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A Calibration Based Thermal Modeling Technique for Complex Multicore Systems

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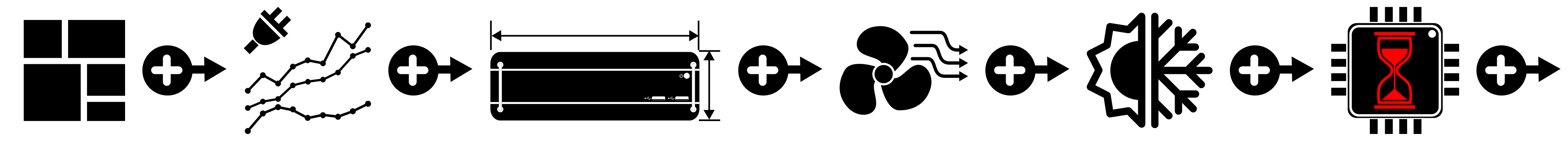
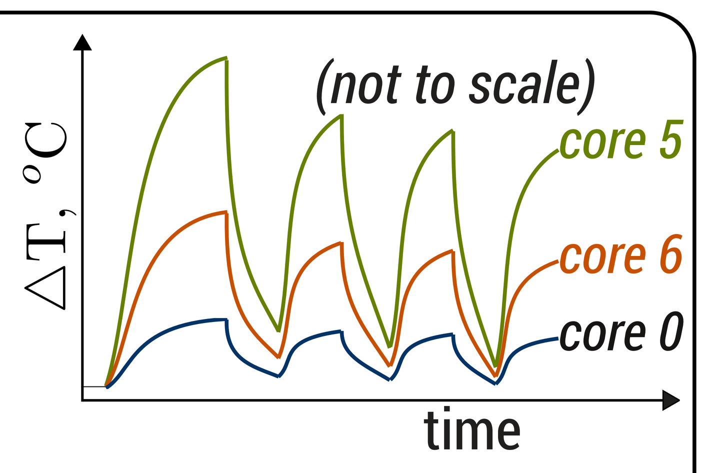
Objective

Predict the temperature of the state-of-the-art processor with speed and accuracy suitable for Design Space Exploration

- offline estimation
- applicable to any processor featuring on-chip temperature sensors
- compute 10K-100K new data points per second
- accuracy ~ 1^oC
- thermally optimized designs (e.g., reduced thermal gradients)

Current Solutions





Difficult to acquire parameters with reasonable accuracy for state-of-the-art processors

infeasibility for practical use

New Solution

Benefits

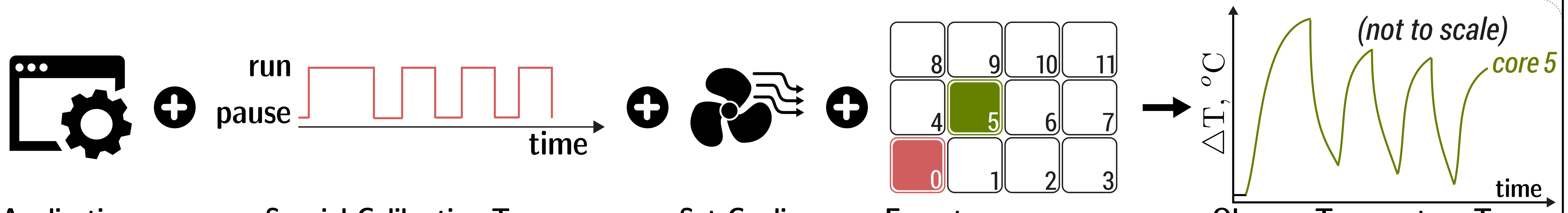
- Computationally Efficient
- Automated
- Fully Software Driven
- Applicable to any state-of-the-art processor

Calibration based Approach

Observe the given system and infer the required thermal parameters for each class of use case scenario.

Reduce model if necessary.

How?



- **Application**: An individual application or a class
- **Special Calibration Trace**: Execution pattern (schedule) for learning dynamic and steady-state thermal behavior
- **Set Cooling**: Set a fan speed
- **Execute on procesor**: Choose core type; Set processor clock speed
- **Observe Temperature Traces**: Record at a predefined sampling rate

→ model

The model needs just few single-application runs for parameter calibration. We developed a technique to compose parameters and estimate temperature traces for multi-application runs[1].

