# AMP: Program-Context Specific Buffer Caching

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# Buffer caching beyond LRU

- Buffer cache speeds up file reads by caching file content
- LRU performs *badly* for large looping accesses

$\boxed{2\ 3\ 4}$

*miss*

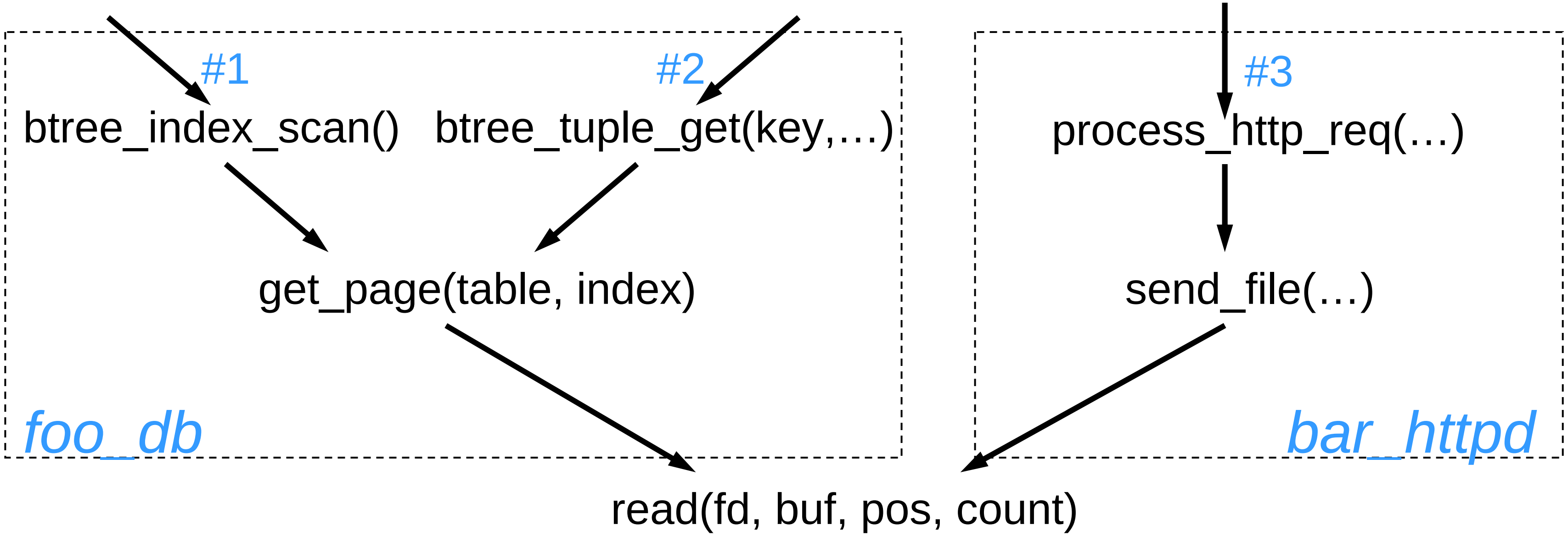
Access stream: 1 1 2 3 4 , Cache Size: 3

0 Hit Rate for any loop over data set larger than cache size

- DB, IR, scientific apps often suffer from this
- Recent work
  - Utilizing frequency: ARC (Megiddo & Modha 03), CAR (Bansal & Modha 04)
  - Detection: UBM (Kim et al. 00), DEAR (Choi et al. 99), PCC (Gniady et al. 04)

# Program Context (PC)

- Program context: current program counter + all return addresses on the call stack




