

An Efficient On-the-fly Detection of First Races in Nested Parallel Programs

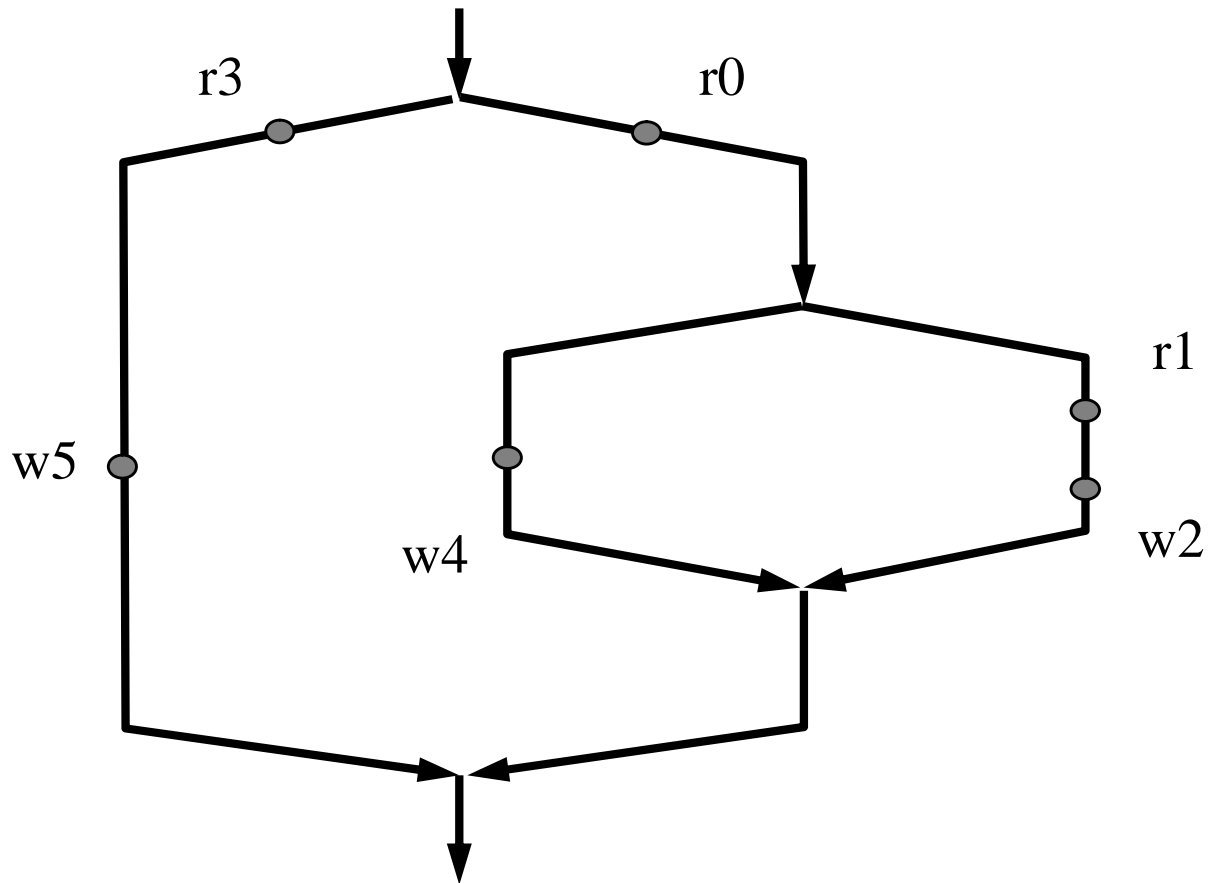
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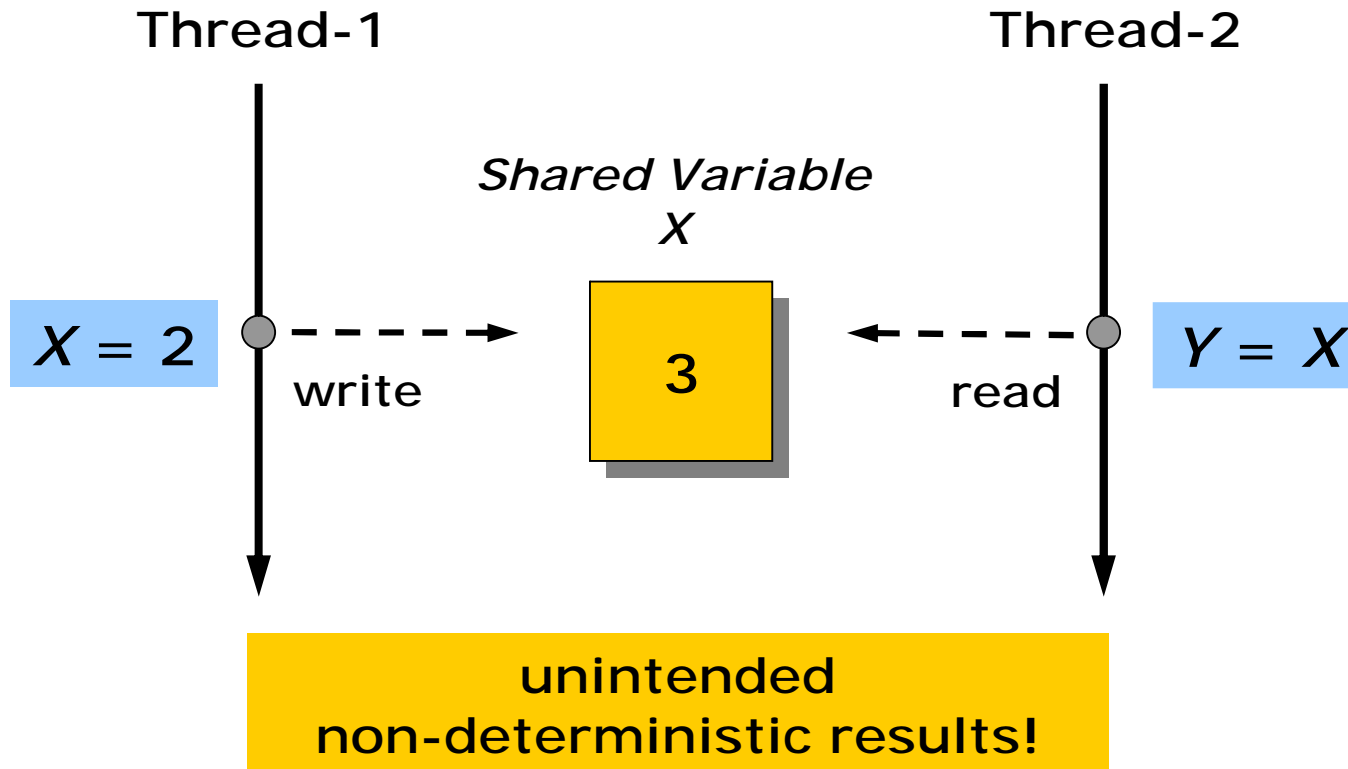
A Nested Parallel Program

```
C$OMP PARALLEL DO SHARED(X)
  DO I = 1, 2
    . . . . .
    IF (I.NE.1) THEN
C$OMP PARALLEL DO
  DO J = 1, I
    . . . . .
  END DO
C$OMP END PARALLEL DO
    END IF
    . . . . .
  END DO
C$OMP END PARALLEL DO
```

