An Approach for Direct Dataflow Execution on Contemporary Multicore Systems

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Outline

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  - Runtime Dataflow Engine
- Evaluation
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  - Effect of dataflow task granularity
  - Cost of synchronization
- Conclusions

Introduction

- Multicore are becoming ubiquitous

- Traditional imperative programming models
  - Explicit and **coarse-grain** parallelism

- Dataflow programming model
  - Implicit and **fine-grain** parallelism

- Dataflow machines are not widely available

Research Question

Can **fine-grain** dataflow programs be efficiently executed on current multicore systems?

Objective

Design, **implement** and **evaluate** a system for direct execution of dataflow programs on multicore systems

Related Work

- Dataflow architectures and simulators
  - Manchester Dataflow Machine (1985)
  - MIT Tagged-token Dataflow Architecture (1990)
  - Manchester Multi-ring Dataflow Simulation (1985)

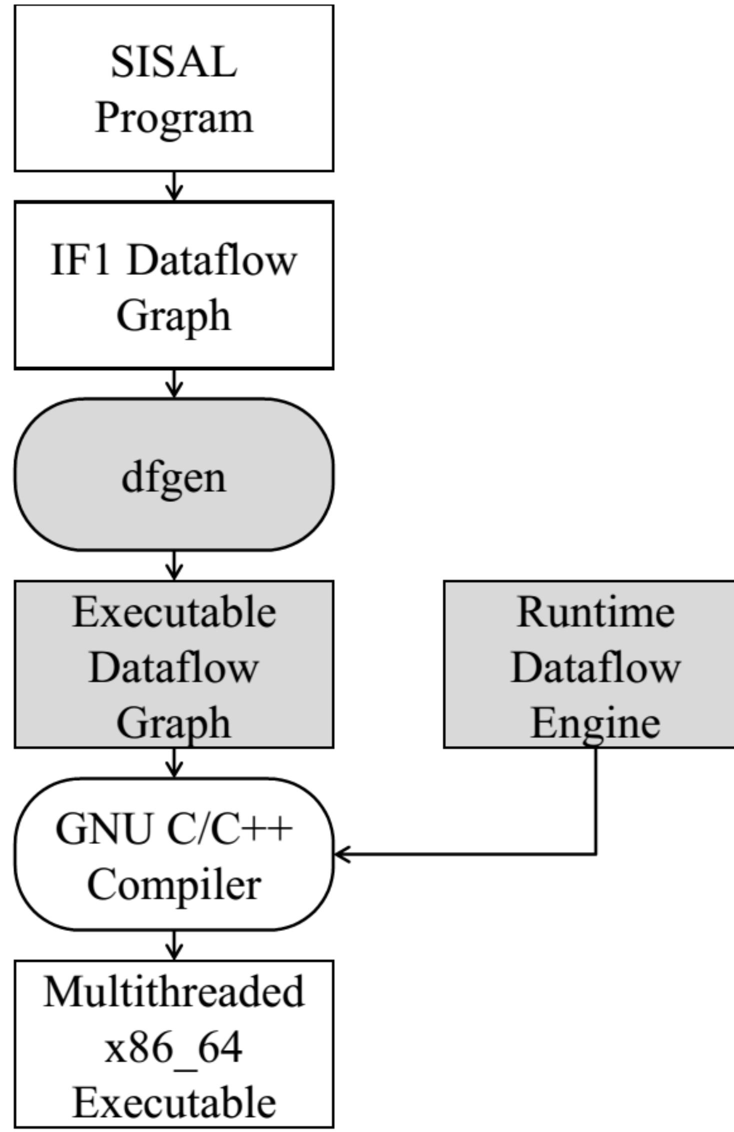
- Dataflow execution on non-dataflow machines
  - Compilers: fsc (1995), sisalc (1996)
  - Programing models and tools
    - Data-driven Multithreading (DDM) (2006)
    - Function-level dataflow execution (2011)

Approach

Two steps:

1. Executable Dataflow Graph (**EDFG**) generation

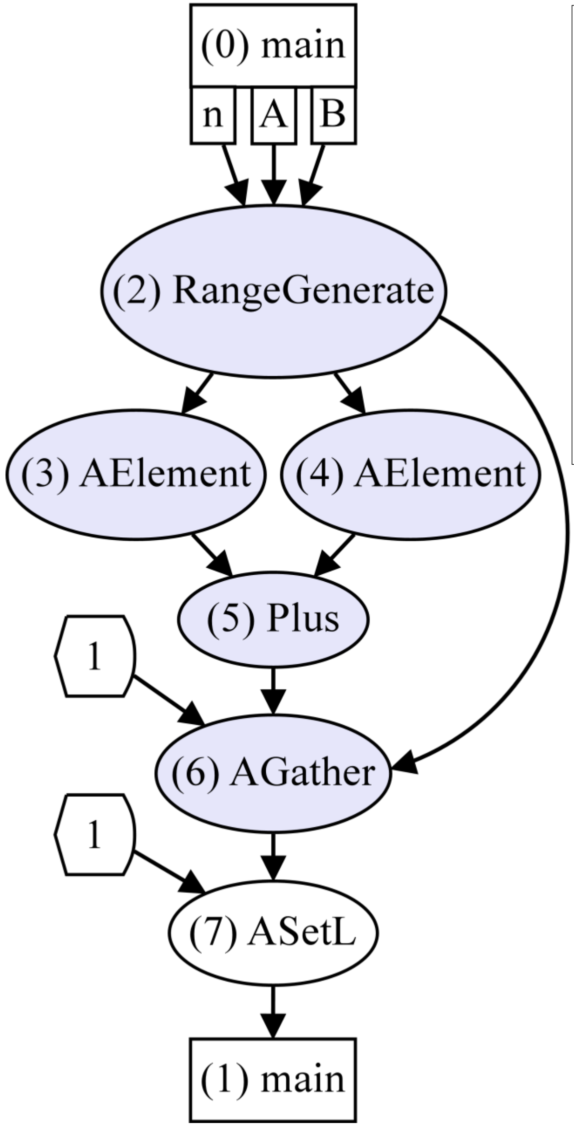
2. Execution of EDFG on Runtime Dataflow Engine



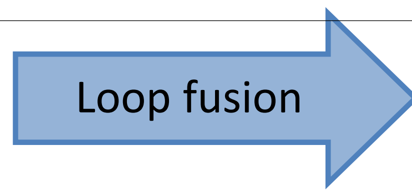
Executable Dataflow Graph

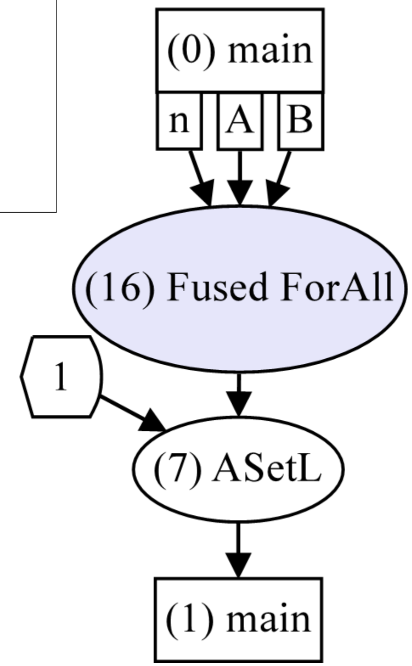
- Fine-grain DF graph to static EDFG
  - Node fusion
    - Fuse loop bodies
    - Fuse functions
  - Node optimization
    - Remove redundant housekeeping nodes
    - Rearrange nodes (e.g. Selector condition)

