The University of Texas at Austin
Electrical and Computer Engineering

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WattWatcher: Fine-Grained Power Estimation for Emerging Workloads

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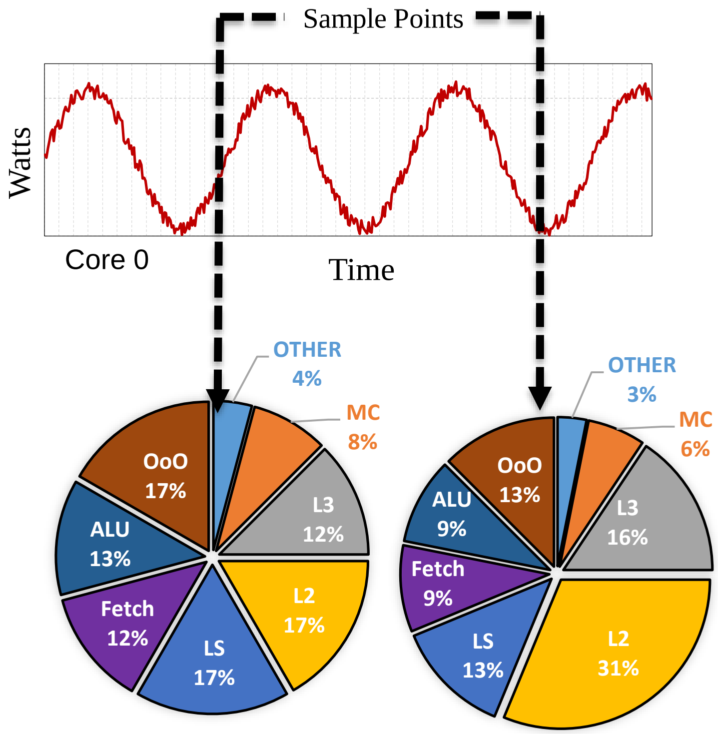
Motivation

- **Understanding power at a fine-granularity is still a challenge**
  - Thermal effects, DVFS policies
- **Not always easy for researchers**
- **Simple and detailed power estimation is extremely useful**
- **Some methods currently available...**



Currently Available Methods

- **Direct Measurements [1]**
  - Hardware probes
- **Curve Fitting [2,3,4,5,6]**
  - Machine learning models
- **Power PMCs [6,7]**
  - E.g. Intel RAPL
- **Simulators[9,10,11,12]**
  - E.g. McPAT plugins to simulation environment

Design Space

- **Diverse design space to explore (subjective taxonomy)**

	Accuracy	Detail	Frequency	Cost ($)	Speed
Direct Measurements	++	-	~us-ms	-	Fast
Power PMCs	+	-	~ms	=	Fast
Curve Fitting	=	=	~us-s	+	Fast/Offline Training
Simulators	+	+	~ns	+	Slow

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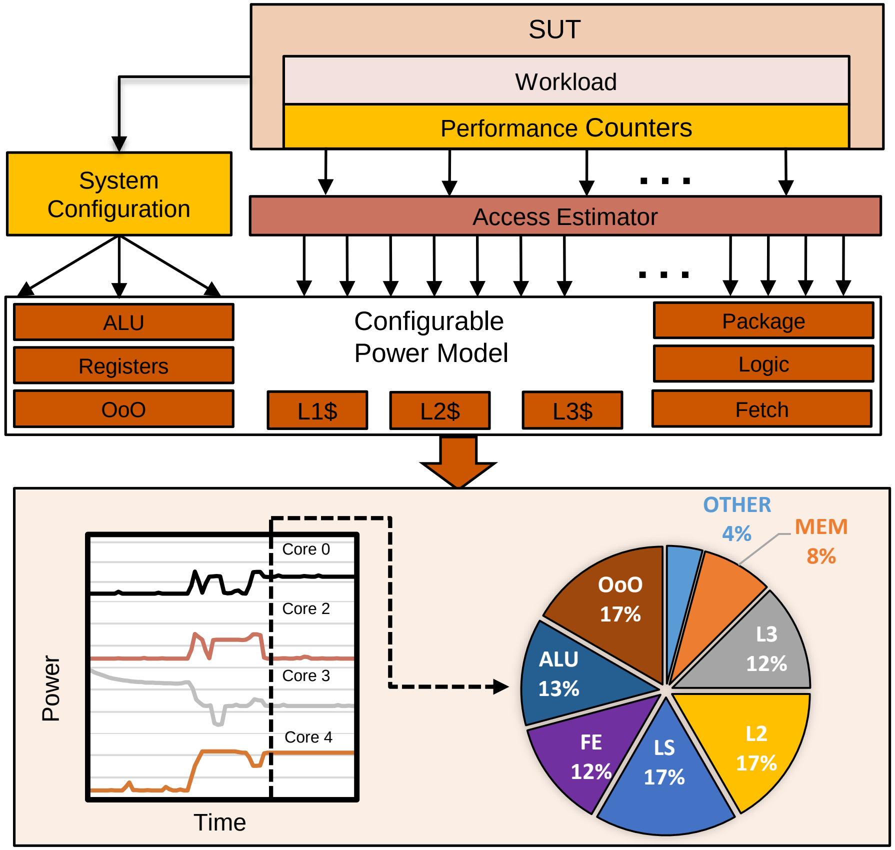
WattWatcher	**+**	**+**	**~ms**	**+**	**Fast**

