DBMS Data Loading: An Analysis on Modern Hardware

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Data loading: A necessary evil

✗ Volume => Expensive

40 zettabytes by 2020*

✗ Velocity => Continuous

Fresh data = Interesting data[Ŧ]

✓ Top query performance

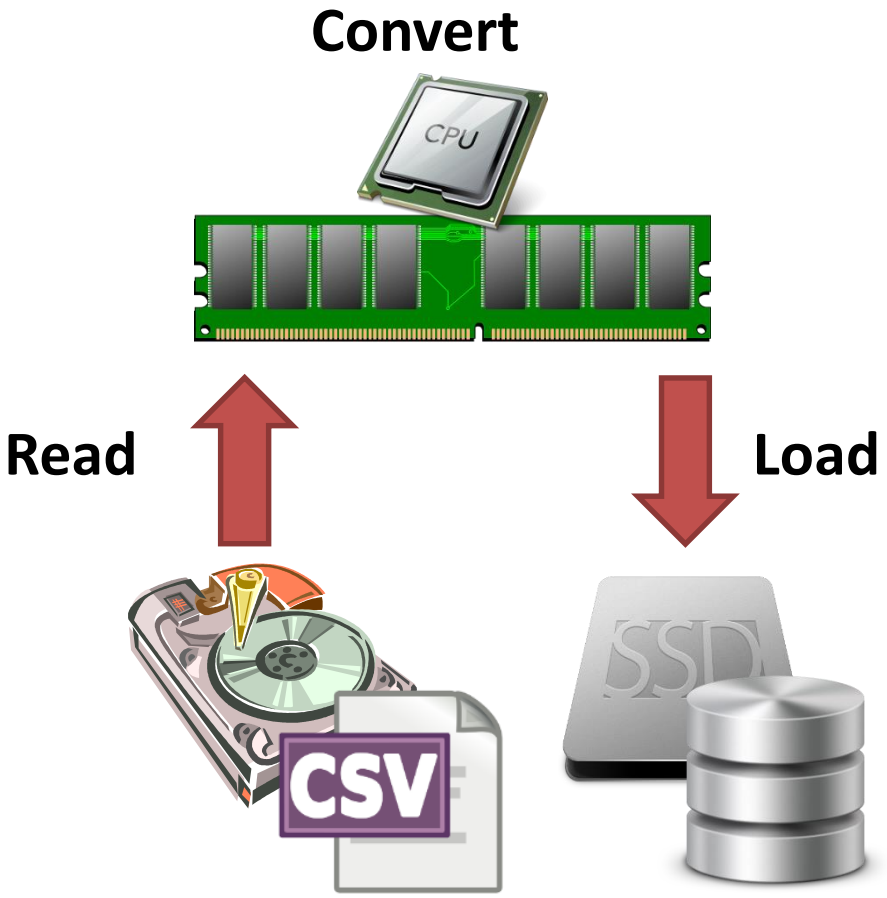
✓ ACID guarantees

* [IDC12]

Ŧ Abad [IISWC12]

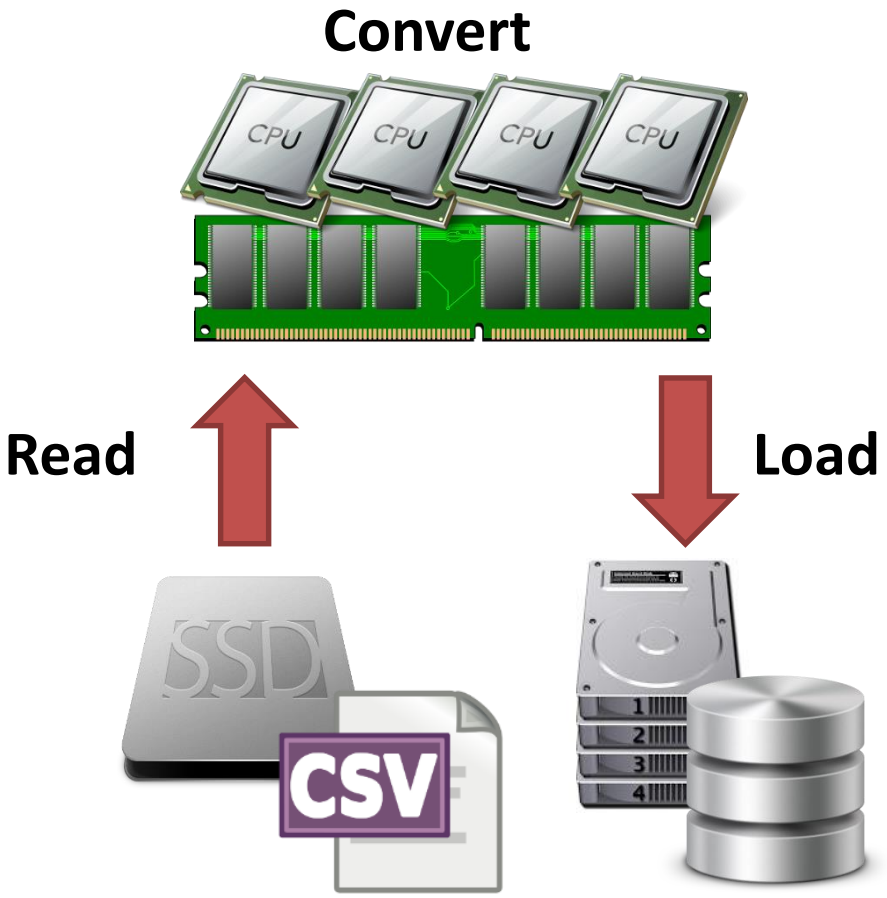
Data loading is a persistent analysis bottleneck

Loading a DBMS



How does hardware affect loading?

Loading a DBMS



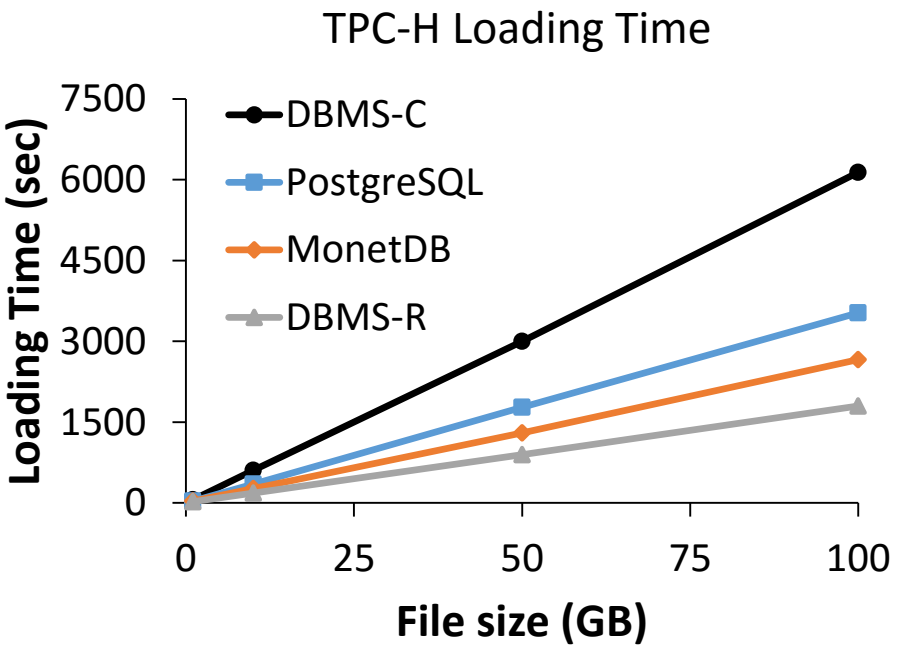
How does hardware affect loading?

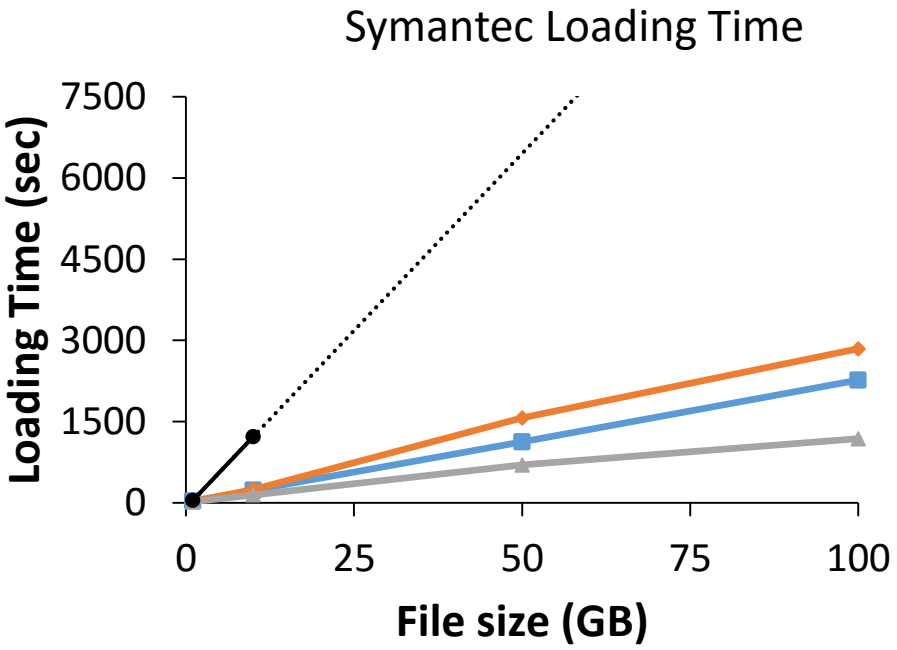
Experimental setup

- Hardware
  - Dual socket 8 cores Intel(R) Xeon(R) CPU E5-2640
  - 64 GB RAM
  - HDD: 4 x 500 GB 7.5k RPM SATA disks
  - SSD: 3 x 200GB SSD disks
  - DAS: 24 x 500 GB 7.5k RPM SATA disks
- Software
  - PostgreSQL, DBMS-R
  - MonetDB, DBMS-C
  - PostgreSQL parallel external loader (**“PCOPY”**)
- Benchmarks & Real-world Datasets

Single-threaded data loading

[Input storage: HDD
Destination storage: DAS]



