Makespan Investigations of Sequential, Parallel, PO, and POCL Plans

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This paper investigates:

How do plan representations influence Makespan?

Makespan: Execution time of the plan. (Here: unit costs!)

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We look at, and compare, 4 typical plan structures:

- Sequential plans (totally ordered; standard)
- Parallel plans (produced by GraphPlan; used in many CSP encodings)
- Partial-order (PO) plans (not too relevant anymore, but simple!)
- PO causal link (POCL) plans (still relevant, e.g., in SAT encodings)

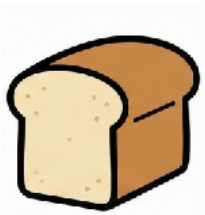
We challenge the common assumption:
The last three can all achieve the same makespan. (No...)

The Problem: Making Breakfast

Initial State:

Water

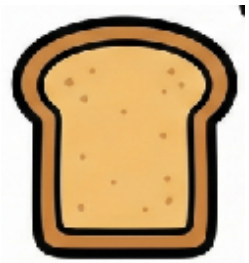
Coffee Beans



Bread

Goal State:

Coffee



Toast

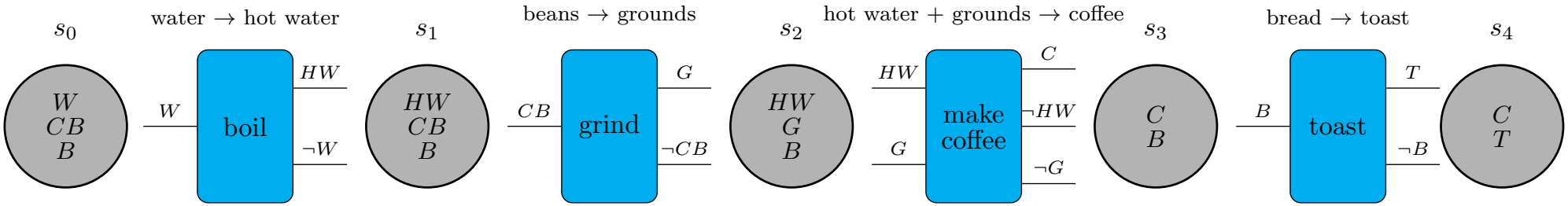
Available Actions:

- **boil**: water $\rightarrow$ hot water
- **grind**: beans $\rightarrow$ grounds
- **make_coffee**: hot water + grounds $\rightarrow$ coffee
- **toast**: bread $\rightarrow$ toast

Each action takes 1 time unit.

