Stabilizing Pipelines for Streaming Applications

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Outline

- Motivation
- Self-Stabilization
- Linear Pipelines
- Other Compositions

Motivation

- Streaming data in distributed systems are abundant.
- What is the guarantee that a distributed system that handles streaming data will stabilize and exhibit the correct behavior?
- We focus on modular architecture of systems handling streaming data.

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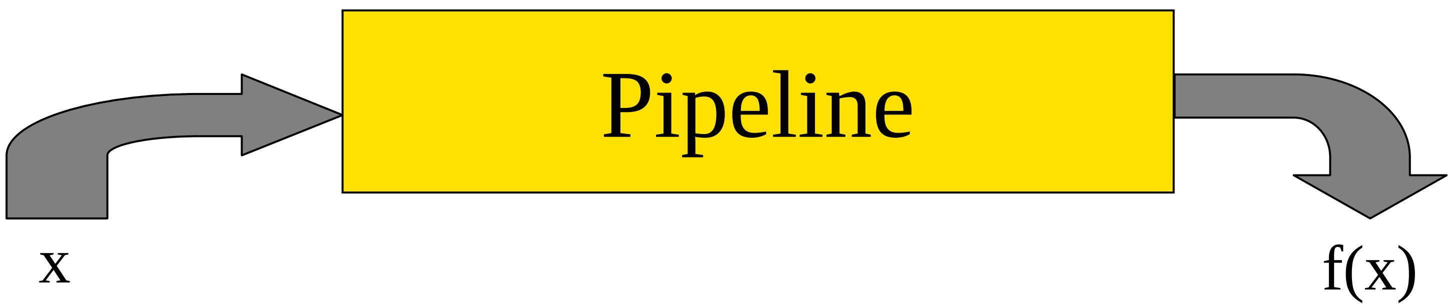
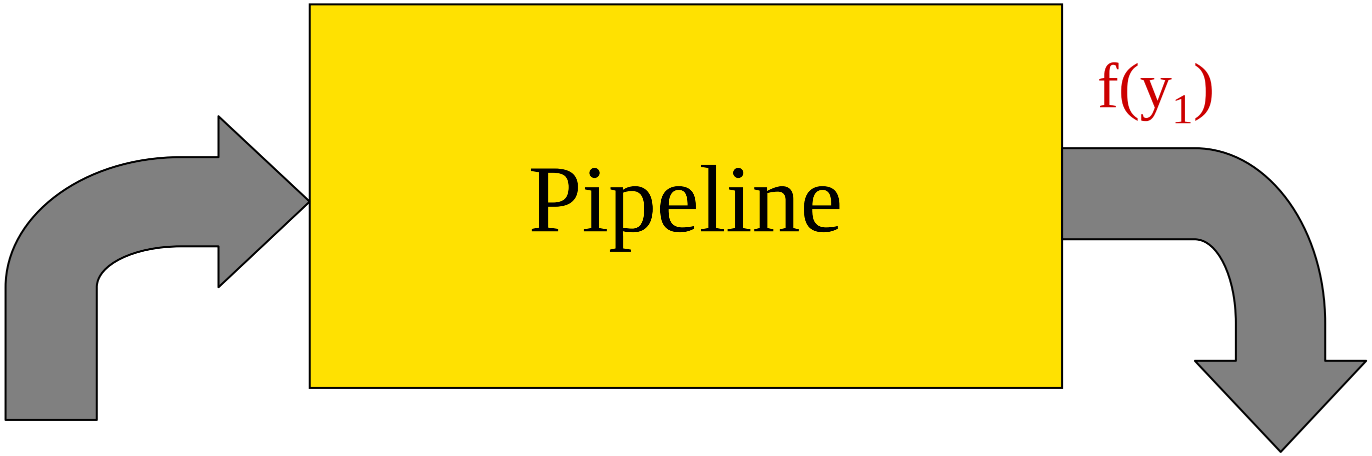
Expected Pipeline Behavior



