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Lightweight GPGPU Checkpoint Modelings

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Outlines

- Motivations
- Background – VCCP
- GPU checkpoint protocols: Memcopy vs simpleStream
- CheCUDA (related work)
- GPU checkpoint protocols: CUDA Streams
- Restart protocols
- Scheduling model and Analysis
- Conclusion

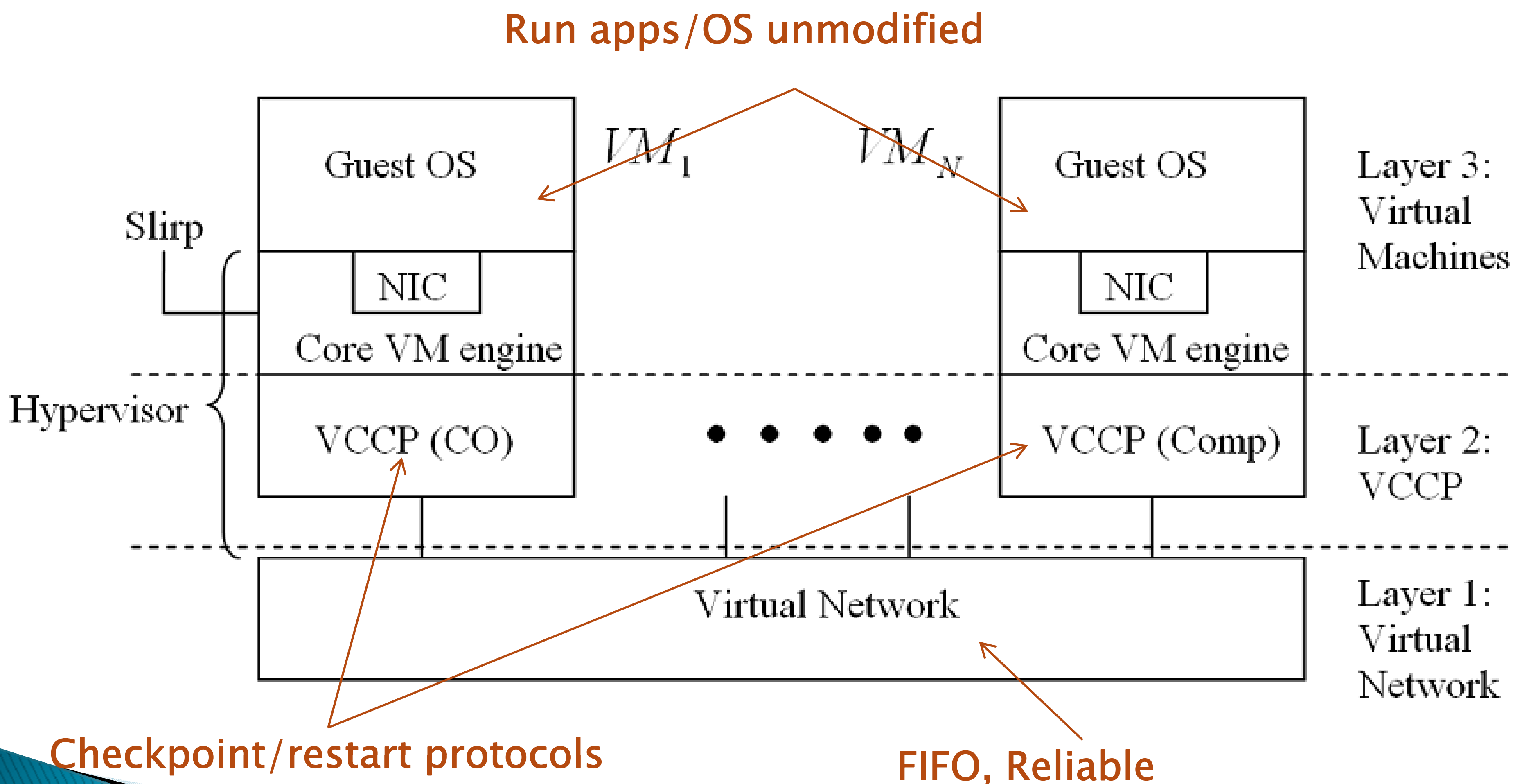
Motivations

- More attention on GPUs
- ORNL-NVDIA 10 petaflop machine
- Large scale GPU cluster -> fault tolerance for GPU applications
  - Normal checkpoint doesn't help GPU applications when a failure occurs.
  - GPU execution isn't saved when do checkpoint on CPU

VCCP: A Transparent, Coordinated Checkpointing System for Virtualization-based Cluster Computing – GOALS

- High transparency
  - Checkpoint/restart mechanisms should be *transparent* to applications, OS, and runtime environments; no modification required
- Efficiency
  - Checkpoint/restart mechanisms should *not* generate unacceptable overheads
    - Normal Execution
    - Communication
    - Checkpointing Delay

