Friendly Barriers: Efficient Work-Stealing With Return Barriers

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The "New" Era of Computing

- Commodity multi-core processors
  - HPC ➔ servers ➔ laptops ➔ mobile devices
- Software parallelism no longer optional
- Wide adoption of managed languages

Research Opportunities Abound ☺

Our Research Question

How can we apply the

capabilities of managed language runtimes

to enable applications with task-based parallelism

to effectively exploit current and future hardware?

Talk Outline

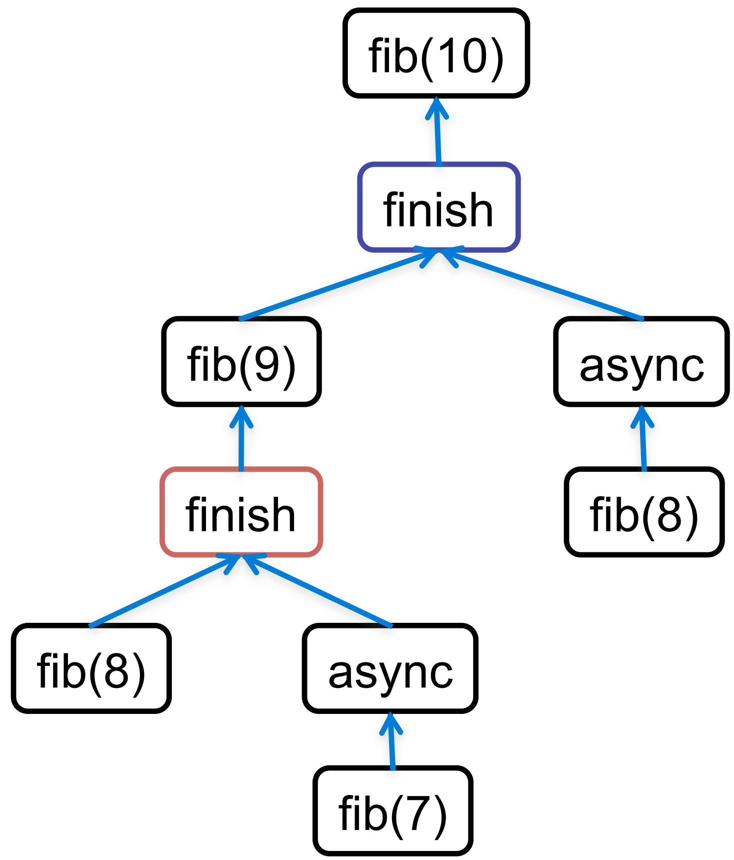
- Background on X10 and Work-Stealing
- Our Base System
  - Try-Catch Work-Stealing [OOPSLA 2012]
- Friendly Barriers [VEE 2014]
  - Motivating analysis
  - How we apply return barriers
  - Performance results
- Conclusions

X10 Summary

- X10 is
  - a programming language
  - an open-source tool chain
    - compiles X10 to C++ or Java
- X10 tackles programming at *scale*
  - scale out: run across many distributed nodes
  - scale up: exploit multi-core and accelerators
  - double goal: *productivity* and *performance*

Task Parallelism in X10

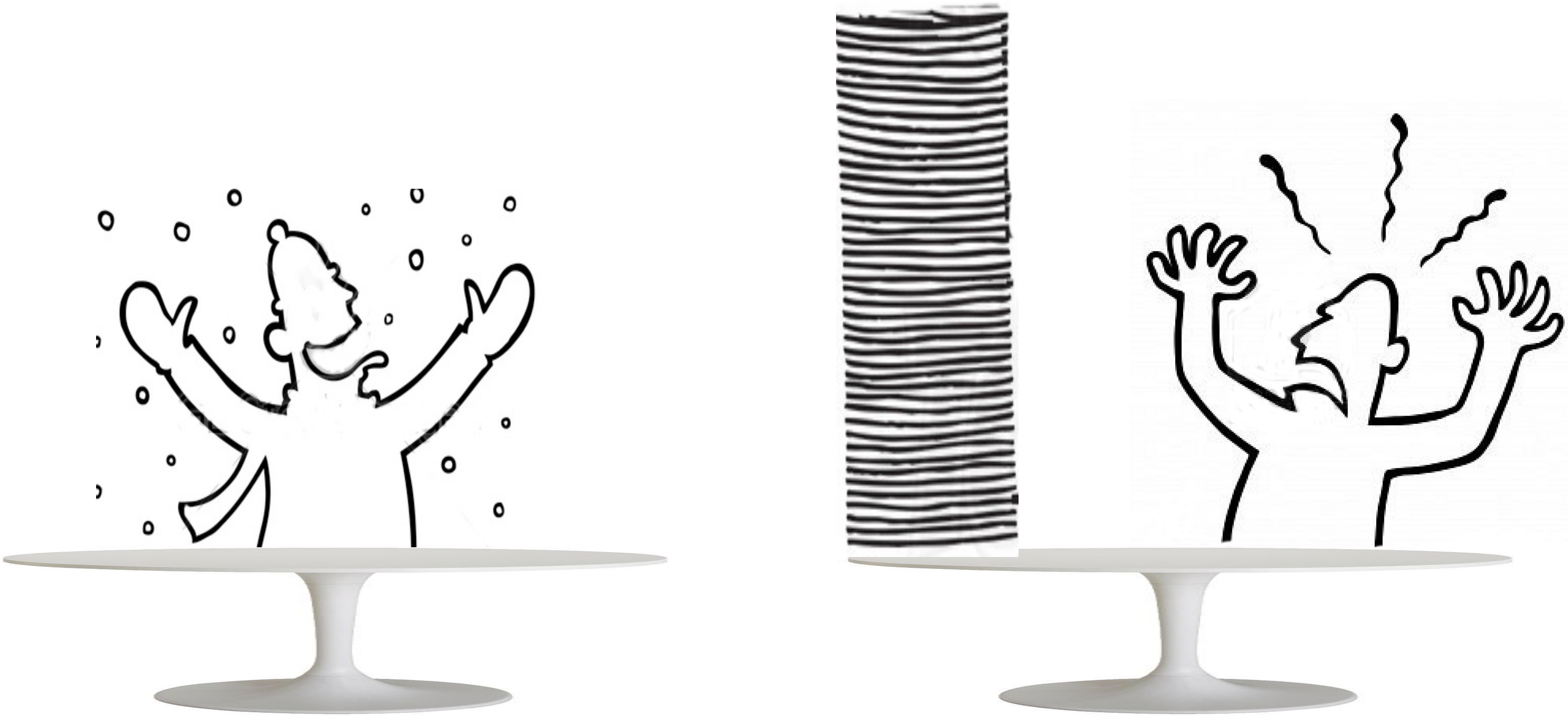
```
static def fib(n:Long):Long {
    val t1, t2:Long;
    if (n < 2) return 1;
    finish {
        async t1 = fib(n-1);
        t2 = fib(n-2);
    }
    return t1 + t2;
}
```