For each input *x* from a constant input stream, the pipeline computes *f(x)*

Pipelines and Self-Stabilization



x_1 Regardless of the initial state of the system, the output stream will have a suffix identical to that which will be produced by the correctly initialized system

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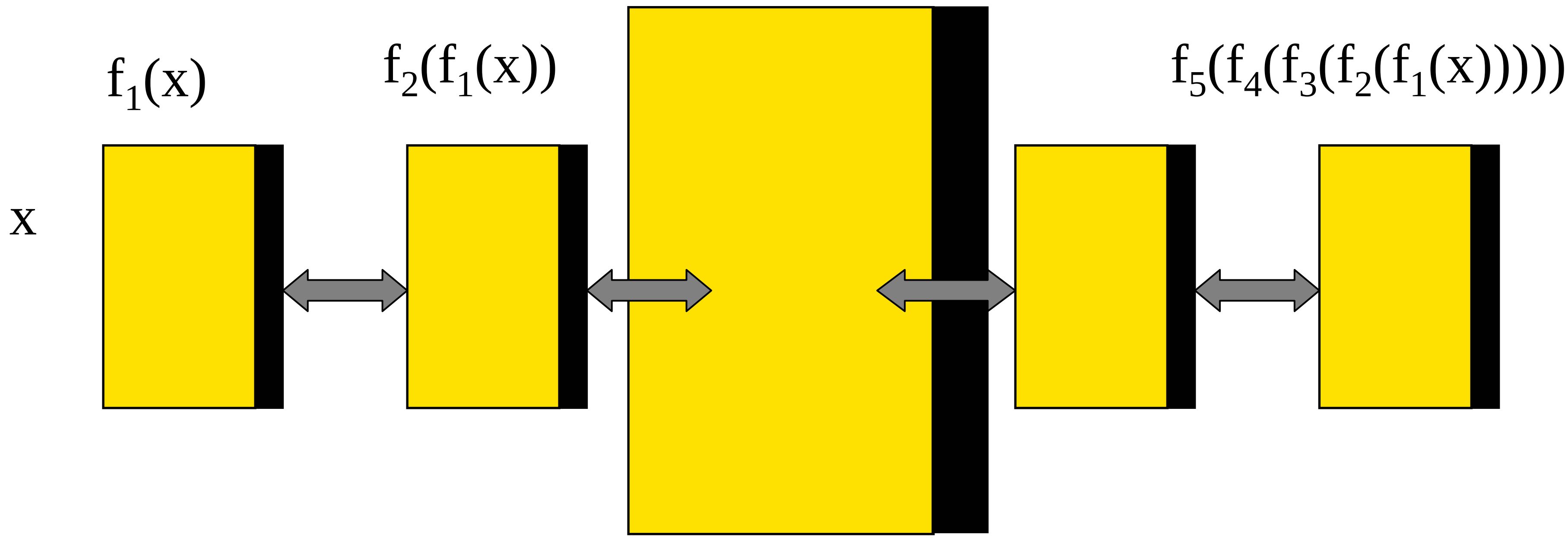
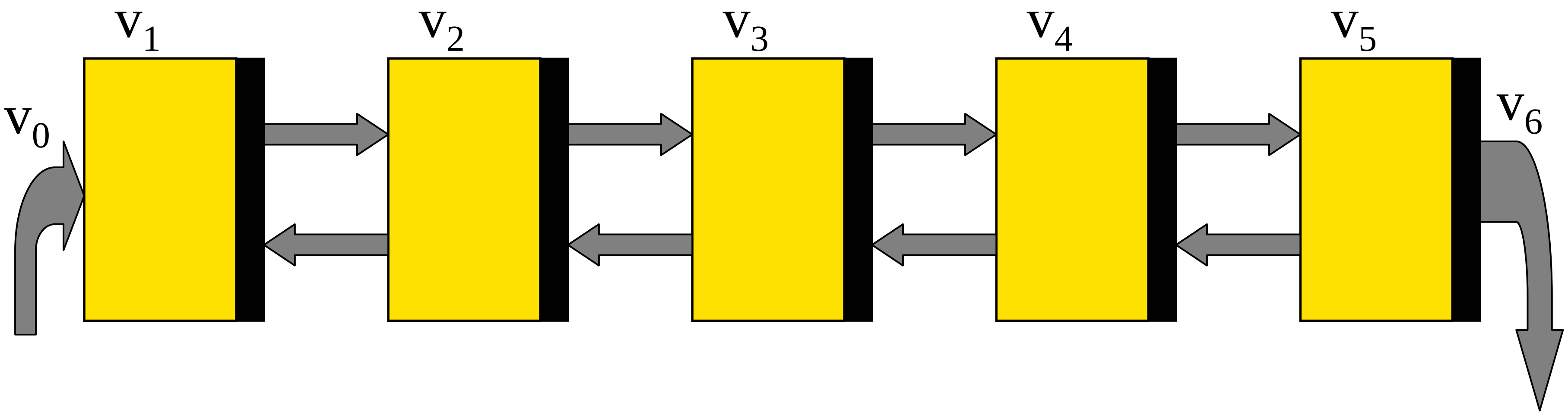
Linear Pipeline



