IWOCL

INTERNATIONAL WORKSHOP ON OPENCL

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Studying Energy Consumption of an OpenCL Application on Mobile GPU: A Case Study

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eGPU Compute Applications

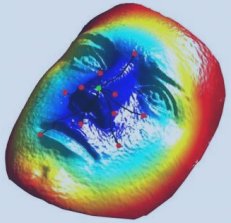
Conventional Domains

Media Codecs

Augmented Reality

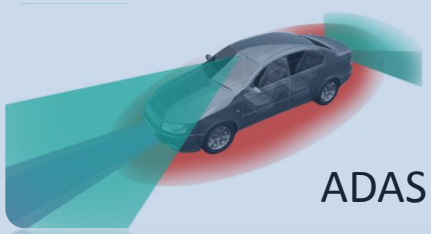
Gaming

Computational Photography



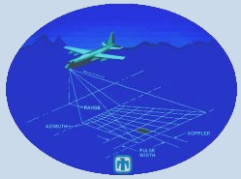
Graphics

Potential Domains



ADAS

Security



Radar Systems: Pattern Detection

Choice of Application

- Aho-Corasick – a pattern matching algorithm
  - Is utilized in security domain among others
  - Relevant for embedded systems – intrusion detection in vehicular systems, mobile devices
  - Not studied for embedded GPUs
  - State of the art parallel implementation available for high-end GPUs

Goal of Our Study

- Study the energy consumption of OpenCL components
- Optimize for embedded GPUs
  - Energy
  - Running times
- Compare with multi-core implementations
  - Tradeoffs

Aho-Corasick (AC)

- It locates patterns of strings in an input text

Patterns: {she, he, his, hers}
Input text: ushers
Output: {she, he, hers}

Aho-Corasick (AC)

- How it works:
  - Combines all input patterns (dictionary) and generates a finite state machine
  - Uses the finite machine to find all the matches in the input text in a single traverse
- Open-source implementation available

Patterns: {she, he, his, hers}
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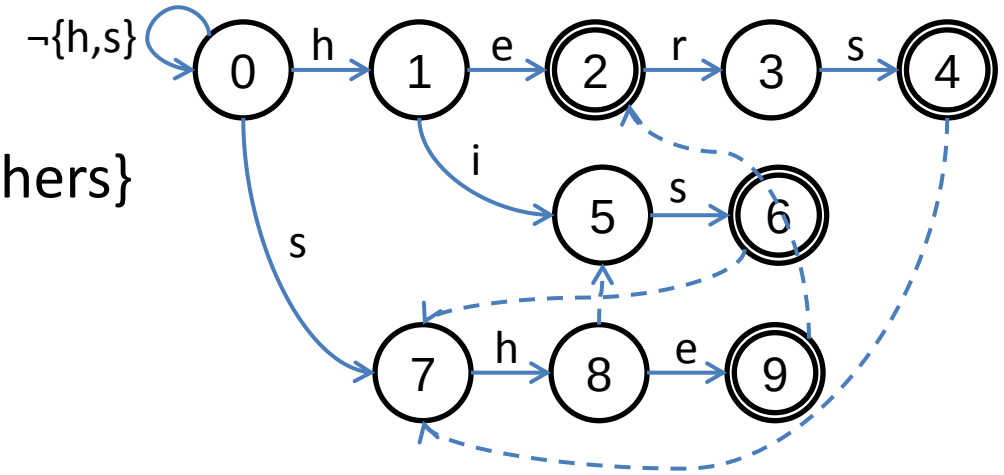
Output: {she, he, hers}