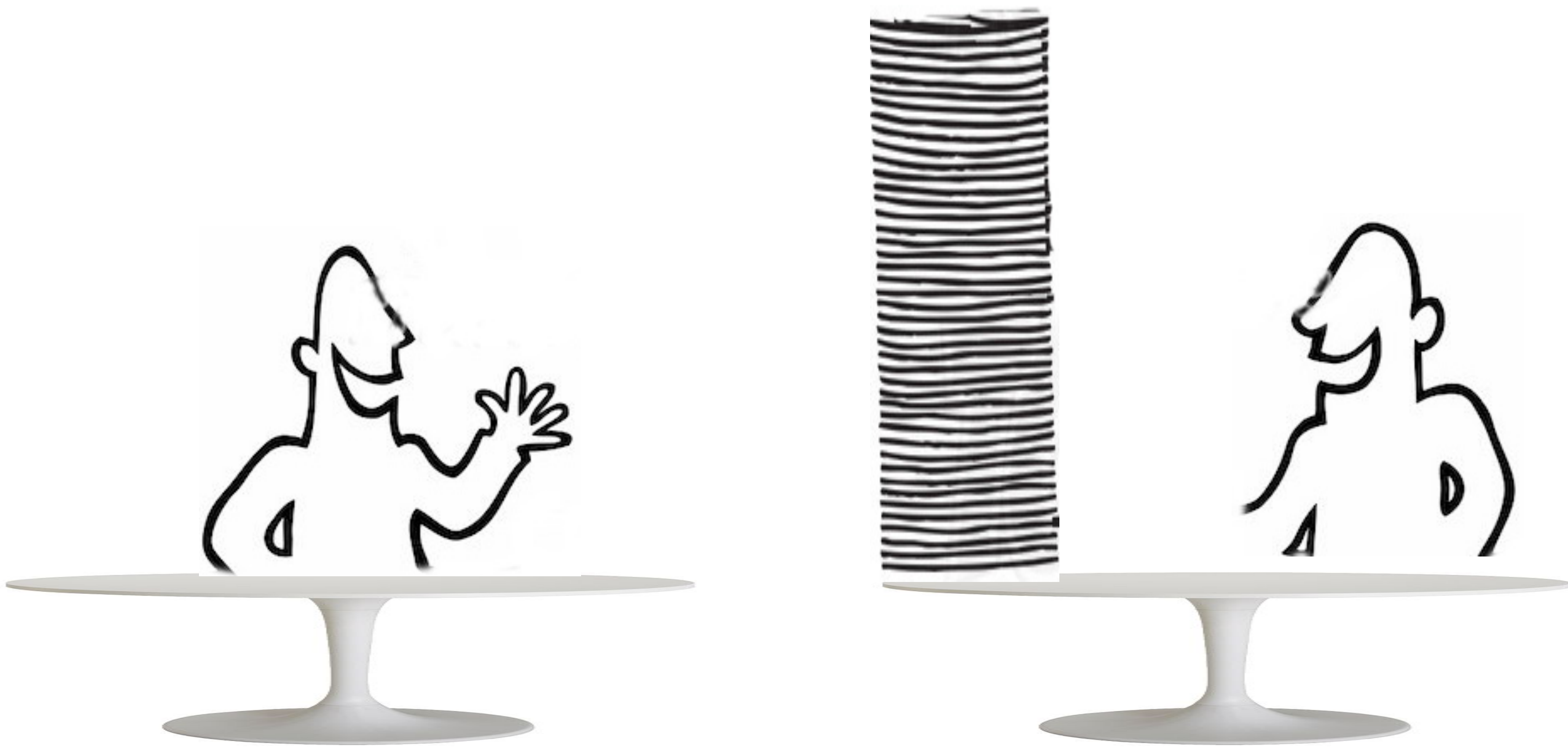
Understanding Work–Stealing

Work–Stealing

Work–Stealing



Work–Stealing



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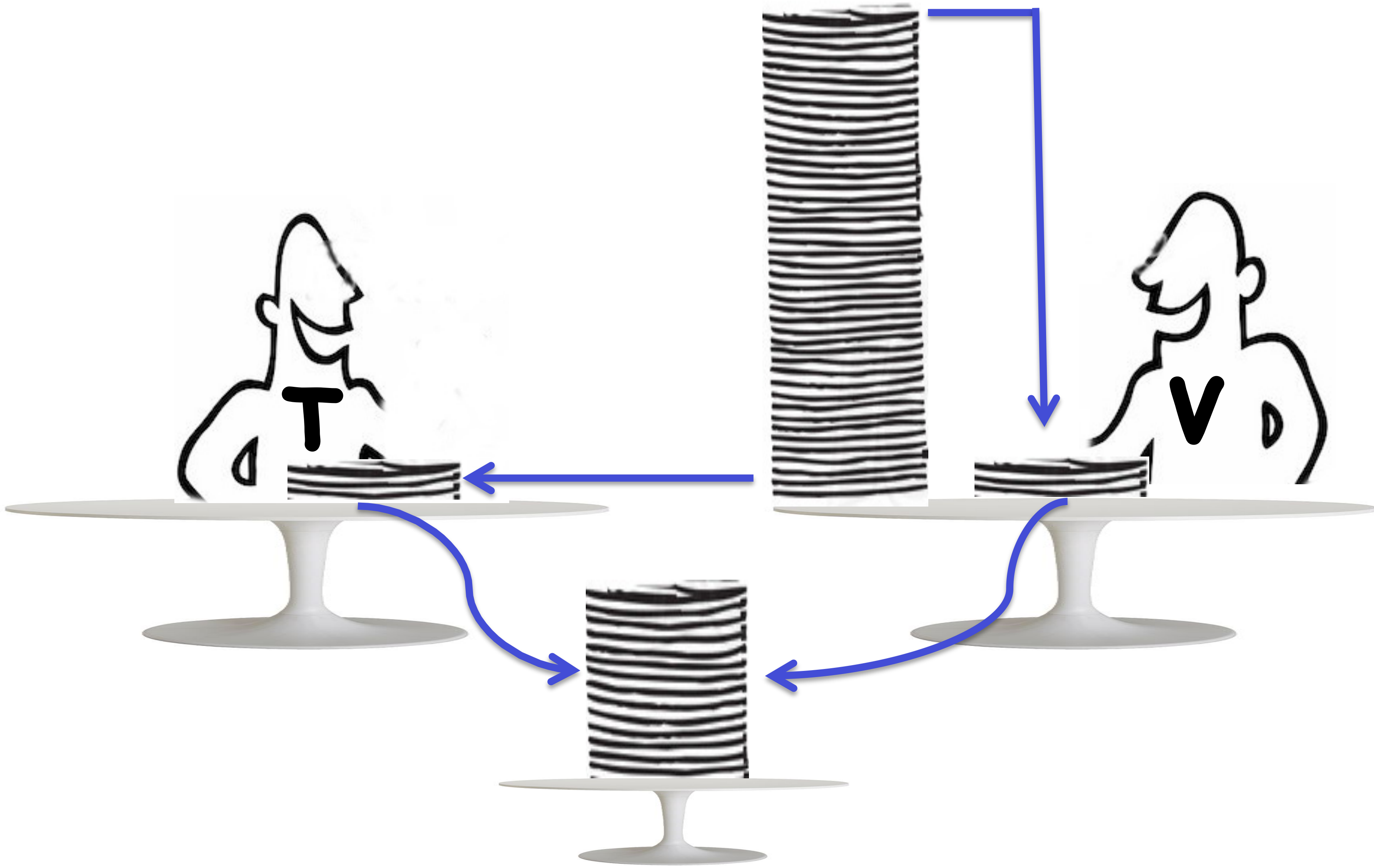

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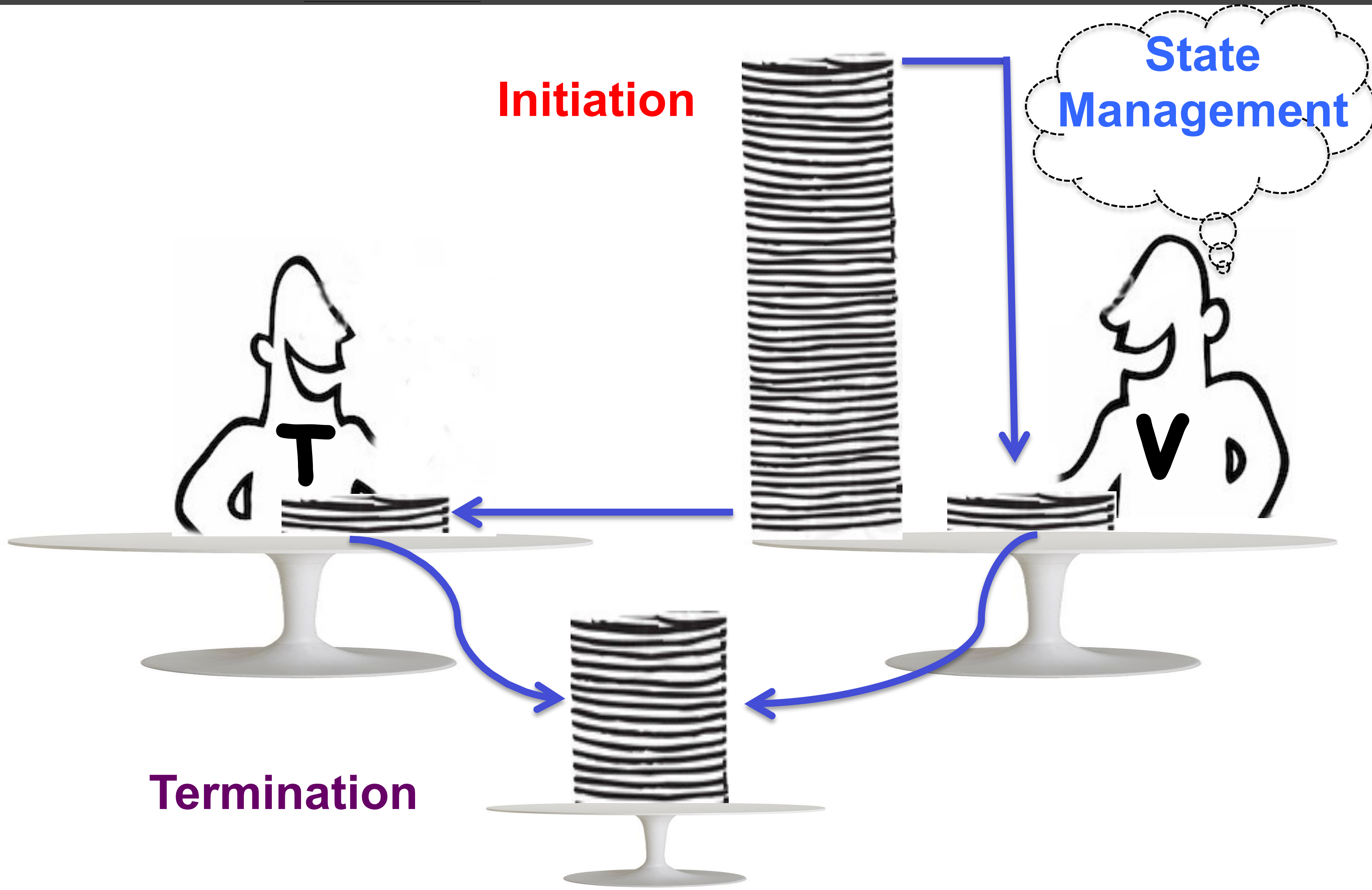

Work-Stealing Schedulers

- Common features
  - a pool of worker threads
  - per-worker deque of pending tasks
  - worker pushes and pops tasks from its deque
  - idle worker steals tasks from another worker's deque
- Widely used
  - Cilk, Java Fork/Join, TBB, X10, Habenero, …

Work-Stealing Without the Baggage

OOPSLA 2012

- JavaWS (Try-Catch)
  - Reduced sequential overheads of work-stealing from 4.1x to 15%
  - Our baseline system
    - DefaultWS

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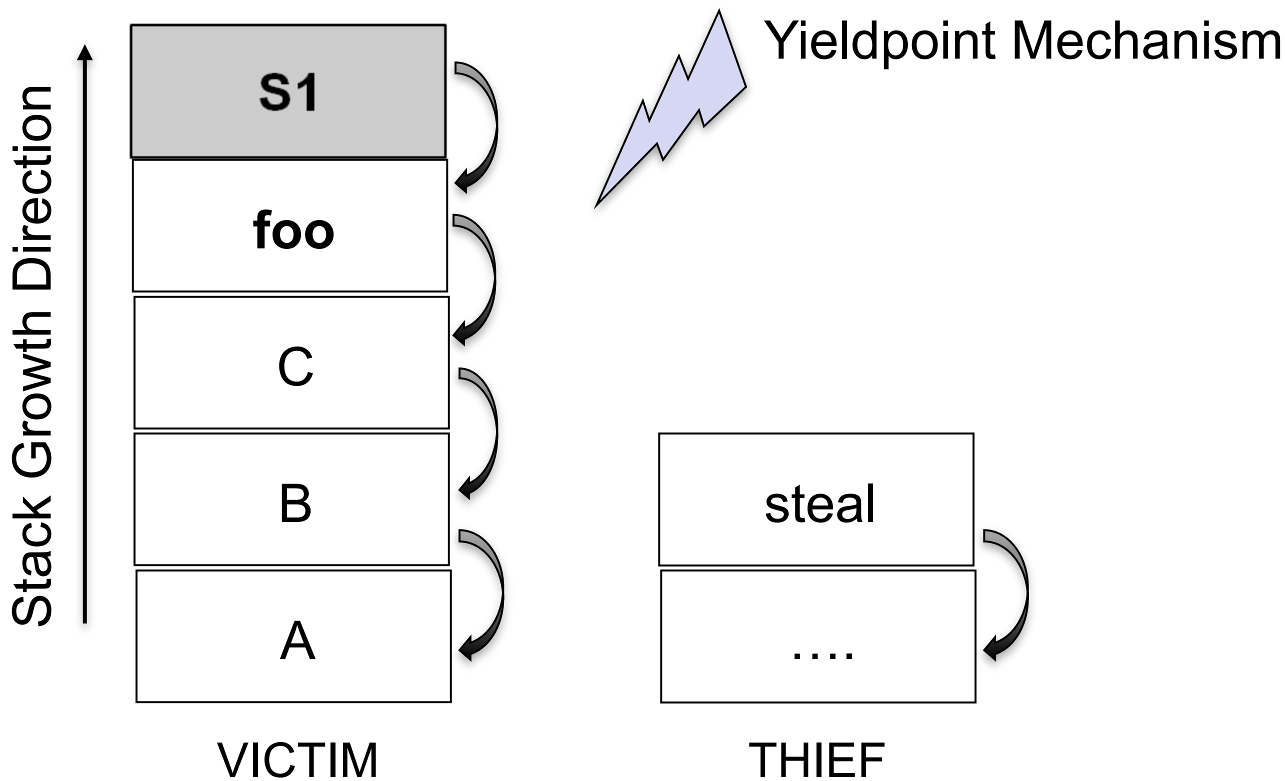
Our Prior Work

```
foo() {
    finish {
        async X = S1();
        Y = S2();
    }
}
```