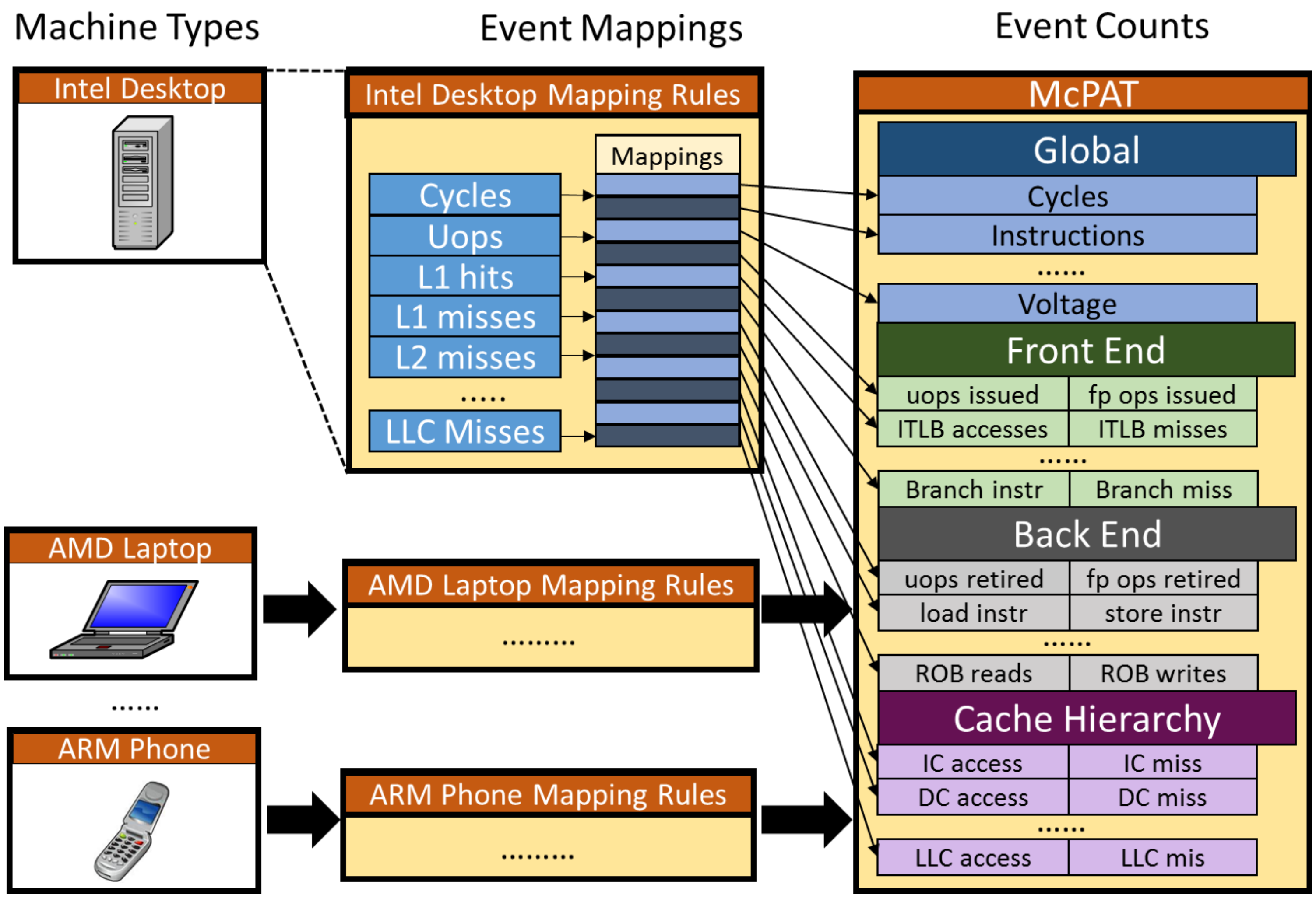
- **WattWatcher offers functional-unit power breakdowns in real-time, on real hardware**

