STORAGE DEVELOPER CONFERENCE

SDC 21

BY Developers FOR Developers

Virtual Conference
September 28-29, 2021

A SNIA Event

Computational Storage APIs

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Agenda

- Overview
- Introducing CS APIs
- API Usage by Example
- Example in Code
- Advanced Topics
- Summary

Computational Storage

Why an API Library?

Why Computational Storage?

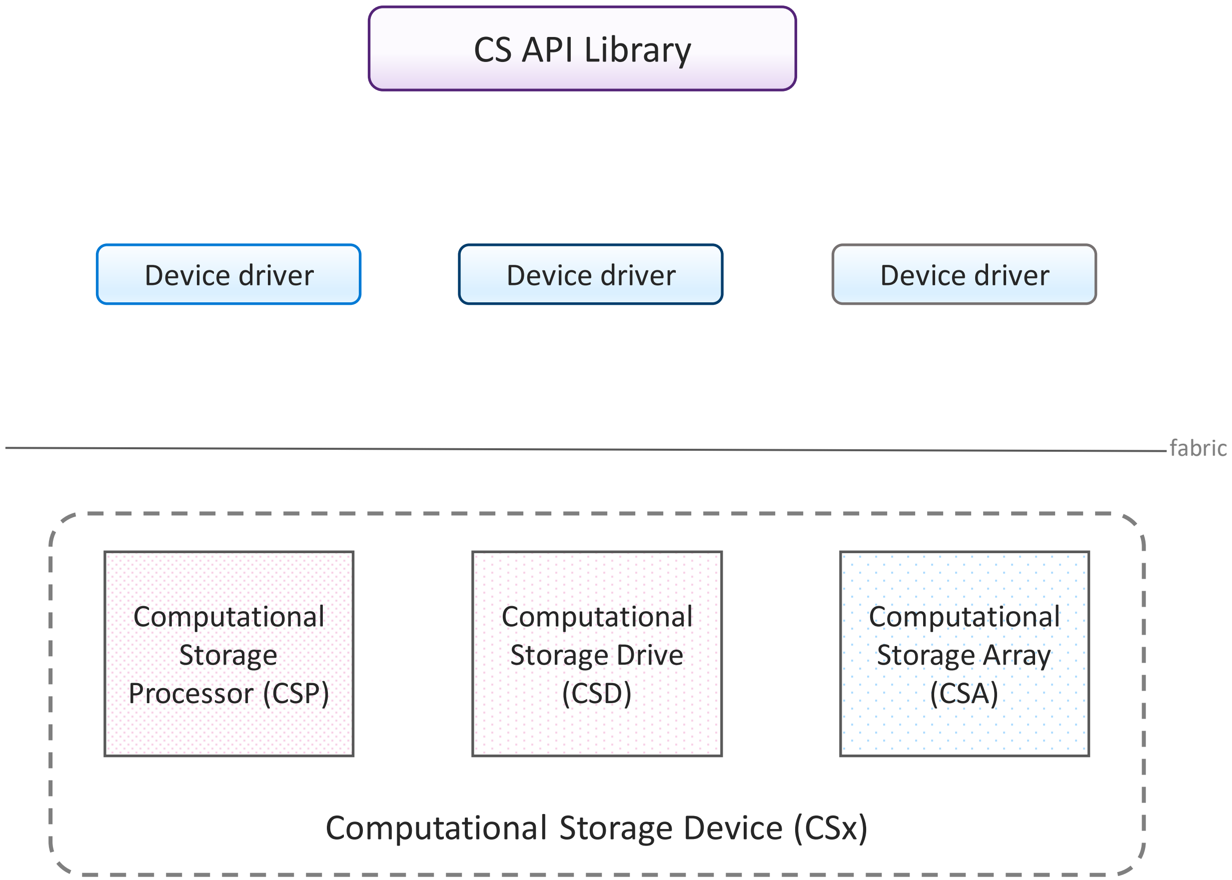
- Data is being created at a exponential rate
- Storage has also grown to account for this growth

- NVMe SSDs provide better performance than ever before
  - But their bandwidth not fully utilized by Host
- General purpose CPUs not able to fully tap this bandwidth
  - Scaling limited by PCIe lanes
- SSDs have more internal bandwidth than utilized

- Computational Storage & Offloads tap into this
  - Process data near storage
  - Add compute to storage