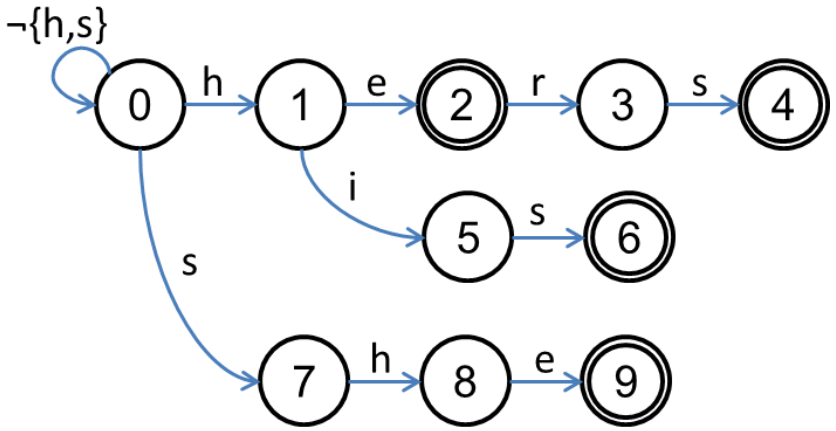


Parallel Failureless AC (PFAC)

- One thread for every input character
  - 10 M threads for a 10 MB input
- Each thread identifies the pattern that begins on that character
- No failure node

Patterns: {she, he, his, hers}
Input text: ushers
Output: {she, he, hers}

6 threads are launched



PFAC GPU Implementation

- Optimization on high-end GPUs
  - Load input text partially from global to local memory

Patterns: {she, he, his, hers}
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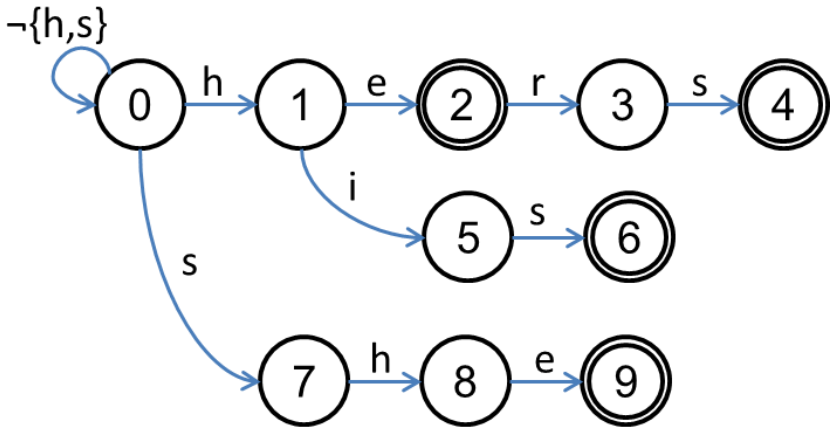

PFAC GPU Implementation

- Optimization on high-end GPUs
  - Load input text partially from global to local memory
  - Uses transition table
  - Load first row of the table into local memory

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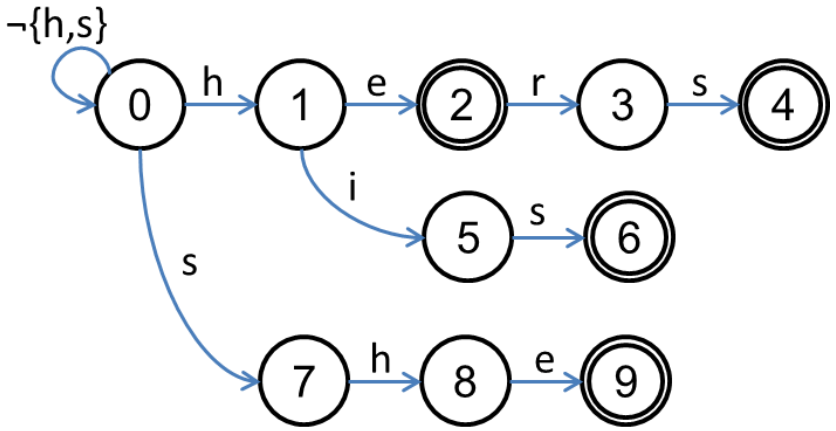


PFAC GPU Implementation

- Optimization on high-end GPUs
  - Load input text partially from global to local memory
  - Uses transition table
  - Load first row of the table into local memory
  - Convert transition table into an array
  - Store transition table in texture memory (cache optimized)