WattWatcher Overview



- **Online / Real-Time**
- **MCPAT-based**
- **Configurable**
- **Low Overhead**

WattWatcher Overview

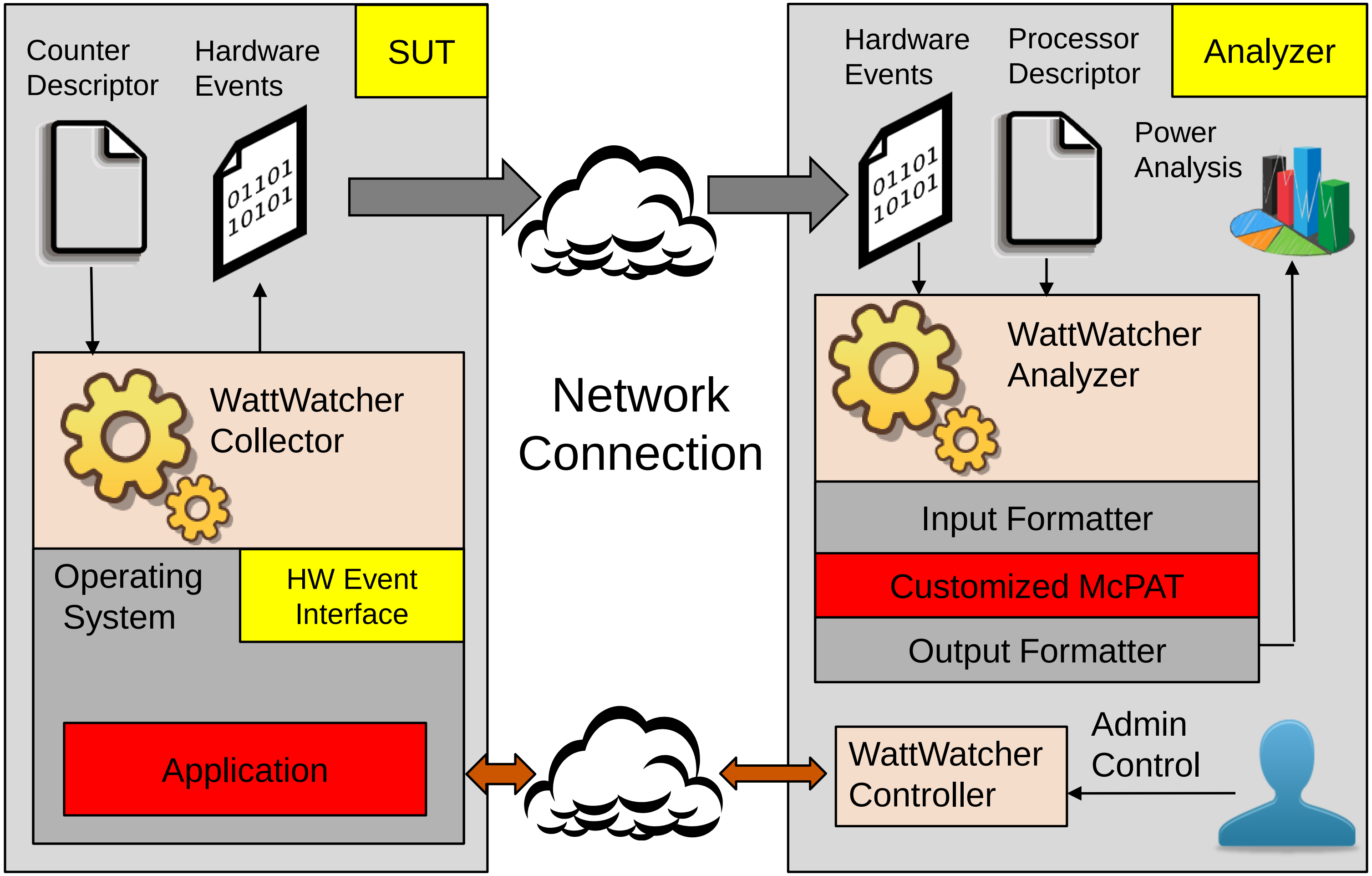


WattWatcher Hardware Events

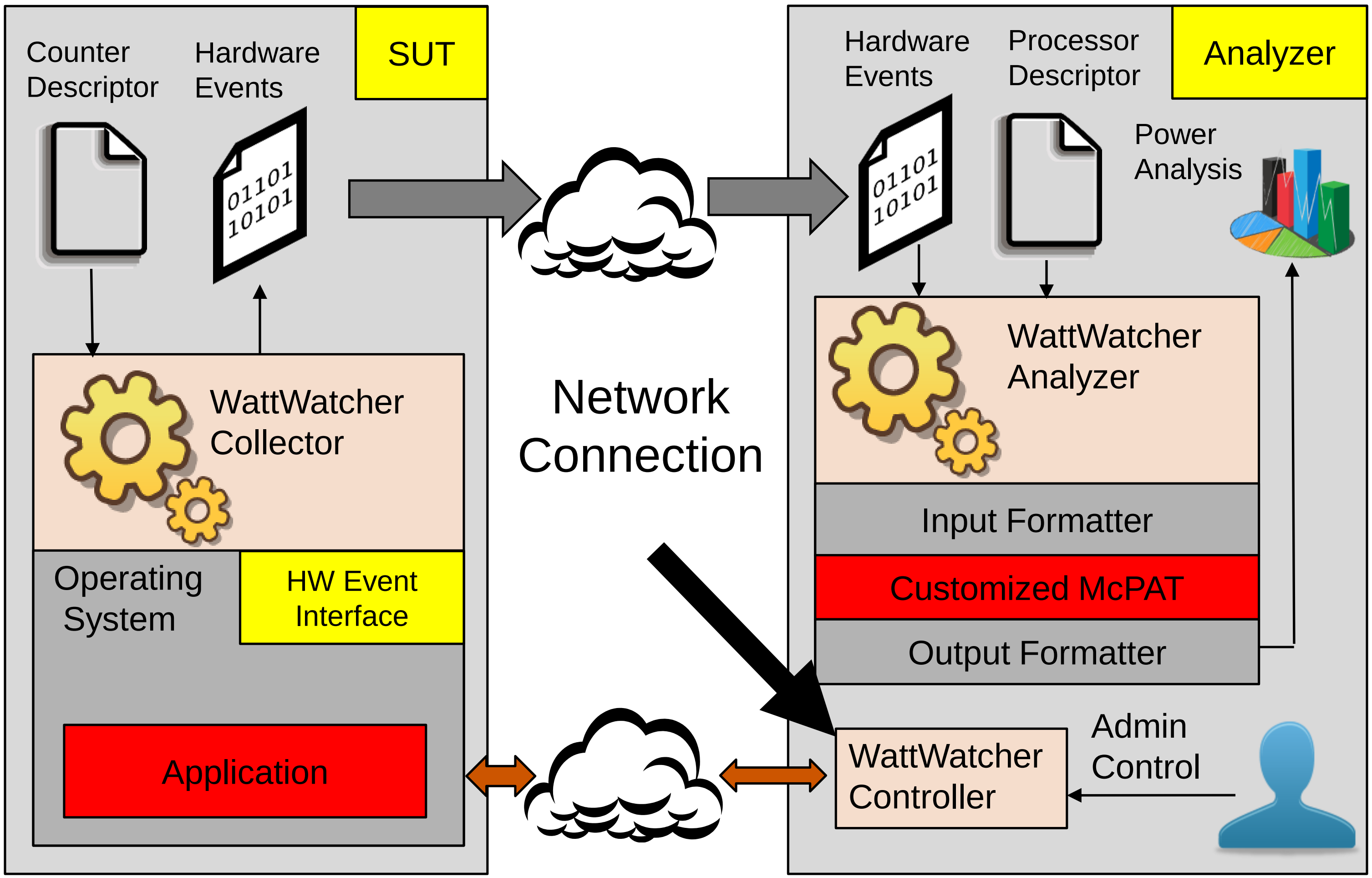
Category	Hardware Event
General	Context Switches Frequency Voltage Cycles
Frontend	Branch Mispredictions IC Misses iTLB Misses uops Issued
LS/Caches	L1 Misses/Hits L2 Misses LLC Misses dTLB Misses
Execution	FP Scalar FP Packed FP Width
Retirement	Uops Retired

- **Hardware performance counters feed McPAT**
- **Some low-level McPAT events unavailable from counters**
- **Unavailable statistics estimated from available counters**