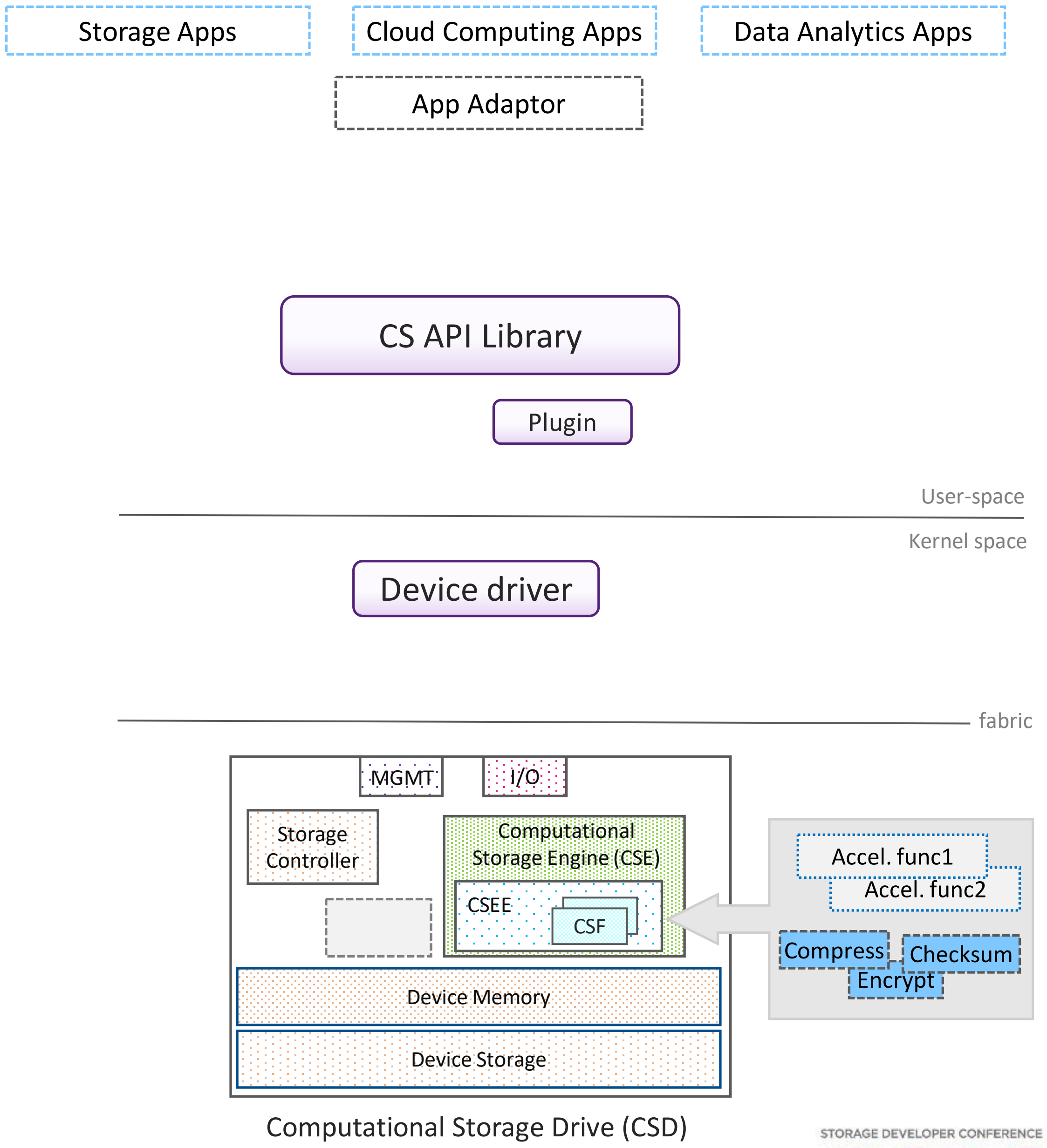
CS API Library Overview

- One Set of APIs across all CSx types
  - CSP, CSD, CSA
  - Common set of APIs for different CS devices
- One interface to different device and connectivity choices
  - Hardware ASIC, CPU, FPGA, etc
  - NVMe/NVMe-oF, PCIe, custom, etc
- Configurations may be local/remote attached
- Hides vendor specific implementation details below library
- Abstracts device specific details
- APIs to be OS agnostic



