KVM FORUM

Live Migration with Hardware Acceleration

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Agenda

- Project Goals
- Architecture Introduction
- Feature Introduction
- Test Results
- Future Works

Project Goals

Project Goals

- Live migration pain points
  - VMs with memory write intensive workloads are difficult to migrate
  - VMs with large memory size takes long time to migrate
  - May consume large network bandwidth
- Existing solution: compression with CPUs
  - Slow
  - Consumes too many CPUs from host
- Our solution
  - Offload the compression part to Intel QAT with efficient approaches
    - Higher migration throughput
    - Lower CPU utilization
  - A common design ready for future more accelerators to join in
    - Data Streaming Accelerator (DSA) and Intel Analytics Accelerator (IAX) coming on Sapphire Rapids CPUs
    - Smart Selection

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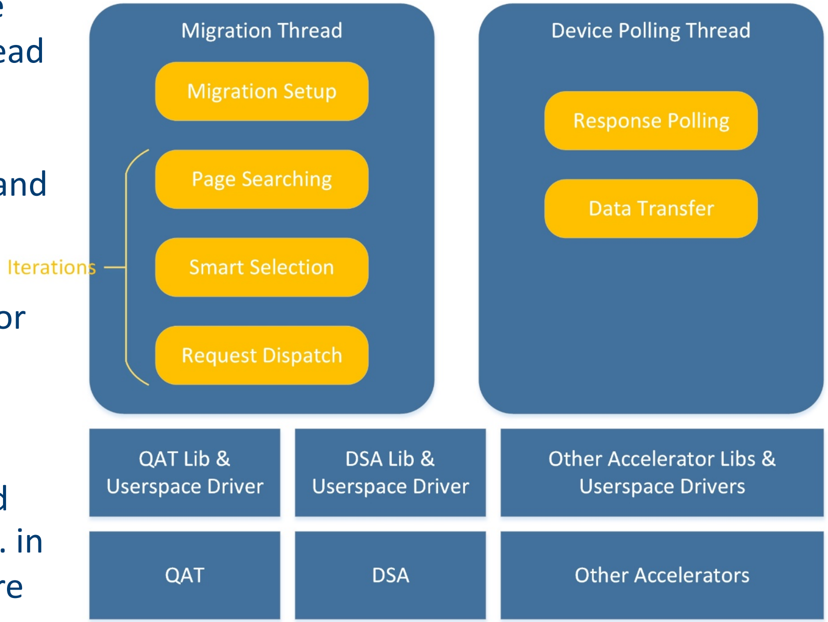
Architecture Introduction

Source Machine

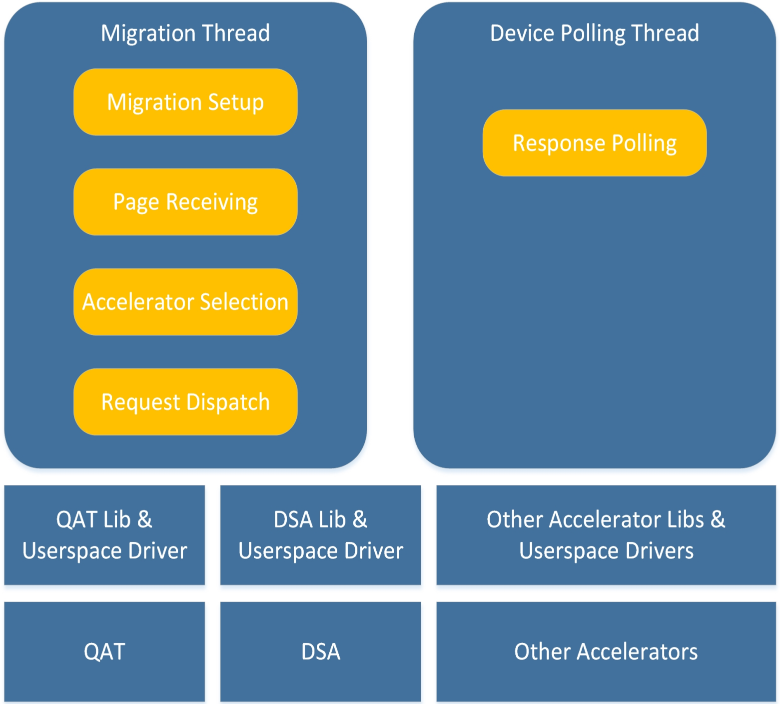
- Migration Setup
  - Preparation for migration, including the accelerator device initialization, device polling thread creation
- Page Searching
  - Searching for pages to process and send
- Smart Selection
  - Select an appropriate accelerator based on the history of the acceleration efficiency
- Request Dispatch
  - Dispatch requests to the related accelerator device instance, e.g. in a round robin fashion if there are multiple device instances