A *stage i* is composed of $k > 0$ processes, and eventually computes $f_i(x)$ for all inputs x

Stabilizing Linear Pipeline



$\{Program\ for\ stage\ i : 1 \le i \le k\}$

do $\quad (v_{i-1} \ne v_i) \wedge (v_{i+1} = v_i) \rightarrow$

$\qquad\qquad B_i := f_i(B_{i-1}); v_i := \neg v_i;$

od

Linear Pipeline Convergence Time

A linear pipeline converges in at most:

$$k(k-1)(1/2) + k(L_{max} - 1) + 1$$

time steps.

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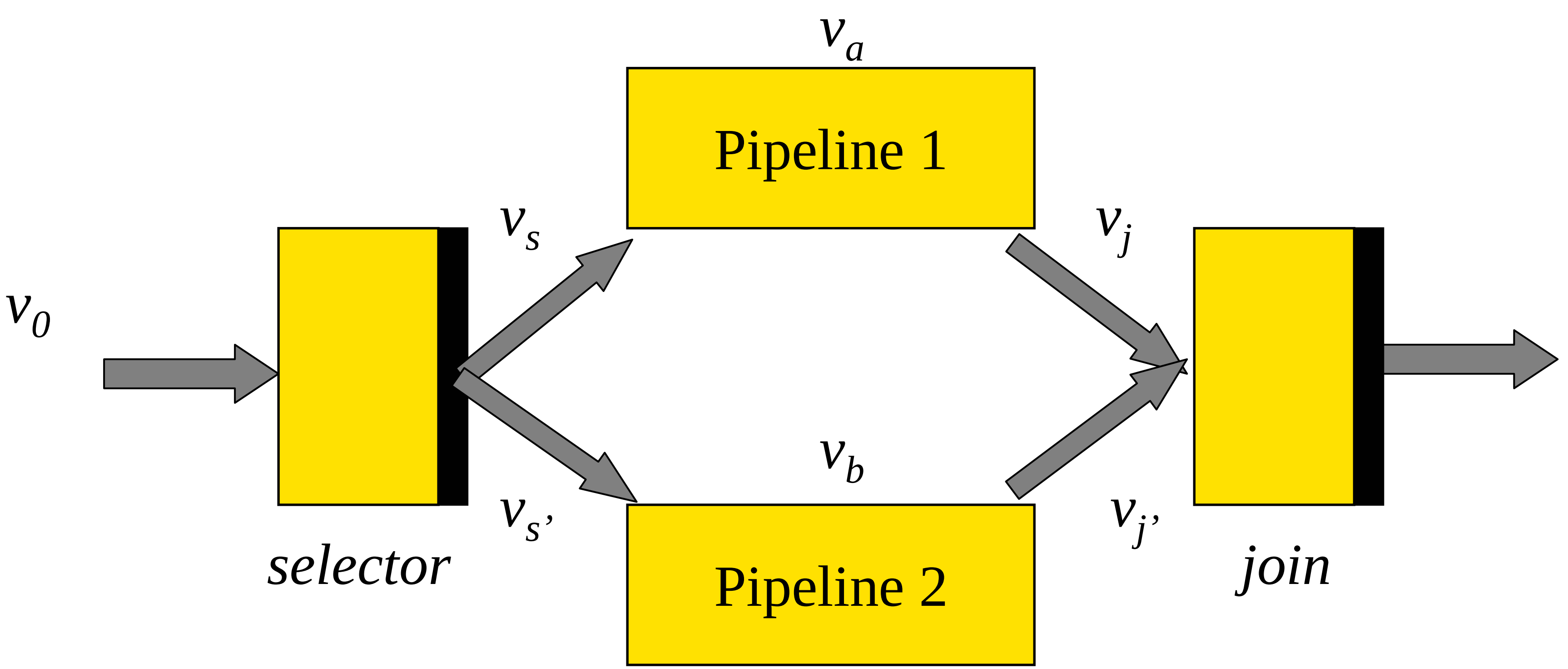
Alternative Composition