About API Library

- Uniform interface for multiple configurations
  - APIs provided in common library
- Each CSx managed through its own device stack
  - Library may interface with additional plugins based on implementation requirements
  - Plugins help connect CSx to abstracted CS interfaces
- Extensible Interface
- CS APIs abstract
  - Discovery
  - Device Access
  - Device Memory (mapped/unmapped)
  - Near Storage Access
  - Copy Device Memory
  - Download CSFs
  - Execute CSFs
  - Device Management



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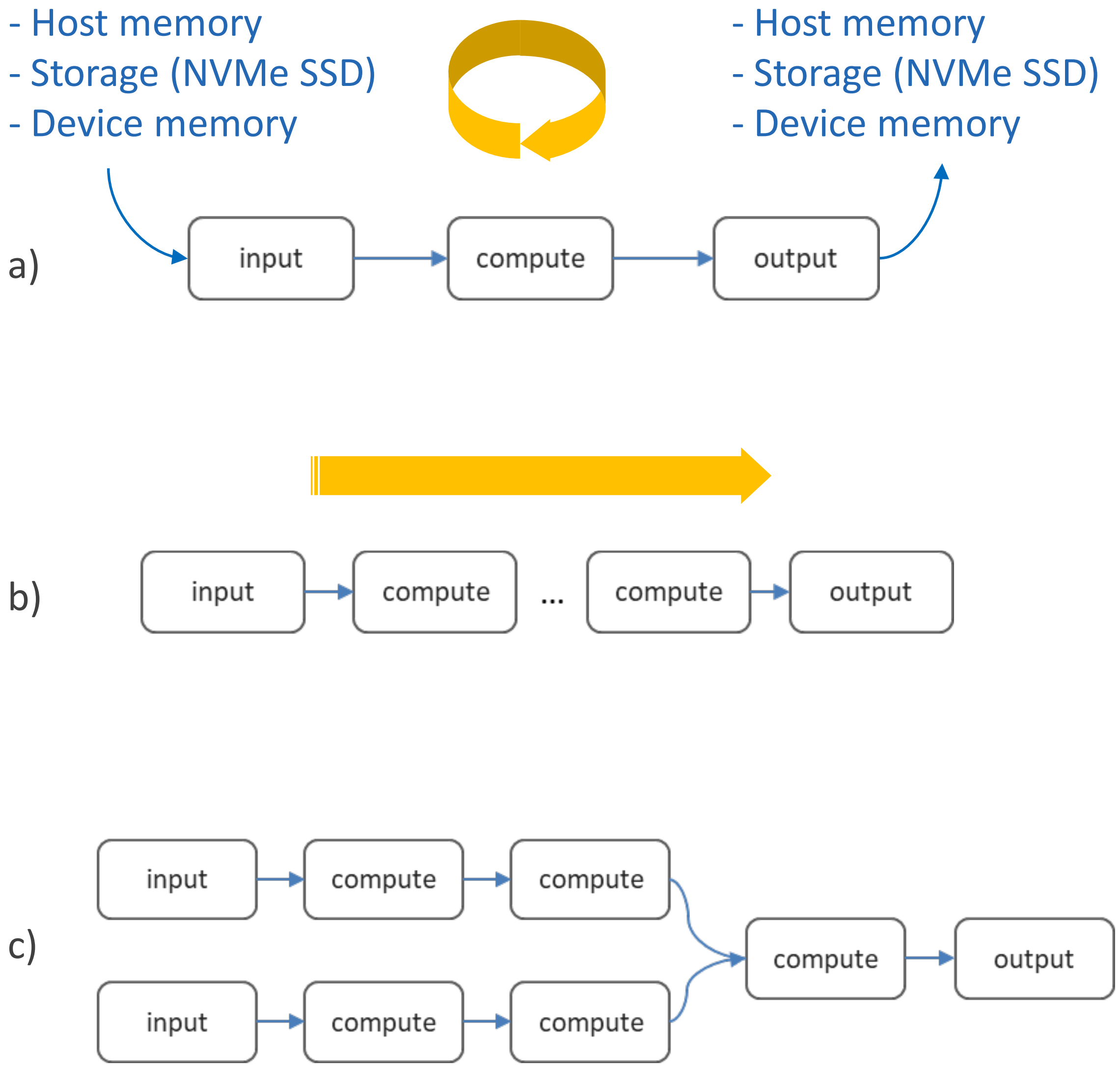
API Requirements