- Yieldpoint mechanism
- On-stack replacement
- Java try/catch exceptions
- Dynamic code patching



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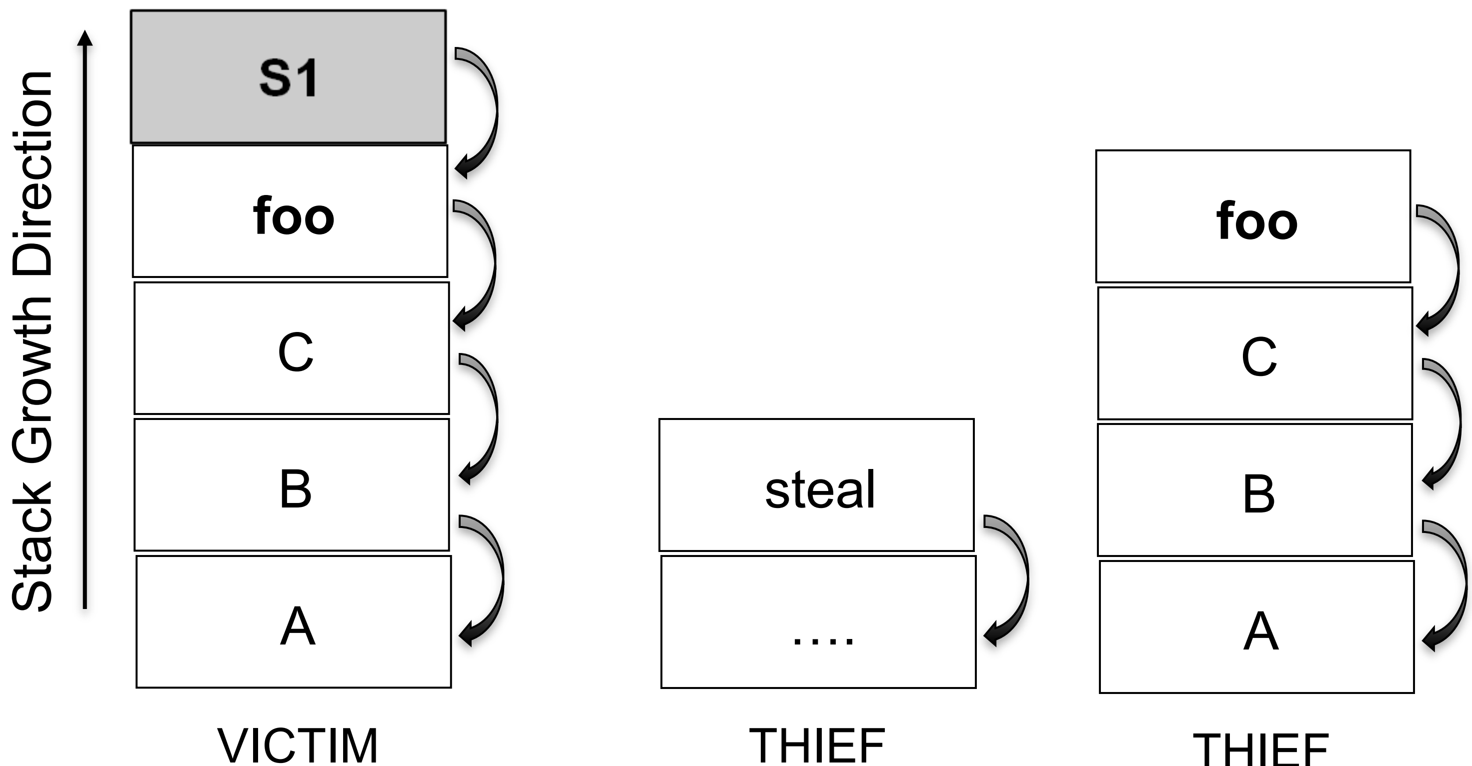

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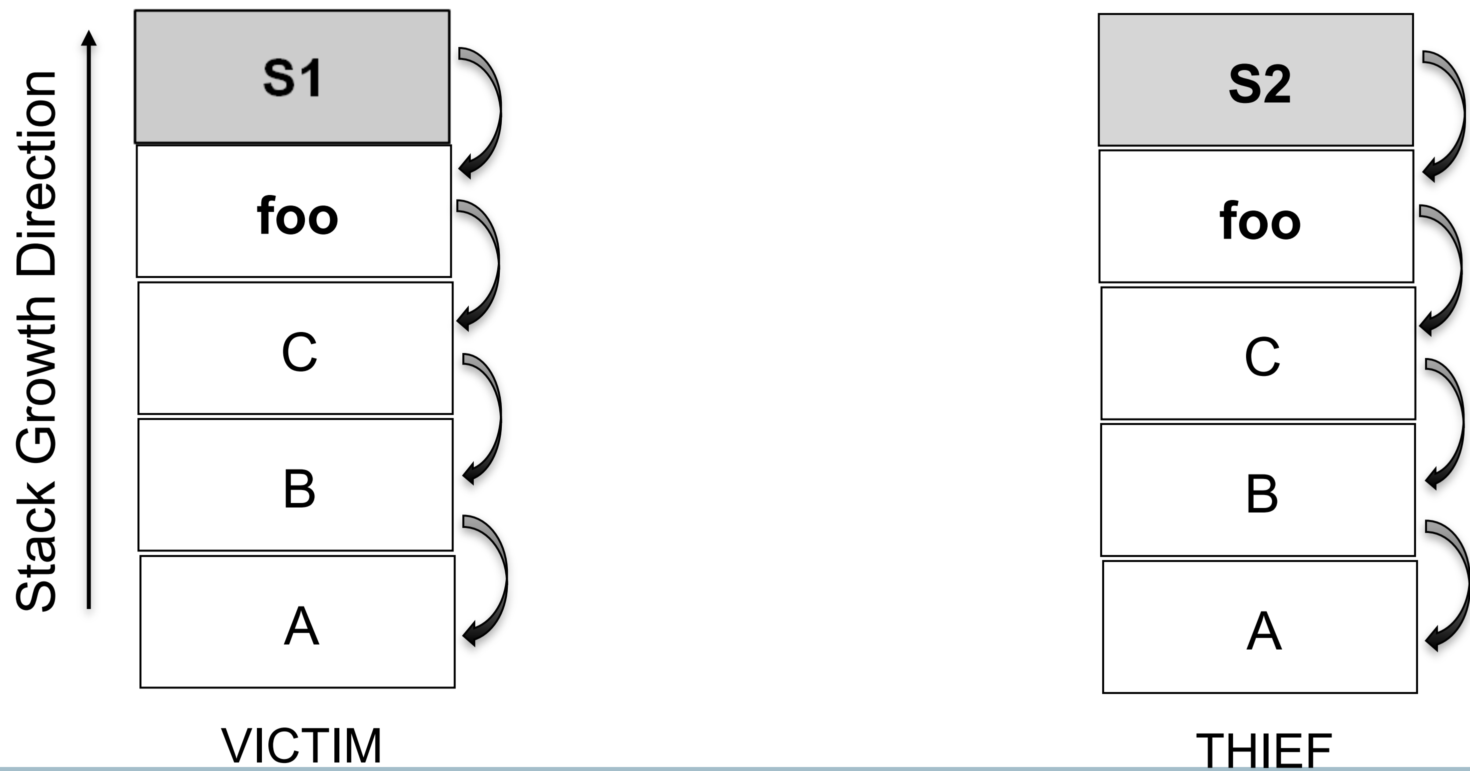