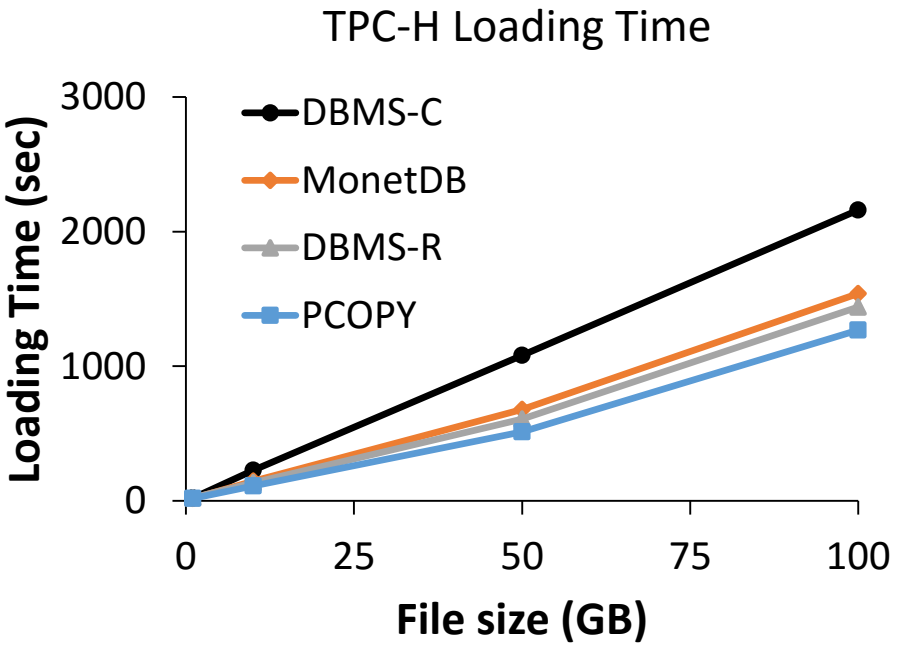


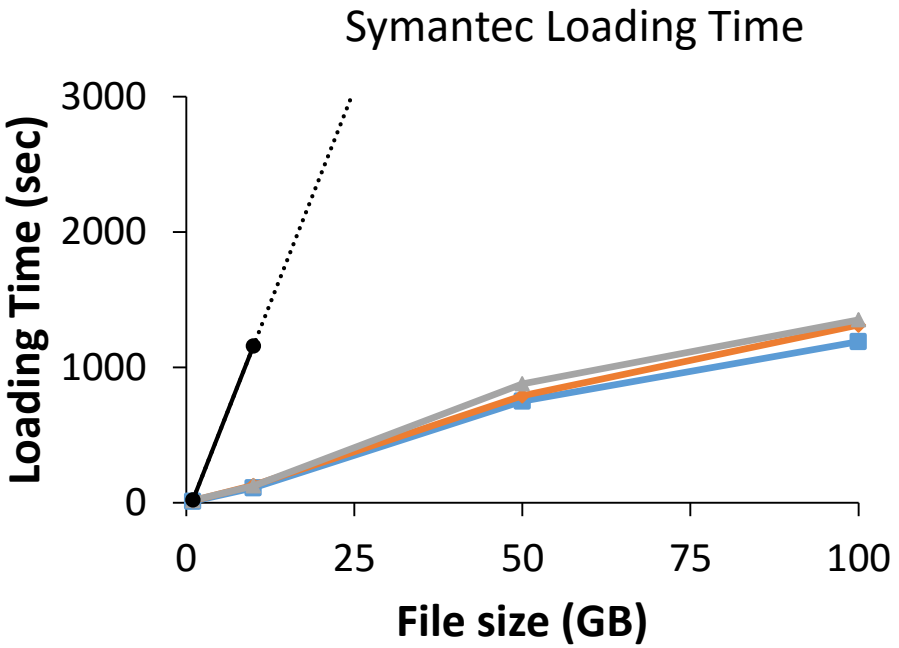
Dataset characteristics matter

Effect of compression

Parallel data loading

Input storage: HDD - Destination storage: DAS
16 threads

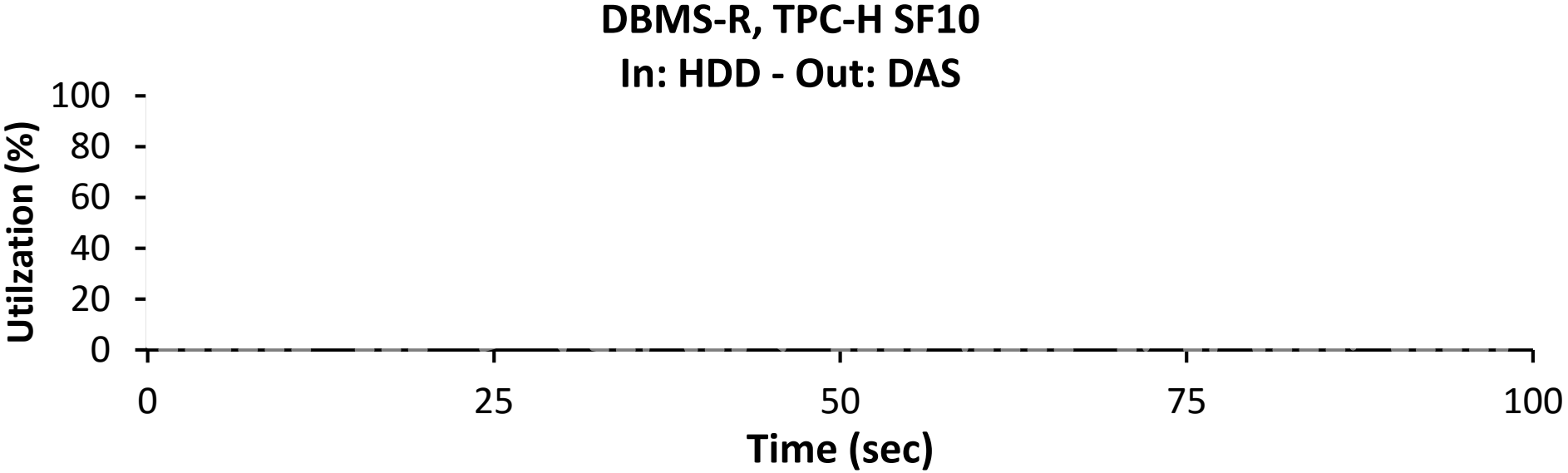




Speedup – 16 threads	DBMS-R	PCOPY	MonetDB	DBMS-C
TPC-H 100GB	1.25	2.77	1.72	2.84
Symantec 100GB	**0.87**	1.9	2.1	-

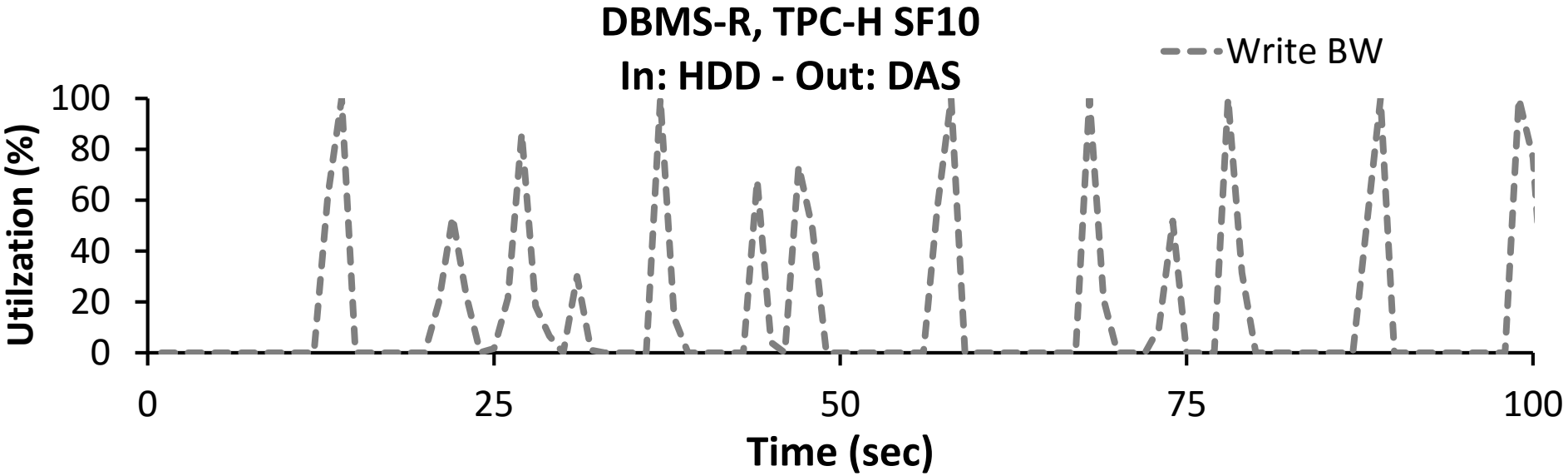
Sublinear speedup for 16 threads

Resource Utilization



Unable to saturate resources

Resource Utilization



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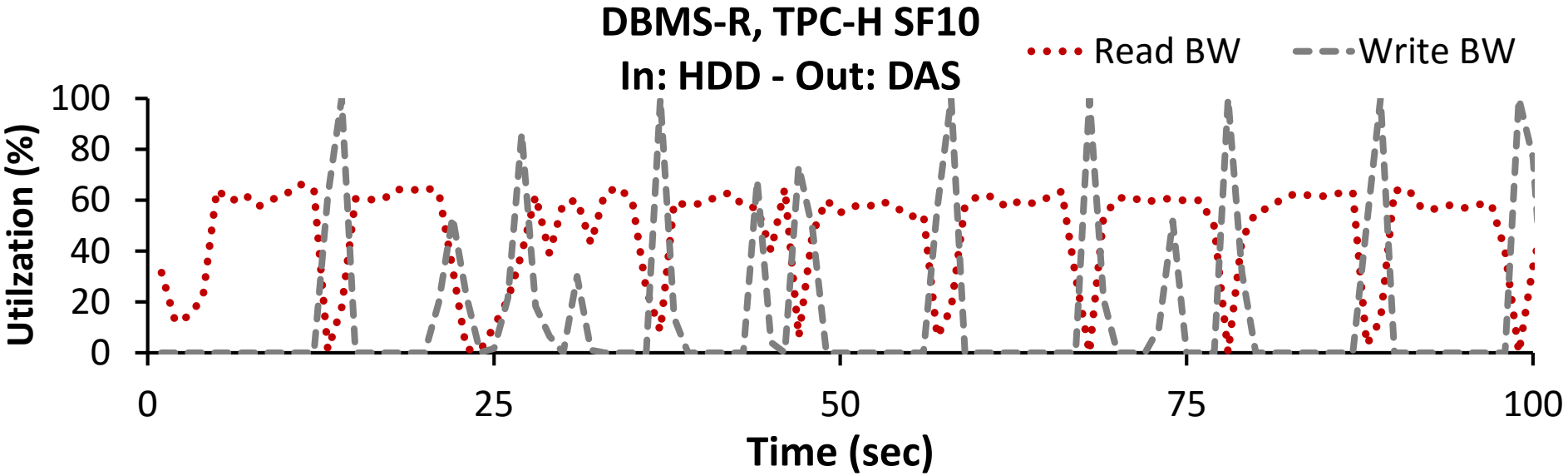

