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Storage Efficient Hardware Prefetching using Delta Correlating Prediction Tables

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Feb 14th 2008

Delta Correlating Prefetch Tables

- Perez et al. did a comparative survey of hardware prefetchers in 2004.
  - Reference Prediction Tables and PC/DC using a Global History Buffer
- Delta Correlating Prediction Tables **combines** these two approaches and adds extra control for avoiding duplicate prefetching.
- Perez et al. also found that you can make **anything** look good provided the right benchmarks and parameters.

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Prefetcher Overview

Sequential RPT PC/DC DCPT

Prefetcher Overview

	Sequential	RPT	PC/DC	DCPT
Sequential				

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Prefetcher Overview

	Sequential	RPT	PC/DC	DCPT
Sequential	✓	✓	✓	✓
Constant Stride	✗	✓	✓	✓

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Prefetcher Overview

	Sequential	RPT	PC/DC	DCPT
Sequential	✓	✓	✓	✓
Constant Stride	✗	✓	✓	✓
Repeating Pattern	✗	✗	✓	✓

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Prefetcher Overview

	Sequential	RPT	PC/DC	DCPT
Sequential	✓	✓	✓	✓
Constant Stride	✗	✓	✓	✓
Repeating Pattern	✗	✗	✓	✓
Complexity	⊕⊕	⊕	⊖⊖	⊖

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Prefetcher Overview

	Sequential	RPT	PC/DC	DCPT
Sequential	✓	✓	✓	✓
Constant Stride	✗	✓	✓	✓
Repeating Pattern	✗	✗	✓	✓
Complexity	++	+	−−	−
Delay	++	++	−−	+

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Prefetcher Overview

	Sequential	RPT	PC/DC	DCPT
Sequential	✓	✓	✓	✓
Constant Stride	✗	✓	✓	✓
Repeating Pattern	✗	✗	✓	✓
Complexity	++	+	−−	−
Delay	++	++	−−	+
Storage Efficiency		+	−	+

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Outline

- Motivation
- Reference Prediction Tables
  - Properties of RPT prefetching
- PC/DC Prefetching
  - Global History Buffer
  - Delta Correlation
  - Properties of PC/DC prefetching
- Delta Correlating Prefetch Tables
- DCPT Properties
- Results
- Concluding Remarks

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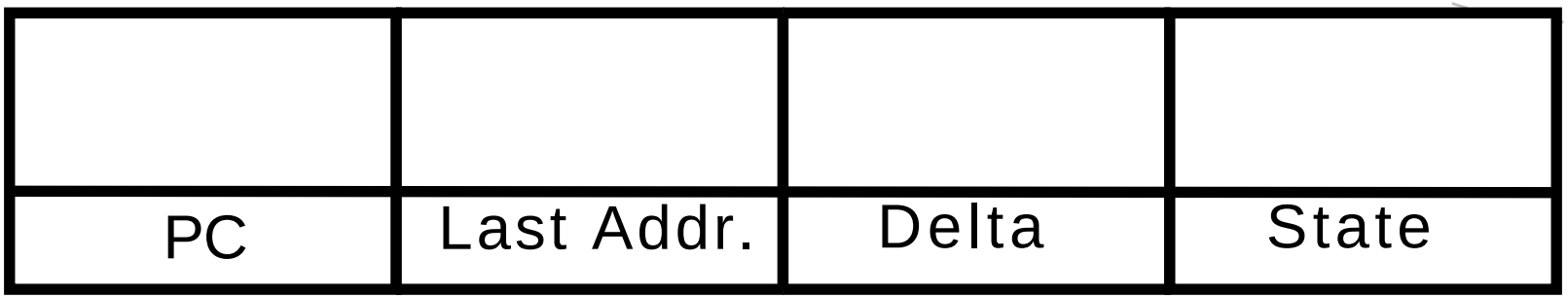
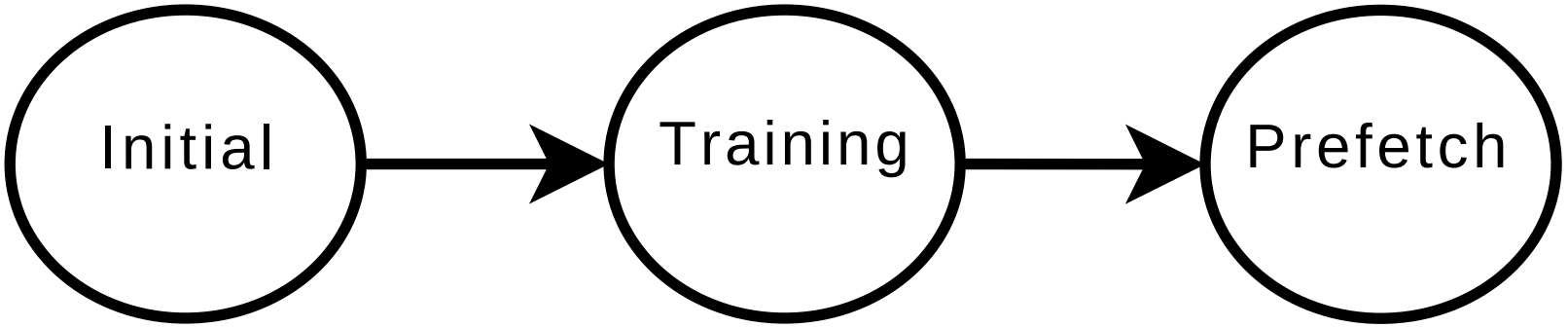
Reference Prediction Tables

Cache Miss:

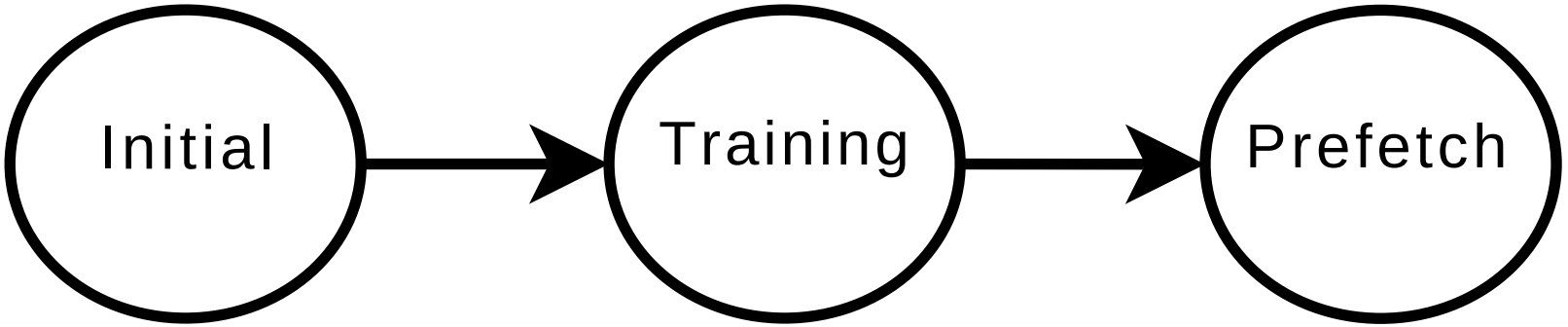




Reference Prediction Tables

Cache Miss: 1

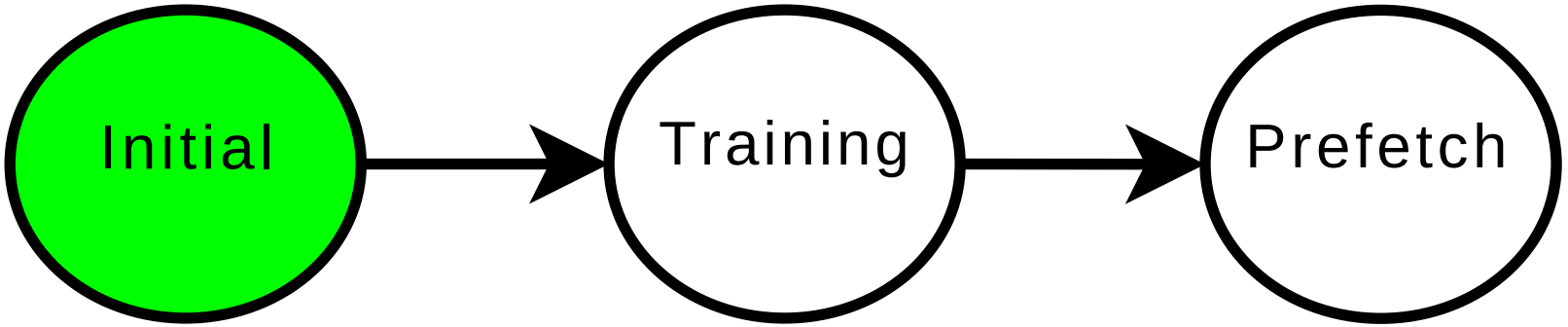
PC	Last Addr.	Delta	State



Reference Prediction Tables

Cache Miss: 1

PC	Last Addr.	Delta	State
100	1	--	Init



Reference Prediction Tables

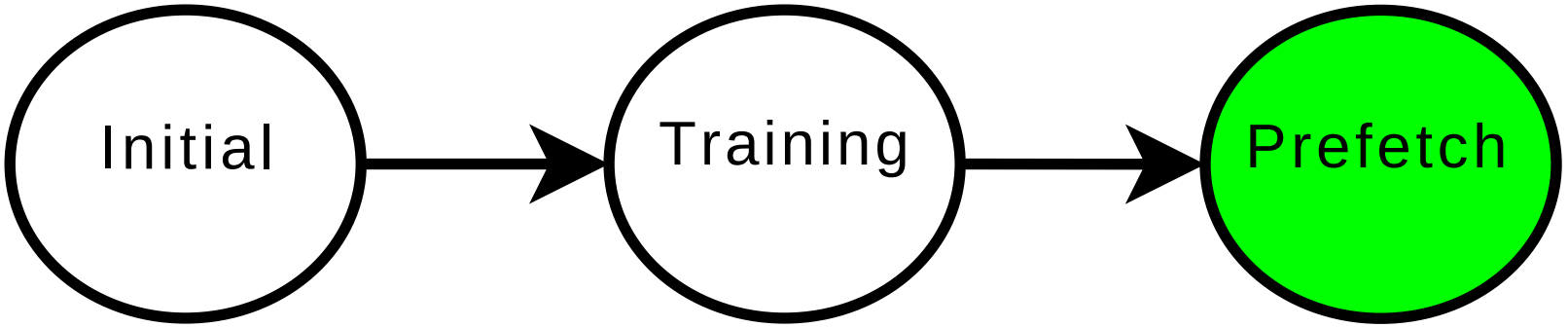
Cache Miss: 1 3

100	3 1	2 --	Train
PC	Last Addr.	Delta	State

Reference Prediction Tables

Cache Miss: 1 3 5

PC	Last Addr.	Delta	State
100	5 3	2 2	Prefetch



Properties of RPT prefetching

- Very high accuracy
- Relatively low cost - Table lookup, comparator and subtraction
- Small memory footprint
- Only able to capture constant strides

