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Accelerating Data Analytics with Computational Storage Drives

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What is a computational storage drive?

Computational Storage Drive or “CSD”
Why use CSDs?

CPU Driven Architecture → Data Driven Architecture
Why use CSDs (Part II)?

Compute-Storage Disaggregation → Data Movement Challenges
CSDs + Data Analytics

Compute Node Compute Node Compute Node Compute Node

Analytic Engines

Storage Node Storage Node Storage Node Storage Node

Column Store Files
What about scan pushdown?

Reduces inter-node data movement, but increases storage node compute load → higher cost
What about scan pushdown with CSDs?

Reduces inter-node data movement without adding additional compute cost to storage nodes.
But there is a challenge…

- Need flexibility to support different column store formats
- CSD scan engines must be programmable
- Use embedded ARM or RISC-V cores
- Inadequate scan performance
... and a solution

Need prevent embedded cores from becoming a bottleneck

**Only Option**: Alleviate embedded cores from touching every single data item during scan

Enhance the column-store file format to enable data skipping during scan

Embed fine-grain metadata into column-store file to facilitate data skipping
Data skipping with fine-grain metadata

Segment Skip Masks

One Column

Segment G₃ | F₃ | Segment G₂ | F₂ | Segment G₁ | F₁

Fᵢ & S = 0?

No

Pass to Host?

No

Yes

Skip and move to next segment

Send segment Gᵢ to host for processing

Process Gᵢ within CSD
Test Results

- 8x ARM Cortex A53 @ 1.4GHz
- Dataset: TPC-H lineitem Table
- Analytics Engine: ClickHouse
- Assumptions:
  - Pipelined data fetching, decompression, and scan inside CSD.
  - Pipelined intra-CSD processing and host processing.

Summary:
- CSD off-load with added metadata reduced query latency 5x compared to host processing alone
- Achieved scan throughput >1GB/s per ARM core
- Granularity of metadata is a key performance tuning factor