- One interface across CS devices
  - CSDs, CSPs, CSAs
- Discovery
- Access
- Configure
- Device Memory Allocation
- Data Movement
  - Input: Host memory, Storage, Device memory
  - Output: Device memory, Storage, Host memory
- Execute
- Device Management
- Queued I/O Requests
- Transparent Local/Remote usages
- Security



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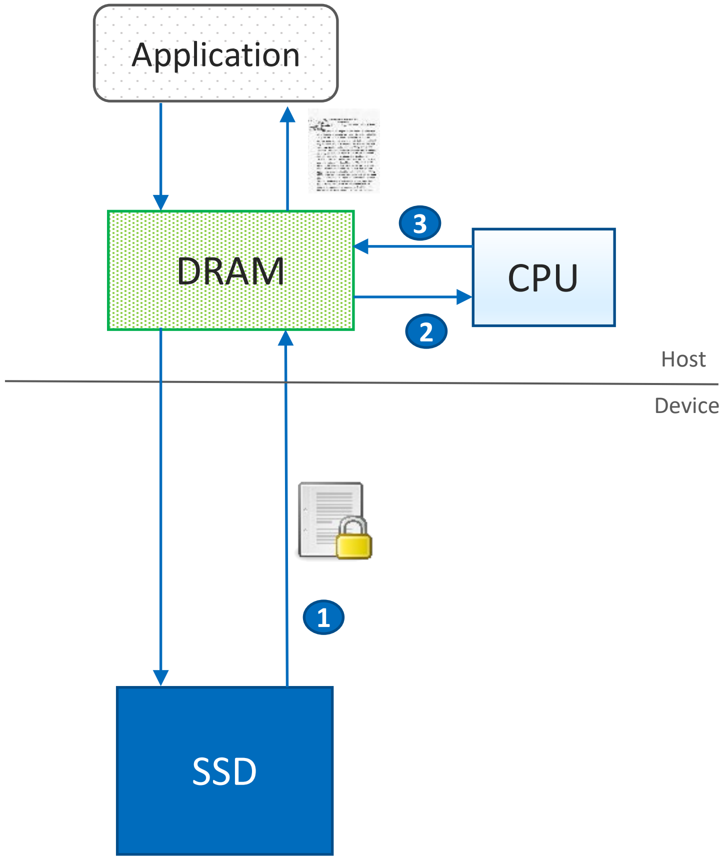
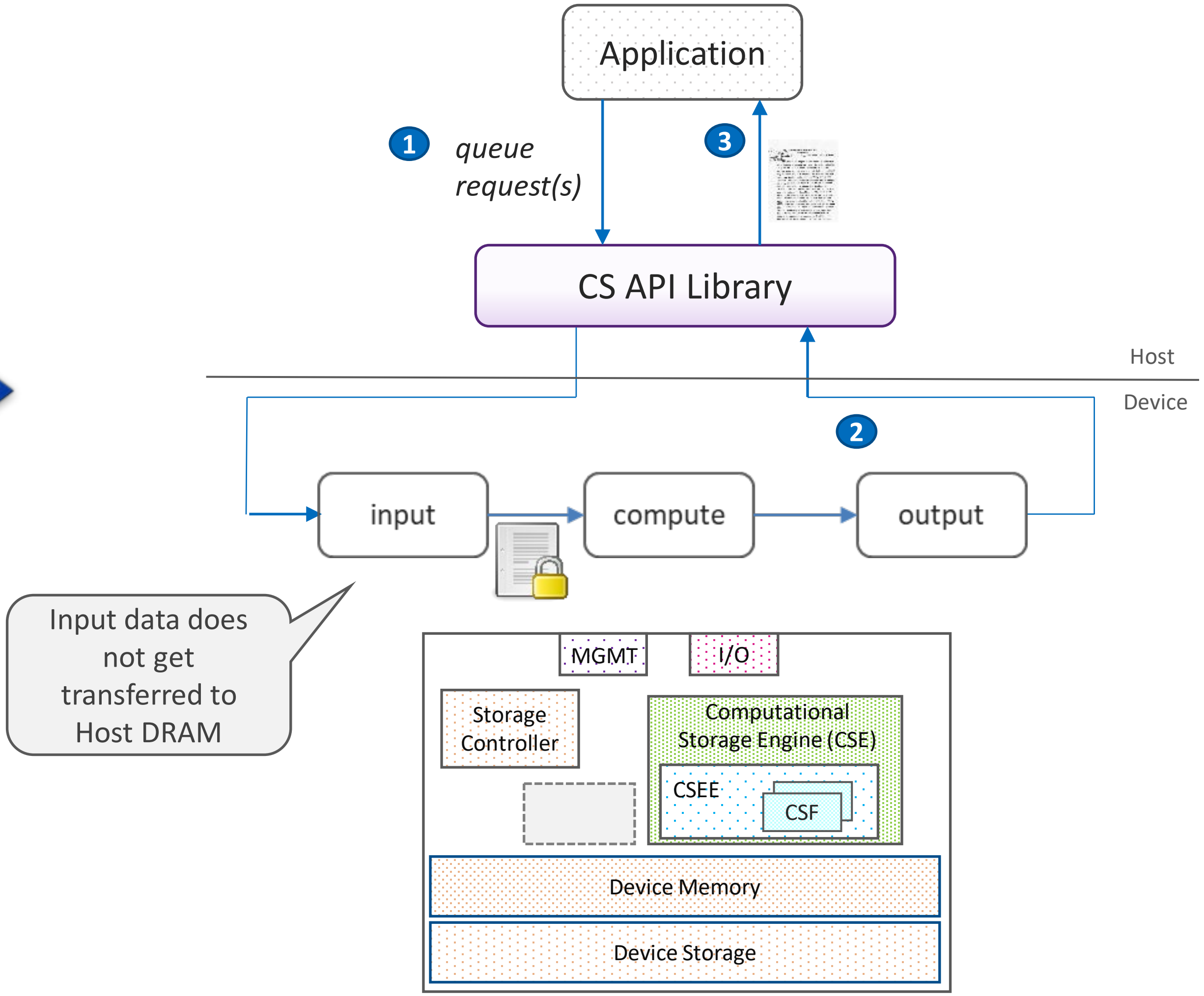
How to use Computational Storage