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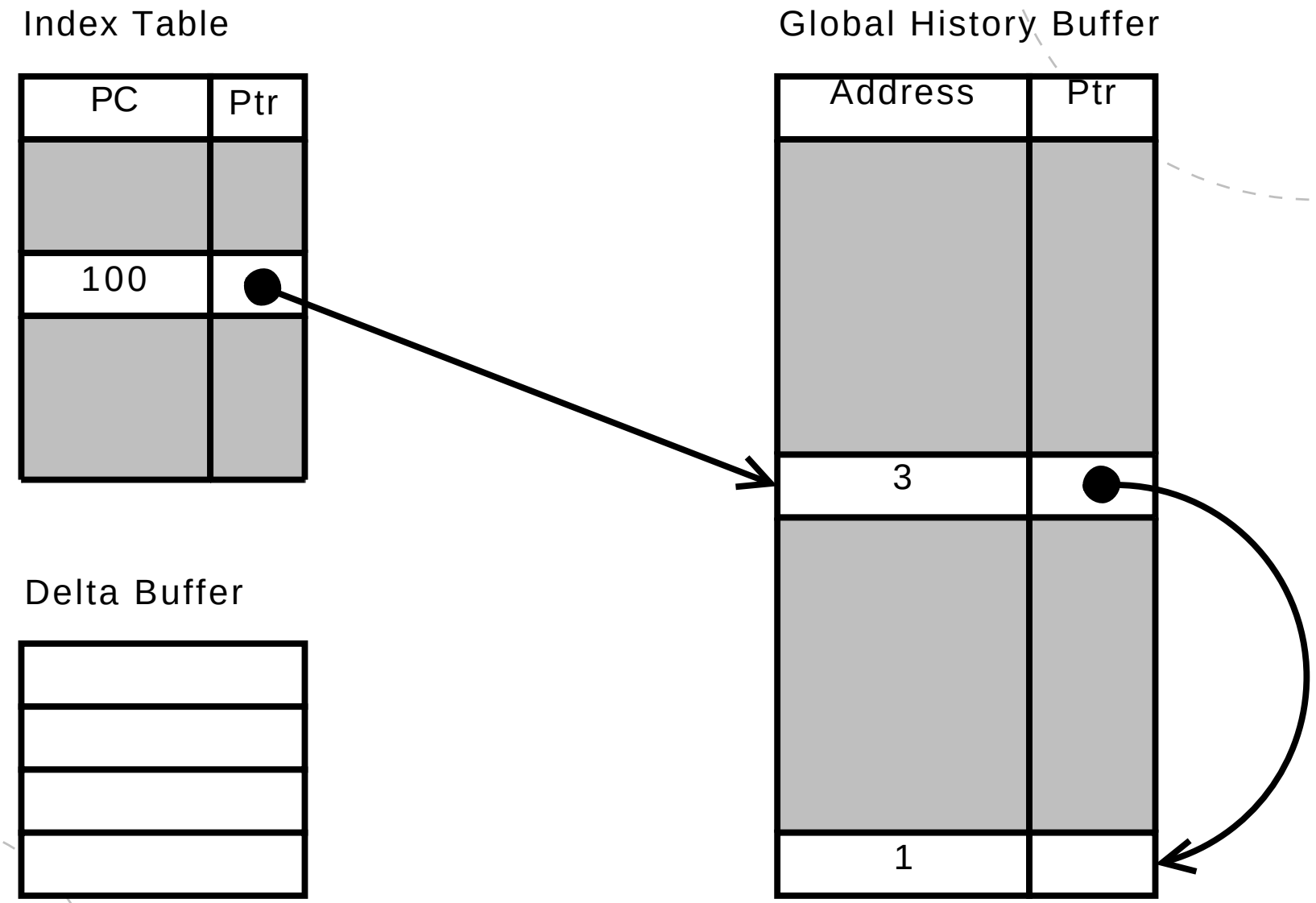
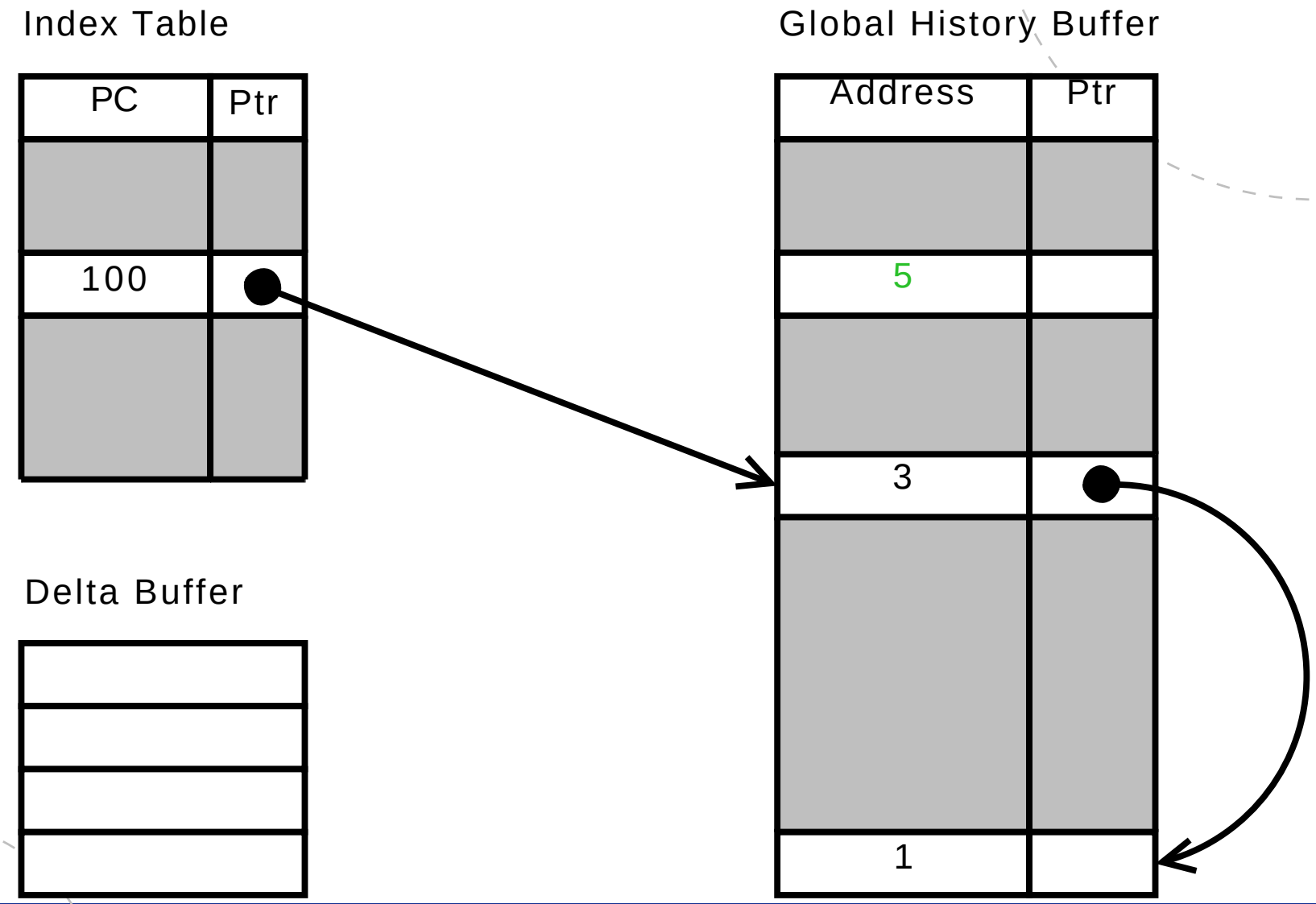
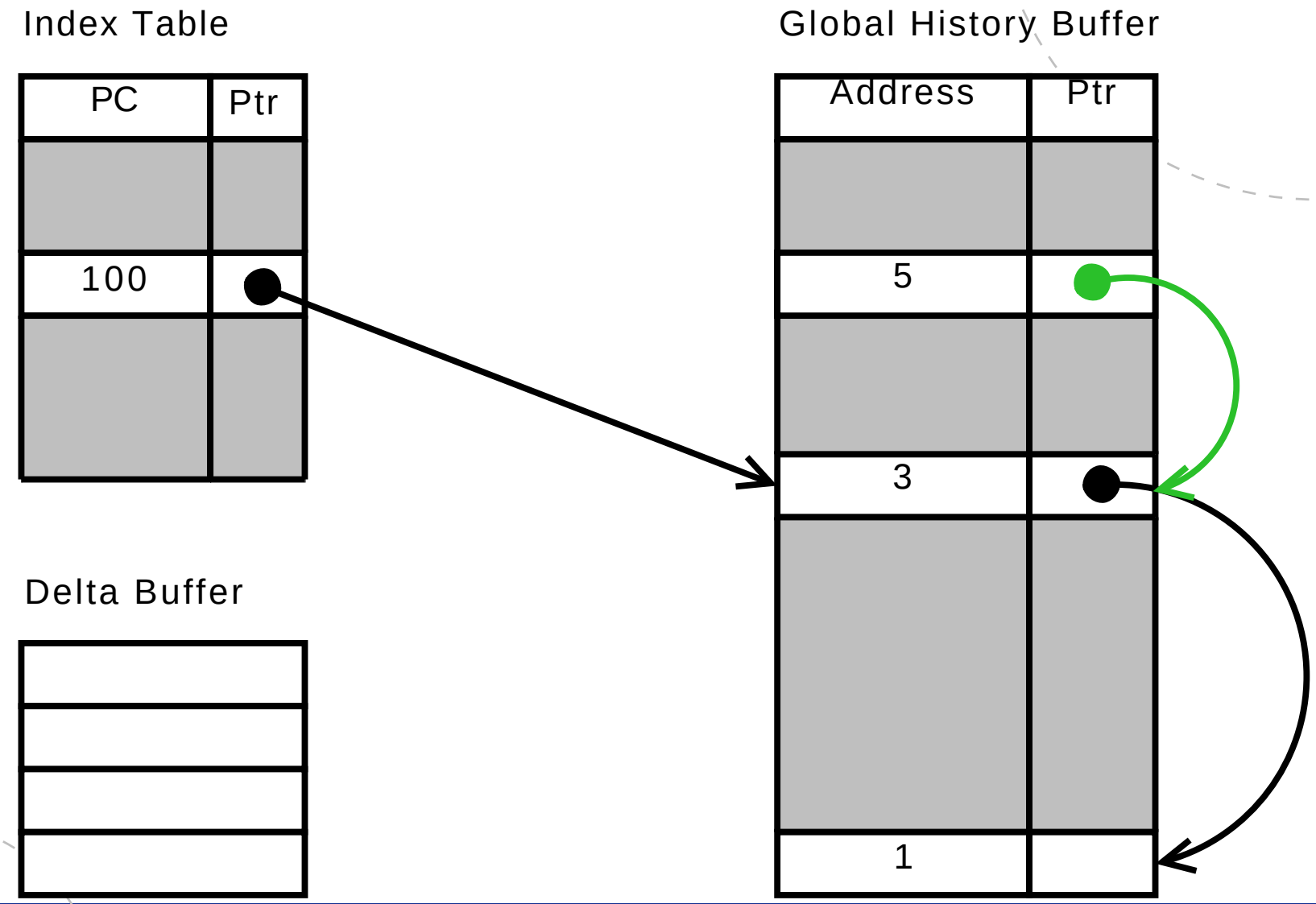
Global History Buffer