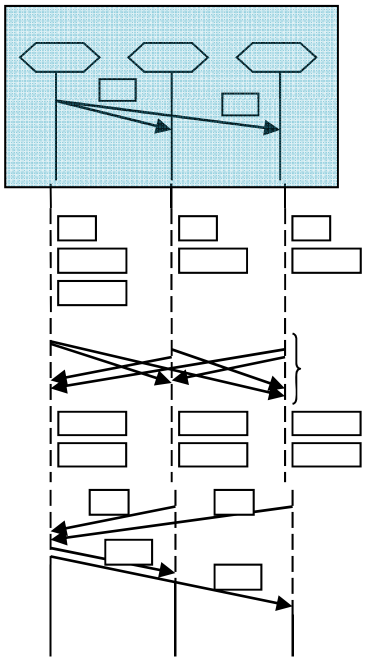
Virtual Cluster Architecture

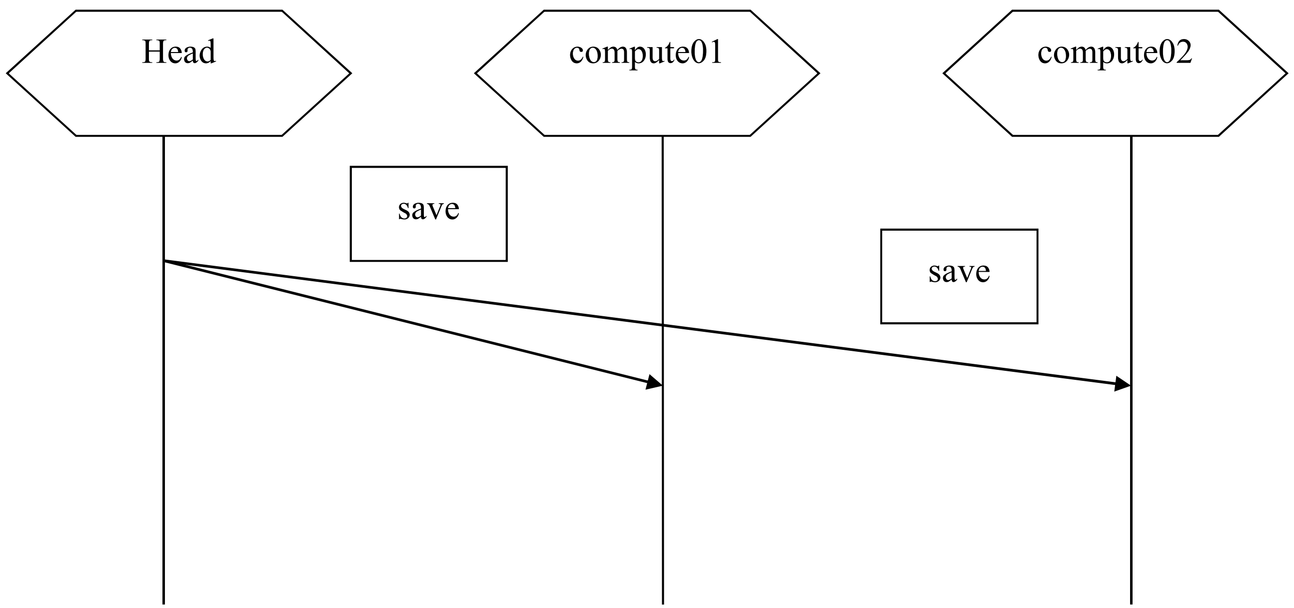


Virtual Cluster CheckPointing (VCCP) Protocol

1. Pauce VM computation
2. Flush messages out of the network
3. Locally Save State of every VM
4. Continue computation

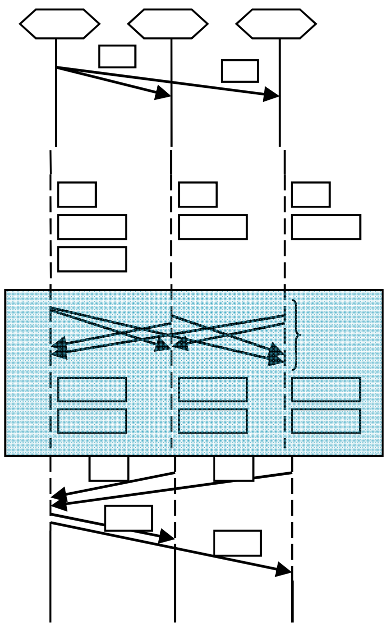
VCCP checkpoint protocol

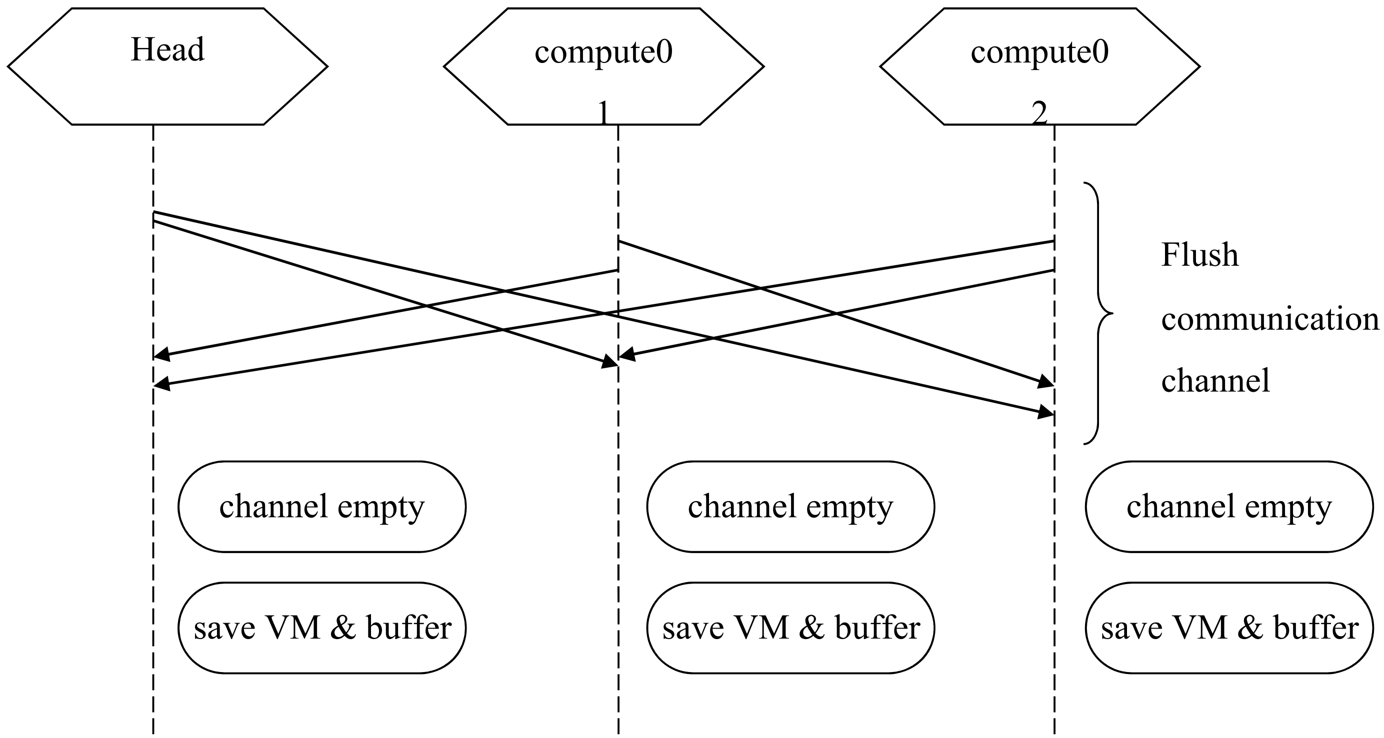




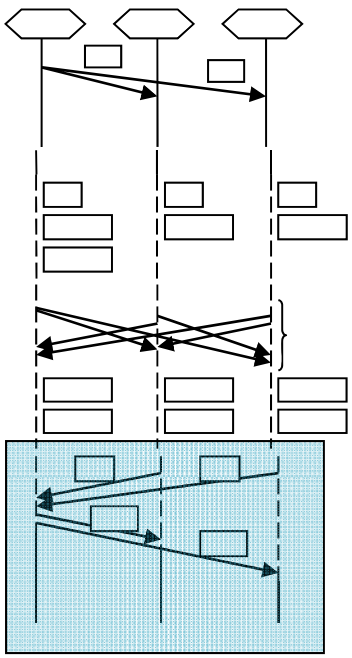
VCCP

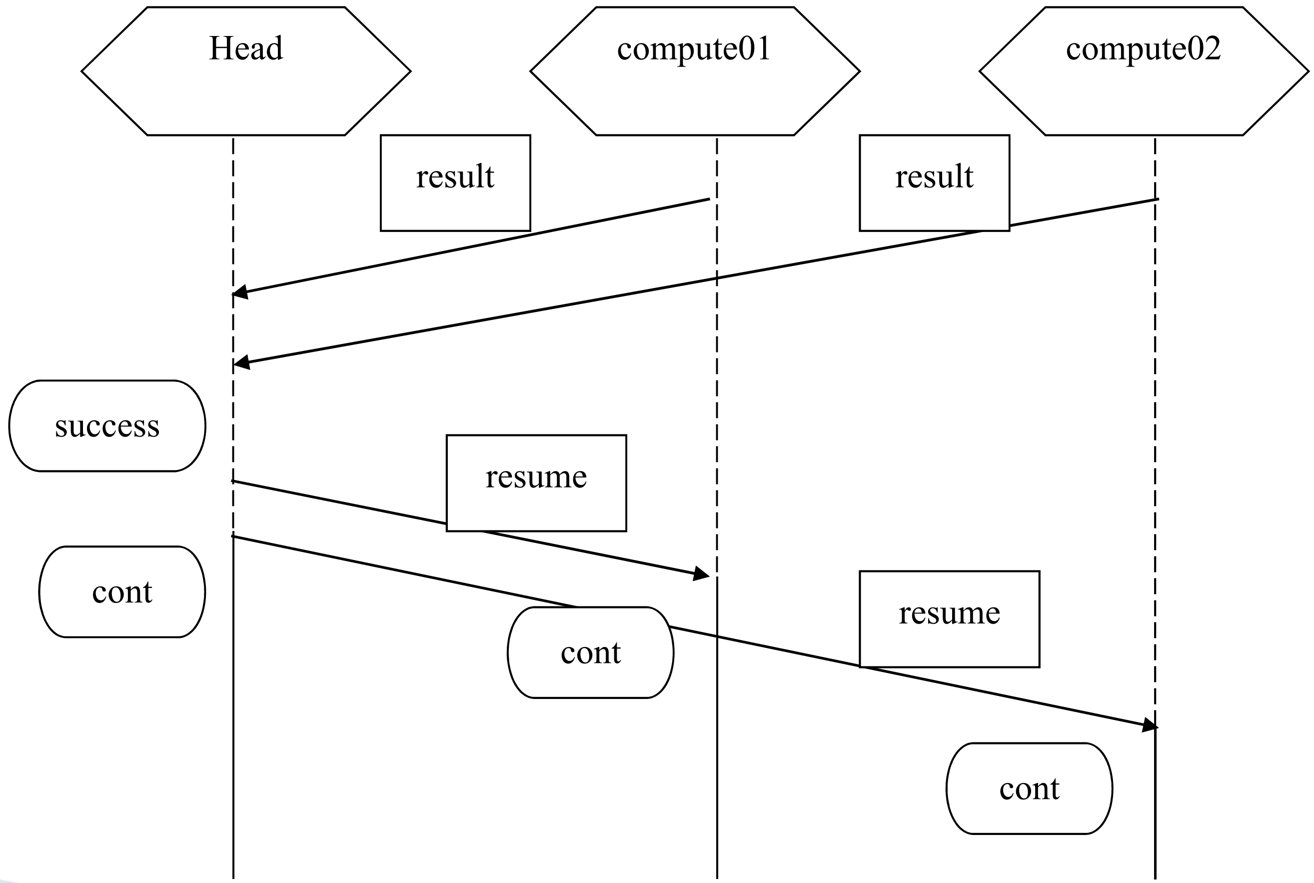
