On Temperature & Power Management for MPSoC

Jiaqi Yan

CONTENTS

CONTENTS

CONTENTS

- Dynamic power and temperature management
- Thermal analysis methods for multi-core processor

CONTENTS

PART 1

PART 1

- Temperature analysis model
- Power analysis model
- Existing management algorithm
- Innovative VP-TALk
- A DPTM prototype system
- Expriment validation

PART 1

TEMP ANALYSIS MODEL

- Equivalent RC circuit

TEMP ANALYSIS MODEL

- Equivalent RC circuit

$$\frac{dT}{dt} = \frac{P}{C_{th}} - \frac{T - T_{amb}}{R_{th}C_{th}} = \alpha P - \beta(T - T_{amb})$$

POWER ANALYSIS MODEL

- Power
- Leakage current
- Switch overhead

POWER ANALYSIS MODEL

- Power

$$P_{active} = CV_{dd}^2 f + N_{gate} I_{leakage} V_{dd}$$

- Leakage current

- Switch overhead

POWER ANALYSIS MODEL

- Power

$$P_{active} = CV_{dd}^2 f + N_{gate} I_{leakage} V_{dd}$$

- Leakage current

$$I_{leakage} = I(V_0, T_0)(AT^2 \exp(\frac{\alpha V_{dd} + \beta}{T}) + B \exp(\gamma V_{dd} + \delta))$$