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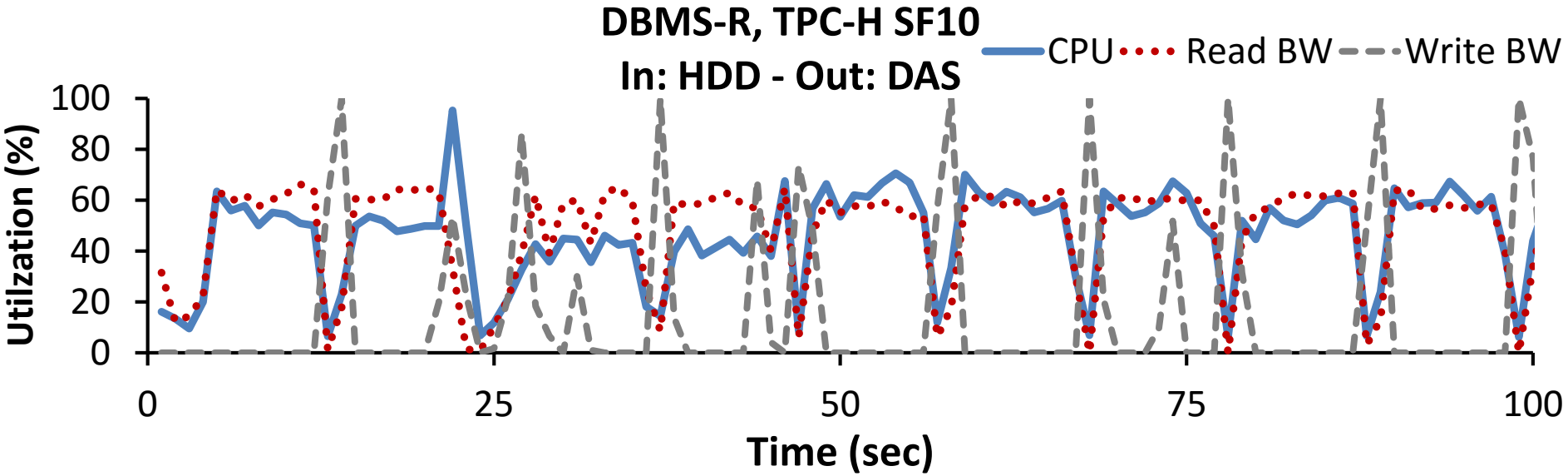

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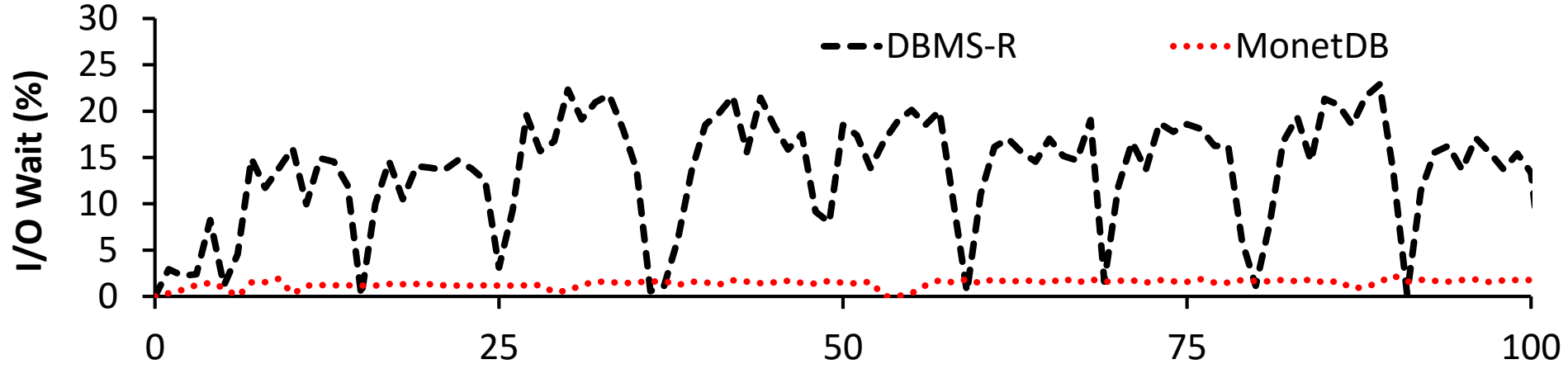
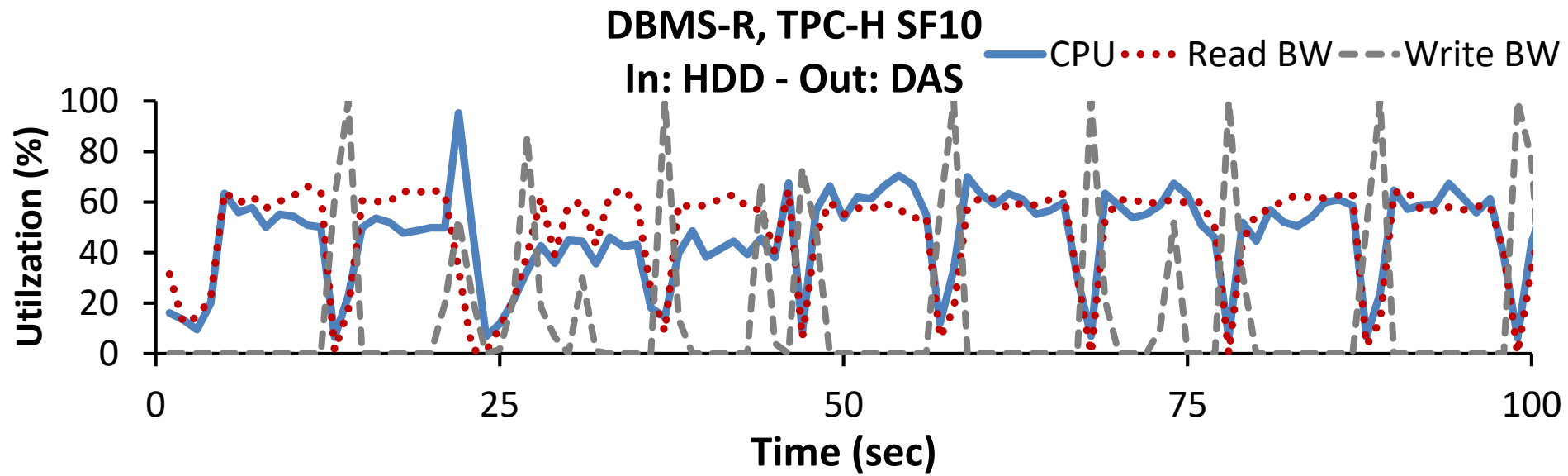


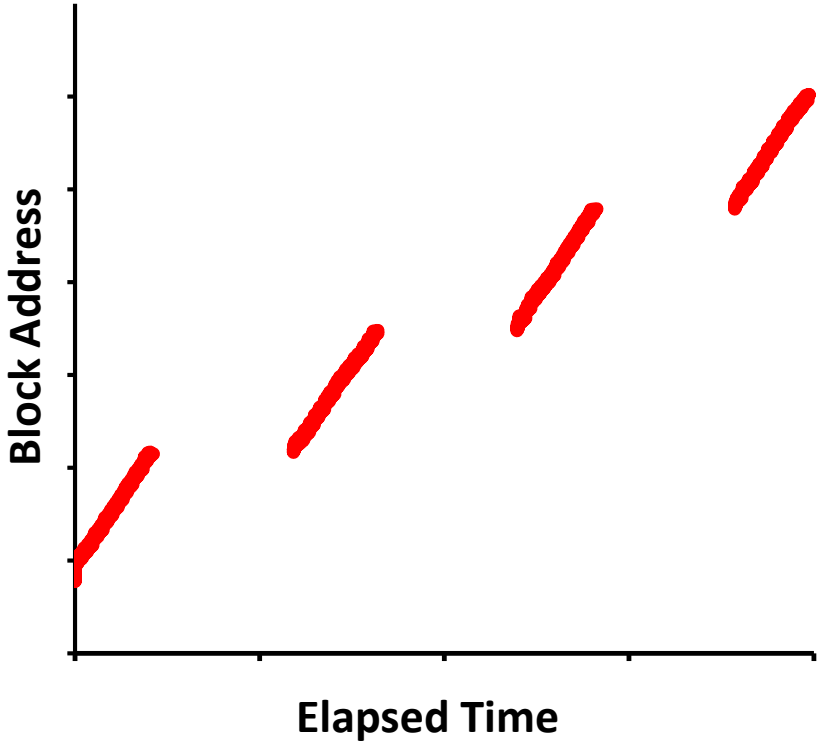


Unable to saturate resources

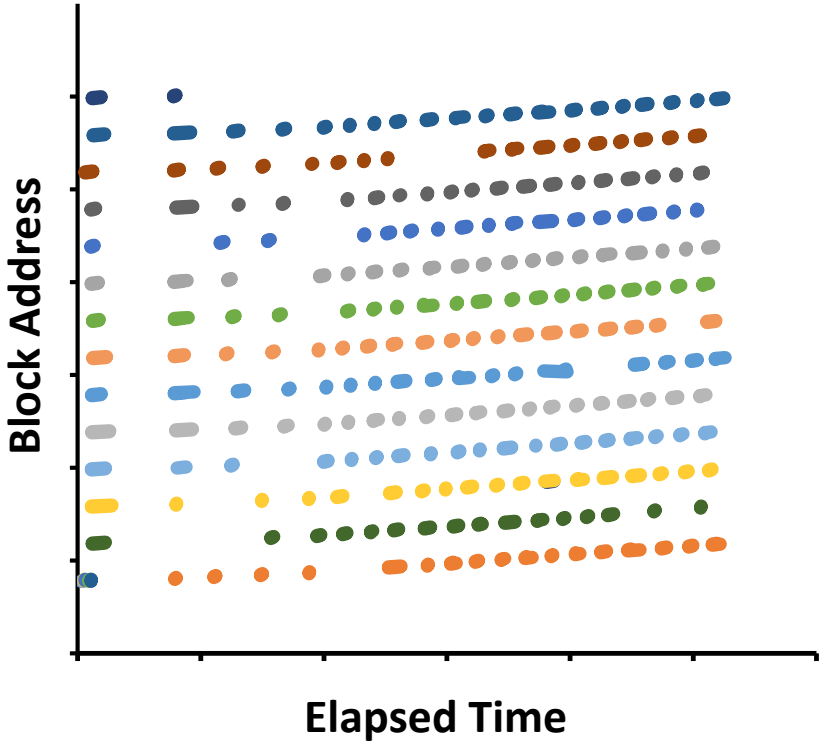
Read patterns

[TPC-H SF10
Input storage: HDD
Destination storage: DAS]