VCCP checkpoint protocol





VCCP checkpoint protocol





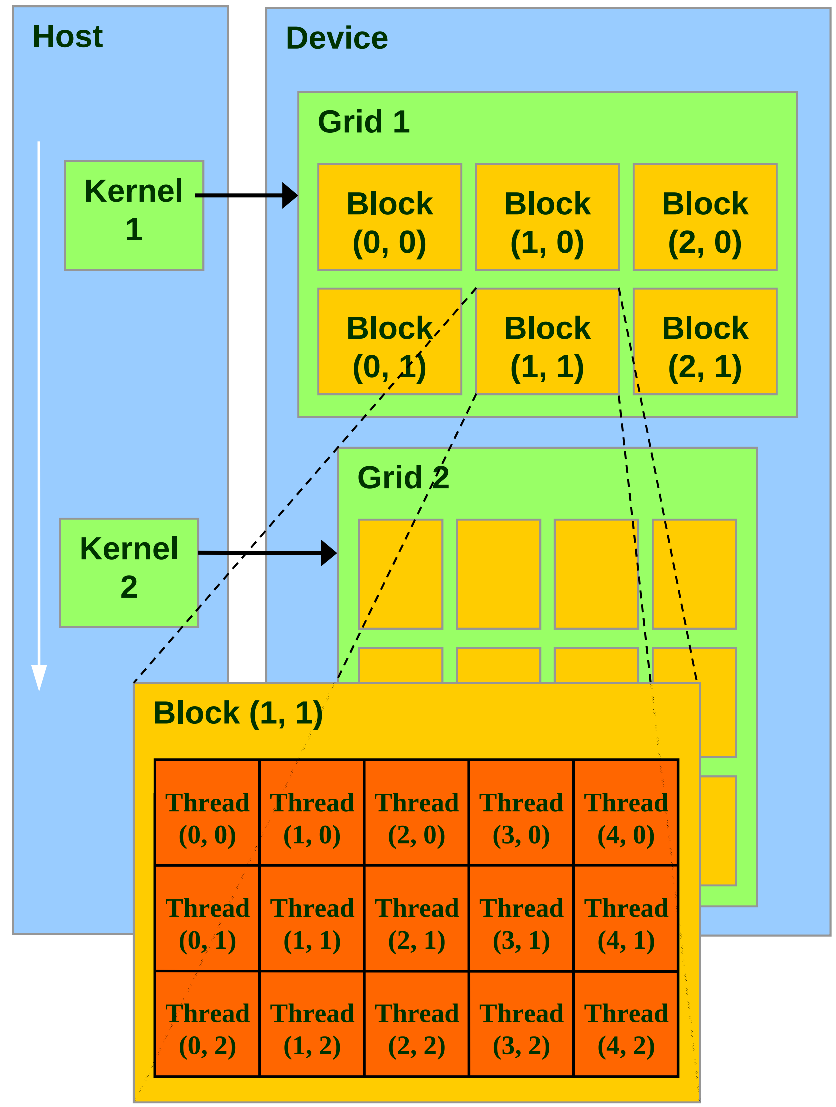
More details in VCCP

- Publication in IEEE cluster 2009
- Average overhead 12%
- Provide transparent checkpoint/restart

Heterogeneous Computing – GPGPU

1. Device Initialization
2. Device memory allocation
3. Copies data to device memory
4. Executes kernel (Calling __global__ function)
5. Copies data from device memory (retrieve results)