Node Fusion



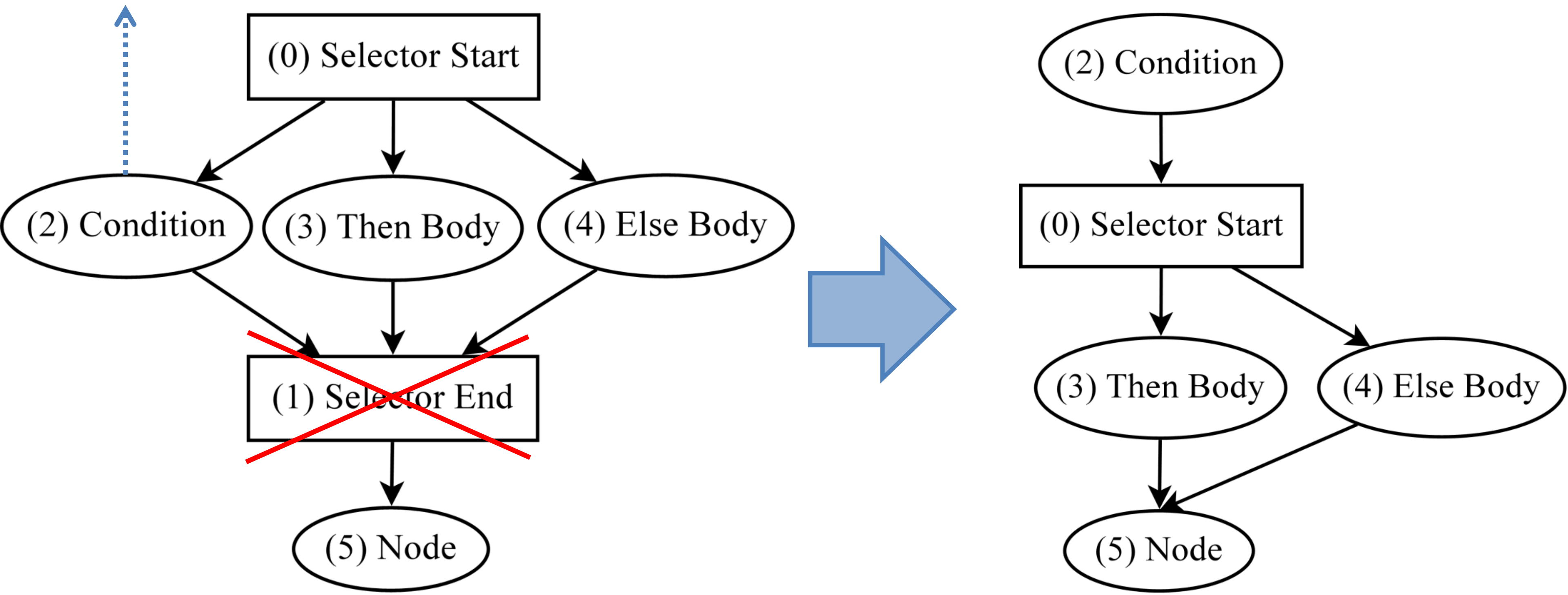

```
define main
type IntArray = array[integer];
function main(n: integer; A, B: IntArray
            returns IntArray)
   for i in 1, n
            returns array of A[i] + B[i]
   end for
end function
```



