A Stall-Free Real-Time Garbage Collector for FPGAs

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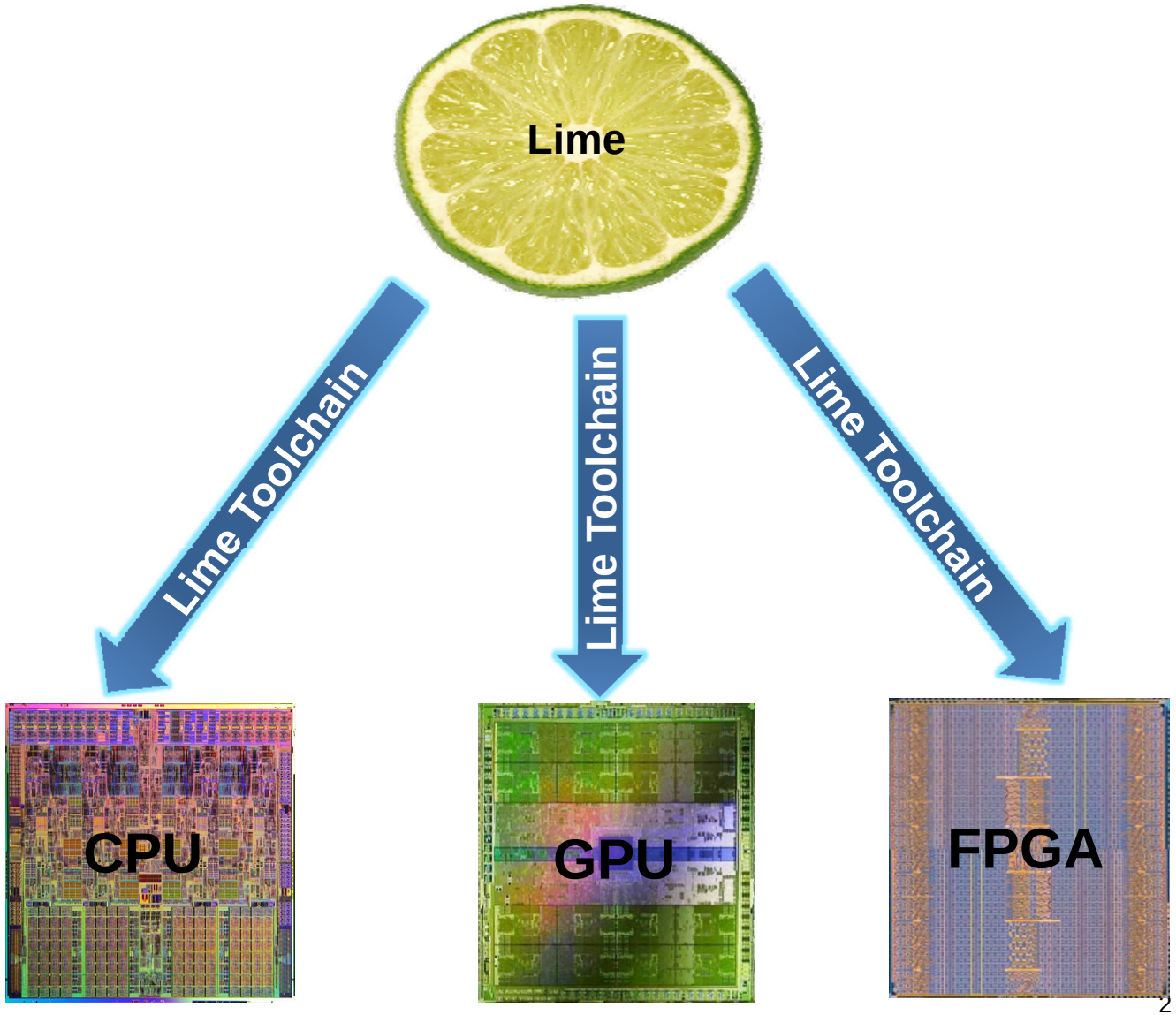
http://www.research.ibm.com/liquidmetal/