WattWatcher Toolkit Overview



WattWatcher Toolkit Overview



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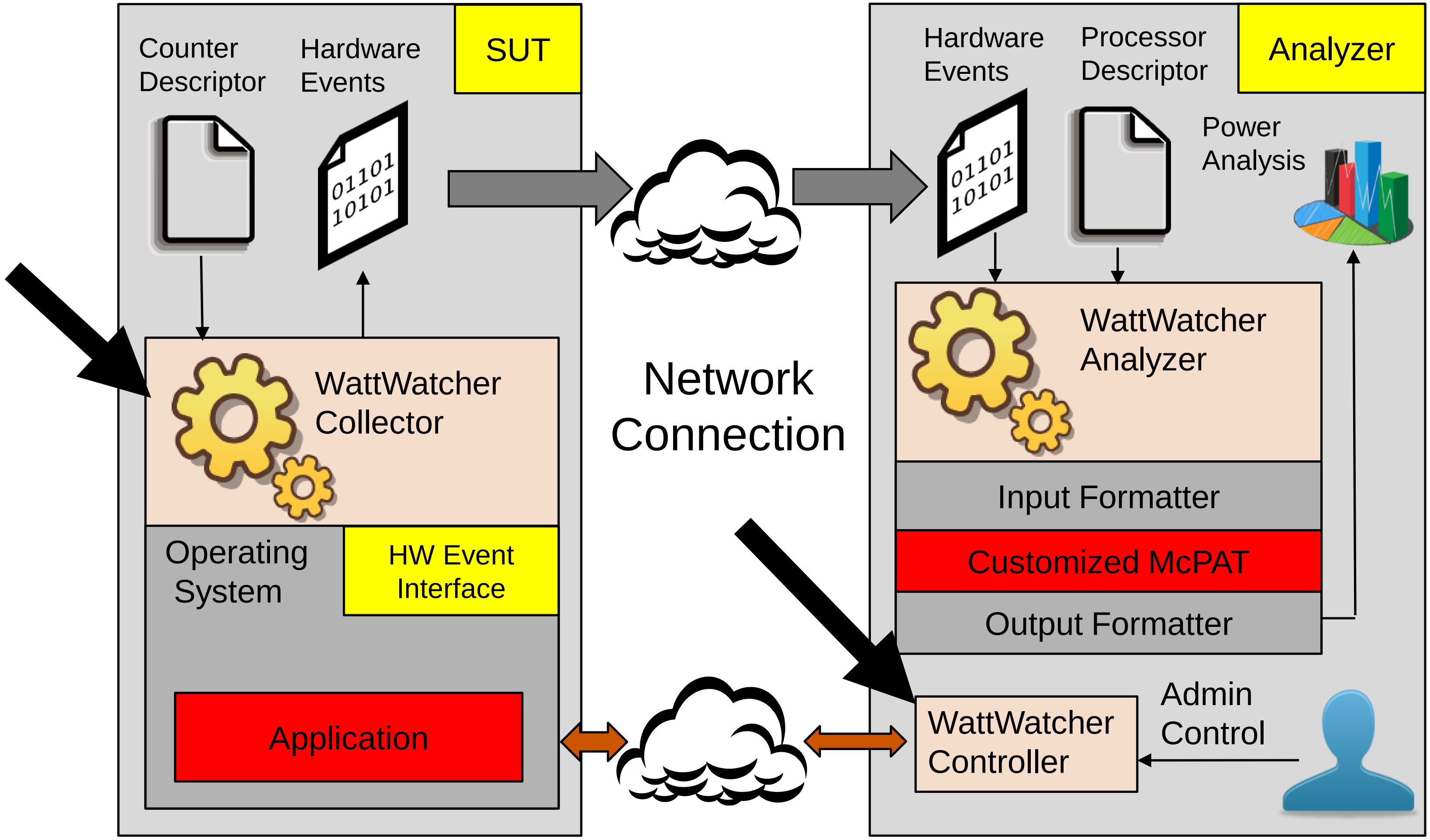