- Switch overhead

MANAGEMENT ALGORITHMS

MANAGEMENT ALGORITHMS

- Pattern-based
- M-oscillating
- TALk

MANAGEMENT ALGORITHMS

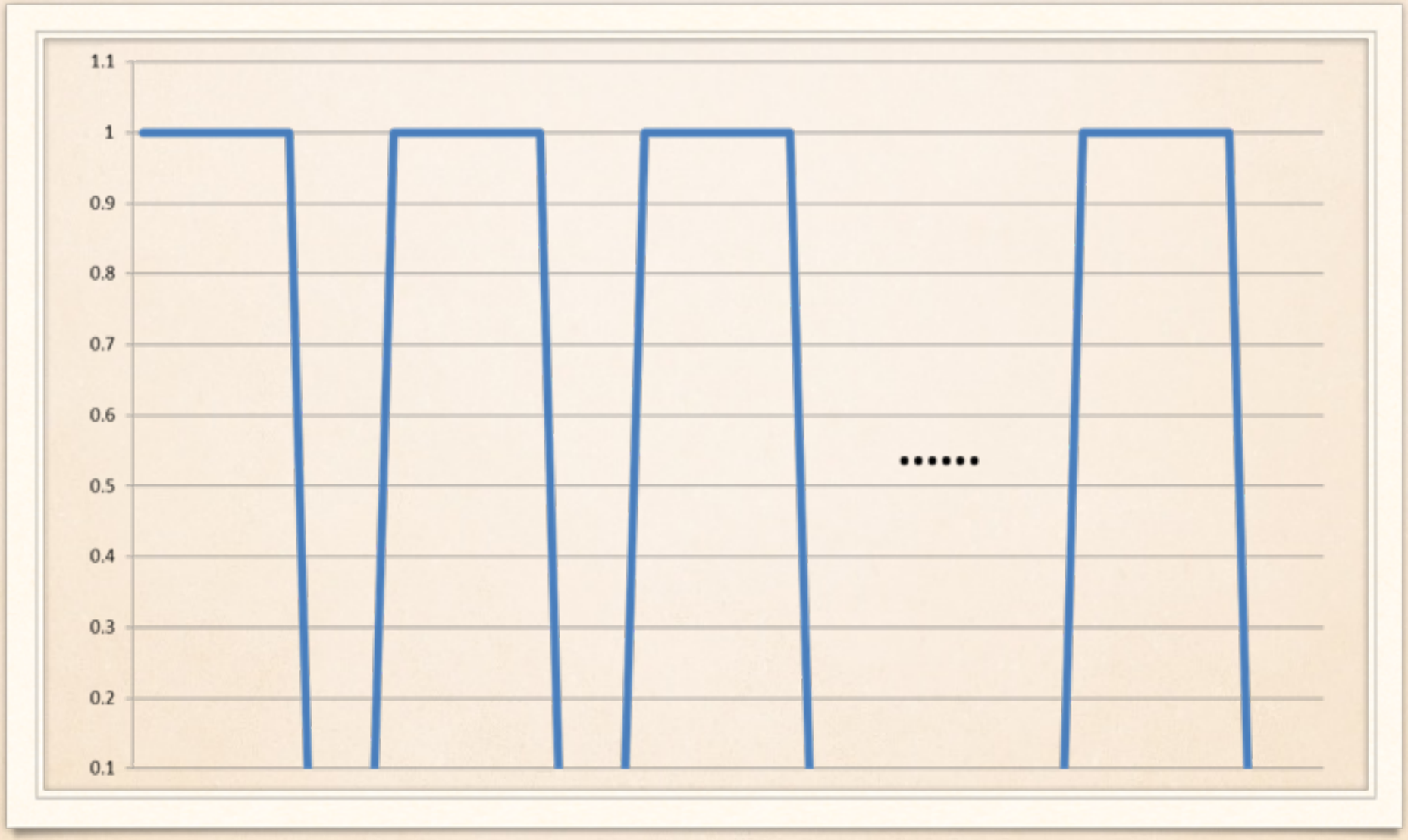
MANAGEMENT ALGORITHMS

Take advantage of DVS or DVFS

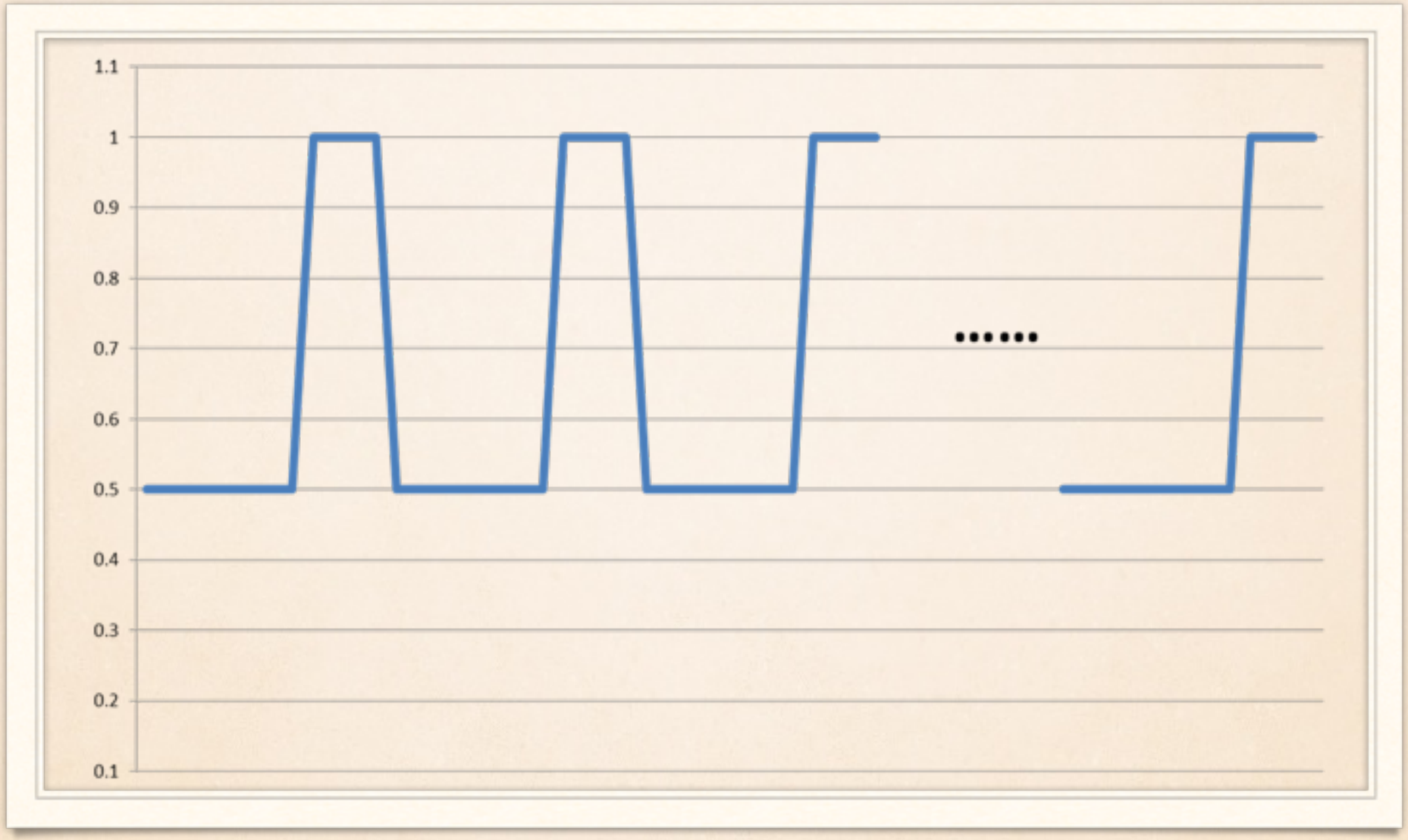
MANAGEMENT ALGORITHMS

Take advantage of DVS or DVFS

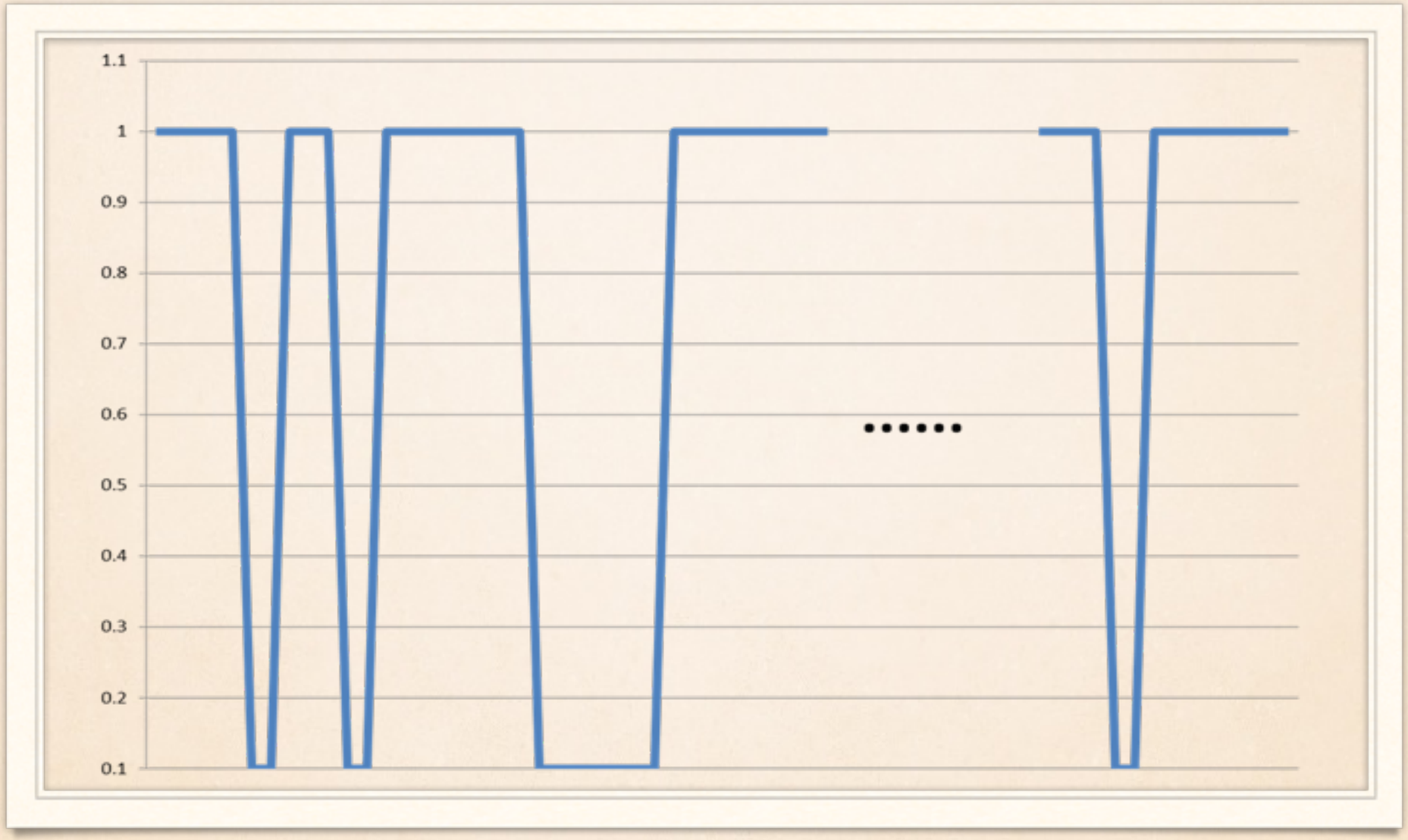
PATTERN-BASED



M-OSCILLATING



TALK



