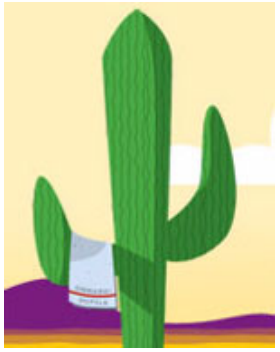
IBM Research - Tokyo

Adaptive Multi-Level Compilation in a Trace-based Java JIT Compiler



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Goal

- Balancing steady-state performance and startup performance has been a challenging task for JIT compilers

Our Goal

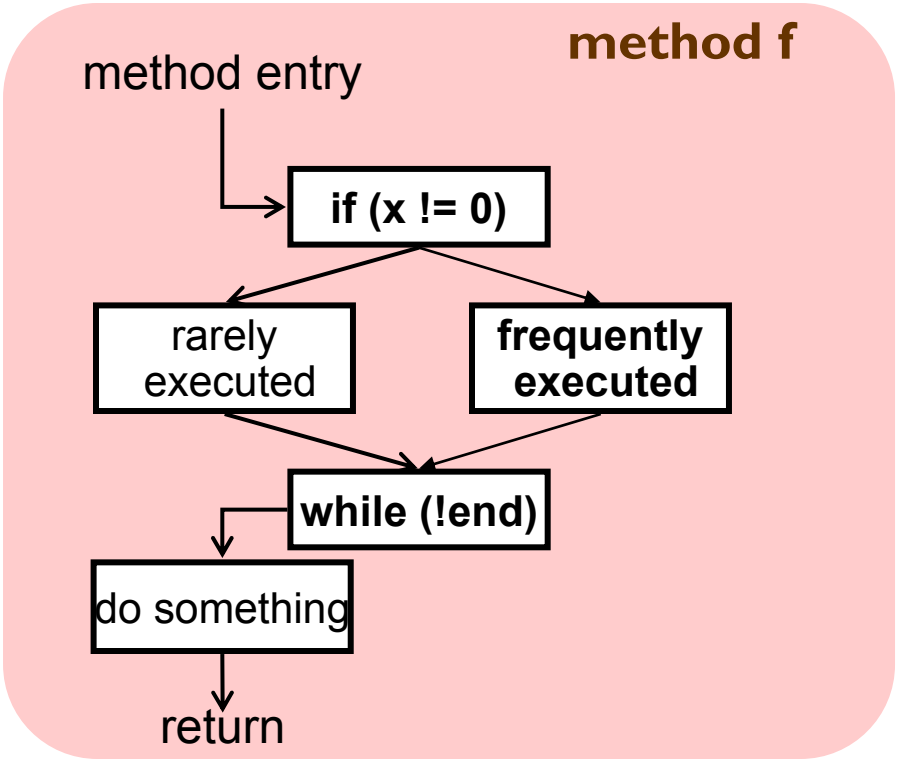
*to improve the steady-state performance without hurting startup performance in a **trace-based** Java JIT compiler*

Our contributions:

1. We show that adaptive multi-level compilation is a practical way to balance the startup time and steady-state performance in a trace-JIT
2. We develop a new technique to efficiently identify hot paths to recompile in a higher optimization level

Background: Trace-based Compilation

- Using a *Trace*, a hot path identified at runtime, as a basic unit of compilation