Optimizations on Embedded GPU

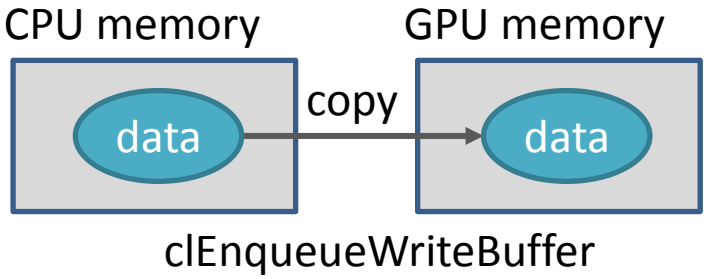
Local memory usage

- Local memory is emulated in global memory
- Using local memory adds an extra overhead
- Exception
  - Adreno 330 has 8KB local memory
  - May benefit only limited applications

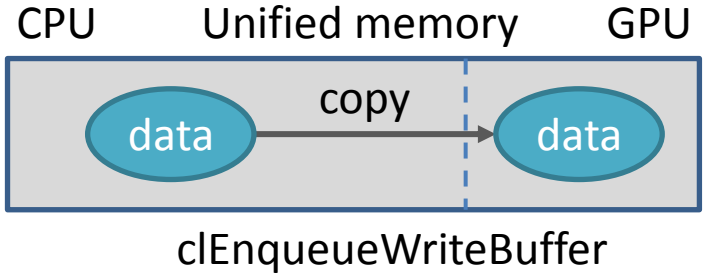
Optimizations on Embedded GPU

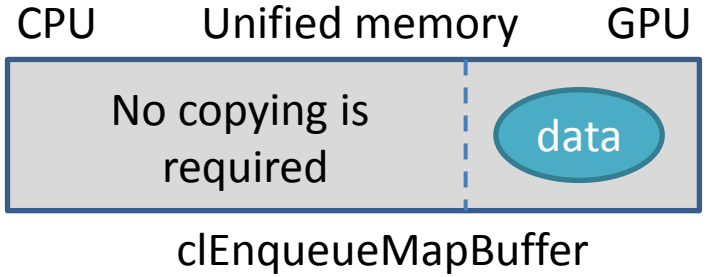
Reduce data communication time

High-end GPU



Embedded GPU

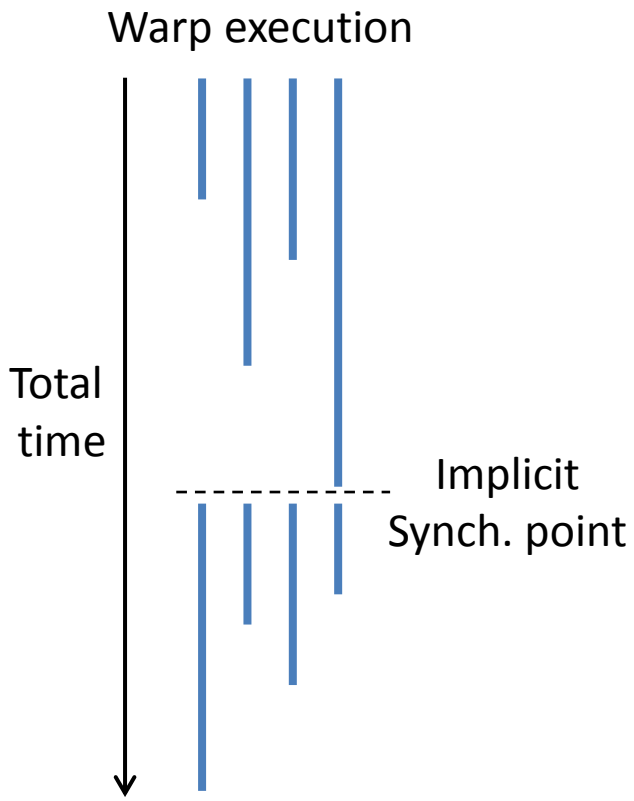




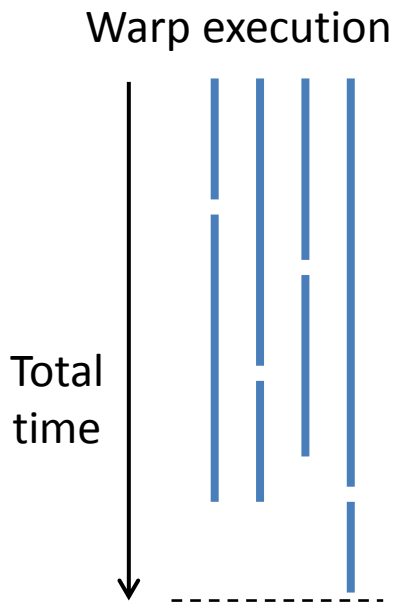
Optimizations on Embedded GPU

Thread granularity

1-char per thread



2-chars per thread



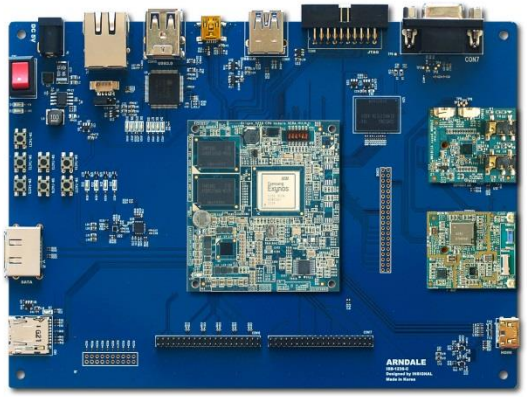
Reduce load imbalance between threads/warps

Implementation Remarks

- *Scalar* variables used in the kernel
- Appropriate work-group sizes chosen
- Kernel included *integer and memory* operations
- Memory bound kernel