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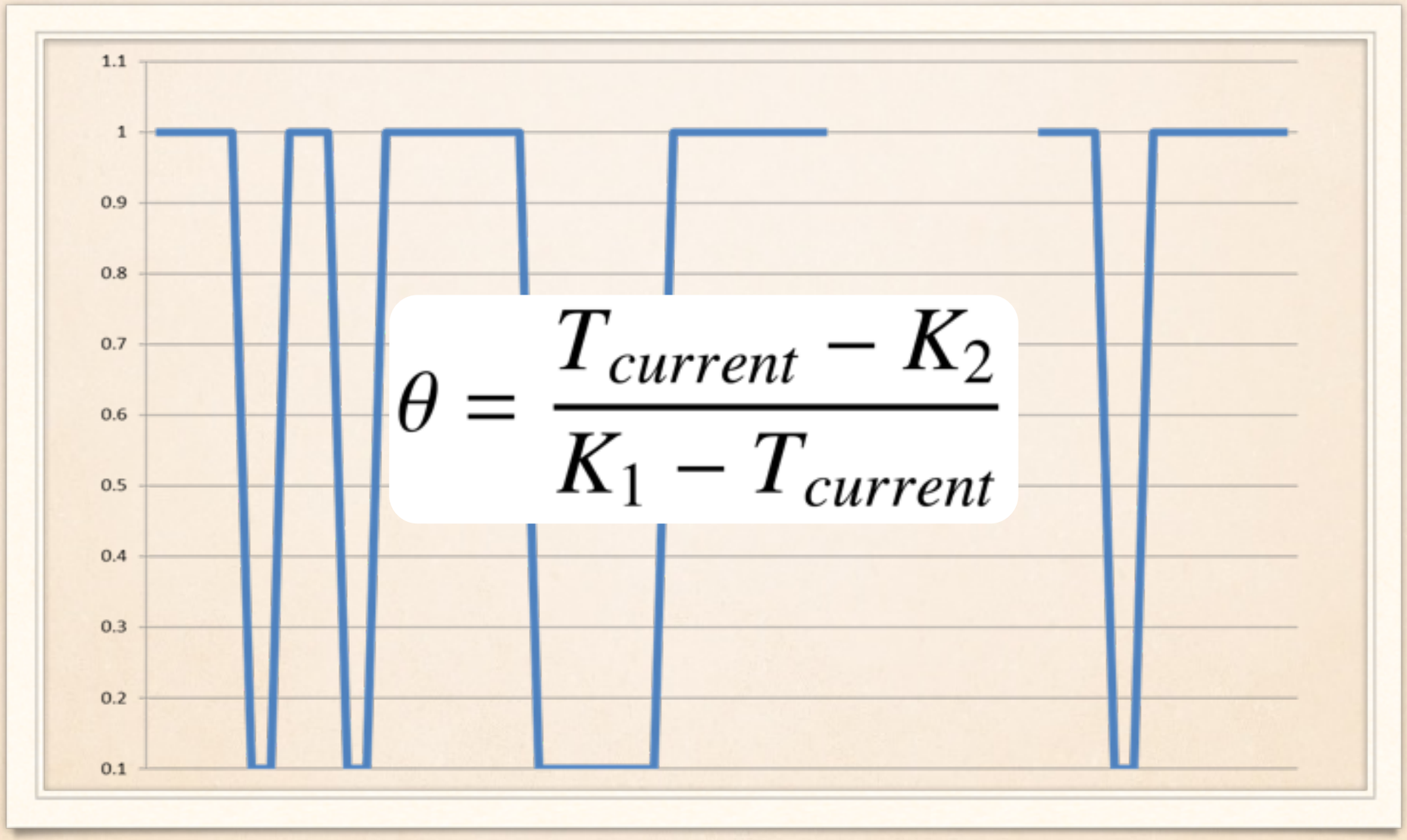
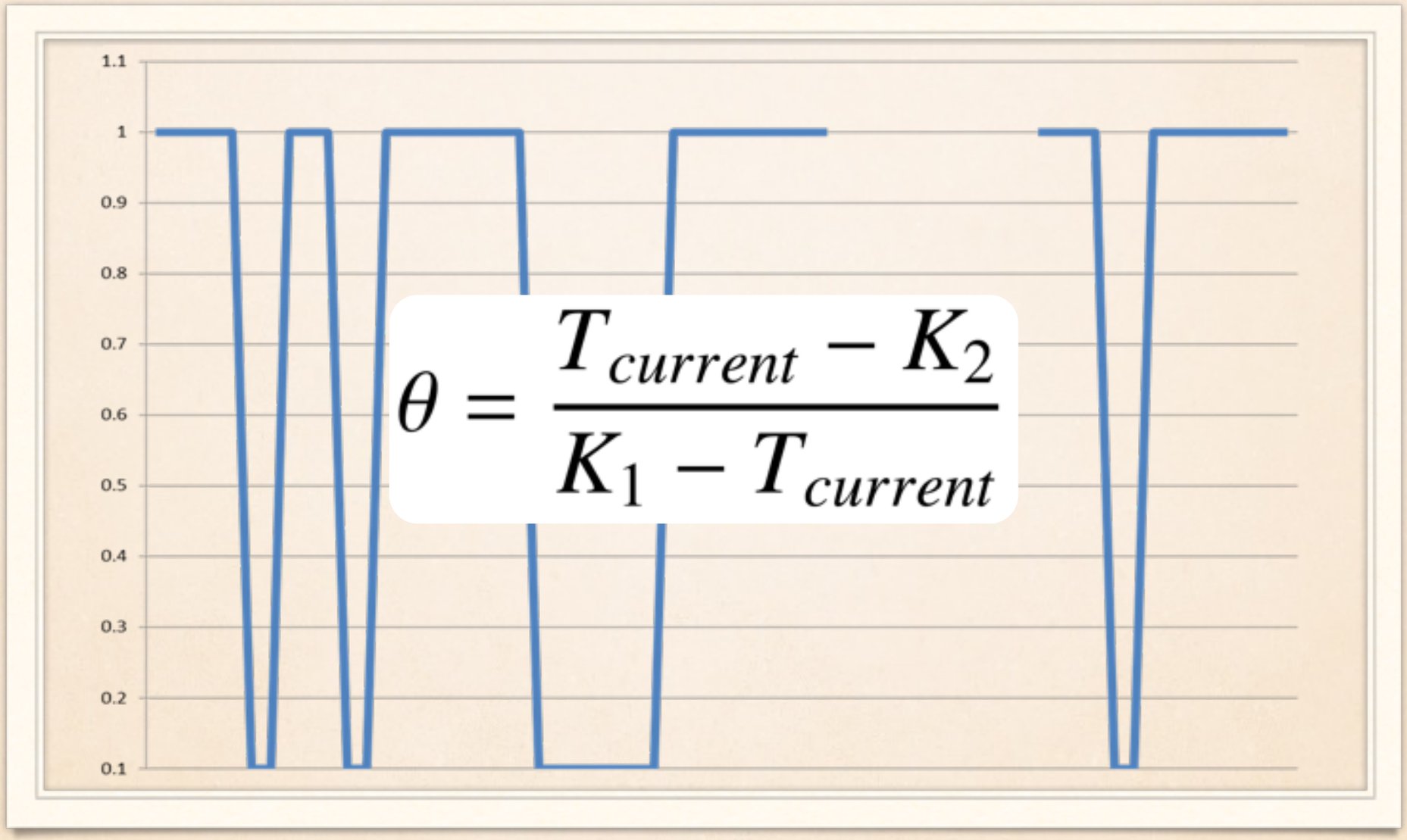

1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
$\theta = \frac{T_{current} - K_2}{K_1 - T_{current}}$

TALK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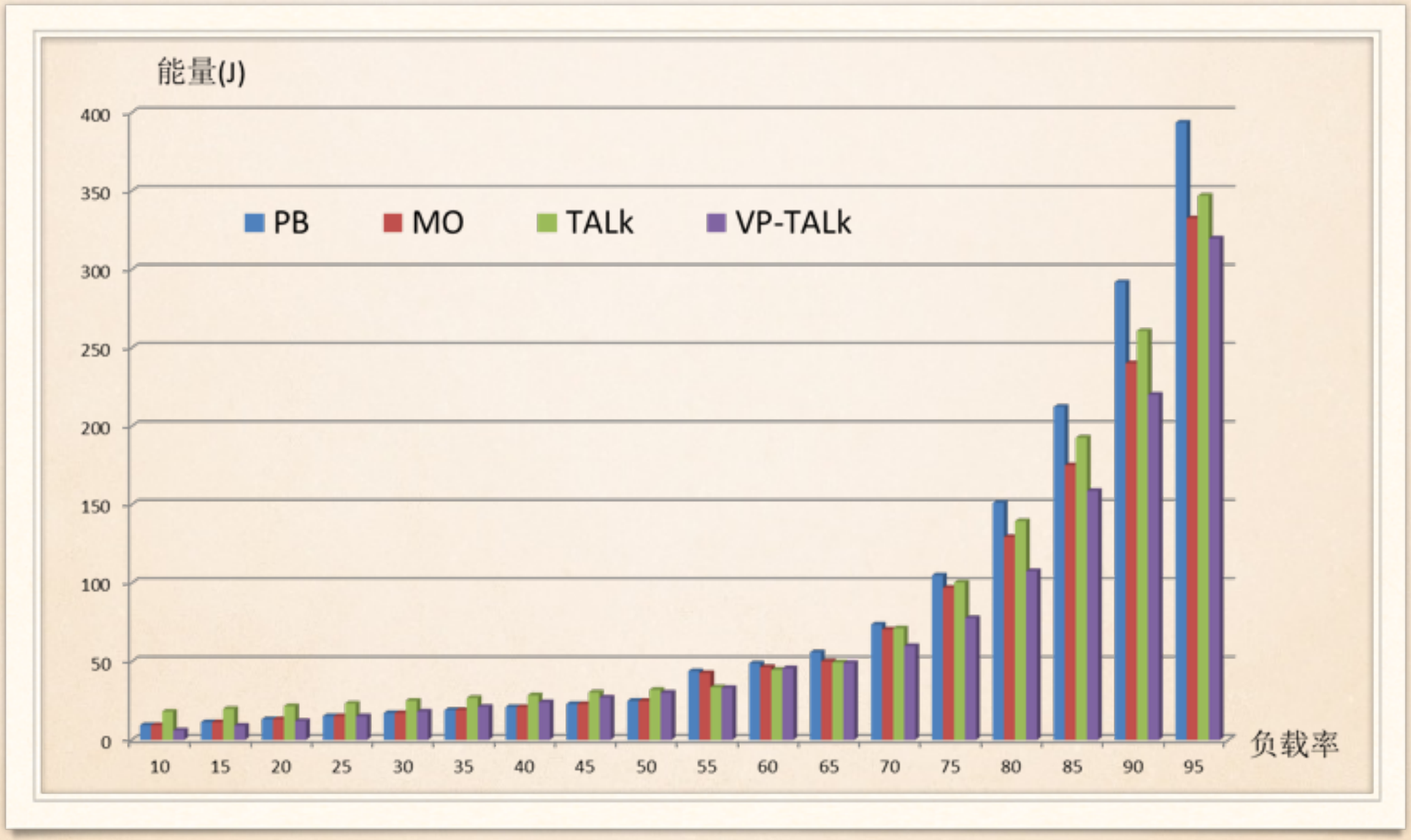
0.3
0.2
0.1
$\theta = \frac{T_{current} - K_2}{K_1 - T_{current}}$

