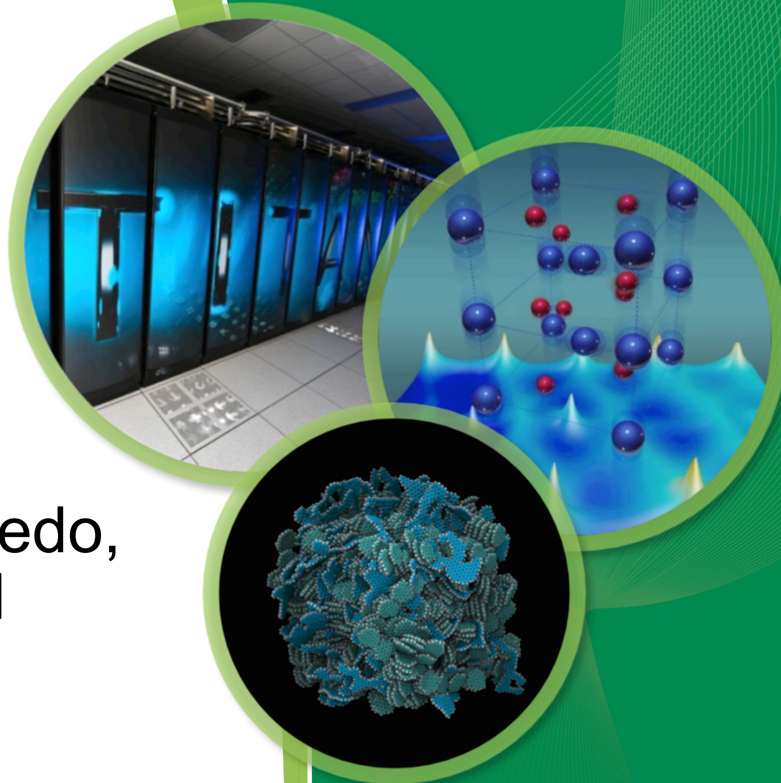
Investigating Data Motion Power Trends to Enable Power-Efficient OpenSHMEM Implementations



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Motivation

- Becoming increasingly necessary to be mindful and more in control of power consumed by extreme-scale systems, specifically for data movement
- Lack of software implementations that support or enable power efficient data movement
- Potential to increase power efficiency for memory accesses through power-aware development of OpenSHMEM implementations