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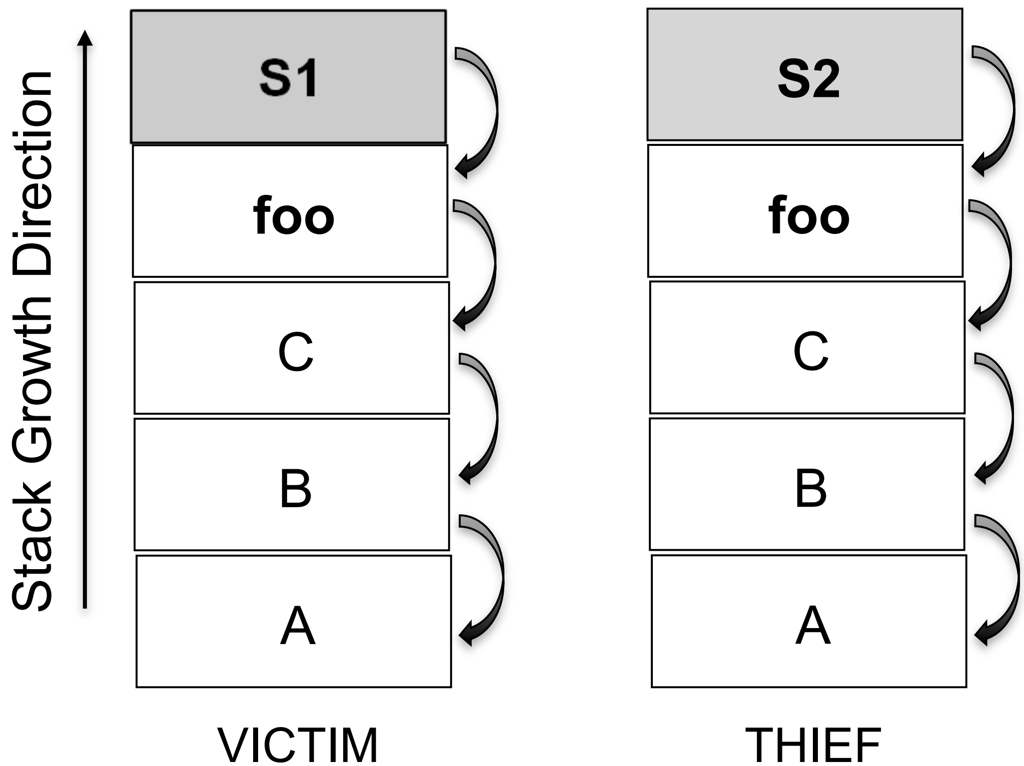
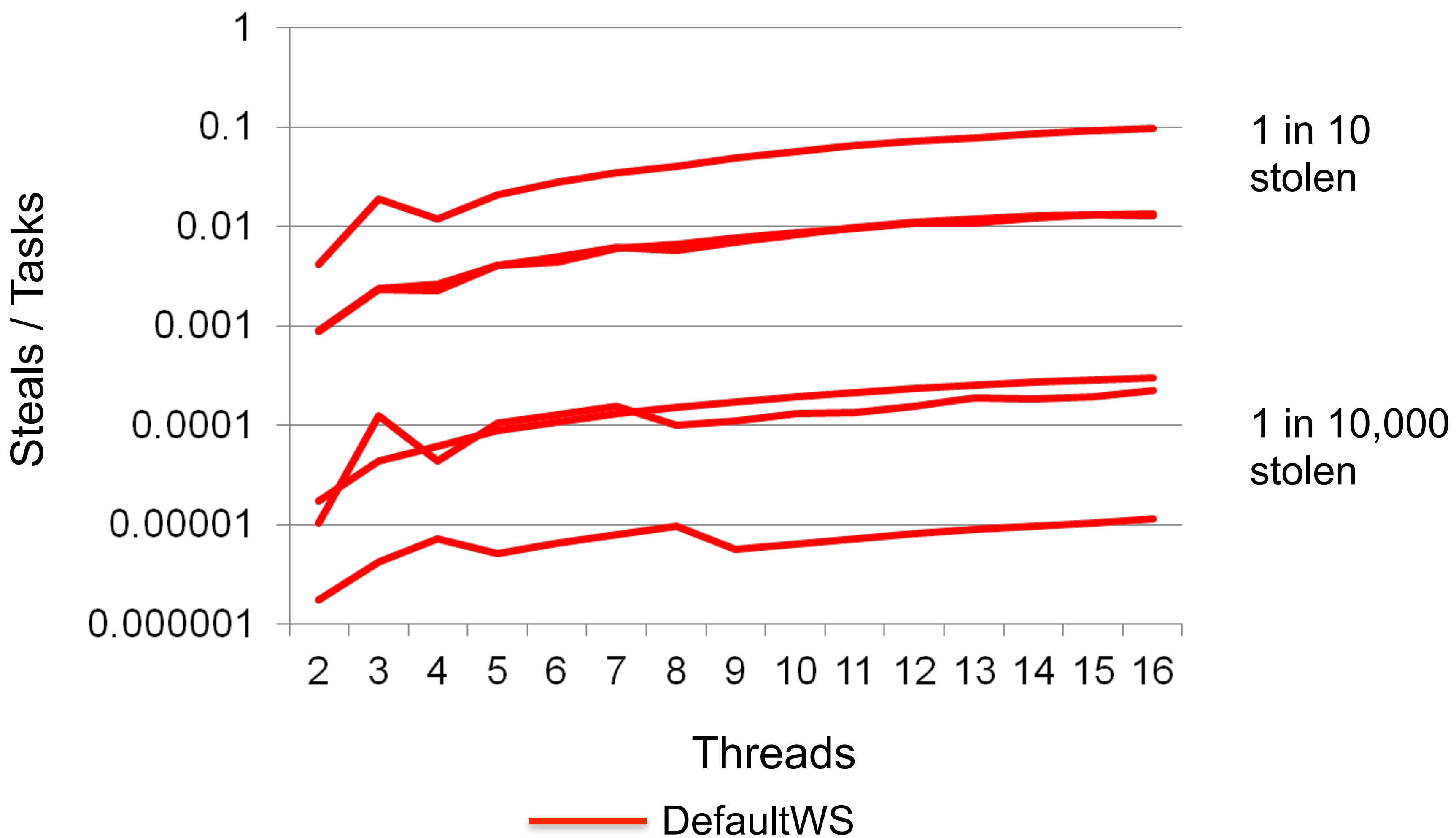


Motivating Analysis

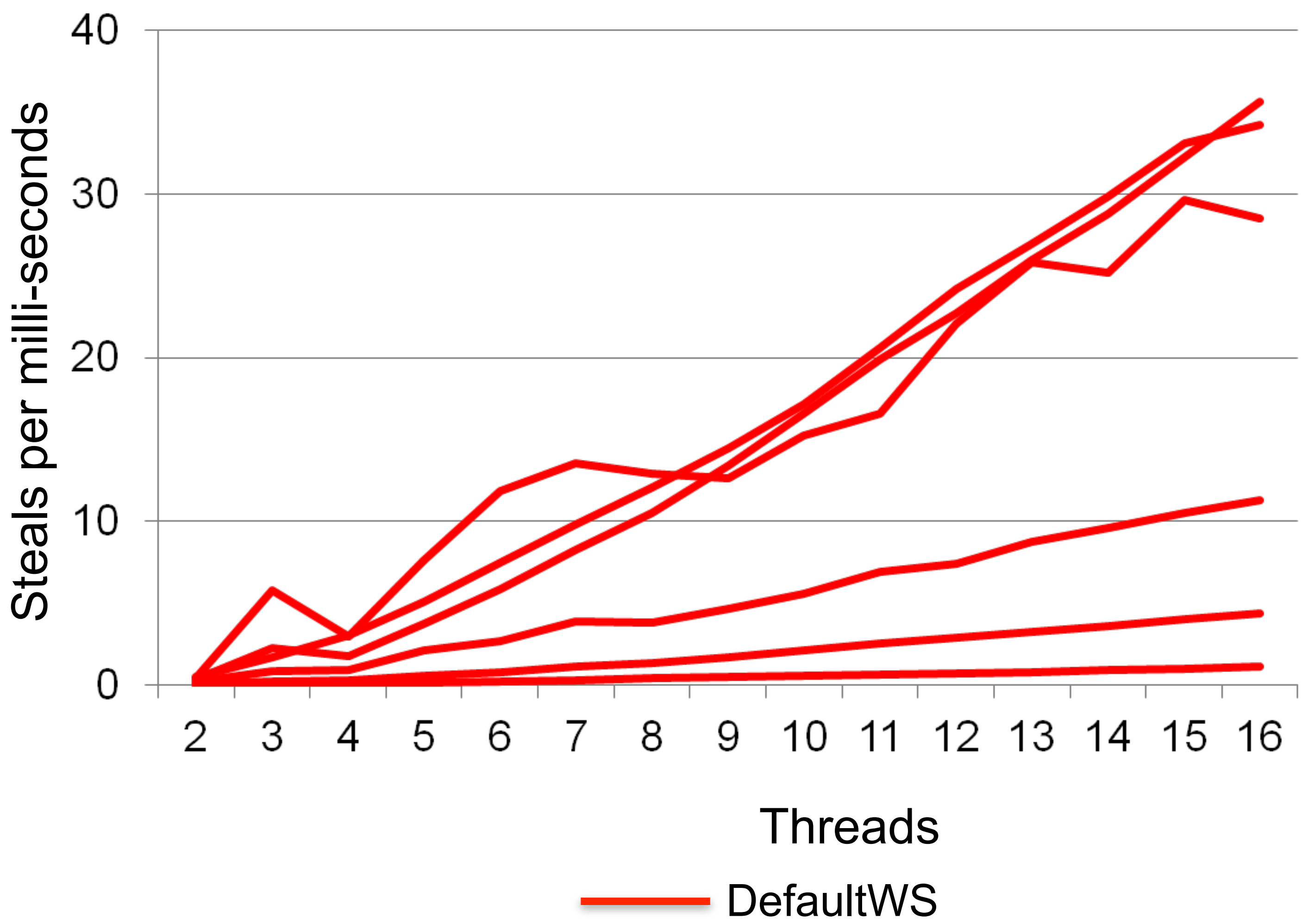
Methodology

- Benchmarks
  - Jacobi
  - FFT
  - CilkSort
  - Barnes-Hut
  - UTS
  - LU Decomposition (LUD)
- Hardware platform
  - 2 Intel Xeon E5-2450
    - 8 cores each
- Software platform
  - Jikes RVM (3.1.3)

