Computational Storage by FPGA
ODSA Data Accelerator Workshop

David McIntyre
Director Product Planning and Business Enablement
Samsung Device Solutions America
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The Infinite Data Ocean
Our Mission

Oceans of data, but how to search effectively?

Data Search and Analytics: No Compromise

- Urgent
- Accurate
- Sustainable
- Results-driven

Scenario Planning
- Medical (Genomics)
- Fintech (Colo Trading)
- Cyberforensics (Security)
- Edge (AI Surveillance)
Today’s Compute and Storage Compromise

- **Latency**: Data transfer to cloud or on-prem host servers for all processing tasks
- **Restricted Bandwidth**: Network congestion to over-provisioned servers
- **Expense**: Cloud instances
- **Security and Privacy Issues**: Data exposure vulnerabilities and sharing across parties
- **Resource dependencies**: Misbalanced provisioning of compute and storage resources (see pic)

![Diagram of compute, network, and storage resources]

Performance Limit: Storage to Host Server Ratio
Computational Storage Resolution

- **Reduced Latency**: Bringing compute to the data for improved response times with data analytics.
- **CapEx and OpEx savings**: Less data center server resources required for reduced TCO.
- **Security and privacy compliance**: Localized data processing provides better protection and control.
- **Flexibility and scalability**: SmartSSD scale up based on customer application requirements.
Computational Storage Explained

- Improved Performance with local on-drive compute resources
- Minimal data movement required
- Secure data attributes
Computational Storage Deployments

Move Compute Closer to Storage

Current Compute/Storage Architecture

- Moving data between storage and host CPU creates performance bottlenecks for data-intensive applications

Computational Storage Architecture

- Data processed directly on the CSD => no large data transfers, faster time-to-insight
- Adding CSDs adds processing power and internal bandwidth => scalable acceleration

Deployment Examples

- Compute/Storage Server
- Smart Cache Layer
- Cloud to Edge compute

Image Source: SNIA

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Computational Storage Product Example

FPGA Accelerator, Flash Controller, 4GB DRAM and 4TB TLC NAND flash
- Peer-to-peer (P2P) communication enables unlimited concurrency

SSD-to-Accelerator data transfers use internal data path
- Save precious L2:DRAM Bandwidth (Compute Nodes) / Scale without costly x86 frontend (Storage Nodes)
- Avoid the unnecessary funneling and data movement of standalone accelerators
- FPGA DRAM is exposed to Host PCIe address space
- NVMe commands can securely stream data from SSD to FPGA peer-to-peer
SmartSSD® Drive Performance and Use cases

◆ Scalable Across Many Applications: Data at Rest and Inline

**Database**
SparkSQL with Parquet Data
- 5.3x overall performance improvement for heavy query
PostgreSQL 11
- 40x faster scan-heavy queries (7 -> 331 queries/hr)

**Rich Media**
H.264 Video Transcoding
- Multi-stream transcoding: 20% higher 1080p frame rate
- Offloading CPU workload: 87% lower CPU usage

**Storage & Big Data Services**
LZ4 Decompression Scale-out
- 3x decompression bandwidth, scales to 24 SmartSSD drives
MPU search Scale-out
- Same regex search time for 10PB as 4TB
Computational Storage and Security

Risks vs standard storage:
- The CSD can delete/add/modify data on the drive
- The CSD functionality can be programmed
- Virtualization

Risks vs external accelerator:
- Direct access to storage
- FPGA programming
- Access to network infrastructure (NVMe-oF)
- Decryption of data prior to processing

The CSD may perform security functions:
- **Authentication.** Host agent to CSD and CSD to host agent
- **Authorization.** Mechanisms for secure data access and permissions control
- **Encryption.** Mechanisms to perform computation on encrypted data that was not encrypted by the CSD. Mechanisms that exchange information necessary for the CSD to encrypt/decrypt data.
- **Auditing.** Mechanisms that allow for generating and retrieving of a secure log
Computational Storage and FPGA security

- FPGAs are SRAM based devices which are programmed by secure bit streams
  - Key is programmed via JTAG port
  - Bitstream in encrypted with design tools
  - FPGA identifies encrypt/no encrypt for field testing
- AES 256 secures bitstream programs
- Additional Security Measures
  - Design Region Isolation
  - JIT Partial Reconfiguration
  - SOC and Bus Isolation
  - PUF files for device dependency
  - E-fusing

https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6849432
### Computational Storage Summary

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#### Cloud to Edge Deployments

![Cloud to Edge Deployments Diagram](image)
Computational Storage: Your Invitation

- Collaborate on workloads and use cases
  - Data Analytics
  - Data Management
  - AI Inference

- Solution development
  - POC trials
  - Ecosystem partners
  - TCO comparisons to alternate technologies

- Reach out to learn more:
  
  David McIntyre
d.mcintyre@samsung.com