System Identification (Linear Models)

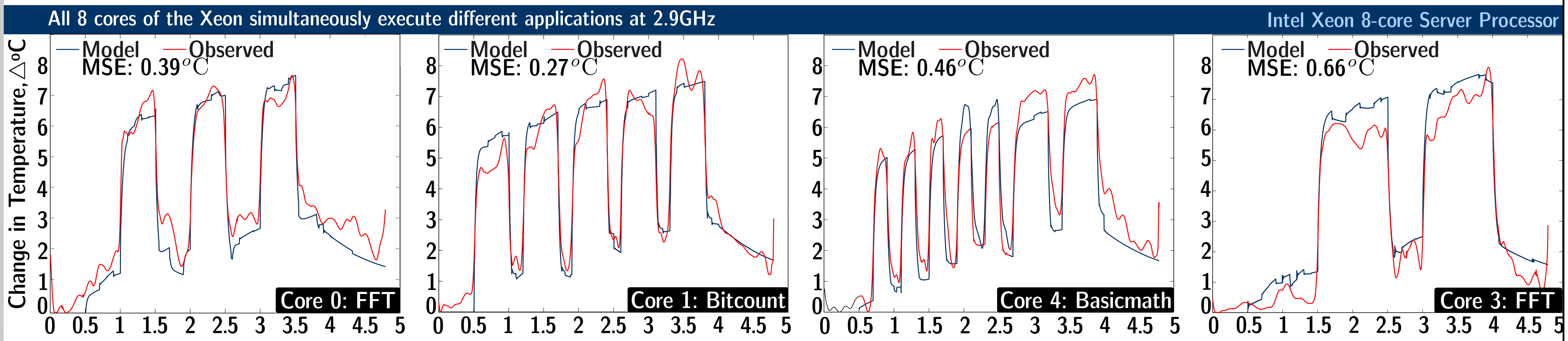
$$\tau = \mathbf{g}(b, \mathbf{M}, c) \stackrel{\text{def}}{=} u \otimes \check{\mathbf{m}}(s) \otimes \mathbf{m}(a, v, d, f)$$

- τ: Temperature trace
- $\mathbf{m}(a, v, d, f)$: thermal model (CPU)
  - a: application (type)
  - v: core type
  - d: distance betwen hot core and observer
  - f: processor clock speed
- $\check{\mathbf{m}}(s)$: thermal model of the fan indexed by fan speed
- u: arbitrary execution pattern