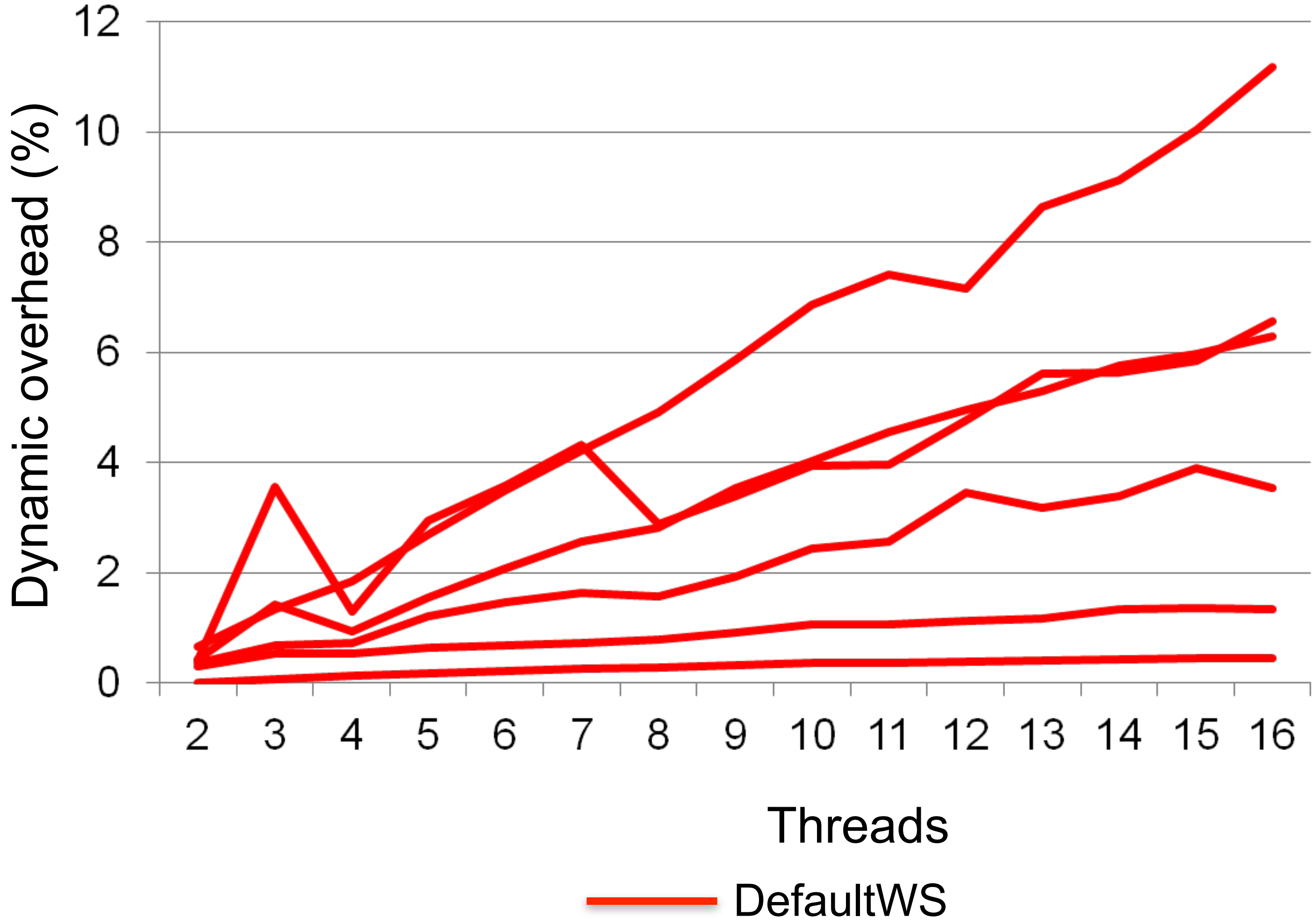
Steals To Task Ratio



Steal Rate


40
30
20
10
0
Steals per milli-seconds
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Threads
DefaultWS

Dynamic Overhead (Victim Stalled)



Insights

- Forcing victim to wait inside yieldpoint at every steal attempt is inefficient
- Re-use existing mechanisms inside modern managed runtime to reduce victim wait time

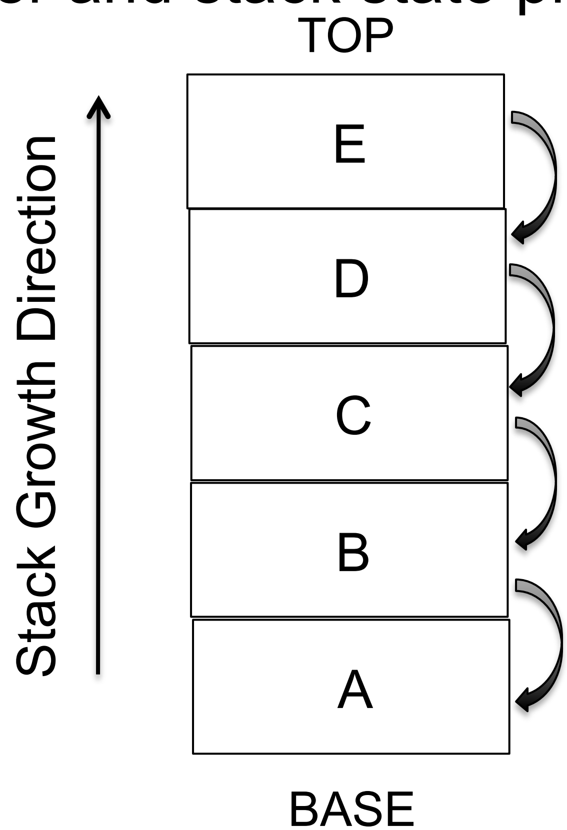
Approach

- Use return barrier to “protect” the victim from thief
  - ✓ Victim oblivious to steal from thief
  - ✓ Cost of barrier only when victim unwind past the barrier
  - ✓ When above the barrier, victim sees no cost
  - ✓ More concurrency between thief and its victim

Implementation

Return Barrier

- Allows runtime to intercept a common event
- Hijack a return and bridge to some other method
- Register and stack state preserved



Frame D

Frame Pointer	Return Address
Frame C	Method C

Return Barrier

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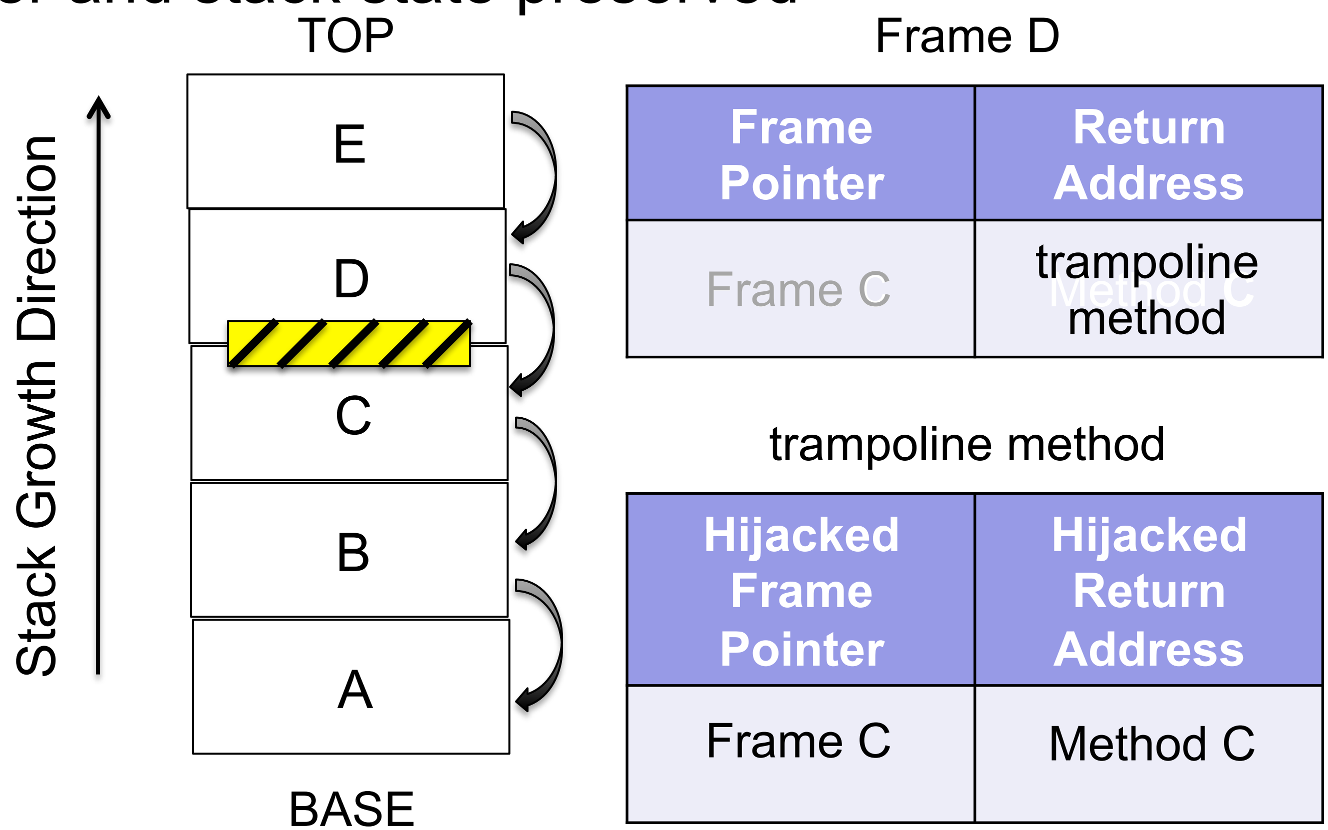
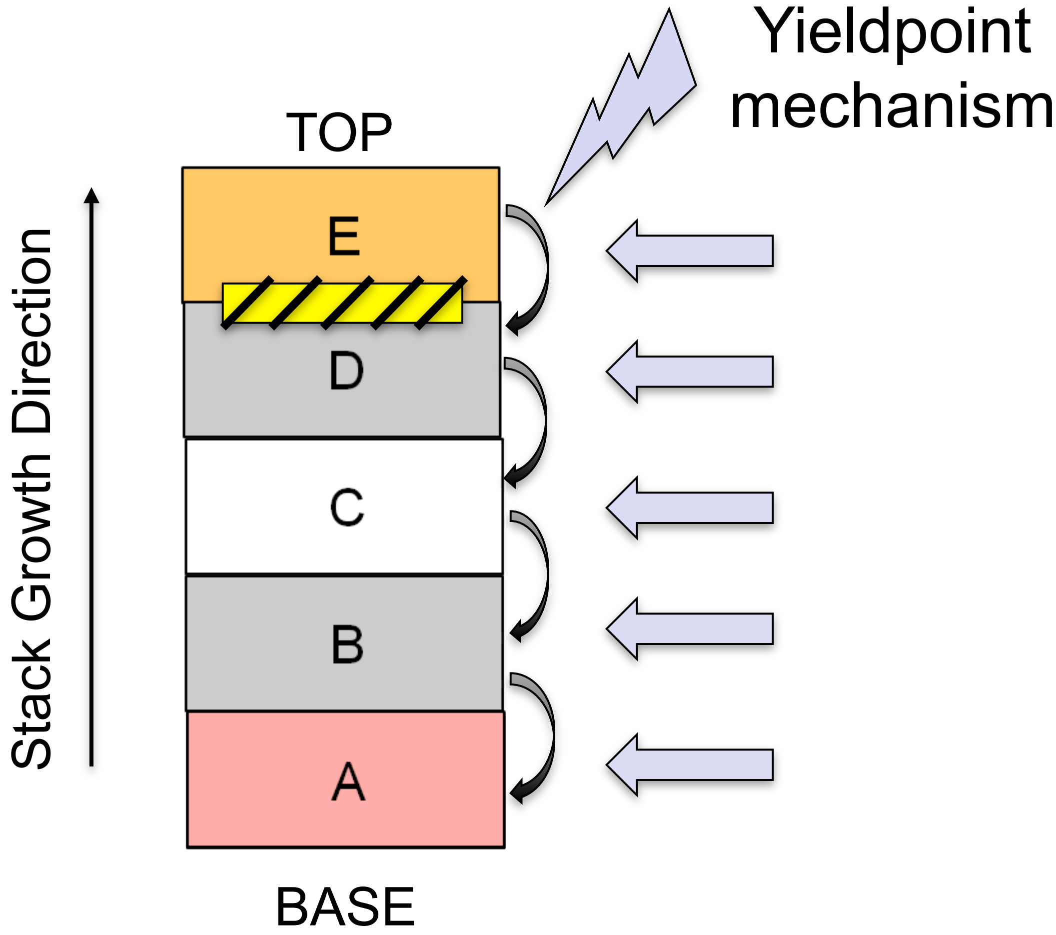
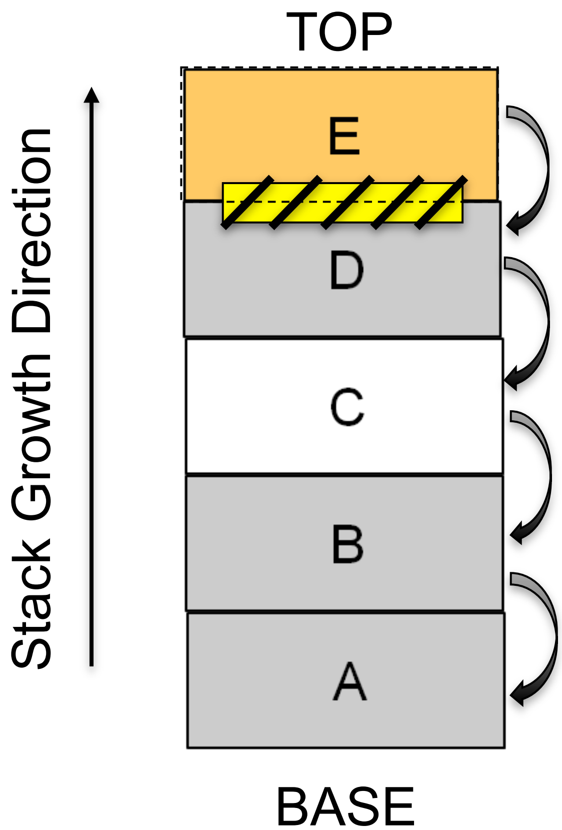


