nKV: Near-Data Processing with KV-Stores on Native Computational Storage





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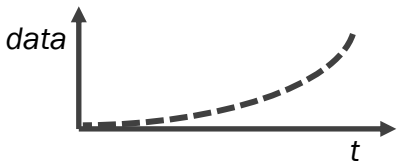
Motivation

High Insertation
+
Update Intensive Workload

High Throughput
+
Analytical Workload



We are „living in exponential world“
Gray et al. [1]

DBMS

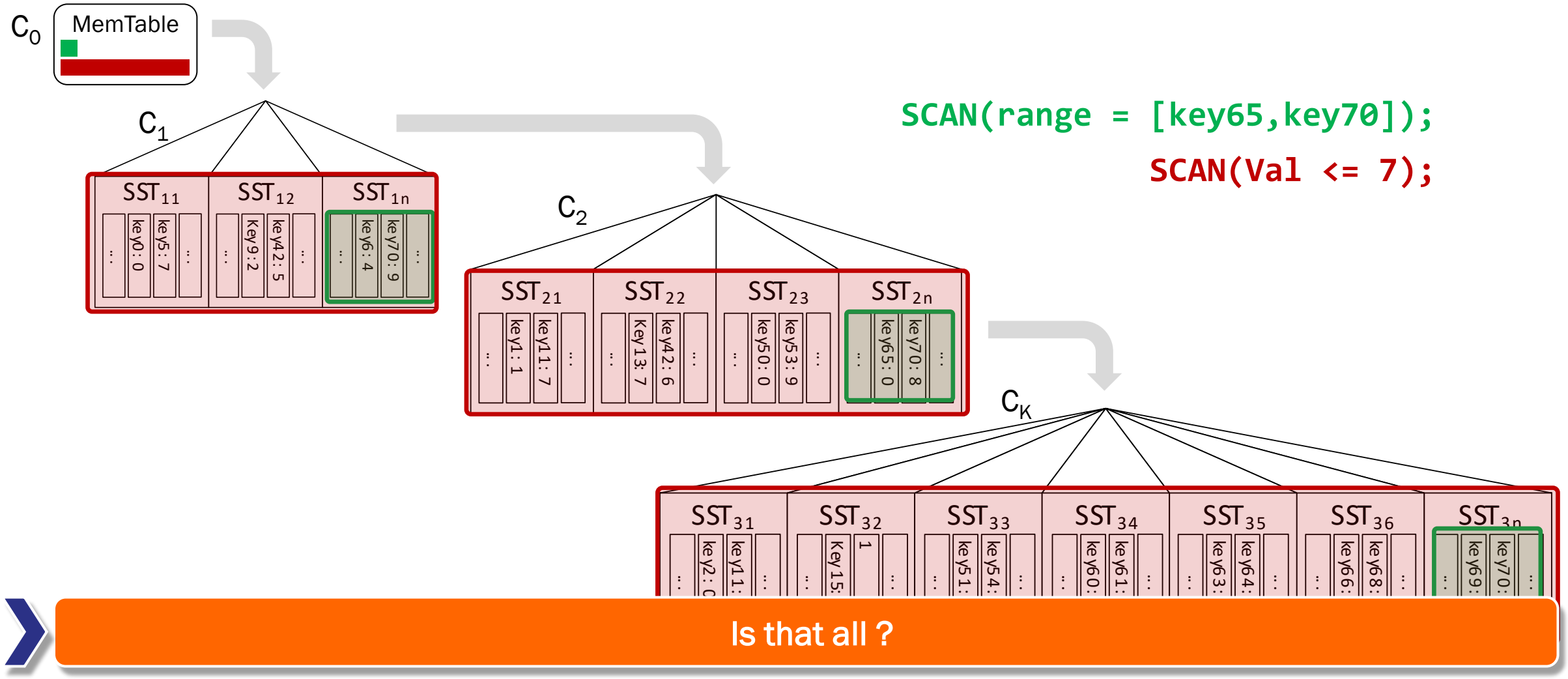
Storage

- Increase in data transfers
- Impair performance/scalability
- Hurt resource-/energy-efficiency

But why ?