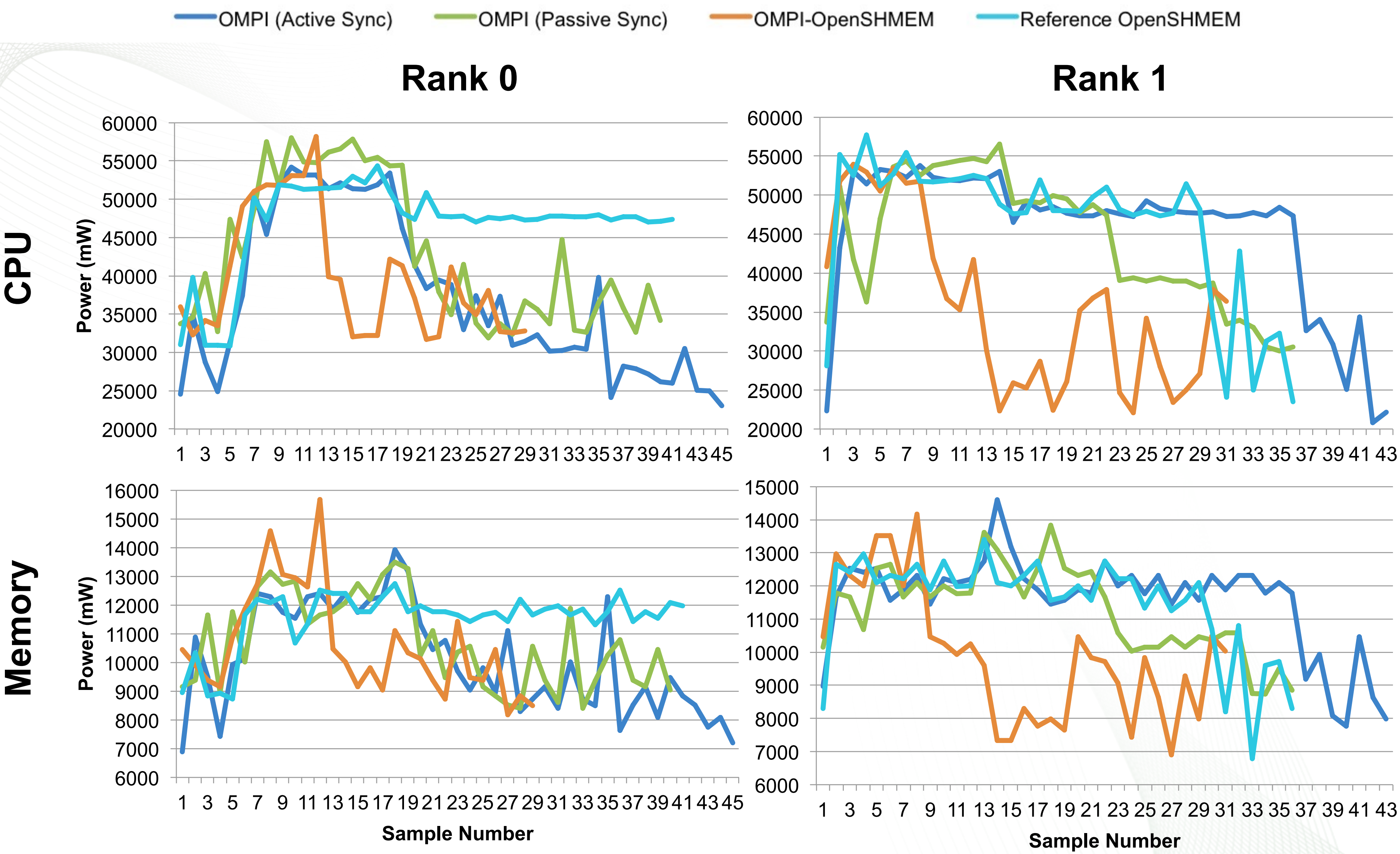
Research Approach

- Current: study power consumption of one-sided RMA operations
  - Profile power consumption for put and get operations for OpenMPI and OpenSHMEM implementations
  - Analyze profiles for significant deviations in power consumption
  - Generate targeted hypothesis for reducing power consumption
- Next: Isolate algorithms within one-sided message passing implementations that could be optimized for power

Power Profiling

- Profiles generated using PowerInsight instrumented cluster
  - Dual Intel Xeon E5-2650v2 i7, 8 cores, 16 threads, a base frequency of 2.6 GHz, and 64GB DDR3-1600 SDRAM
- Benchmarks
  - Ohio State University Micro-Benchmark Suite
    - OpenSHMEM and one-sided MPI put and get latency benchmarks
  - OpenSHMEM implementation of High Performance Conjugate Gradient (HPCG) Benchmark