Motivation: Liquid Metal

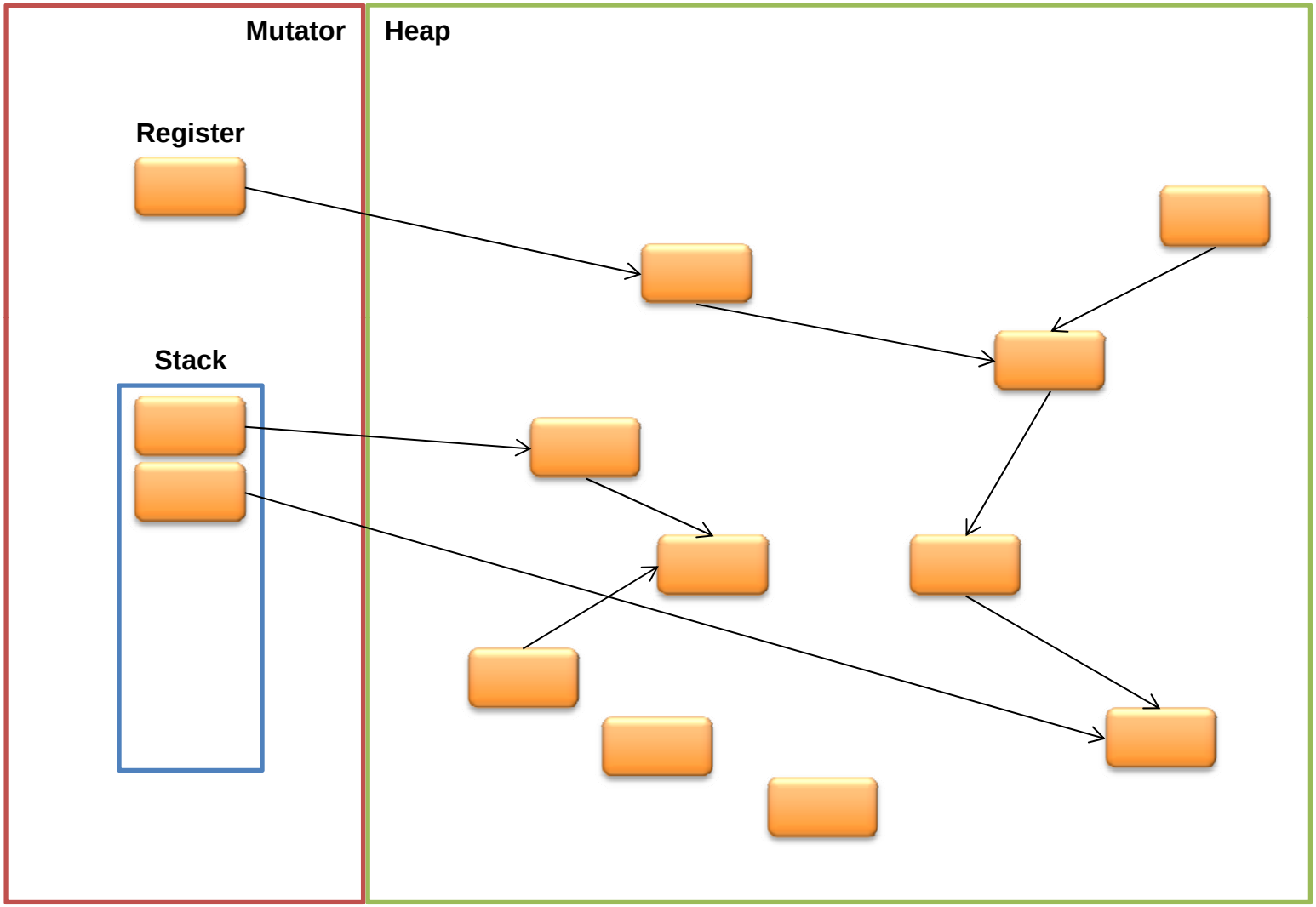
Language

Toolchain = IDE + Compiler + Debugger

Platform = Hardware + Runtime



What is Garbage Collection?



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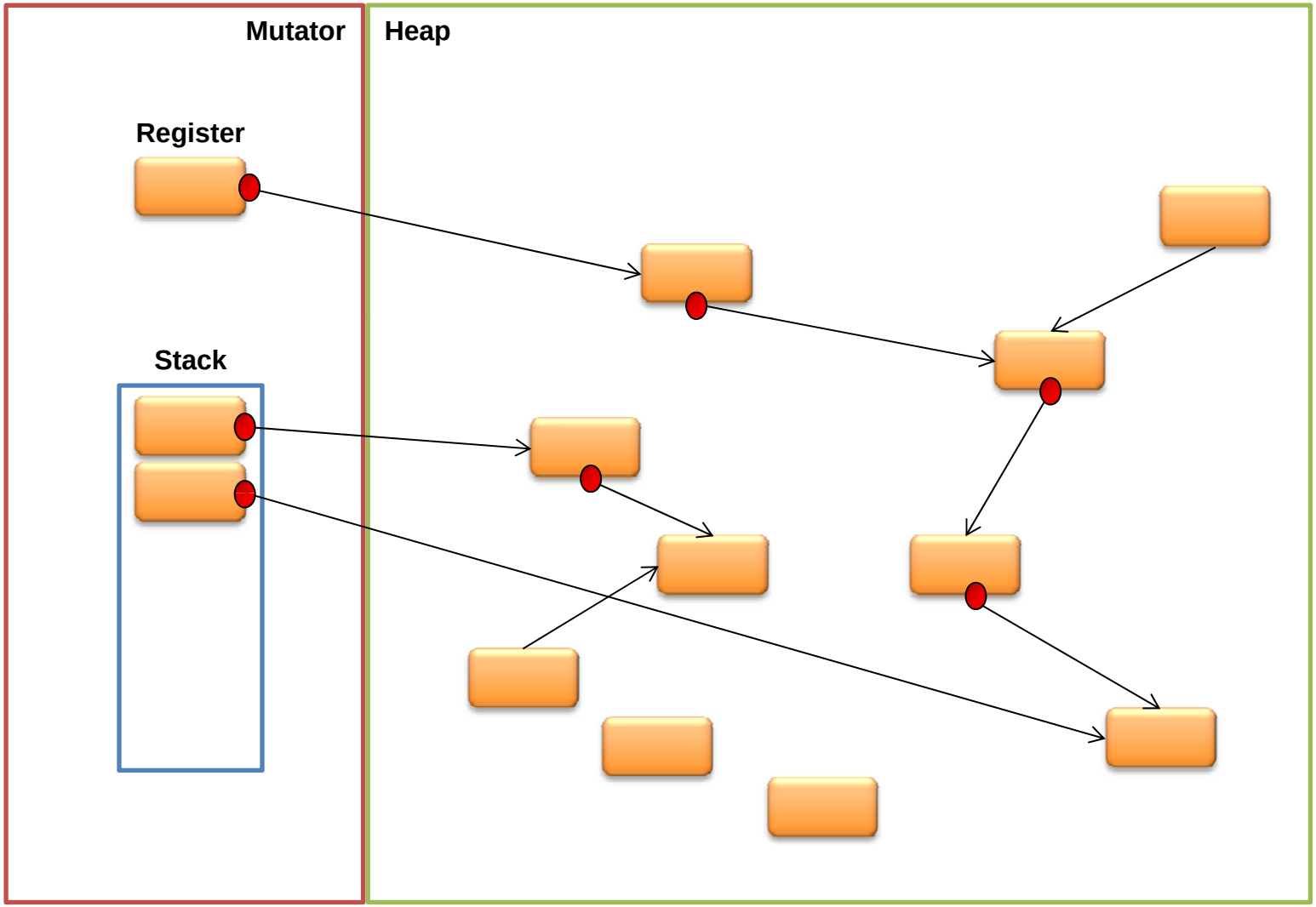
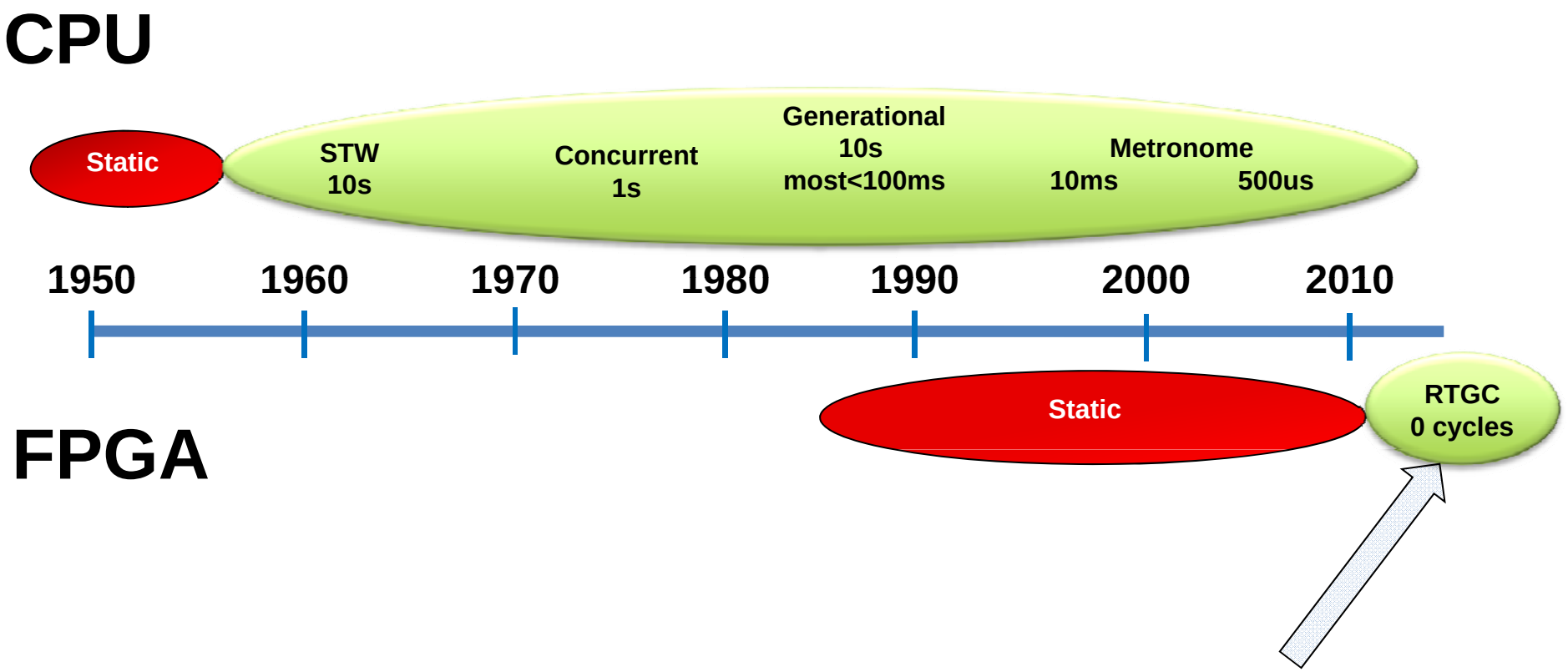