- Issues – latency round trip data movement



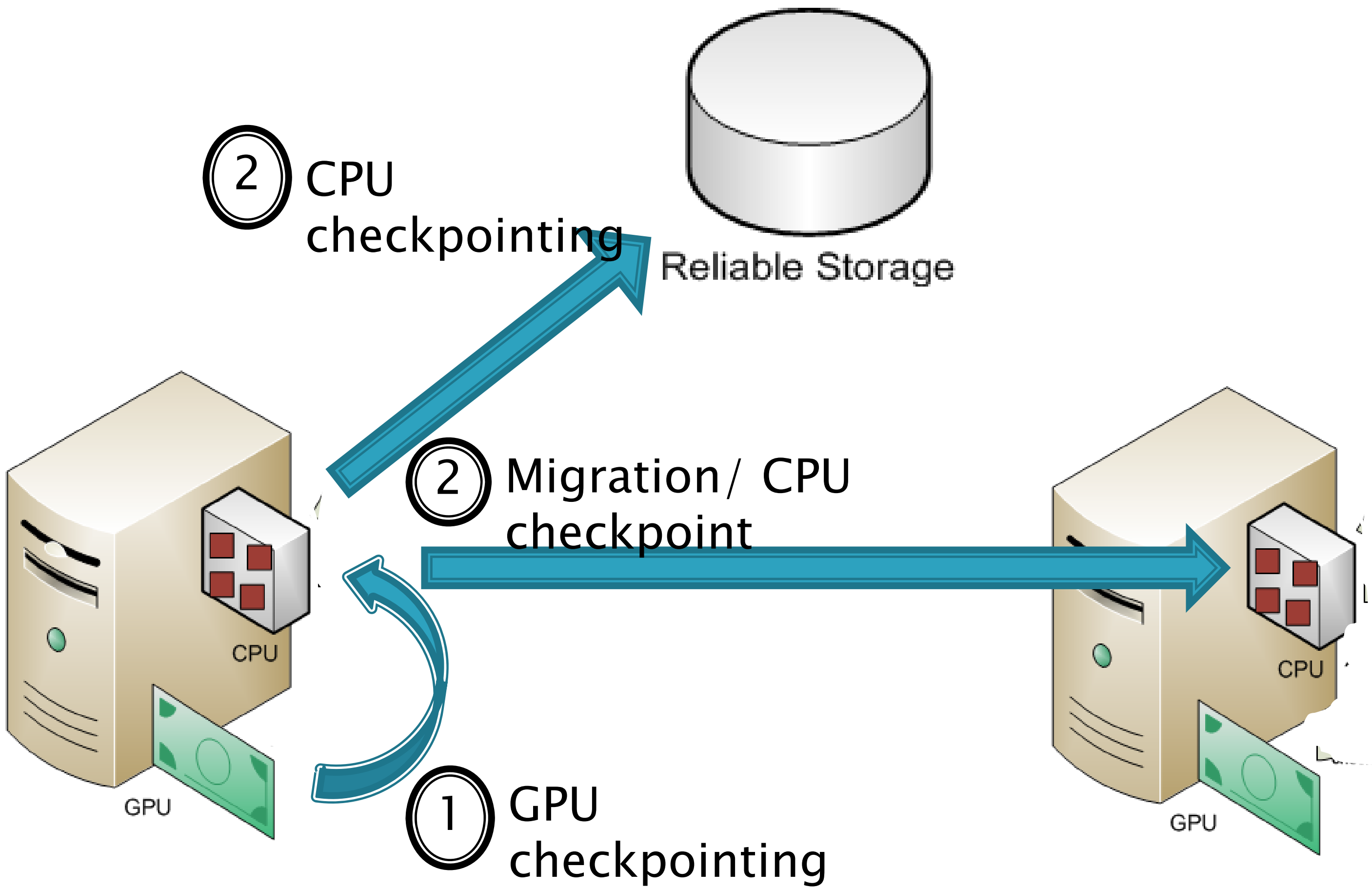
Our approach

- Long running GPU application
- High (relatively) failure rate in a large scale GPU cluster in MPI & GPU environment
- Save GPU software state
- Move data back from GPU in low latency
  - Memcopy (pauce GPU) vs simpleStream (concurrency)

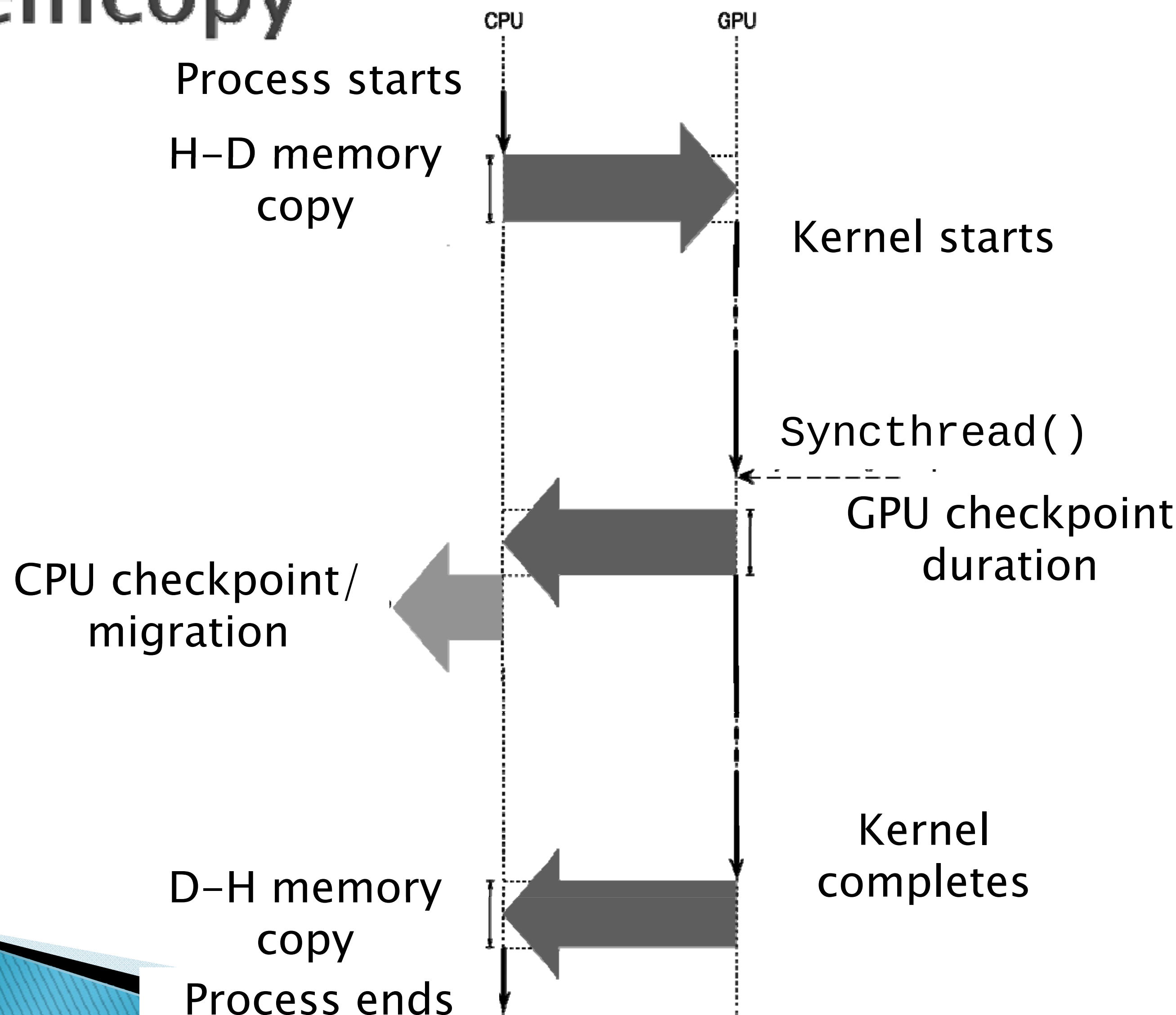
Related Work (CheCUDA)

- "CheCUDA: A Checkpoint/Restart Tool for CUDA Applications" by H. Takizawa, K. Sato, K. Komatsu, and H. Kobayashi
- A prototype of an add-on package of BLCR for GPU checkpointing
- Memcopy approach

GPGPU Checkpoint protocols



GPU checkpoint protocol: memcopy



CheCUDA: Checkpoint Protocol

1. Copying all the user data in the device memory to the host memory
2. Writing the current status of the application and the user data to a checkpoint file