Usage by example

Applying Computational Storage





Computational Storage Drive (CSD)

Computational Storage API Details

Discovery & Access APIs

```
CS_STATUS csGetCSxFromPath(char *Path, unsigned int *Length, char *DevName);
CS_STATUS csQueryFunctionList(char *Path, unsigned int *Length, char *Buffer);

CS_STATUS csOpenCSx(char *DevName, void *DevContext, CS_DEV_HANDLE *DevHandle);
CS_STATUS csCloseCSx(CS_DEV_HANDLE DevHandle);

CS_STATUS csGetFunction(CS_DEV_HANDLE DevHandle, char *Name, void *Context, CS_FUNCTION_ID *FunctionId);
```

- Discovery
  - Discover CSx devices
    - By device path, file/directory path or all
  - Discover CSFs by requirement
- Access
  - Access CSx once discovered for CS usage
  - Get access to a specific CSF for execution

This presentation discusses SNIA work in progress, which is subject to change without notice

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Device Memory

```
CS_STATUS csAllocMem(CS_DEV_HANDLE DevHandle, int Bytes, unsigned int MemFlags, CS_MEM_HANDLE *MemHandle,
                     CS_MEM_PTR *VAddressPtr);
CS_STATUS csFreeMem(CS_MEM_HANDLE MemHandle);
```

- Allocate / Deallocate Device Memory
- Manage Device Memory
  - Memory scheme
    - Memory mapped (PCIe BAR)
    - Opaque
  - Memory organization
    - Host managed
    - Device managed
- Mapping of memory to application space depends on the device
- Transparent to fabric usages
- Returns memory handle
  - Virtual address pointer when applicable

Storage I/O

```
typedef struct {
   enum CS_STORAGE_REQ_MODE Mode;
   CS_DEV_HANDLE DevHandle;
   union {
      csBlockIo BlockIo;
      csFileIo FileIo;
   } u;
} csStorageRequest;
```

```
CS_STATUS csQueueStorageRequest(csStorageRequest *Req, void *Context, csQueueCallbackFn CallbackFn,
                                CS_EVT_HANDLE EventHandle, u32 *CompValue);
```