Memory Management: CPU vs. FPGA

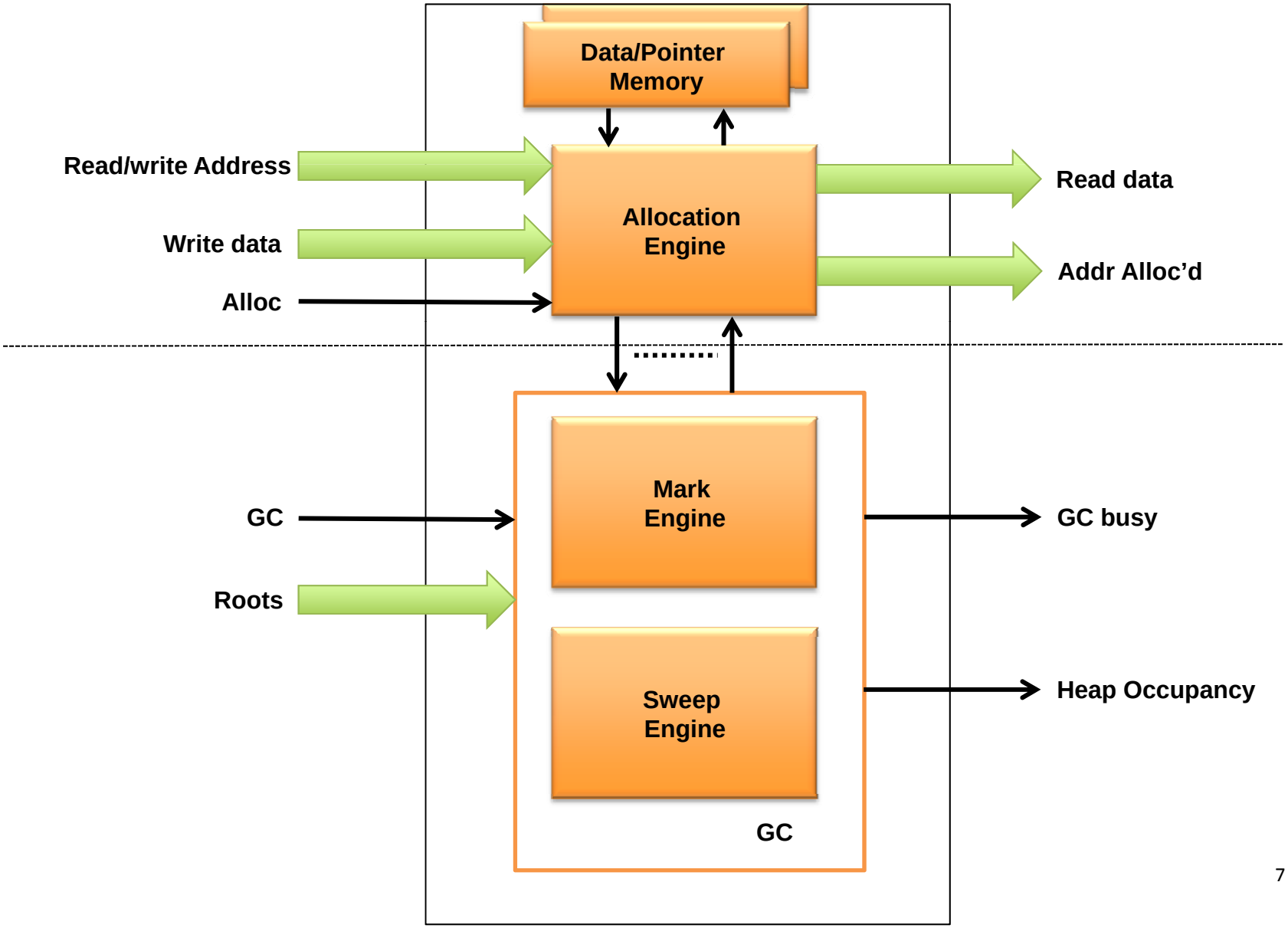


PLDI'12: "And Then There Were None: A Stall-Free Real-Time Garbage Collector for Reconfigurable Hardware"
- D. Bacon, P. Cheng, S. Shukla