CheCUDA: Restart protocol

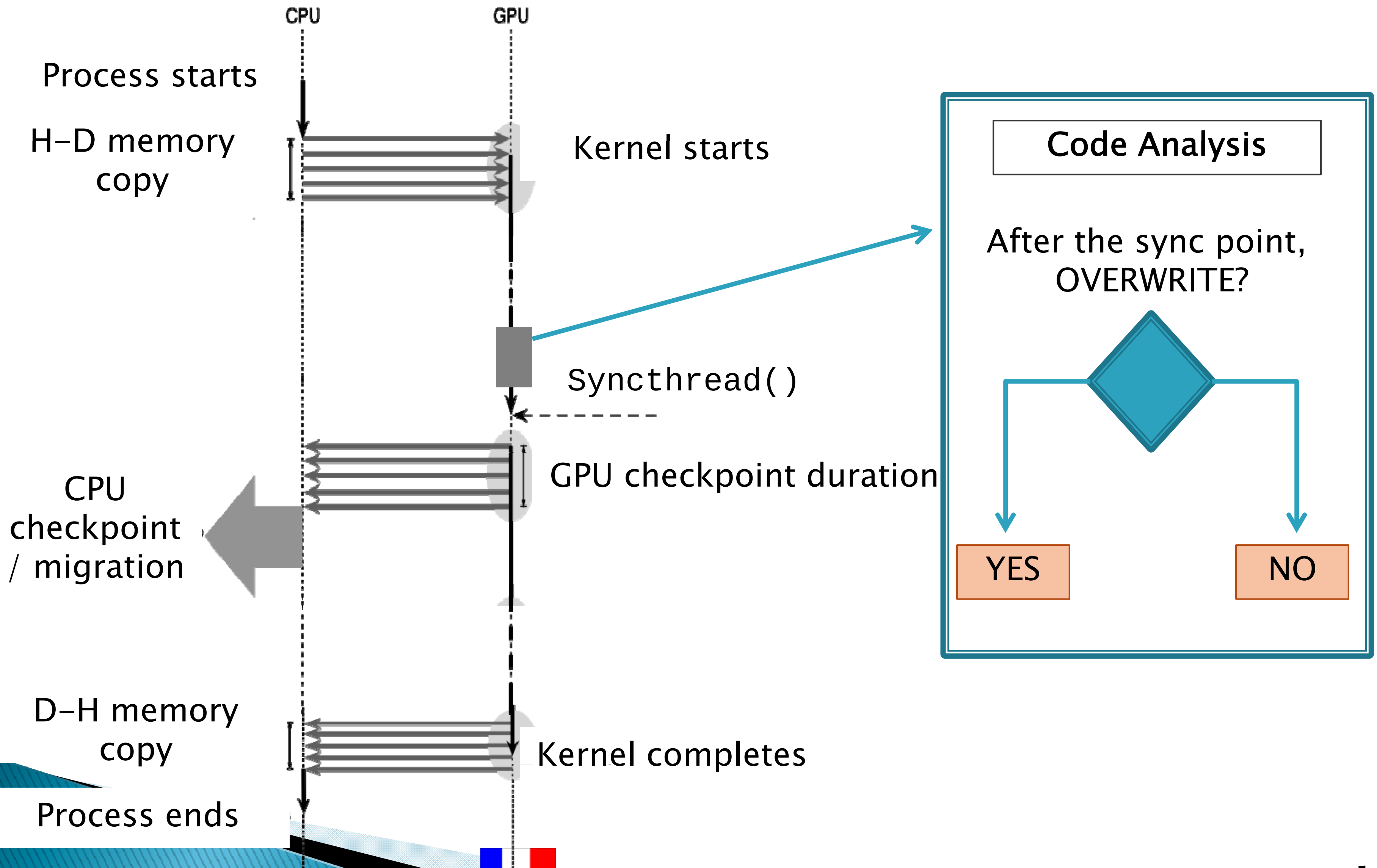
1. Read the checkpoint file
2. Initialize the GPU and recreating CUDA resources
3. Sending the user data back to the device memory

GPU checkpoint protocol: memcopy vs simpleStream

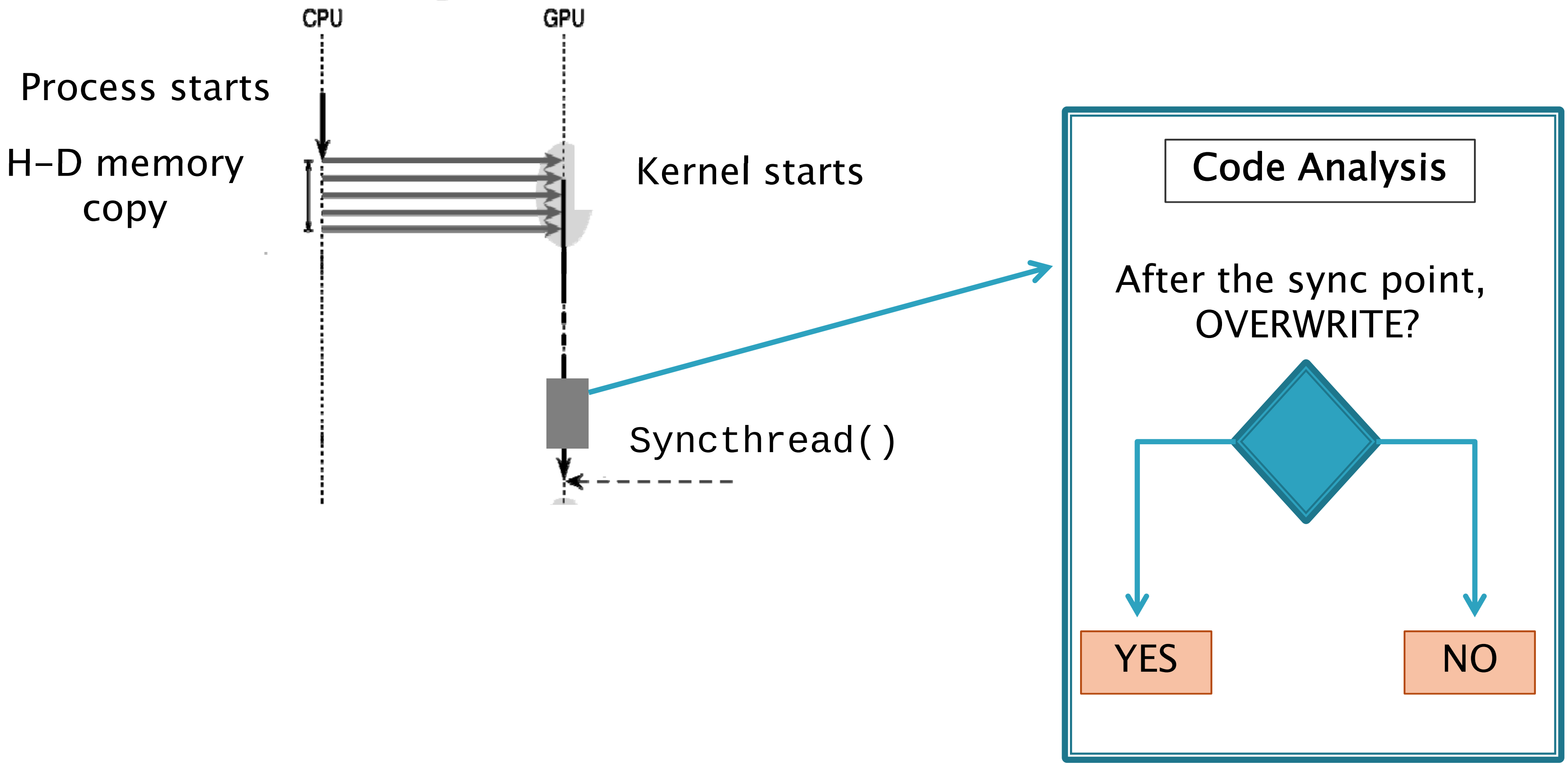
- Transfer data from device to host = overhead
  - Must pauce GPU computation until the copy is completed

- SimpleStream
  - Using latency hiding (Streams) to reduce the overhead
  - CUDA streams = overlap memory copy and kernel execution