Sequential Plan

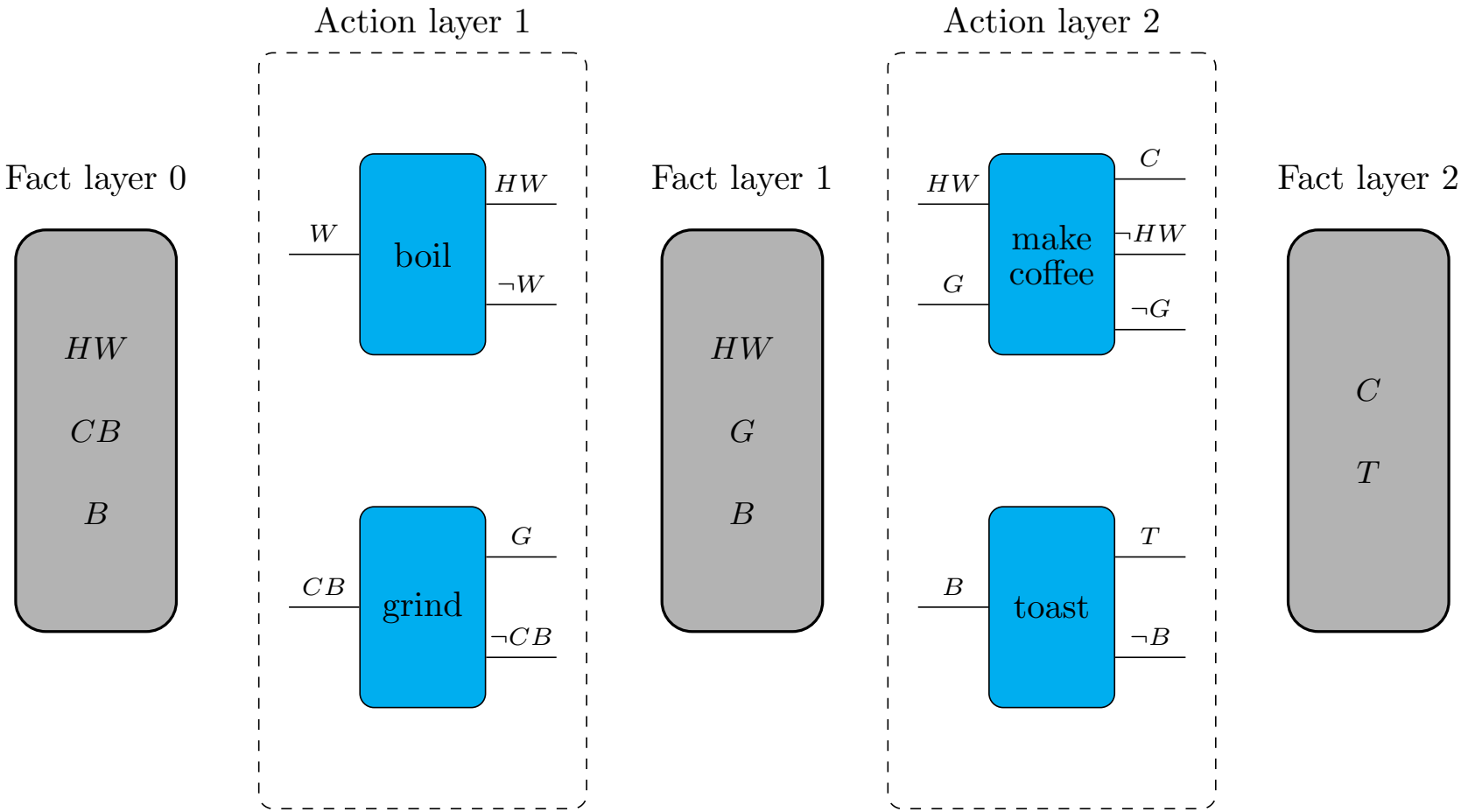
Example plan:



Here, we have/see:

- Total-order plan has 4 actions (the boxes)
- We have 5 states (the circles), initial, 3 intermediate, and a goal state
- Each action's precondition is satisfied in its state
- Makespan is 4, and we have 1 total order.