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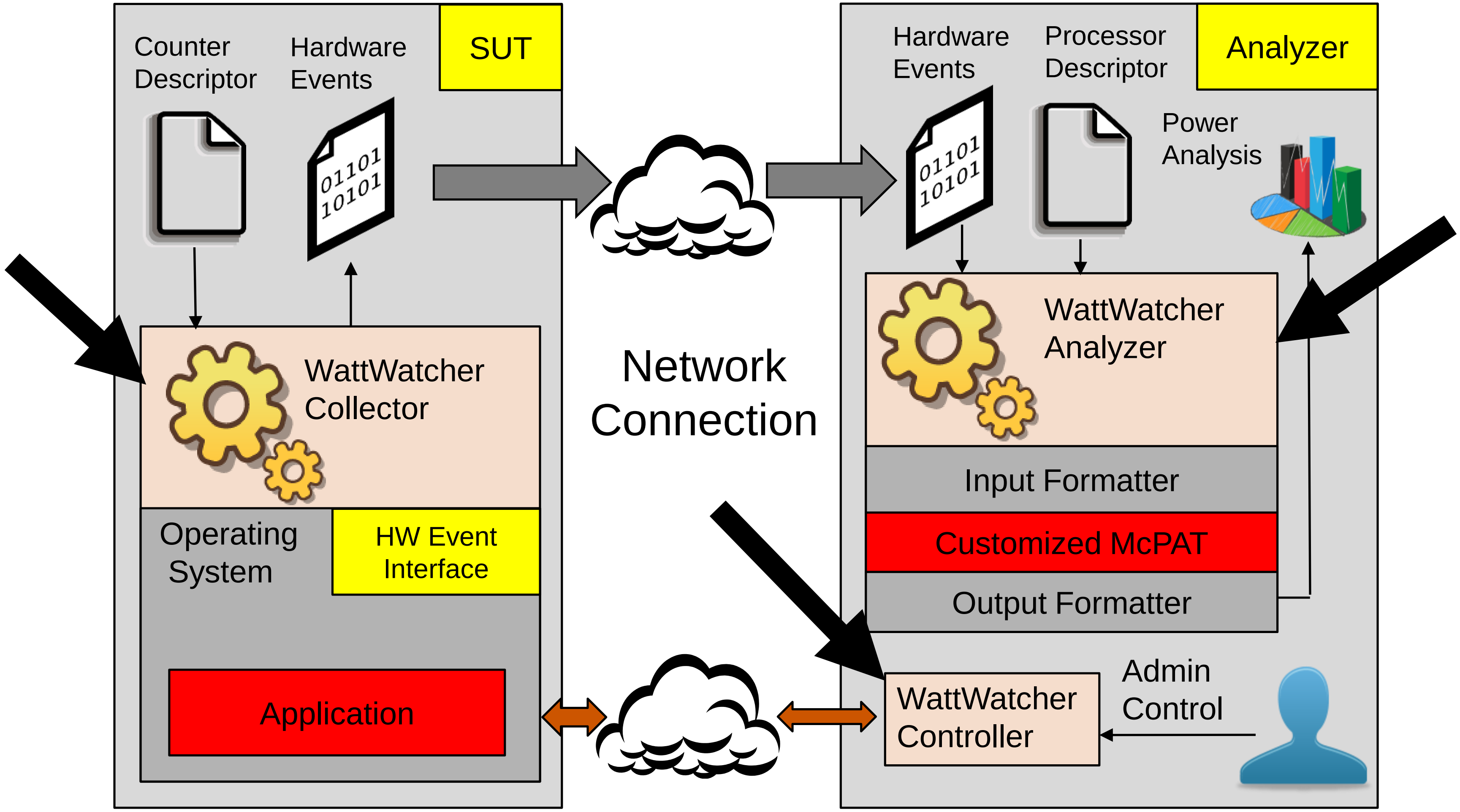
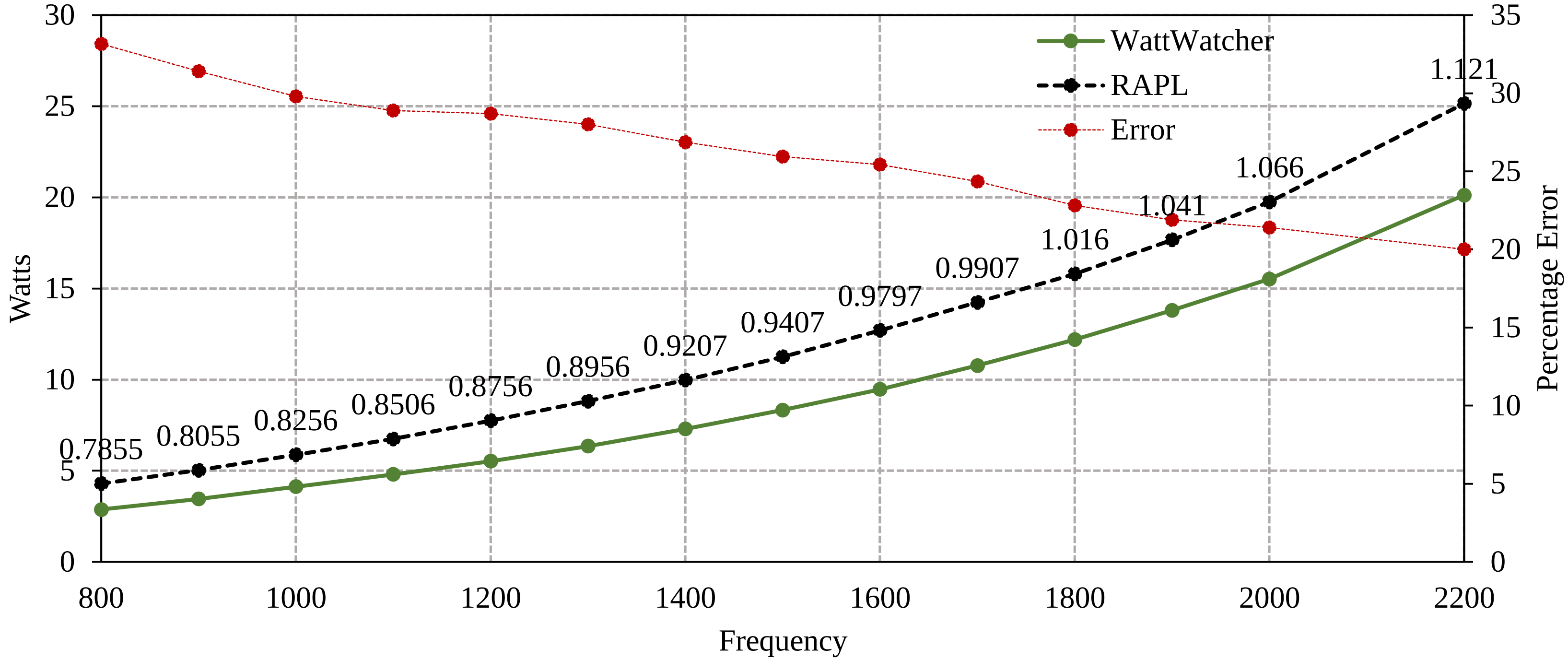


WattWatcher Calibration



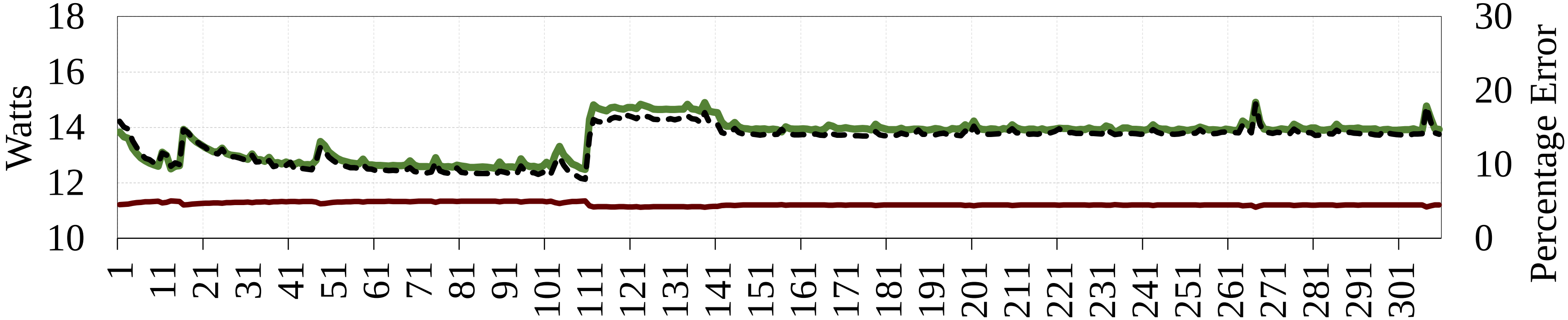
- **McPAT typically underestimates power [10]**
- **Small amount of course-grained calibration required**
- **More sophisticated corrections are available [13]**