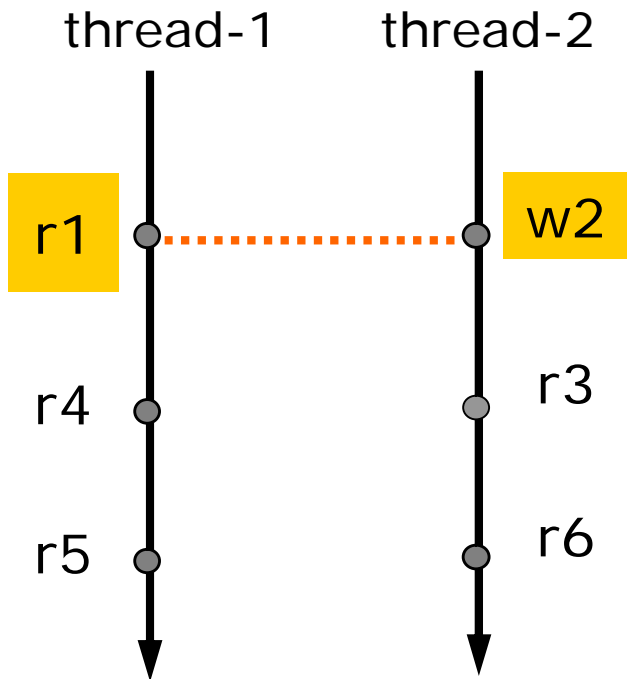
Partial Order Execution Graph



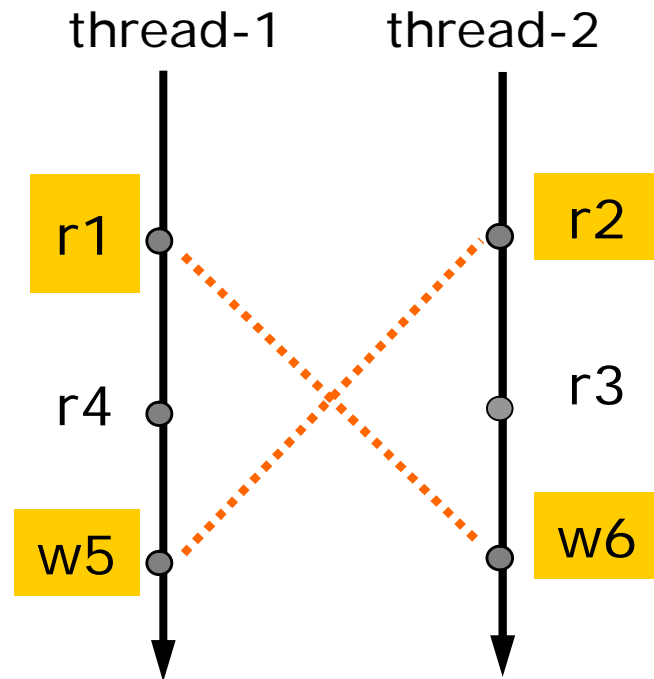
Data Race



The First Race



(a)



(b)

On-the-fly First Race Detection

■ First Race

- Not causally preceded by any other races
 - removal may make the other races disappear
 - involve at most two accesses in a thread block
 - practical in space rather than trace analysis

■ On-the-fly Detection

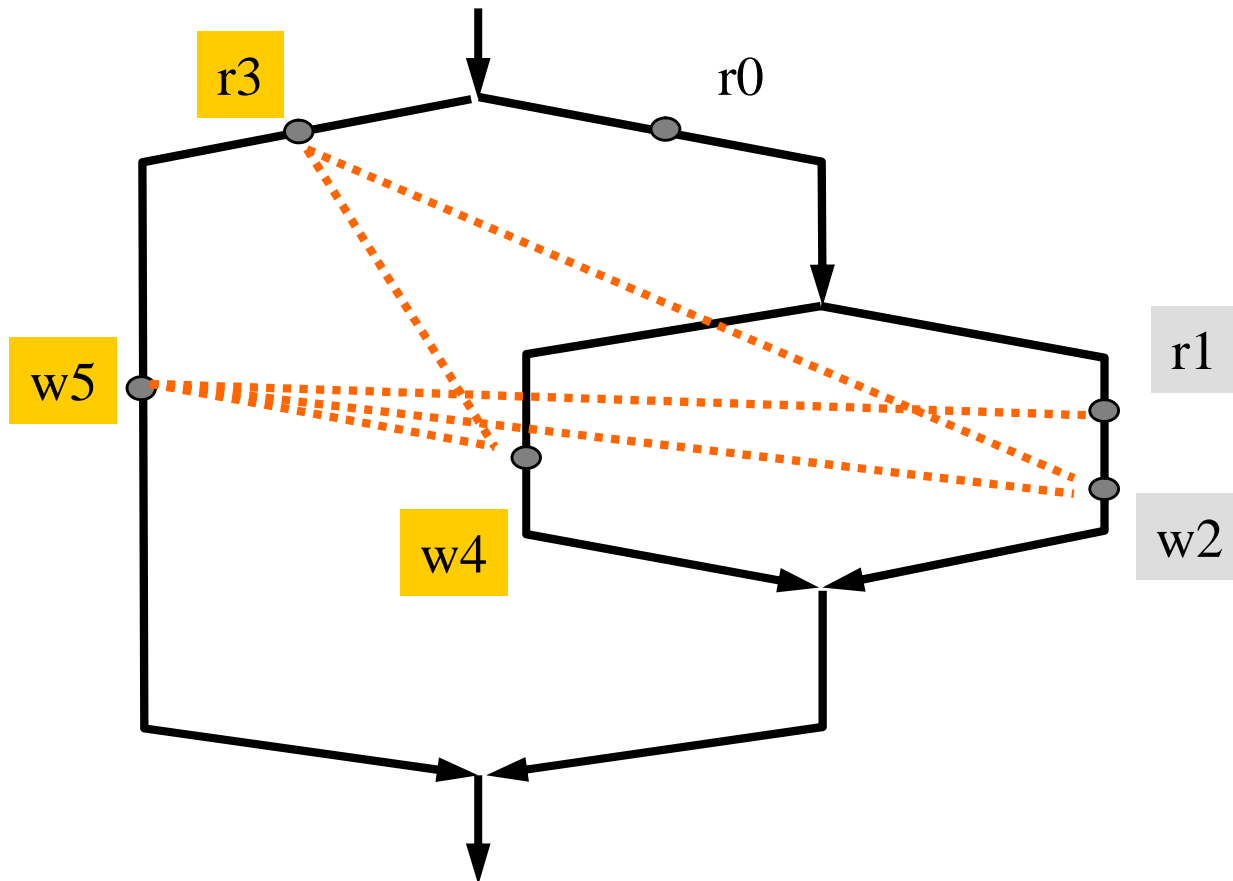
- checks every access
 - in every thread of a monitored execution
 - to compare with the previous accesses
 - in a shared data structure (called access history)

