COMP 322: Fundamentals of Parallel Programming

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Lecture 15: Point-to-point Synchronization, Pipeline Parallelism, Phasers (contd)

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Announcements

- Homework 4 due by 5pm on Wednesday, Feb 16th
    - We will try and return graded homeworks by Feb 23rd
- Guest lecture on Bitonic Sort by John Mellor-Crummey on Friday, Feb 18th
- Feb 23rd lecture will be a Midterm Review
- No lecture on Friday, Feb 25th since midterm is due that day
    - Midterm will be a 2-hour take-home written exam
        - Closed-book, closed-notes, closed-computer
    - Will be given out at lecture on Wed, Feb 23rd
    - Must be handed in by 5pm on Friday, Feb 25th

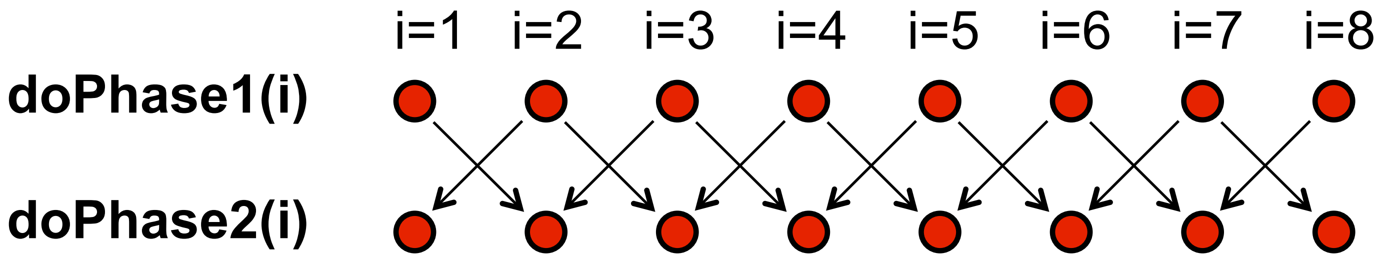
Acknowledgments for Today's Lecture

- [1] "X10: an object-oriented approach to non-uniform computing". Philippe Charles et al. OOPSLA 2005.
- [5] Phasers: a unified deadlock-free construct for collective and point-to-point synchronization. Jun Shirako et al. ICS '08
- Handout for Lectures 14 and 15

Point-to-Point Synchronization: Example 1 (Left-Right Neighbor Synchronization)

```
finish { // Expanded finish-for-async version of forall
  for (point[i] : [1:m])
    async {
      doPhase1(i);
       // Iteration i waits for i-1 and i+1 to complete Phase 1
      doPhase2(i);
    }
}
```