- Response Polling
  - Poll for responses from all the devices
  - Blocks when no responses are ready
- Data Transfer
  - Send the compressed data, along with the related header, to network

Destination Machine

- Page Receiving
  - Receive data from the network
  - Parsing the migration protocols, e.g. multi-page
- Accelerator Selection
  - The received data has headers to tell which accelerator to use



- Response Polling
  - Poll for decompressed data from each device
  - Blocks when no responses are ready
  - Decompressed data DMA to the QEMU memory

Feature Introduction

Important Features

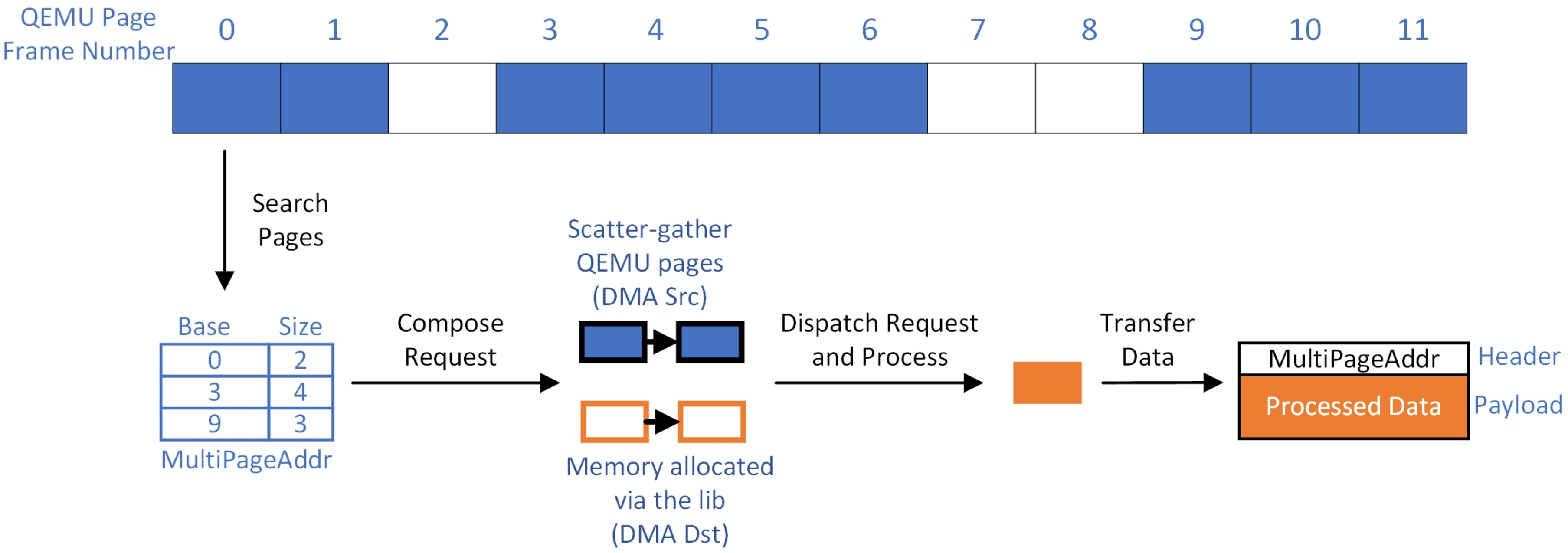
- Zero-copy
  - Allow the acceleration device to directly access to the guest(QEMU) memory
- Multi-page Processing
  - Support the whole migration flow to process multiple pages each time
- Acceleration Request Caching
  - Caching the acceleration request data structure for efficient memory allocation