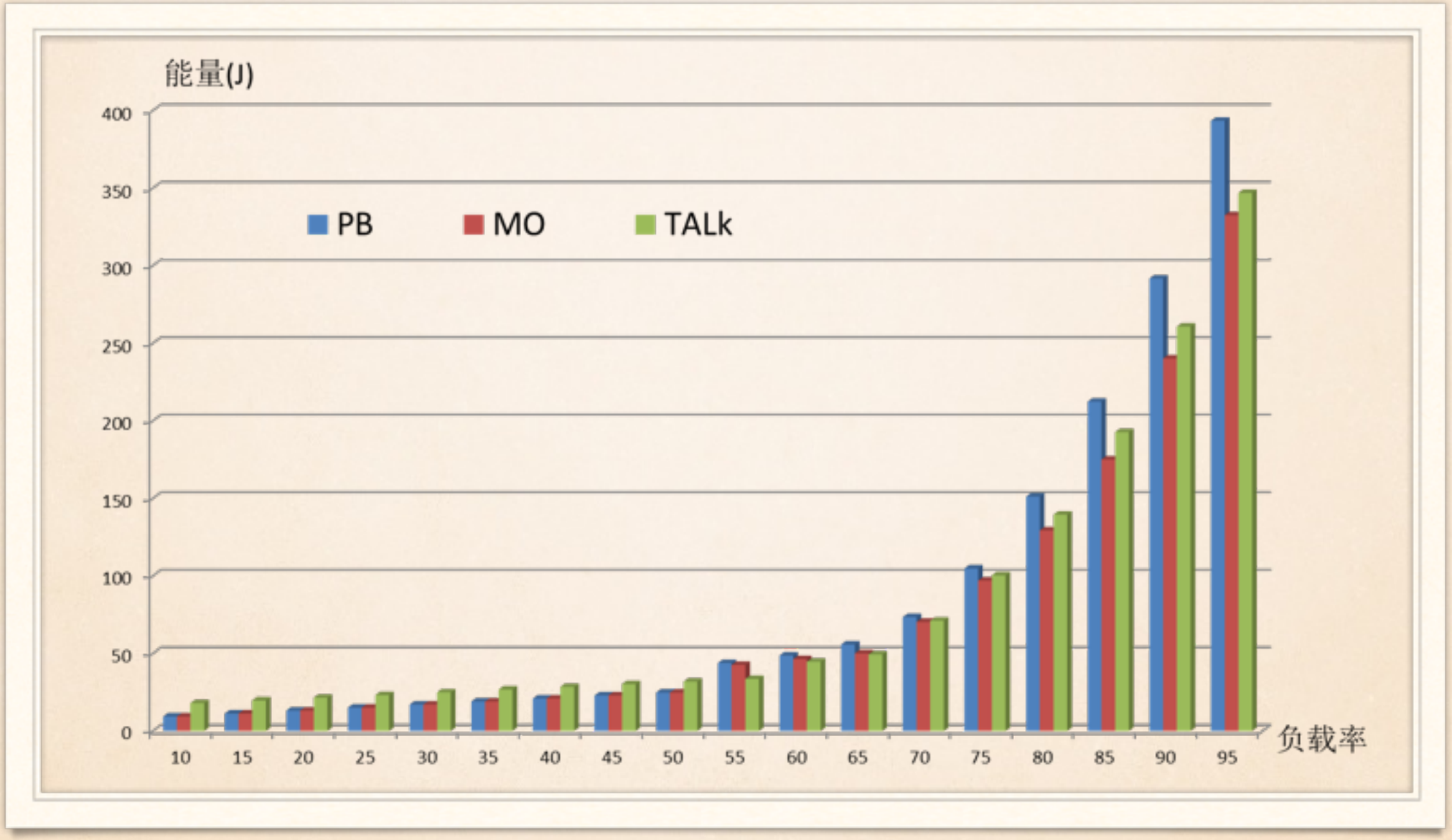
VP-TALK


能量(J)
400
350
300
250
200
150
100
50
0
PB
MO
TALk
VP-TALk
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
负载率

A DPTM PROTOTYPE SYSTEM

- A motivative example
- Workload prediction with time series analysis
- DPTM system with online assessment

MOTIVATION


能量(J)
400
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200
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100
50
0
PB
MO
TALk
10
15
20
25
30
35
40
45
50
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60
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70
75
80
85
90
95
负载率

WORKLOAD PREDICTION

Decomposing into Predictable Components and Composing Prediction Together

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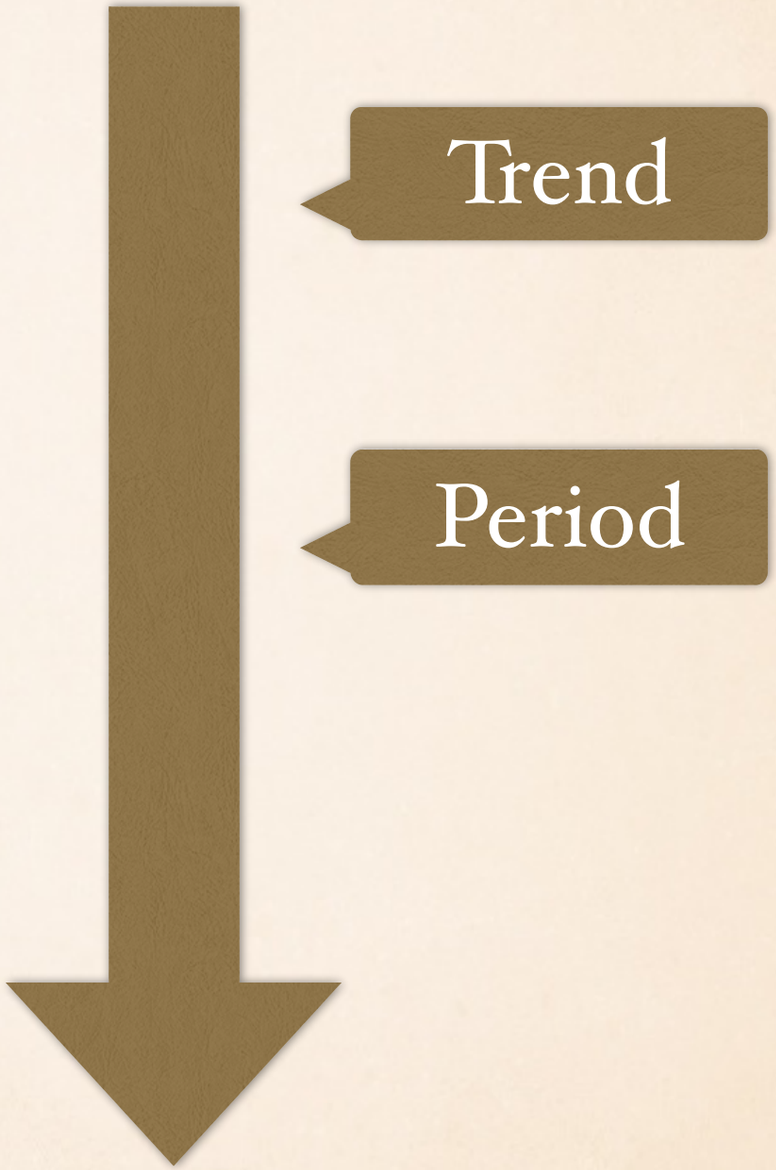

WORKLOAD PREDICTION

Decomposing into Predictable Components and Composing Prediction Together

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Decomposing into Predictable Components and Composing Prediction Together

ONLINE ASSESSMENT

- Score for a DPTM strategy
- Pick up the historic best

ONLINE ASSESSMENT

- Score for a DPTM strategy

$$w_{kt} = 1 - \sum_{j=t_0}^{t-1} \frac{E_{k,j}\lambda_j}{\sum_{i=1}^{N} E_{i,j}}$$