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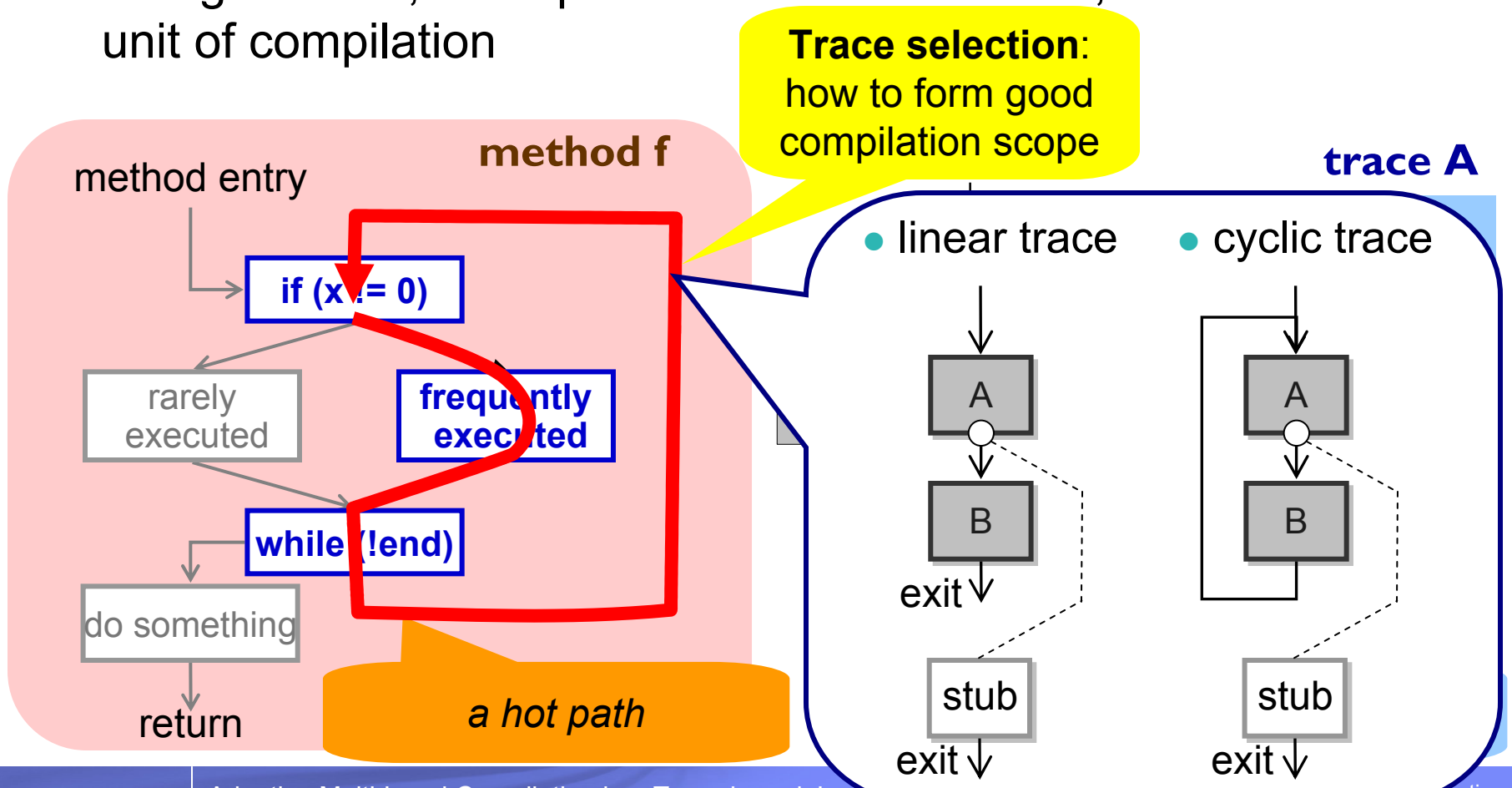


Background: Trace Selection and Performance

- Steps of trace selection
  1. Identify a hot trace head
     - a target of a backward branch, a exit point of an existing trace
  2. Record next execution path starting from the trace head
  3. Stop recording when the trace being recorded
     - forms a cycle, reaches pre-defined maximum length

- Generating longer traces (compilation scopes):
  - ☺ yields **better steady-state performance**
    - more optimization opportunities for compilers
    - smaller trace transitioning overhead
  - ☹ but it **hurts startup performance**
    - longer compilation time
    - more duplicated code among traces

Our Approach: Adaptive multi-level compilation for trace-JIT

1. Interpreted execution

   ⇩ *identify hot paths by counting the execution count for each potential trace head (e.g. loop backedge)*