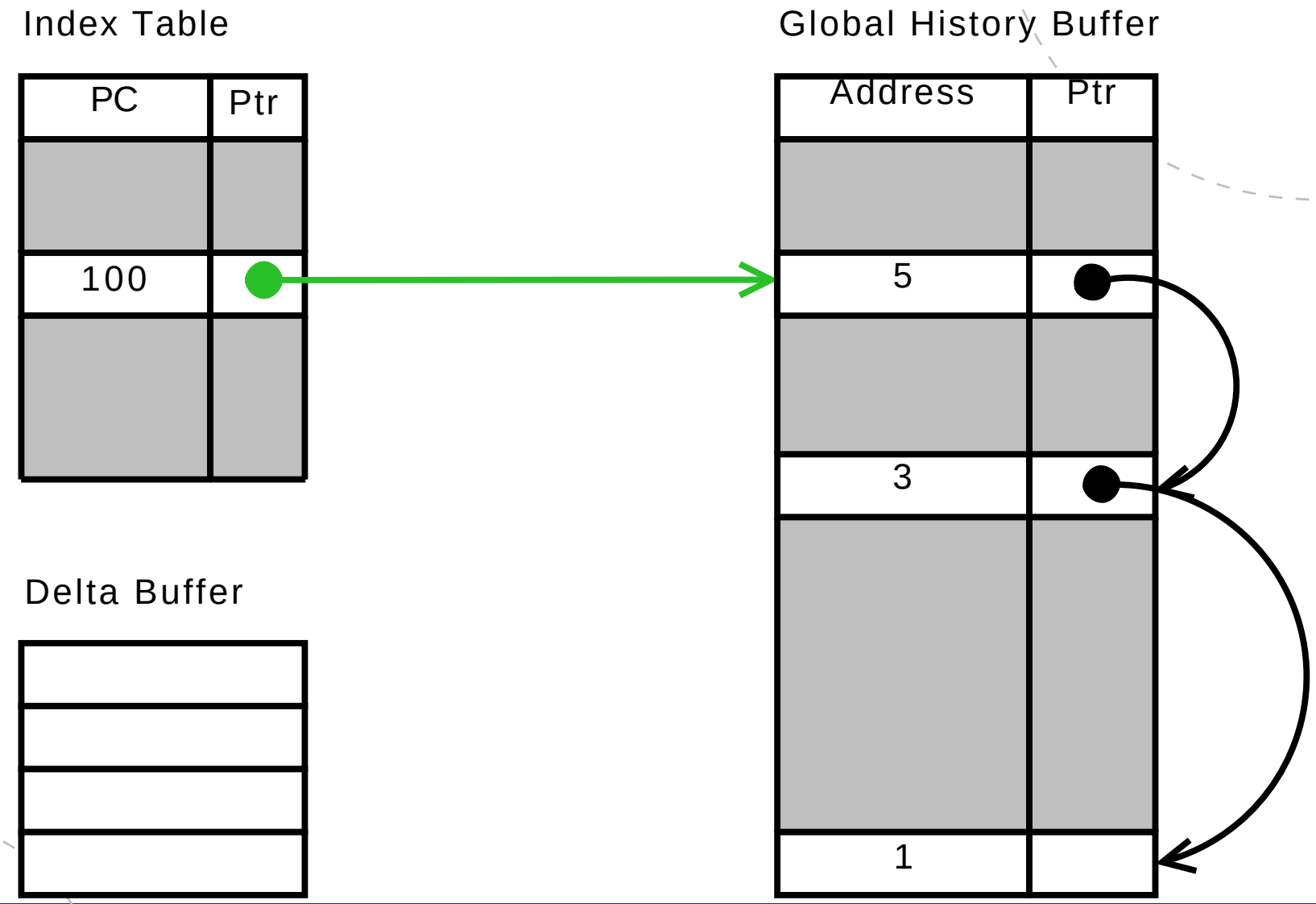
Global History Buffer



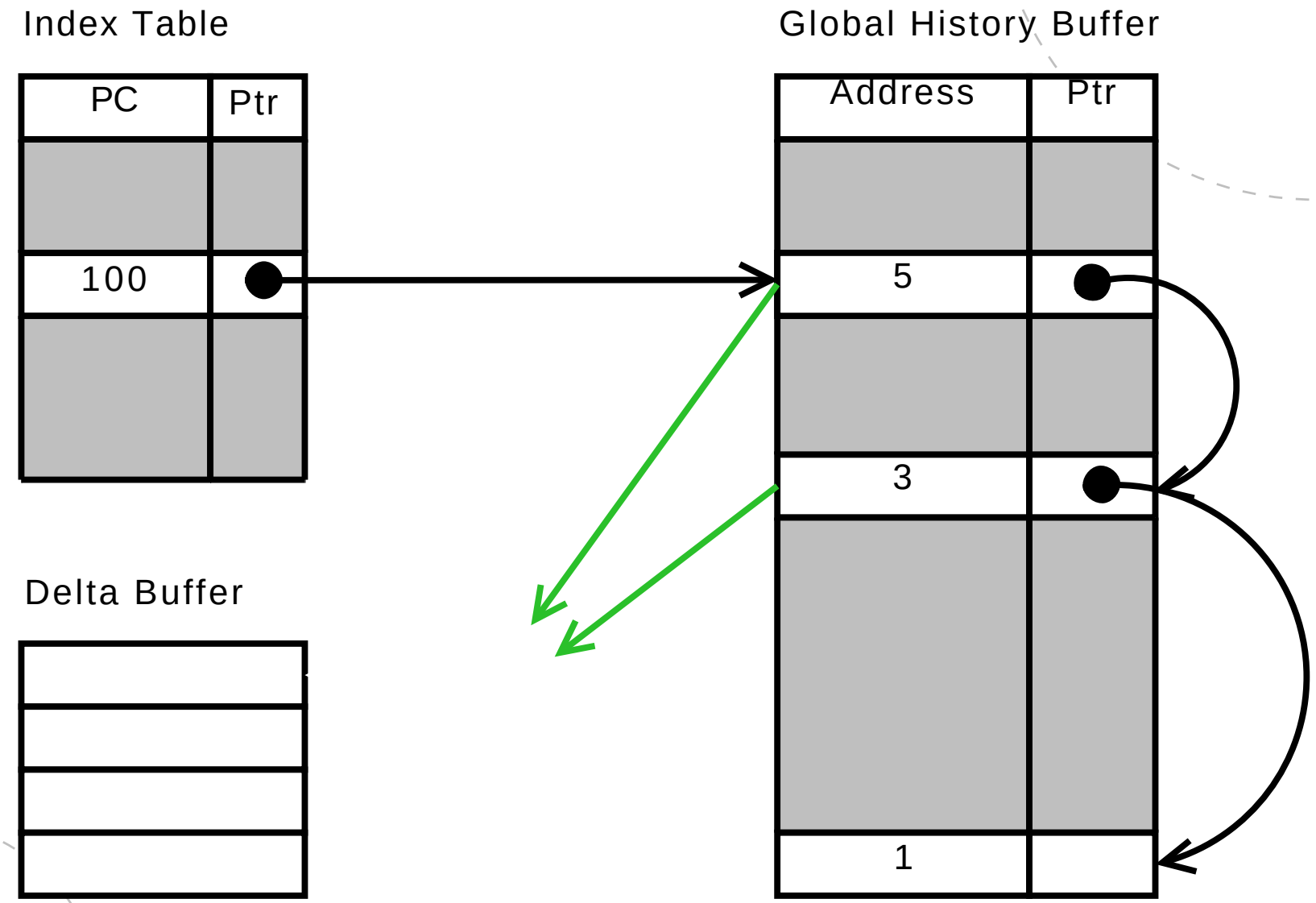
Global History Buffer



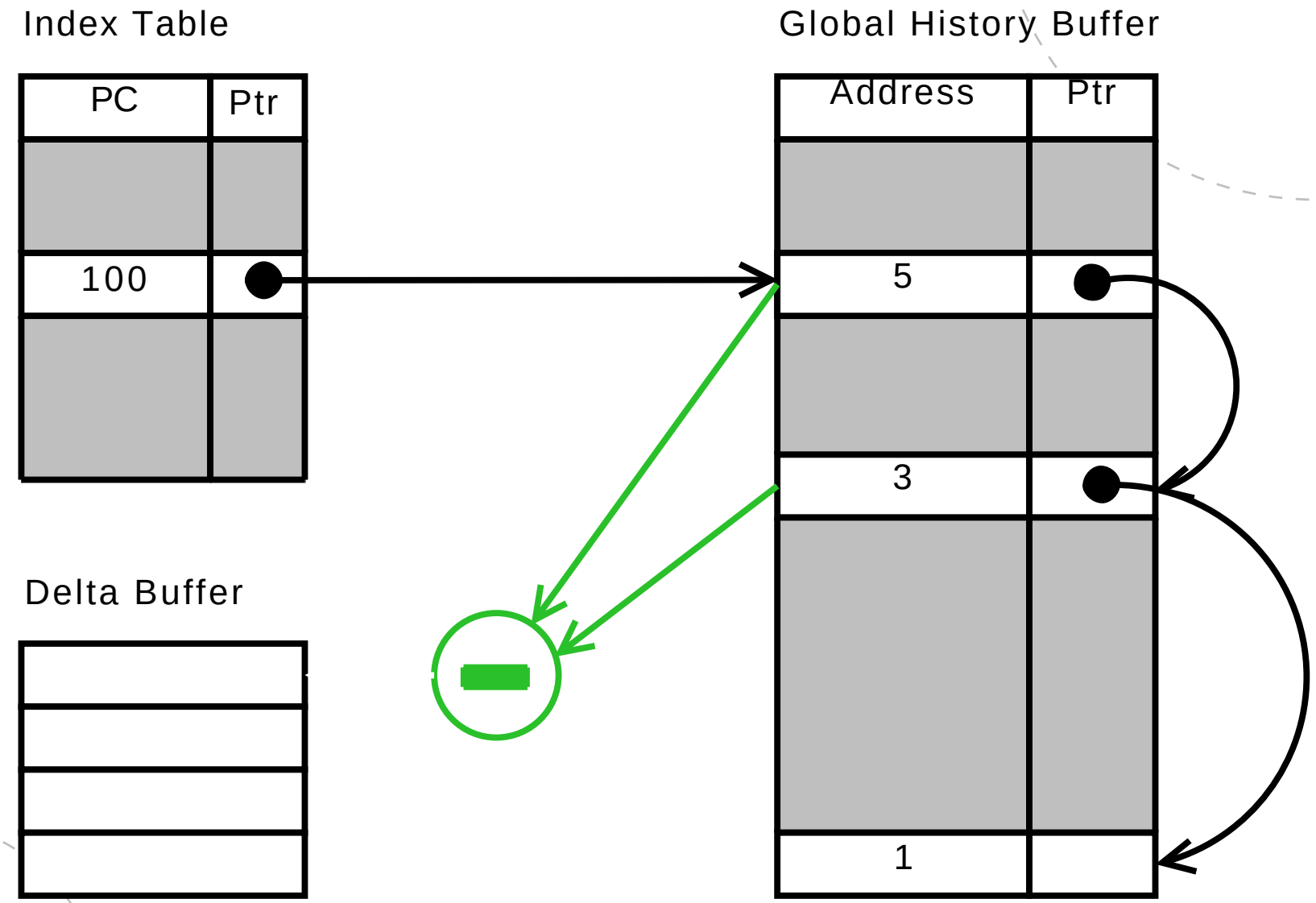
Global History Buffer



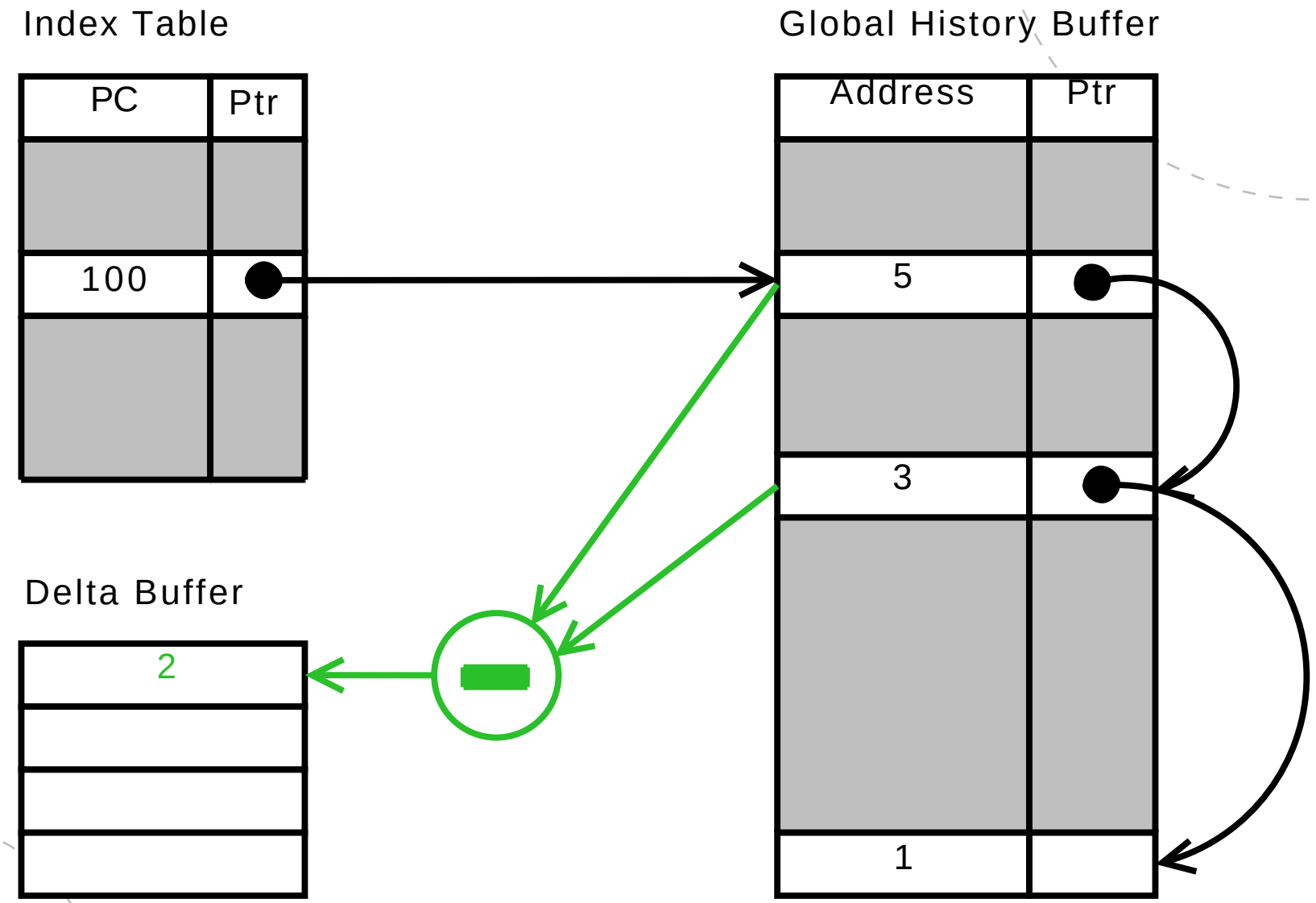
Global History Buffer