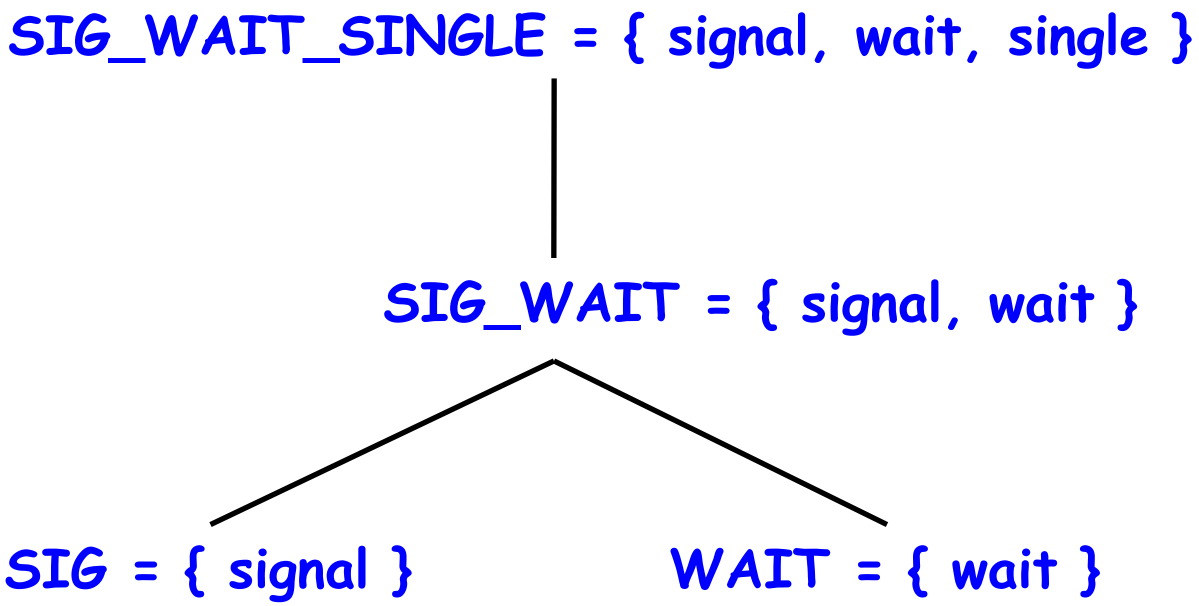
- Need synchronization where iteration i only waits for iterations i-1 and i+1 to complete their work in doPhase1() before it starts doPhase2(i)? (Less constrained than a barrier)



Summary of Phaser Construct

- Phaser allocation
  - phaser ph = new phaser(mode);
    - Phaser ph is allocated with registration mode
    - *Phaser lifetime is limited to scope of Immediately Enclosing Finish (IEF)*
- *Registration Modes*
  - *phaserMode.SIG*
  - *phaserMode.WAIT*
  - *phaserMode.SIG_WAIT*
  - *phaserMode.SIG_WAIT_SINGLE*
- Phaser registration
  - async phased (ph_1<$mode_1$>, ph_2<$mode_2$>, …) <stmt>
    - Spawned task is registered with ph_1 in $mode_1$, ph_2 in $mode_2$, …
    - *Child task's capabilities must be subset of parent's*
    - async phased <stmt> propagates all of parent's phaser registrations to child
- Synchronization
  - next;
    - *Advance each phaser that current task is registered on to its next phase*
    - Semantics depends on registration mode

