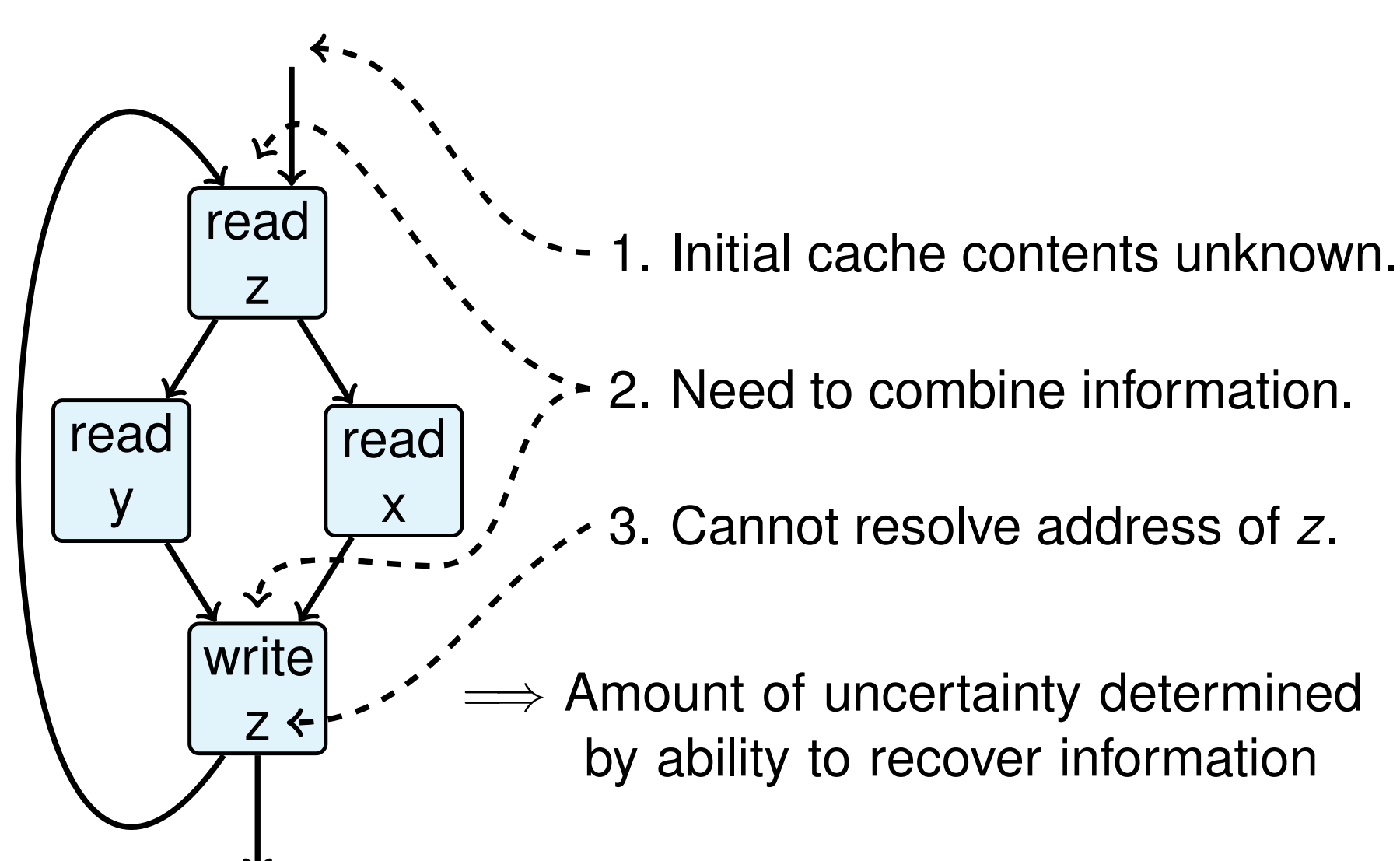


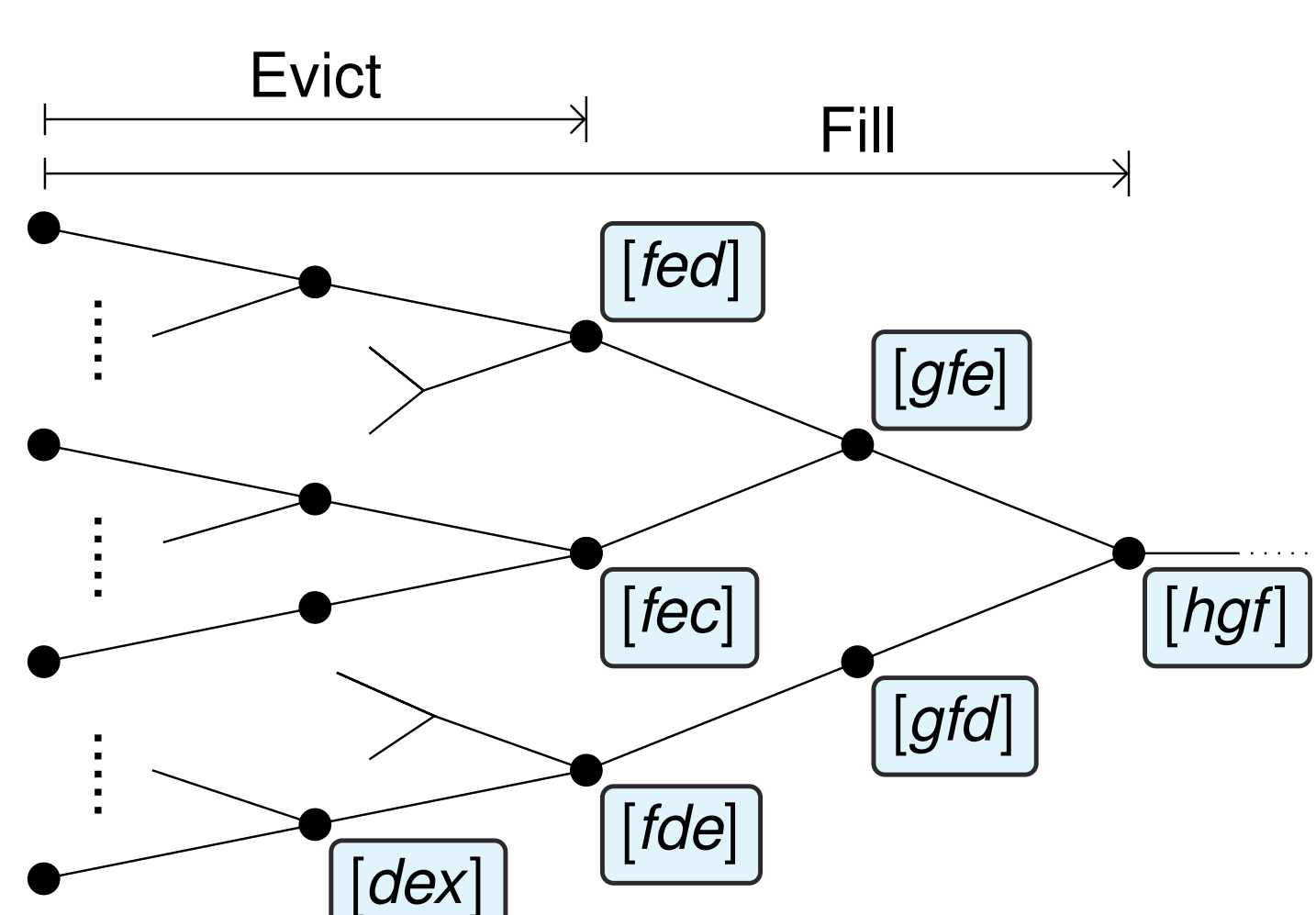
Caches in WCET Analysis

Predictability Limits on the Precision of Cache Analysis

Uncertainty in Cache Analysis



Predictability Metrics



Evaluation of Policies

Policy	Evict(k)	Fill(k)	Evict(8)	Fill(8)
LRU	k	k	8	8