- Initiate direct internal transfers between storage (SSD) and allocated Device Memory
  - Seamlessly manages mapped/unmapped device memory
  - P2P transfers through file system if device supports memory mapped P2P BAR
- Single interface to support block & file; extensible
- Transparent to fabric usages

- Follows common completion modes
  - Synchronous
  - Asynchronous callback
  - Asynchronous event

Some modes not available in all configurations

Compute

```
typedef struct {
   CS_DEV_HANDLE DevHandle;
   CS_FUNCTION_ID FunctionId;
   int NumArgs;
   CsComputeArg Args[1];
} csComputeRequest;
```

```
CS_STATUS csQueueComputeRequest(csComputeRequest *Req, void *Context, csQueueCallbackFn CallbackFn,
                                CS_EVT_HANDLE EventHandle, u32 *CompValue);
```

- Initiate execution of a CSF with its input and output parameters
- API extensible for parameters
- Transparent to fabric usages

- Follows common completion modes
  - Synchronous
  - Asynchronous callback
  - Asynchronous event

Some modes not available in all configurations

Copy Device Memory

```
typedef struct {
  enum CS_MEM_COPY_TYPE Type;
  void *HostVAddress;
  csDevAFDM DevMem;
  unsigned int Bytes;
} csCopyMemRequest;
```

```
typedef enum {
  CS_COPY_TO_DEVICE,
  CS_COPY_FROM_DEVICE
} CS_MEM_COPY_TYPE;
```

```
typedef struct {
  CS_MEM_HANDLE MemHandle;
  unsigned long ByteOffset;
} csDevAFDM;
```

CS_STATUS **csQueueCopyMemRequest**(csCopyMemRequest *Req, void *Context, csQueueCallbackFn CallbackFn, CS_EVT_HANDLE EventHandle, u32 *CompValue);

- Transfer data between Host memory and allocated Device Memory
- Single interface for transfer operations
  - Transparent to fabric usages
- Follows common completion modes

- Common completion modes
  - Synchronous
  - Asynchronous callback
  - Asynchronous event

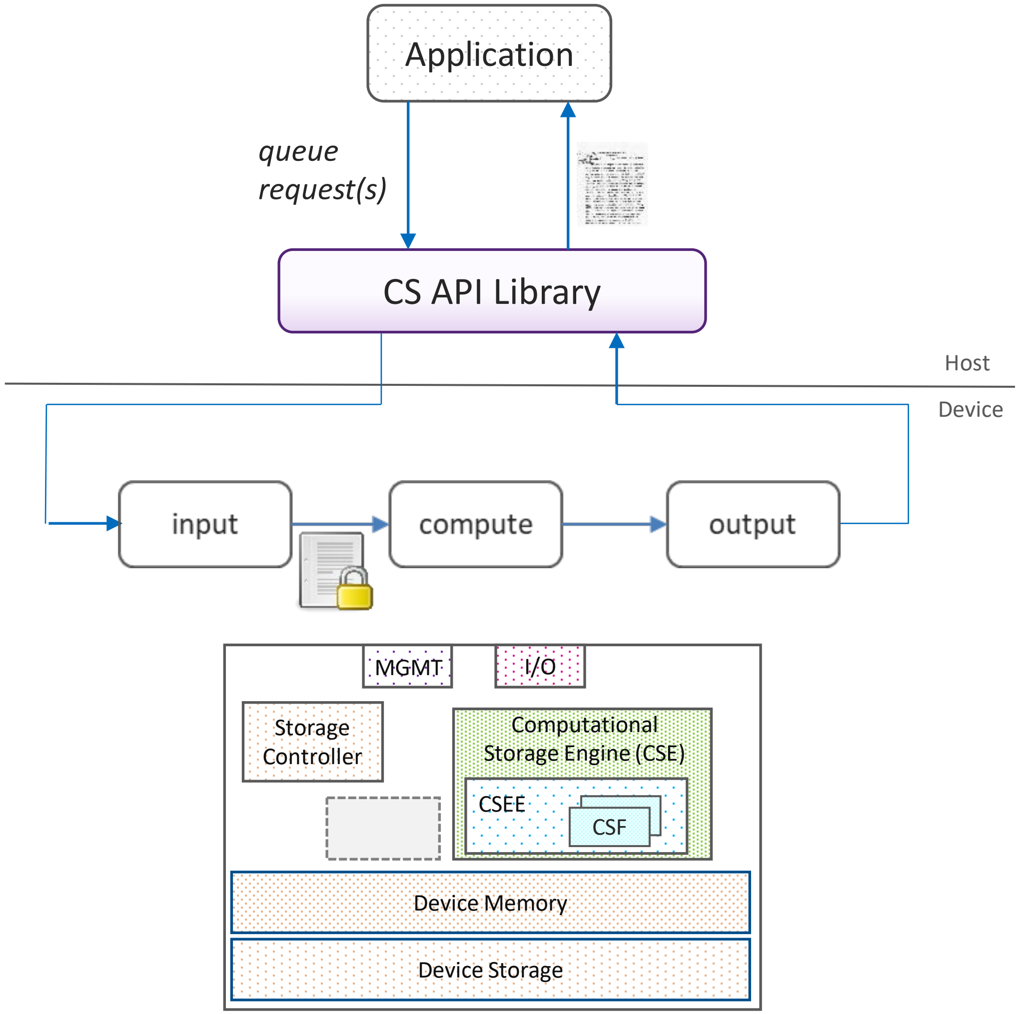
Some modes <u>not</u> available in all configurations