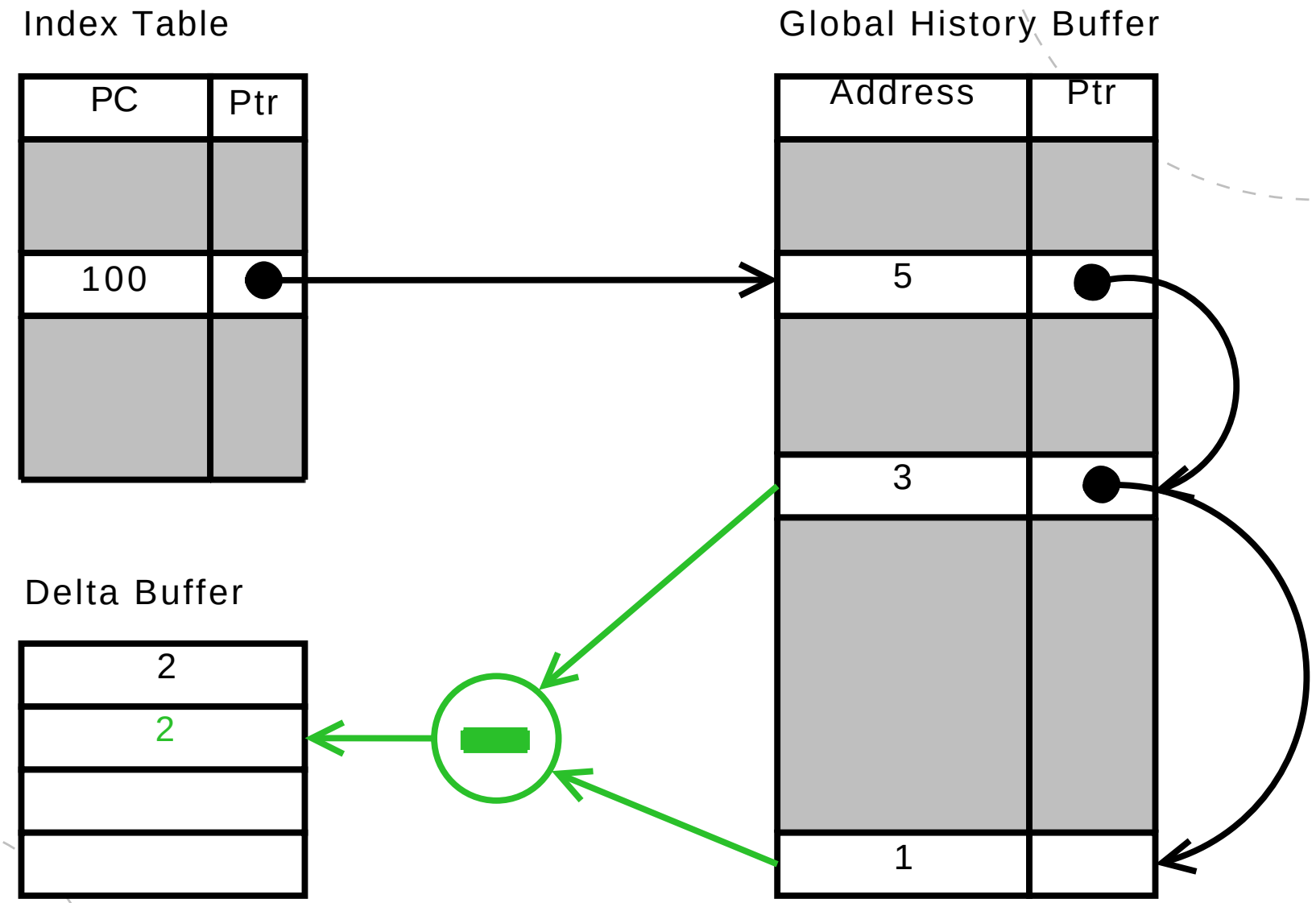
Global History Buffer



Global History Buffer



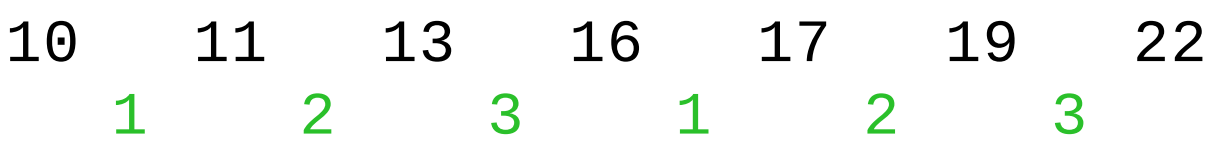
Global History Buffer



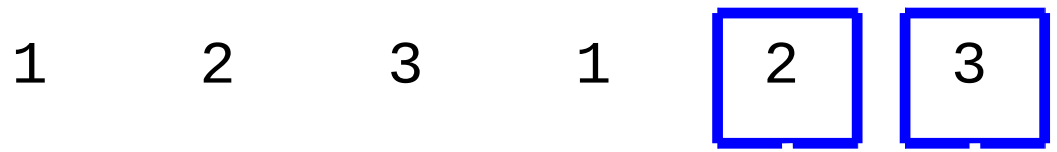
Delta Correlation

```
10    11    13    16    17    19    22
```