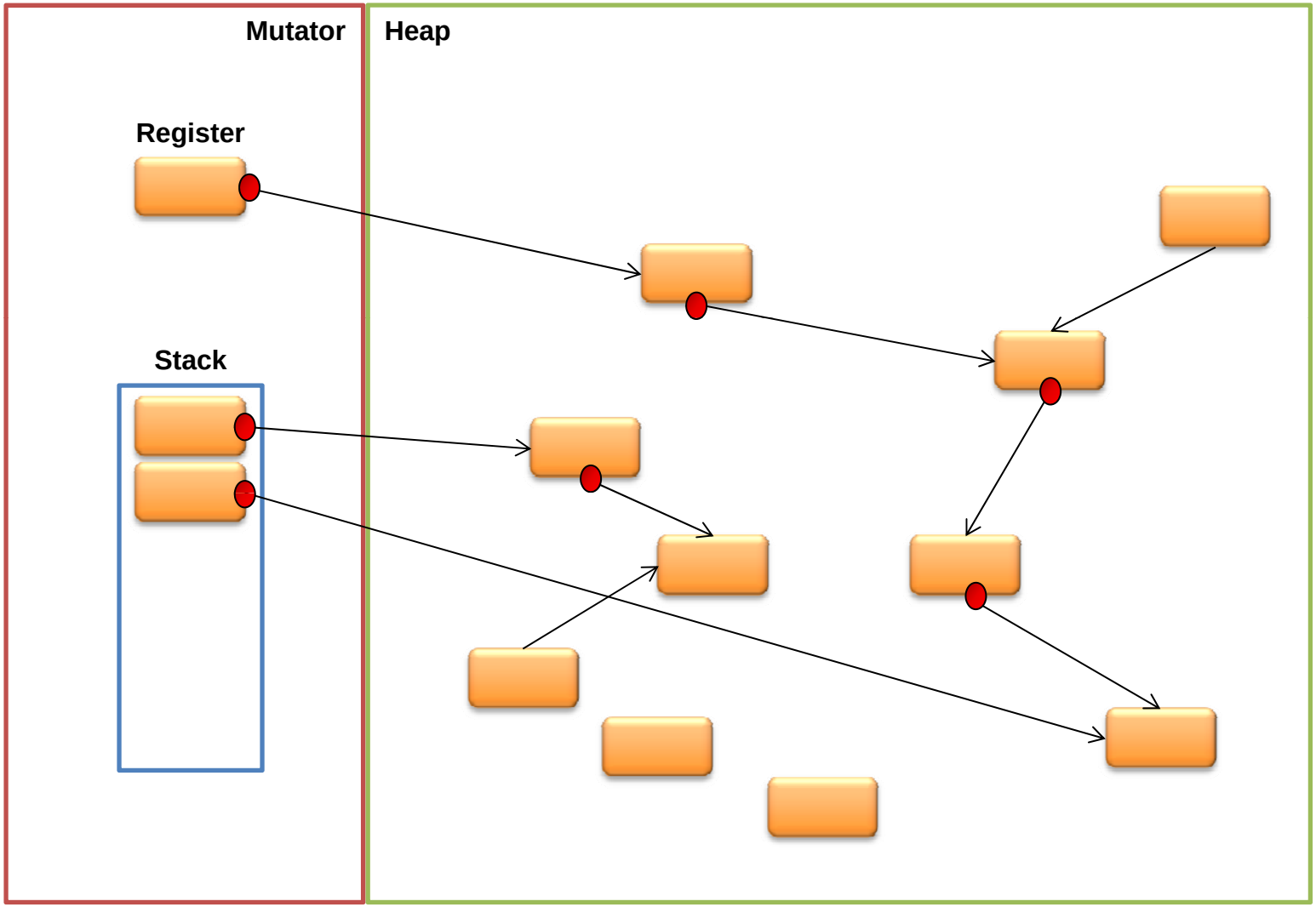
Heap - features

- Homogeneous objects
  - 2 pointer fields
  - Programmable number of data fields
- Minimum mutator utilization (MMU) of 100%
- Validated analytical bounds on the WCET
- Implemented in Verilog