[1] A. Szalay, J. Gray; Science in an exponential world

Read Amplification of LSM-Trees

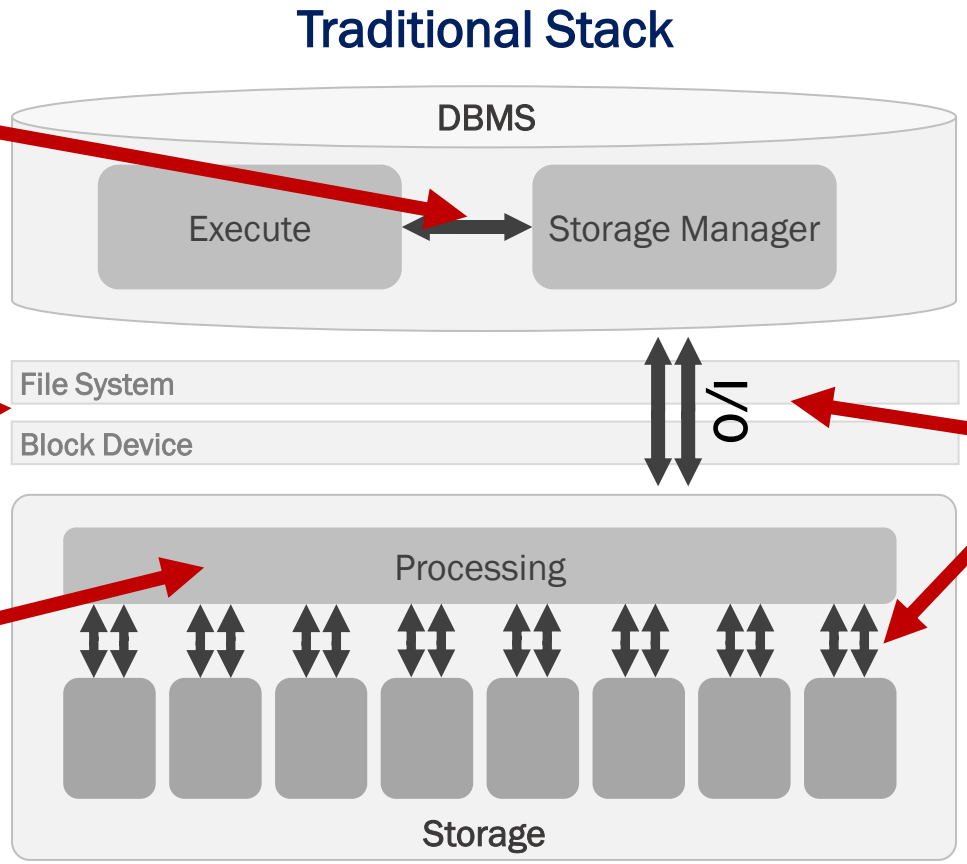


System Drawbacks

System Paradigm:
only „Data-to-Code“

Intermediate Layers:
introduce levels of indirection

Resources:
used for compatibility



Bandwidth:
Device ↔ Host ≪ On-Device

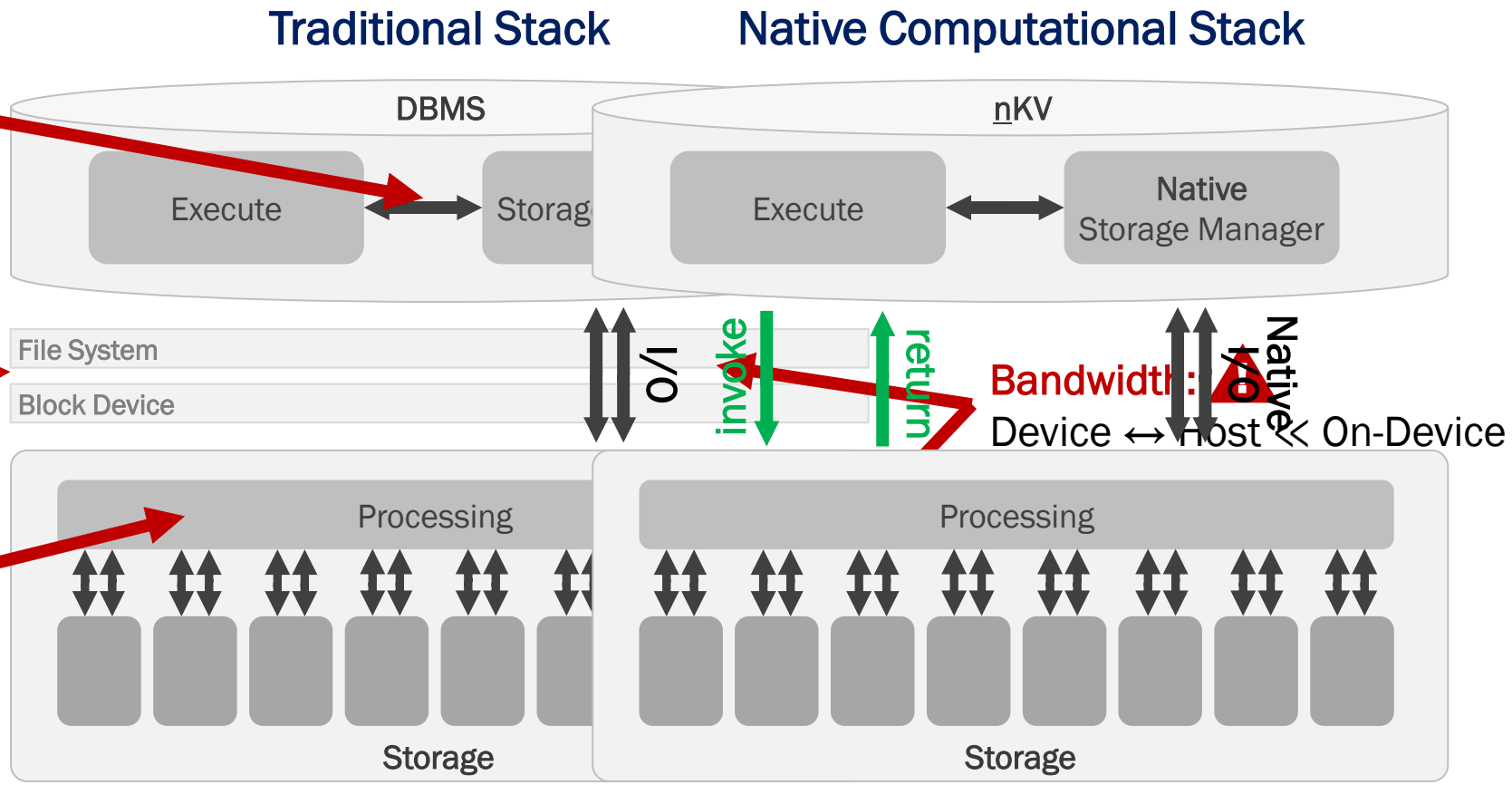
Several elements impair performance – how do we address these?