Ideal policies

#1: MRU for loops

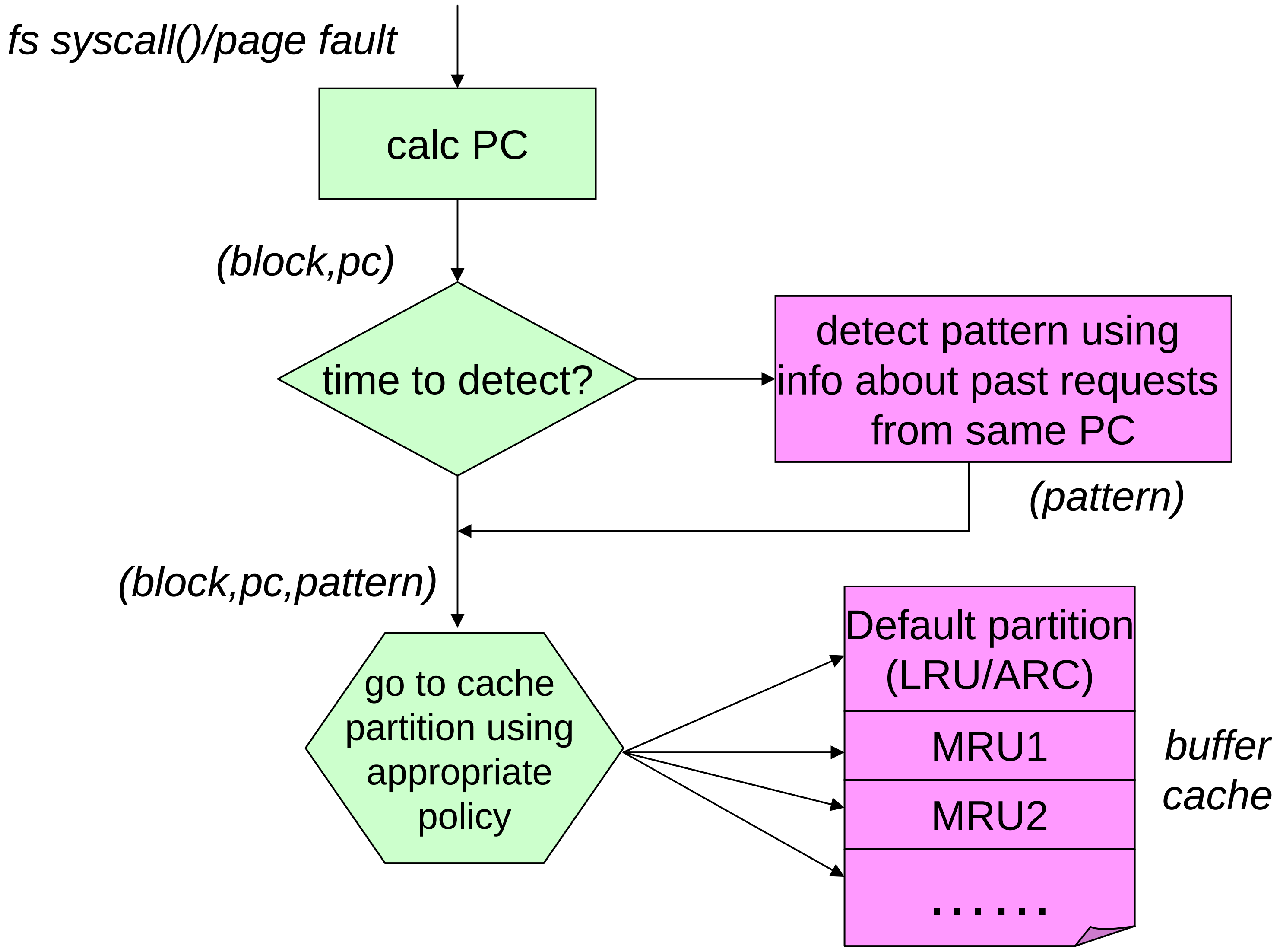
#2, #3: LRU/ARC for all others

# Contributions of AMP

- PC-specific organization that treats requests from different *program contexts* differently*
- Robust looping pattern detection algorithm
  - reliable with irregularities
- Randomized partitioned cache management scheme
  - much cheaper than previous methods

** Same idea is developed concurrently by Gniady et al (PCC at OSDI'04)*

# Adaptive Multi-Policy Caching (AMP)

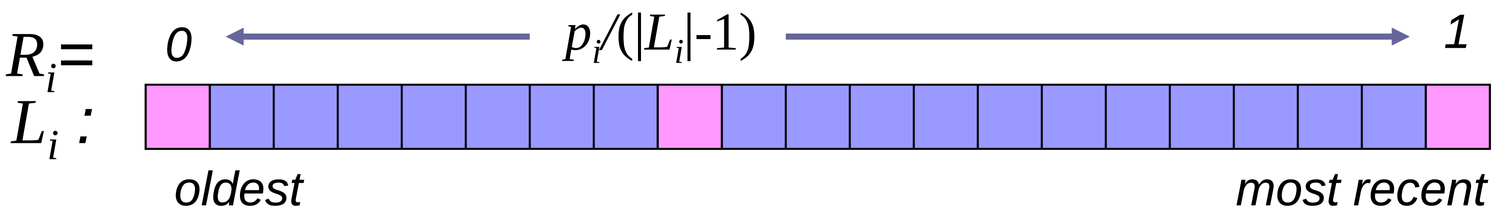


# Looping pattern detection

- Intuition:
  - Looping streams always access blocks that has not been accessed for the longest period of time, i.e. the *least recently used* blocks.
    1 2 3 1 2 3
  - Streams with locality (temporally clustered streams) access blocks that has been accessed recently, i.e. *recently used* blocks.
    1 2 3 3 4 3 4
- What AMP does: measure a metric we call *average access recency* of all block accesses