MonetDB



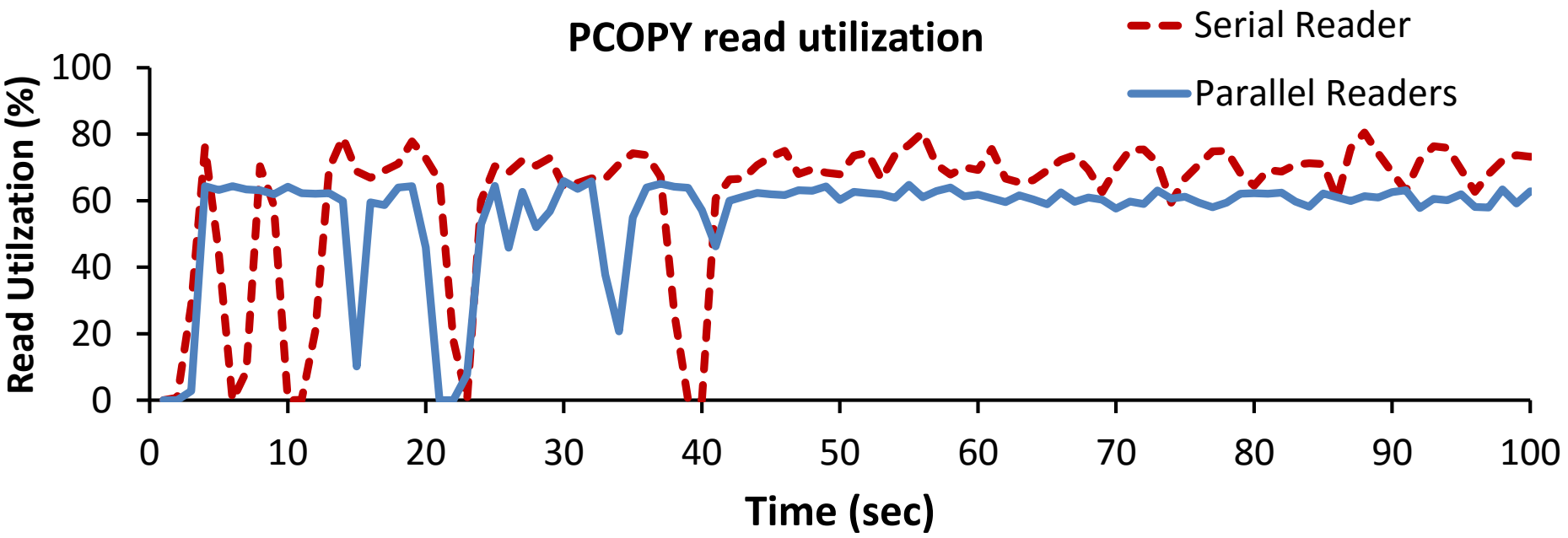
DBMS-R



Random I/O causes underutilization

Serial reader vs. Parallel readers

[TPC-H SF10
Input storage: HDD
Destination storage: DAS]



Serial reader improves read utilization

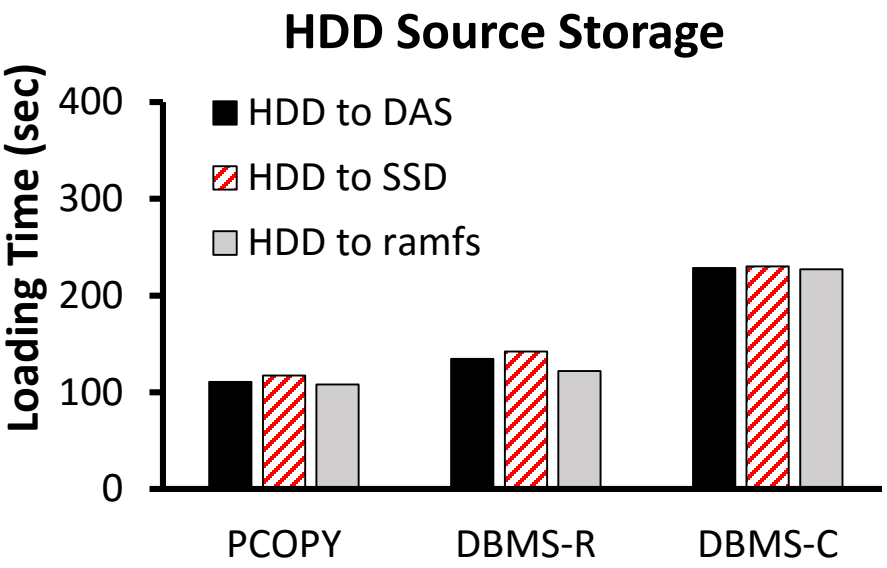
 # readers depends on input device speed

Impact of storage

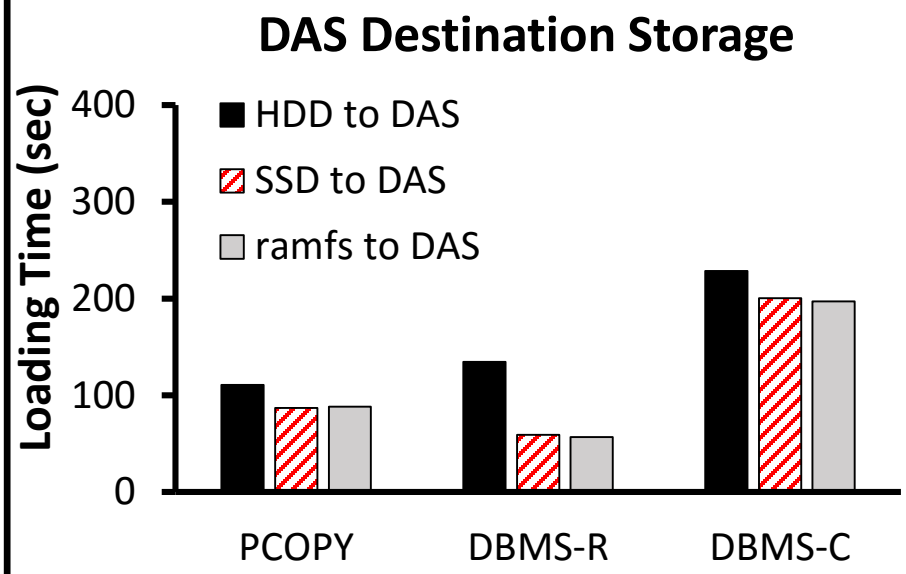
Impact of storage

[TPC-H SF10]

Slow input storage



Varying input storage

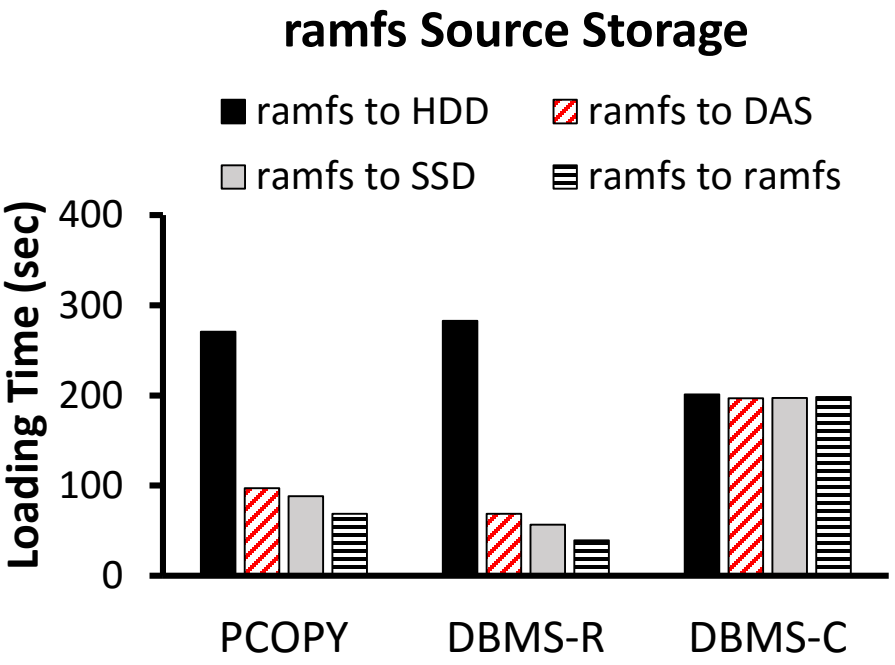


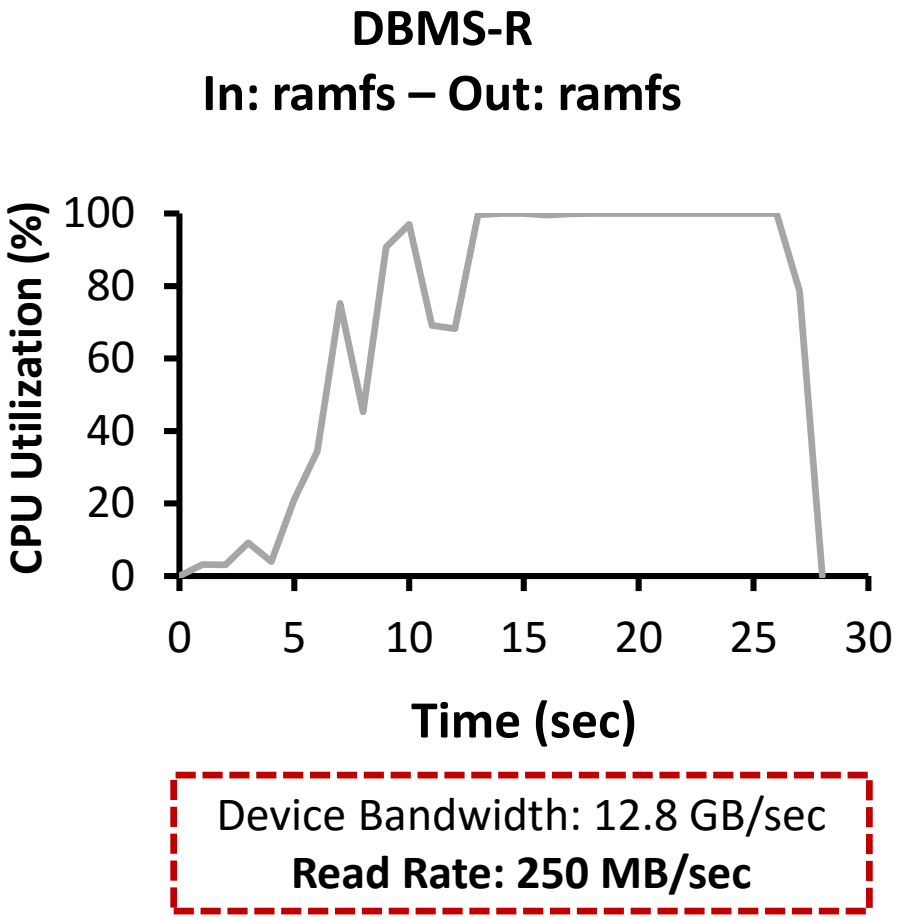
Slow source storage bottlenecks all systems

Write bottleneck when source storage is fast

Best-case storage scenario

[TPC-H SF10]