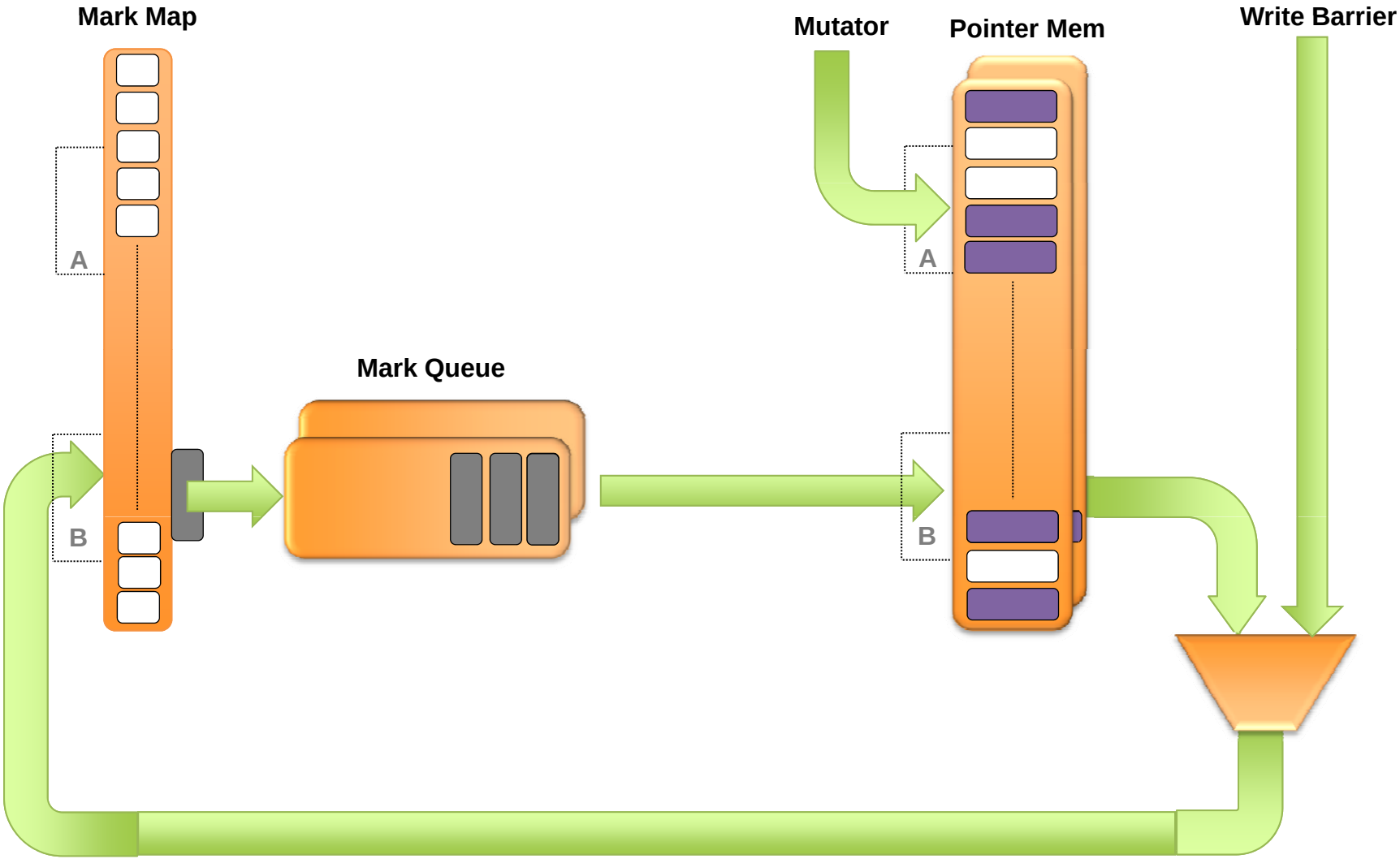
Heap - Block Diagram



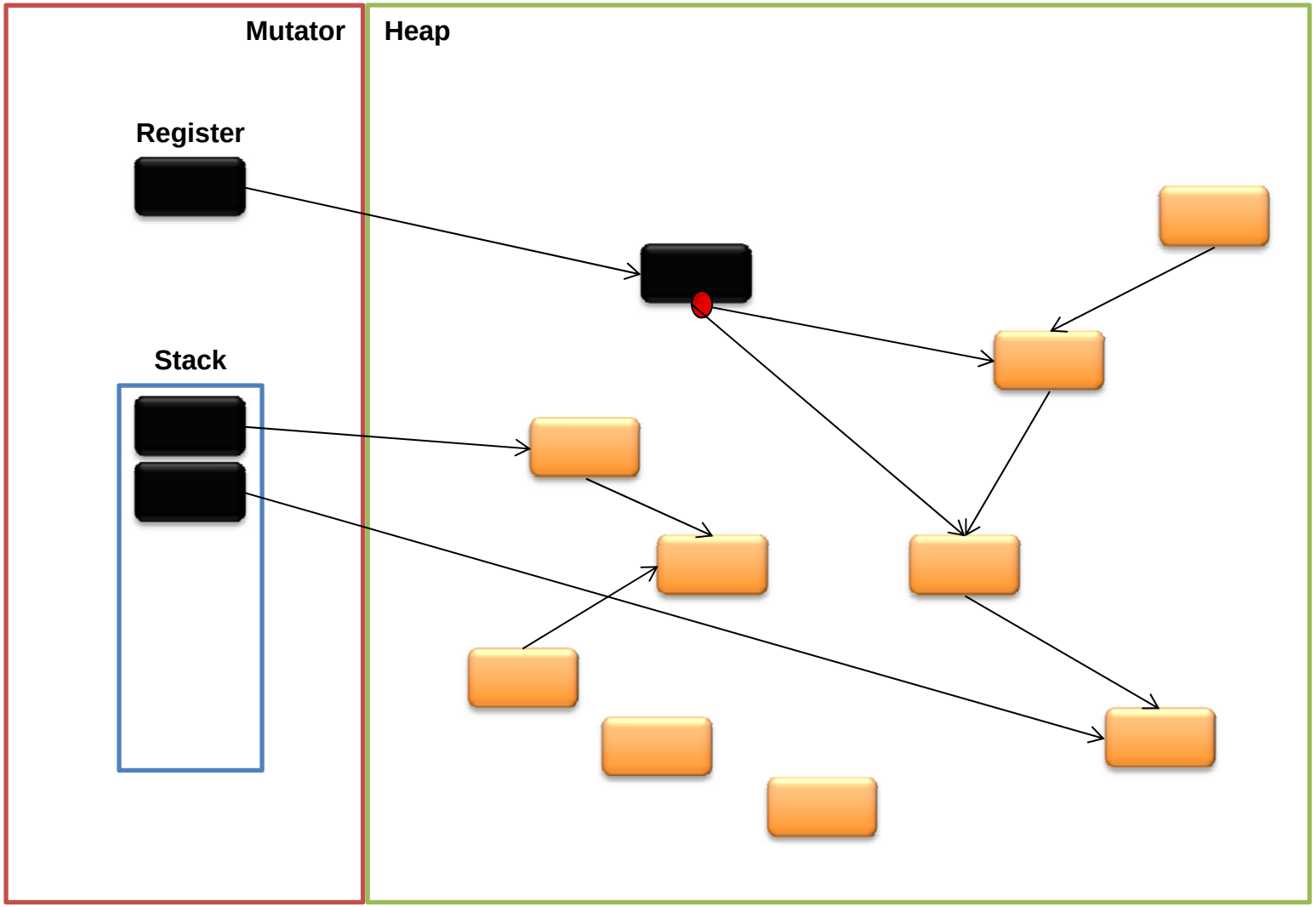
Marking



Mark Engine



Mark Engine: Write Barriers



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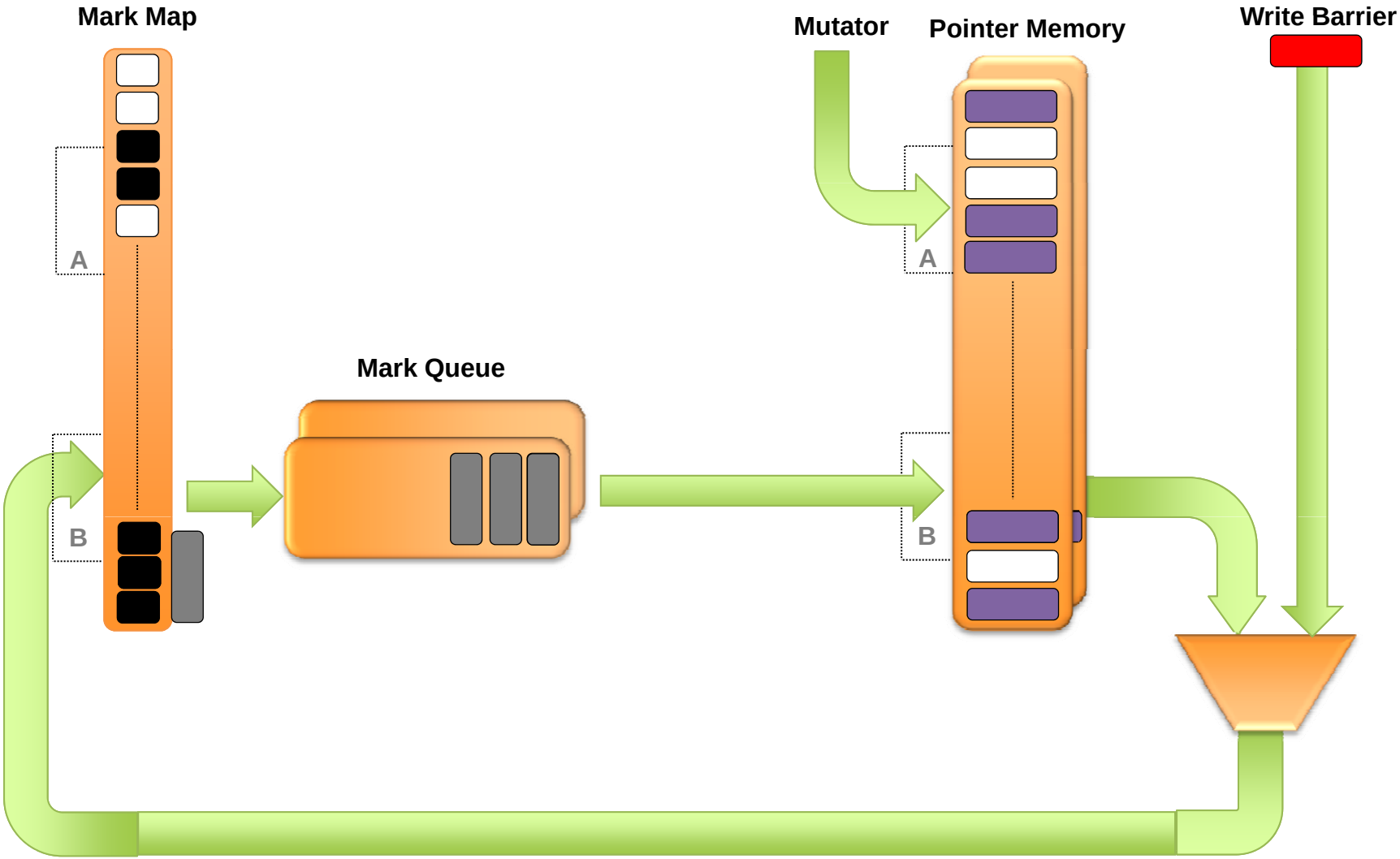