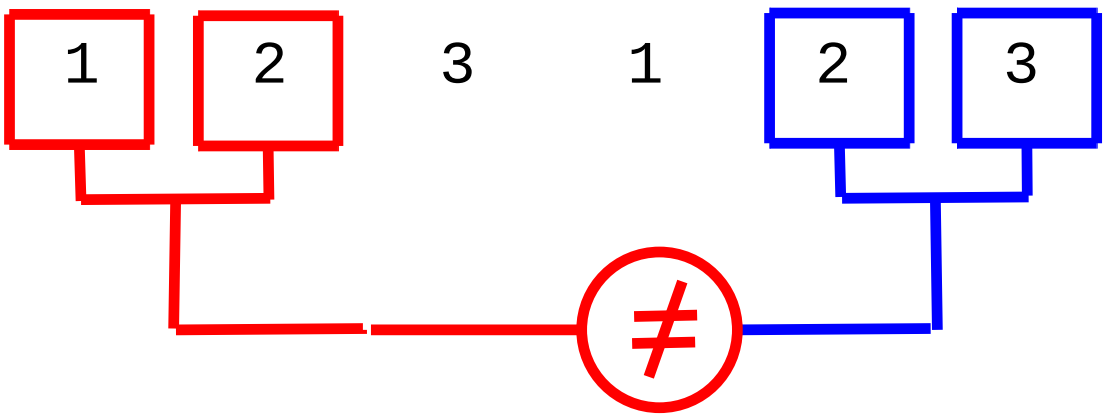
Delta Correlation



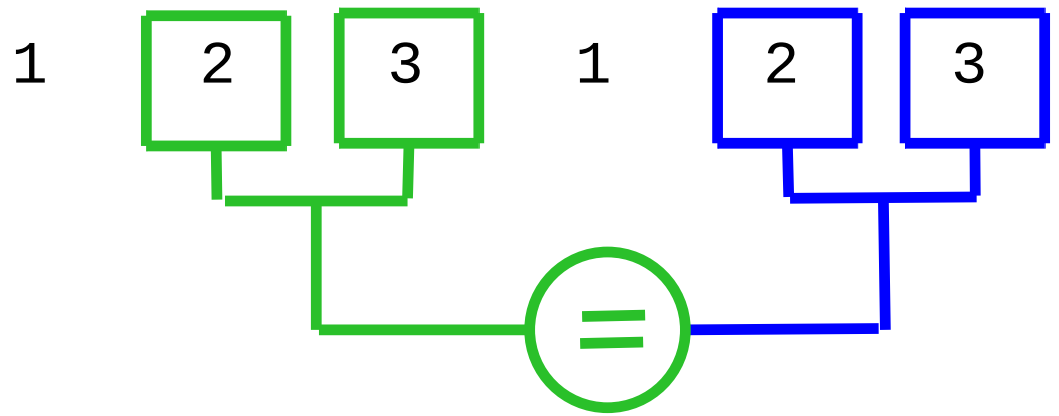
Delta Correlation



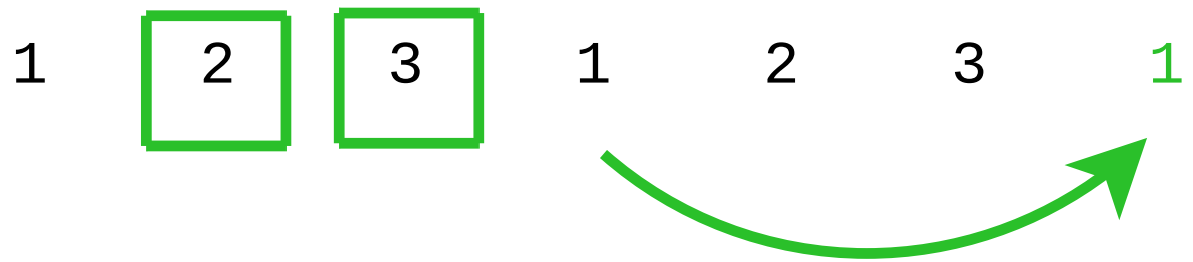
Delta Correlation



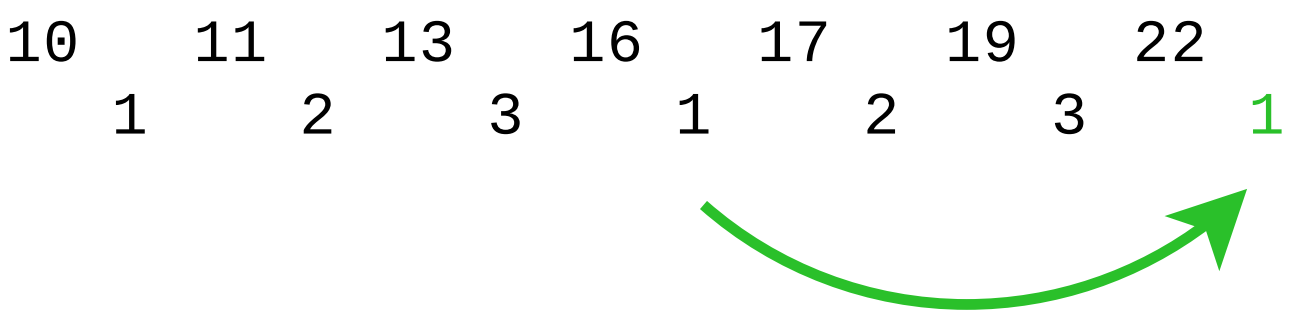
Delta Correlation



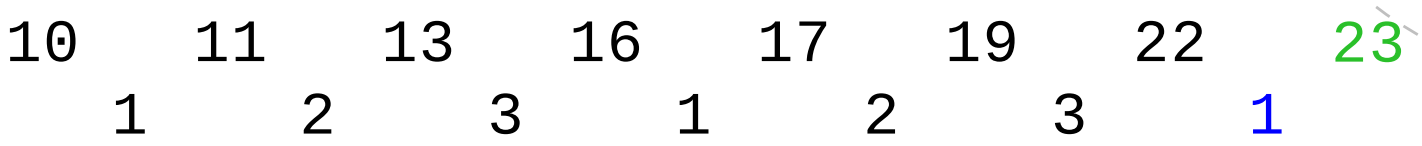
Delta Correlation



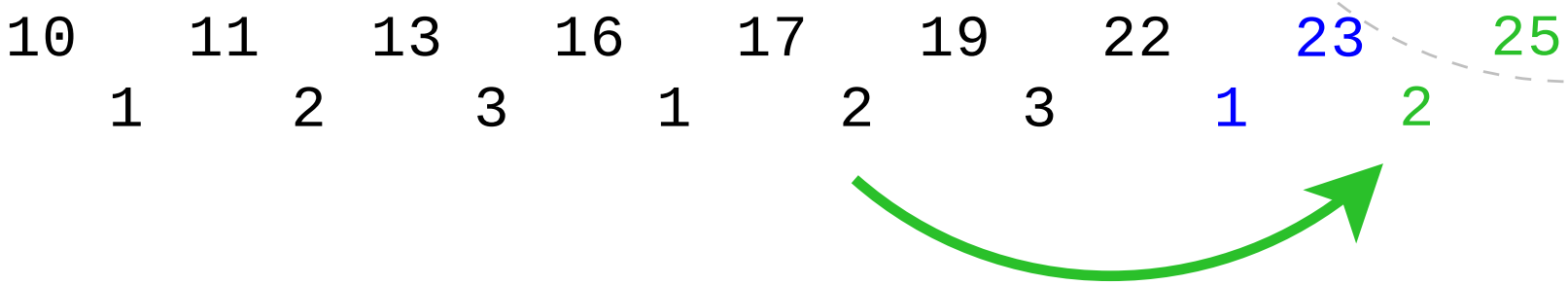
Delta Correlation



Delta Correlation



Delta Correlation



Properties of PC/DC prefetching

- Can capture a very wide range of patterns
- High accuracy and performance
- The global history must be very large to capture relevant data
- Pointer chasing
- The deltas are recalucated every time
- The number of deltas can vary

Delta Correlating Prefetch Tables

PC	Last Addr.	Last Pref.	D	D	D	D	D	D	Ptr

Delta Correlating Prefetch Tables

10

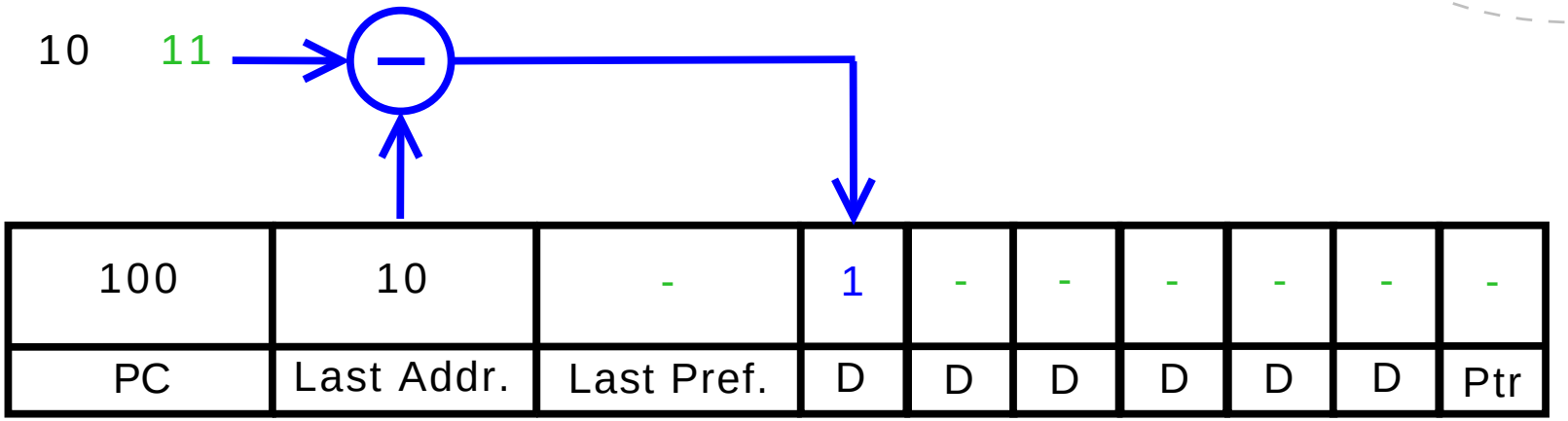
100	10	-	-	-	-	-	-	-	-
PC	Last Addr.	Last Pref.	D	D	D	D	D	D	Ptr

Delta Correlating Prefetch Tables

10 11

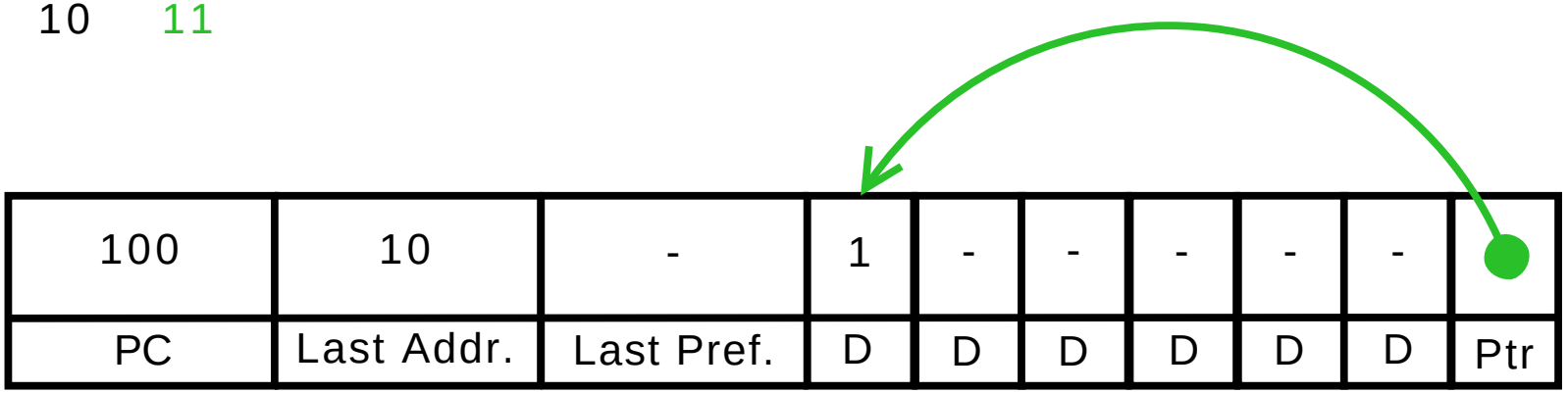
100	10	-	-	-	-	-	-	-	-
PC	Last Addr.	Last Pref.	D	D	D	D	D	D	Ptr