Capability Hierarchy



SIG_WAIT_SINGLE = { signal, wait, single }

SIG_WAIT = { signal, wait }

SIG = { signal }

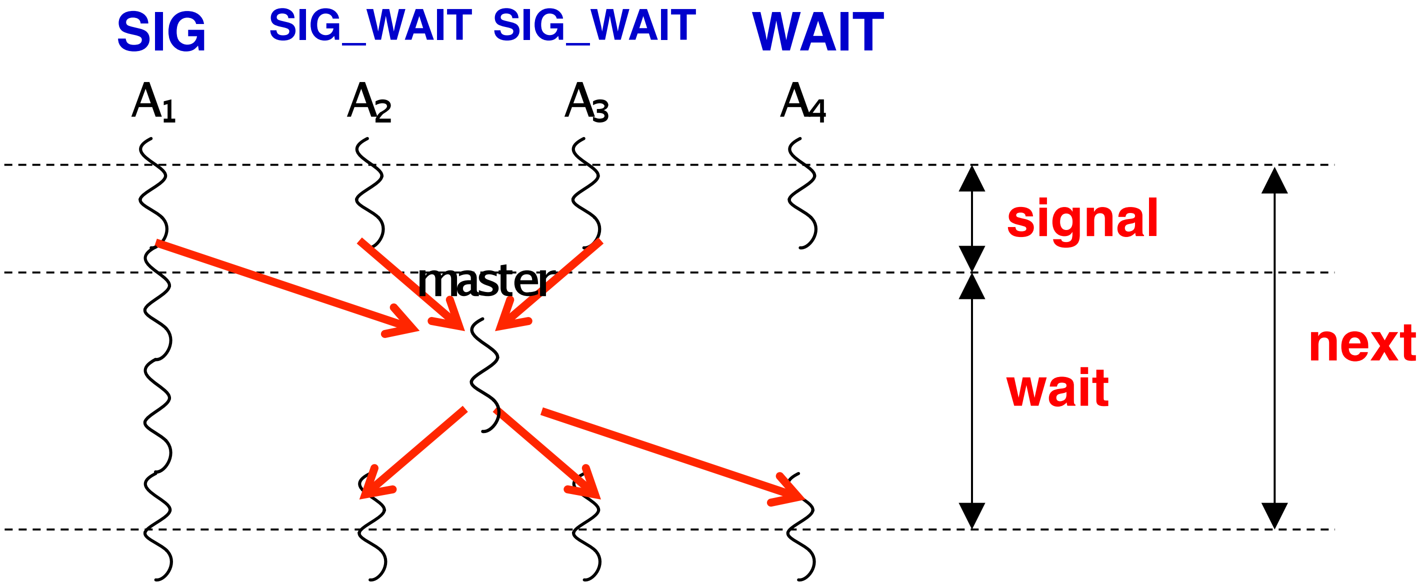
WAIT = { wait }

- At any point in time, a task can be registered in one of four modes with respect to a phaser: SIG_WAIT_SINGLE, SIG_WAIT, SIG, or