OSU Micro-Benchmark: Put Operations



 Computational Research and Development Programs

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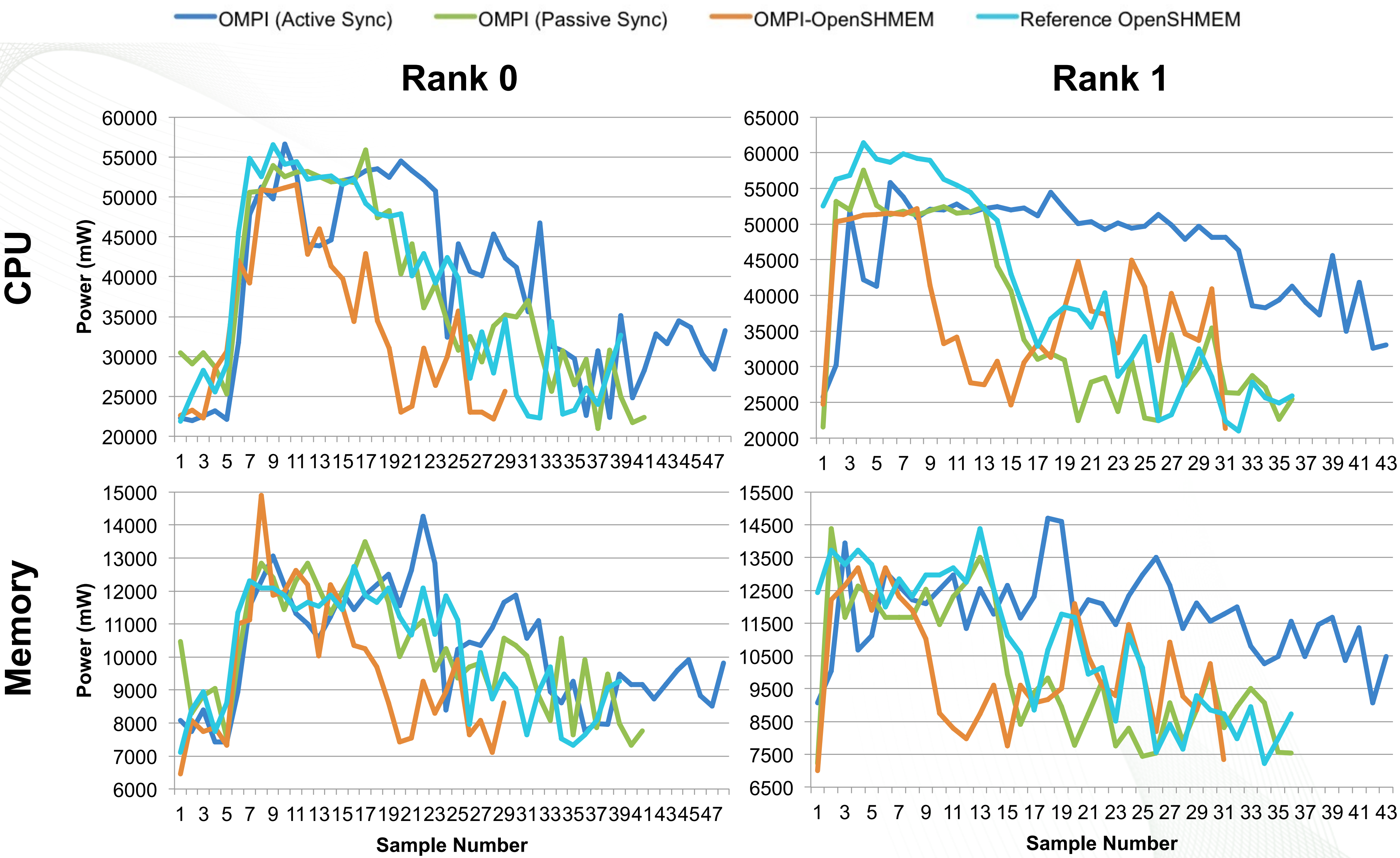
Put Benchmark Observations

- OpenSHMEM Reference implementation has a consistently higher power profile on active process (rank 0) than all other one-sided implementations
  - CPU: On average consumes ~16W – 11W more power, and ~ 63J – 33J more energy
  - Memory: On average consumes ~ 2W more power, and ~ 14J – 3J more energy
- On passive process (rank 1)
  - OpenSHMEM Reference implementation on average consumes more power & energy than the OpenMPI-OpenSHMEM implementation (~12W & 22J cpu, ~2W & 3J memory)
  - OpenSHMEM Reference has comparable power consumption to OpenMPI with active synchronization (< 1W) but consume much less energy (~12J)