GPU checkpoint protocol: Streams

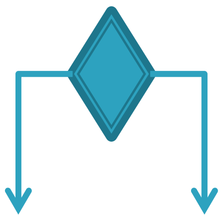


GPU checkpoint protocol: ensure consistency

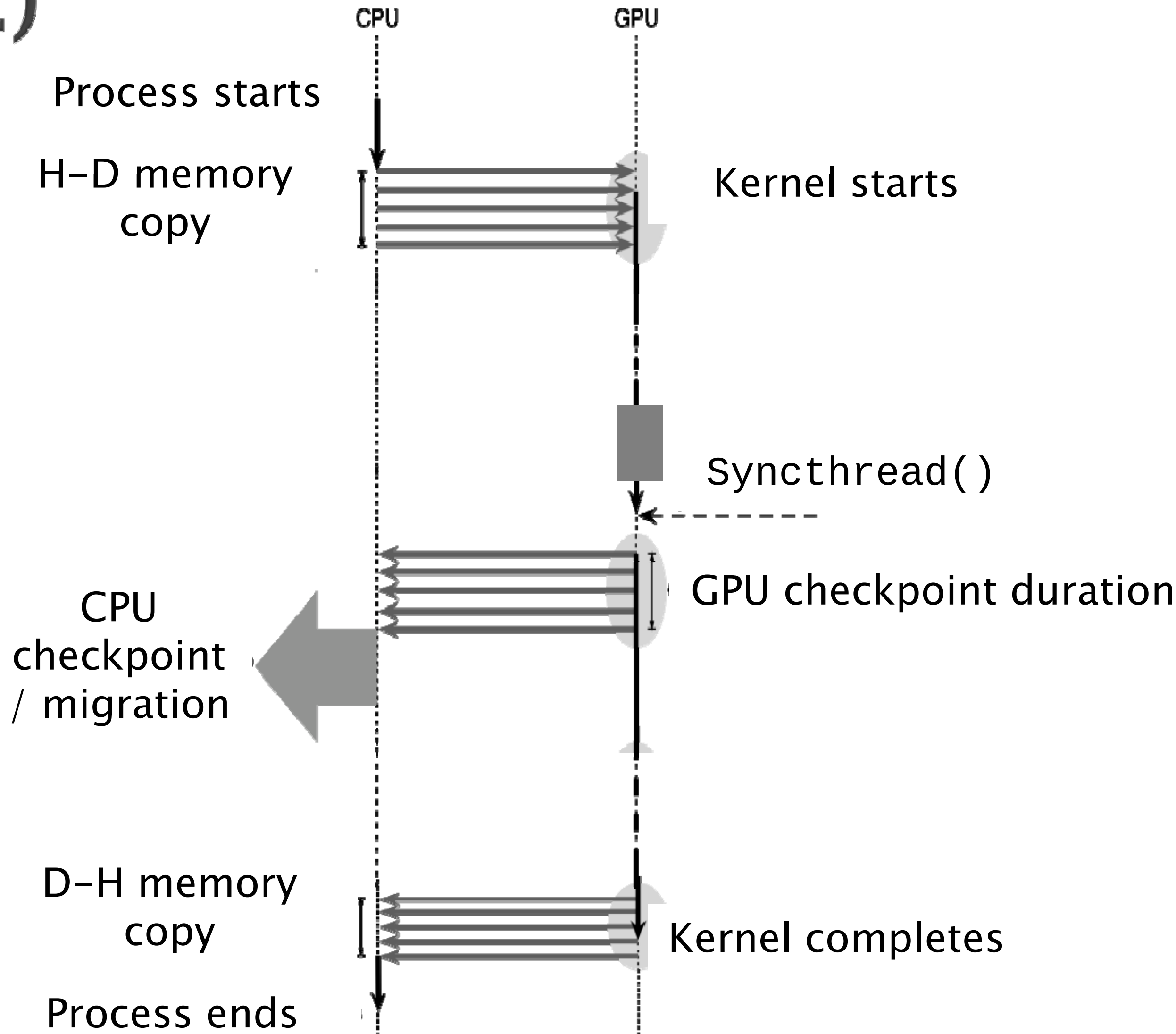


GPU checkpoint Protocol: Streams (cont.)

After the sync point, OVERWRITE?

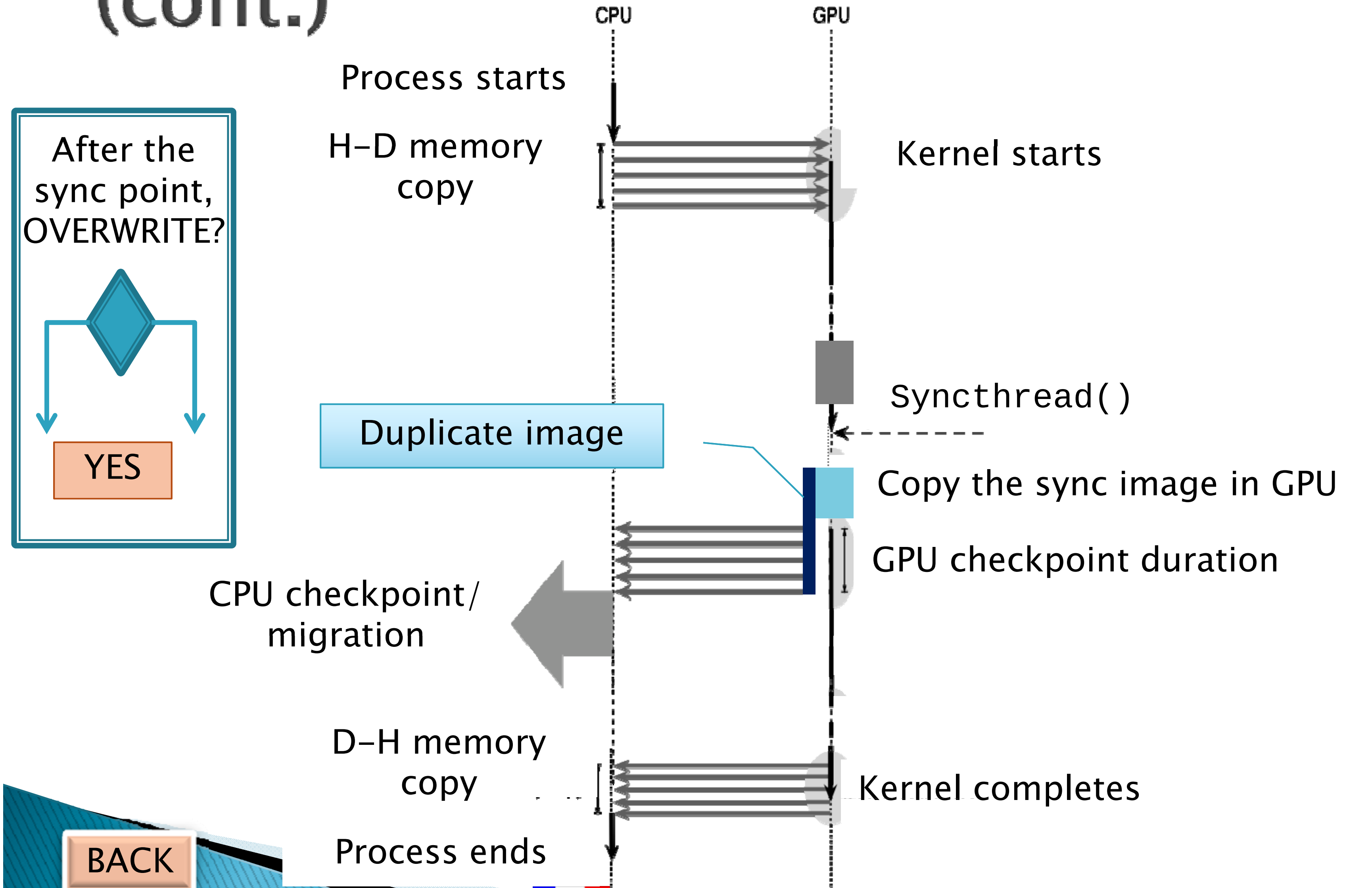


NO



BACK

GPU Checkpoint Protocol: Streams (cont.)



