HiHAT asynchronous operations

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OUTLINE

Background

Requirements and assumptions

Proposal

Questions?

Background

- Architecture vs. implementation
- Actions – invocation, data mgt, data movement, sync
- Action handles
  - Enables reference to and querying overall status of an action
  - Most common dependence link from one action to another
  - Some actions perform logical operations on ActionHndls, link multiple predecessors
- Sync objects
  - May be one or more per action (could be a graph), but one post-dominates all others

Requirements Overview

Action handles

- A.1/ **Link actions** according to dependences via ActionHndl
  [already covered by input dep in hhuInvoke/hhuCopy/...]
- A.2/ Create logical **AND/OR of multiple action handles**
  [already covered by hhuSync(Any|All)]
- A.3/ **Query action status** via action handle
- A.4/ Obtain and operate on an action's underlying **sync object**

Interoperability on sync objects without HiHAT's involvement

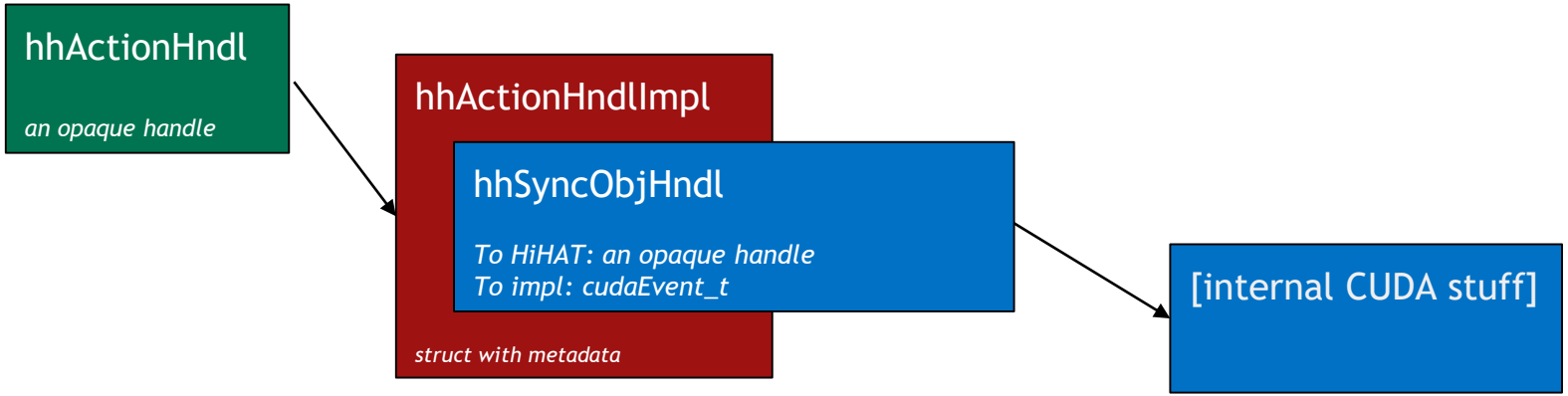
- S.1/ Based on sync object's memory semantics description
- S.2/ Based on sync object's type

Design

- What client (above HiHAT) owns
  - Pointer to ActionHndl
- What HiHAT owns
  - ActionHndl – created when submitted, destroyed with a Clean operation or explicitly
    - Members of ActionHndl, which may include sync object(s) should get cleaned up by destroy
- What implementations plugged in under HiHAT own
  - Sync object(s), which may be a member in ActionHndl
  - Management of dependences, evaluation of readiness to execute
    - Polling and triggering of sync objects; whether native or programmatic interfaces are used