- Pick up the historic best

ONLINE ASSESSMENT

- Score for a DPTM strategy

$$w_{kt} = 1 - \sum_{j=t_0}^{t-1} \frac{E_{k,j}\lambda_j}{\sum_{i=1}^{N} E_{i,j}}$$

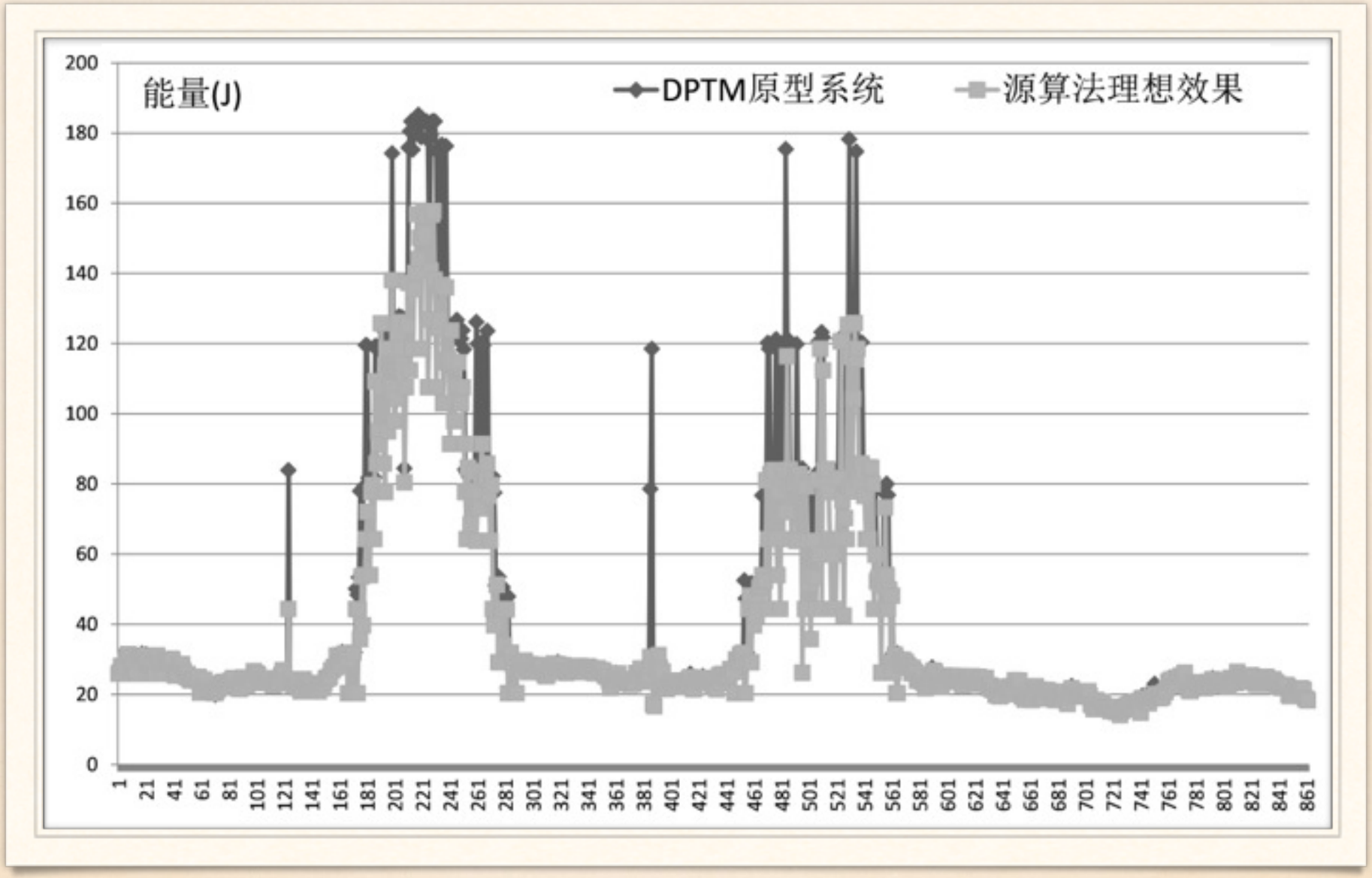
- Pick up the historic best

$$DPTM_t = \arg\left(\max_{1 \le k \le N}(w_{k,t})\right)$$

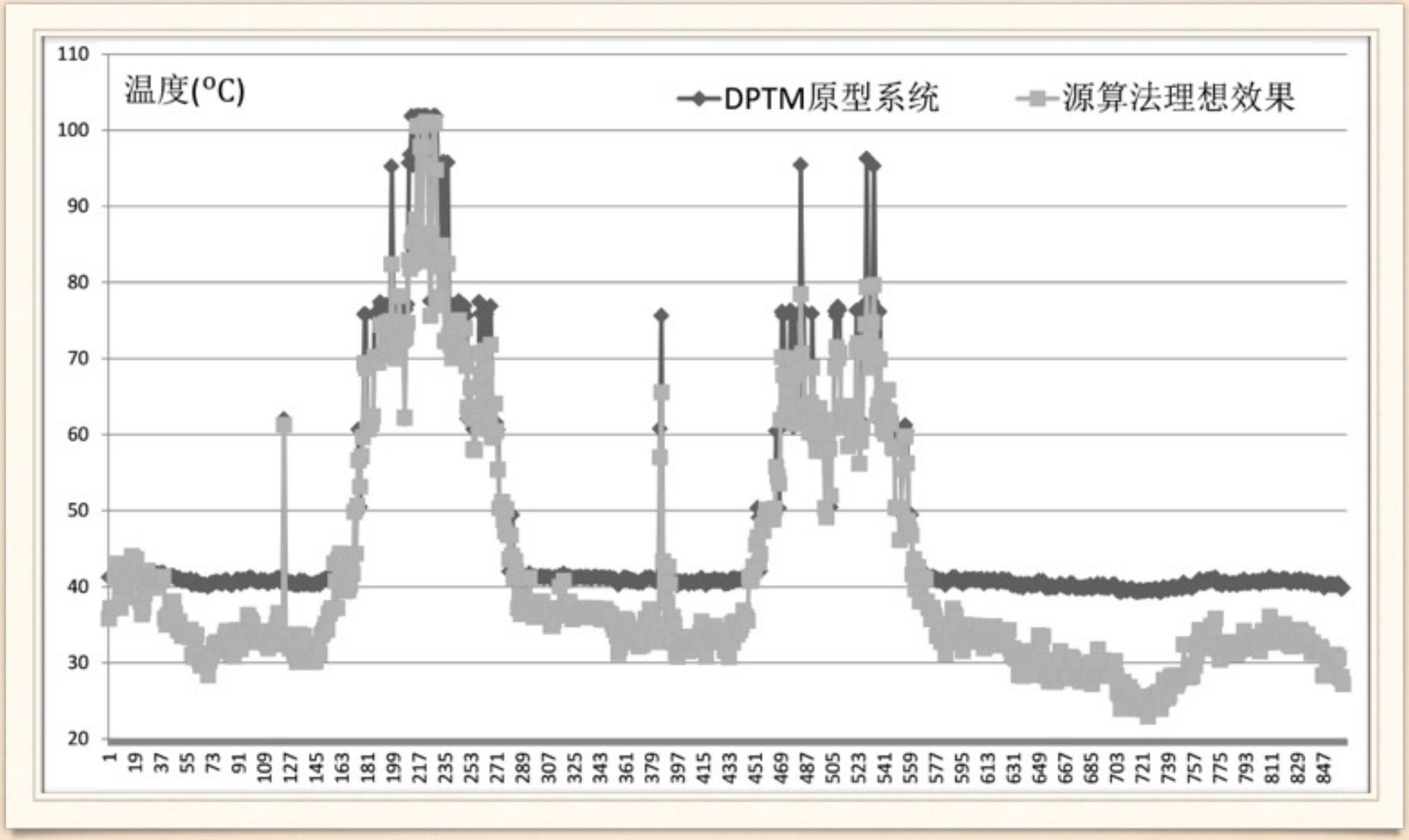
EXPRIMENT VALIDATION

- Prototype system V.S. Avg. effect
- Prototype system V.S. Ideal effect

ENERGY CONSUMPTION



PEAK TEMPERATURE



CONTENTS

- Dynamic power and temperature management
- Thermal analysis methods for multi-core processor