Related Work

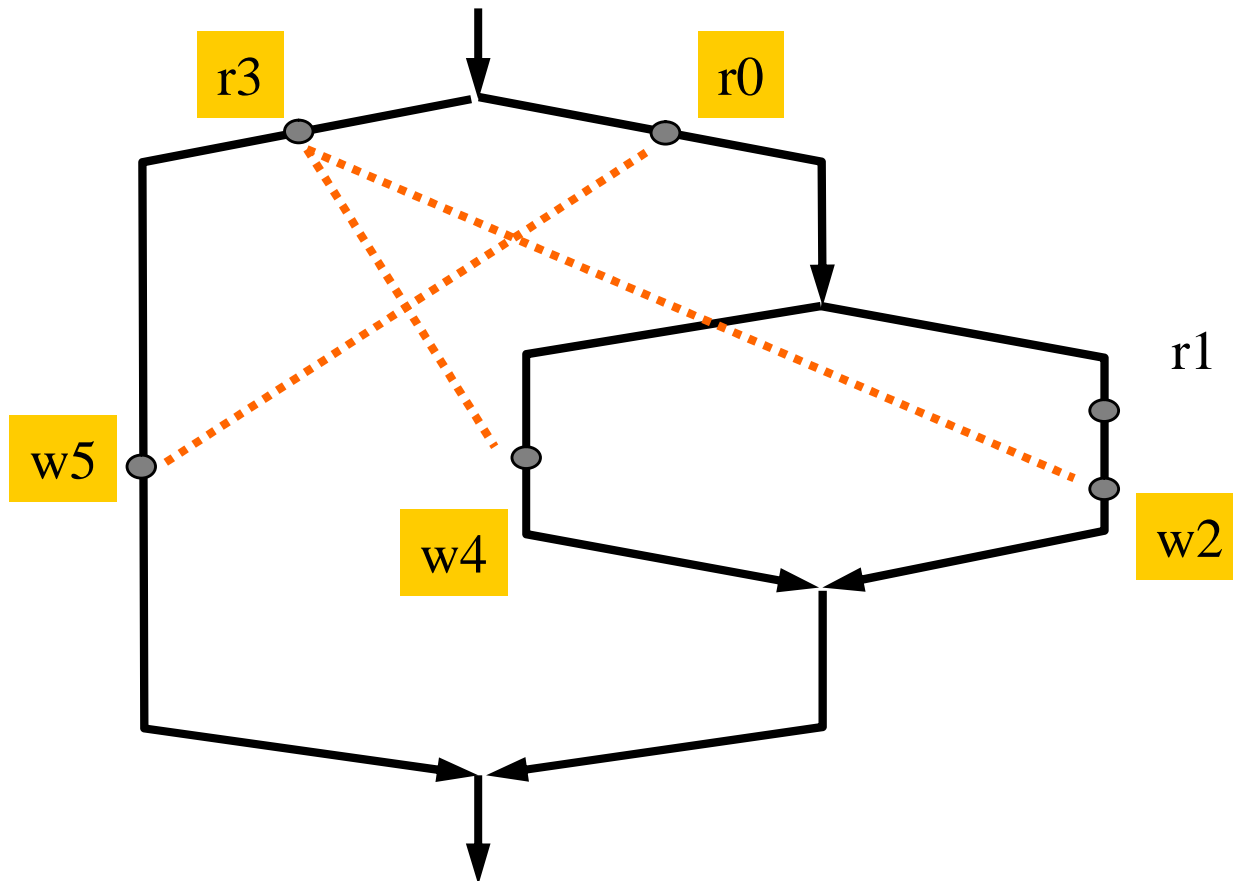
$V = \#$ of monitored shared variables
 $T =$ maximum parallelism