FIFO	2k - 1	3k - 1	15	23
MRU	2k - 2	$\infty/3k - 4$	14	$\infty/20$
PLRU	$\frac{k}{2} \log_2 k + 1$	$\frac{k}{2} \log_2 k + k - 1$	13	19

LRU is optimal wrt. metrics
 FIFO, MRU, PLRU less predictable

→ use LRU

Competitiveness

Cache Analyses for FIFO, PLRU, etc.

Relative Competitiveness

Problem:

Cache Analyses for LRU only

Idea:

Transfer guarantees for LRU to FIFO, PLRU, etc.

Solution:

Relative Competitiveness

Definition (Relative miss competitiveness)

Policy **P** is (k, c) -miss-competitive relative to policy **Q** if

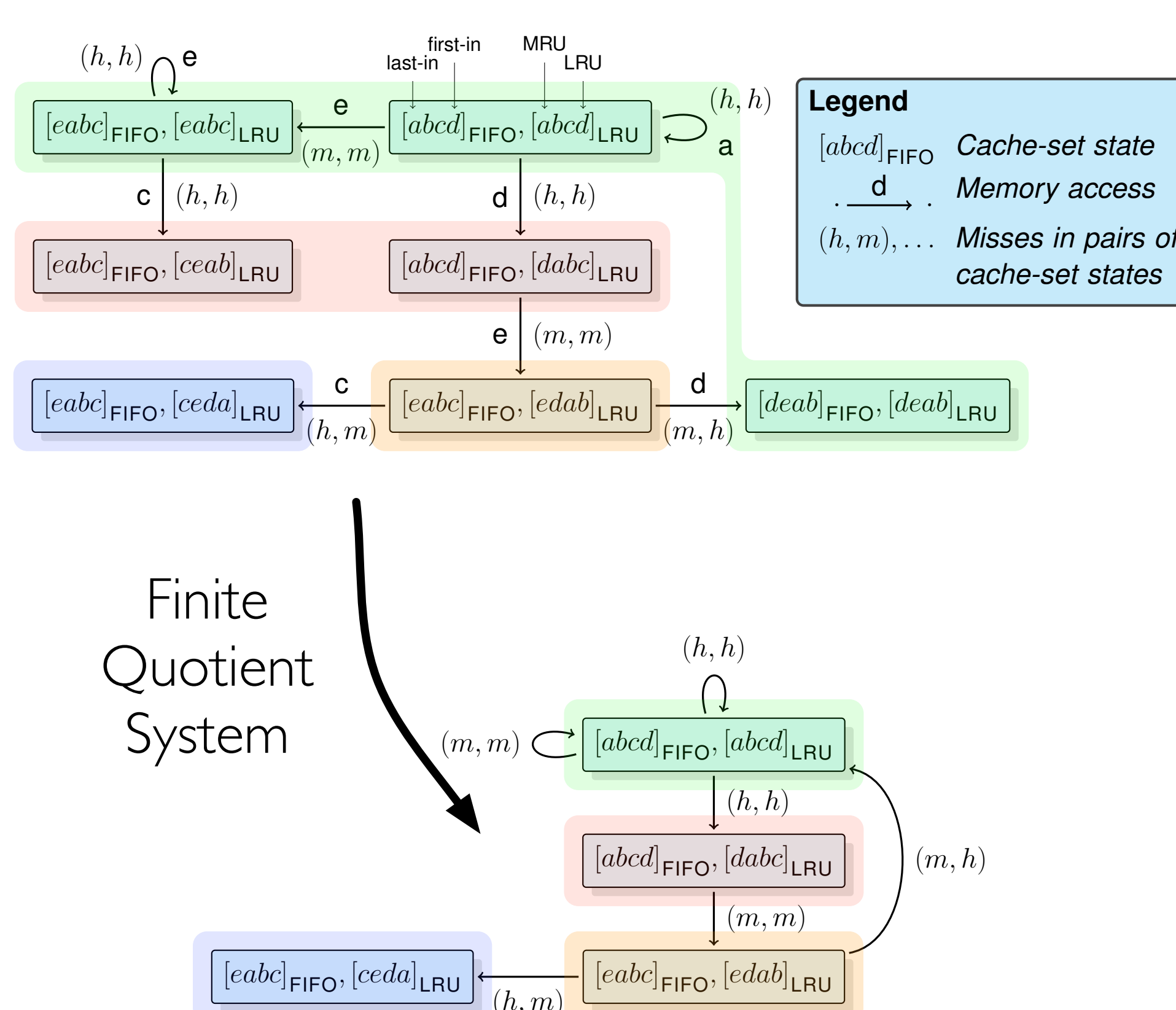
$$m_P(p, s) \leq k \cdot m_Q(q, s) + c$$

