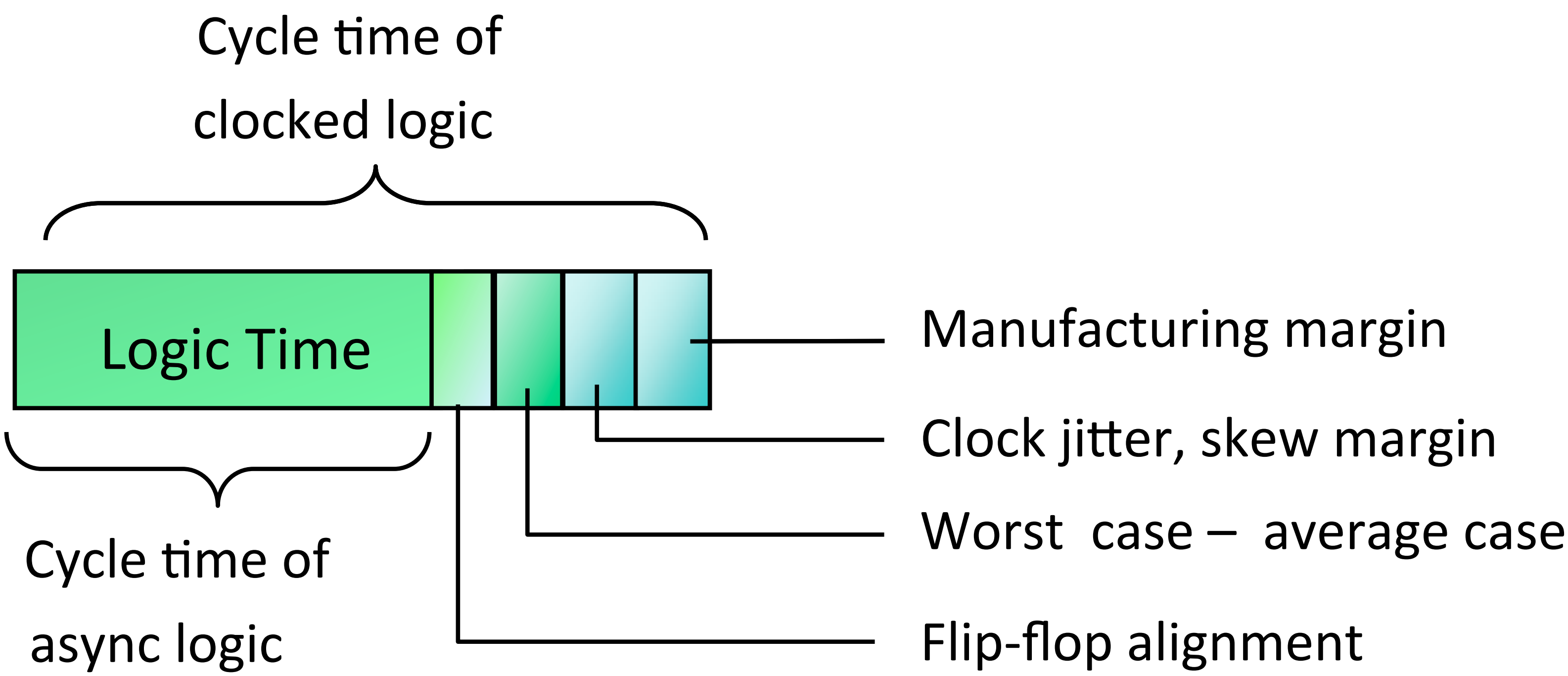
Optimization of Conditional Asynchronous Circuits with Average-Case Performance Constraints

Mehrdad Najibi

(Advisor: Peter A. Beerel)

MHI Pitch

The Advantage Asynchrony



Async logic removes wasteful margins and can achieve faster circuits with lower power consumption