Protocols	Space	Time	Nested Parallelism
Single-pass	$O(VT)$	$O(T)$	No
Multi-Pass	$O(VT)$	Non-deterministic Re-executions	Yes
Two-Pass	$O(VT)$	$O(T \log_2 M)$	Yes

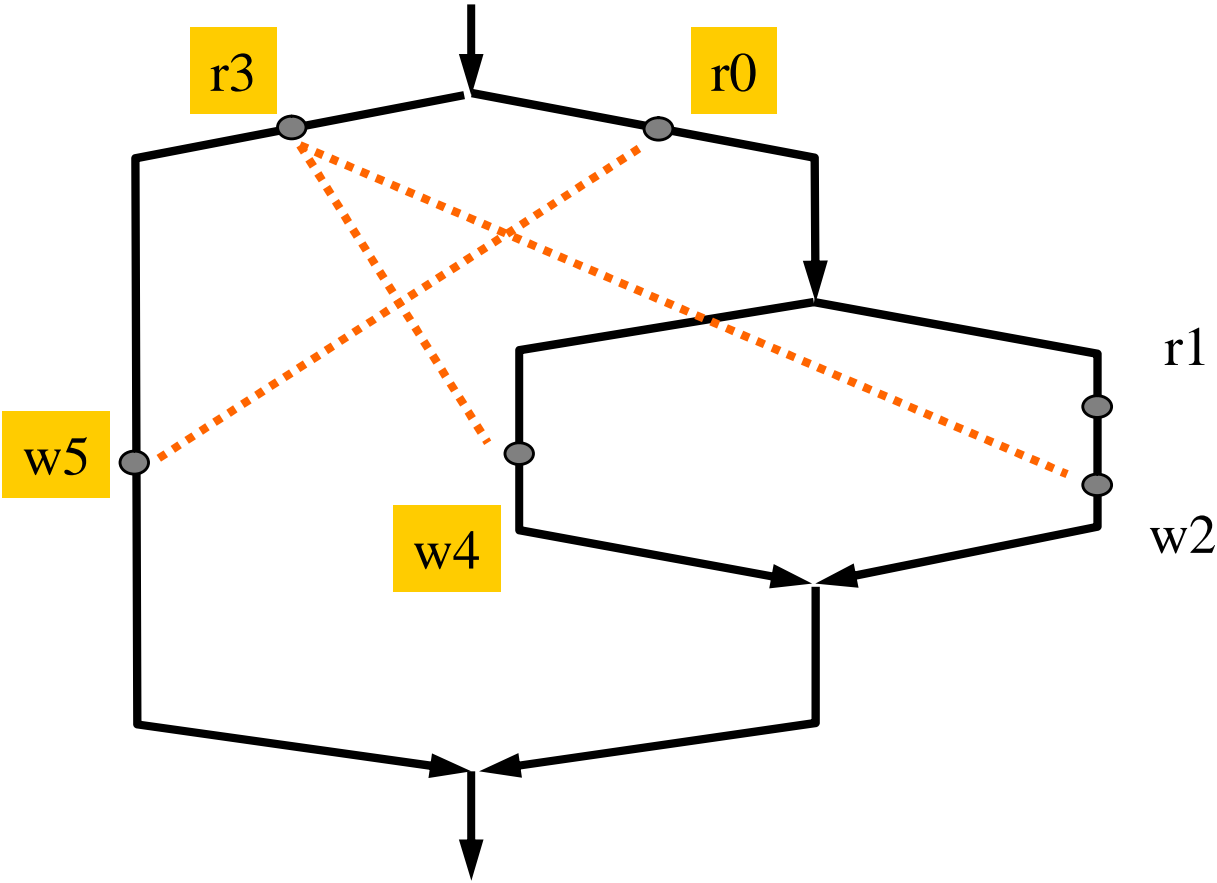
Two-Pass Detection: Pass-1



Two-Pass Detection: Pass-2



New Pass-2



Efficiency

V = # of monitored shared variables
 T = maximum parallelism

Protocols	Space	Time	# of event comparison
Previous	$O(VT)$	$O(T \log_2 N)$	$O(T)$
New	$O(V)$	$O(\log_2 N)$	$O(1)$