Experimental Platforms

Samsung Arndale Board

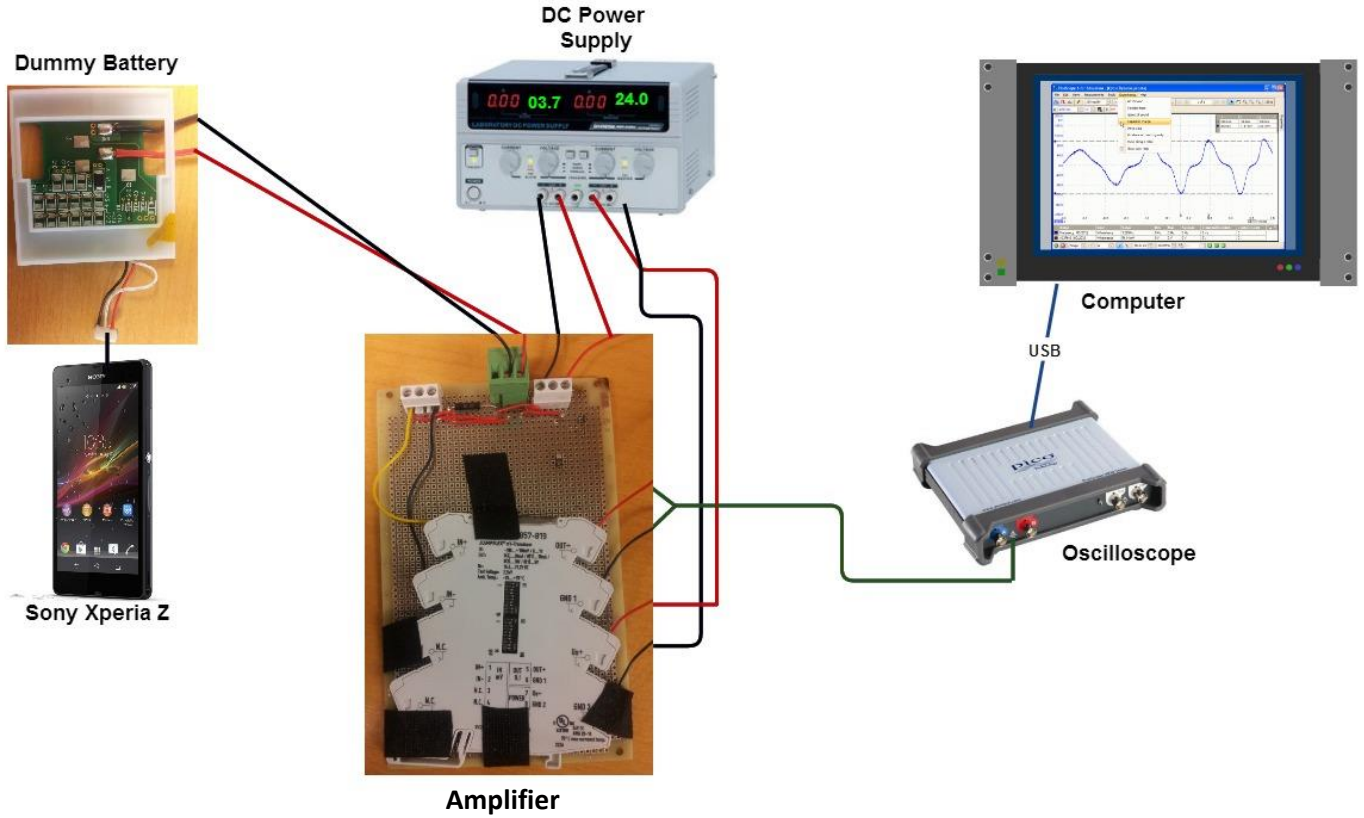


SoC: Exynos 5250
CPU: 1.7 GHz dual-core ARM Cortex-A15
GPU: ARM Mali-T604, 4 cores at 533 MHz, 68 GFLOPS

Sony Xperia Z Ultra

SoC: Snapdragon 800
CPU: up to 2.26 GHz quad-core ARM Cortex-A15
GPU: Adreno 330