Main Contribution

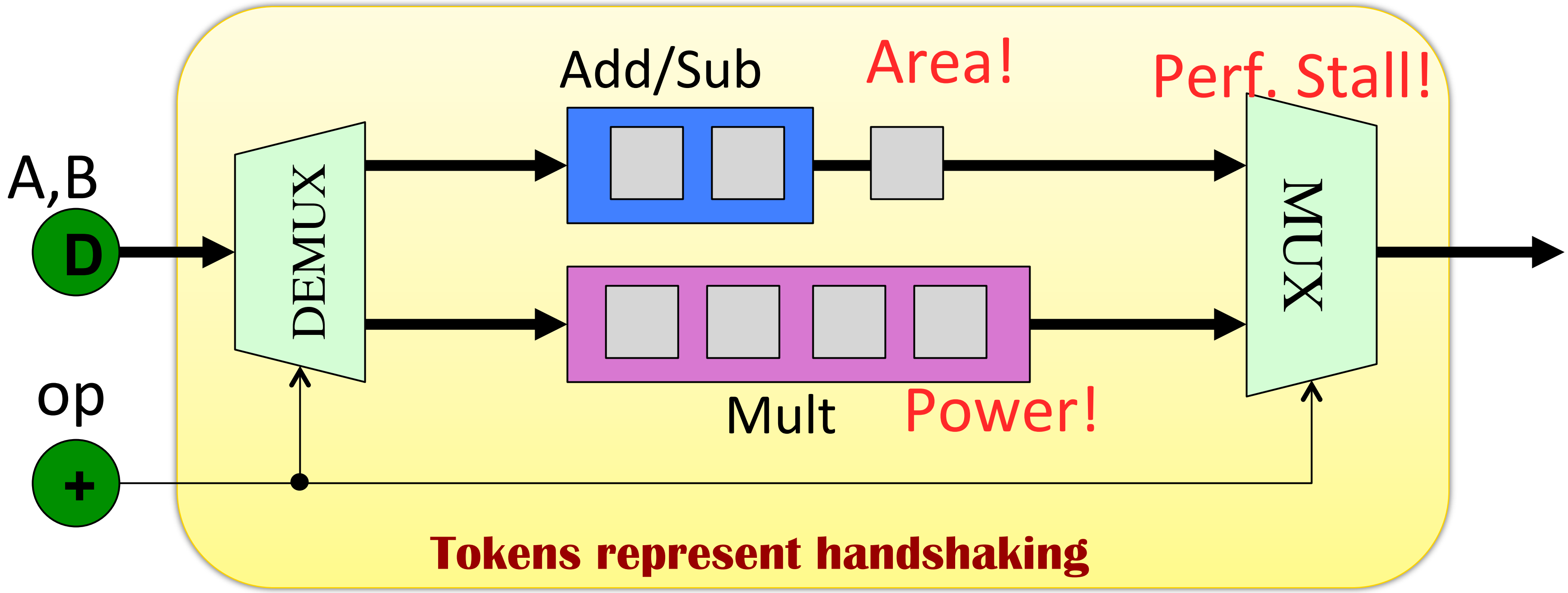
Average-case performance bounds!

- Asynchrony leads to average-case **performance**
  - But current practical performance models are conservative!
- Conditional communication is the key to **low power**
  - Lack in performance analysis techniques for conditional circuits!

Impact of the research

- Average case bounds lead to better tradeoffs and lower **overheads**!