Zero-copy

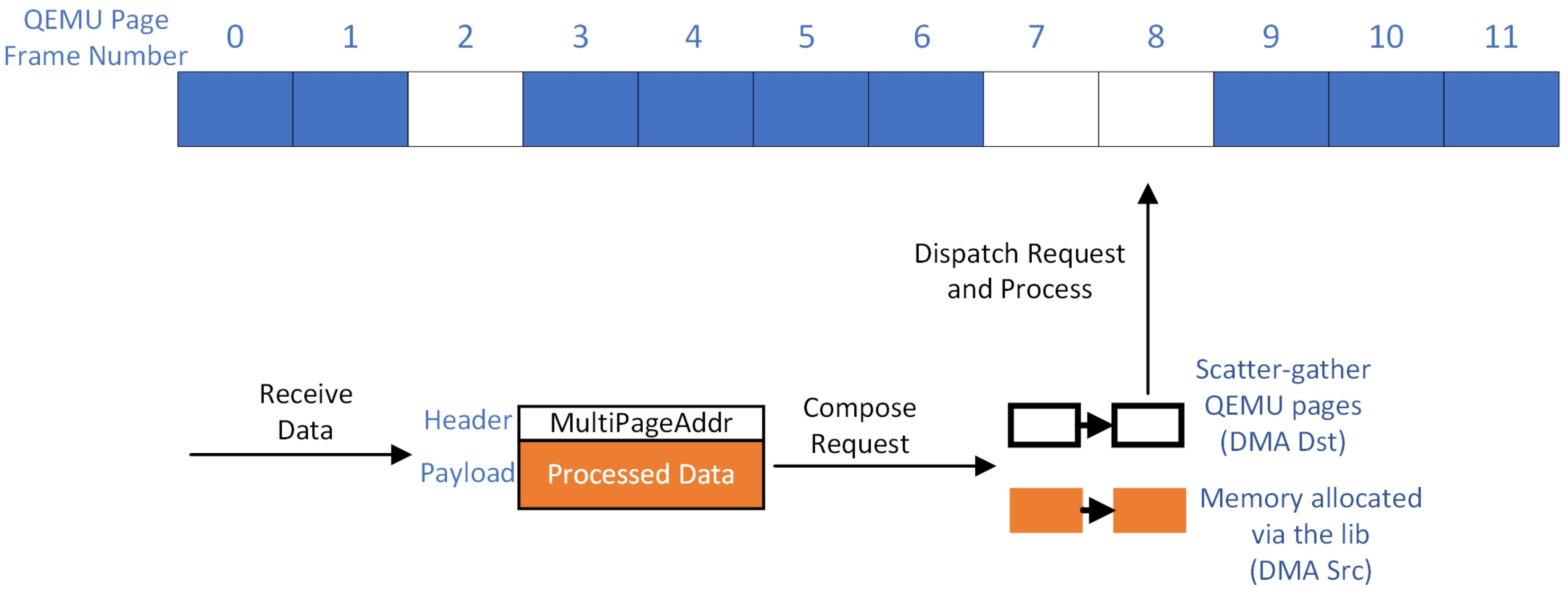
- Migration setup
  - Pre-alloc and pin all the QEMU memory
  - Destination side memory unpinned when migration is done
- Request Composing
  - Source side
    - DMA read buffer points to QEMU memory
    - DMA write buffer allocated via accelerator lib
  - Destination side
    - DMA read buffer allocated via accelerator lib
    - DMA write buffer points to QEMU memory

Multi-page Processing

source machine



Multi-page Processing
destination machine



Acceleration Request Caching

- Device Setup
  - Pre-allocate some amount of acceleration requests and fill them into the cache pool
- Request Composing
  - Take requests from the cache pool first
  - Initialize the request based on the new pages to send
- Response Polling
  - Free the request to the cache pool after it’s processed