Native Computational Stack

System Paradigm:
only „data-to-code“

Compatibility Layers:
introduce levels of indirection

Resources:
used for compatibility



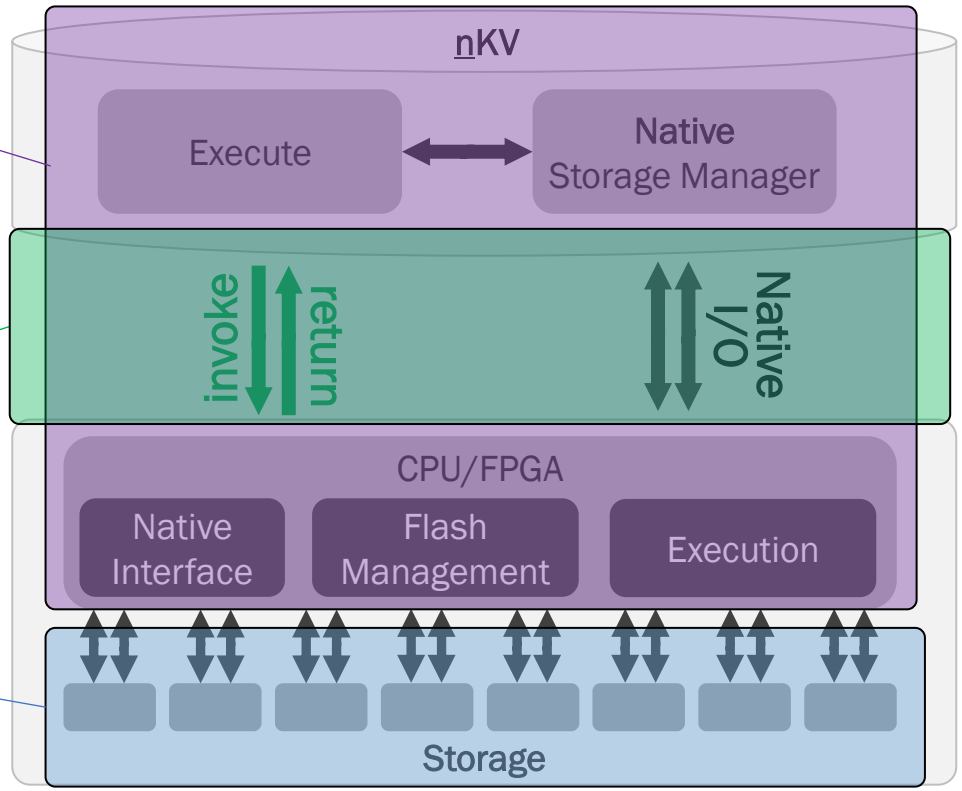
nKV uses NDP to utilise on-device resources and to reduce data transfers

Key Aspects for “Code-to-Data”

Computation Placement:
- Depending on the operation/workload computation can be placed in Host/on-Device CPU or FPGA

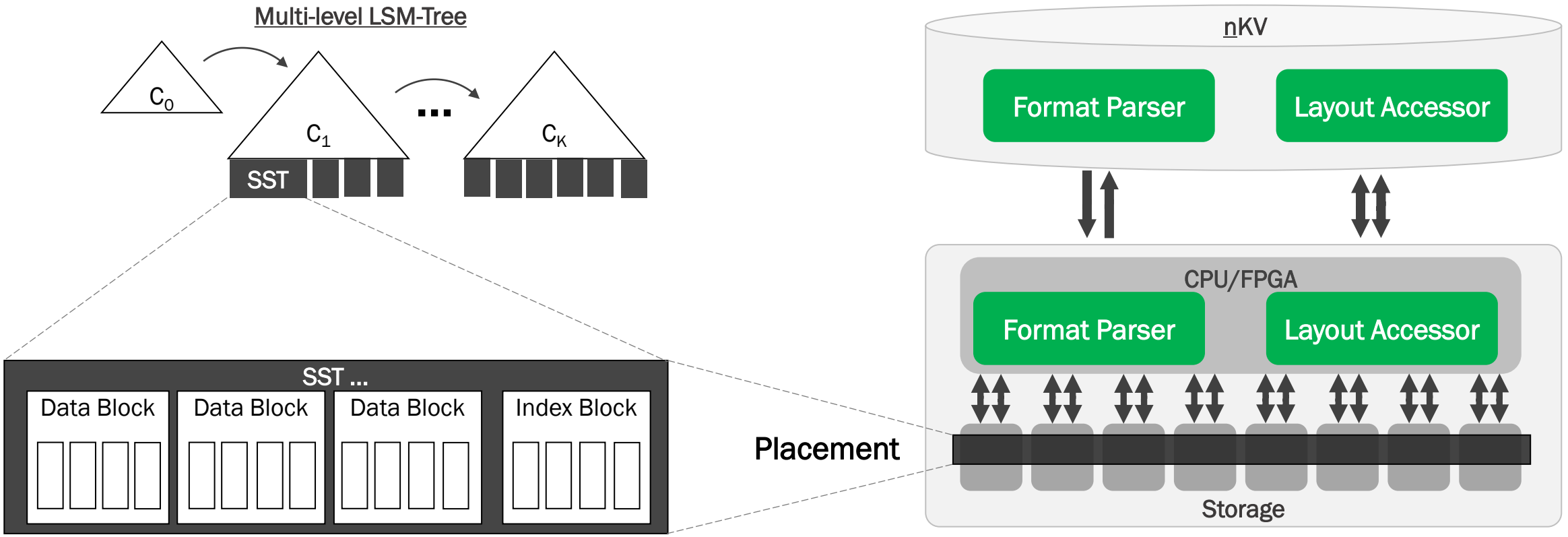
NDP Interface Extension:
- NVMe Support: Seamless integration in Database
- Synchronous and Asynchronous task scheduling