CONTENTS

PART 2

PART 2

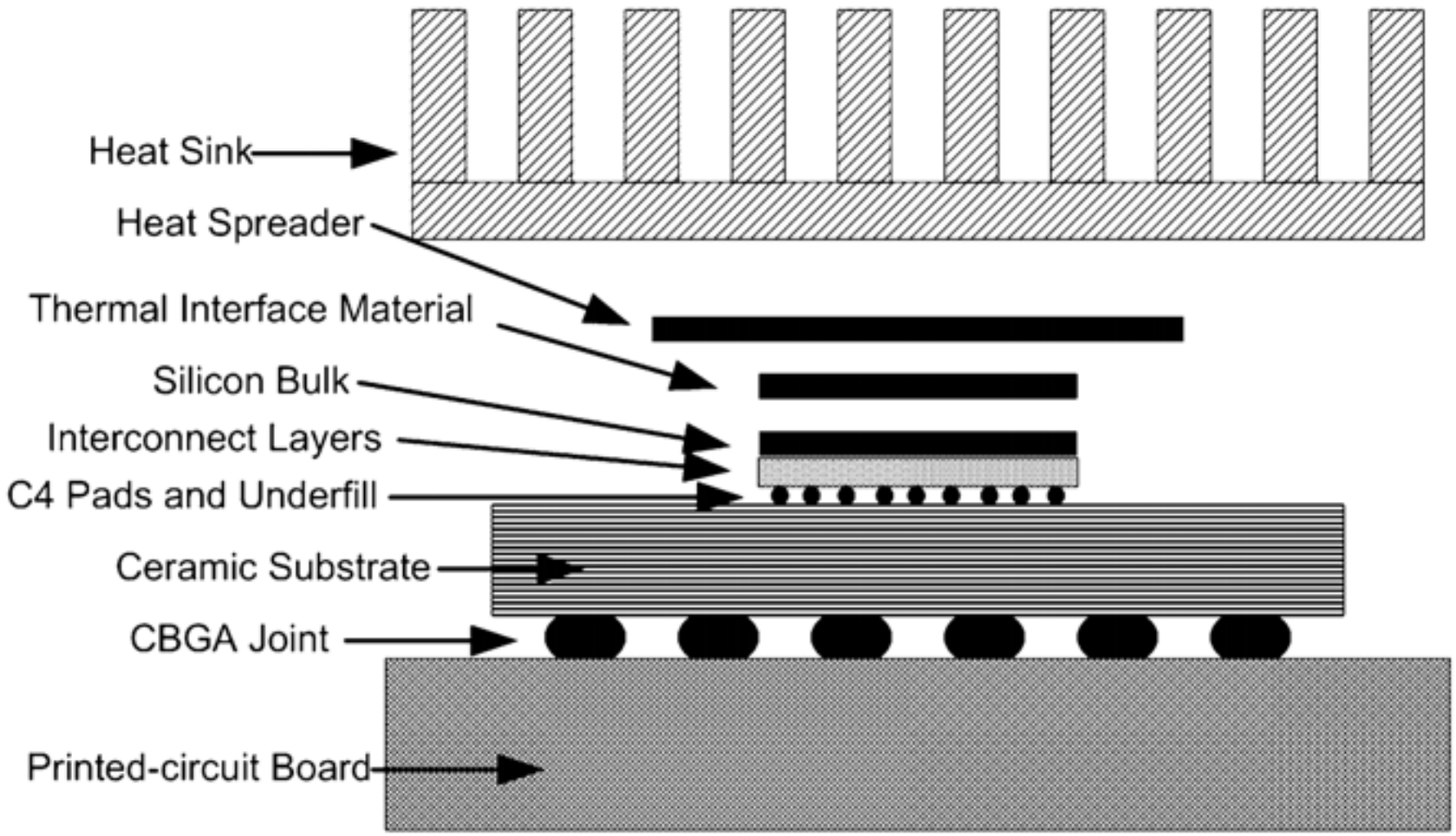
- Thermal analysis model
- HotSpot
- Temperature dependence on leakage power/current
- Architecture-level thermal analysis methods
- Expriment validation