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Test Results

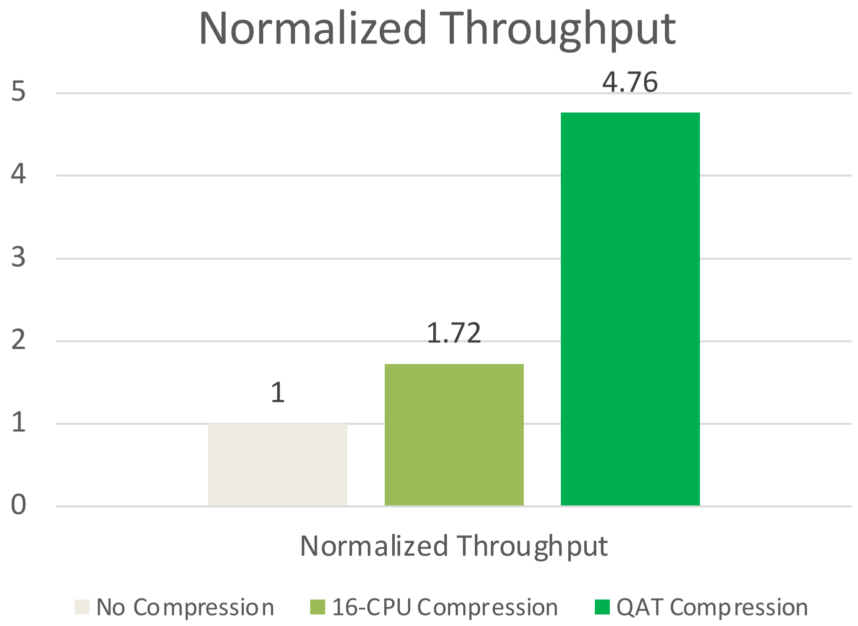
Test Environment

- Testbed
  - CPU: Intel Xeon CPU E5-2699 V4 @2.2GHZ
  - QAT: 8960 PCIe card, Gen3
  - DRAM: DDR4, 2666MHZ
  - NIC: XL710, 40GB
- Live migration
  - Downtime: 300 ms (default)
  - Network bandwidth: No limit (i.e. 40G)
  - Compress level: 1
  - Multi-page: 63 (Max)
- Guest
  - 4 vCPUs, 32G RAM, running a workload writing compression-friendly data
  - 4 vCPUs, 32G RAM, running a workload writing sequence numbers
  - 8 vCPUs, 128G RAM, running memcached with reading/writing random numbers

Memory Dirty with Compress-Friendly Data

- Run in guest: ./dirty_workload –t 10 –i 500000 –m 1 1000 –s
  - Write “1”s in specified dirty rate (e.g. 1000 MB/s above)

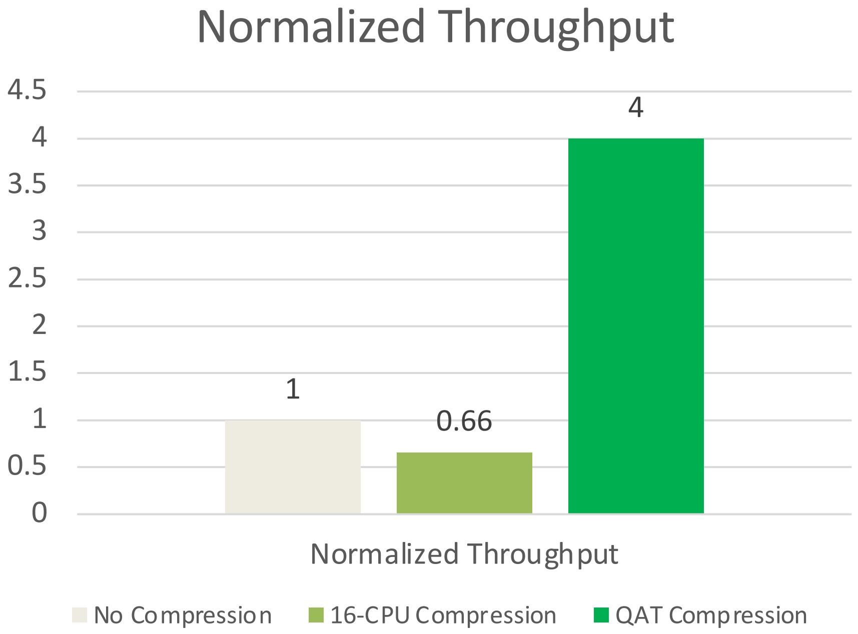
	No Compression	16 CPU Compression	QAT Compression
Throughput (Pages per Second * 10000)	17 ~ 29	39 ~ 50	133 ~ 138
Largest Migratable Dirty Rate (MB/s)	1100	1900	5000
Extra CPU Utilization (%)	No	678	< 40
Compression Ratio	No	87.6	922