# Loop detection scheme

- For the $i$-th access
  - $L_i$: list of all previously accessed blocks, ordered from the oldest to the most recent by their last access time.
  - $p_i$: position in $L_i$ of the block accessed ($0$ to $|L_i|-1$)
  - Access recency: $R_i=p_i/(|L_i|-1)$



# Loop detection scheme cont.

- *Average access recency* $\overline{R} = avg(R_i)$
- Detection result:
  - *loop*, if $\overline{R} < T_{loop}$ (e.g. 0.4)
  - *temporally clustered*, if $\overline{R} > T_{tc}$ (e.g. 0.6)
  - *others*, o.w. (near 0.5)
- Sampling to reduce space and computational overhead

# Example: loop

- Access stream: [1 2 3 1 2 3]

| $i$ | block | $L_i$ | $p_i$ | $R_i$ |
|---|---|---|---|---|
| 1 | 1 | empty | $\perp$ | $\perp$ |
| 2 | 2 | 1 | $\perp$ | $\perp$ |
| 3 | 3 | 1 2 | $\perp$ | $\perp$ |
| 4 | 1 | 1 2 3 | 0 | 0 |
| 5 | 2 | 2 3 1 | 0 | 0 |
| 6 | 3 | 3 1 2 | 0 | 0 |

- $\overline{R}$ =0, detected pattern is *loop*

# Example: non-loop

- Access stream: [1 2 3 4 4 3 4 5 6 5 6], $\overline{R}$ =0.79

| $i$ | block | $L_i$ | $p_i$ | $R_i$ |
|---|---|---|---|---|
| 1 | 1 | empty | $\perp$ | $\perp$ |
| 2 | 2 | 1 | $\perp$ | $\perp$ |
| 3 | 3 | 1 2 | $\perp$ | $\perp$ |
| 4 | 4 | 1 2 3 | $\perp$ | $\perp$ |
| 5 | 4 | 1 2 3 4 | 3 | 1 |
| 6 | 3 | 1 2 3 4 | 2 | 0.667 |
| 7 | 4 | 1 2 4 3 | 2 | 0.667 |
| 8 | 5 | 1 2 3 4 | $\perp$ | $\perp$ |
| 9 | 6 | 1 2 3 4 5 | $\perp$ | $\perp$ |
| 10 | 5 | 1 2 3 4 5 6 | 4 | 0.8 |
| 11 | 6 | 1 2 3 4 6 5 | 0 | 0.8 |

# Randomized Cache Partition Management

- Need to decide cache sizes devoted to each PC
- Marginal gain (MG)
  - the expected number of extra hits over unit time if one extra block is allocated
  - Local optimum when every partition has the same MG
- Randomized scheme
  - Expand the default partition by one if ghost buffer hit
  - Expand an MRU partition by one every *loop_size/ghost_buffer_size* accesses to the partition
  - Expansion is done by taking a block from a random other part.
- Compared to UBM and PCC
  - O(1) and does not need to find smallest MG