BACK

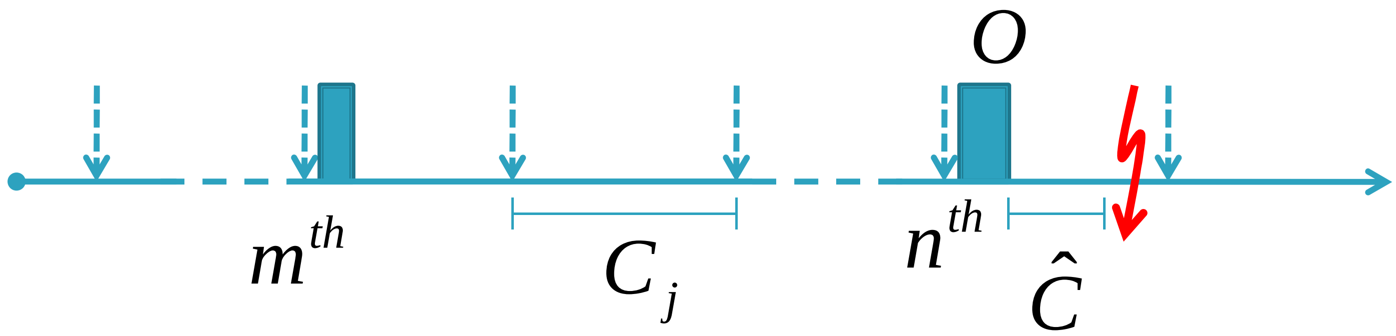
GPU Restart Protocol

- Restart CPU
- Transfer the last GPU checkpoint back to CPU
- Recreate CUDA context from the CKpt file
- Restart the kernel execution from the marked synchronization point

Scheduling Model

- GPU checkpoint after a thread synchronization
- NOT every thread synchronization
- QUESTION???
  - Which thread synchronization should a checkpoint be invoked?
- FACTORs
  - GPU checkpoint overhead
  - Chance of a failure occurrence

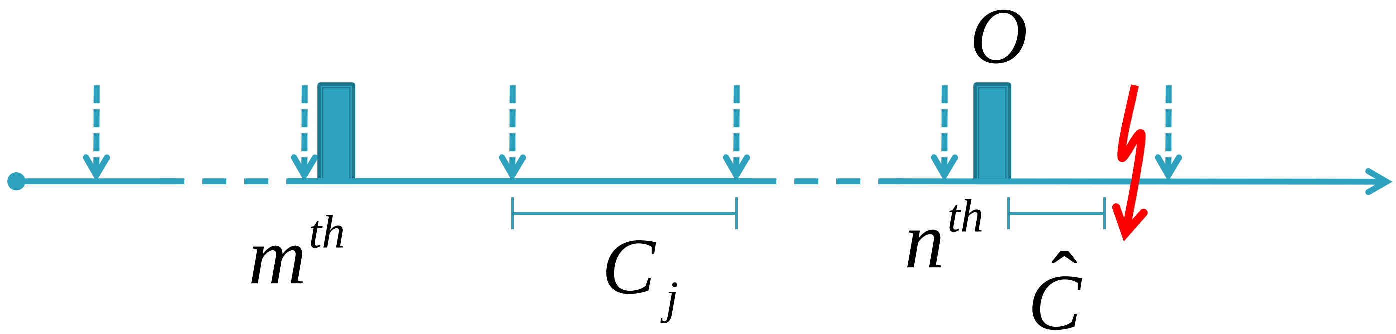
Scheduling model (cont.)



$$P_f\left(\sum_{j=m}^{n} C_j + \hat{C}\right)$$

Perform the checkpoint: $P_f\left(O+\hat{C}\right)+\left(1-P_f\right)O$

Scheduling model (cont.)



Skip the checkpoint: $$P_f\left(\sum_{j=m}^{n} C_j + \hat{C}\right)$$

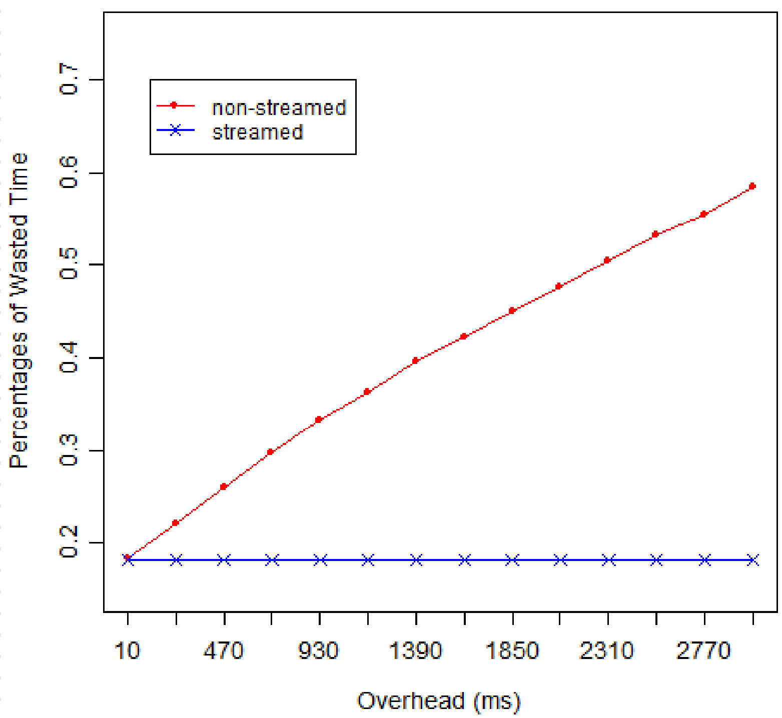
Perform the checkpoint: $$P_f\left(O+\hat{C}\right)+\left(1-P_f\right)O$$

$$P_f\left(\sum_{j=m}^{n} C_j\right) > O \;\Rightarrow$$ Perform the checkpoint

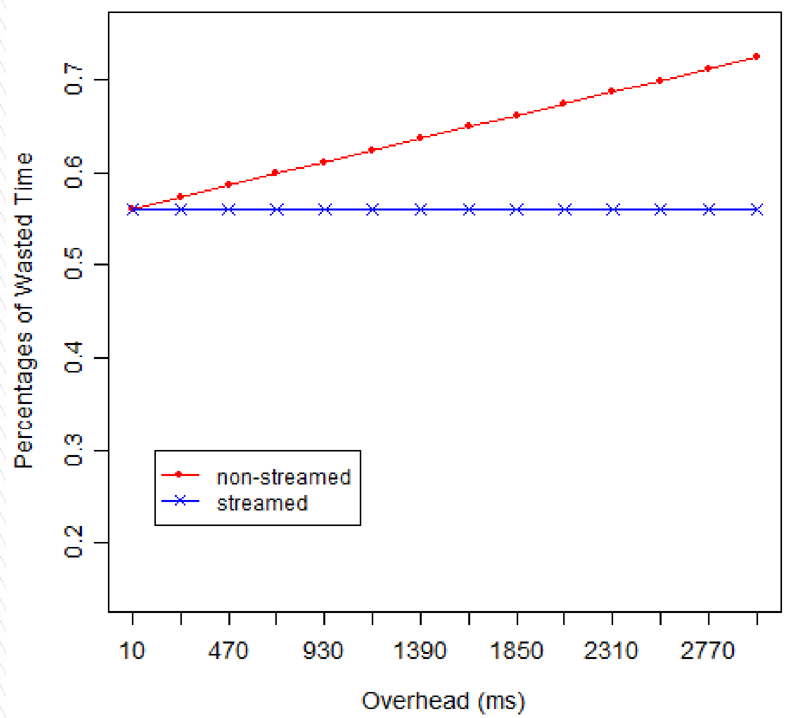
Model Analysis

- Simulate failures & the wasted time
  - total checkpoint overhead + re-computing due to a failure
- Overhead
  - Non-stream: 10 milliseconds – 3 seconds
  - Streams: negligible
- MTTF: 12 hours – 7 days
- Thread sync interval: 10 and 30 minutes

Results (various overhead = size of transfer)