Stabilizing Alternative Composition

- The *selector* stage may “starve” one of the pipelines
- To be self-stabilizing, all executions of the selector of length *m* must include at least one output to each pipeline

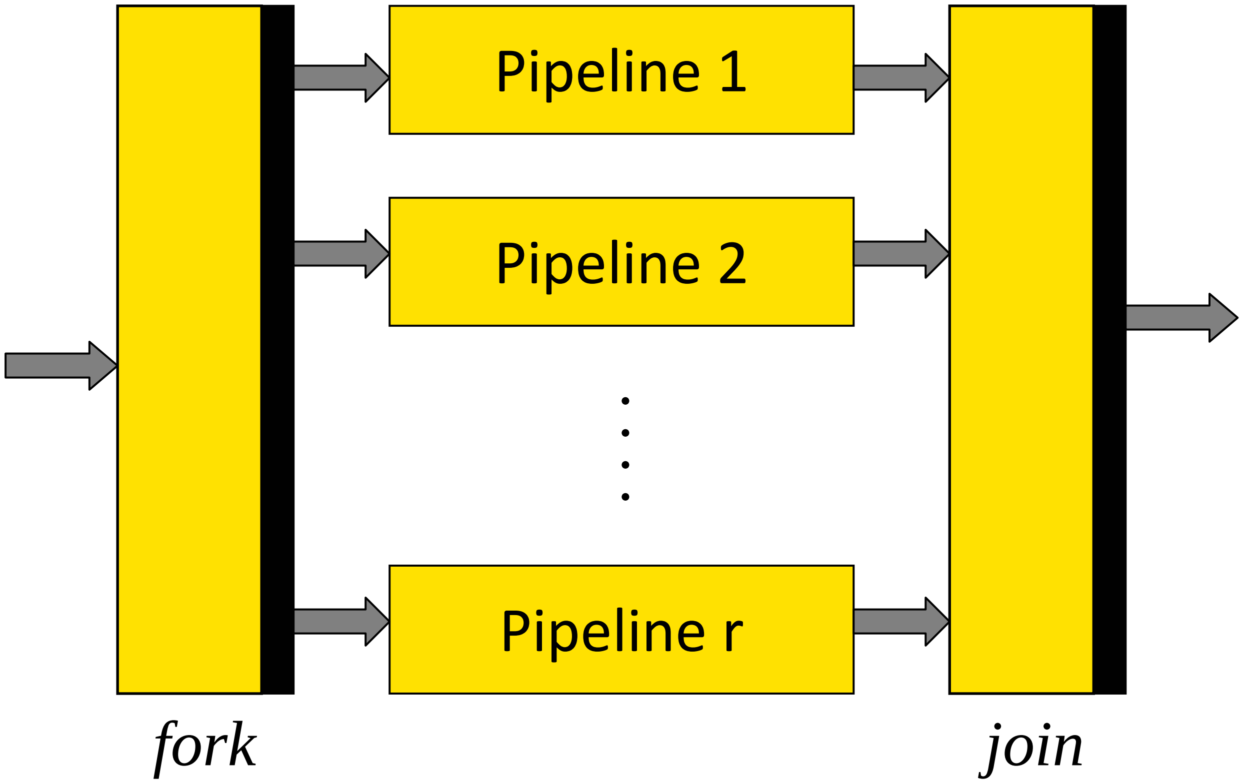
Alternative Pipeline Convergence Time

An alternative pipeline converges in at most:

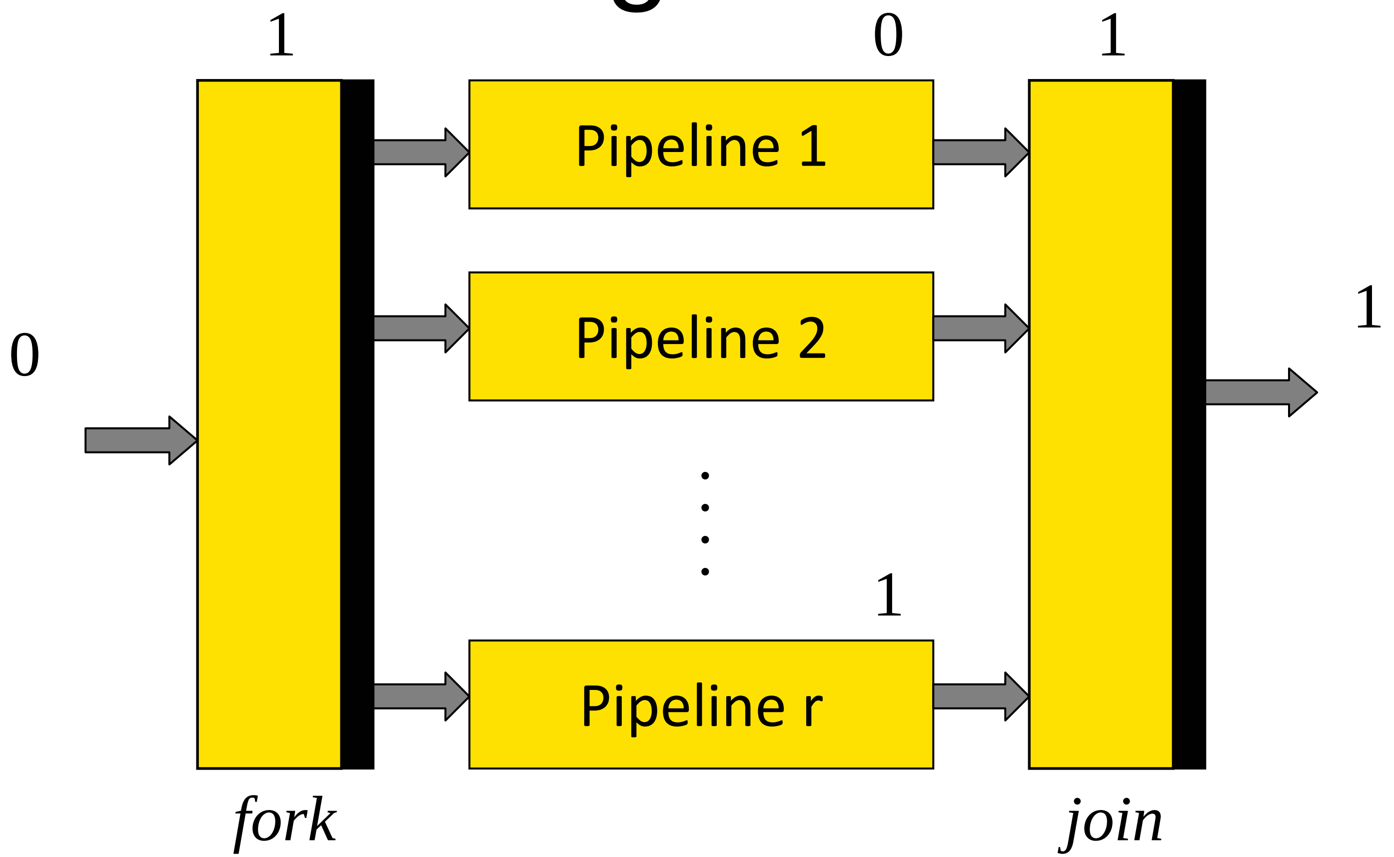
$t(t\text{-}1) + mtL_{max} + 1$

time steps.