# Robustness of loop detection

| | | | | | | | |
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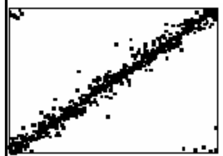
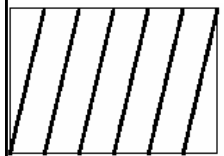
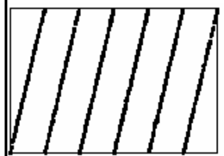
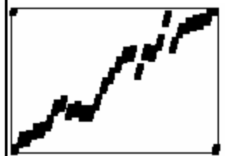
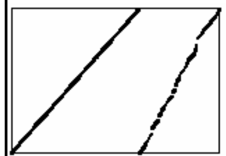
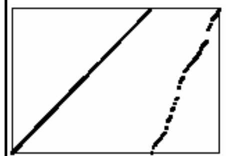
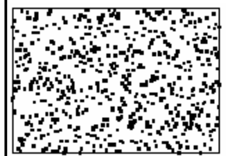
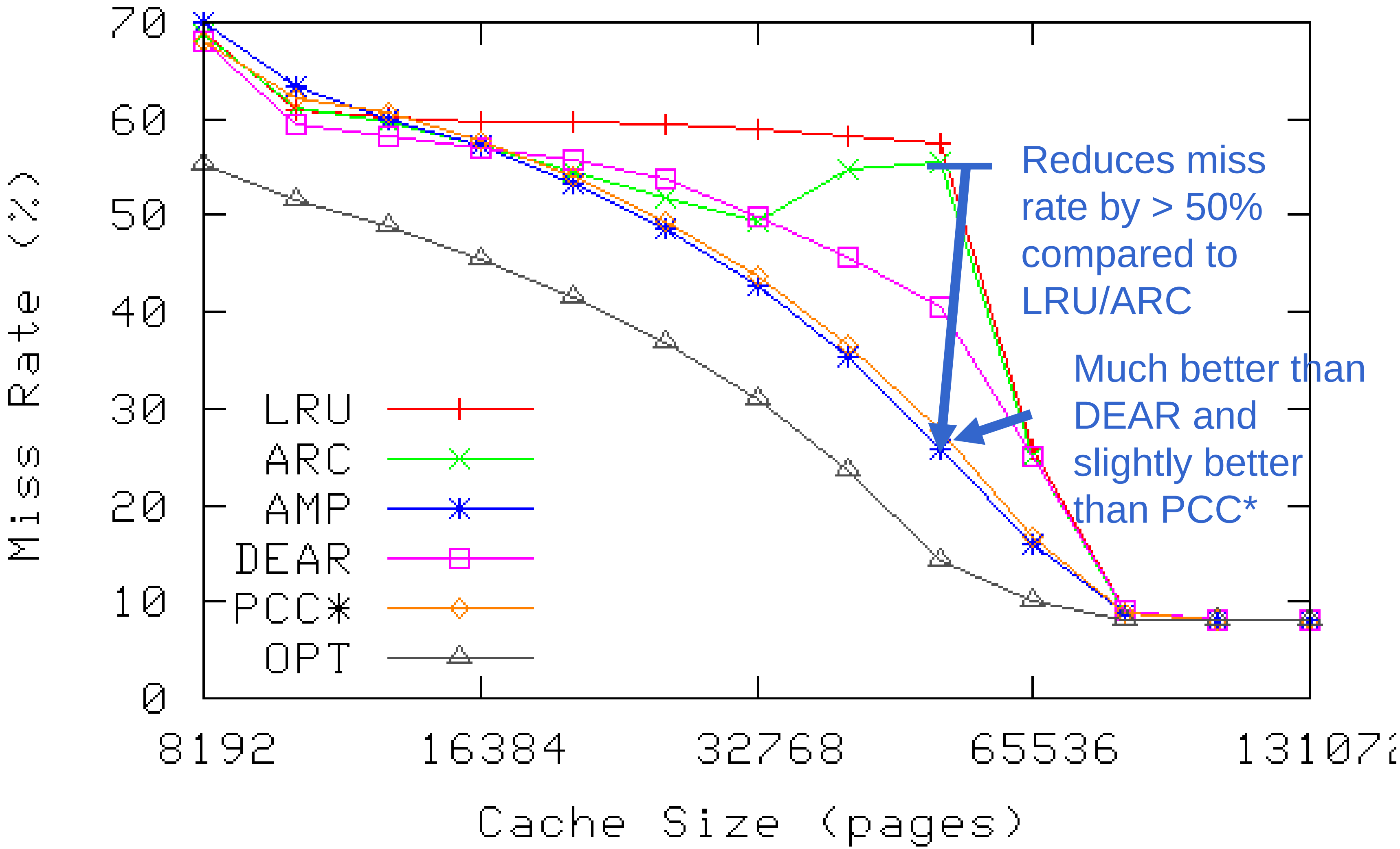
| |  |  |  |  |  |  |  |
| AMP $\overline{R}$ | tc 0.755 | loop 0.001 | loop 0.347 | tc 0.617 | loop 0.008 | loop 0.010 | other 0.513 |
| DEAR | other | loop | *other* | other | loop | *other* | other |
| PCC | *loop* | loop | loop | *loop* | loop | *other* | *loop* |

"tc"=temporally clustered

Colored detection results are wrong

Classifying *tc* as *other* is deemed correct.

# Simulation: *dbt3 (tpc-h)*



# Implementation

- Kernel patch for Linux 2.6.8.1
- Shortens time to index Linux source code using glimpseindex by up to 13% (read traffic down 43%)
- Shortens time to complete DBT3 (tpc-h) DB workload by 9.6% (read traffic down 24%)

- http://www.cs.berkeley.edu/~zf/amp
- Tech report
- Linux implementation
- General buffer cache simulator