Verification

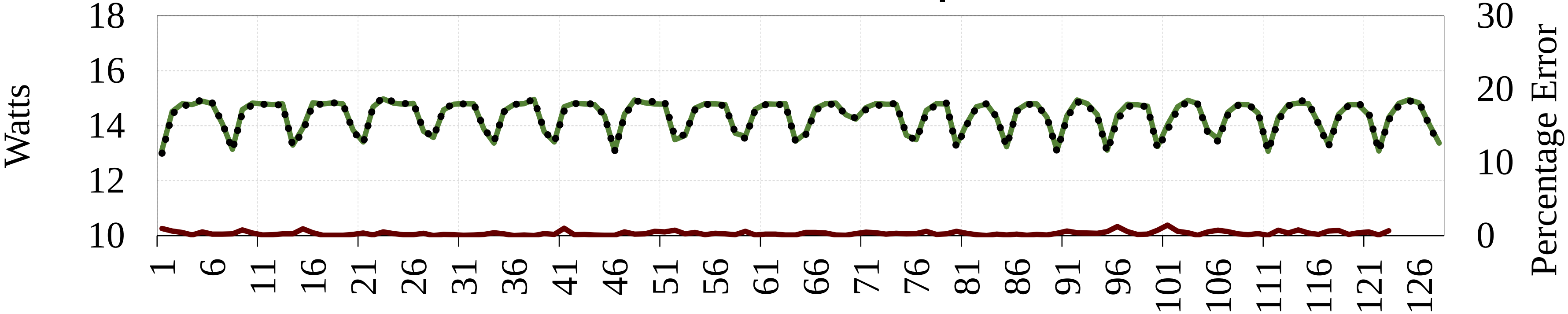
- **Intel Sandy Bridge Laptop**
  - Intel i7 2720QM
  - 32nm Process
  - 45W TDP
- **Workloads: SPECFP + SPECINT[11], PARSEC[12]**
- **Compared against RAPL counters**
- **Other SUTs: Intel Haswell and AMD Piledriver**
- **All results use previous coarse-grained calibration**