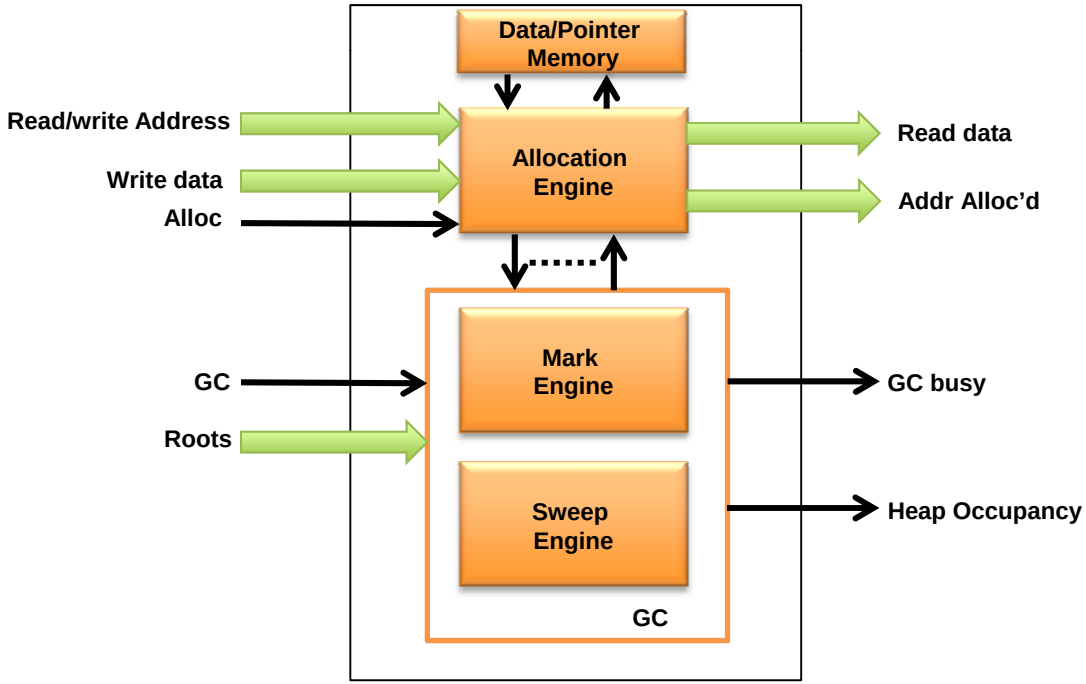


Evaluation

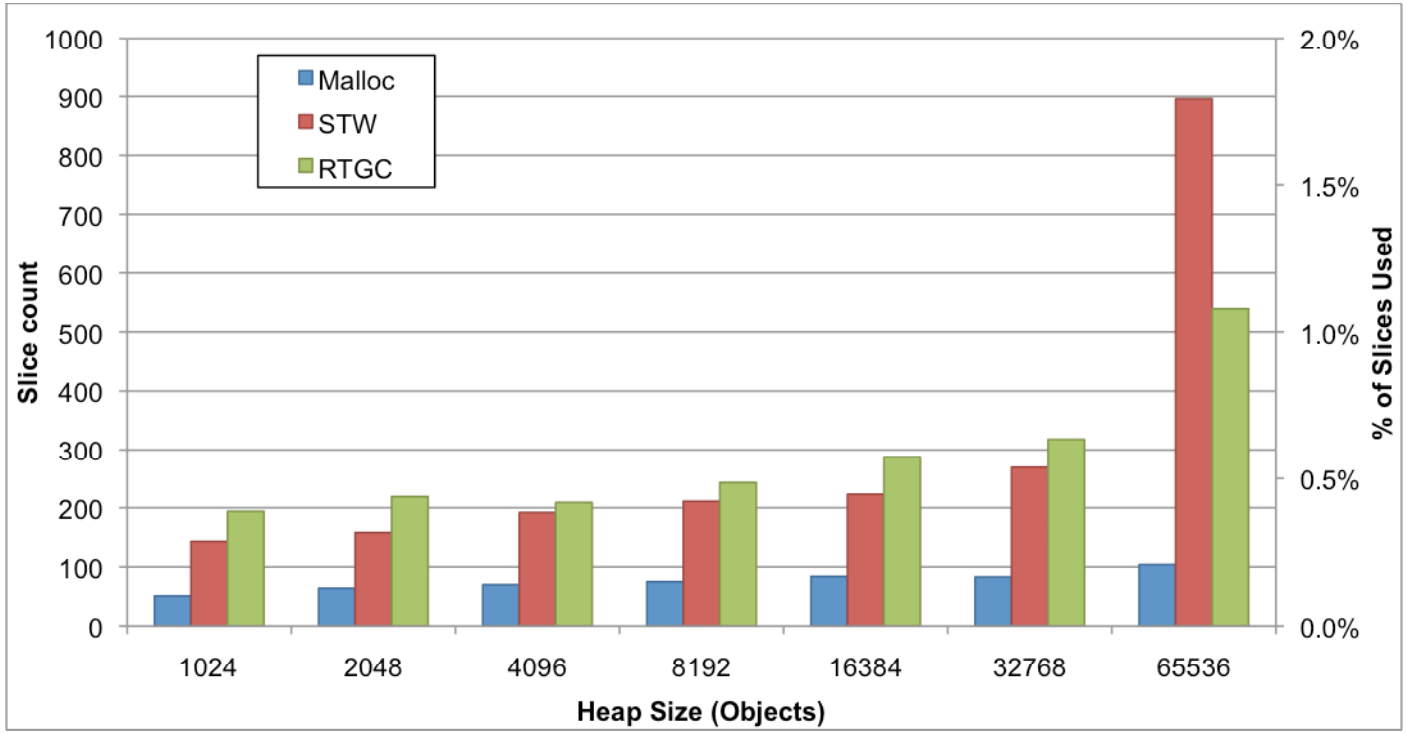
1. Static memory manager (“Malloc”)
2. Stop-the-world collector (“STW”)
3. Concurrent collector (“RTGC”)