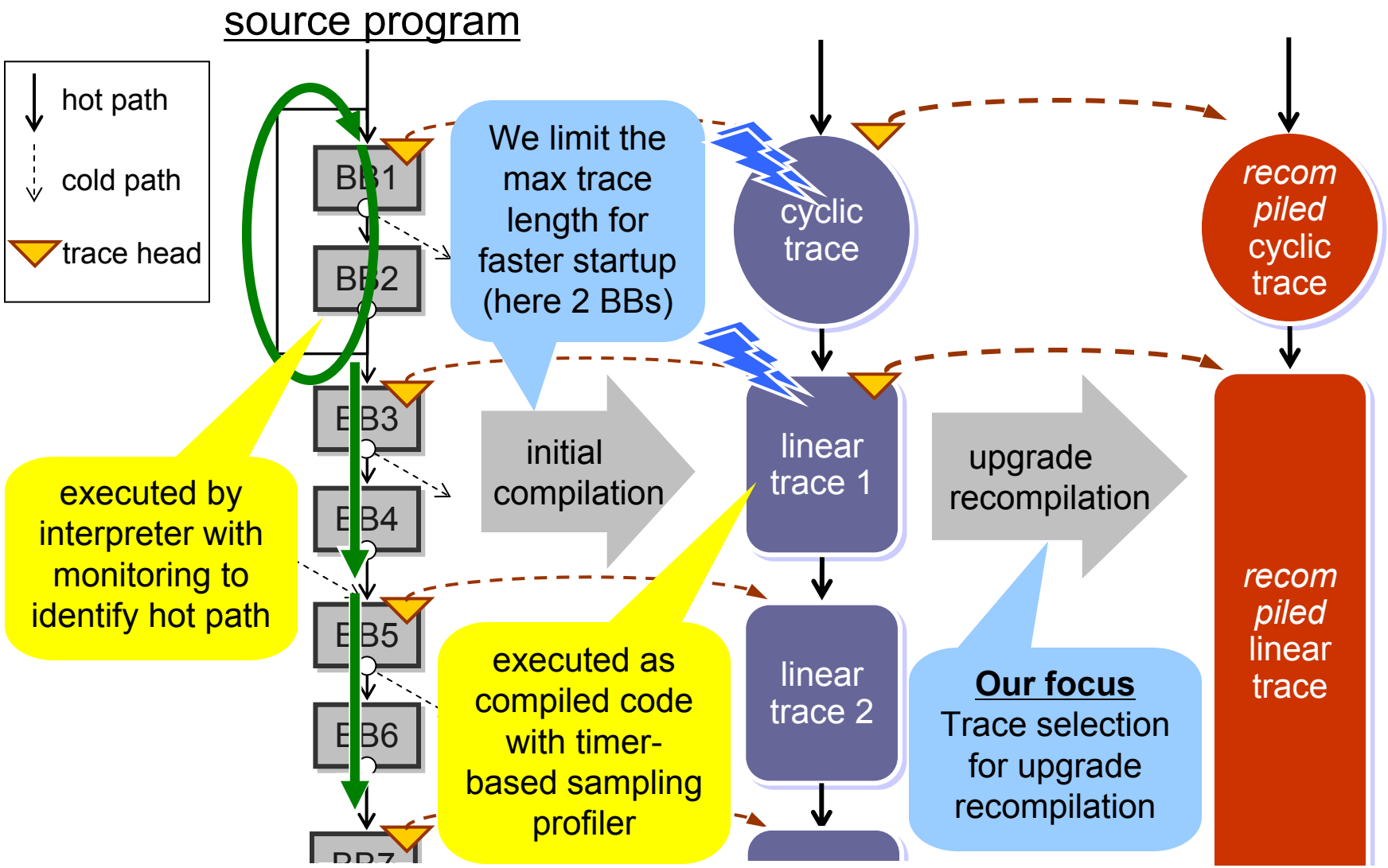
2. Initial compilation for faster startup
   - smaller compilation scope
   - lower optimization level

   ⇩ *identify really hot paths by using timer-based sampling profiler*

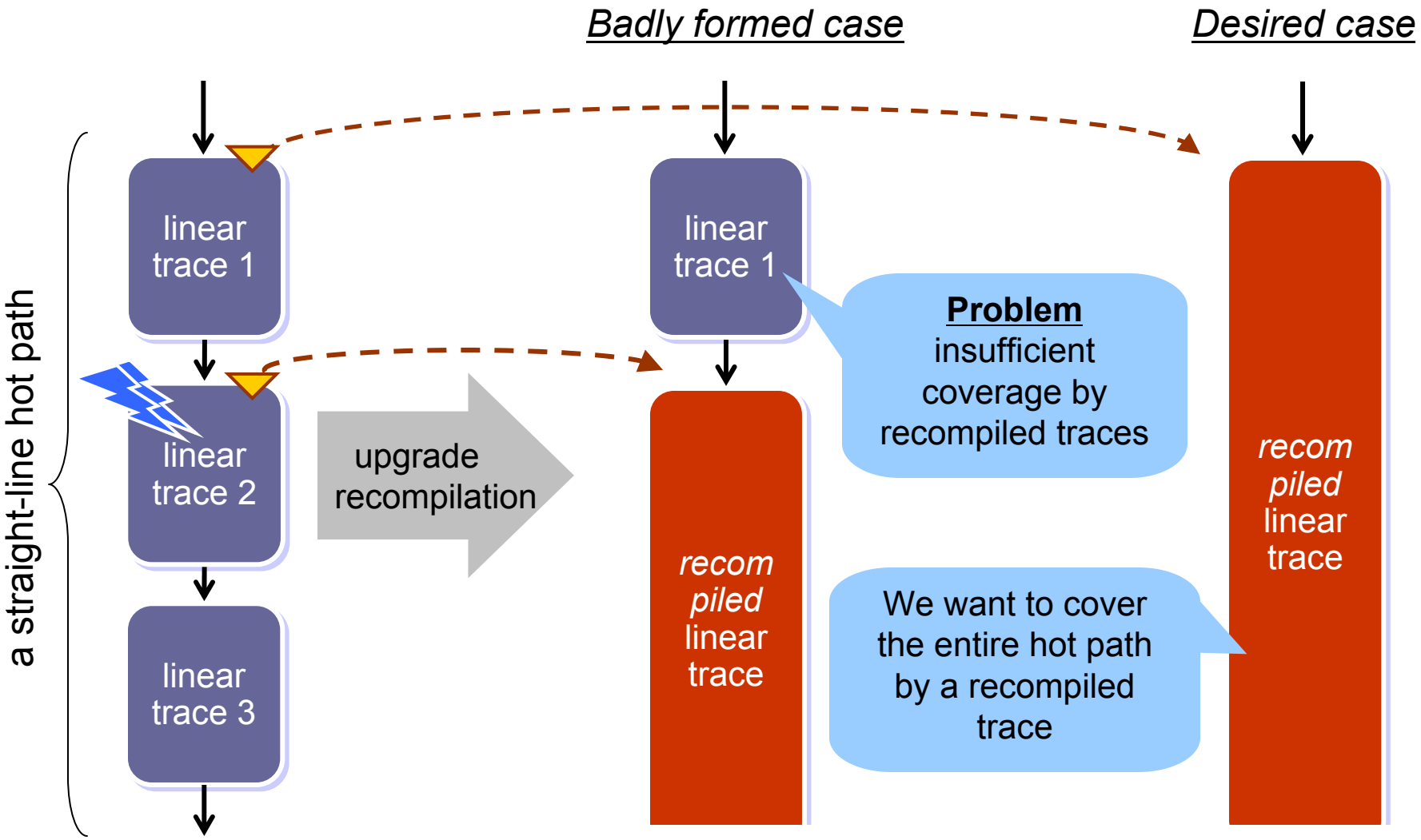
3. Upgrade recompilation for higher steady-state performance
   - larger compilation scope
   - higher optimization level