Coding the Example

Applying APIs to example

APIs Required for Example

1. Discover CSx & CSF
2. Allocate Device Memory
3. Queue Storage Request
4. Queue Compute Request
5. Queue Copy Memory Request



Computational Storage Drive (CSD)

Sample Code – Decrypt file

```
#include <cs.h>

int cs_decode(char *file_path, int fd, void *decode_buf)
{
   // discover my CS device (CSx) and CSF                                 1
   length = sizeof(csxBuffer);
   status = csGetCSxFromPath(file_path, &length, &csxBuffer);
   status = csOpenCSx(csxBuffer, &MyDevContext, &devHandle);
   status = csGetFunction(devHandle, myFunction, NULL, &functId);
   // allocate device memory for input and output buffers                2
   status = csAllocMem(devHandle, CHUNK_SIZE, 0, &inMemHandle, NULL);
   status = csAllocMem(devHandle, CHUNK_SIZE, 0, &outMemHandle, NULL);

   // allocate storage request & read chunk size data from file handle fd
   storReq = calloc(1, sizeof(CsStorageRequest));                        3
   if (!storReq) { ERROR_OUT("memory alloc error\n"); }
   storReq->Mode = CS_STORAGE_FILE_IO;
   storReq->DevHandle = devHandle;
   storReq->u.CsFileIo.Type = CS_STORAGE_LOAD_TYPE;
   storReq->u.CsFileIo.FileHandle = fd;
   storReq->u.CsFileIo.Offset = 0;
   storReq->u.CsFileIo.Bytes = CHUNK_SIZE;
   storReq->u.CsFileIo.DevMem.MemHandle = inMemHandle;
   storReq->u.CsFileIo.DevMem.ByteOffset = 0;
   status = csQueueStorageRequest(storReq, storReq, NULL, NULL, NULL);
```

```
   // allocate compute request for 3 args & issue compute request        4
   compReq = calloc(1, sizeof(CsComputeRequest) + (sizeof(CsComputeArg) * 3));
   if (!compReq) { ERROR_OUT("memory alloc error\n"); }
   compReq->DevHandle = devHandle;
   compReq->FunctionId = functId;
   compReq->NumArgs = 3;
   argPtr = &compReq->Args[0];
   csHelperSetComputeArg(&argPtr[0], CS_AFDM_TYPE, inMemHandle, 0);
   csHelperSetComputeArg(&argPtr[1], CS_32BIT_VALUE_TYPE, CHUNK_SIZE);
   csHelperSetComputeArg(&argPtr[2], CS_AFDM_TYPE, outMemHandle, 0);
   status = csQueueComputeRequest(compReq, NULL, NULL, NULL, NULL);

   // allocate copy request & copy results to host buffer                5
   copyReq = calloc(1, sizeof(CsCopyMemRequest));
   if (!copyReq) { ERROR_OUT("memory alloc error\n"); }
   copyReq->Type = CS_COPY_FROM_DEVICE;
   copyReq->HostVAddress = decode_buf;
   copyReq->DevMem.MemHandle = outMemHandle;
   copyReq->DevMem.ByteOffset = 0;
   copyReq->Bytes = CHUNK_SIZE;
   status = csQueueCopyMemRequest(copyReq, NULL, NULL, NULL, NULL);

   return 0;
}
```