4 cores at 450/578 MHz, 115 to 148 GFLOPS

Experimental Setup

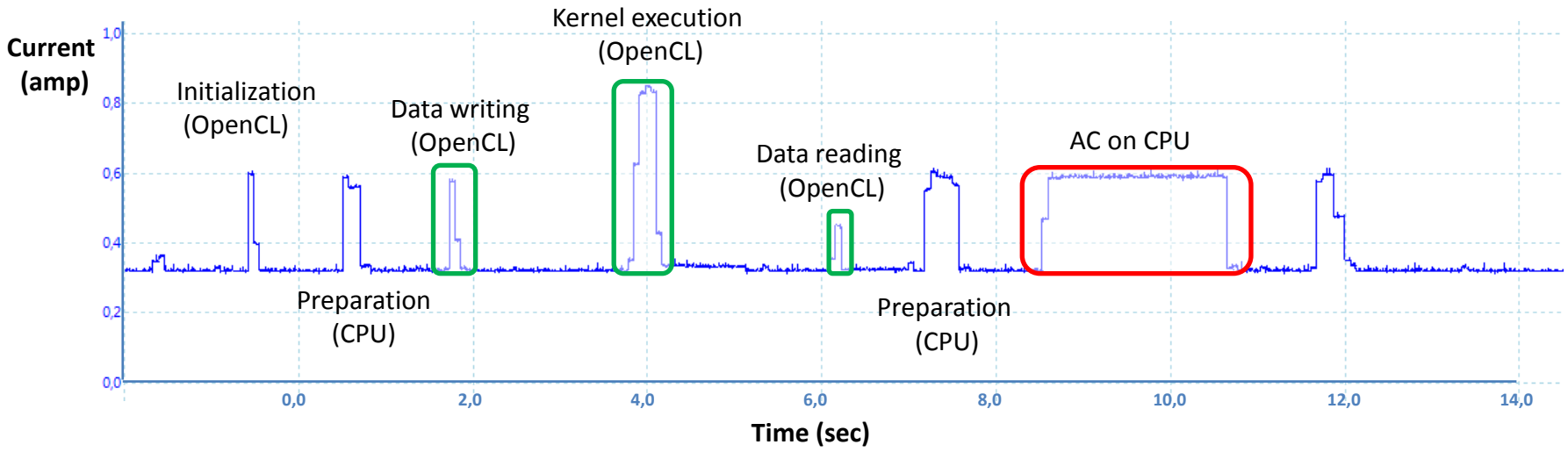


Experimental Input

- Input parameters:
  - 1000 Test patterns with maximum size of 128 characters and input text of size 10 MB
  - Extracted from Snort V2.8
  - FSM included 27570 nodes
  - GPU consumed 44 MB of memory