Our focus
Trace selection for upgrade recompilation

Steps of Our Multi-level Compilation

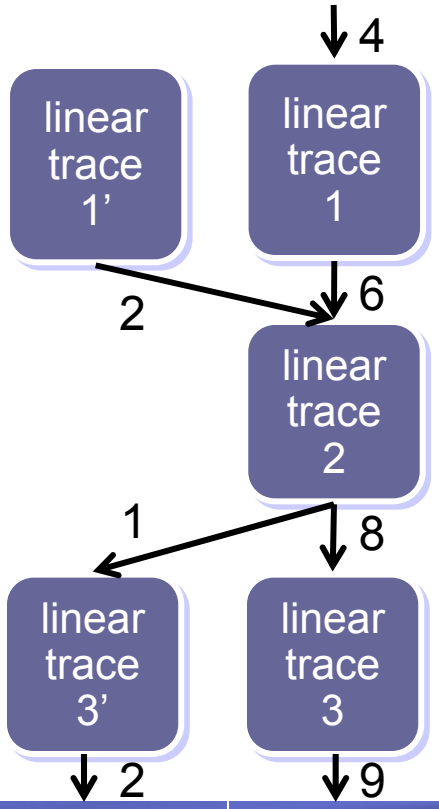


An Example of Inefficient Selection for Recompilation



Our Solution: Trace Transition Graph (*TTgraph*)

- *Trace-Transition Graph* (*TTgraph*) is a weighted directed graph representing the control flow among traces

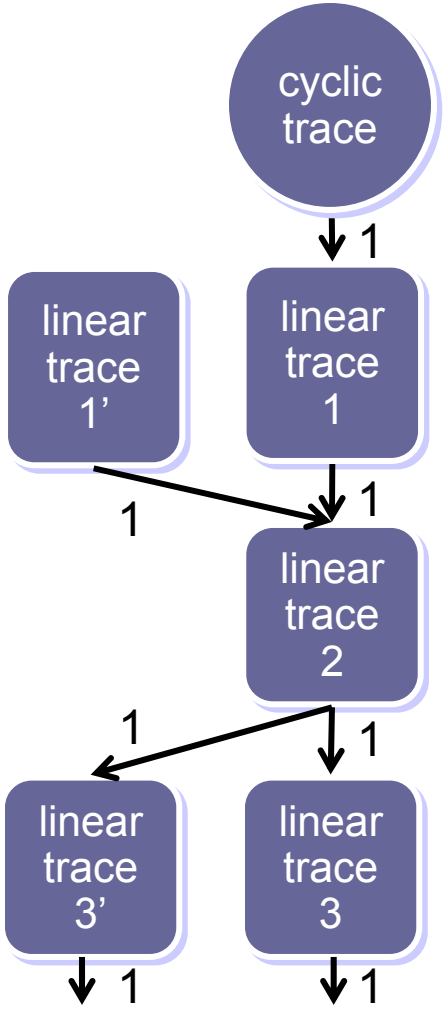


- Node: compiled trace
- Edge: transition between two traces
  - weight represents relative frequency