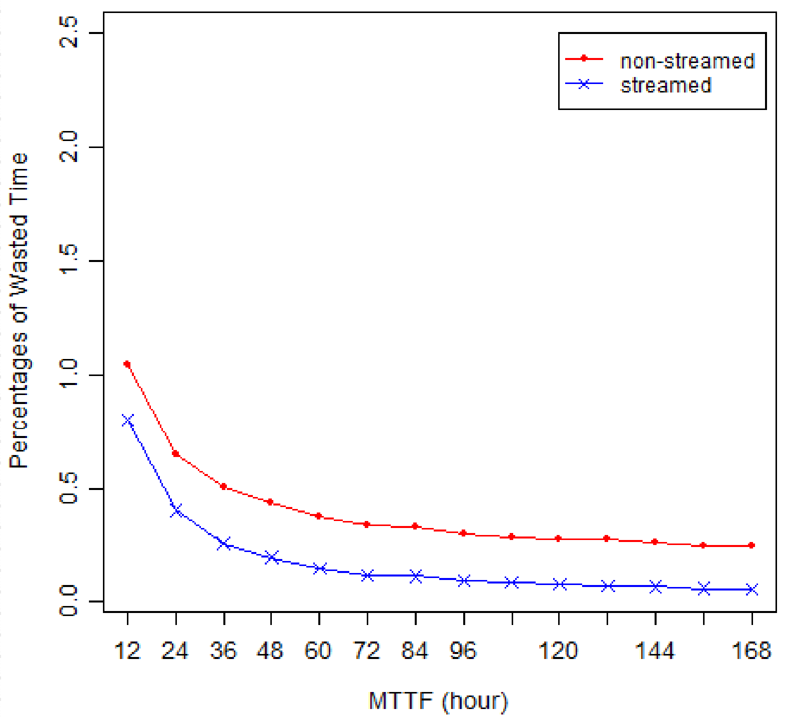


Thread sync interval = 10 mins

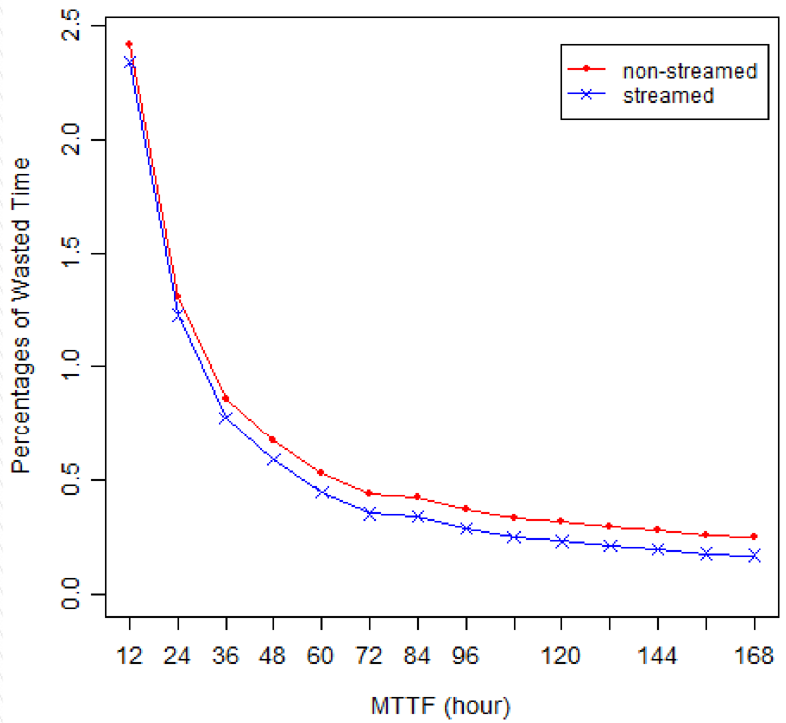


Thread sync interval = 30 mins

Results (various MTTF)

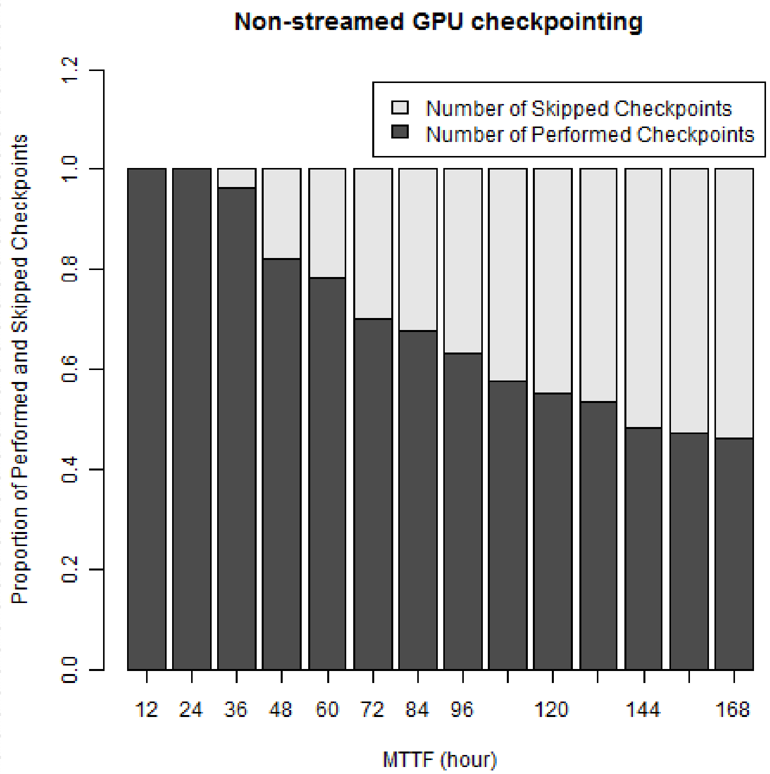


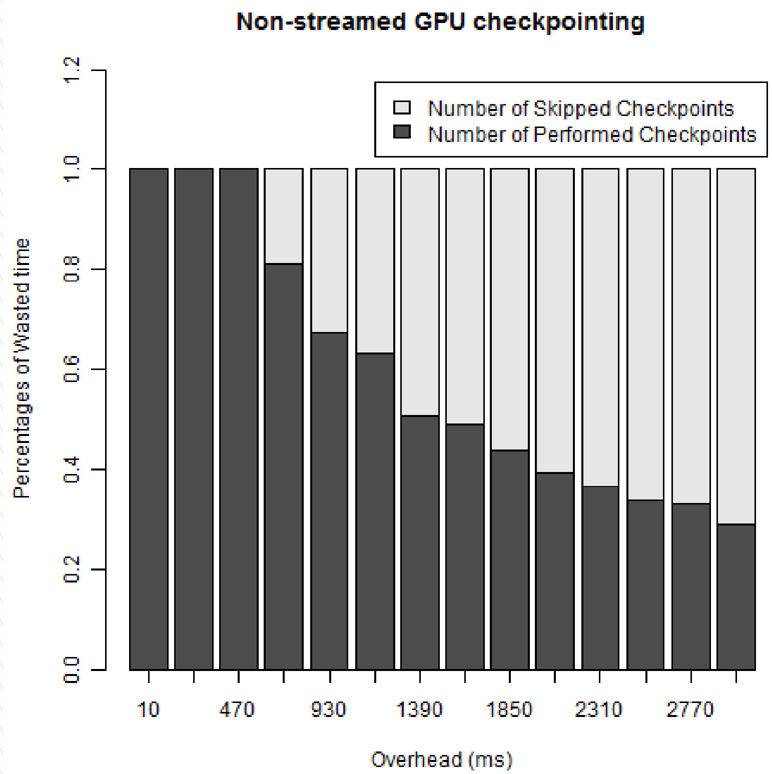
Thread sync interval = 10 mins



Thread sync interval = 30 mins

Results (skipped VS non-skipped)





Against MTTFs

Against overheads

Conclusions

- GPU checkpointing with Stream to reduce overhead
- Non-stream and stream checkpoints are insignificantly different if data transfer is insignificant
- BUT stream checkpoint potentially performs better when the checkpoint overhead of memcopy is larger.

Future work

- Implement GPU checkpoint/restart mechanism
- Work on other checkpoint protocol
- Include GPU process migration