Delta Correlating Prefetch Tables

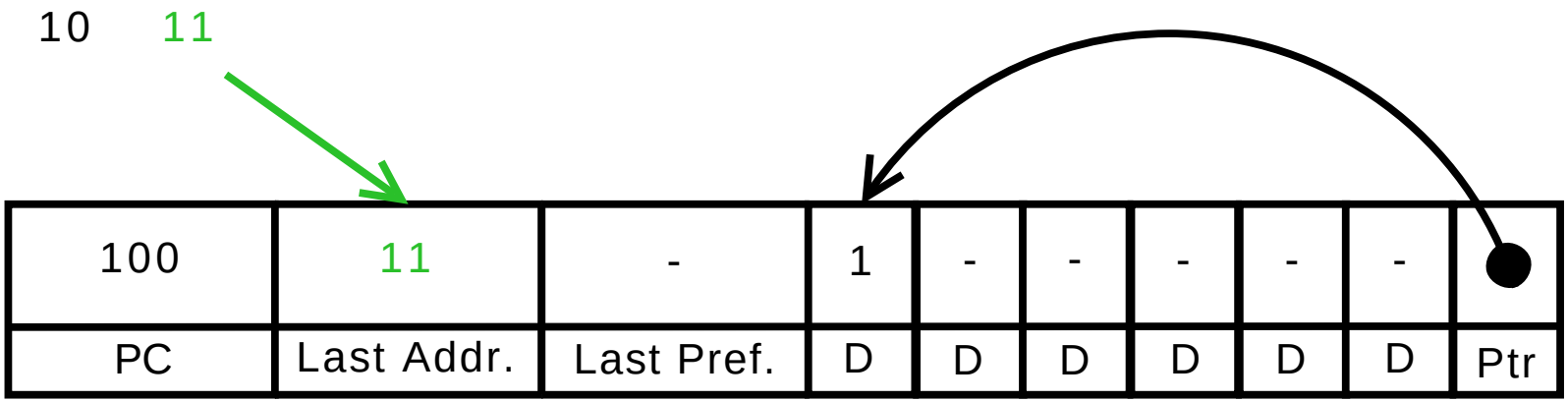


Delta Correlating Prefetch Tables

10 11

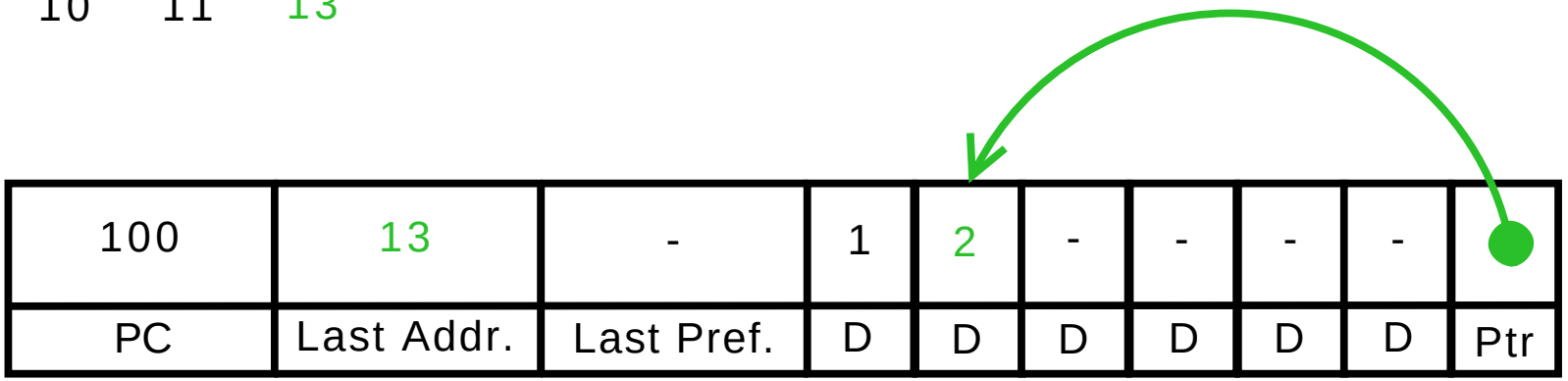


Delta Correlating Prefetch Tables



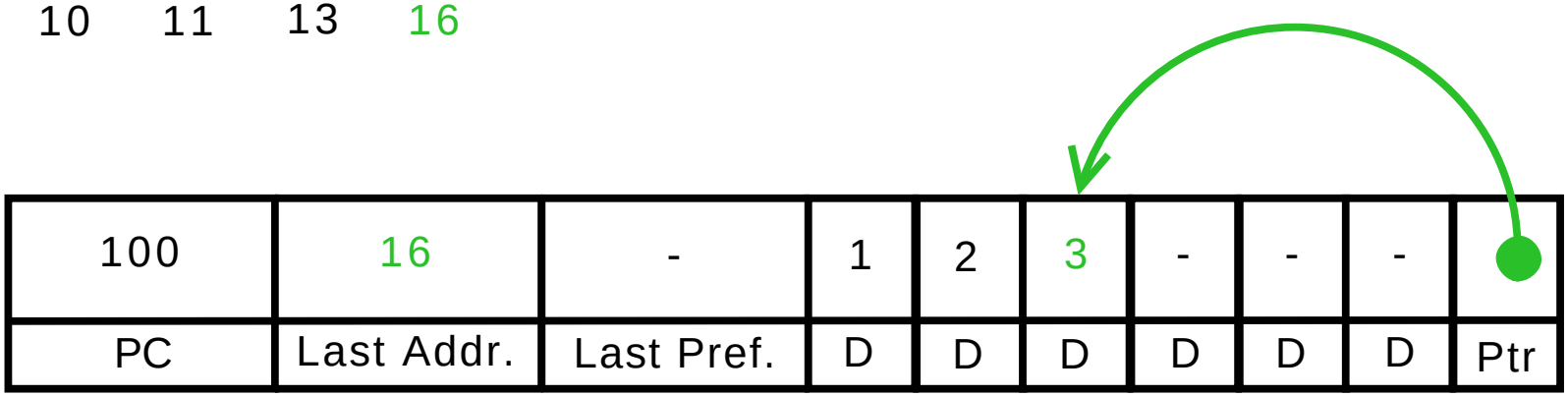
Delta Correlating Prefetch Tables

10 11 13



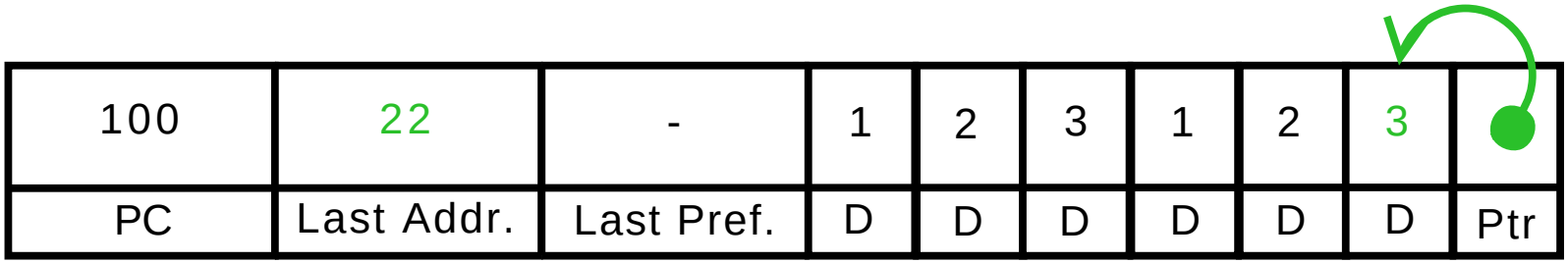
Delta Correlating Prefetch Tables

10 11 13 16



Delta Correlating Prefetch Tables

10 11 13 16 17 19 22

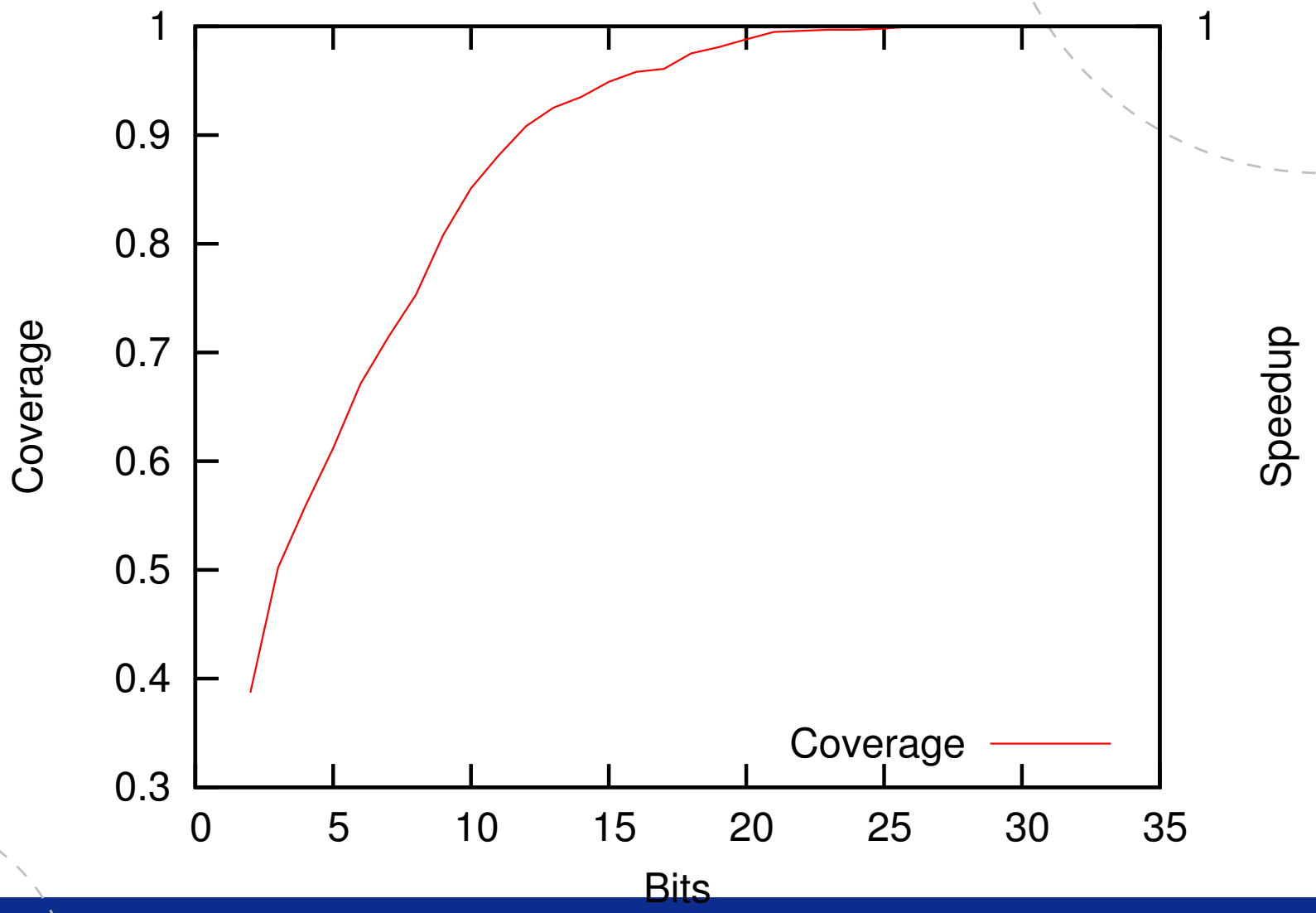