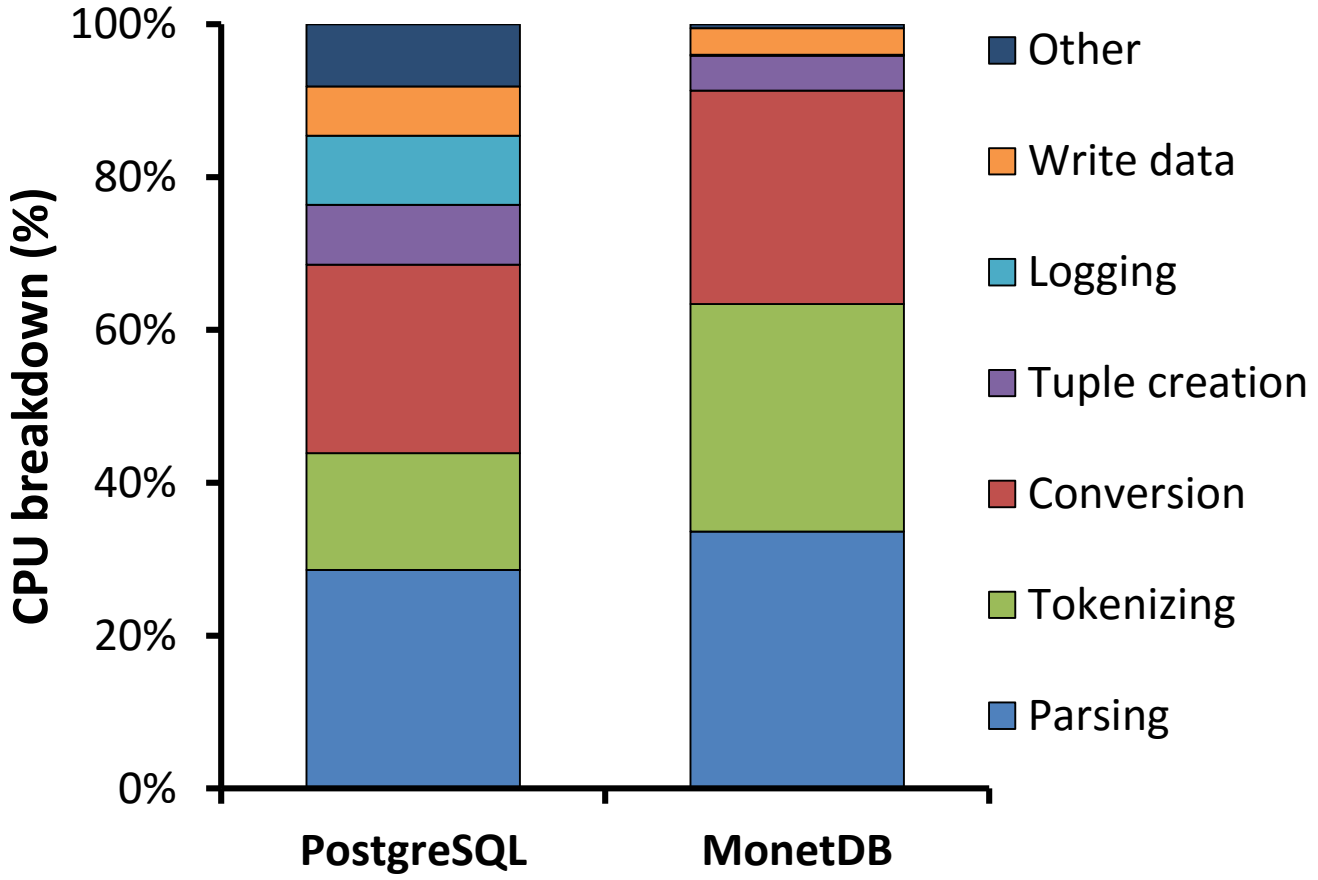


Device Bandwidth: 12.8 GB/sec
Read Rate: 250 MB/sec

100% CPU utilization, yet B/W still underutilized

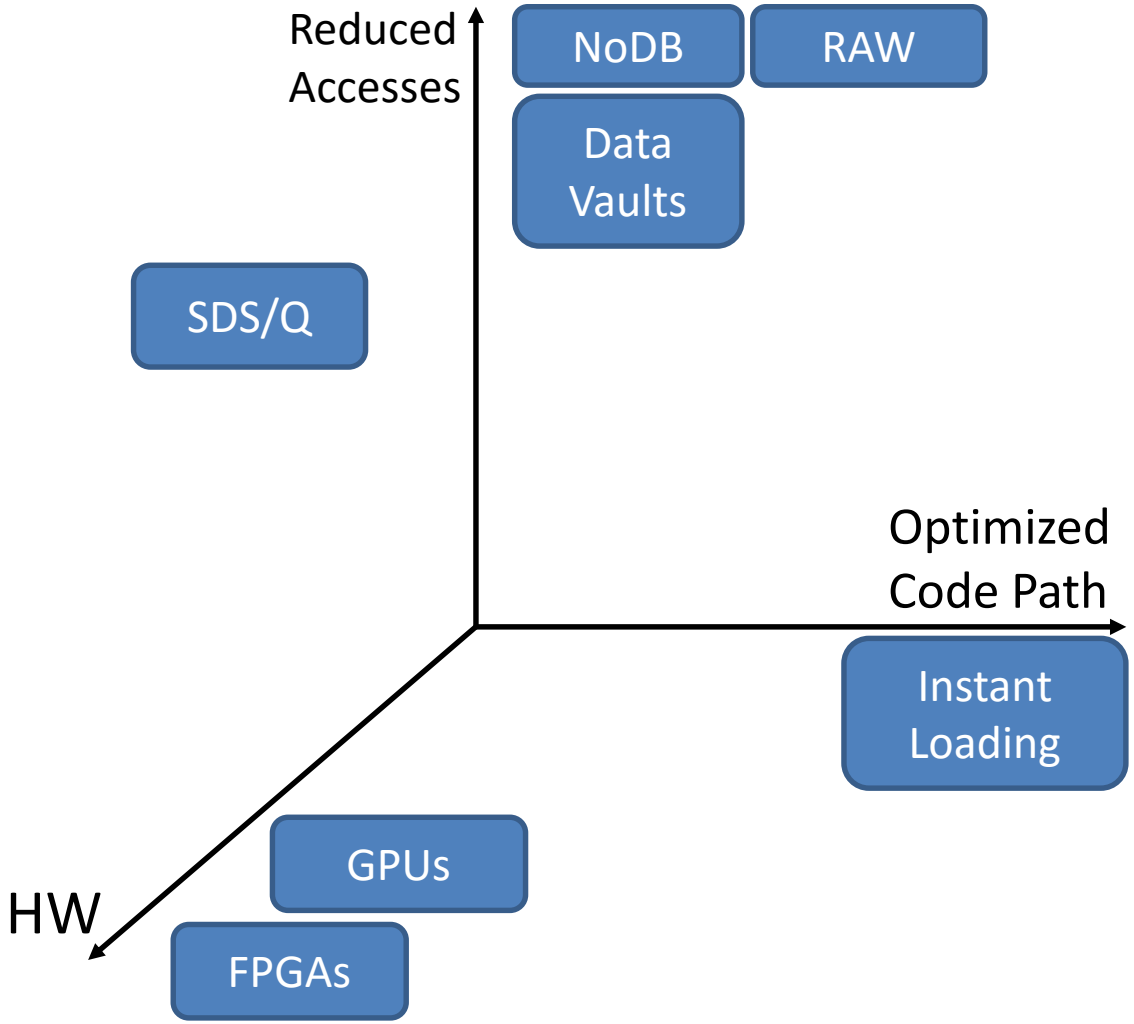
Data loading: Where does time go?

[10 int columns; 10GB]



Parsing, conversion, tokenization hotspots

Reducing data loading overheads



Bulk loading on modern hardware

- General case: Resource under-utilization
- Slow destination storage matters
- Complex code paths bound max speed

Bulk loading on modern hardware

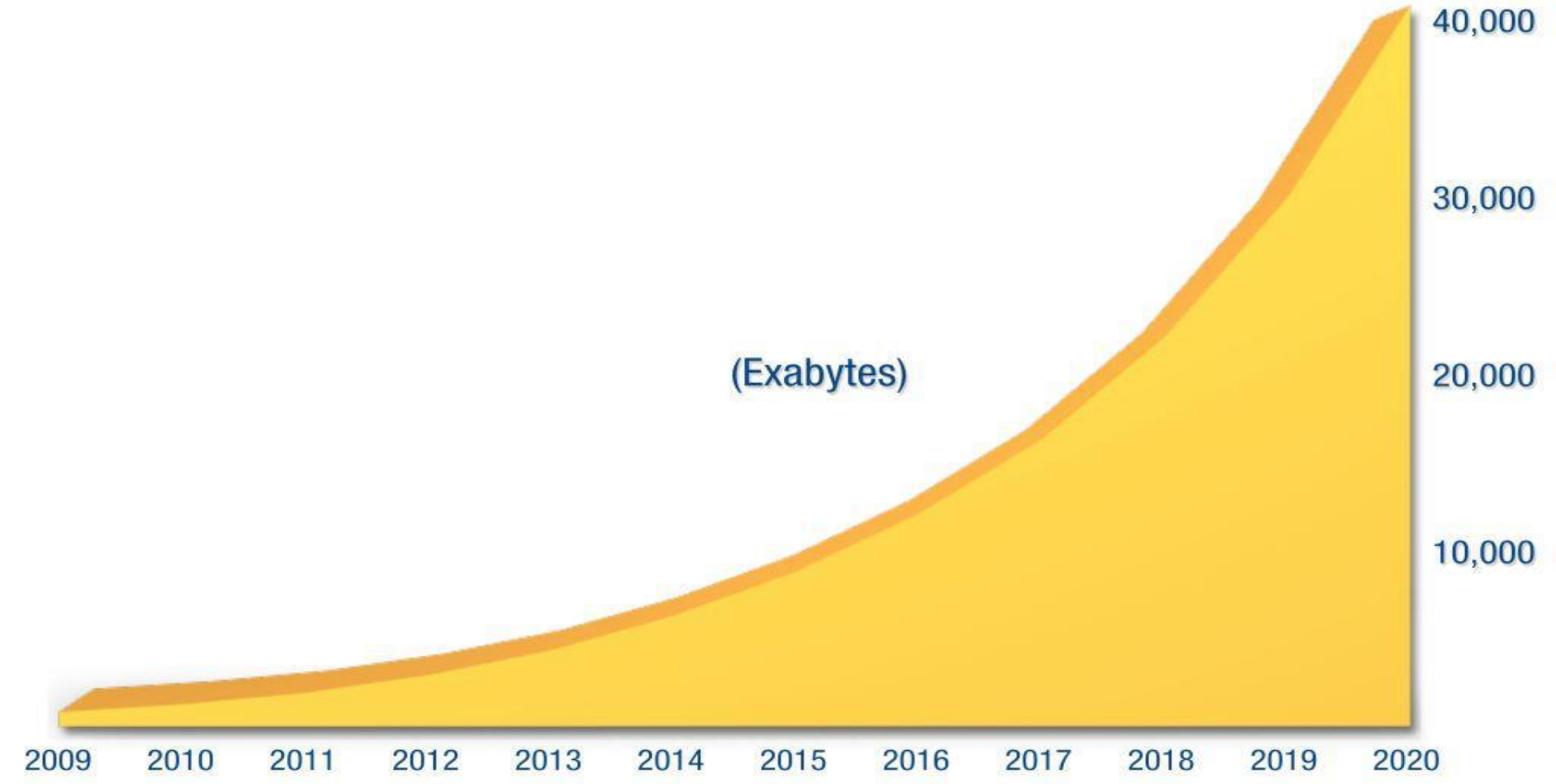
- General case: Resource under-utilization
- Slow destination storage matters
- Complex code paths bound max speed

Thank You!
Questions?