Anatomy and ownership of an hhActionHndl

Illustrated by the case of a cudaEvent_t



- owned by the client

- owned by HiHAT

- owned by the implementation

PROPOSAL

A.1/ Link actions according to dependences via ActionHndl

Already there in the API. To list a few examples:

```
hhRet hhuCopy(
            hhDataView dst,
            size_t dst_offset,
            hhDataView src,
            size_t src_offset,
            size_t num_bytes,
            hhExecPol exec_pol,
            hhExecCfg exec_cfg,
            hhResrcHndlSet exec_resrc,
            hhActionHndl input_dep,
            hhActionHndl *out_action_hndl);
```

```
hhRet hhuInvoke(
            hhTaskHndl reg_task,
            void *dblob,
            hhExecPol exec_pol,
            hhExecCfg exec_cfg,
            hhResrcHndlSet exec_resrc,
            hhActionHndl input_dep,
            hhActionHndl *out_action_hndl);
```

```
hhRet hhuUnregMem(
            hhDataView mem_hndl,
            hhExecPol exec_pol,
            hhExecCfg exec_cfg,
            hhResrcHndlSet exec_resrc,
            hhActionHndl input_dep,
            hhActionHndl *out_action_hndl);
```

A.2/ Create logical AND/OR of multiple action handles

```
hhRet hhuSyncAll(
            hhActionHndlSet  input_deps,
            hhExecPol        exec_pol,
            hhExecCfg        exec_cfg,
            hhResrcHndlSet   exec_resrc,
            hhActionHndl    *out_action_hndl);
```

A logical AND of input_deps.

```
hhRet hhuSyncAny(
            hhActionHndlSet  input_deps,
            hhExecPol        exec_pol,
            hhExecCfg        exec_cfg,
            hhResrcHndlSet   exec_resrc,
            hhActionHndlSet *out_triggered,
            hhActionHndl    *out_action_hndl);
```

A logical OR of input_deps.

A.3/ Query action status via action handle

```
// Retrieve status of an individual action handle
// New addition
hhRet hhnActionHndlGetActionState(
    hhActionHndl hndl,
    hhActionStateEnum *out_state);
```

```
// Actively blocks until all actions are completed
// Already present.
hhRet hhnSyncAll(
    hhActionHndlSet actions);
```

```
// Actively blocks until any of the actions is completed
// Returns the actions which have been triggered in out_triggered
// Already present.
hhRet hhnSyncAny(
    hhActionHndlSet actions,
    hhActionHndlSet *out_triggered);
```

A.4/ Obtain and operate on an action's underlying sync object

```
// Caller does not gain ownership of out_sync_obj_descr
// Expected users: client, implementation
// May fail if block_until_available == False and impl has not yet set the sync obj on an action hndl
hhRet hhneActionHndlGetPostdominatingSyncObj(
    hhActionHndl action_hndl,                   // input action handle
    bool block_until_available,                 // whether to block until the sync obj is available
    hhSyncObjHndl *out_sync_obj,                // output sync object handle
    const hhSyncObjDescr **out_sync_obj_descr   // output sync object description
);

// For the implementation to set the postdominating sync object on an action handle
//
// Caller does not cede ownership of sync_obj_descr
// Expected users: implementation
hhRet hhneActionHndlSetPostdominatingSyncObj(
    hhActionHndl action_hndl,               // input action handle
    hhSyncObjHndl sync_obj,                 // input sync object
    const hhSyncObjDescr *sync_obj_descr    // input sync object description
);
```

S.1/ Interop on sync objects based on sync object's description

```
typedef struct hhSyncObjDescr {
    int64_t type_index;
    size_t sync_object_bytes;

    hhSyncTriggerKindEnum kind;
    size_t state_field_offset;
    size_t state_field_bytes;
    int64_t triggered_val;
    int64_t untriggered_val;
    int64_t uninit_val;

    hhRet (*query_syncobj_state_fn)(hhSyncObjHndl,
            hhSyncObjDescr *, hhSyncObjStateEnum*);
    hhRet (*free_syncobj_fn)(hhSyncObjHndl, hhSyncObjDescr *);
} hhSyncObjDescr;


typedef void* hhSyncObjHndl;
```

```
typedef enum {
    HH_TRIGGER_NOT_DESCRIBED,
    HH_TRIGGER_EQ,
    HH_TRIGGER_GE,
    HH_TRIGGER_GT,
    HH_TRIGGER_LE,
    HH_TRIGGER_LT
    /* possible further values */
// G = greater, L = less
// T = than, and E/EQ = equal
} hhSyncTriggerKindEnum;


typedef enum {
    HH_SYNCOBJ_UNINIT,
    HH_SYNCOBJ_UNTRIGGERED,
    HH_SYNCOBJ_TRIGGERED
} hhSyncObjStateEnum;
```

S.2/ Interop on sync objects based on sync object's type

Allow HiHAT's clients and implementations to cooperate "natively" on a synchronization object without HiHAT's involvement, based on the clients' knowledge of the nature of the synchronization object.