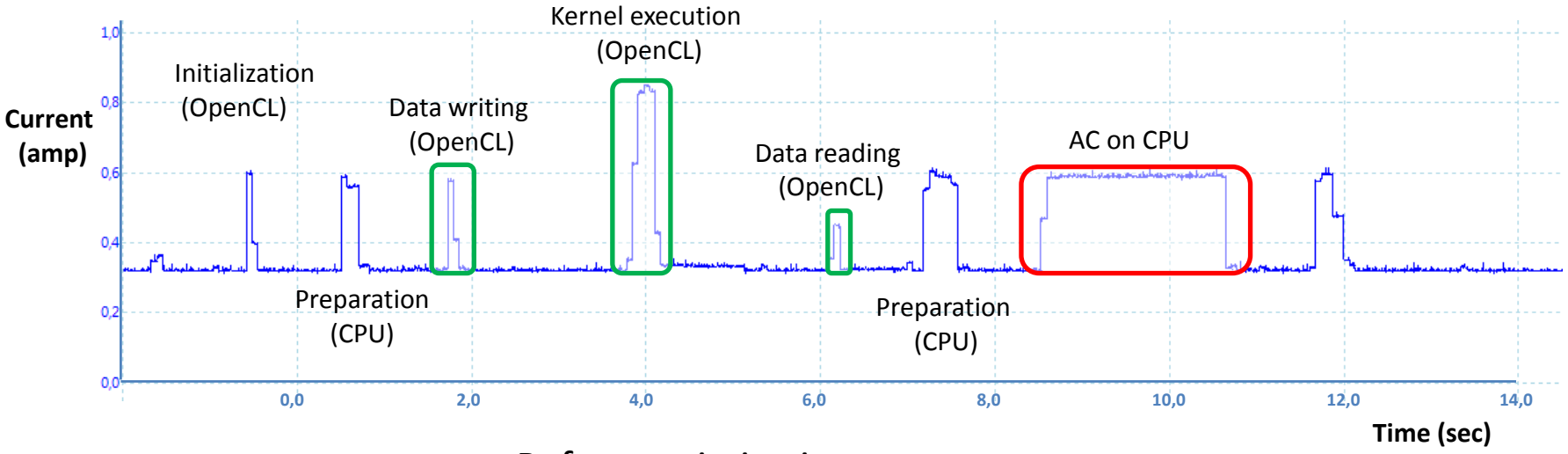
Energy Measurement

- Sample snapshot from the Oscilloscope



Experiment was performed on Arndale board

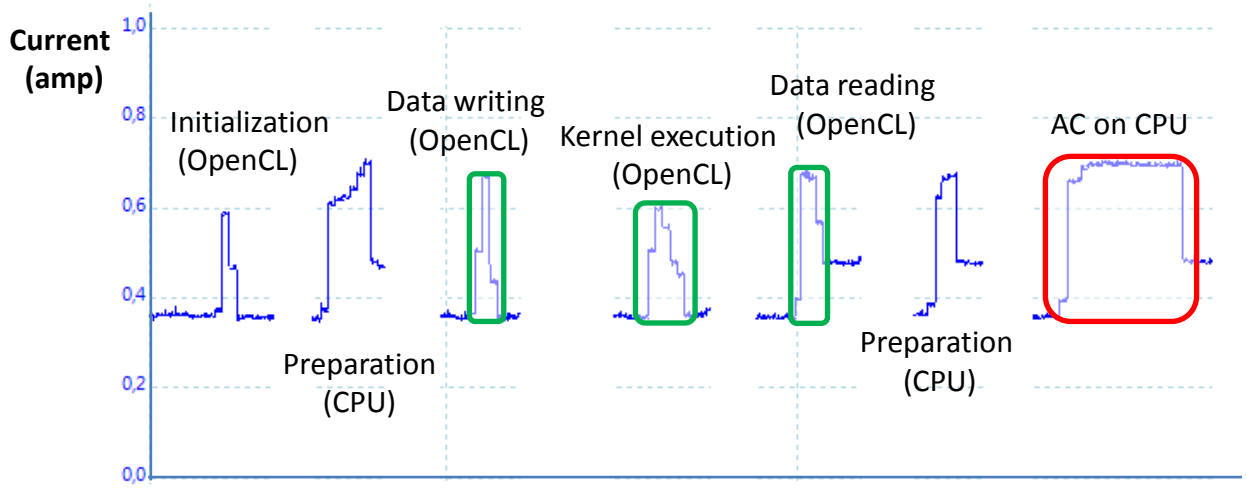
ARNDALE BOARD



Before optimization

After optimization

SONY XPERIA Z ULTRA



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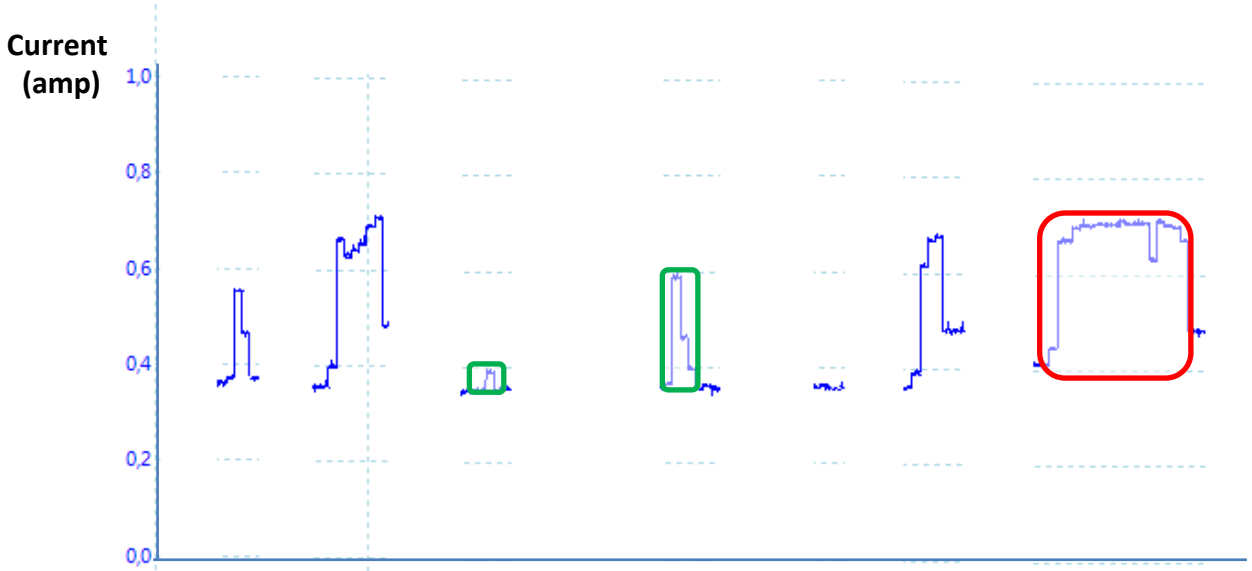

After optimization

Experimental Results

time units are in milliseconds

SONY XPERIA Z ULTRA

OPTIMIZATIONS				RESULTS						
DATA_TX	USE_LOCAL	WG_SIZE	THR_GRAN	WRDEV	KERNEL_EXE	RDDEV	TX_OVH	GPU_TOT	SPEED UP	ENG IMPROV.
no map	yes	128	1	113	208	171	58%	492	2,1	2,7
map	yes	128	1	34	208	0	14%	242	4,3	7,2