WAIT. The mode defines the set of capabilities — signal, wait, single — that the task has with respect to the phaser. The subset relationship defines a natural hierarchy of the registration modes.

next operation

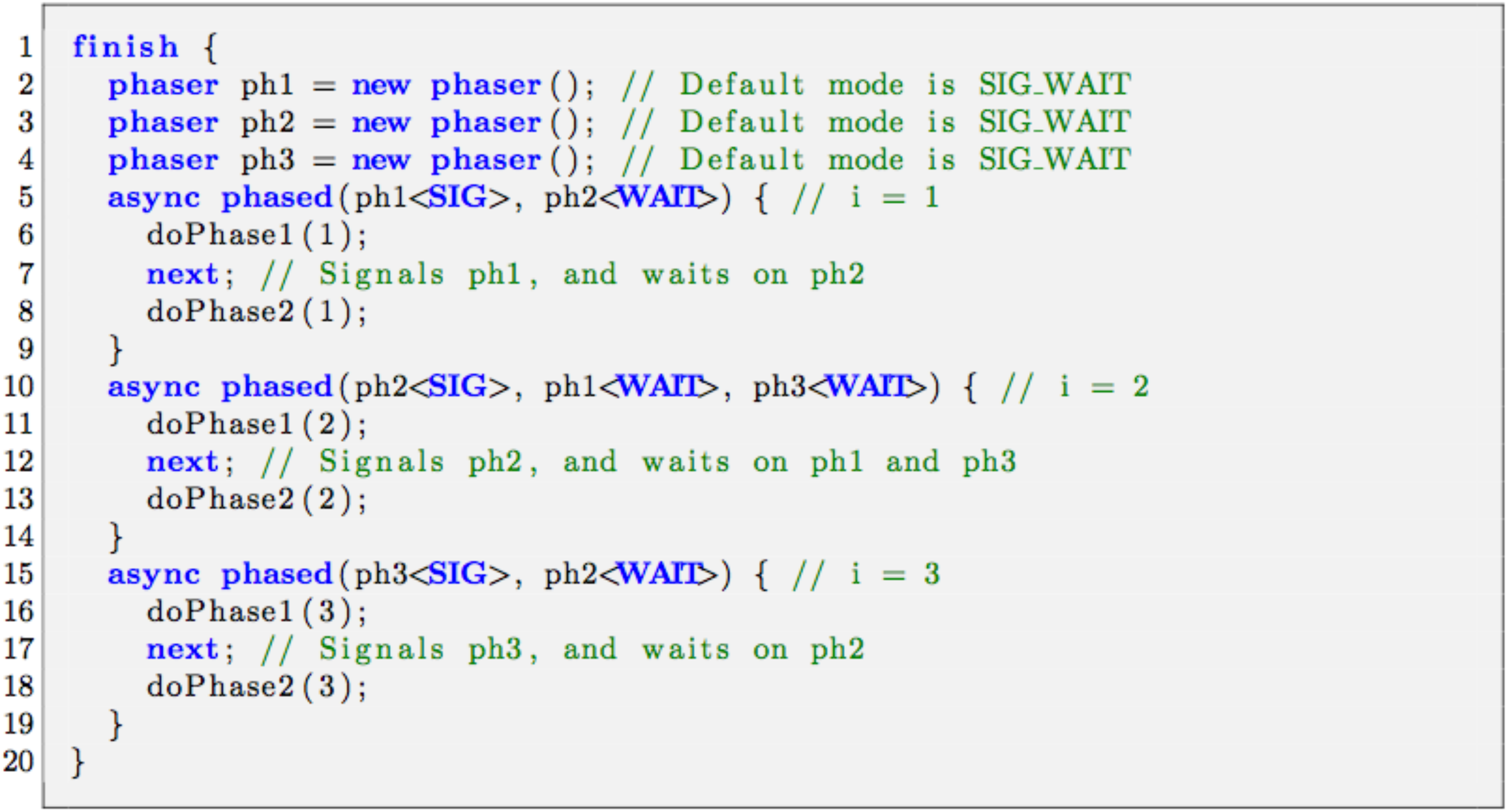
Semantics of next depends on registration mode