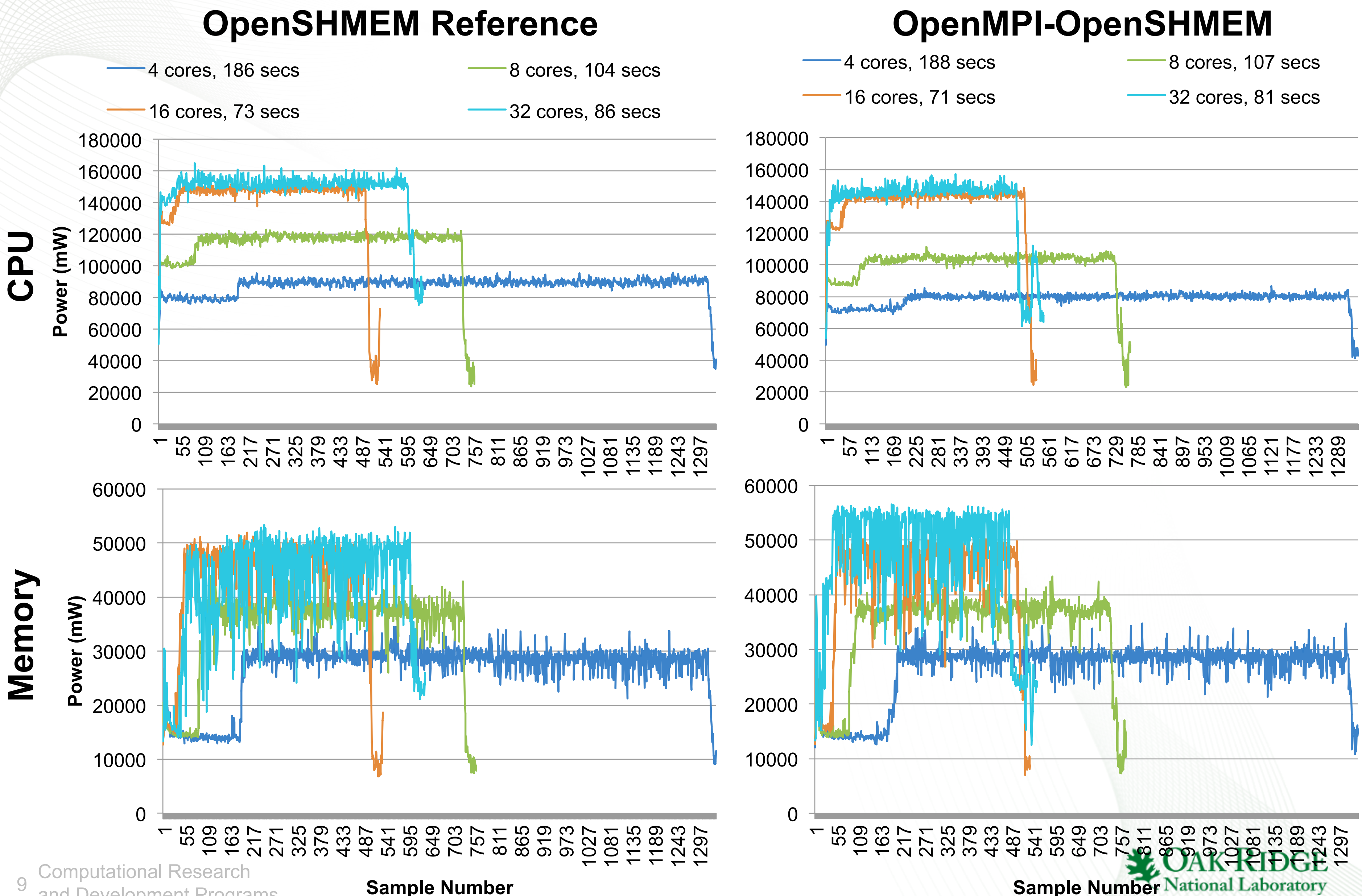
OSU Micro-Benchmark: Get Operations



Get Benchmark Observations

- The OpenMPI-OpenSHMEM implementation on average consume less power and energy on the active process
  - CPU: ~9W – 5W less power, ~125J – 63J less energy
  - Memory: < 2W less power, ~31J – 16J less energy
- On passive process:
  - OpenSHMEM reference implementation consumes less power than OpenMPI-OpenSHMEM (~5W cpu, < 0.5W memory) but consumes more energy (~12J cpu,~ 6J memory)