THERMAL ANALYSIS MODEL

Model Dissipation System

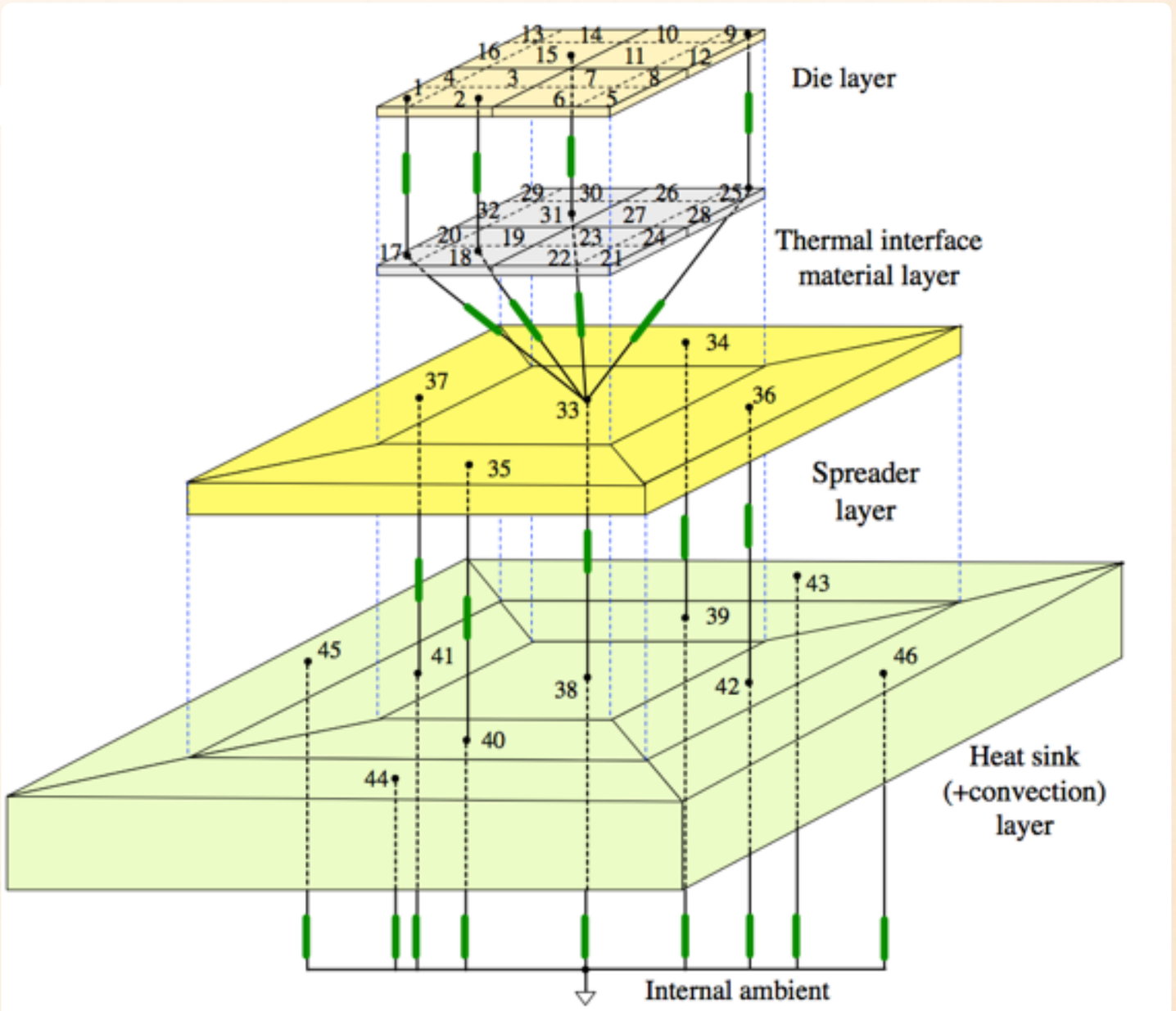
THERMAL ANALYSIS MODEL

Model Dissipation System



HOTSPOT

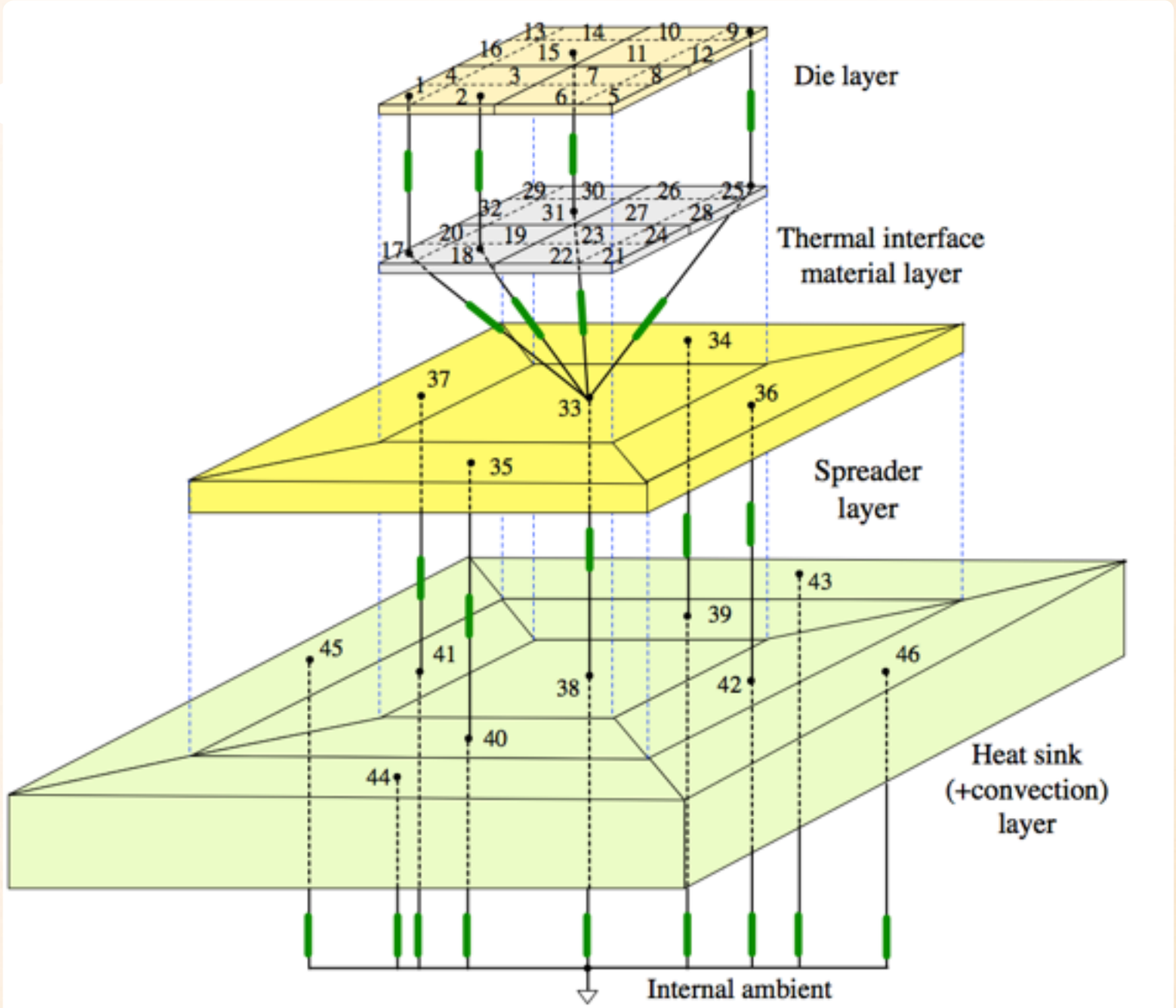
HOTSPOT


Die layer
Thermal interface material layer
Spreader layer
Heat sink (+convection) layer
Internal ambient

