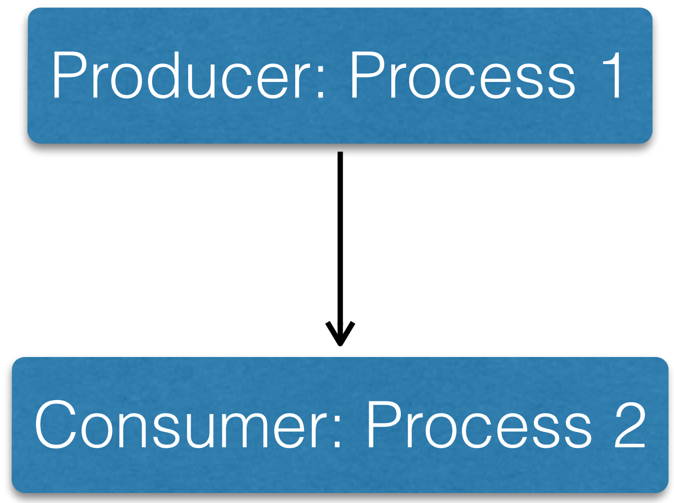


Phaser Constructs

- **Registration**
  - — phaser_create(…) : creates a phaser in a specified mode
    - – SIGNAL
    - – WAIT
    - – SIGNAL_WAIT
  - — spawn(…) : adds a new process to an existing phaser

- **Synchronize**
  - — next(…) : synchronizes according to the mode

Producer-Consumer Example



Process 1

```
if(ME == 1)
        phaser_create(ME, ph, SIG,…)
        spawn<WAIT, ph>(fn,…)[2]
        produce_data()
        next(ph)
        .
        .
        .
```

Process 2

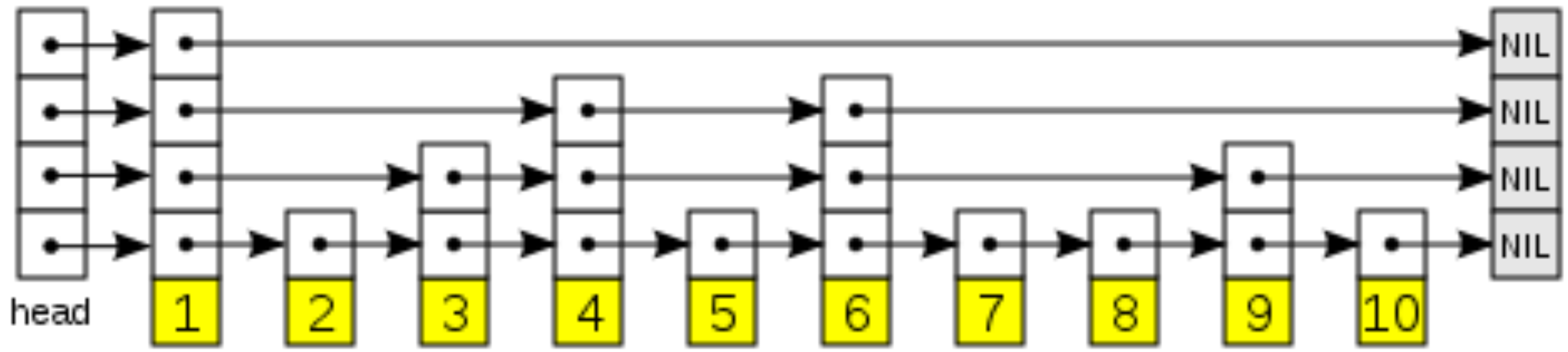
```
fn(…)
        next(ph)
        consume_data()
        .
        .
        .
end
```

Design Challenges

- **Scalability**
  - — Need to support thousands if not millions of participants
- **Concurrency**
  - — Scalable parallelism requires concurrent operations
- **Distribution**
  - — All significant operations involve interactions between multiple agents
- **Dynamism**
  - — Must support dynamic addition/deletion of processes
- **Correctness**
  - — Operations must be free of deadlock and livelock