Evaluation roadmap

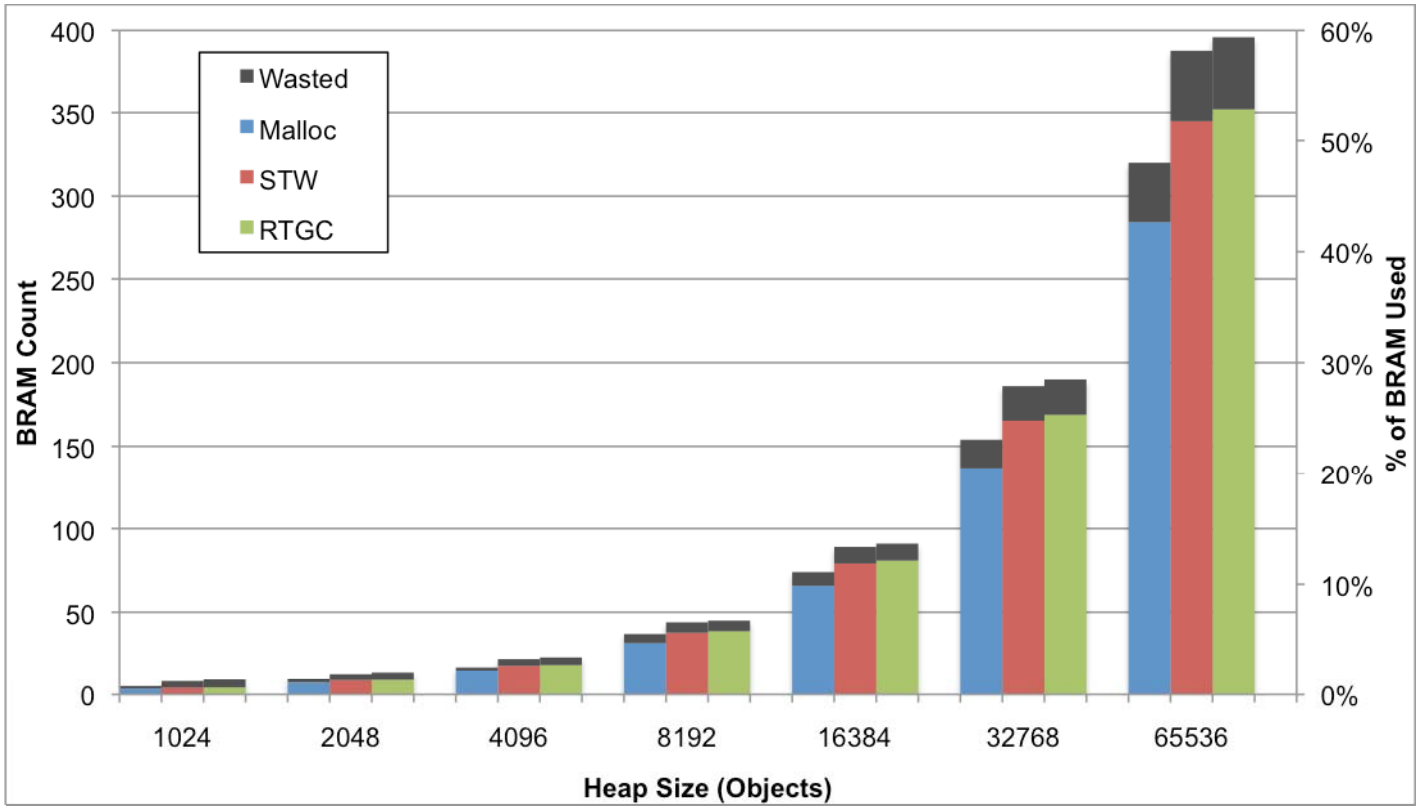
- GC (Space, Frequency)
- Application + GC (Time, Energy)