for all access sequences $s \in M^*$ and cache-set states $p \in \mathcal{C}^P, q \in \mathcal{C}^Q$ that are compatible $p \sim q$.

Definition (Competitive miss ratio of P relative to Q)

The smallest k , s.t. **P** is (k, c) -miss-competitive rel. to **Q** for some c .

Automatic Computation



Results and Generalizations

Associativity:	2	3	4	5	6	7	8
LRU vs FIFO	2,1	3,2	4,3	5,4	6,5	7,6	8,7
LRU vs PLRU	1,0	-	2,1	-	-	-	5,4
LRU vs MRU	1,0	2,1	3,2	4,3	5,4	6,5	7,6
FIFO vs LRU	2,1	3,2	4,3	5,4	6,5	7,6	8,7
FIFO vs PLRU	2,1	-	4,4	-	-	-	8,8
FIFO vs MRU	2,1	3,3	4,4	5,5	6,6	MEM	MEM
PLRU vs LRU	1,0	-	∞	-	-	-	∞
PLRU vs FIFO	2,1	-	∞	-	-	-	∞
PLRU vs MRU	1,0	-	∞	-	-	-	MEM
MRU vs LRU	1,0	2,1	3,2	4,3	5,4	6,5	7,6
MRU vs FIFO	2,1	4,3	6,5	8,7	10,9	MEM	MEM
MRU vs PLRU	1,0	-	4,3	-	-	-	MEM

PLRU(k) is (1,0) comp. rel. to LRU(1 + log₂k),
 → LRU-must-analysis can be used for PLRU

FIFO(k) is ($\frac{1}{2}, \frac{k-1}{2}$) hit-comp. rel. to LRU(k), whereas
 LRU(k) is (0,0) hit-comp. rel. to FIFO(k), but

LRU(2k - 1) is (1,0) comp. rel. to FIFO(k), and
 LRU(2k - 2) is (1,0) comp. rel. to MRU(k).
 → LRU-may-analysis can be used for FIFO and MRU
 → optimal with respect to predictability metric Evict