Native Storage:
- Physical Data Placement
- Leverage internal Flash parallelism e.g. Channels/Luns



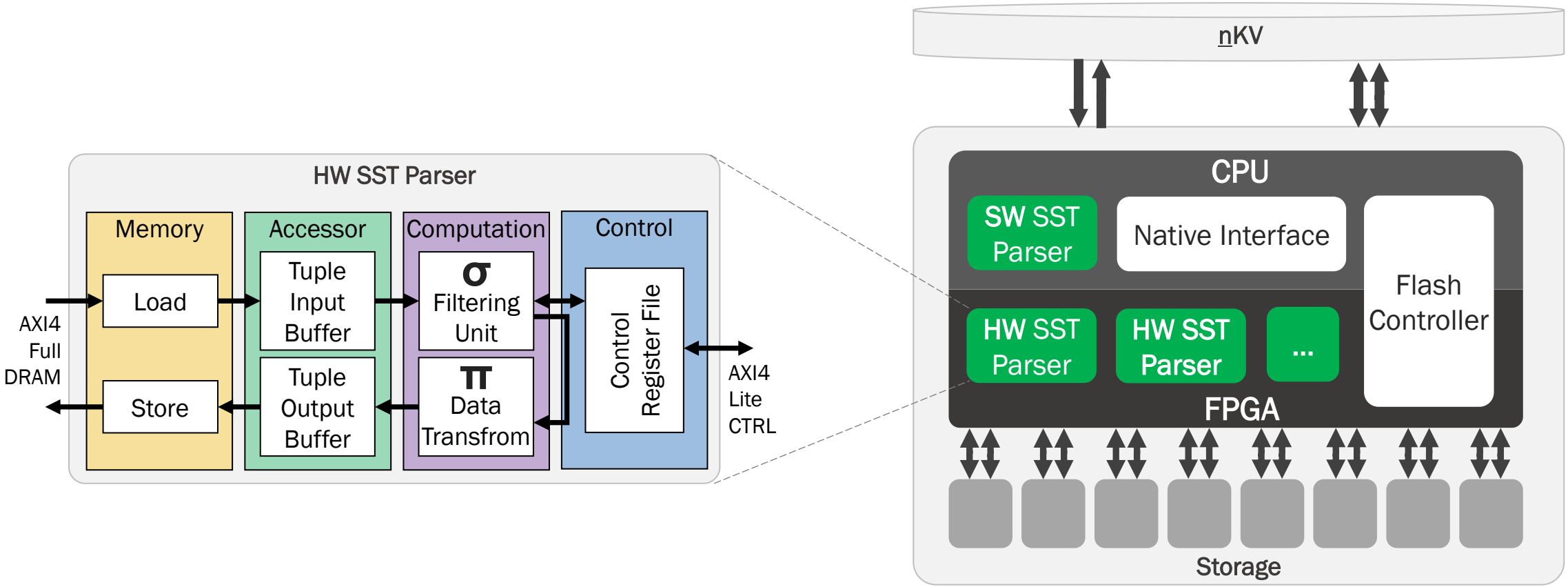
Native Storage, NDP interface extension and computation placement are essential parts of nKV