Skip Lists as a Building Block for Phasers

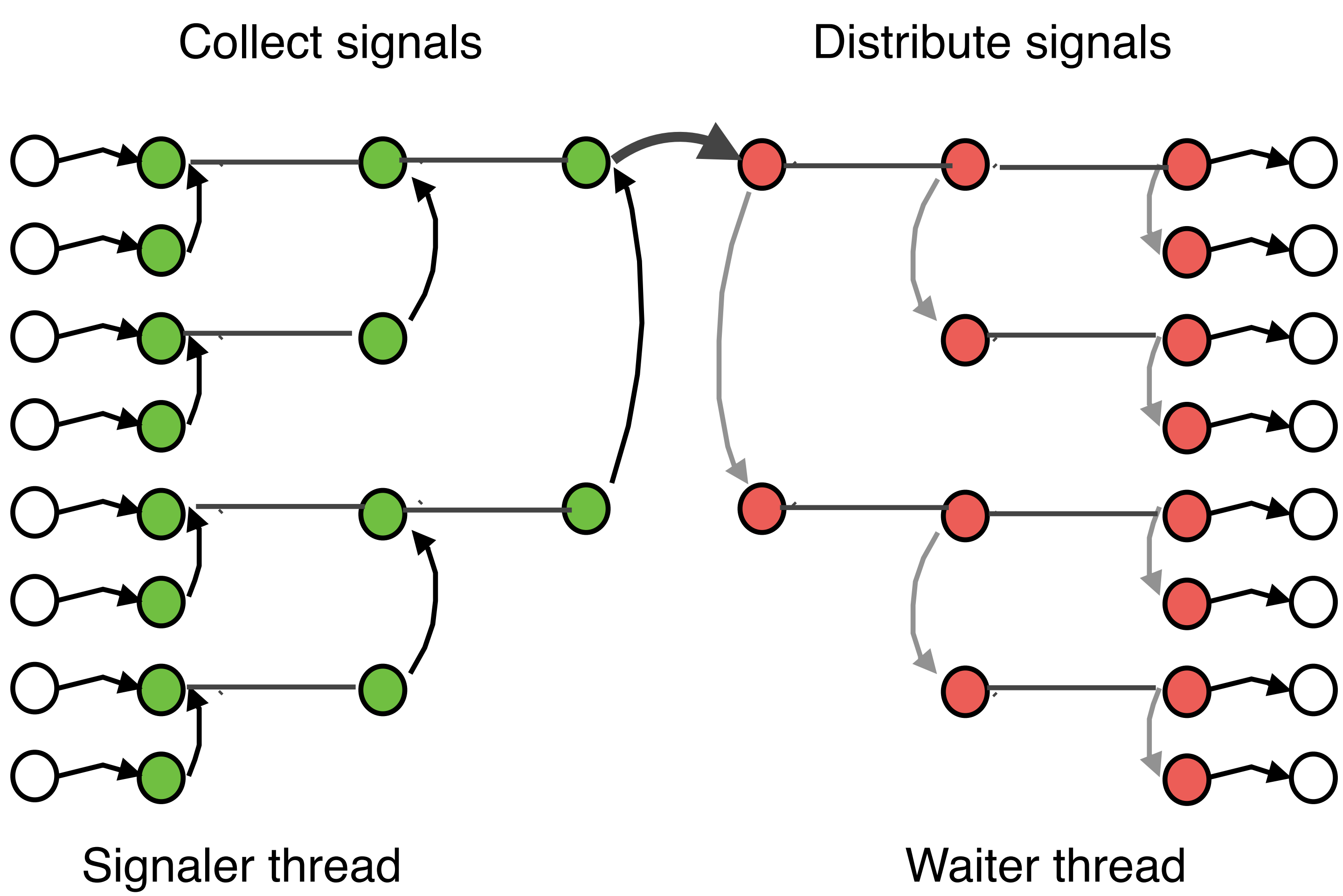
- Probabilistic replacement to balanced trees
- Addition/deletion without rebalancing
- Logarithmic space/time complexity for operations