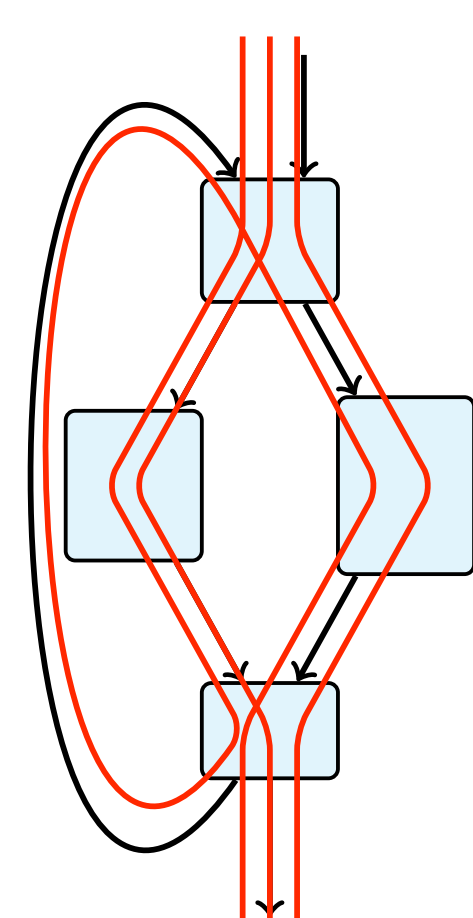
Sensitivity Caches in Measurement-based WCET Analysis

Measurement-based WCET Analysis

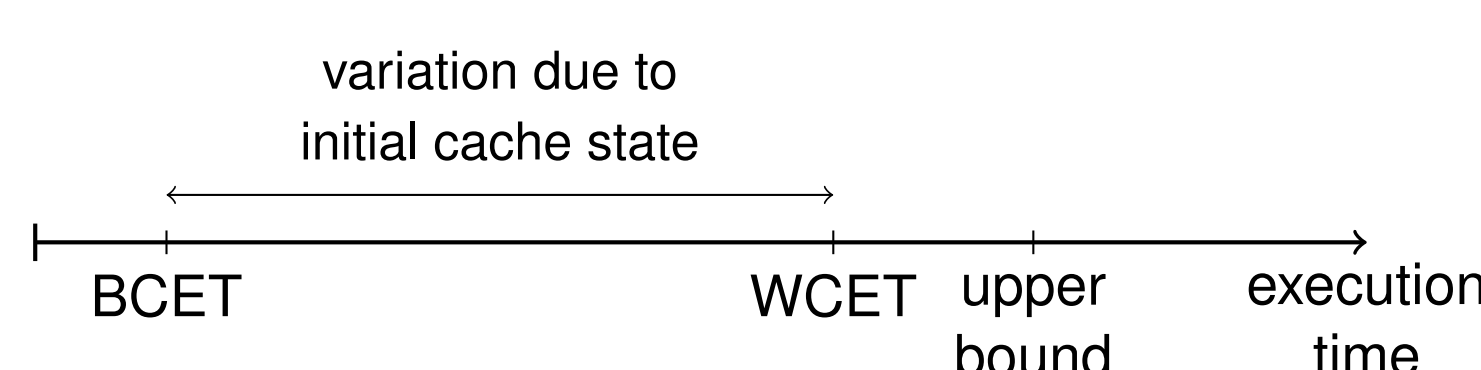
1. Measure execution times of basic blocks

2. Combine measurements for basic blocks to obtain estimate of WCET

How wrong can this get?



Influence of Initial State



Definition (Miss sensitivity)

Policy **P** is (k, c) -miss-sensitive if

$$m_P(p, s) \leq k \cdot m_P(p', s) + c$$

for all access sequences $s \in M^*$ and cache-set states $p, p' \in \mathcal{C}^P$.

Sensitivity Results

Policy	2	3	4	5	6	7	8
LRU	1,2	1,3	1,4	1,5	1,6	1,7	1,8
FIFO	2,2	3,3	4,4	5,5	6,6	7,7	8,8
PLRU	1,2	-	∞	-	-	-	∞
MRU	1,2	3,4	5,6	7,8	MEM	MEM	MEM

LRU is optimal:
 minimal influence of initial state
 FIFO, MRU, PLRU:
 great influence of initial state

References:

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- Jan Reineke, Daniel Grund, Christoph Berg, and Reinhard Wilhelm: Timing predictability of cache replacement policies. Real-Time Systems, 37(2):99-122, November 2007.

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