➔ We identify the hot paths to recompile using the TTgraph

  - to capture the entire hot path by traversing the edges backward

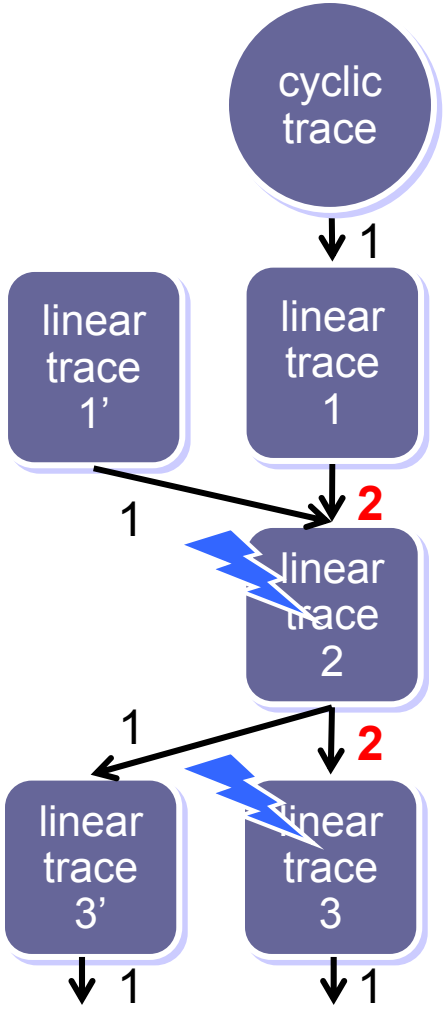
Steps to Build TTgraph



1. We add an node when a trace is compiled
2. We add an edge between two traces when we link them (trace linking)
3. We increment weight of an edge by timer-based sampling profiler

See the paper for more detail (e.g. how we profile transition and how we employ bursty tracing)

Steps to Build TTgraph



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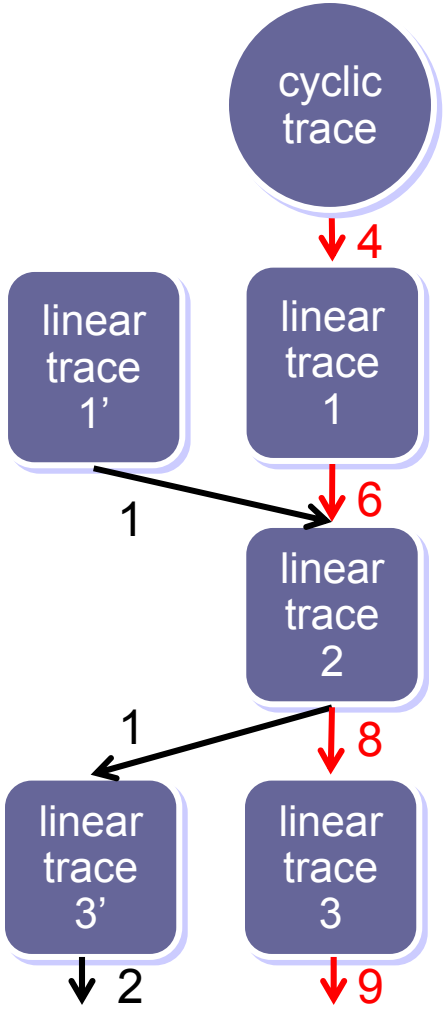