Thief Installs Return Barrier



Victim Moves The Return Barrier



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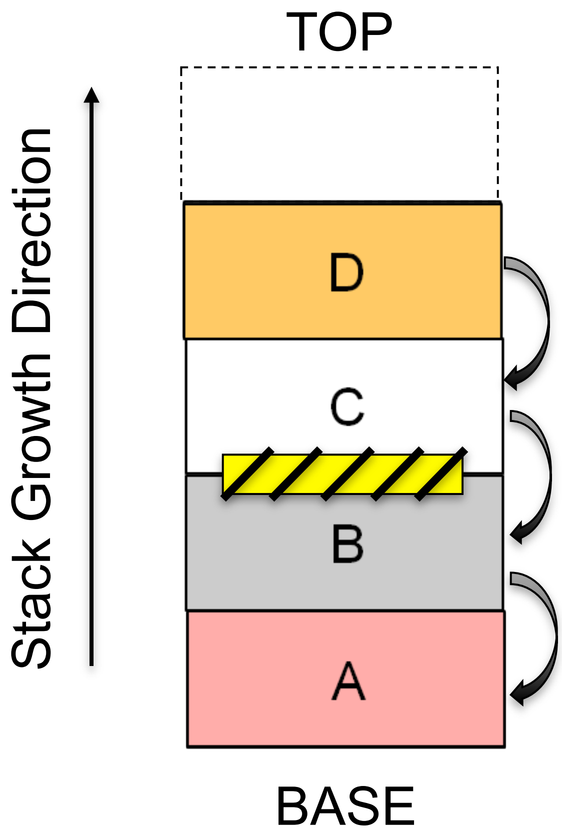
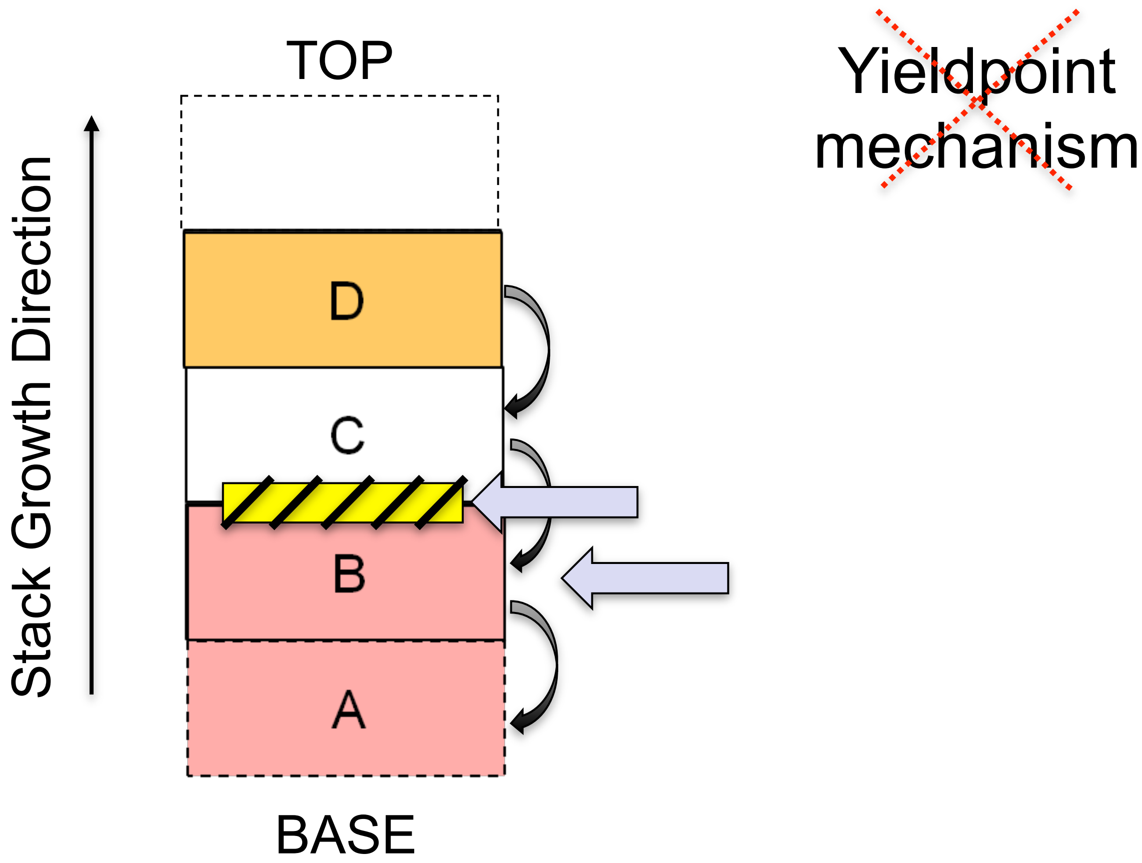