HOTSPOT

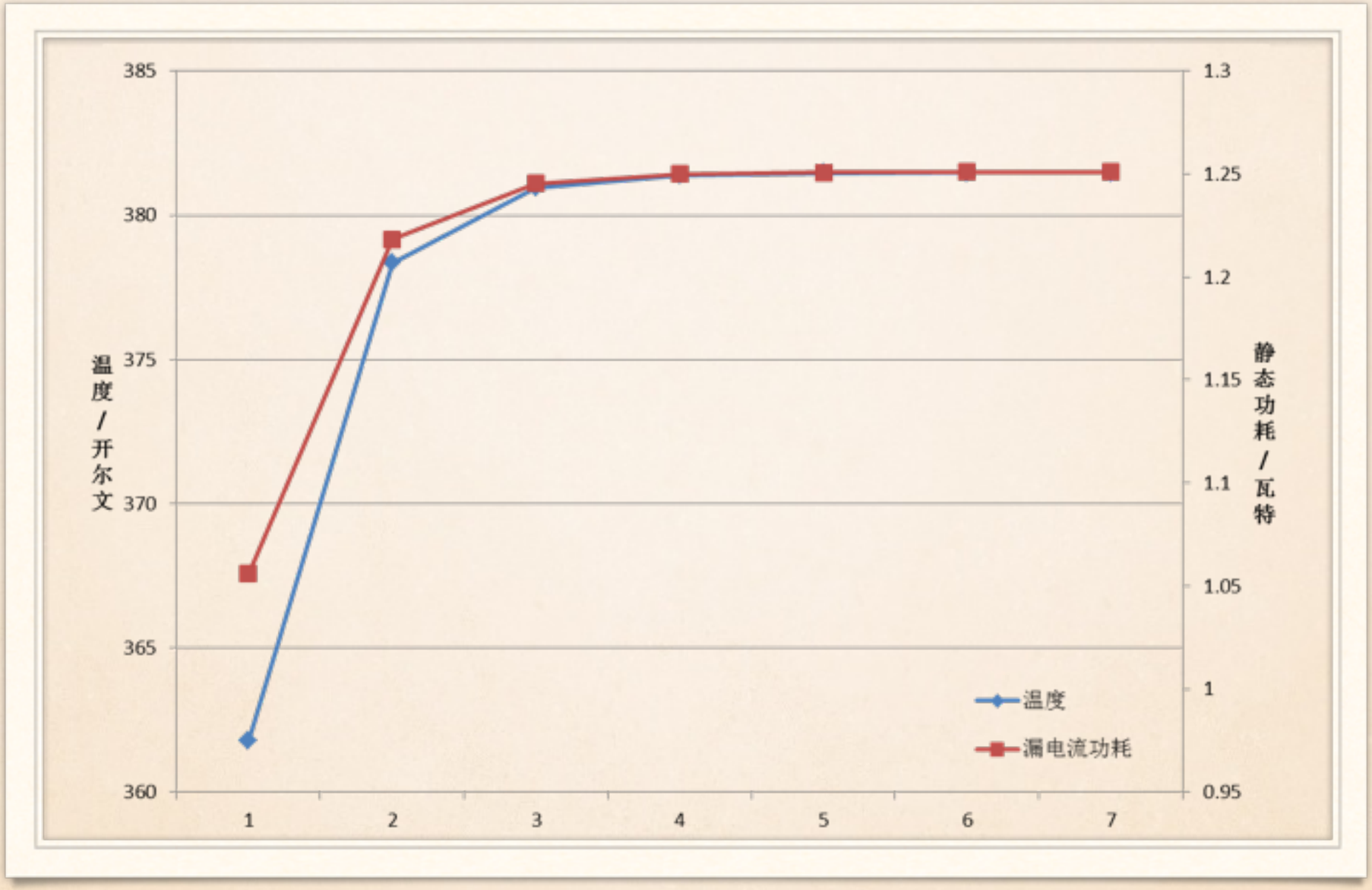
- Equivalent RC model

$$G \times T = P$$



TACKLE TEMP DEP ON LEAK

T-P Iteration



ARCHITECTURE-LEVEL ANALYSIS

ARCHITECTURE-LEVEL ANALYSIS

- BlockTAM

ARCHITECTURE-LEVEL ANALYSIS

- BlockTAM
- CoreTAM

ARCHITECTURE-LEVEL ANALYSIS

- BlockTAM
- CoreTAM
- BlockInsideCoreTAM

BLOCK-TAM

BLOCK-TAM

L2_Left_4	Core_4	L2_Left_8	Core_8	L2_Left_12	Core_12	L2_Left_16	Core_16
L2_4	L2_Right_4	L2_8	L2_Right_8	L2_12	L2_Right_12	L2_16	L2_Right_16
L2_Left_3	Core_3	L2_Left_7	Core_7	L2_Left_11	Core_11	L2_Left_15	Core_15
L2_3	L2_Right_3	L2_7	L2_Right_7	L2_11	L2_Right_11	L2_15	L2_Right_15
L2_Left_2	Core_2	L2_Left_6	Core_6	L2_Left_10	Core_10	L2_Left_14	Core_14
L2_2	L2_Right_2	L2_6	L2_Right_6	L2_10	L2_Right_10	L2_14	L2_Right_14
L2_Left_1	Core_1	L2_Left_5	Core_5	L2_Left_9	Core_9	L2_Left_13	Core_13
L2_1	L2_Right_1	L2_5	L2_Right_5	L2_9	L2_Right_9	L2_13	L2_Right_13

CORE-TAM

L2_Left_4	Core_4	L2_Left_8	Core_8	L2_Left_12	Core_12	L2_Left_16	Core_16
L2_4	L2_Right_4	L2_8	L2_Right_8	L2_12	L2_Right_12	L2_16	L2_Right_16
L2_Left_3	Core_3	L2_Left_7	Core_7	L2_Left_11	Core_11	L2_Left_15	Core_15
L2_3	L2_Right_3	L2_7	L2_Right_7	L2_11	L2_Right_11	L2_15	L2_Right_15
L2_Left_2	Core_2	L2_Left_6	Core_6	L2_Left_10	Core_10	L2_Left_14	Core_14
L2_2	L2_Right_2	L2_6	L2_Right_6	L2_10	L2_Right_10	L2_14	L2_Right_14
L2_Left_1	Core_1	L2_Left_5	Core_5	L2_Left_9	Core_9	L2_Left_13	Core_13
L2_1	L2_Right_1	L2_5	L2_Right_5	L2_9	L2_Right_9	L2_13	L2_Right_13

BLOCK-INSIDE-CORE-TAM

L2_Left_4	Core_4	L2_Left_8	Core_8	L2_Left_12	Core_12	L2_Left_16	Core_16
L2_4	L2_Right_4	L2_8	L2_Right_8	L2_12	L2_Right_12	L2_16	L2_Right_16
L2_Left_3	Core_3	L2_Left_7	Core_7	L2_Left_11	Core_11	L2_Left_15	Core_15
L2_3	L2_Right_3	L2_7	L2_Right_7	L2_11	L2_Right_11	L2_15	L2_Right_15
L2_Left_2	Core_2	L2_Left_6	Core_6	L2_Left_10	Core_10	L2_Left_14	Core_14
L2_2	L2_Right_2	L2_6	L2_Right_6	L2_10	L2_Right_10	L2_14	L2_Right_14
L2_Left_1	Core_1	L2_Left_5	Core_5	L2_Left_9	Core_9	L2_Left_13	Core_13
L2_1	L2_Right_1	L2_5	L2_Right_5	L2_9	L2_Right_9	L2_13	L2_Right_13

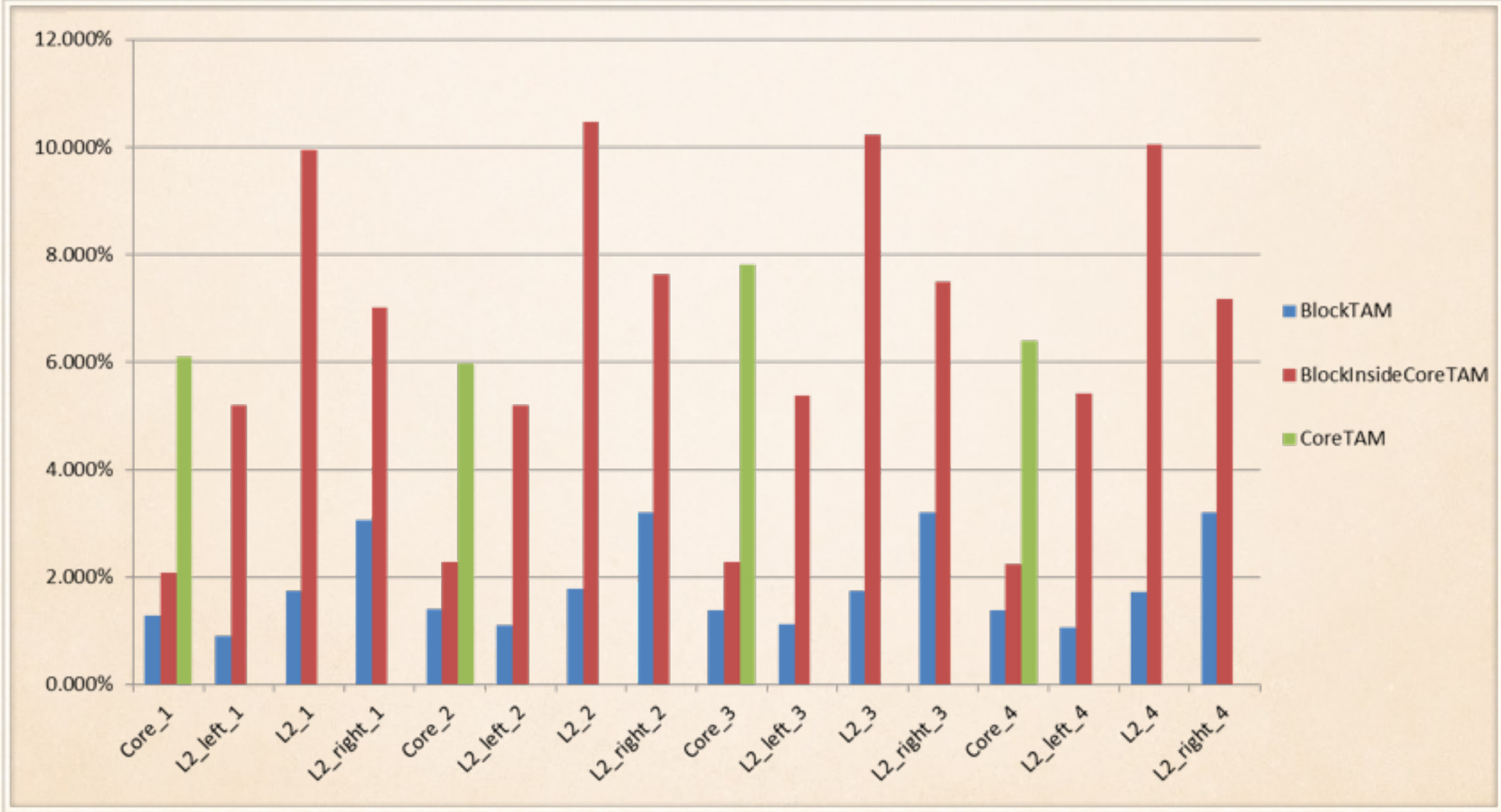
EXPRIMENT VALIDATION

EXPRIMENT VALIDATION

- Analysis accuracy
- Analysis speedup

EXPRIMENT VALIDATION

Accuracy Validation



EXPRIMENT VALIDATION

Speedup Validation

表 5.4　1000组热分析各算法计算耗时及加速倍数X对比

分析算法	HotSpot	BlockTAM	CoreTAM	BlockInsideCoreTAM
T_{Anls}/s	61.301	1.216	0.414	0.927
T_{Totl}/s	61.301	4.663	4.374	4.374
X_{Anls}	BASE	50.416	147.962	66.100
X_{Totl}	BASE	13.147	15.876	14.014

SUMMARY

- An innovative management algorithm
- A DPTM prototype system
- Architecture-level thermal analysis methods