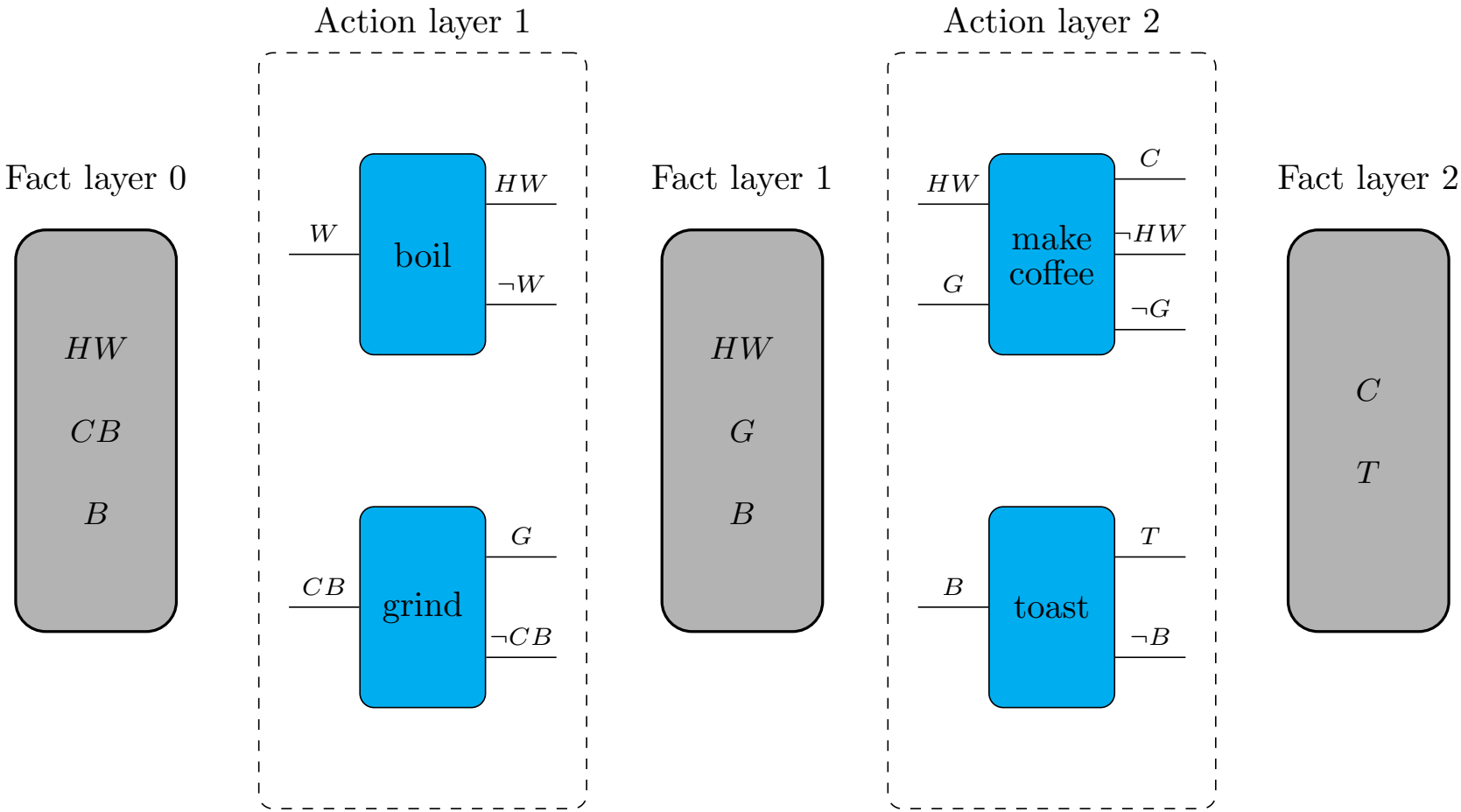
Parallel Plan



Parallel plans are alternating fact and action layers, such that:

- All actions must be applicable in any order, and
- generate a unique successor state/fact layer