- **SIG_WAIT: next = signal + wait**
- **SIG: next = signal (Don't wait for any task)**
- **WAIT: next = wait (Don't disturb any task)**



A master task receives all signals and broadcasts a barrier completion

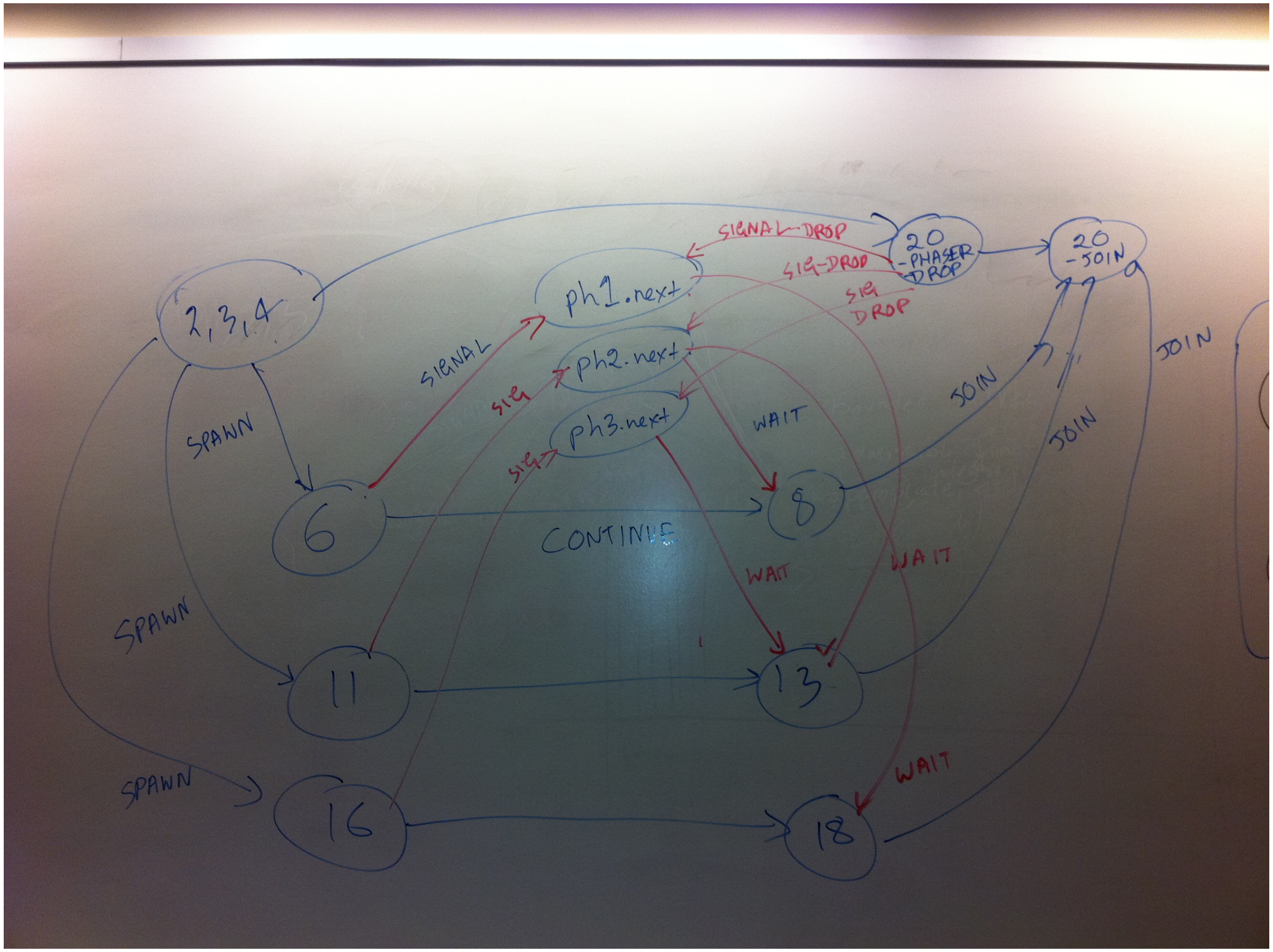
Left-Right Neighbor Synchronization Example for m=3 using Phasers



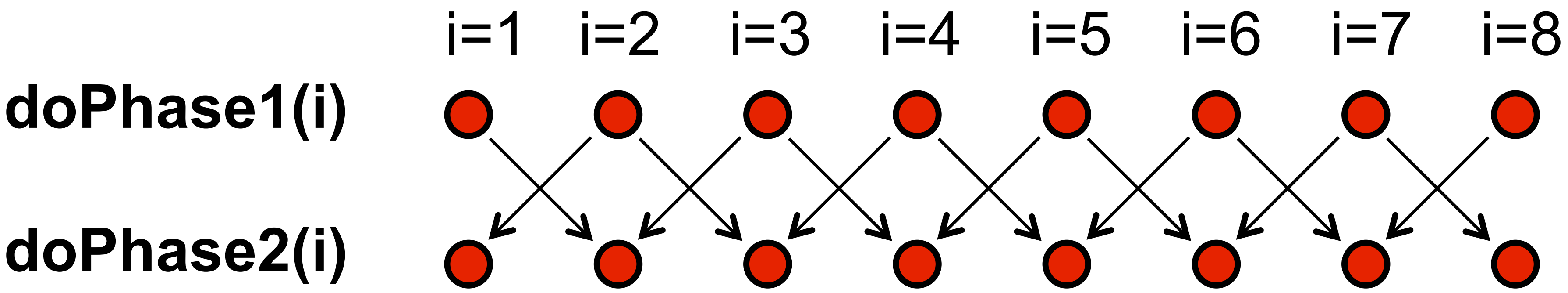
```
finish {
  phaser ph1 = new phaser(); // Default mode is SIG_WAIT
  phaser ph2 = new phaser(); // Default mode is SIG_WAIT
  phaser ph3 = new phaser(); // Default mode is SIG_WAIT
  async phased(ph1<SIG>, ph2<WAIT>) { // i = 1
    doPhase1(1);
    next; // Signals ph1, and waits on ph2
    doPhase2(1);
  }
  async phased(ph2<SIG>, ph1<WAIT>, ph3<WAIT>) { // i = 2
    doPhase1(2);
    next; // Signals ph2, and waits on ph1 and ph3
    doPhase2(2);
  }
  async phased(ph3<SIG>, ph2<WAIT>) { // i = 3
    doPhase1(3);
    next; // Signals ph3, and waits on ph2
    doPhase2(3);
  }
}
```