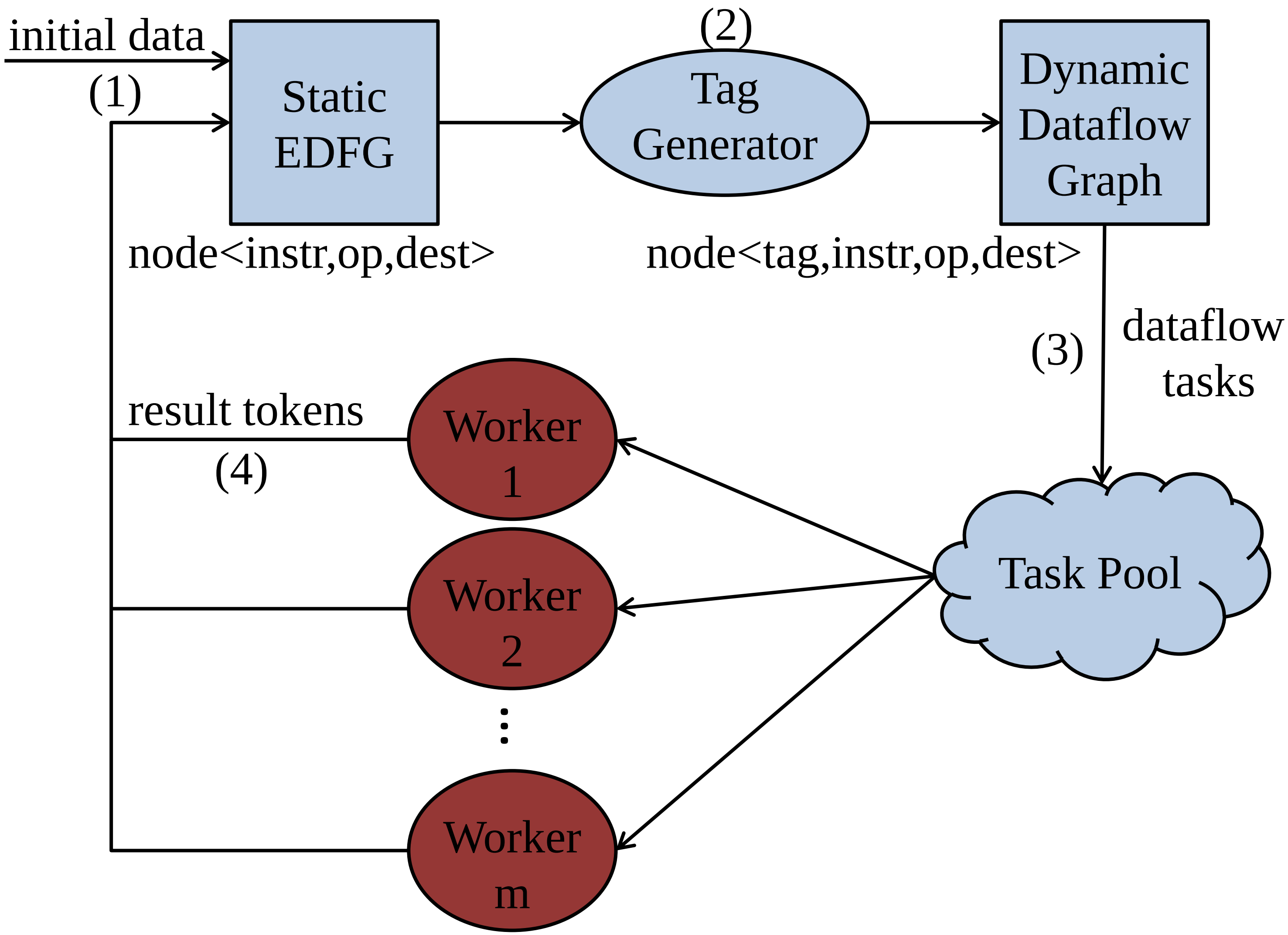


Node Optimization

```
if Condition then …
else …
end if
```



Runtime Dataflow Engine



Evaluation

- Programs
  - **MM(n)** – matrix multiplication on square matrices of size **n**
  - **PR(n)** – prime number counting in range 1, **n**

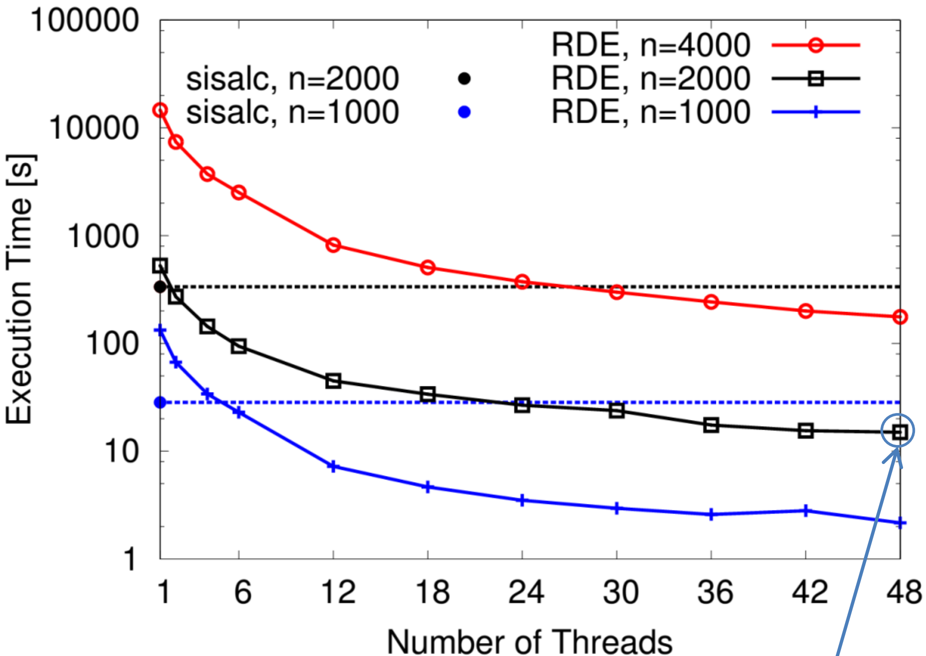
- Granularities
  - **Φ1** - no fusion
  - **Φ2** - fused inner-most loop body or function
  - **Φ3** - fused all, except the outer-most loop
  - **Φ4** - fused outer-most loop until number tasks equals number of cores
  - **Φ5** - fused into one dataflow task