E.g.: Is the synchronization object a cudaEvent_t? If so, I want to use it directly (because e.g. my hardware understands it natively).

Facilitated by `int64_t hhSyncObjDescr::type_index`.

type_index (1/2)

HiHAT needs *a* type index. How clients/implementations come up with that index is up to them.

As one of possible solutions, HiHAT will ship a header file that enumerates some possible synchronization object types and their descriptions. Same header will declare pointers to sync obj descriptors. <see next slide for a strawman>

HiHAT will not use this file internally.

The type is not registered with HiHAT *per se*.

type_index (2/2)

hhhSyncObjTypes.h:

```
#ifndef HHH_SYNCOBJ_TYPES_
#define HHH_SYNCOBJ_TYPES_

enum hhSyncPrimitives {
  HHH_CUDA_EVENT_T,
      /*!< hhSyncObjHndl can be cast to cudaEvent_t */
  HHH_EGLSyncKHR
      /*!< hhSyncObjHndl can be cast to EGLSyncKHR */
};

// fwd decl
struct hhSyncObjDescr;

extern const
struct hhSyncObjDescr *HHH_CUDA_EVENT_T_DESCR;
extern const
struct hhSyncObjDescr *HHH_EGLSyncKHR_DESCR;
extern const
struct hhSyncObjDescr *HHH_FILE_DESCRIPTOR_DESCR;


#endif // ndef HHH_SYNCOBJ_TYPES_
```

hhhSyncObjTypes.cpp:

```
#include "hhhSyncObjTypes.h"
#include "<HiHAT header that defines struct hhSyncObjDescr>"
#include <cuda.h>

static hhRet _QueryCudaEvent(hhSyncObjHndl hndl,
        hhSyncObjDescr *descr, hhSyncObjStateEnum *out_state)
{
    assert(descr->type_index == HHH_CUDA_EVENT_T);
    if (cudaSuccess == cudaEventQuery((cudaEvent_t)hdnl)) {
        *out_state = HH_SYNCOBJ_TRIGGERED;
    } else {
        *out_state = HH_SYNCOBJ_UNTRIGGERED;
    }
    return HHRET_SUCCESS;
}

static hhRet _FreeCudaEvent(hhSyncObjHndl hndl, hhSyncObjDescr *descr)
{
    assert(descr->type_index == HHH_CUDA_EVENT_t);
    cudaEventDestroy((cudaEvent_t)hndl);
    return HHRET_SUCCESS;
}

static const struct hhSyncObjDescr HHH_CUDA_EVENT_T_DESCR_STR =
    { HHH_CUDA_EVENT_T, sizeof(cudaEvent_t),
      HH_TRIGGER_NOT_DESCRIBED, 0, 0, 0, 0, 0,
      _QueryCudaEvent, _FreeCudaEvent };

const struct hhSyncObjDescr *HHH_CUDA_EVENT_T_DESCR =
    &HHH_CUDA_EVENT_T_DESCR_STR;
```

SAMPLES

Sample 1/5: using hhnActionHndlGetActionState() [client code]

```
int main() {
    // ...

    hhActionHndl action_hndl;
    CHECK_HIHAT(hhuInvoke( <...>, &action_hndl));

    hhActionStateEnum action_state;
    do {
        CHECK_HIHAT(hhnActionHndlGetActionState(action_hndl, &action_state));
    } while (action_state == HH_ACTION_PENDING);

    // ...
}
```