100	22	-	1	2	3	1	2	3	
PC	Last Addr.	Last Pref.	D	D	D	D	D	D	Ptr

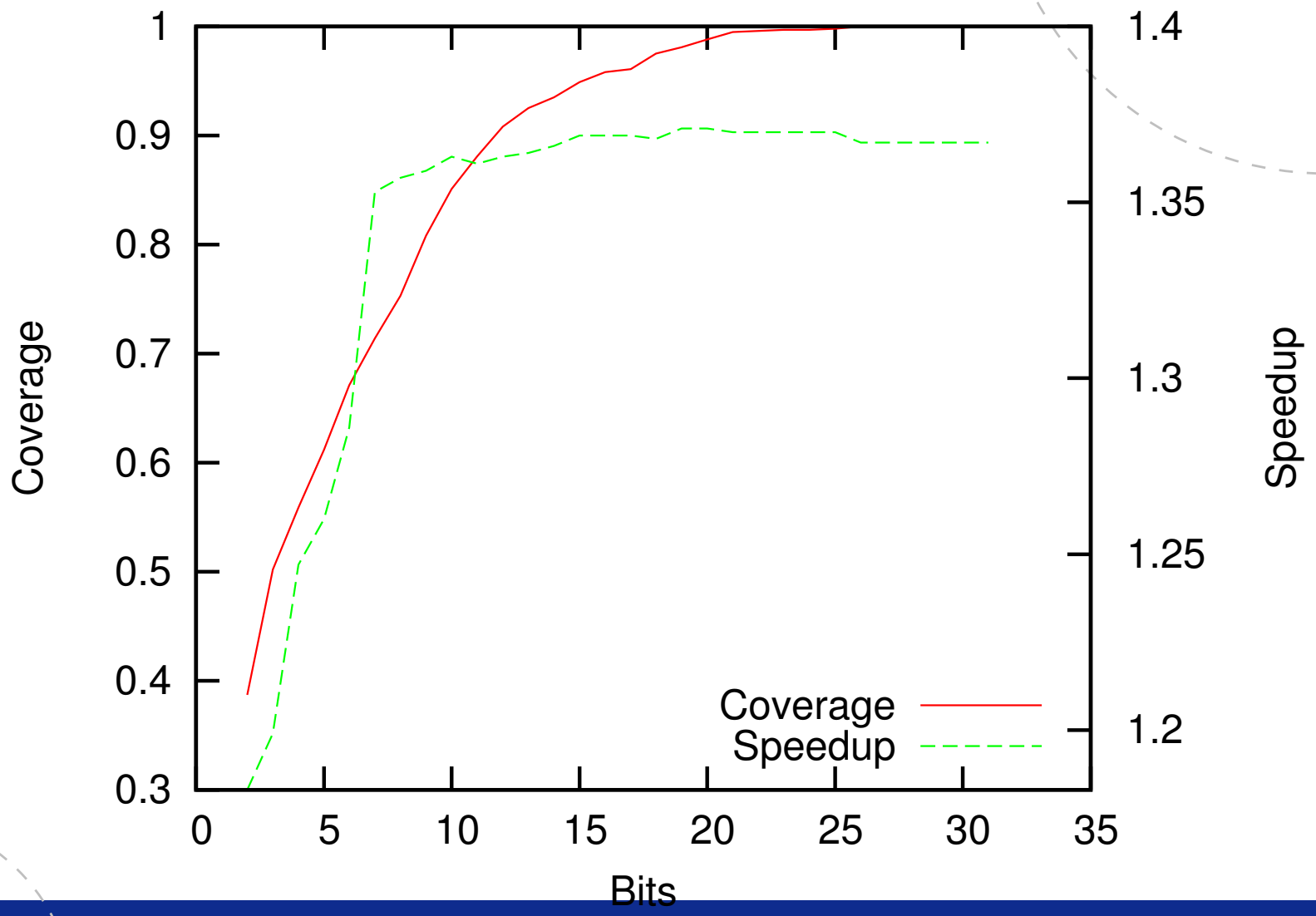
DCPT Properties

- Able to capture the same patterns as PC/DC
- Only stores deltas
  - Uses less memory to store the same data
  - No need to recalcuate the deltas
  - Fixed number of deltas - Fixed timeliness
- Constant delay
- Tracks issued prefetches to avoid overlap

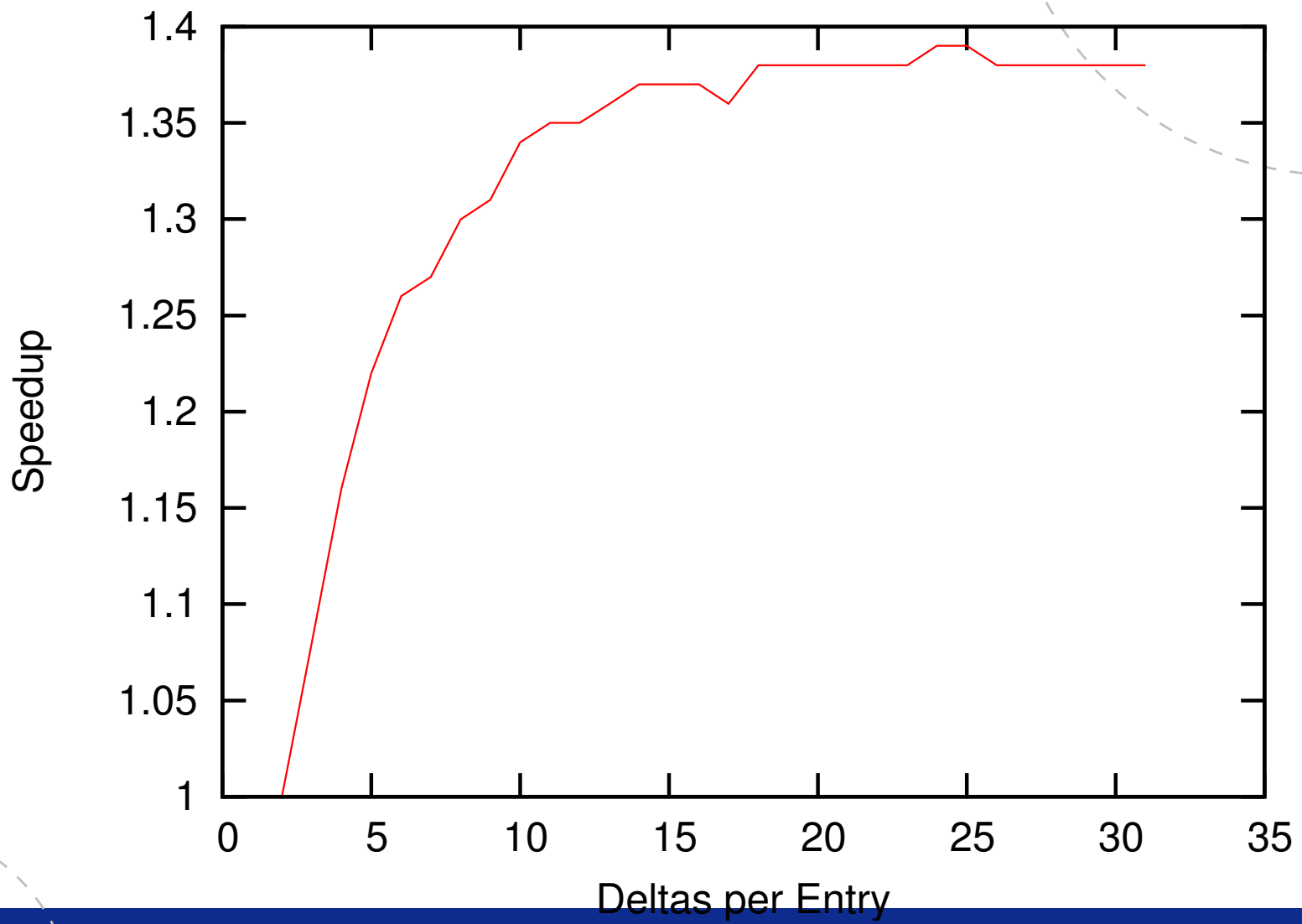
Number of bits used to represent a delta