GC: Area



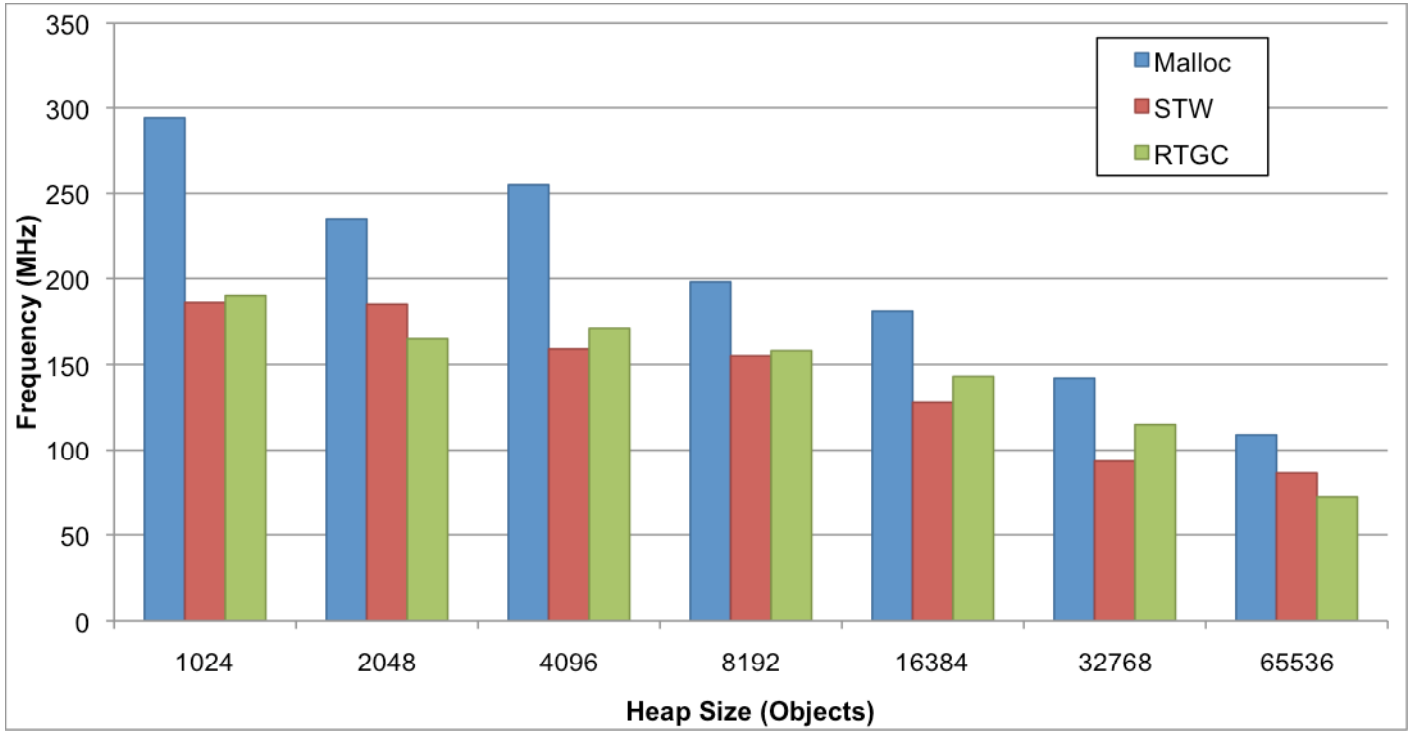
Available slices: 51,840

GC: Memory (BRAM)



Available BRAM: 648 (1.45 MB)

GC: Frequency



Evaluation Roadmap

- GC (Space, Time, Frequnecy)
- Application + GC (Time, Energy)

Applications

Binary Tree

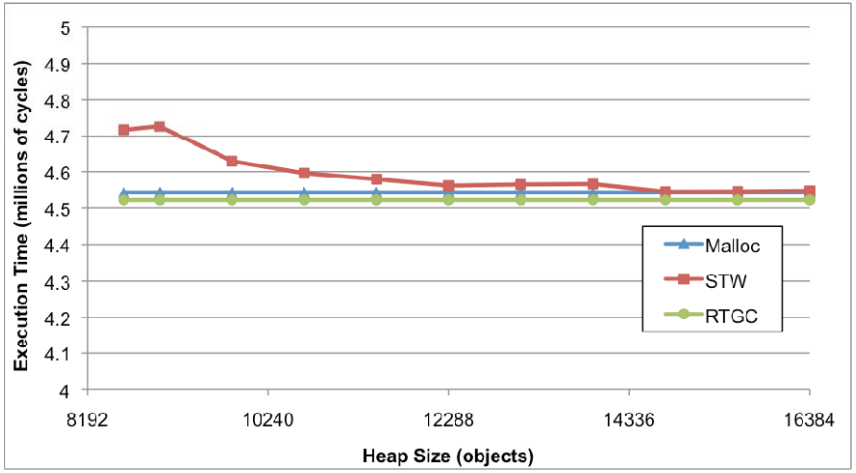
- Operation: insert, delete, traverse
- Bursty operation
- Avg. mutation rate = 0.02 pointer writes/cycle
- Avg. allocation rate (α) = 0.009 objects/cycle

Doubly ended queue (deque)

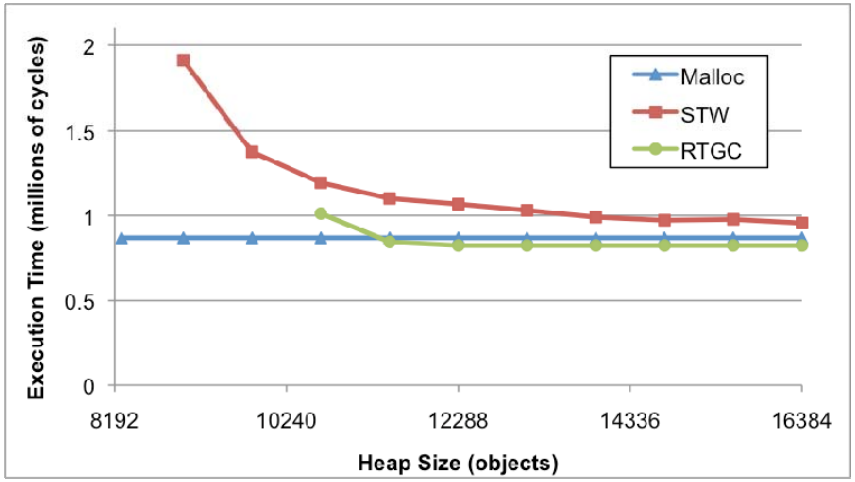
- Two link lists growing from opposite ends
- mutation rate = 0.13 pointer writes/cycle
- Avg. allocation rate (α) = 0.07 objects/cycles

App+GC: Time (cycles)

Binary Tree

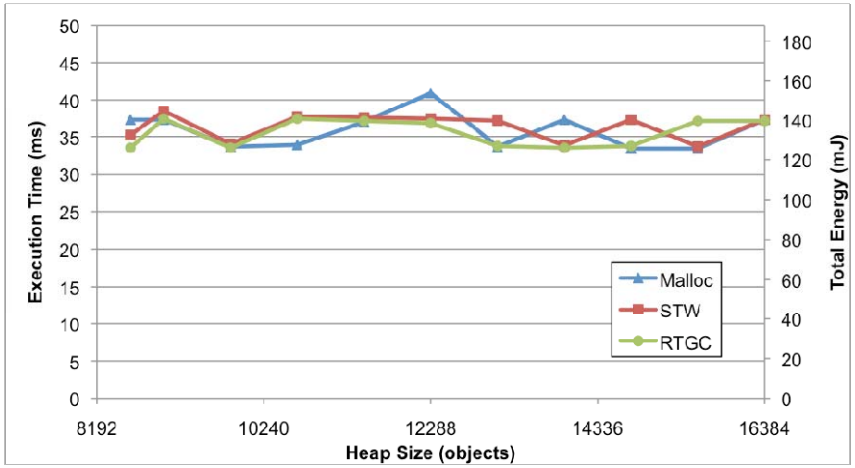


Deque



App+GC: Time (ms), Energy (mJ)

Binary Tree



Deque

Time (s) = Time (M cycles) / Clock_Frequency (MHz)

Energy (J) = Power (W) * Time (s)

Conclusion

- First design & implementation of a GC on FPGA
- First GC to entirely eliminate mutator interference by the collector
- Big leap in the field of HLS

THANK YOU

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