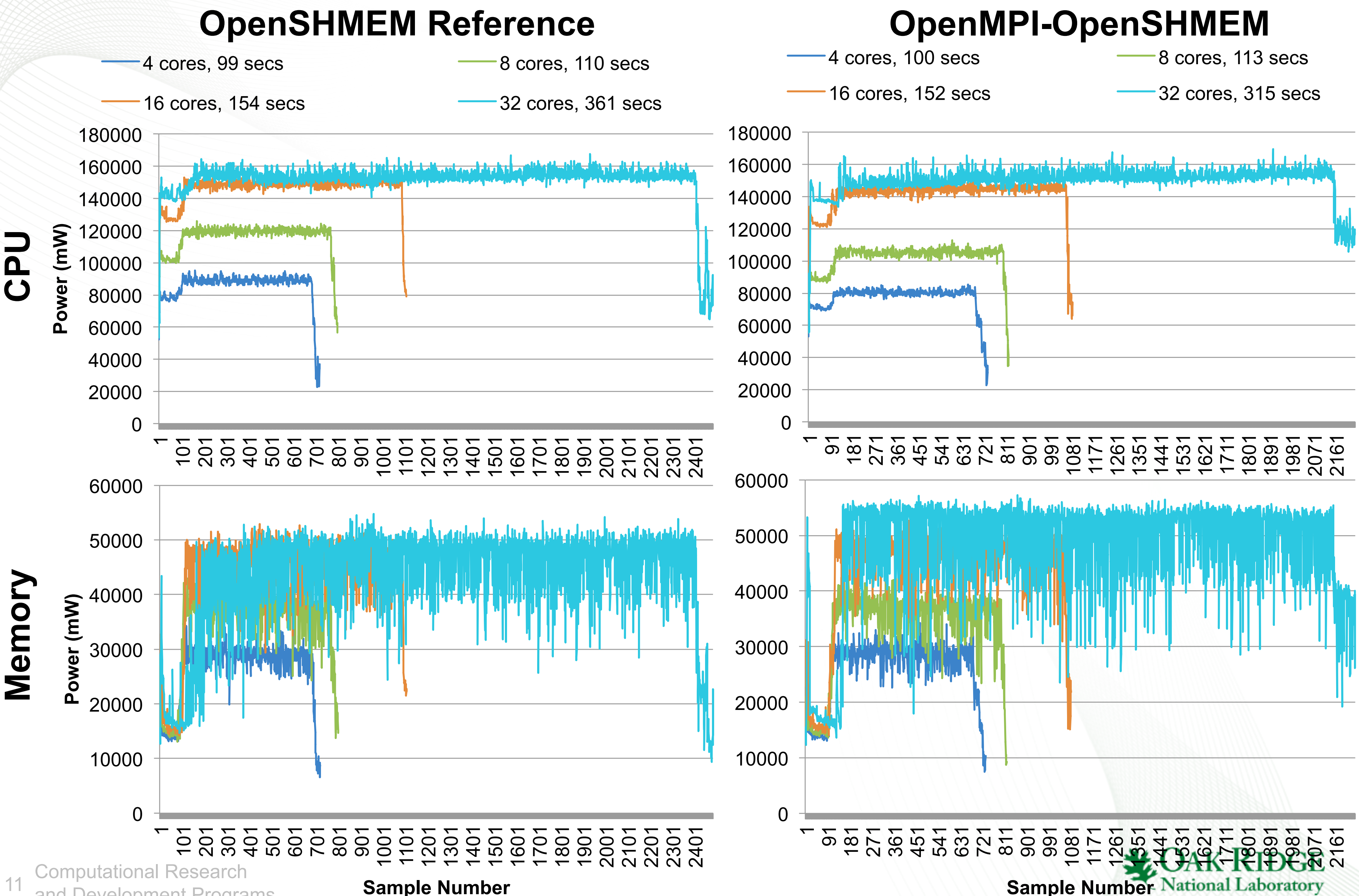
HPCG: Strong Scaling



HPCG Observations

- For both implementations:
  - Non hyper-threaded executions (4-16 cores):
    - delta for cpu power consumption doubles as the number of physical processing cores doubles
    - peak memory power consumption is nearly equivalent across implementations and delta for peak memory power remains constant at ~10W as the number of physical cores doubles
  - For hyper-threaded executions of 32 processes, cpu power consumption nearly equivalent to 16 processes
- Memory power consumption for OpenSHMEM Reference implementation for 32 processes nearly equivalent to 16
  - OpenMPI-OpenSHMEM peak memory power for 32 processes increases by ~ 5W
- OpenSHMEM reference implementation has a peak power profile of about 9W more than the OpenMPI-OpenSHMEM

HPCG: Weak Scaling



Hypothesis from Analysis

- There is not a one-to-one mapping of performance to power consumption in message passing implementations, particularly for memory accesses
- There is a threshold for performance optimizations directly correlating with power optimizations (especially when considering hyper-threaded executions)
- A less power efficient implementation may be optimized for power without degrading performance

Next Steps

- Add power profiles for OpenSHMEM over UCX
- Isolate put and get implementations and determine algorithmic differences in implementations that contribute to disparity in power consumption
- Determine if software re-engineering of put and get operations would result in increase power-efficiency
- Study synchronization models

Acknowledgements

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Questions?