Backup Slides

50x data growth from 2010 to 2020

[IDC2012]



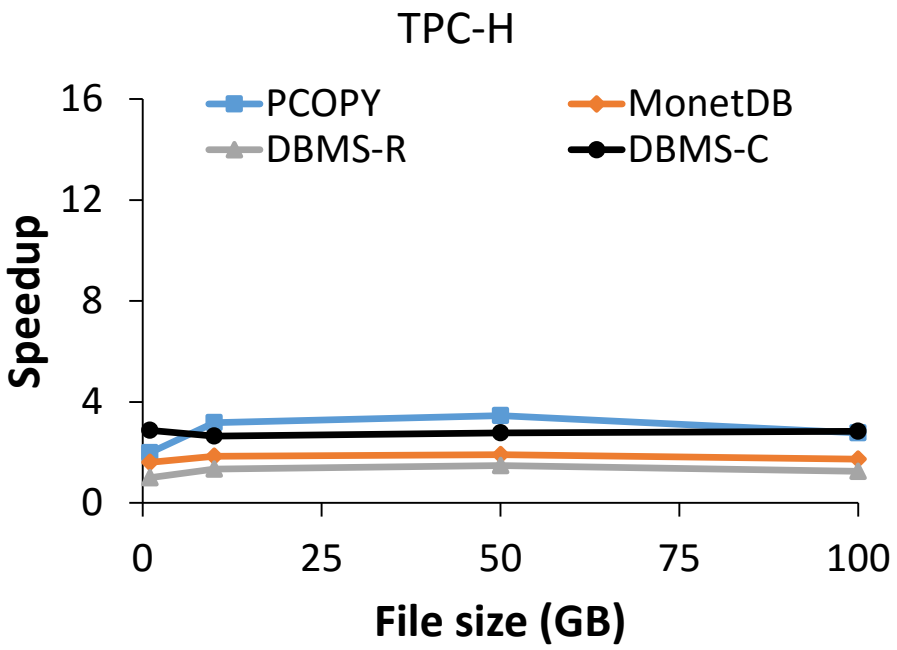
Can DBMS keep up with data growth?

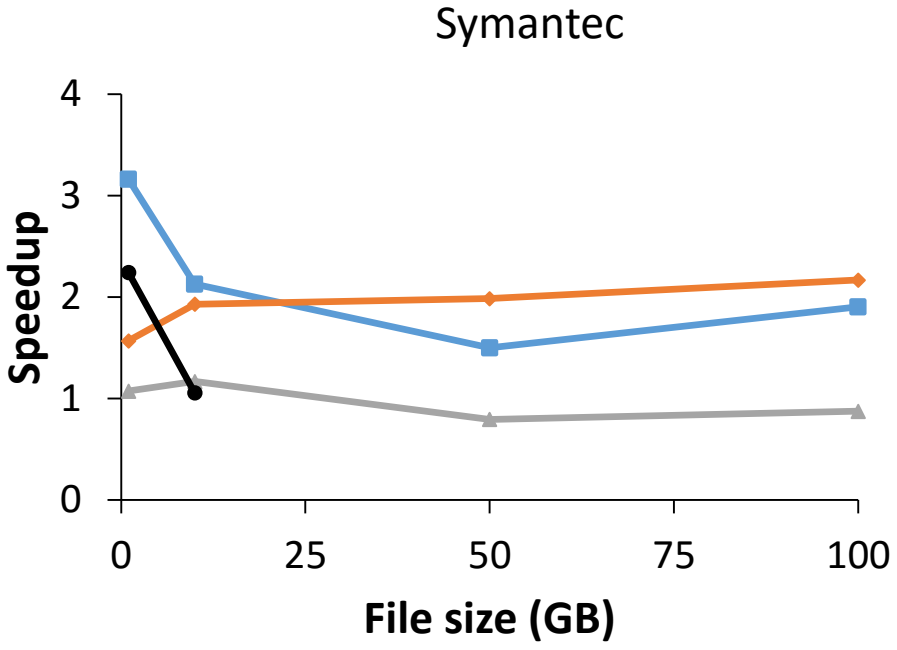
Storage Characteristics

Name	Capacity	Configuration	Read Speed	Write Speed	RPM
HDD	2TB	4 x HDD (RAID-0)	170 MB/s	160 MB/s	7.5K
DAS	12TB	24 x HDD (RAID-0)	1100 MB/s	330 MB/s	7.5K
SSD	600GB	3 x SSD (RAID-0)	565 MB/s	268 MB/s	n/a

Parallel data loading – 16 threads

[Input storage: HDD
Destination storage: DAS]