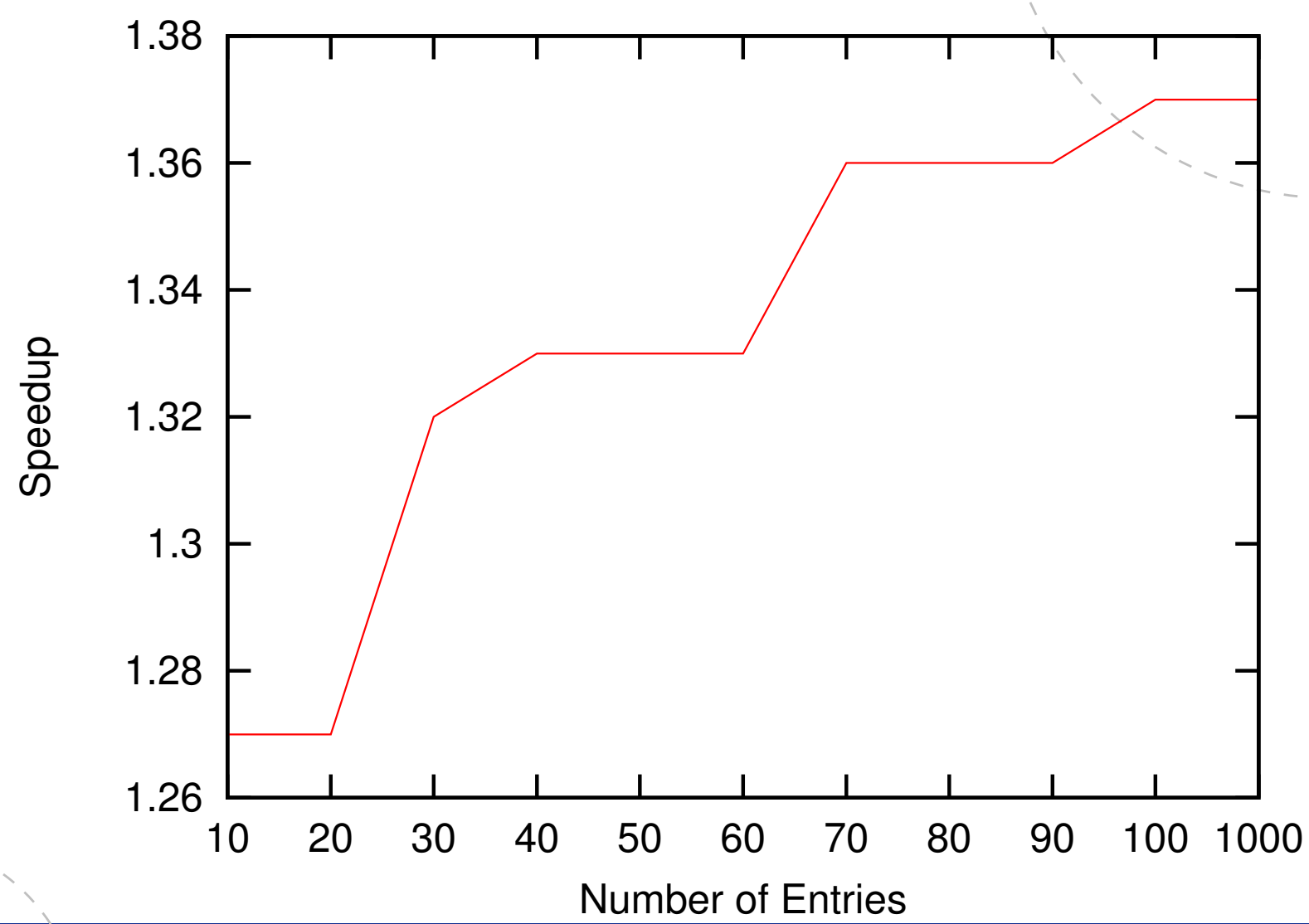
Number of bits used to represent a delta



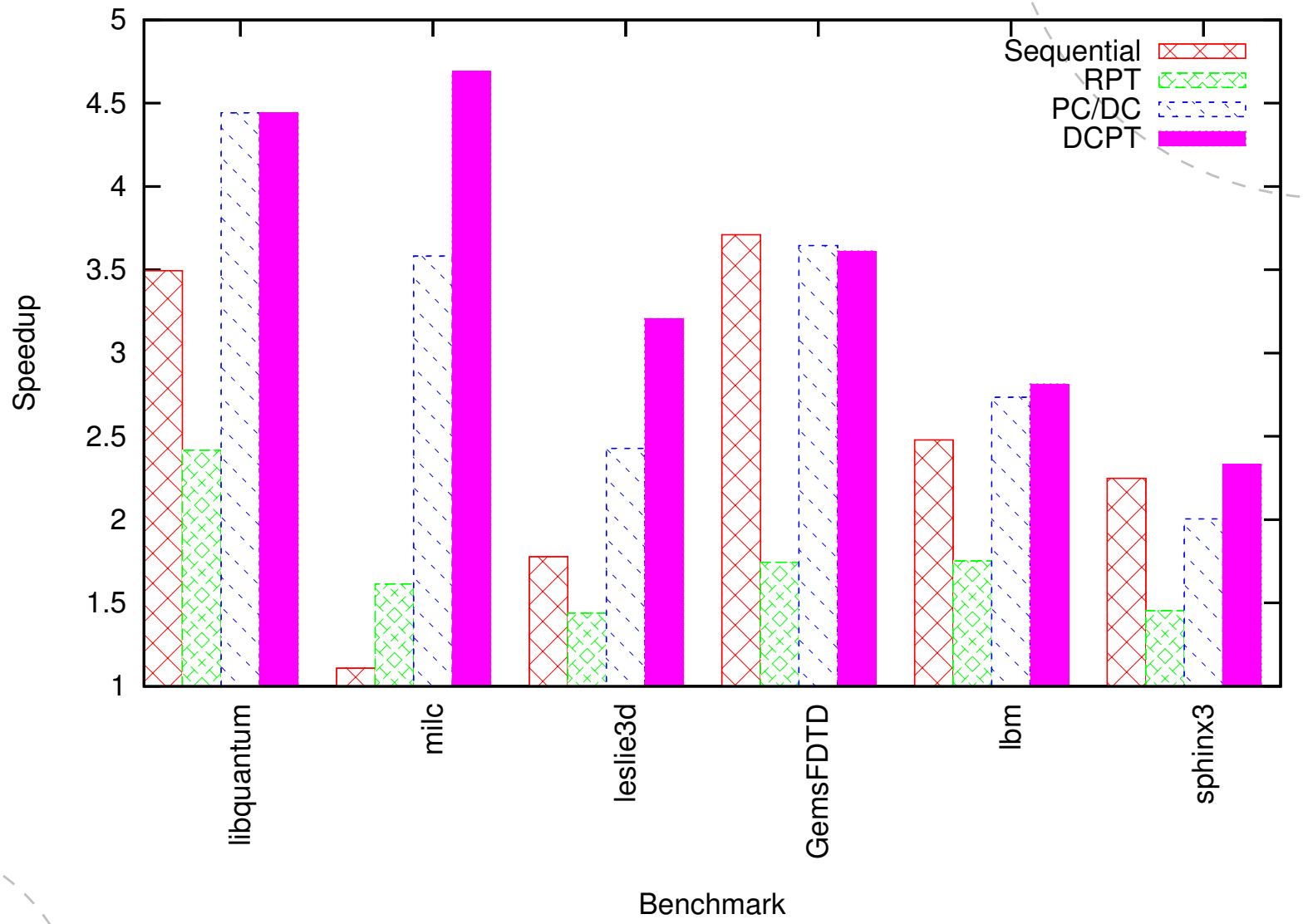
Deltas per table entry



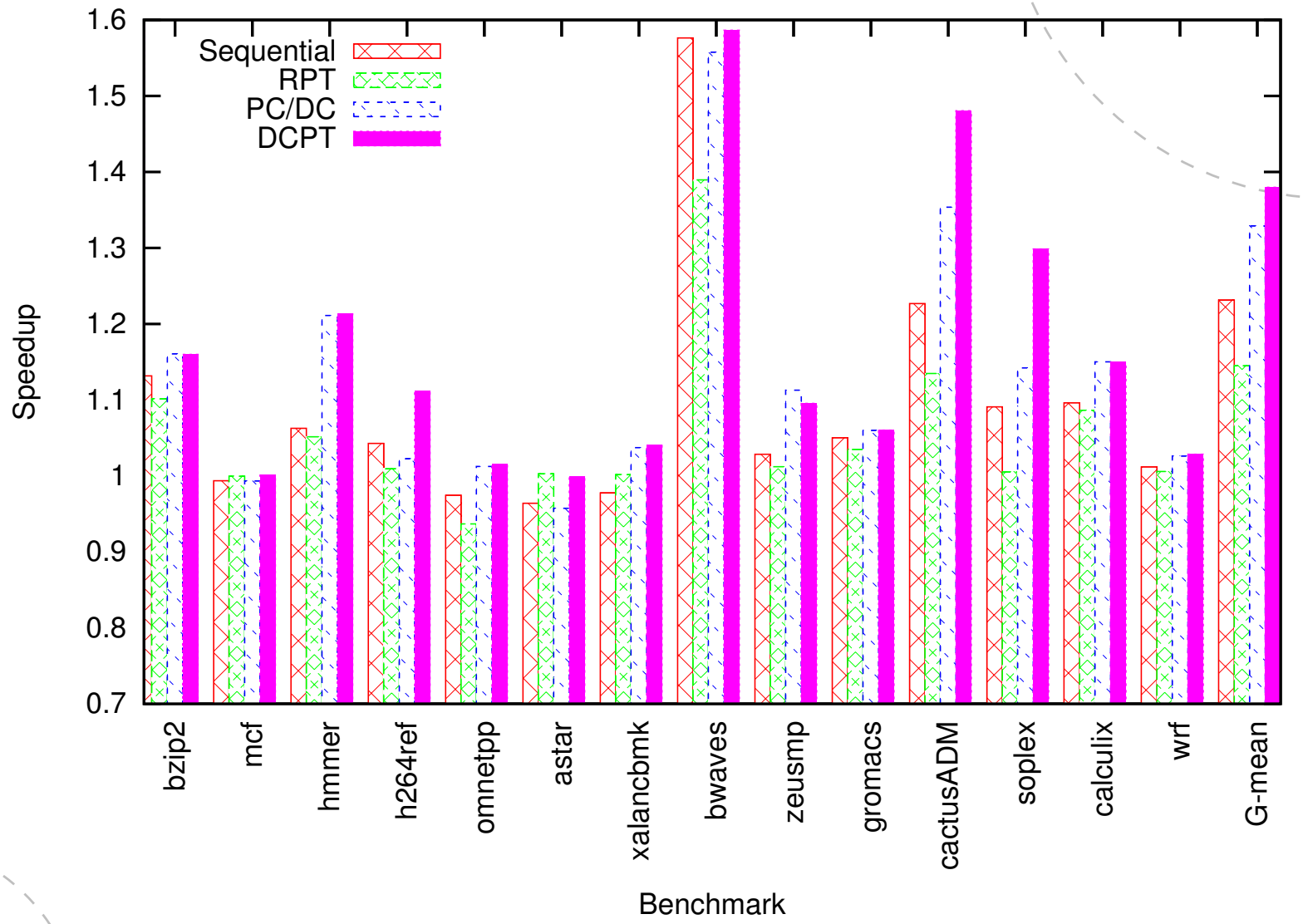
Number of table entries



Results I


Speedup
Benchmark
Sequential
RPT
PC/DC
DCPT
5
4.5
4
3.5
3
2.5
2
1.5
1
libquantum
milc
leslie3d
GemsFDTD
lbm
sphinx3

Results II


Sequential
RPT
PC/DC
DCPT
Speedup
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
bzip2
mcf
hmmer
h264ref
omnetpp
astar
xalancbmk
bwaves
zeusmp
gromacs
cactusADM
soplex
calculix
wrf
G-mean
Benchmark

Concluding Remarks

- Delta Correlating Prediction Tables is a hybrid of RPT and PC/DC prefetching.
- Combines the table based design of RPT and the pattern matching techniques of PC/DC.
- Compact representation
- Calculation in constant time

Thank you for listening

Are there any questions?