fine

coarse

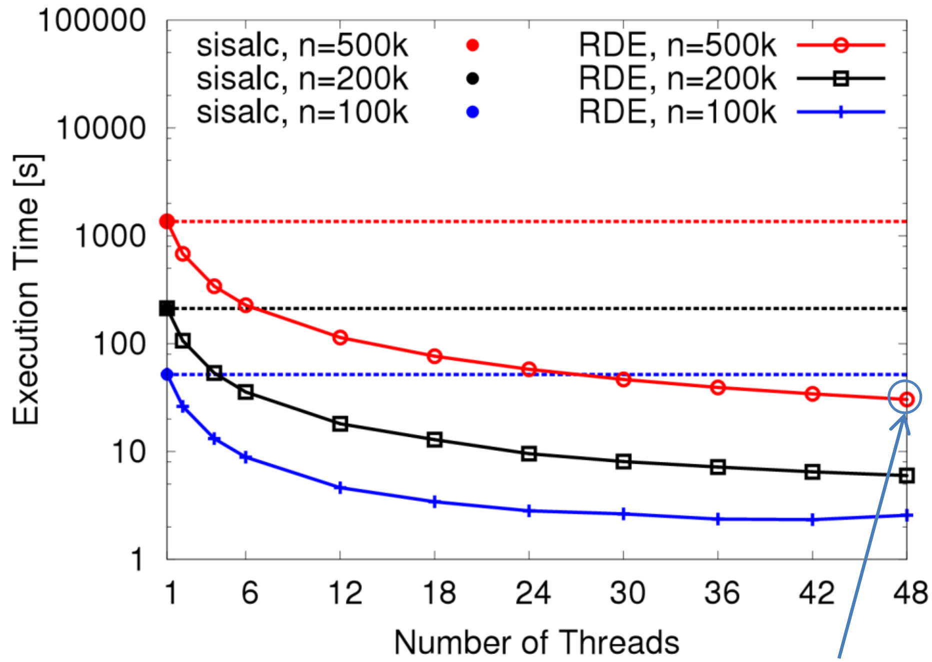
- System
  - 48-core AMD Opteron, 64GB memory (NUMA)