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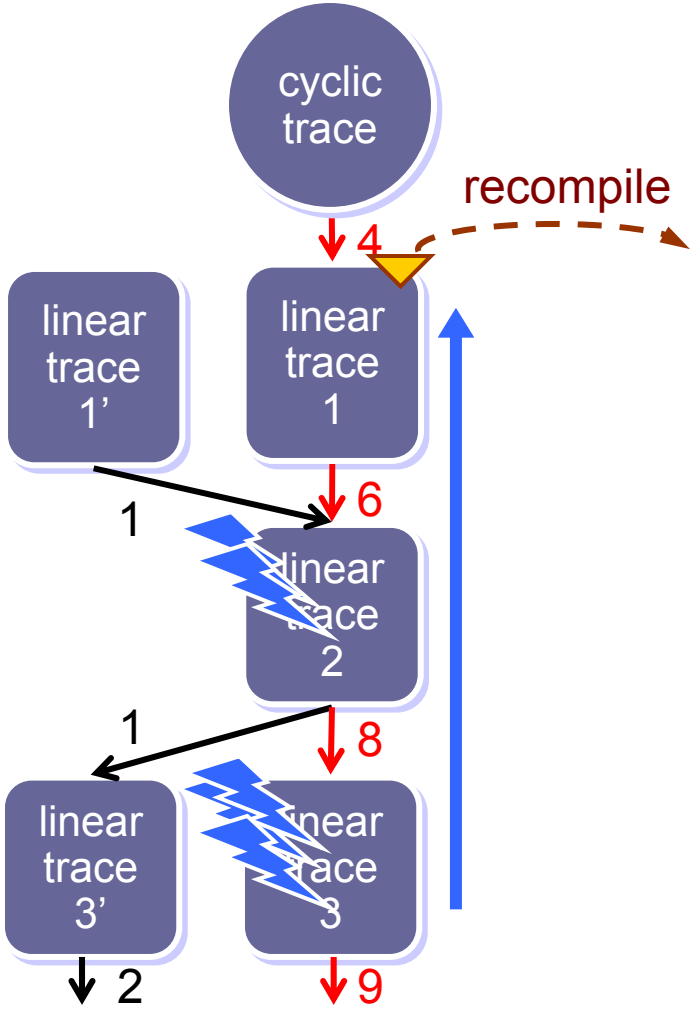
Recompilation Based on TTgraph



We traverse the hot edges backward to identify the new trace head for recompilation

- we stop the backward traversal when hitting a cyclic trace (our system does not capture cyclic and linear path in one trace)
- If there are multiple hot incoming edges for a node, we track both of them