Verification

xalancbmk : SPECint

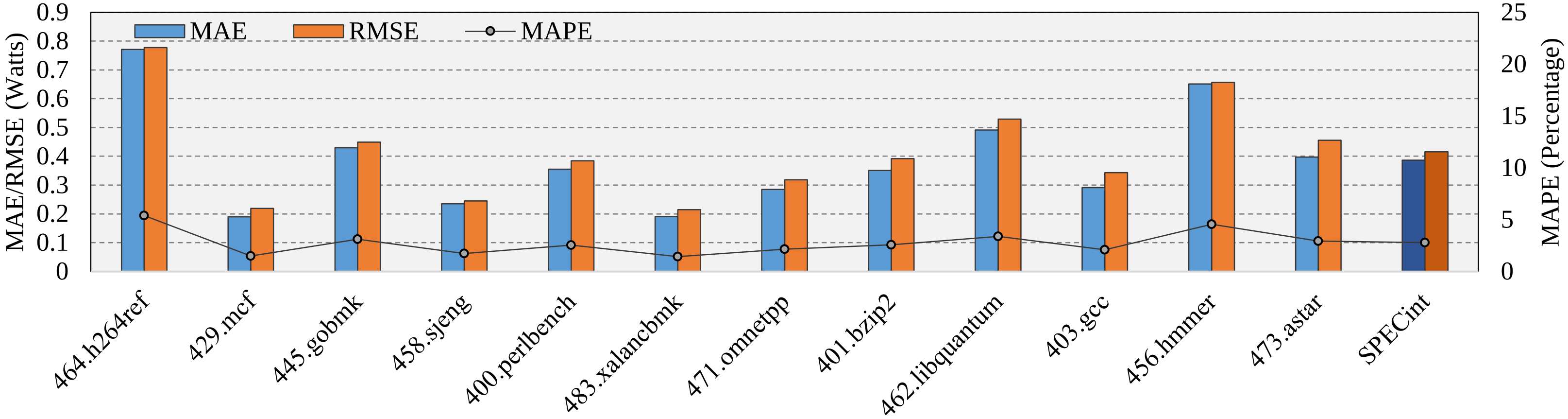


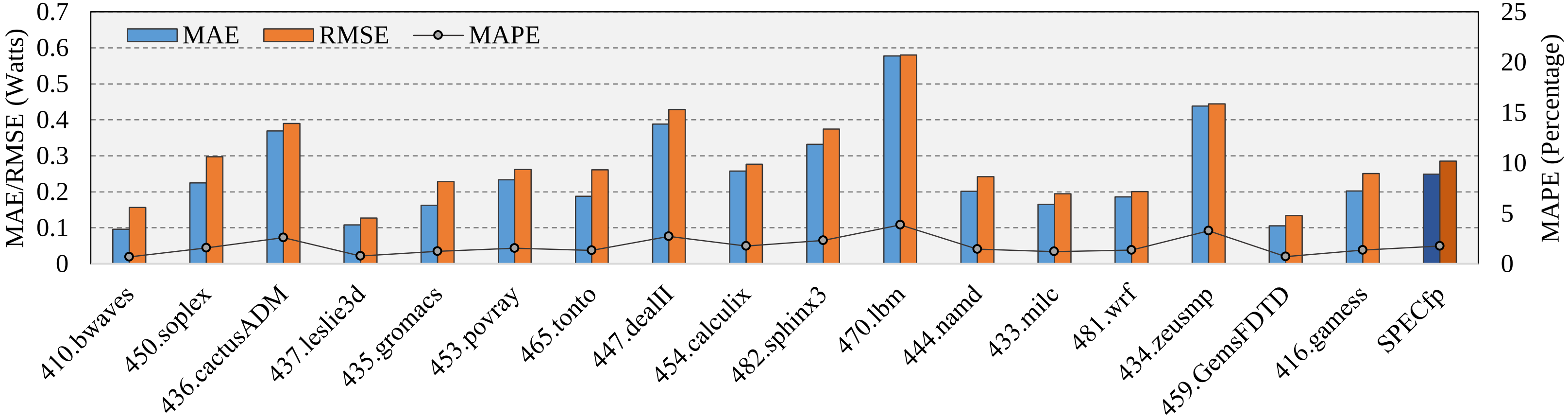
bwaves : SPECfp



- **Pearson correlation coefficient (0.982, 0.995)**

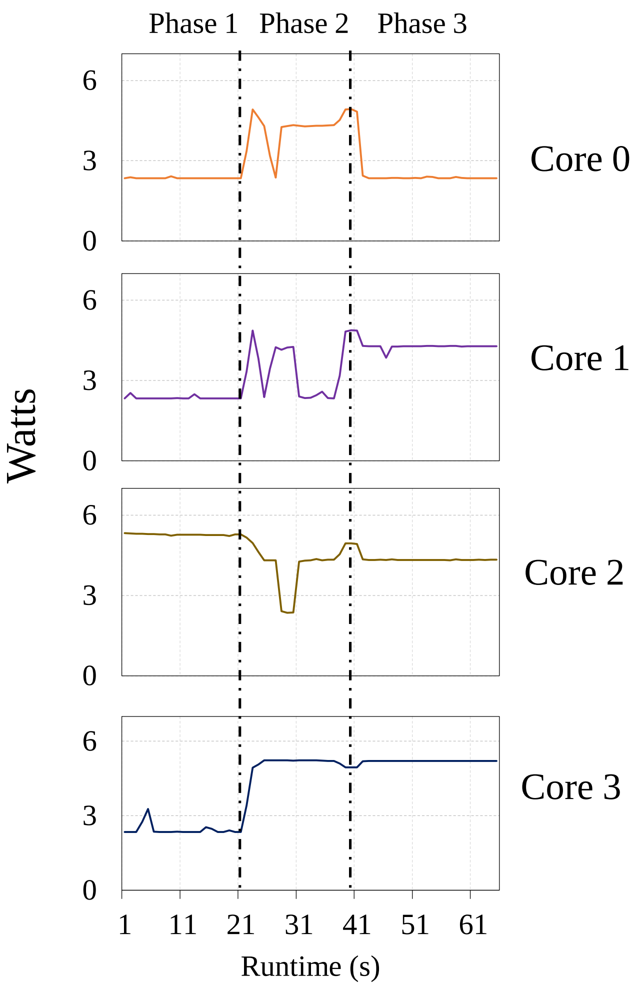
Verification

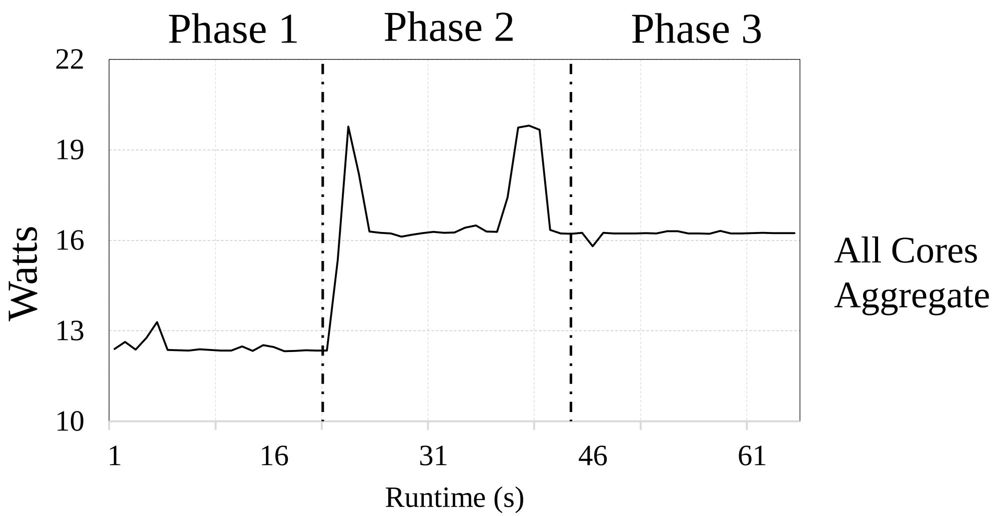




- **MAPE over all workloads is 2.67%**

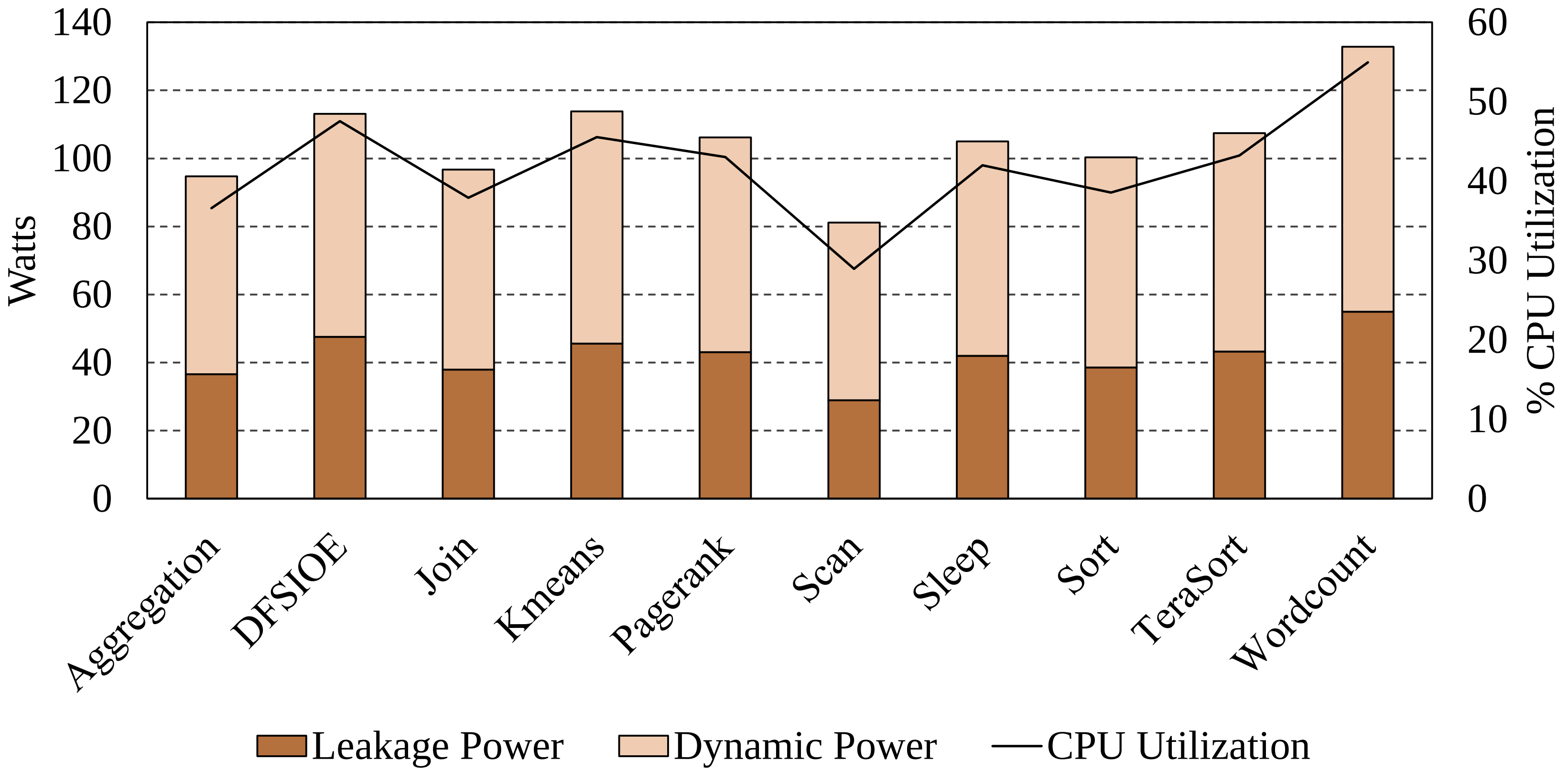
Case Studies 1: Per Core Power Measurements