Effect of Problem Size using Φ3



MM

22 speedup



44 speedup

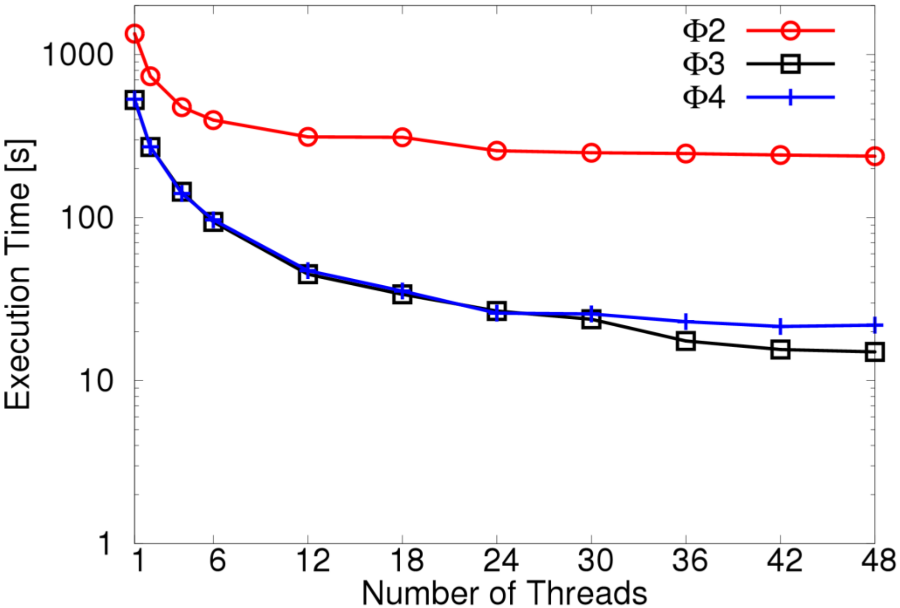
PR

O1: Low overhead of dataflow task management on medium-size granularity

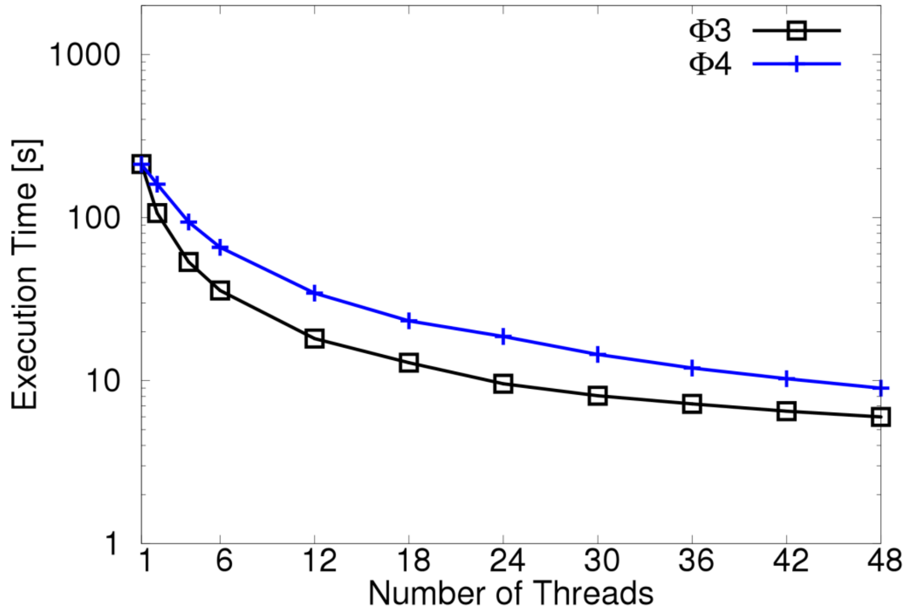
Effect of Granularity

Φ_1 - fine-grain, ran out of memory

Φ_5 – sequential, close to sisalc



MM(n=2000)