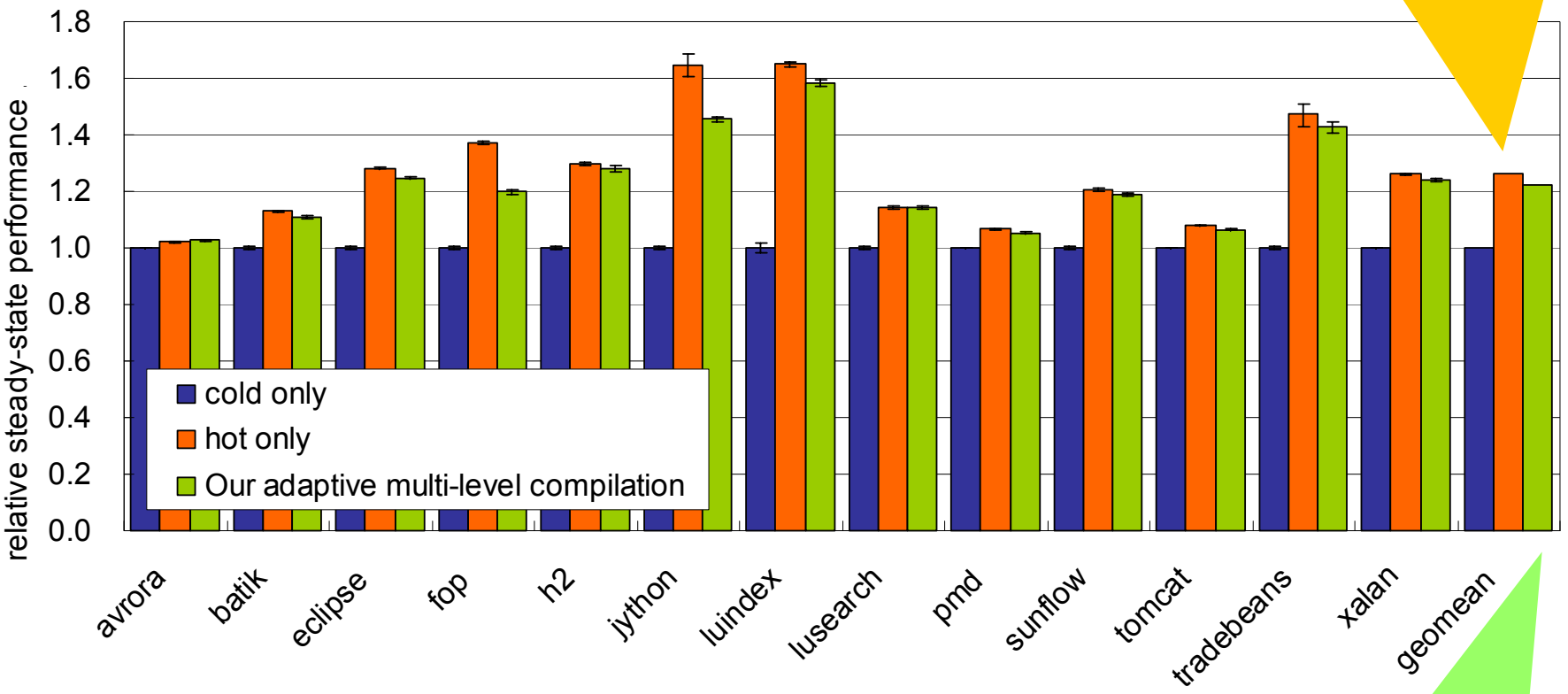
See the paper for more detail

Performance Evaluation

- Hardware: IBM BladeCenter JS22
  - 4 cores (8 SMT threads) of POWER6 4.0GHz
  - 16 GB system memory
- Our trace-JIT:
  - Extended IBM JVM for Java 6 (32-bit) to support trace compilation
  - Two optimization levels (both trace selection and code generation), **cold** and **hot**
  - We compare cold only, hot only, and our adaptive multi-level compilation
- Benchmark:
  - DaCapo benchmark suite 9.12

Steady-state Performance

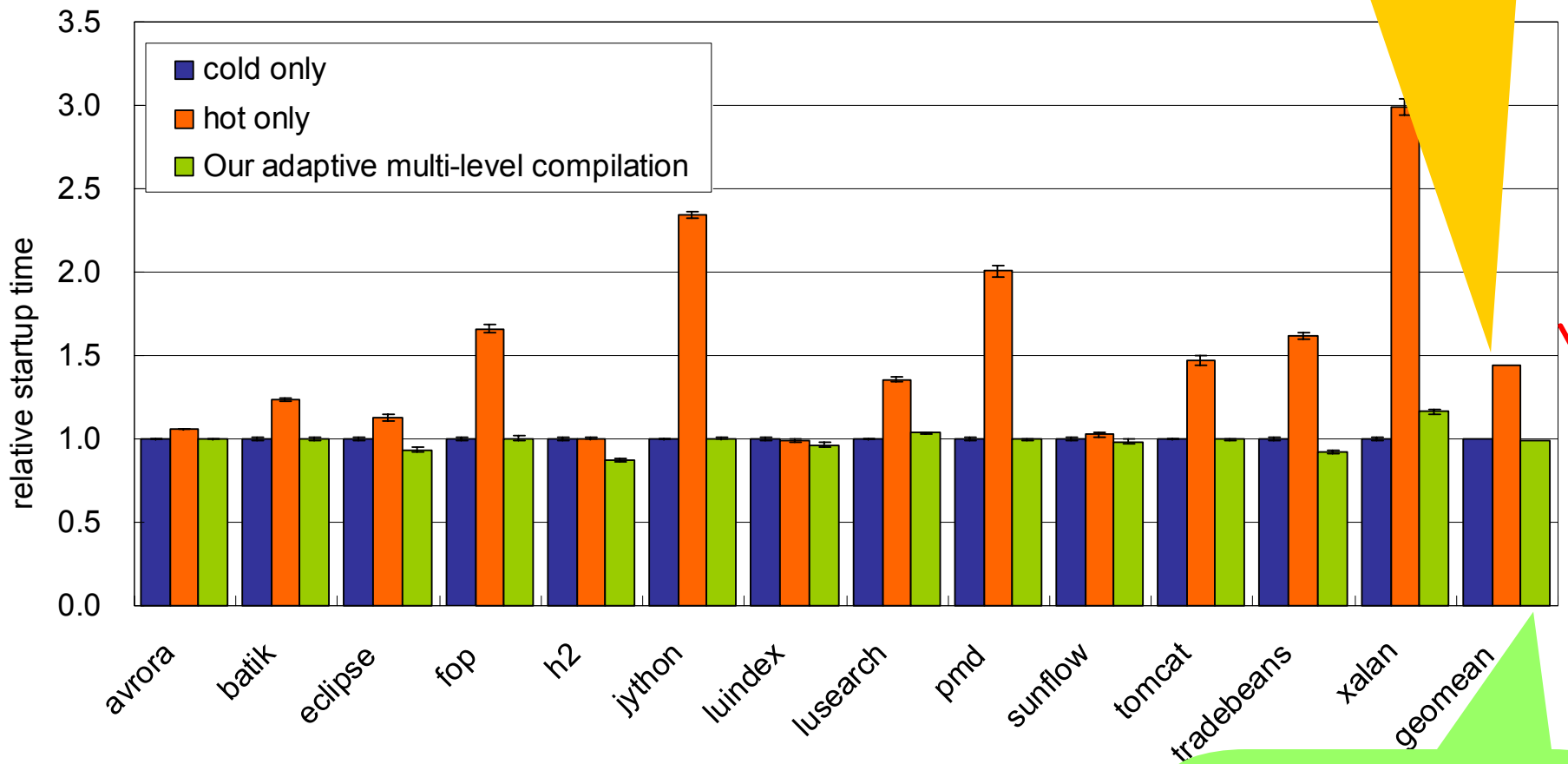
always using hot level gives 26% gain in steady state