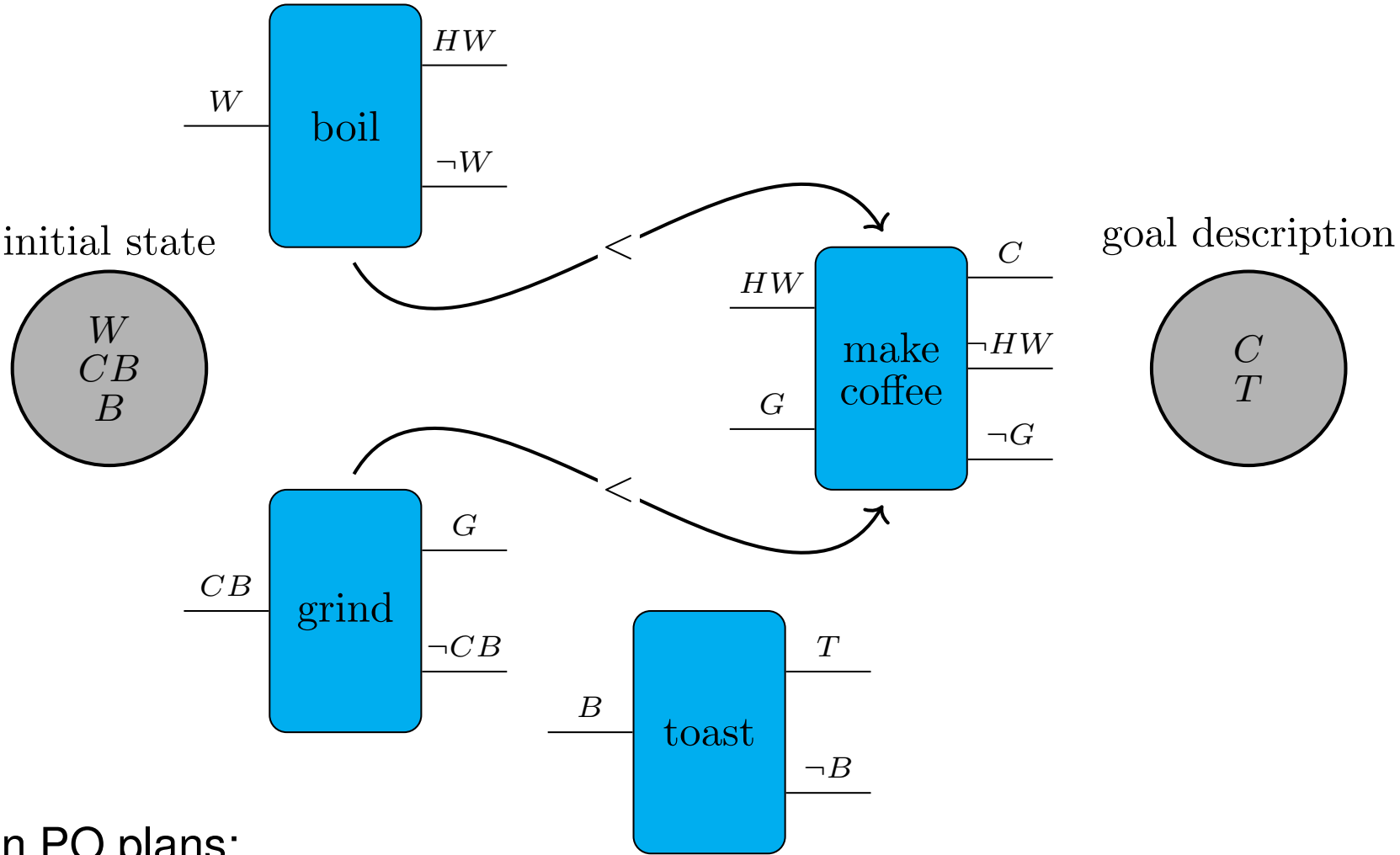
Parallel Plan



Here, we have/see:

- Makespan is only 2!
- We have 4 total orders, but only 1 under parallelism

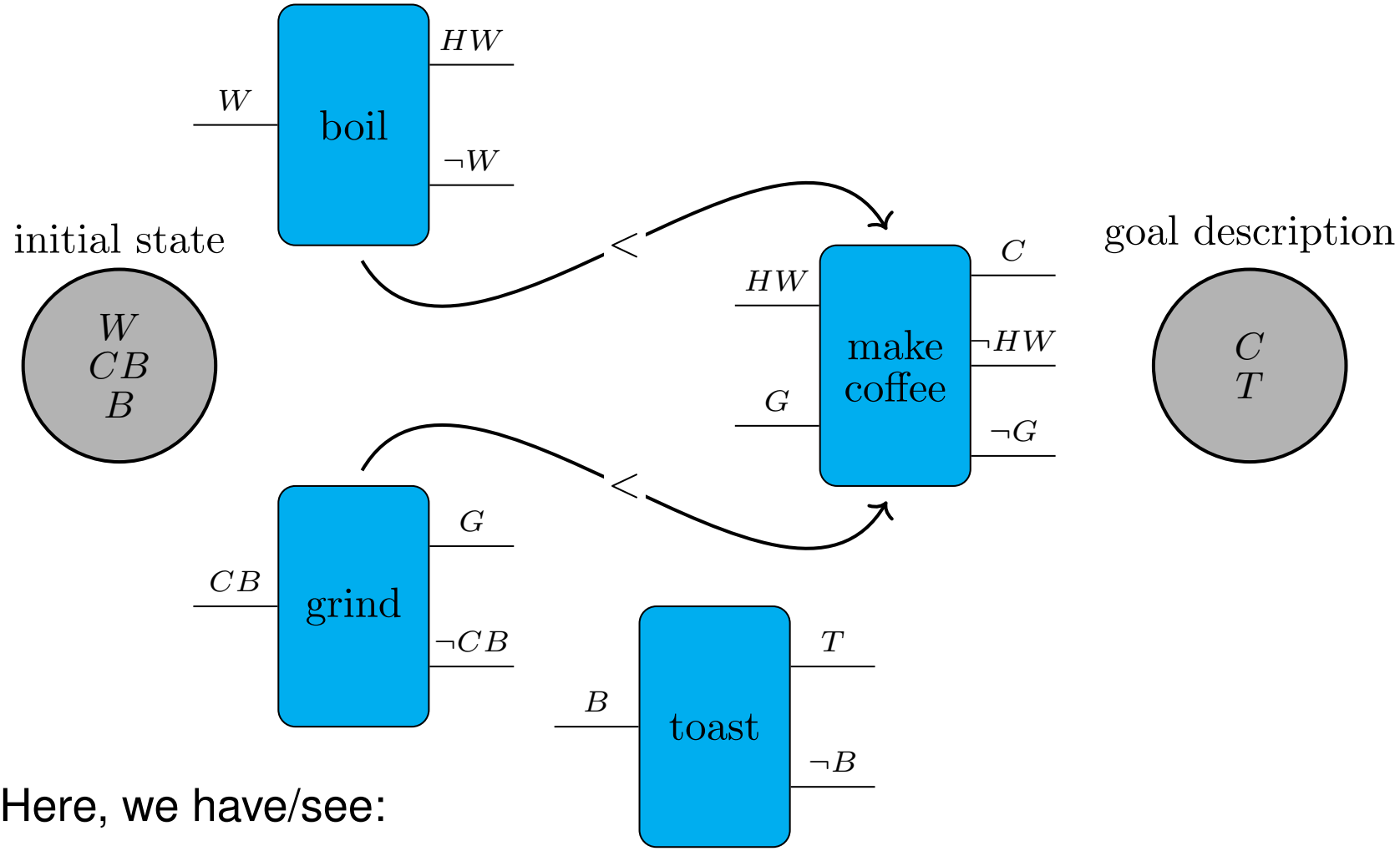
Partial-Order (PO) Plan



In PO plans:

- Every linearization must be a sequential plan.