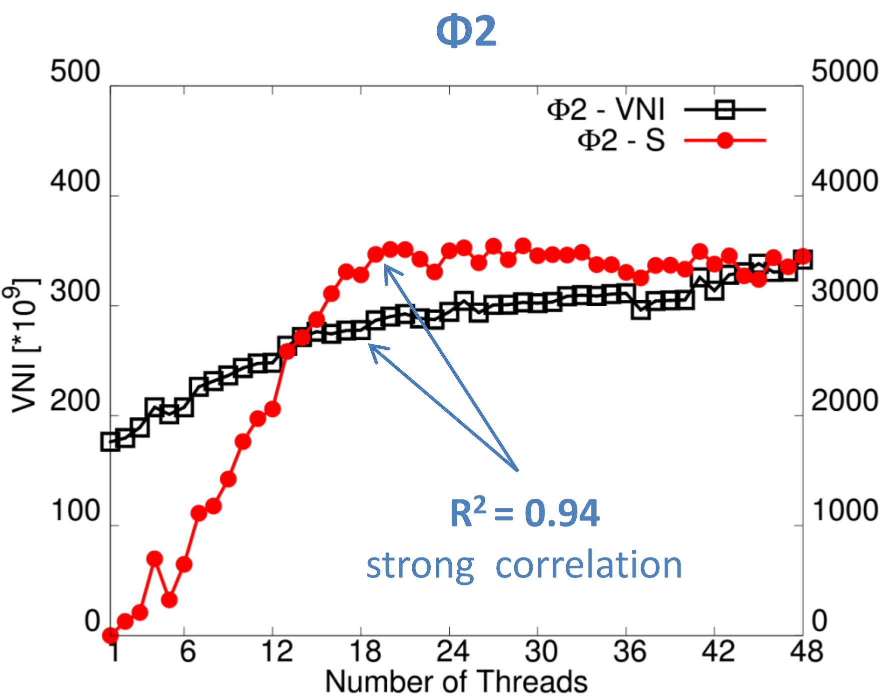


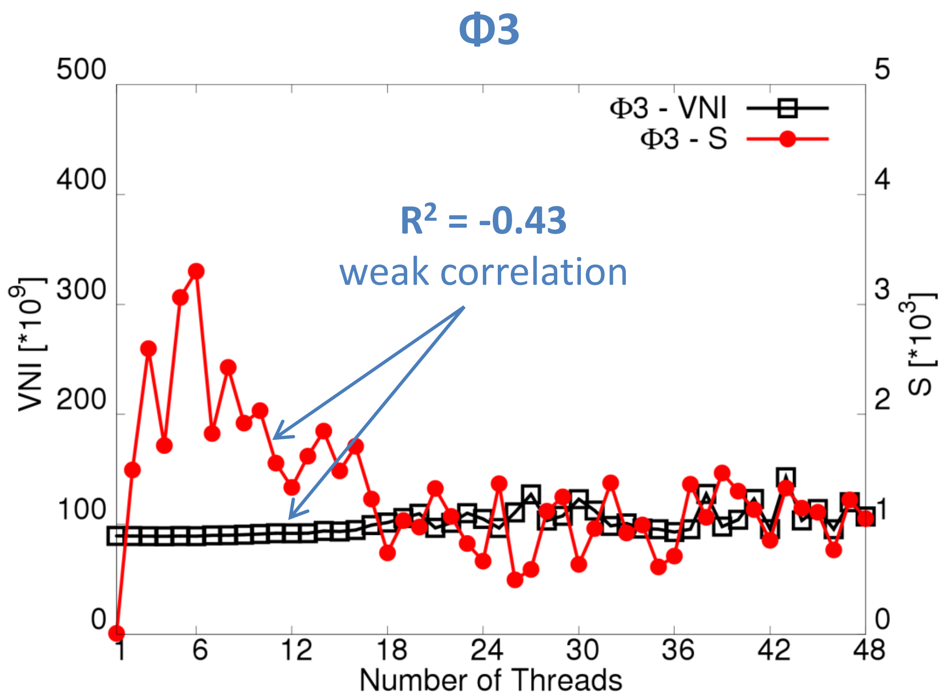
PR(n=200k)

O2: Medium granularity achieves the best performance.

O3: Medium-large granularity suffers from lack of work.

Cost of Synchronization – MM(n=2000)





- VNI – von Neumann instructions (perf)
- S - # of synchronization in OS kernel (strace)

O4: Higher cost of synchronization for fine-grain dataflow tasks.

Conclusions

- An approach for direct execution of dataflow programs on multicore systems
  - EDFG with node fusion optimizations with different task granularities
  - RDE for multithreaded direct EDFG execution

- Preliminary Evaluation
  - Medium size granularities achieve good performance
  - Medium-large size granularity suffers from work shortage
  - Fine-grain dataflow tasks execution suffer from high synchronization overhead

Future Work

- Adaptive application execution
  - Generation of EDGF with malleable tasks
  - RDE with dynamic task granularity selection and execution
- Heterogeneous dataflow execution
  - CPU-GPGPU
  - von Neumann-dataflow
- Use other languages as starting point

Q&A

Thank you!

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