Sample 2/5: cudaEvent_t [client code]

```
int main() {
    // ...

    hhActionHndl action_hndl;
    CHECK_HIHAT(hhuInvoke( <...>, &action_hndl));

    hhSyncObjHndl sync_obj;
    hhSyncObjDescr *sync_descr;
    CHECK_HIHAT(hhneActionHndlGetPostdominatingSyncObj(action_hndl, 1, &sync_obj, &sync_descr));

    if (sync_descr->type_index == HHH_CUDA_EVENT_T) {
        CHECK_CUDA(cudaEventSynchronize((cudaEvent_t) sync_obj));
    } else {  /* default to querying HiHAT's API */
        hhActionStateEnum action_state;
        do {
            CHECK_HIHAT(hhneActionHndlGetActionState(action_hndl, &action_state));
        } while (action_state != HH_ACTION_COMPLETED);
    }

    // ...
}
```

Sample 3/5: cudaEvent_t [implementation]

```
hhuInvokeCUDAImpl(..., hhActionHndl input_dep, ...) {
    hhSyncObjHndl sync_obj;
    hhSyncObjDescr *sync_descr;
    CHECK_HIHAT(hhneActionHndlGetPostdominatingSyncObj(
            input_dep, 1, &sync_obj, &sync_descr));

    if (sync_descr->type_index == HHH_CUDA_EVENT_T) {
        cudaEvent_t cuda_event = (cudaEvent_t) sync_obj;
        CudaStream cuda_stream = getCudaStreamOfHiHATTask(task);
        cudaStreamWaitEvent(cuda_stream, cuda_event, 0);
    } else {
        // fallback: note to self that before this task is executed,
        //           I must actively wait on input_dep.
    }

    // Schedule/enqueue this task.
}
```

Enqueue dependency in CUDA Runtime.

Sample 4/5: cudaEvent_t and EGLSyncKHR interop [implementation]

```
hhuInvokeCUDAImpl(..., hhActionHndl input_dep, ...) {
    hhSyncObjHndl sync_obj;
    hhSyncObjDescr *sync_descr;
    CHECK_HIHAT(hhneActionHndlGetPostdominatingSyncObj(
            input_dep, 1, &sync_obj, &sync_descr));

    if (sync_descr->type_index == HHH_CUDA_EVENT_T) {
        cudaEvent_t cuda_event = (cudaEvent_t) sync_obj;
        CudaStream cuda_stream = getCudaStreamOfHiHATTask(task);
        cudaStreamWaitEvent(cuda_stream, cuda_event, 0);
    } else if (sync_descr->type_index == EGLSyncKHR) {
        cudaEvent_t cudaEvent;
        cudaEventCreateFromEGLSync(&cuda_event, (EGLSyncKHR) sync_obj, cudaEventDefault);
        CudaStream cuda_stream = getCudaStreamOfHiHATTask(task);
        cudaStreamWaitEvent(cuda_stream, cuda_event, 0);
    } else {
        // fallback: note to self that before this task is executed,
        //           I must actively wait on input_dep.
    }

    // Schedule/enqueue this task.
}
```

Create a cudaEvent_t from EGLSyncKHR

Enqueue the newly created cudaEvent_t

Sample 5/5: memory description interface [implementation]

```
hhuInvokeFancyImpl(..., hhActionHndl input_dep, ...) {
    hhSyncObjHndl sync_obj;
    hhSyncObjDescr sync_descr;
    CHECK_HIHAT(hhneActionHndlGetPostdominatingSyncObj(action_hndl, 1, &sync_obj, &sync_descr));

    if (sync_descr.type_index == HHH_MY_SPECIAL_TYPE_THAT_I_KNOW) {
        assert(sync_descr.kind == HH_TRIGGER_EQ);           // debug-only
        assert(sync_descr.triggered == (int64_t) 127);      // again, debug only
        assert(sync_descr.state_field_offset == 0);         // again, debug only
        assert(sync_descr.state_field_bytes == 8);          // again, debug only

        while (*((volatile int64_t*) sync_obj) != 127) {
            /* we can spin now if we have nothing else to do */
        }
    } else {
        // fallback: note to self that before this task is executed,
        //           I must actively wait on input_dep.
    }

    // Schedule/enqueue this task.
}
```

Potentially, do the read/wait on the device.

Questions?

Thank you