Experimental Results

time units are in milliseconds

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map	yes	128	1	34	208	0	14%	242	4,3	7,2
map	no	128	1	34	150	0	18%	184	5,7	10,7

Experimental Results

time units are in milliseconds

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map	yes	128	1	34	208	0	14%	242	4,3	7,2
map	no	128	1	34	150	0	18%	184	5,7	10,7
map	no	64	1	34	168	0	17%	202	5,2	10,0
map	no	128	1	34	150	0	18%	184	5,7	10,7
map	no	256	1	34	140	0	20%	174	6,0	11,3

Experimental Results

time units are in milliseconds

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map	no	64	1	34	168	0	17%	202	5,2	10,0
map	no	128	1	34	150	0	18%	184	5,7	10,7
map	no	256	1	34	140	0	20%	174	6,0	11,3
map	no	256	4	34	99	0	26%	133	7,9	13,3
map	no	256	8	34	80	0	30%	114	9,2	15,1
map	no	256	12	34	202	0	14%	236	4,4	10,6
map	no	256	16	34	198	0	15%	232	4,5	10,7

Experimental Results

SONY XPERIA Z ULTRA

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map	yes	128	1	34	208	0	14%	242	4,3	7,2
map	no	128	1	34	150	0	18%	184	5,7	10,7
map	no	64	1	34	168	0	17%	202	5,2	10,0
map	no	128	1	34	150	0	18%	184	5,7	10,7
map	no	256	1	34	140	0	20%	174	6,0	11,3
map	no	256	4	34	99	0	26%	133	7,9	13,3
map	no	256	8	34	80	0	30%	114	9,2	15,1
map	no	256	12	34	202	0	14%	236	4,4	10,6
map	no	256	16	34	198	0	15%	232	4,5	10,7

ARNDALE BOARD

OPTIMIZATIONS				RESULTS						
DATA_TX	USE_LOCAL	WG_SIZE	THR_GRAN	WRDEV	KERNEL_EXE	RDDEV	TX_OVH	GPU_TOT	SPEED UP	ENG IMPROV.
no map	yes	128	1	91	295	60	34%	446	4,7	3,3
map	yes	128	1	91	295	6	25%	392	5,4	3,6
map	yes	128	1	91	295	6	25%	392	5,4	3,6
map	no	128	1	91	150	6	39%	247	8,5	8,2
map	no	64	1	91	155	6	38%	252	8,3	8,2
map	no	128	1	91	150	6	39%	247	8,5	8,2
map	no	256	1	91	143	6	40%	240	8,8	8,3
map	no	256	4	91	114	6	46%	211	10,0	9,0
map	no	256	8	91	104	6	48%	201	10,4	9,3
map	no	256	12	91	101	6	49%	198	10,6	9,3
map	no	256	16	91	97	6	50%	194	10,8	9,5

GPU vs. Multi-core

- PFAC implemented on multi-core with OpenMP

SONY Z ULTRA	PFAC OPENMP				MOST OPTIMIZED on GPU
	1 CORE	2 CORE	3 CORE	4 CORE	
TIME (ms)	348	175	118	89	GPU_KERNEL TIME = 80 (ms) GPU_OVERALL TIME = 114 (ms)
KERNEL SPEED UP	4,4	2,2	1,5	1,1	
OVERALL SPEED UP	3,0	1,5	1,0	0,8	
ENERGY IMPROV.	5	4	4	4	

ARNDALE	PFAC OPENMP		MOST OPTIMIZED on GPU
	1 CORE	2 CORE	
TIME (ms)	680	620	GPU_KERNEL TIME = 97 (ms) GPU_OVERALL TIME = 194 (ms)
KERNEL SPEED UP	7,0	6,4	
OVERALL SPEED UP	3,5	3,1	
ENERGY IMPROV.	3,3	4,9	

Takeaways

- Embedded GPUs – alternative to save energy
- Nonconventional applications may benefit from GPU computing in embedded systems
- Micro-architecture specific optimizations are required to get efficient performance

Aknowledgments

- Sony Mobile Lund

- Adrian Horga

Questions?