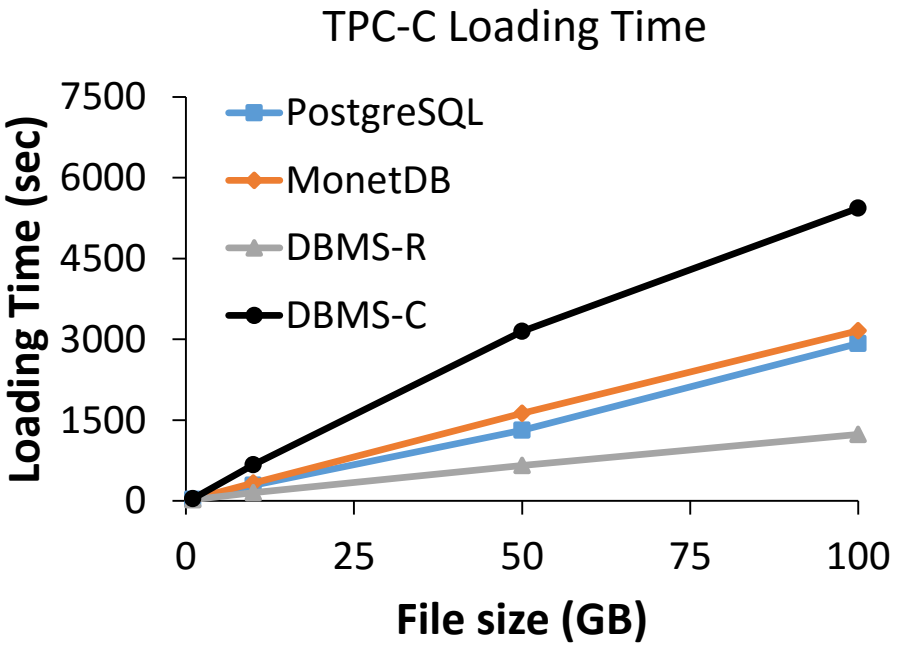


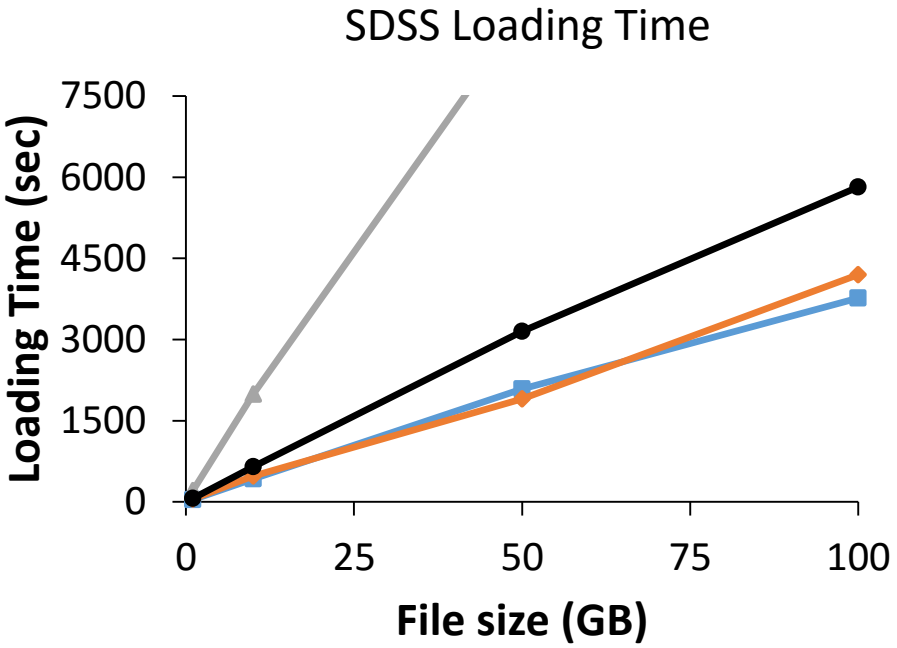


Sublinear speedup for 16x DoP

Single-threaded loading – Extra datasets

Input storage: HDD
Destination storage: DAS

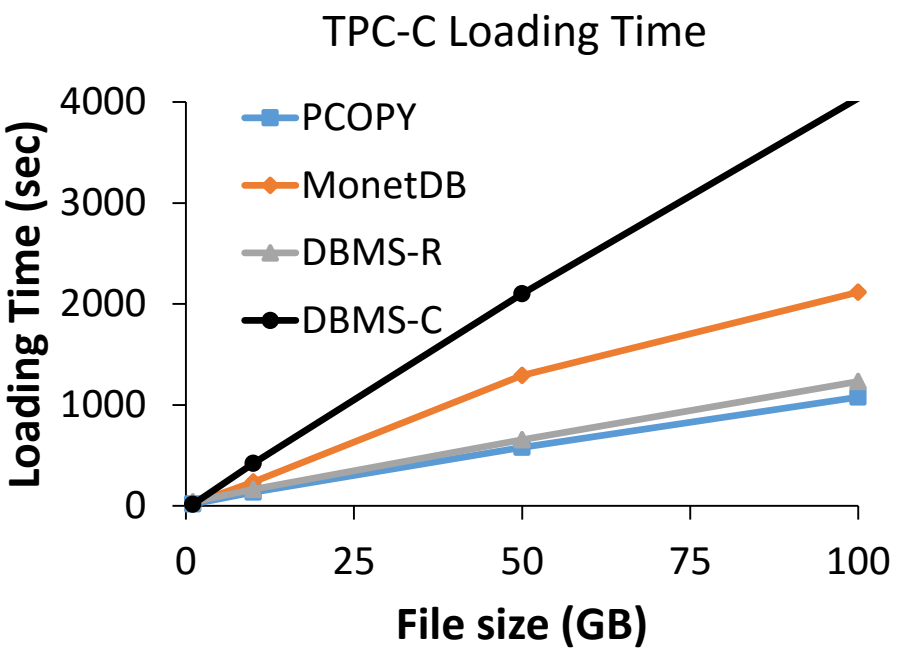


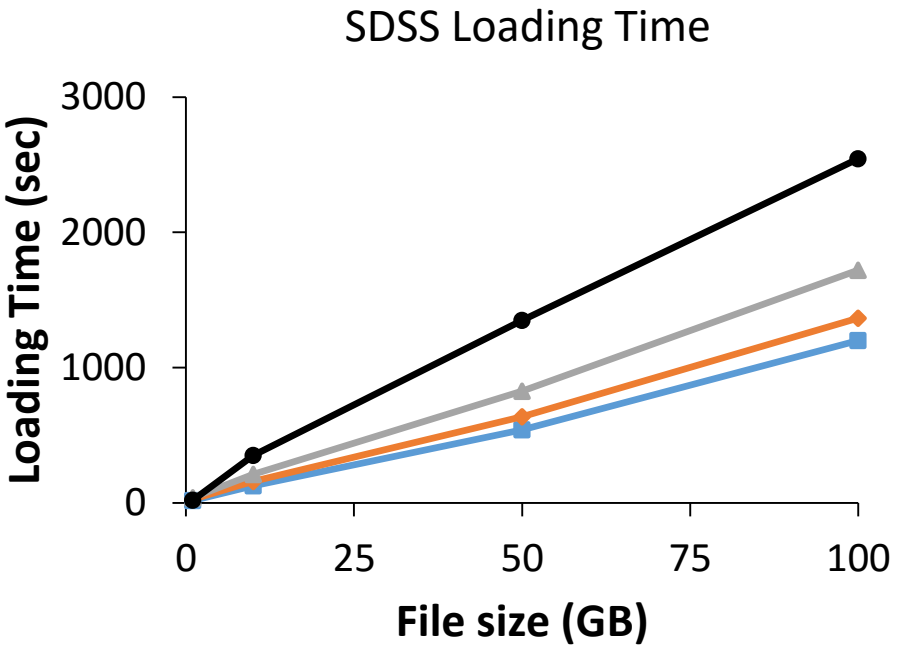


Column stores invest in compression

Parallel data loading – Extra datasets

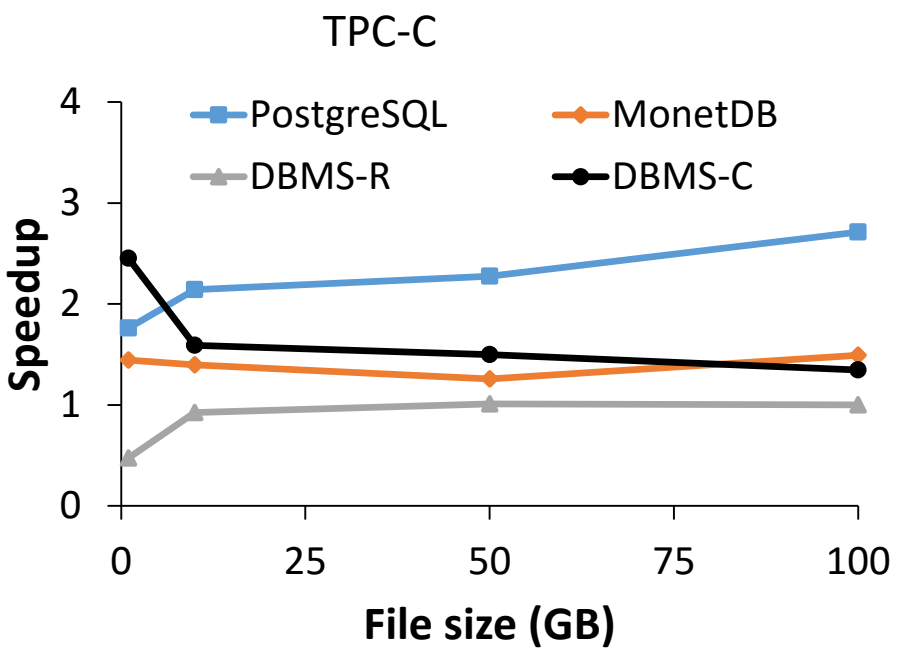
Input storage: HDD
Destination storage: DAS

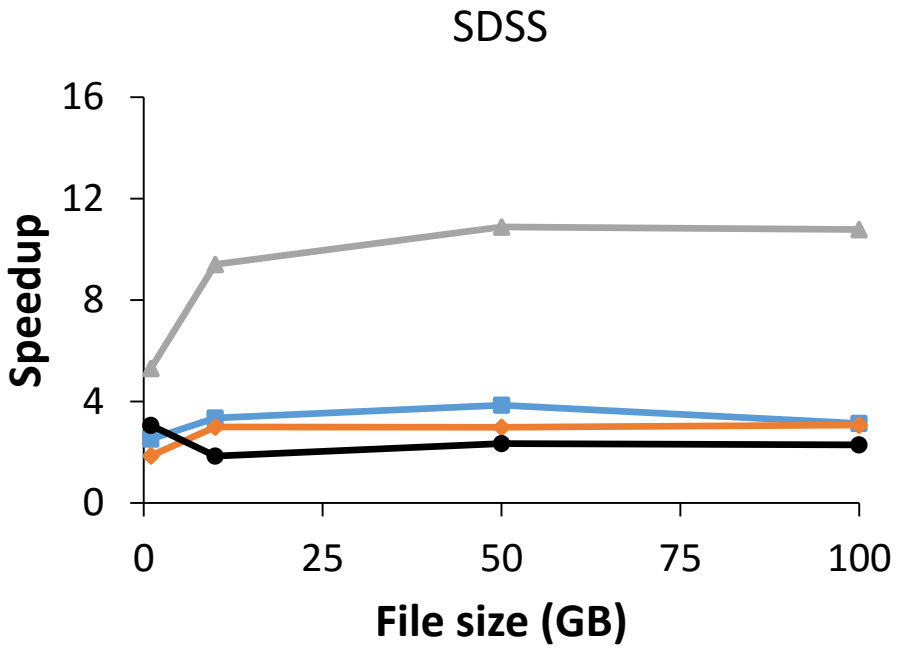




Parallel data loading – Extra datasets

Input storage: HDD
Destination storage: DAS





The effect of compression

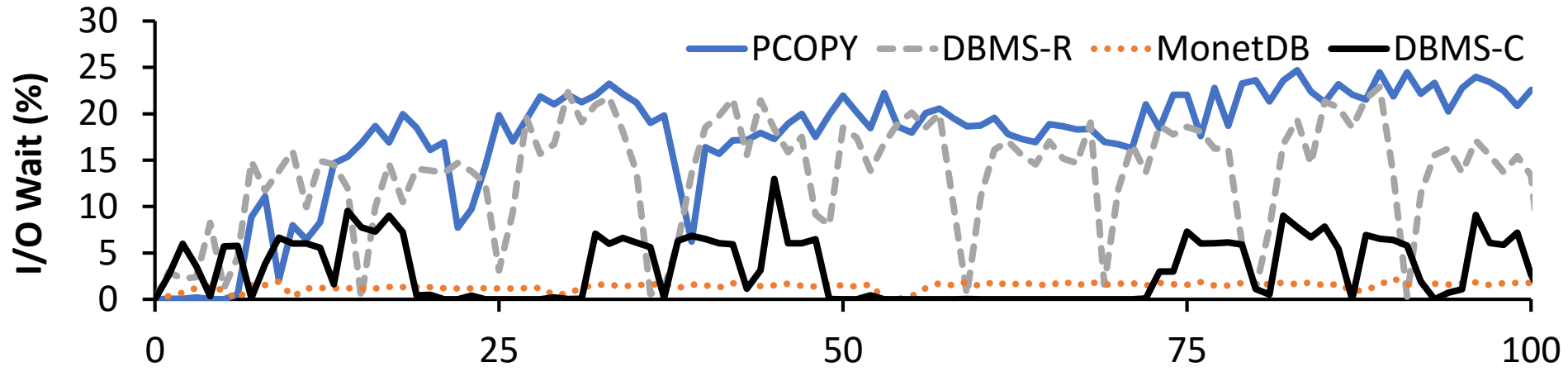
[10GB]

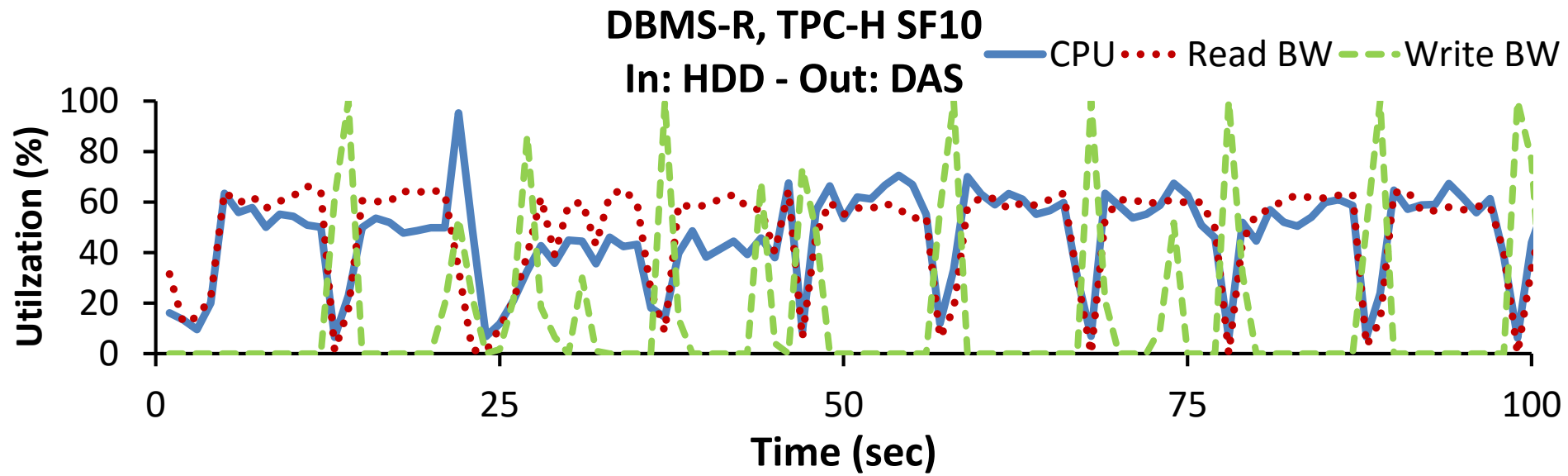
DB size / input file

Name	TPC-H	TPC-C	SDSS	Symantec
DBMS-R	1.5	1.3	1.5	1.5
PostgreSQL	1.4	1.4	1.4	1.1
DBMS-C	0.27	0.82	0.18	0.25
MonetDB	1.1	1.4	1.0	0.92