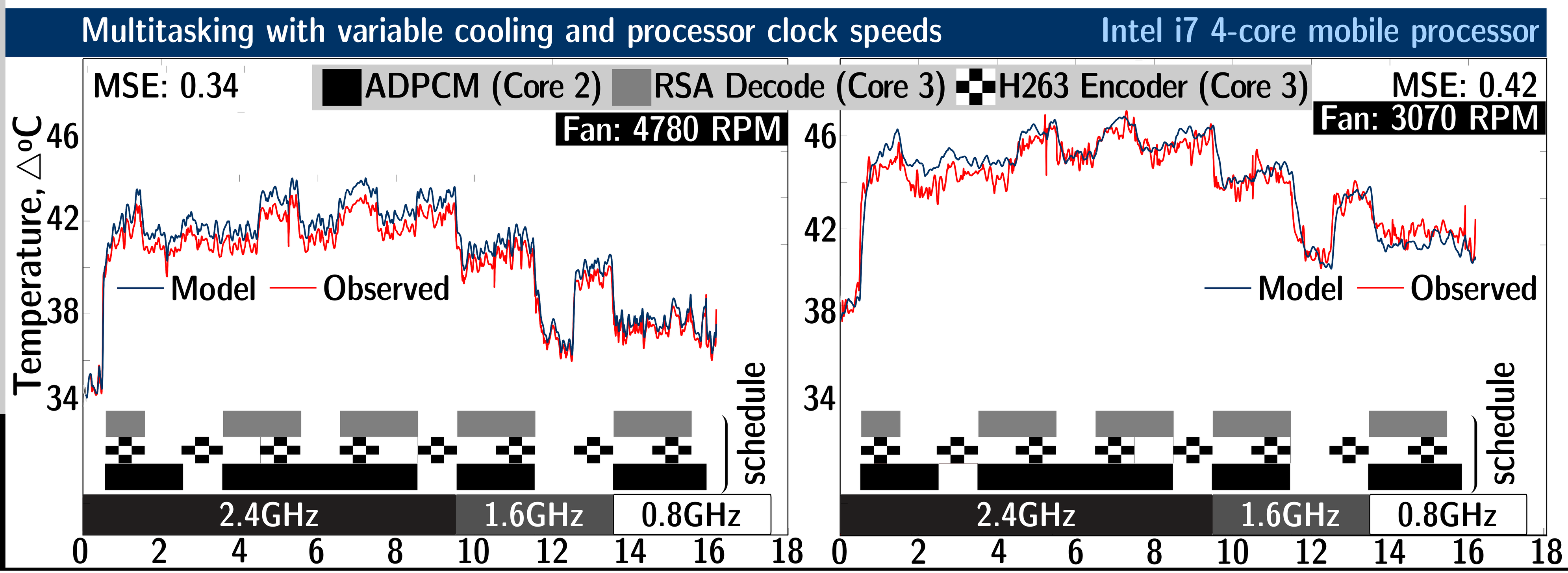
Experiments & Validation

Maximum complexity of any model: 5 poles, 5 zeros. Worst case compute complexity for each new data point: 10 multiplies, 1 division, 10 additions. Memory: 21 units/model

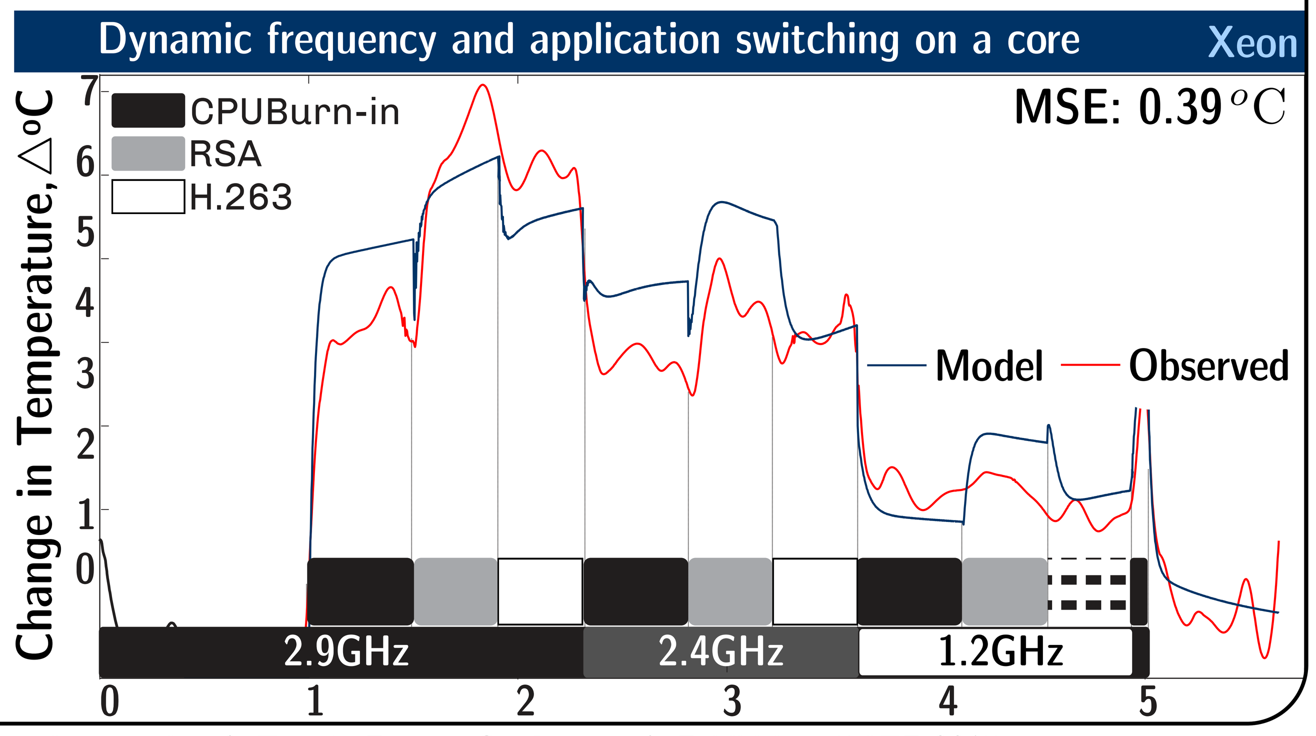
All 8 cores of the Xeon simultaneously execute different applications at 2.9GHz — Intel Xeon 8-core Server Processor



Multitasking with variable cooling and processor clock speeds — Intel i7 4-core mobile processor



Dynamic frequency and application switching on a core — Xeon



[1]. D. Rai and L. Thiele. A Calibration Based Thermal Modeling Technique for Complex Multicore Systems, In Proceedings of the 2015 Design, Automation & Test in Europe Conference & Exhibition, DATE 2015.