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A Case for Work-stealing on FPGAs with OpenCL Atomics

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Motivation

- HLS tools do well on “regular” structures with static analysis
- But what if your computation is “irregular”?
  - data-dependent execution time
  - dynamic task creation
  - e.g. tree traversal
- Workload imbalance may result in idle processing units
- Processing units need to communicate with each other to balance workload

Atomics

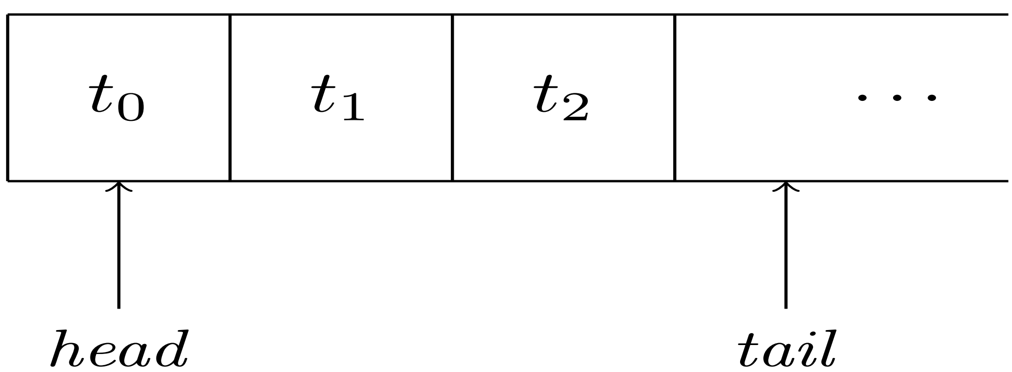
- Inter-thread communication: Atomic operations (atomics) are fastest in multiprocessor world!
- Atomics appear to occur *instantaneously* (read-modify-write)
- For FPGAs, atomics are either not supported or "expensive"

> **Attention:** The use of atomic functions might lower the performance of your design.
>
> Altera SDK for OpenCL: Programming Guide, UG-OCL002 2015.11.02, A-7

- Atomics allow for parallel algorithms without critical sections

Work-stealing with atomics

- Task-based dynamic load balancing for irregular workloads
- Cederman-Tsigas explored work-stealing on GPUs in 2008
- Primitive: Double-ended queues with atomics



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Case Study: K-means Clustering

- kd-tree traversal to find closest center for every data point
- Task of traversing a node is irregular because
  - Pruning of potential center candidates (Elimination process)
  - Dynamic traversal decisions
- Previous FPGA implementations rely on static partitioning
- With work-stealing on OpenCL, **1.5× faster**!

Results

Work-items	1	2	4	8	16	32
Speedup	$0.8\times$	$1.0\times$	$1.2\times$	$1.5\times$	$1.7\times$	$1.9\times$
RAM overhead	57%	45%	68%	58%	58%	39%

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Conclusion

- We show **1.5$\times$ speedup** for K-means clustering **despite the use of atomics**
- The use of atomics in the right context can lead to improved hardware performance
- Our paper describes more details and OpenCL code is available at `https://github.com/nadeshr/kmeans-stealing.git`
- See you at our poster!

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