Listing 3: Extension of example in Listing 1 with three phasers for $m = 3$

Whiteboard picture from lecture (Computation Graph for previous slide)



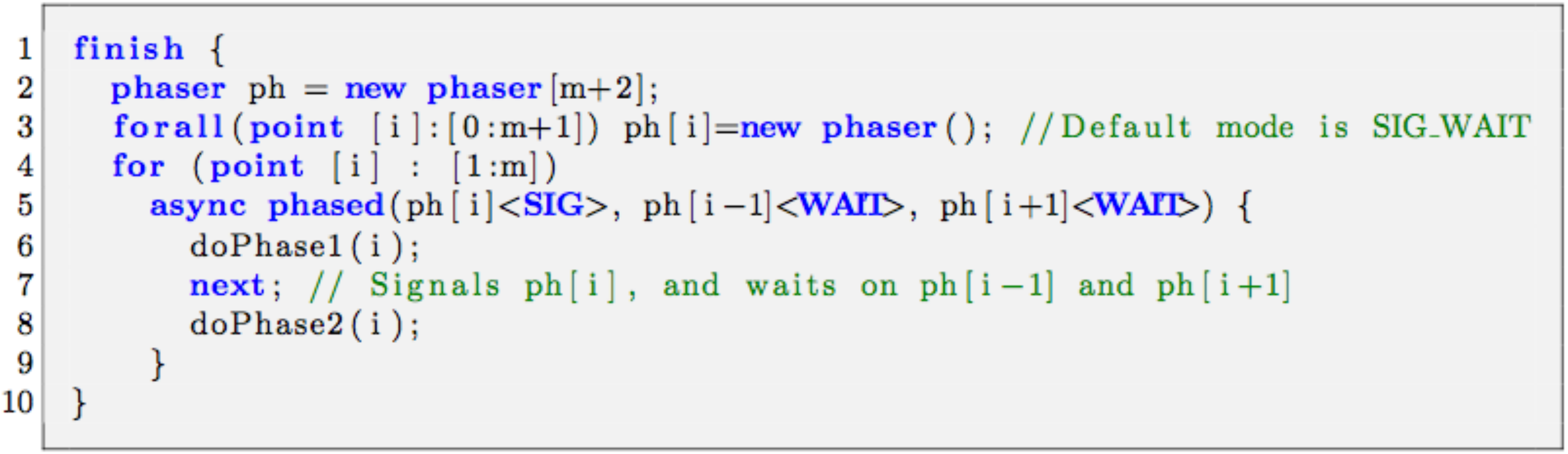
Left-Right Neighbor Synchronization Example for General m



i=1 i=2 i=3 i=4 i=5 i=6 i=7 i=8

doPhase1(i)

doPhase2(i)



```
finish {
  phaser ph = new phaser[m+2];
  forall(point [i]:[0:m+1]) ph[i]=new phaser(); //Default mode is SIG_WAIT
  for (point [i] : [1:m])
    async phased(ph[i]<SIG>, ph[i-1]<WAIT>, ph[i+1]<WAIT>) {
      doPhase1(i);
      next; // Signals ph[i], and waits on ph[i-1] and ph[i+1]
      doPhase2(i);
    }
}
```

Listing 4: Extension of example in Listing 1 with array of $m+2$ phasers for general m