Example: Purely Unconditional ALU

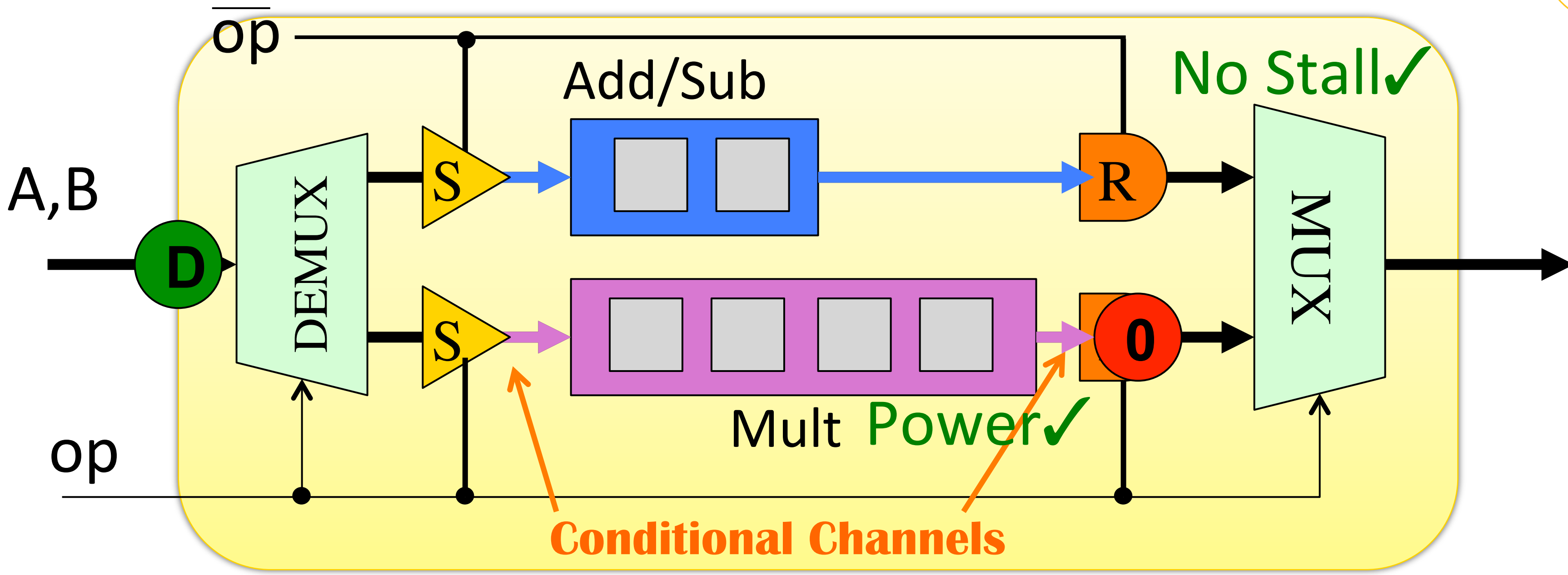


The Slack Matching Problem - Add minimum number of pipeline buffers to the circuit to meet a target cycle time τ.

Intelligent use of conditional communication is the Key!

to reduce power/speed/area overheads in asynchronous design

Conditional Communication



Modes: A subset of channels are active during ADD/Mult.

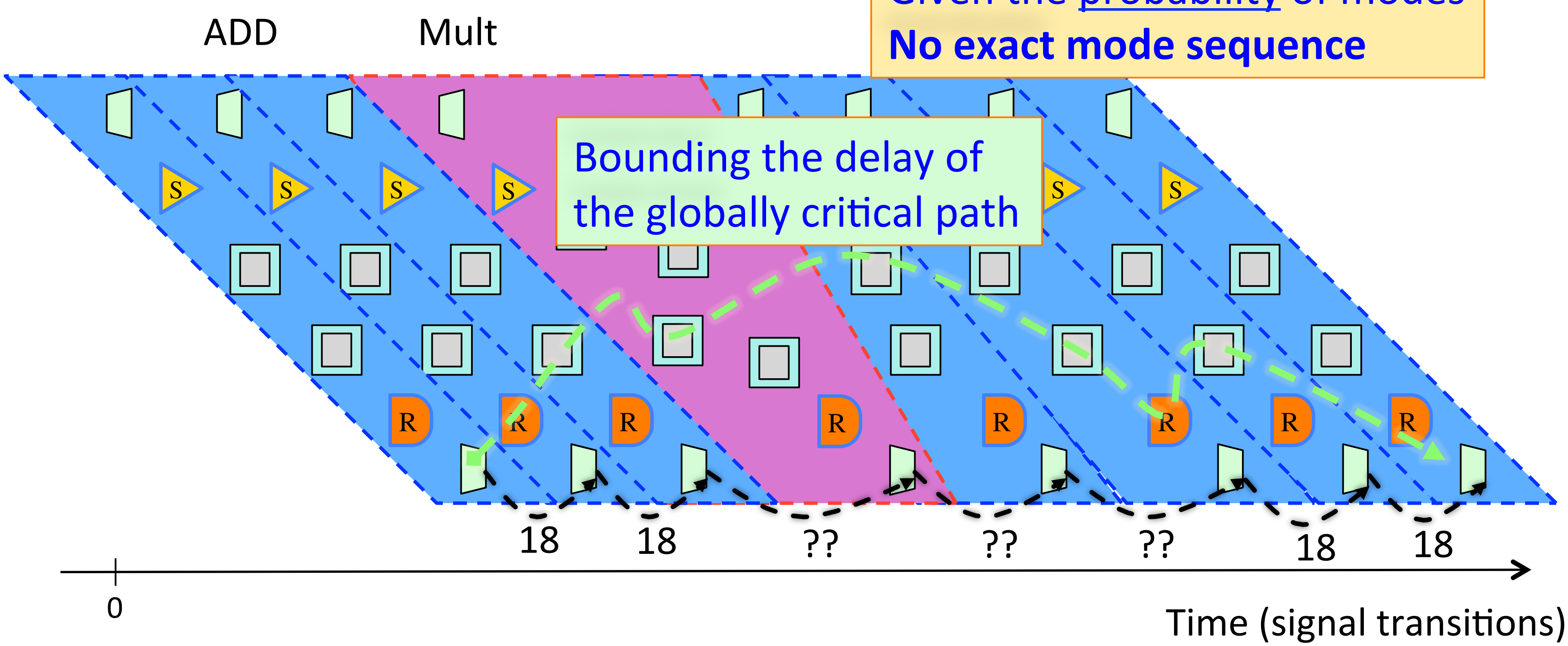
- At circuit level, a subset of channels activated together is considered as a **mode of operation**.