Column stores: Reduced footprint favors OLAP

Resource Utilization

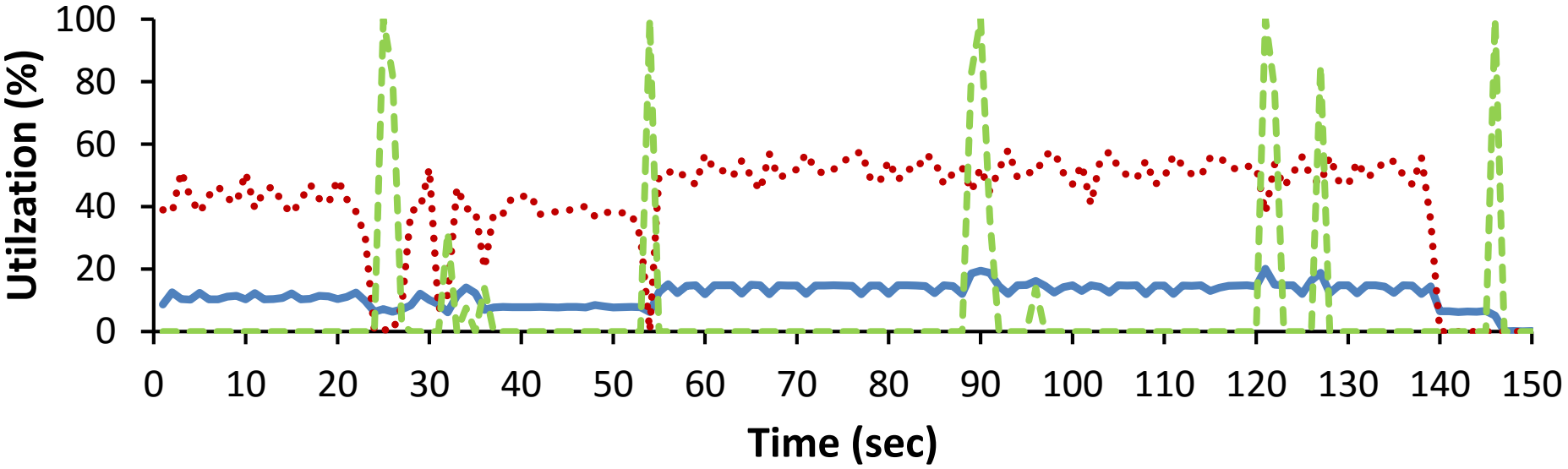




Unable to saturate resources

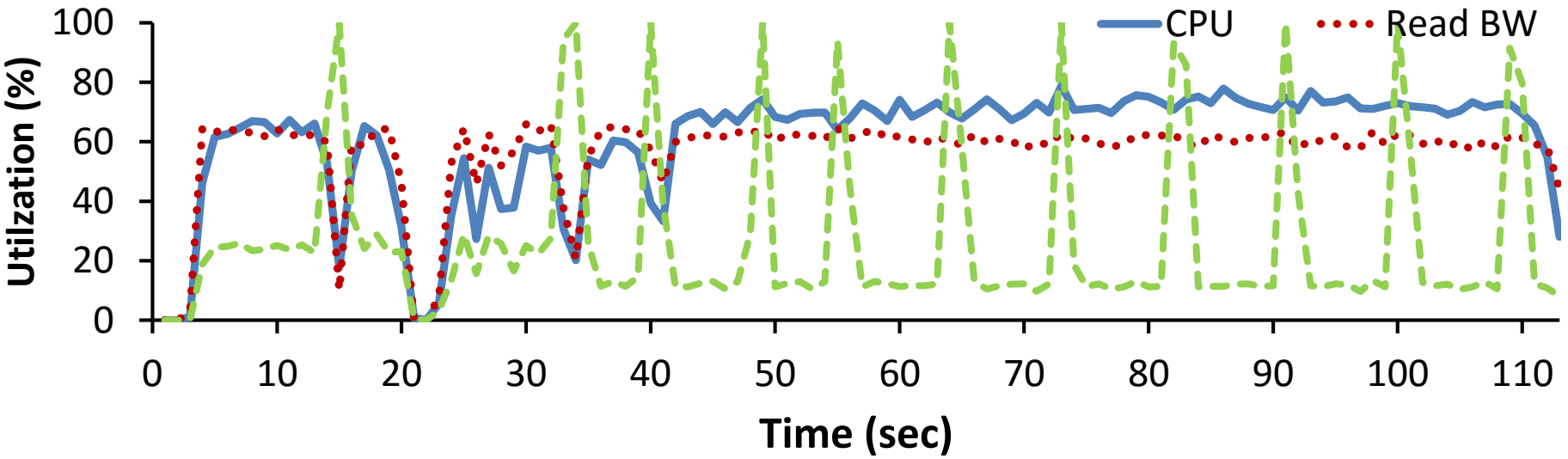
MonetDB utilization

[Data: TPCH – SF10
Input storage: HDD
Destination storage: DAS]



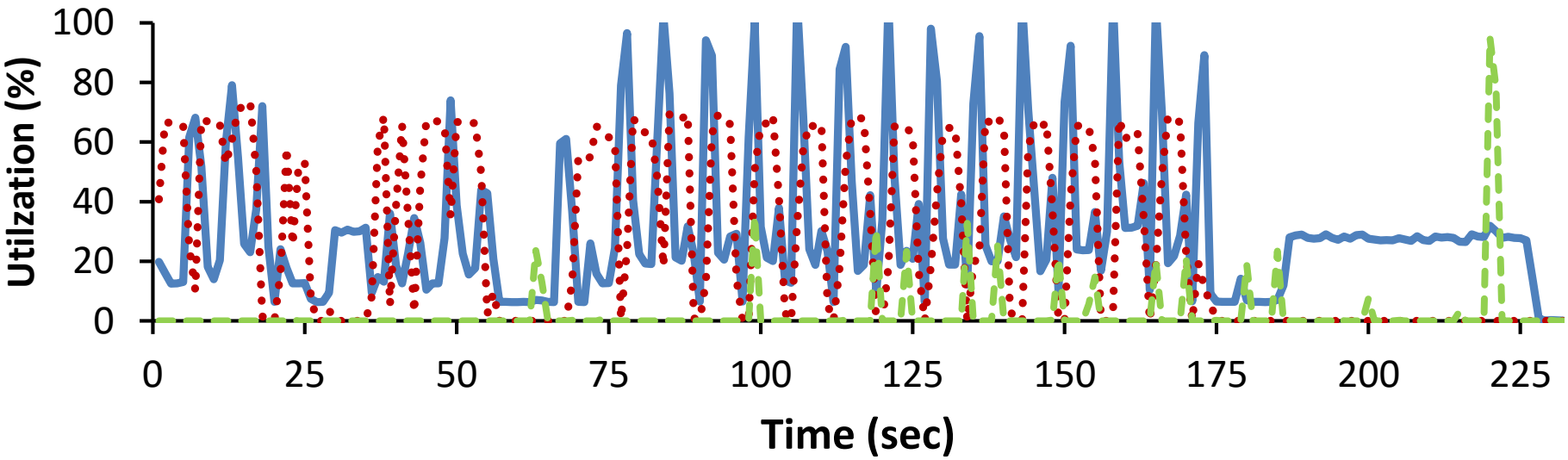
PCOPY utilization

[Data: TPCH – SF10
Input storage: HDD
Destination storage: DAS]

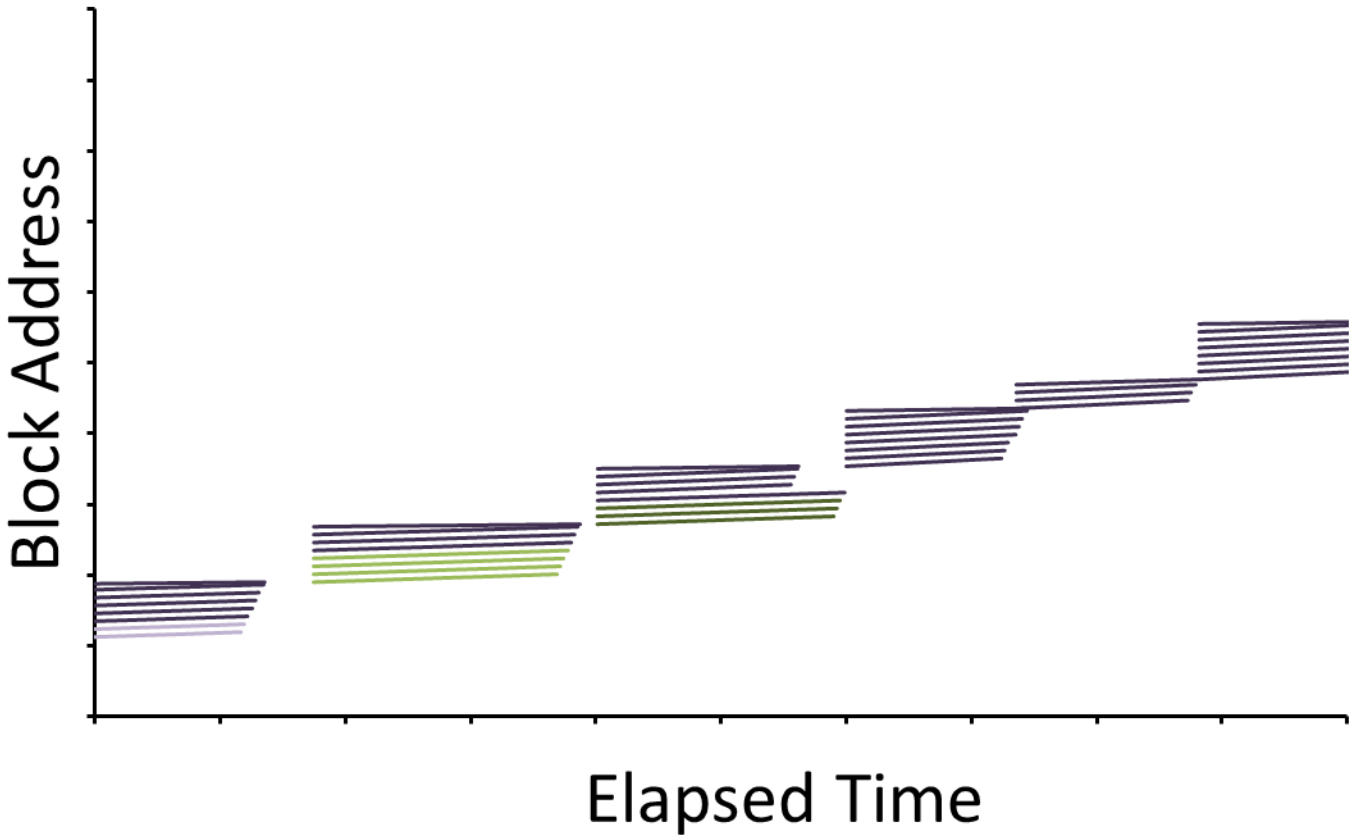


DBMS-C utilization

[Data: TPCH – SF10
Input storage: HDD
Destination storage: DAS]



DBMS-C read patterns



Reducing data loading overheads

- In situ querying [SIGMOD12, VLDB14]
- Data Vaults: Exploit metadata [Ivanova12,Kargin15]
- Instant Loading: SIMD & Code gen. [Muehlbauer13]
- Accelerators (FPGAs, GPUs)