The Energy Case for Graph Processing on Hybrid Platforms

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Graphs are Everywhere

1B users
150B friendships

1.4B pages, 6.6B links
Challenges and Opportunities

**CPUs**

*Poor locality*

*Data-dependent memory access patterns*

*Low compute-to-memory access ratio*

*Large memory footprint as large as 1TB*

*Varying degrees of parallelism (both intra- and inter-stage)*

Caches + summary data structures
Challenges and Opportunities

CPUs

- Poor locality
- Data-dependent memory access patterns
- Low compute-to-memory access ratio
- Large memory footprint

GPUs

- Caches + summary data structures
- Massively hardware multithreading
- Varying degrees of parallelism (both intra- and inter-stage)
- CPUs as large as 1TB
- GPUs up to 12GB!

Assemble a hybrid platform
Past Work

Performance Modeling
- Predicts speedup
- Intuitive

A Yoke of Oxen and a Thousand Chickens for Heavy Lifting Graph Processing, Gharaibeh et al., PACT 2012

On Graphs, GPUs, and Blind Dating: A Workload to Processor Matchmaking Quest, Gharaibeh et al., IPDPS 2013

Totem
- A graph processing engine for hybrid systems
- Applies algorithm-agnostic optimizations

Partitioning Strategies
- Workload to processor matchmaking

Main outcome: hybrid platforms enable significant performance gains
Past Work

Performance Modeling
- Predicts speedup
- Intuitive

Totem
- A graph processing engine for hybrid systems
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Partitioning Strategies
- Workload to processor matchmaking

Main outcome: hybrid platforms enable significant performance gains

Focused on time to solution as a success metric
Motivating Question

Is it **energy** efficient to use **GPU-accelerated platforms** for **large-scale graph processing**?
Evaluation Platform

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SandyBridge (Xeon 2650)</th>
<th>Kepler (K20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware Threads / Proc.</td>
<td>16</td>
<td>2496</td>
</tr>
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GPU has double TDP

Power is measured at the wall AC outlet
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High idle power is due to large DRAM space.

GPUs are power hungry at peak utilization.

At peak utilization, RAM consumes as much as dual CPUs!

The CPU is relatively power efficient at peak utilization!

Power is measured at the wall AC outlet.
Challenges and Opportunities

- **Warning**: GPU draws significant amount of power
- **Warning**: The workload is Irregular and memory-bound
- **Opportunity**: GPU has low idle power (25W)
- **Opportunity**: Offloading to GPU enables faster “race-to-idle”
Evaluation Study

- **Workloads**
  - Real and synthetic
  - Large: cannot fit on GPU memory

- **Benchmarks**
  - Breadth-First Search (BFS)
  - PageRank

- **Metrics**
  - Raw performance (TEPS)
  - Raw power (Watts)
  - Power normalized by processing rate (Watts/TEPS)

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| Workload   | |V|   | |E|   |
|------------|---|---|---|---|
| Twitter    | 41M| 1.5B|
| UK-Web     | 105M| 3.7B|
| RMAT27     | 128M| 2.0B|
| RMAT28     | 256M| 4.0B|
| RMAT29     | 512M| 8.0B|
| RMAT30     | 1,024M| 16.0B|
GPU-offloading is useful for large graphs.

Raw Performance

Performance scales with more processors.

S = CPU Socket

G = GPU
Power Consumption

BFS

1S1G ≤ 2S!
Power Consumption

load imbalance → more variability
Power Consumption

BFS

PageRank

PageRank draws more power
Normalizing by Processing Rate

In most cases, 1S1G > 2S
Normalizing by Processing Rate

Energy efficiency scales with more processors
Normalizing by Processing Rate

Similar results on PageRank
Energy-Delay Product (EDP)

Higher relative advantage
Conclusions

- A hybrid configuration is more energy and power efficient than a symmetric one

- A “race-to-idle” strategy leads to better energy efficiency

- RAM is a major power consuming component
Questions

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