Robbing A Victim With Return Barrier



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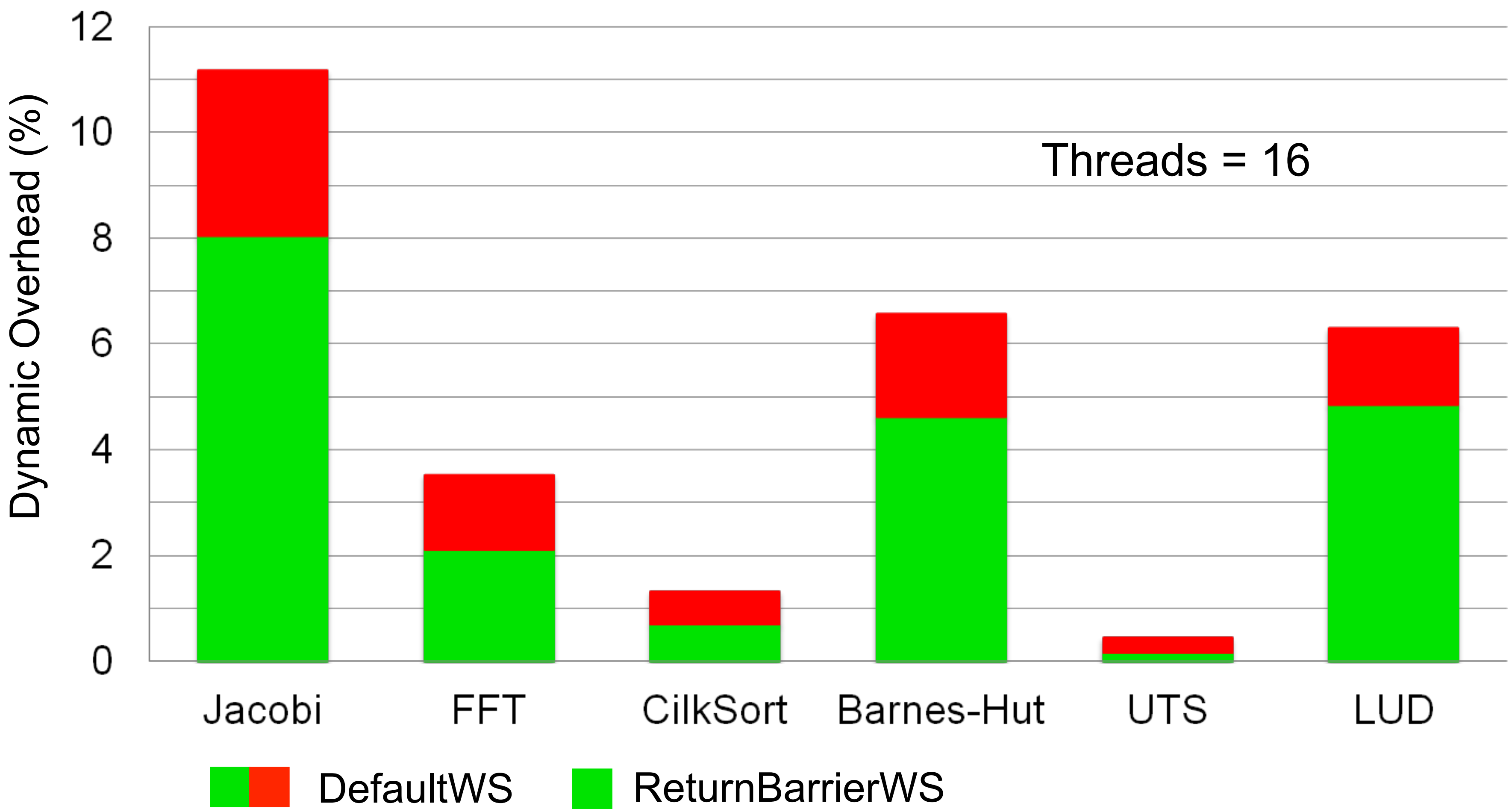
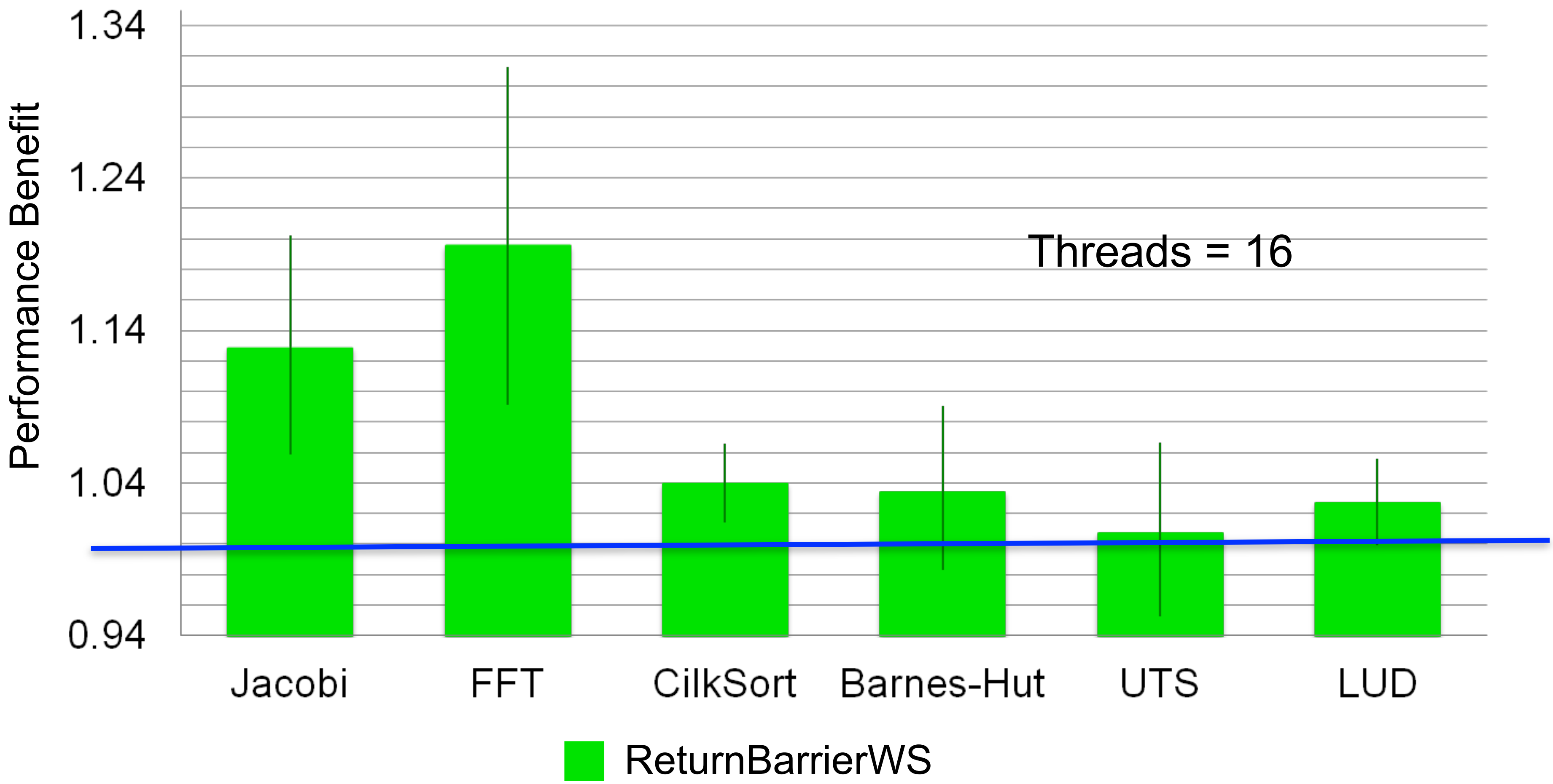
Performance Evaluation