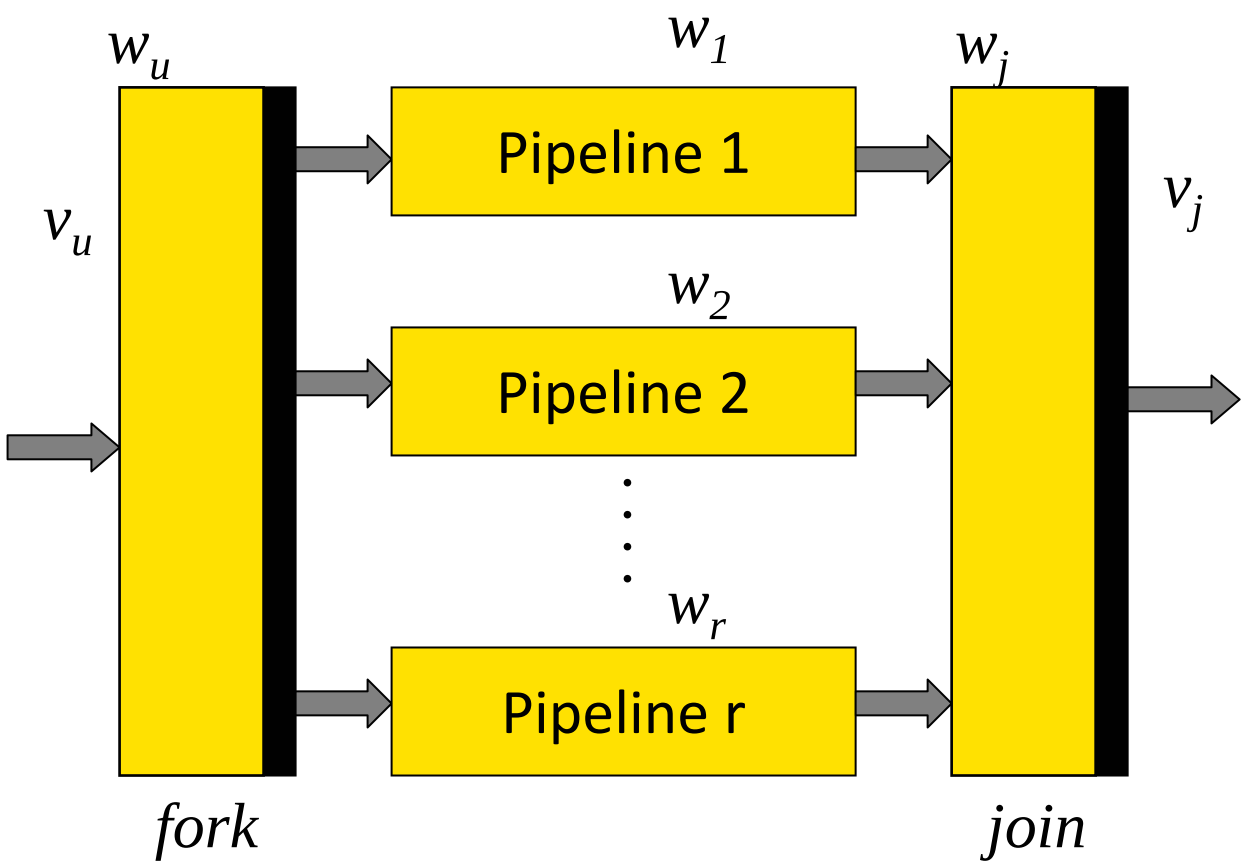
Concurrent Composition



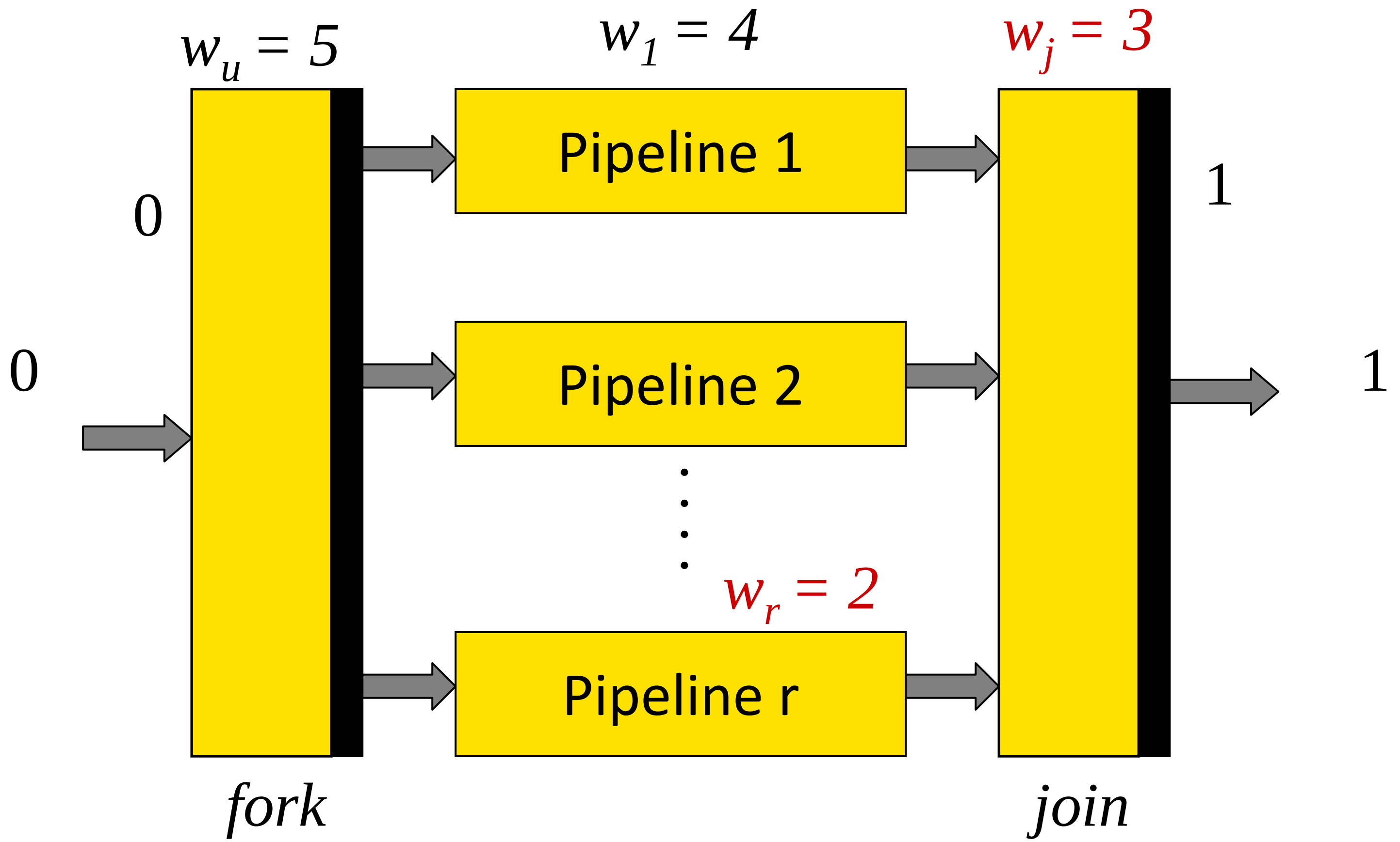
Concurrent with Boolean Signals



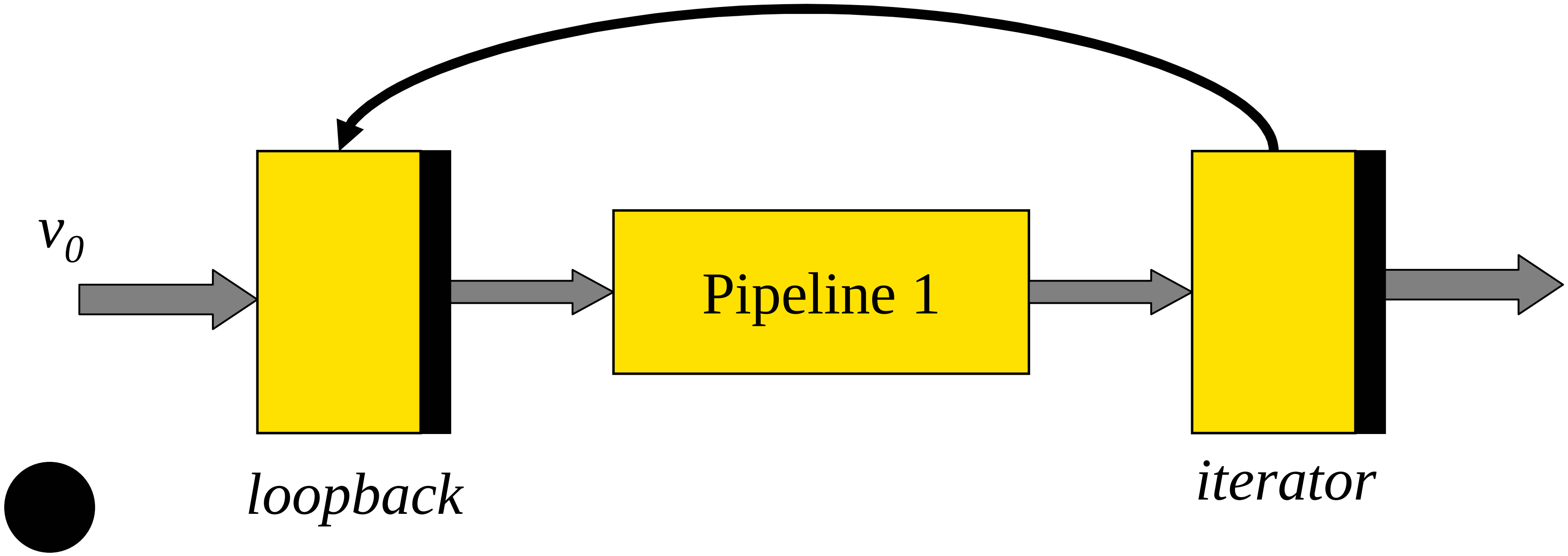
Stabilizing Concurrent Composition



Stabilizing Concurrent Composition



Repetitive Composition



Stabilizing Repetitive Composition

- Similar to the alternative composition, we have to make sure the iterator doesn't "starve" the environment

Final Points

- Any of these stabilizing compositions can be replaced with any other stabilizing composition
- Results are possible with bounded sequence numbers

Thank You!

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