Methods of Experiment

■ Environment

- RedHat-6.2 Linux OS
- Omni-OpenMP 1.3 Compiler

■ 8 OpenMP-C Kernel Programs

- Thread structure
 - Unit parallelism: same # of threads for each fork
 - Nested Depth: 2, 3
- Access Event
 - Shared Variable: 1
 - Read event: occurrence of every thread
 - Write event: occurrence in the most inner nested loop

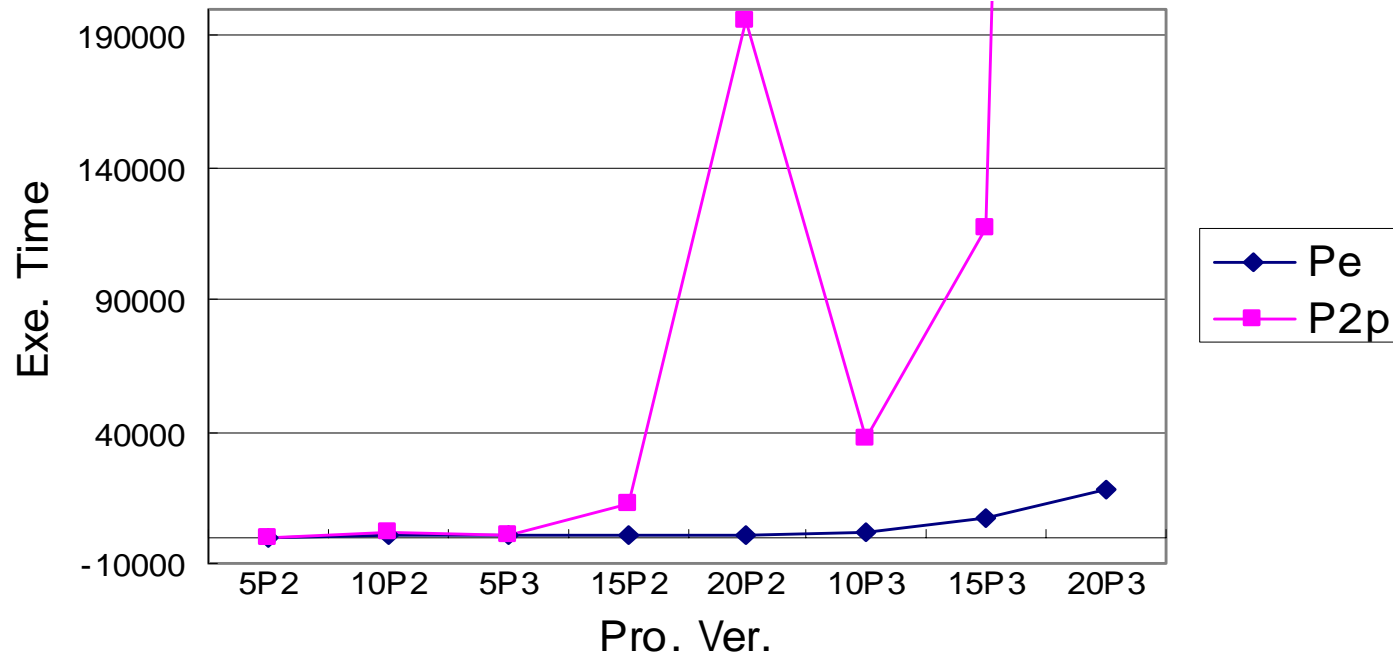
Kernel Programs

Unit Parallelism (t)	Nested Depth (M)	Program Version	Maximum Parallelism (T)
5	2	5P2	25
	3	5P3	125
10	2	10P2	100
	3	10P3	1000
15	2	15P2	225
	3	15P3	3375
20	2	20P2	400
	3	20P3	8000

Protocol Time

Execution Time of Protocol

Unit: μ s



Total Execution Time

Total Execution Time

Unit: μs