**API return status values are not shown to check for success and errors to ease readability*

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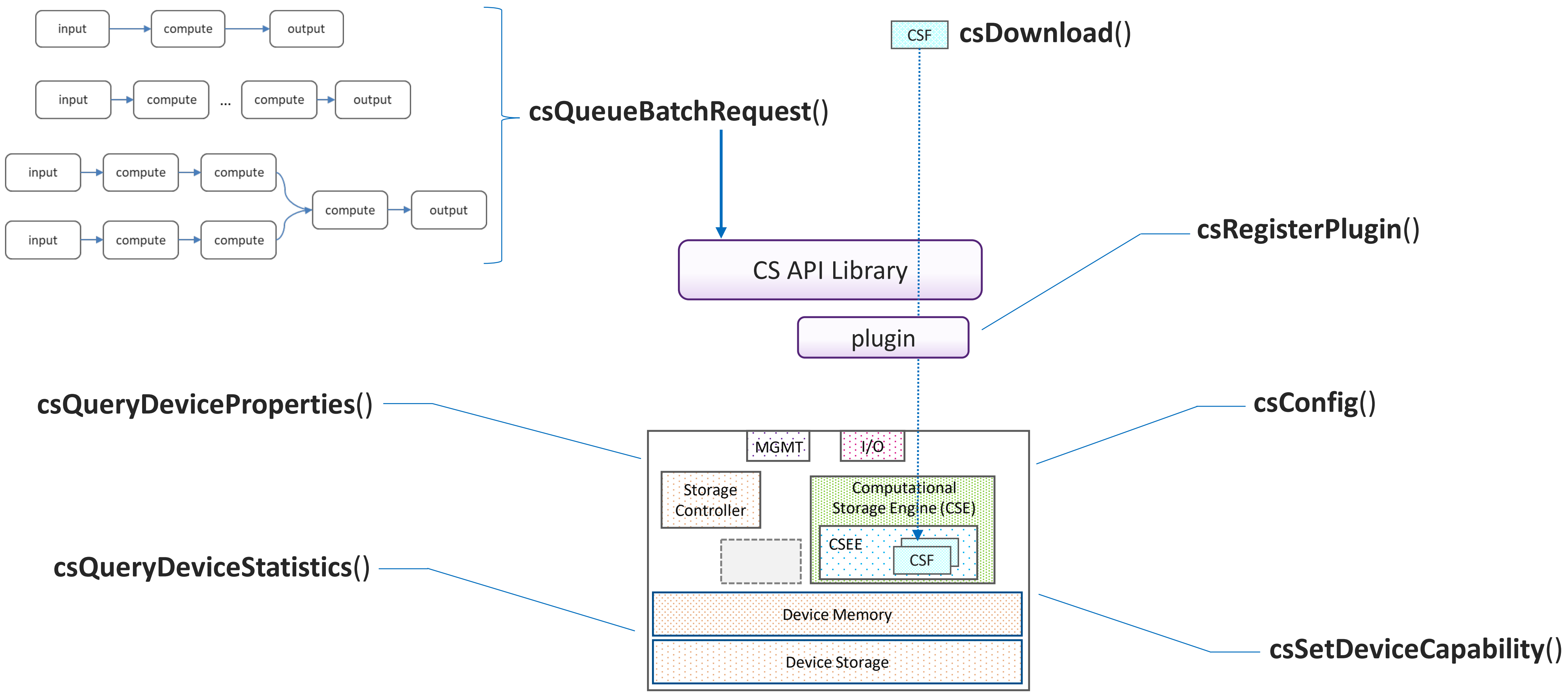
Other APIs

What else can the APIs do?

Other Interfaces



Call for Action

- Other sessions on Computational Storage
  - Samsung Keynote – Yang Seok Ki
  - Moving forward with an Architecture & API – Bill Martin
  - Computational Storage Update from SNIA WG – Scott Shadley & Jason Molgaard
  - NVMe Computational Storage Update – Kim Malone & Stephen Bates
- Join the standardization efforts
  - SNIA, NVMe
- Help build the ecosystem

Thank You

Please take a moment to rate this session.

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