https://github.com/tewuapple/SkipList

Propagate Signals Using Skip List

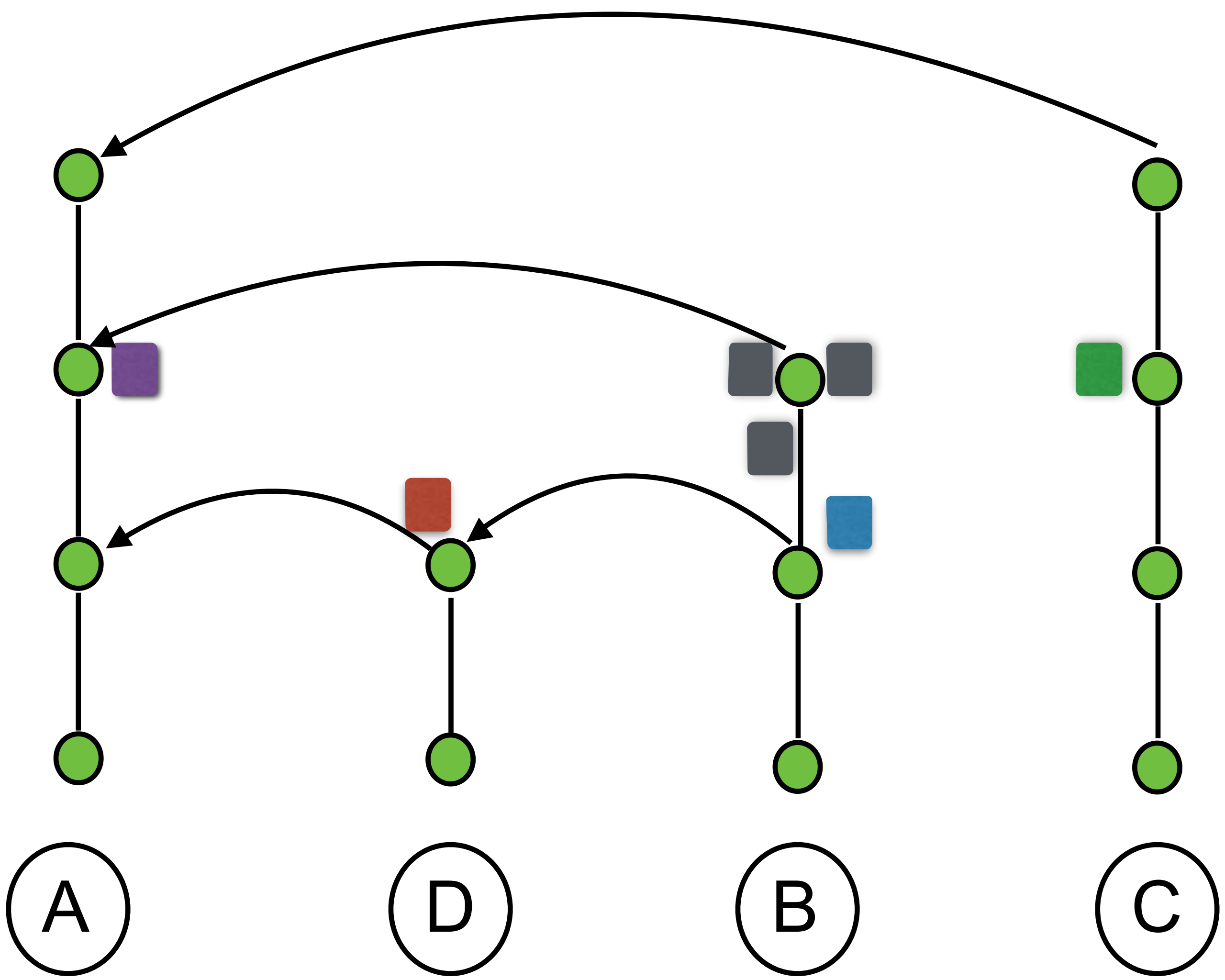
- One skip list for signalers and one for waiters
- Signaler root collects the signals from all signalers
- Passes it to waiter root
- Waiter root distributes signal to all the waiters



Operations to Maintain the Skip List

- **Creation**
  - Recursive doubling
- **Addition**
  - Spawnee included into the skip-list before the spawn call returns
    - eager-single-link-modify (to avoid blocking of spawner)
    - lazy-multi-link-modify (move to the required height)
- **Deletion**
  - Lazy level by level deletion

Single Level Addition to a Skip List



- Find current signal to_neighbor
- Find next signal to_neighbor
- Find right_neighbor at level
- Ready for move up
- Acknowledgements

Verification of the protocol

- **Phaser protocol involves many participants**
  - — Addition/deletion/signaling happens simultaneously
  - — Too many messages in flight
  - — Proving properties is non-trivial
- **Model Checking is the solution**
  - — Explore the whole state space, i.e., all potential interleaving
- **Challenges**
  - — Size of the state space increases exponentially with the number of participants
  - — Exhaustive search not possible
    - – approximate methods are necessary

Verification using SPIN

- **SPIN**
  - Tool to automate verification of large distributed systems
  - Write an algorithm to be checked in PROMELA
  - Approximate Model-checking capability
  - Progress and correctness properties expressed in Linear Temporal Logic
- **Phaser properties currently modeled**
  - No signals are lost
  - Eventually neighbors should become consistent
- **Our approach**
  - Analyze sufficient set of interleavings to drive an agent through all configurations of the phaser protocol

Summary

- **Phaser unifies barrier and point-to-point synchronization**
- **Skip list used as backbone structure**
  - Scalability
  - Flexibility
- **Protocol Verification done using SPIN**
  - Employ approximate methods to model check the entire state space