On-device Data Parsing



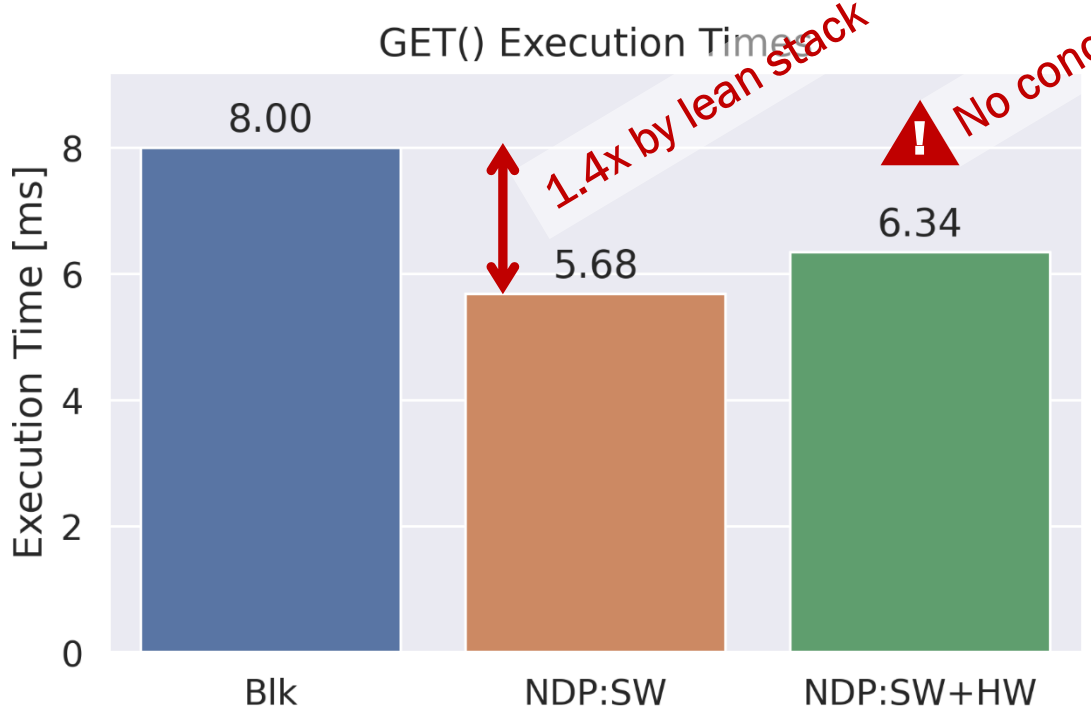
Accessors and parsers must be available in the host and on-Device for nKV