Our technique achieved 22% gain in steady state

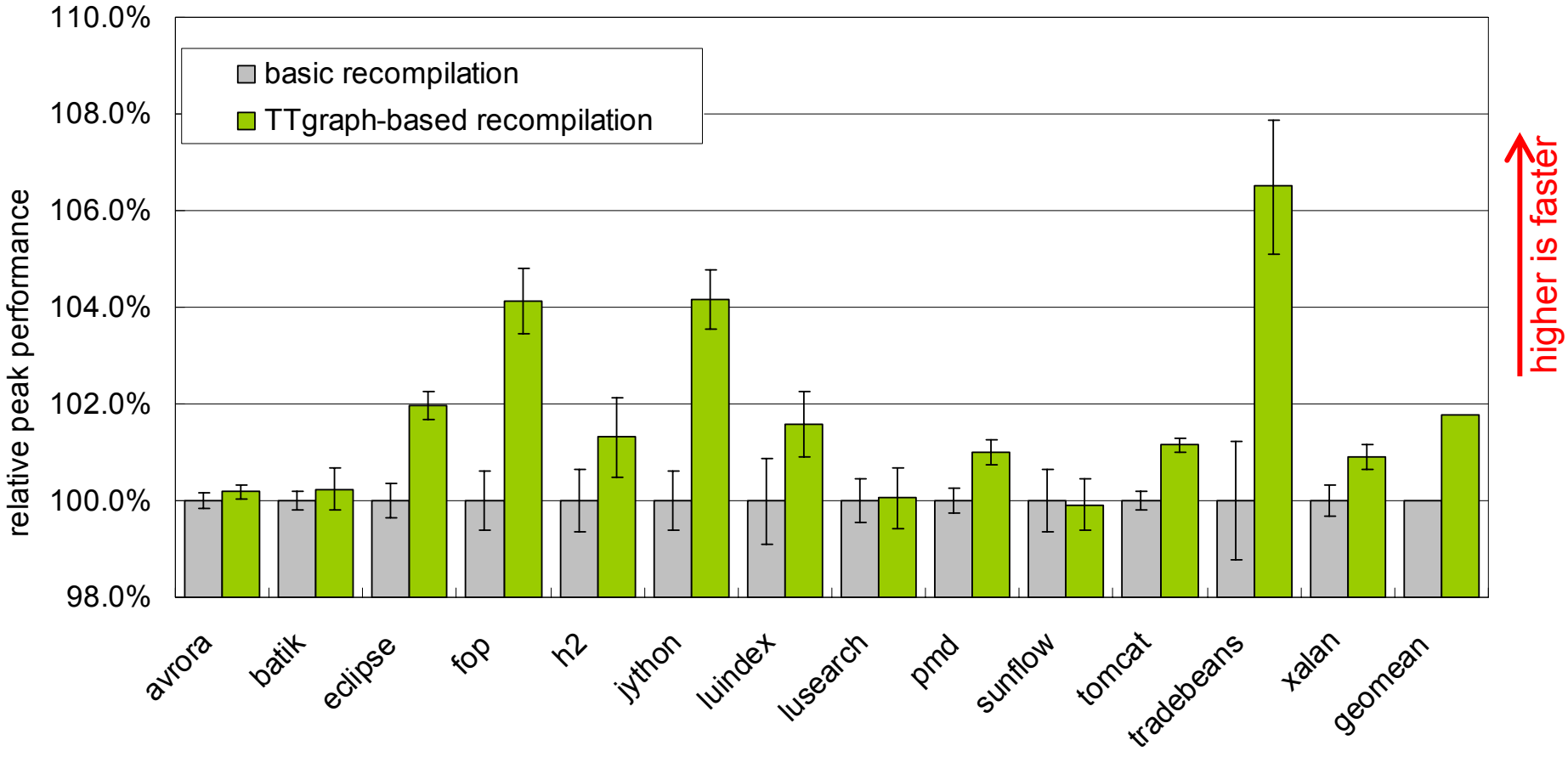
Startup Time (Execution time of fi

using hot level makes the startup 50% (up to 3x) slower!



Our technique does not hurt the startup performance!

Improvement by TTgraph-Based Recompilation



Summary

- We showed that adaptive multi-level compilation is a practical way to balance the startup time and steady-state performance in a trace-JIT
- We developed an efficient technique based on TTgraph to identify hot paths. We described the trace selection engine, the timer-based sampling profiler, and the code generator work together for effective recompilation.

Thank you!

Backup

CPU Time Breakdown