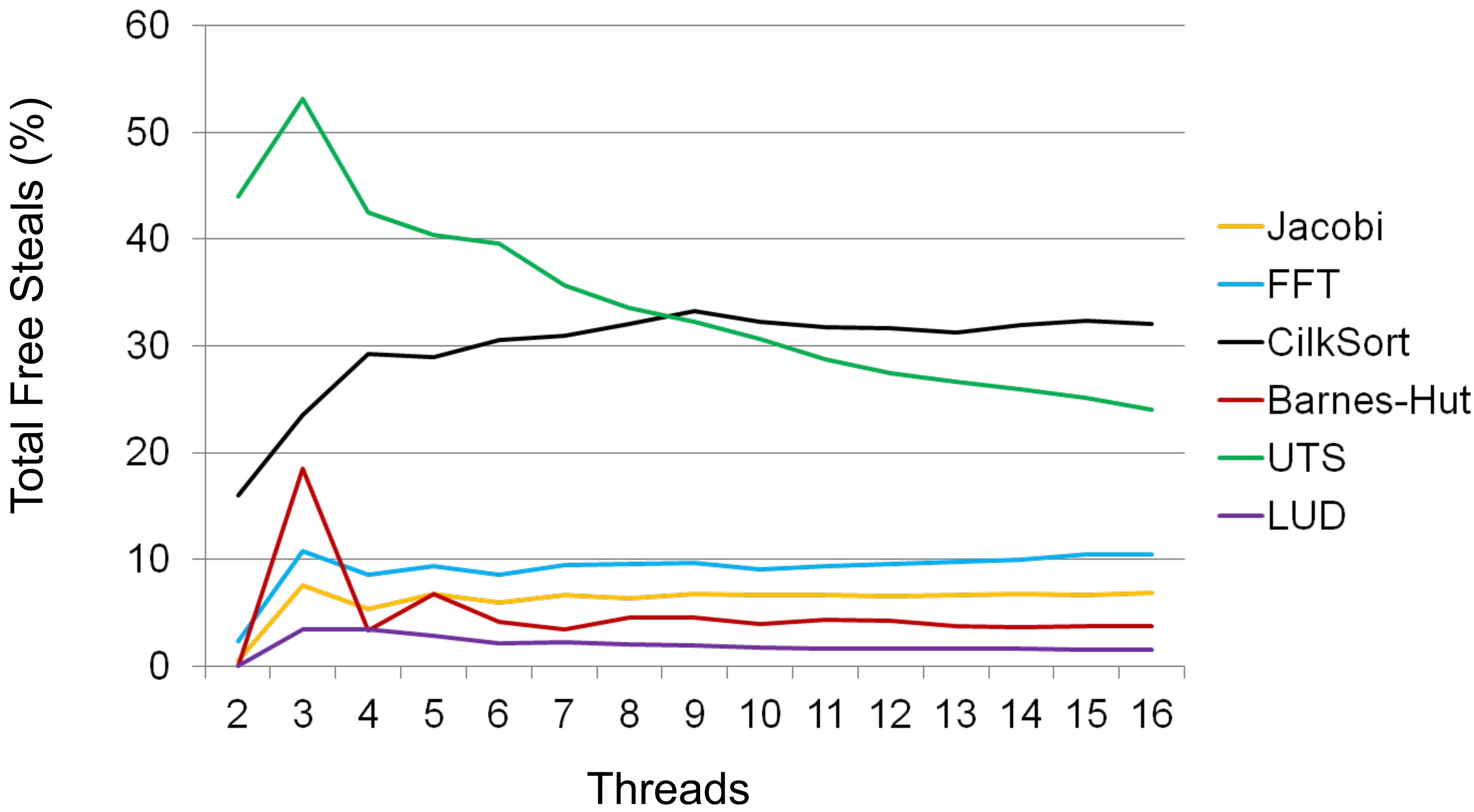
Dynamic Overhead



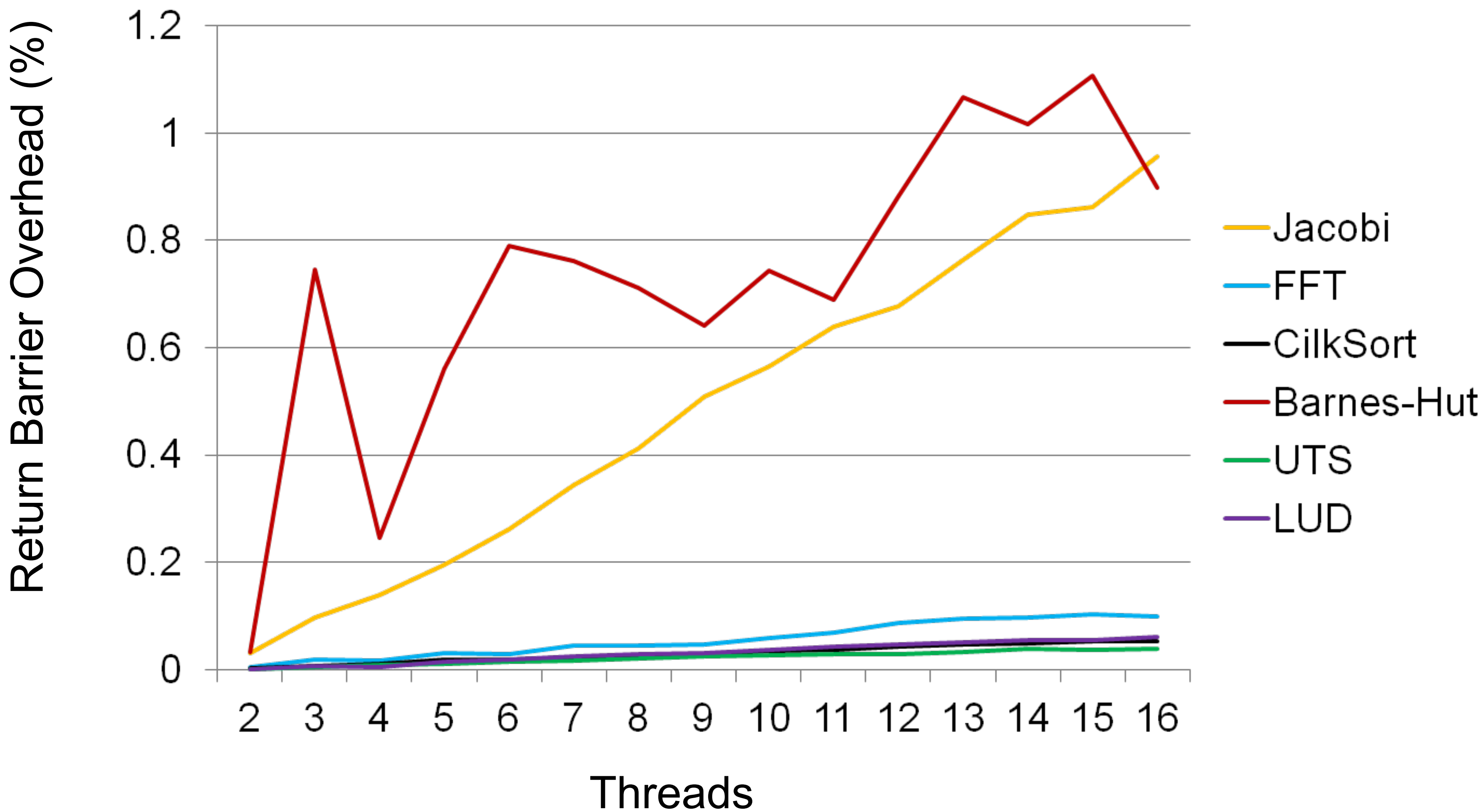
Performance Benefit Relative to DefaultWS



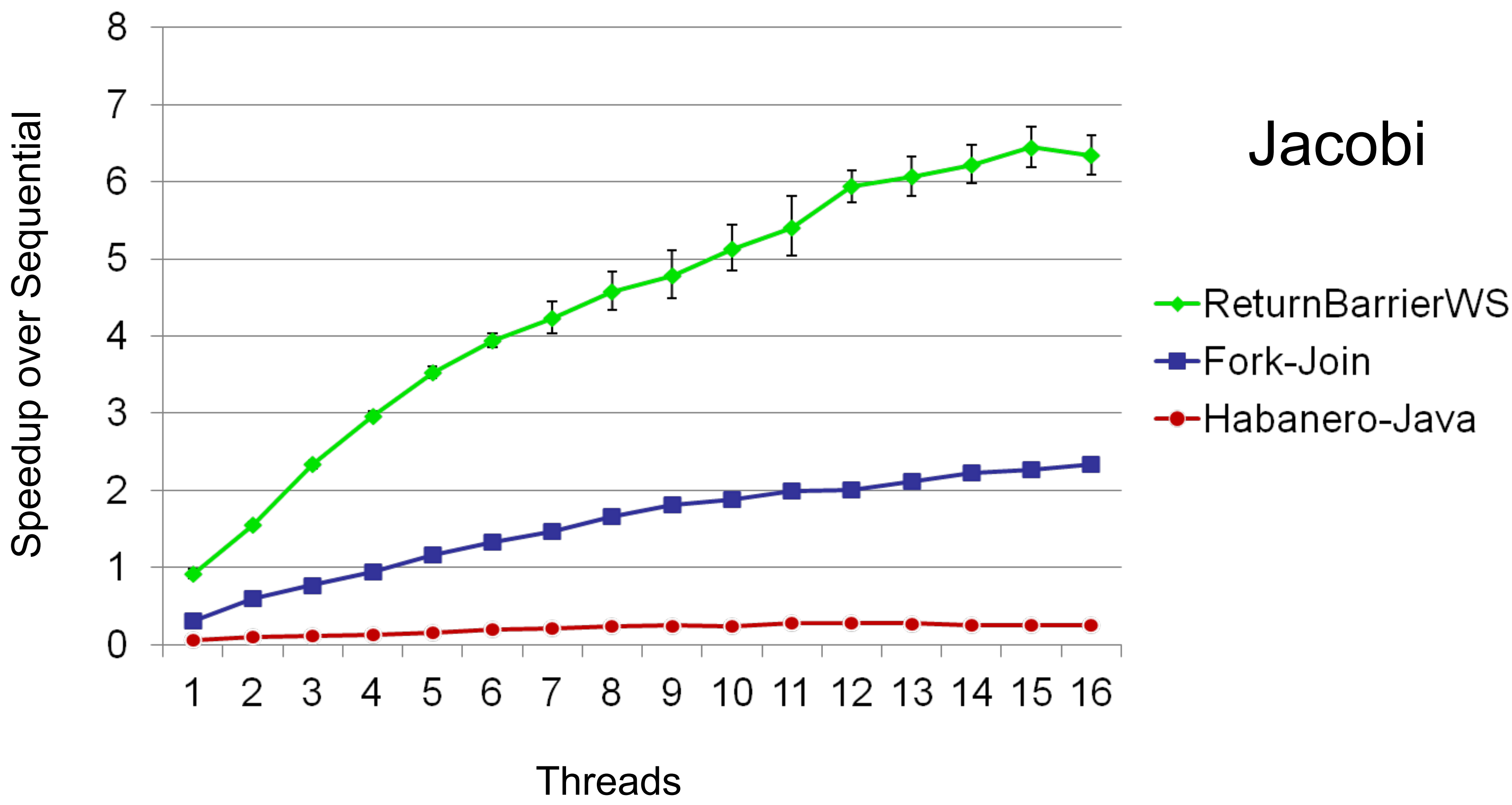
Free Steals From Return Barrier



Overhead of Executing Return Barrier



Comparative Performance



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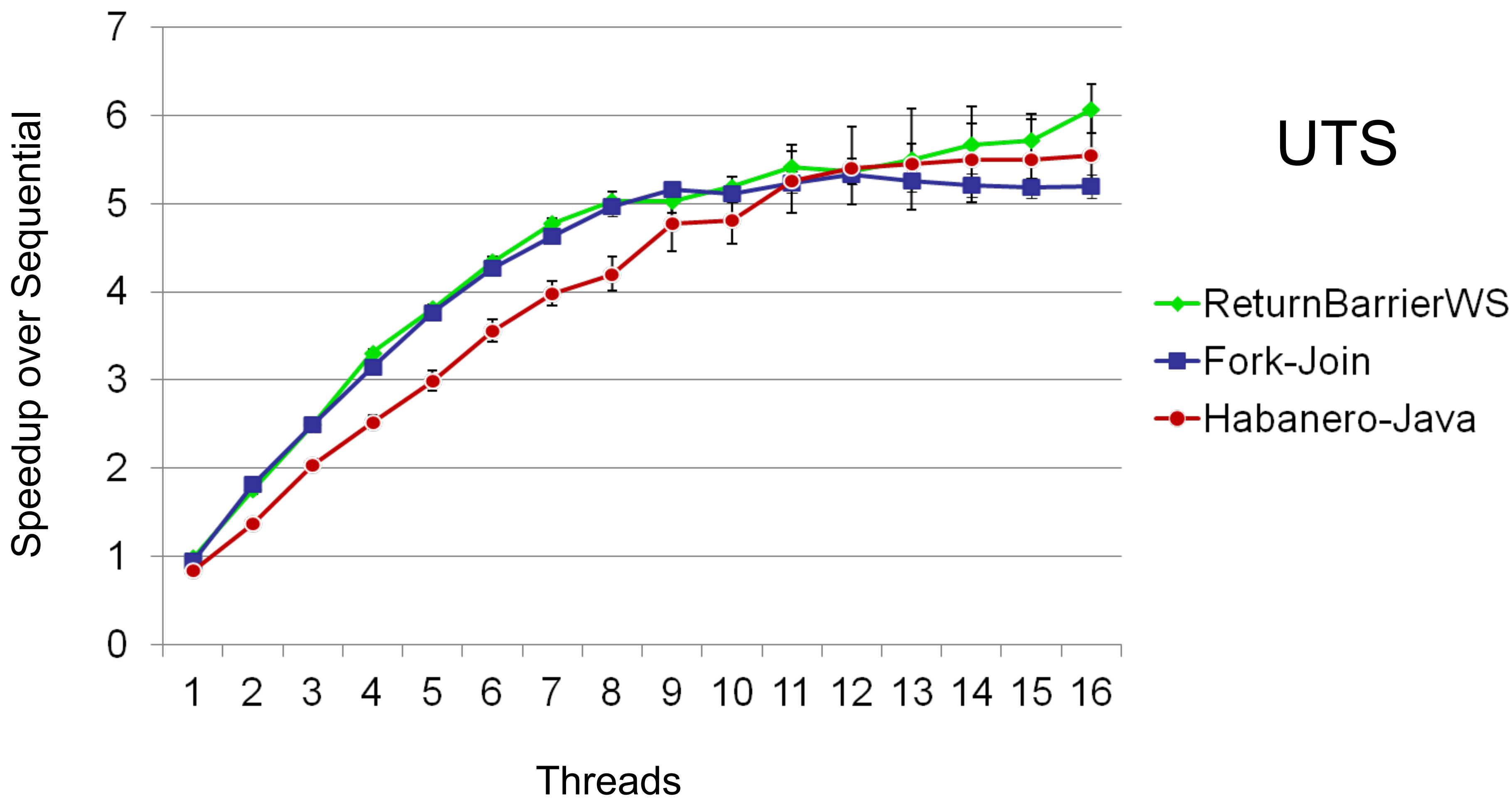

Summary and Conclusion

- Big Picture: Laziness pays off
  - DefaultWS extremely efficient/effective
- Tackling dynamic overheads
  - grows as parallelism increases
  - grows as steal rate increases
- Return barrier mechanism *protects* victim from thief
  - Victim oblivious to thief's activities
- Return barrier *halves* dynamic overhead
- Performance benefit (vs DefaultWS) of up to 20%