T4: Compiling Sequential Code for Effective Speculative Parallelization in Hardware

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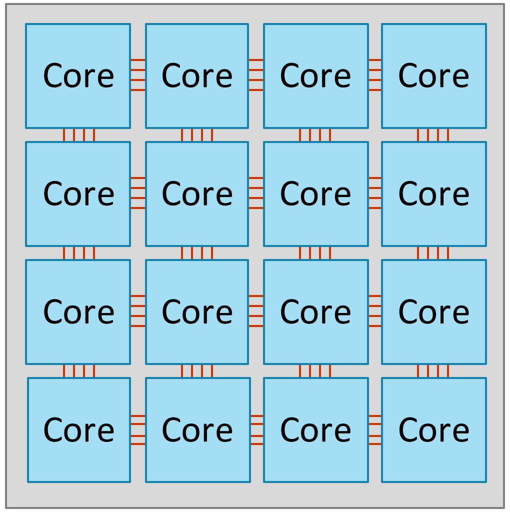
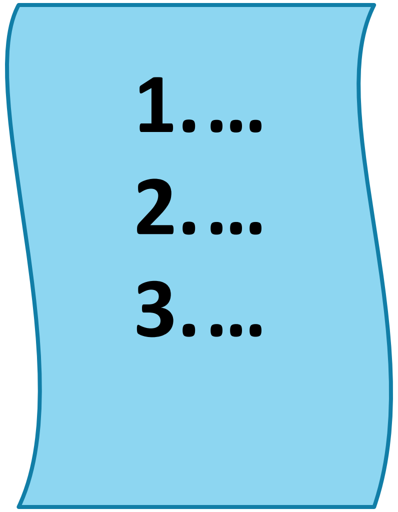
Multicores are everywhere



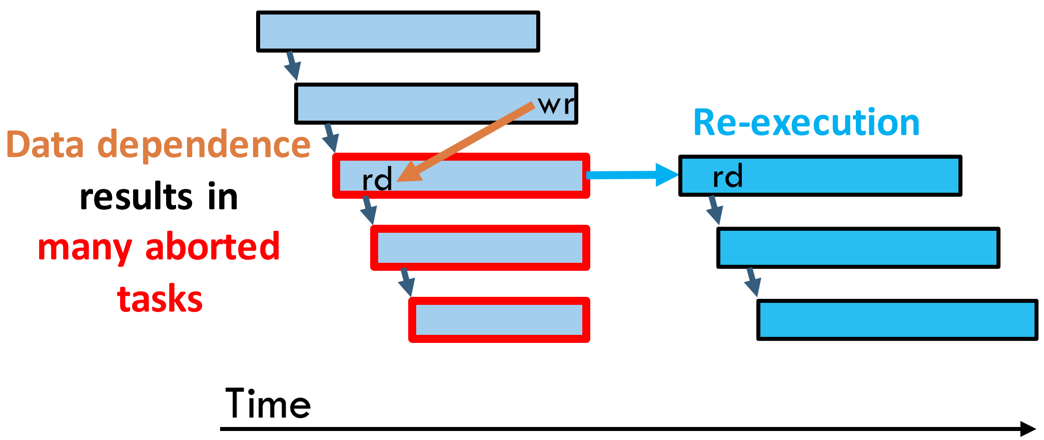
Programmers write sequential code



Speculative parallelization: combining architectures and compilers to parallelize sequential code without knowing what is safe to run in parallel

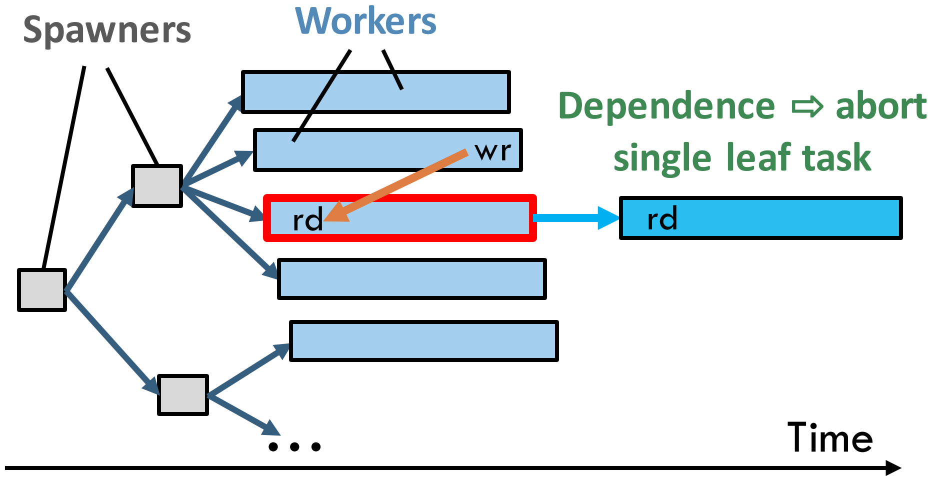
Key idea: Task trees for effective parallelization

Prior work: chains of task spawns



- If dependence is violated, all later tasks abort and re-execute
- Serial task spawn & commit

Task trees avoid serial bottlenecks



- Independently spawned leaf tasks enable selective aborts
- Distributed spawn & commit

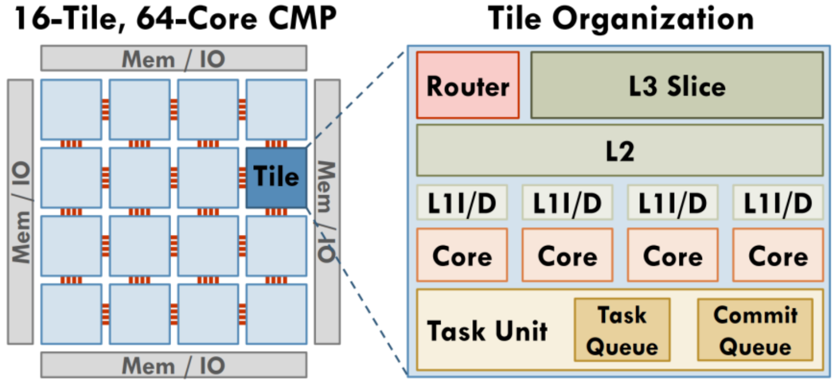
T4: Trees of Tiny Timestamped Tasks

T4 compiler systematically uncovers fine-grained parallelism

- Timestamps encode order, let tasks spawn out-of-order
- Trees unfold branches in parallel for high-throughput spawn
- Efficient parallel spawns support tiny tasks (tens of instructions)
- Tiny tasks can exploit locality, reduce communication

T4 exploits the Swarm architecture [Jeffrey et al. MICRO’15]

- Tasks appear to run sequentially, in timestamp order
- Selectively aborts dependent tasks
- Distributed task units can
  - » Spawn and commit many tasks per cycle
  - » Run hundreds of concurrent speculative tasks



Parallelizing entire real-world programs

T4 automatically divides a whole program into tasks
- Tasks boundaries at loop iterations and function calls

T4 introduces novel code transformations:
- Progressive loop expansion
- Call stack elimination
- Optimizations to make task spawns cheap
- Spatial-hint generation

T4 scales hard-to-parallelize C/C++ benchmarks from SPEC CPU2006
- Modest overheads: 31% on 1 core
- Speedups up to 49× on 64 cores

T4 is open source

swarm.csail.mit.edu