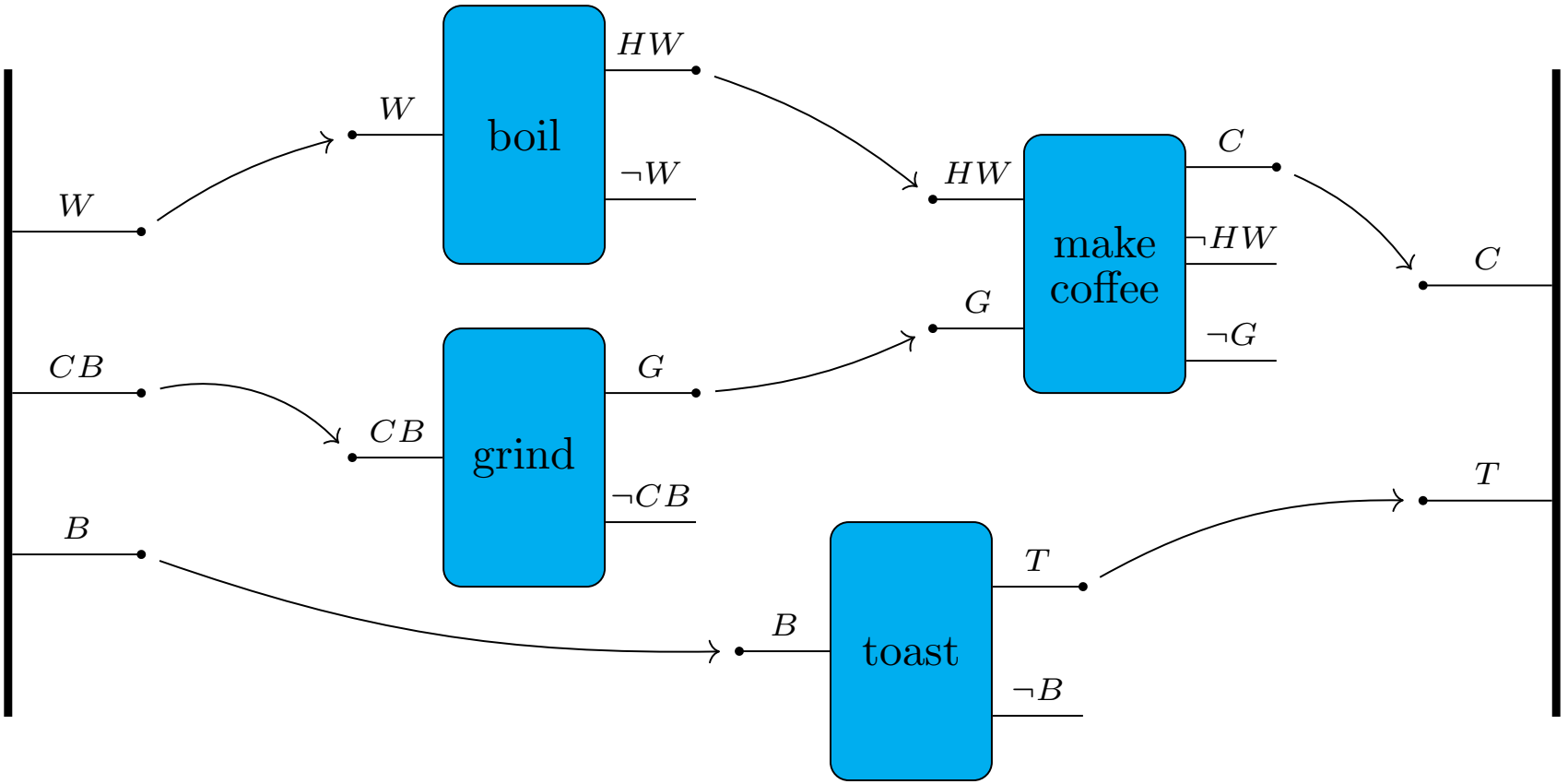
Partial-Order (PO) Plan



Here, we have/see:

- Makespan is again 2
- We have 8 total orders, and 19 under parallelism

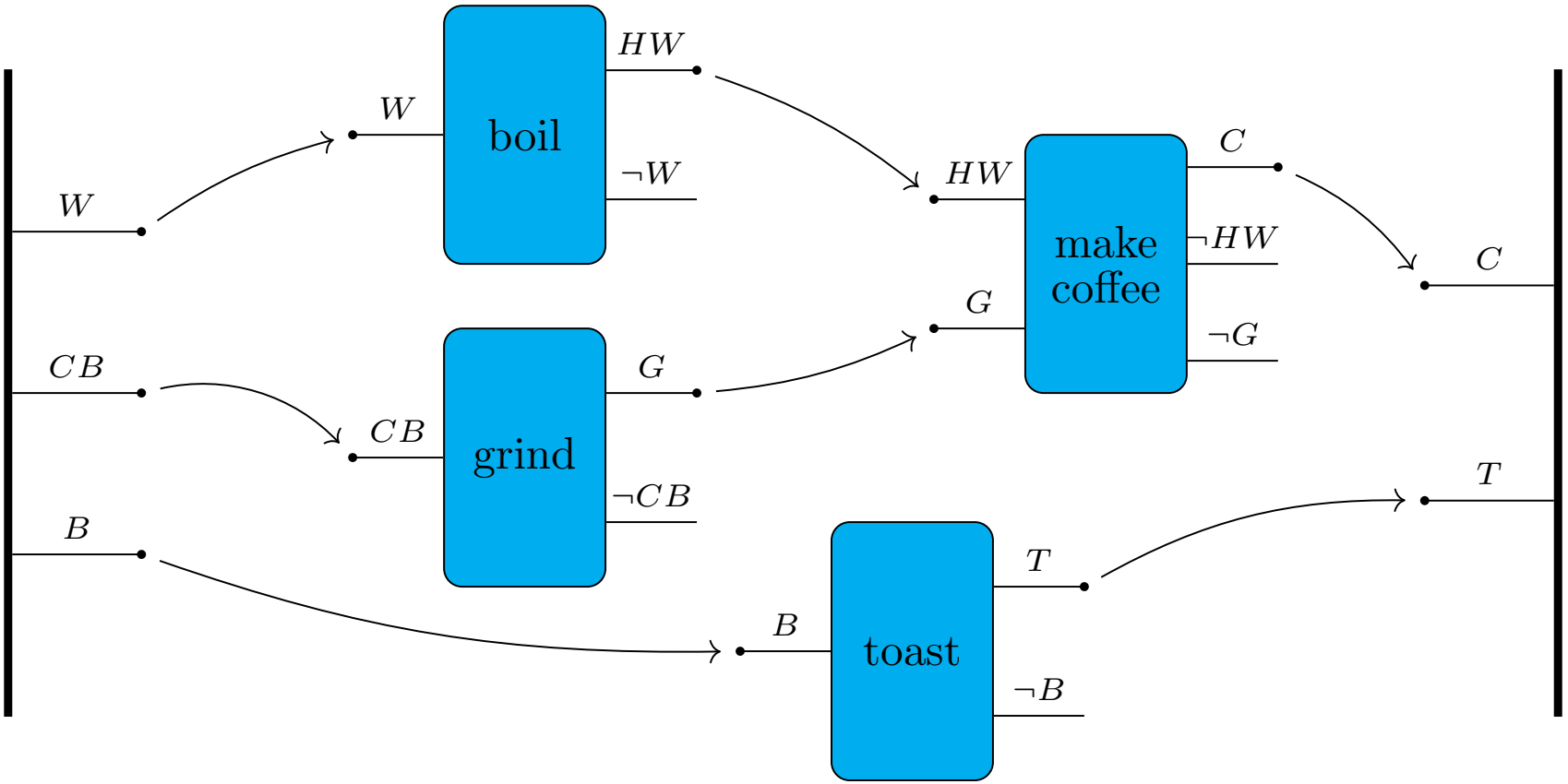
Partial Order Causal Link (POCL) Plan



In POCL plans:

- Solution criteria connect preconditions and effects;
- they *imply* that every linearization is a sequential plan.

Partial Order Causal Link (POCL) Plan



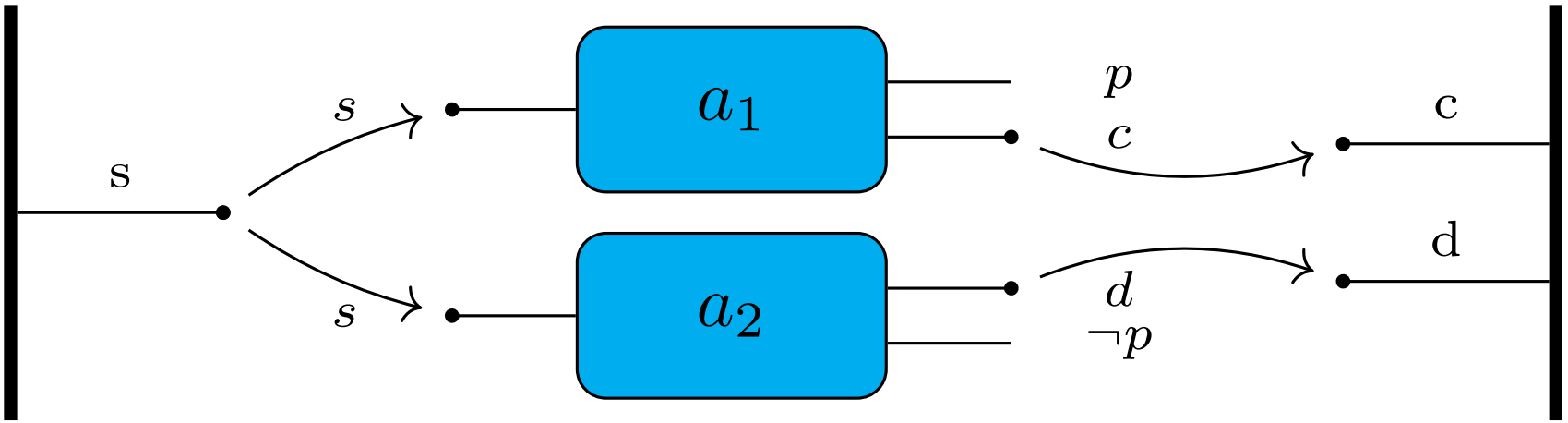
Here, we have/see:

- All properties are (coincidentally) identical to those of the PO plan
- But in general POCL plans have fewer linearizations

Parallel ≡ PO ≡ POCL?

Are parallel plans as makespan-compact as POCL plans?