Opportunity : Each mode can be optimized individually

Challenge : Performance evaluation is hard!

Problem 1: Average-case Performance

Given the probability of modes
No exact mode sequence

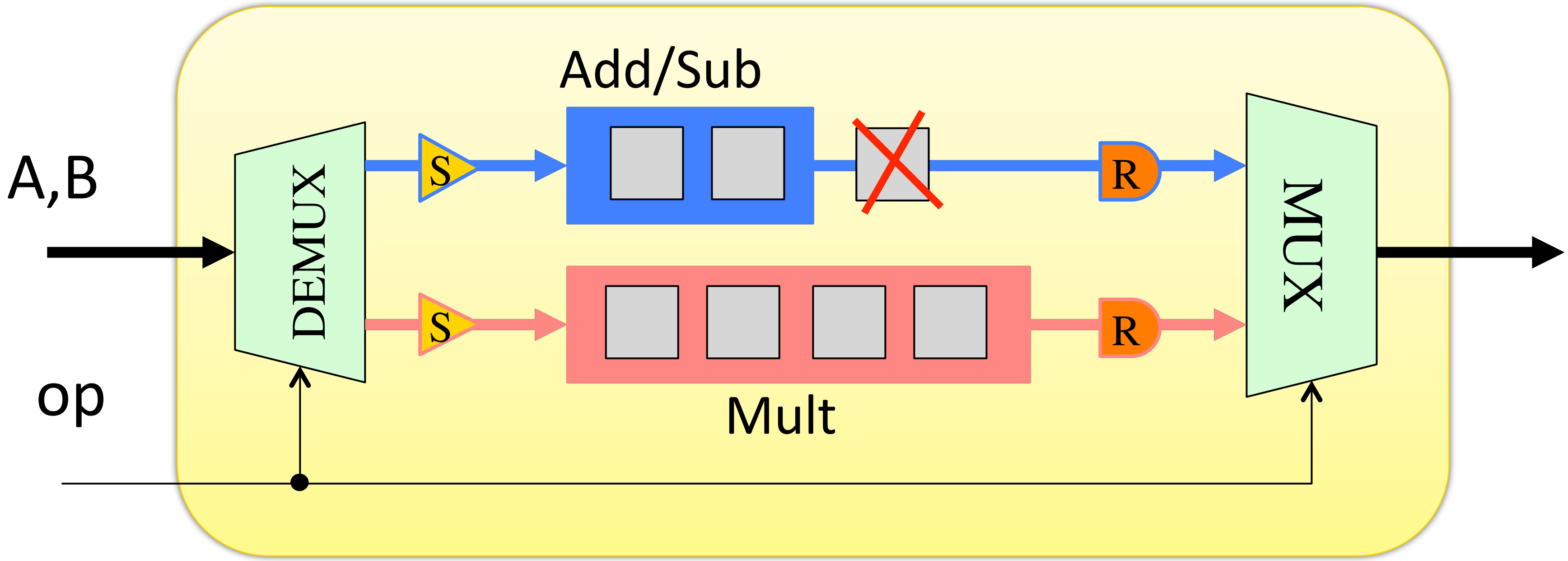


Observation: Impact of mode change spans multiple cycles

How to bound the impact of mode changes on circuit's average cycle-time?

*We are interested in a **mode order agnostic** performance bound.*

Problem 2: Mode Based Conditional Slack Matching



Conditional Slack Matching Advantage – Conditional behavior yields less stalls and thus not as many pipeline buffers needed.

- Previously ignored – conservatively modeled as unconditional
- **30% area & power saving**

Conclusions

- A **new performance analysis method** based decomposing Petri net behavior into marked components.
- **Average-case performance bounds** are derived for conditional asynchronous circuits with mode based behavior.
  - Using Linear Programing (easy to incorporate in optimization)
- Application of the derived bounds are shown in **conditional slack matching**
- Several other applications for the proposed theory
  - Integrated slack-matching and Fanout optimization.
  - Reconditioning with performance considerations.
  - Optimization of asynchronous circuits considering process variation.