HW Support

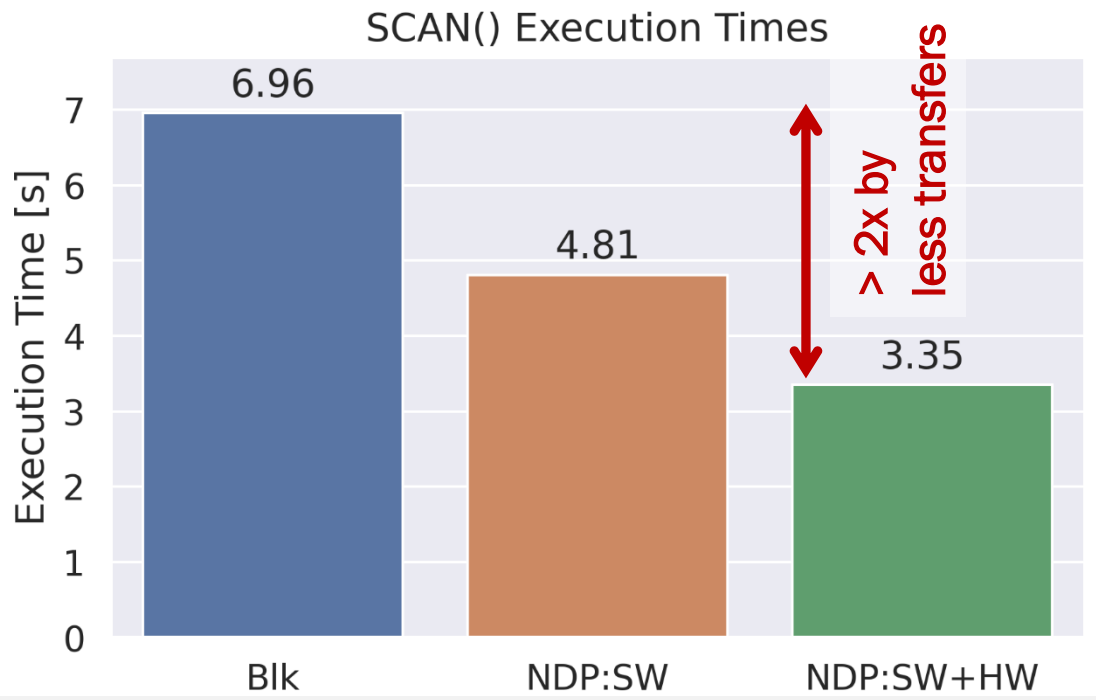


HW/SW Co-Design of nKV allows leveraging hardware resources efficiently

Experimental Evaluation



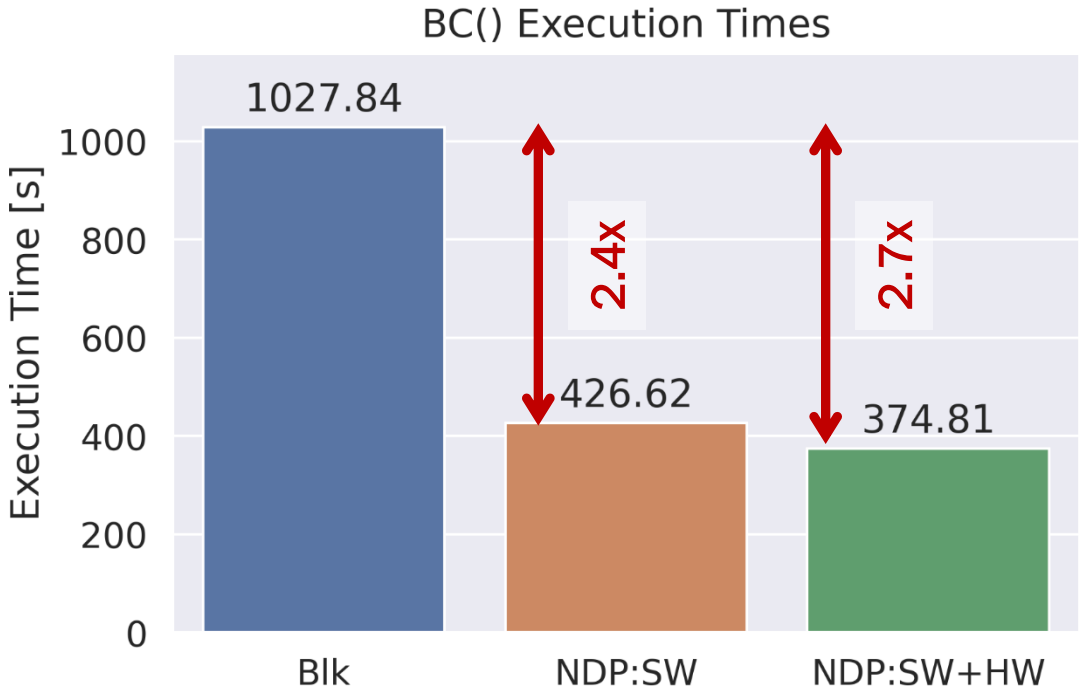
Experiment 1: Lean Native Stack

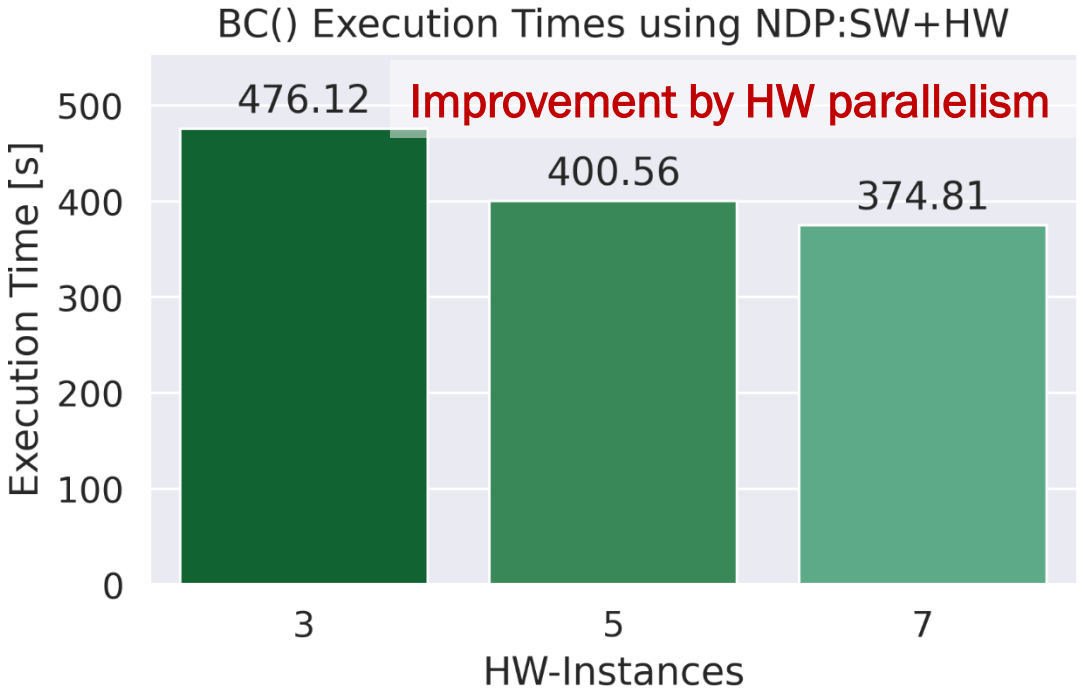


Experiment 2: Data Transfer Reduction

nKV's lean stack and less data transfers improve performance

Experimental Evaluation





Experiment 3: Lean Native Computational Storage

Experiment 4: Execution Parallelism

nKV speed up complex queries by a lean stack, less data transfers and leveraging hardware resources

Conclusion

nKV

native Computational Storage

- **Elimination of intermediary layers** for compatibility reasons (e.g. block device)
- **Physical data placement** according to storage device characteristics (e.g. Channels/LUNs)
- Seamlessly **embedded NVMe interface** with (a)/synchronous task scheduling

near-Data Processing

- **NDP interface extension** with a generic command
- **Data format parsers and accessors** in software and hardware
- **Flexible scheduling** across on-Device processing units (e.g. CPU/FPGA)

Evaluation

- **Lean stack** of simple lookups: **1.4x**
- **Data transfer reduction: >2x**
- **HW/SW Co-designed** of complex queries: **2.7x**

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