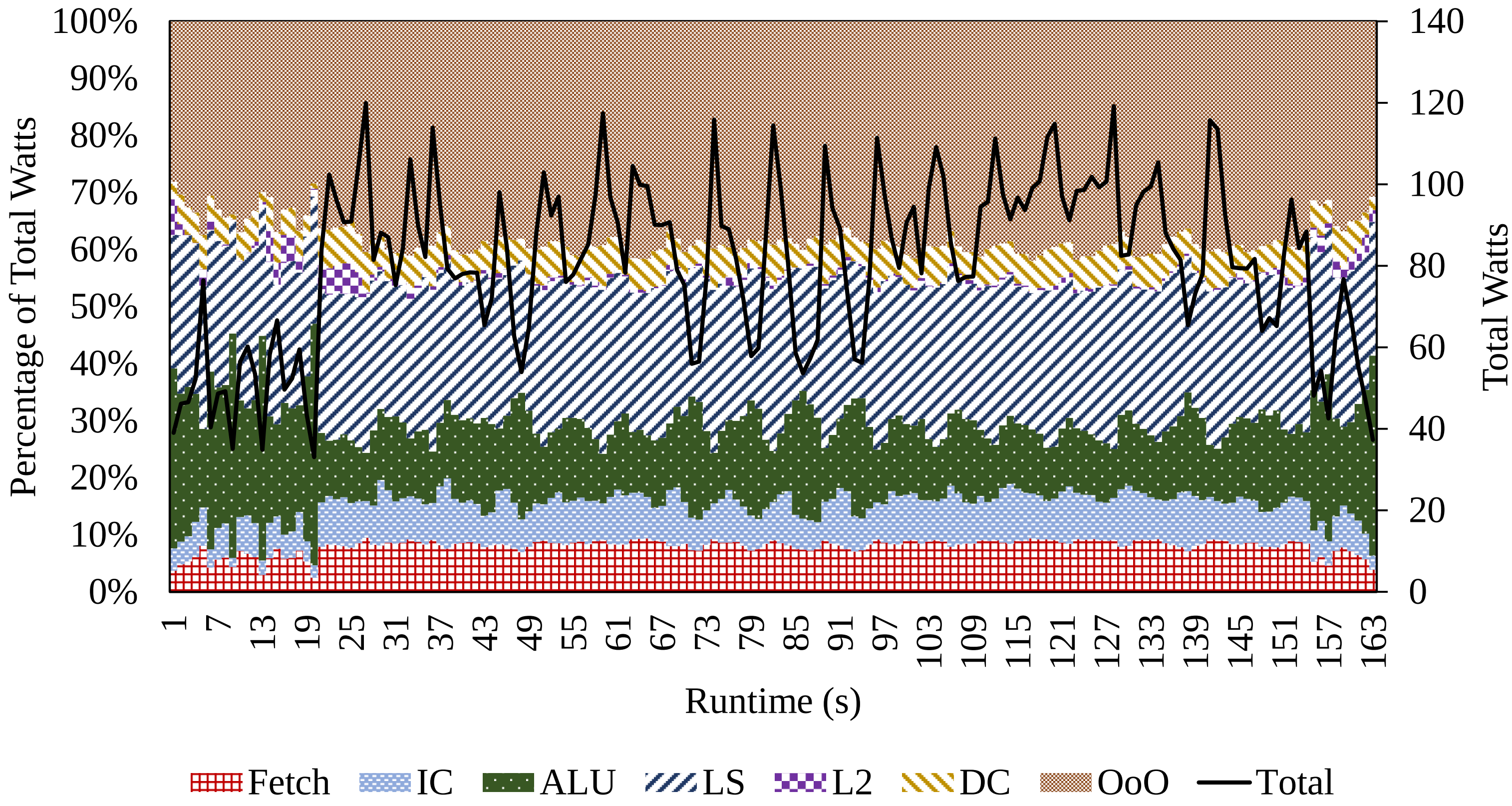
- **canneal workload (PARSEC)**
- **Per core and aggregate breakdown**
- **RAPL cannot provide core level breakdown**

Case Studies 2: Big Data Workloads



- **Big Data Workloads: Hadoop**

Case Studies 3: Functional Unit Breakdowns



- **Word count power breakdown**

Conclusion

- **WattWatcher fills an important role in power estimation techniques**
  - Real time results on real hardware
  - Highly configurable models
  - Minimal calibration required
  - Verified over different processors and vendors
    - MAPE = 2.67% averaged over all benchmarks
  - Illustrated over a number of interesting case studies

Thank you!

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