Many assume so, but they are not:

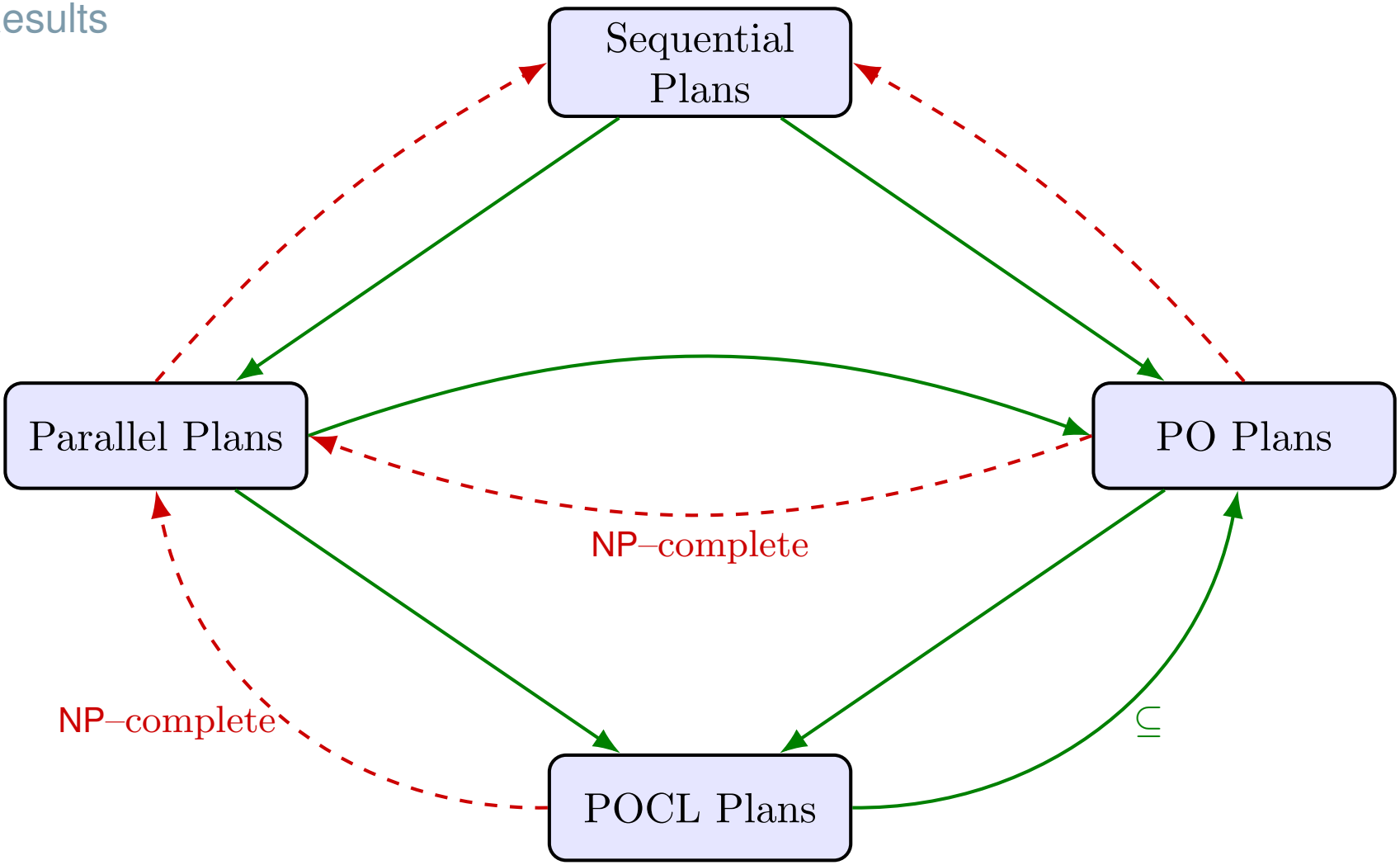


Here, we have/see:

- This POCL and PO plan has makespan 1, but:
- its parallel plan has makespan 2! (since the state is not unique.)

Can we sometimes achieve the same makespan? How to detect?

Results



Implication:

Heuristics admissible for parallel plans are *not* admissible for POCL/PO plans!