Memory Dirty with Sequence Numbers

- Run in guest: ./dirty_workload –t 10 –i 500000 –m 3 1000 –s
  - Write sequence data in specified dirty rate (e.g. 1000 MB/s above)

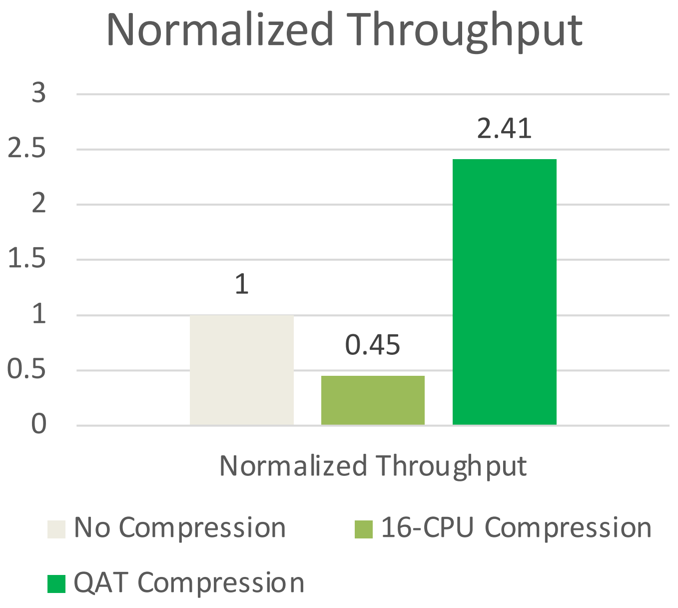
	No Compression	16 CPU Compression	QAT Compression
Throughput (Pages per Second * 10000)	17 ~ 29	~19	81~116
Largest Migratable Dirty Rate (MB/s)	1100	700	4200
Extra CPU Utilization (%)	No	1600	< 70
Compression Ratio	No	4.97	4.81



Memcached with Random Numbers

- Memcached Server
  - 16 servers, each with 4GB RAM
- Memslap Client
  - 16 threads,16 concurrency
  - Set/Get ratio 9:1
  - key length 128 bytes, value length 2048 bytes

	No Compression	16 CPU Compression	QAT Compression
Throughput (Pages per Second * 10000)	18 ~ 22	7 ~ 10	48 ~ 53
Migration Time (second)	Infinite	Infinite	60
Dirty Sync Count	Infinite	Infinite	10
Compression Ratio	No	1.6	1.6



- VM fails to be migrated in the “no compression” and “cpu compression” cases, and successfully migrated with QAT acceleration

Future Works

VFIO Driver based Zero-Copy

- Current Zero-copy is implemented based on the UIO based QAT driver
  - Requires QEMU to be root privilege to get VA-to-PA mappings via pagemap
  - Requires QEMU to pin its memory
- VFIO supports the above with QEMU running with non-root privilege
  - QAT’s VFIO based userspace driver and library are work in progress

Smart Acceleration Support

- DSA compares the dirty memory, and sends the "diff" to the destination only
  - Good when the guest only modifies a small part of a page
  - Bad when the entire pages are changed
- Smart Acceleration
  - Dynamically switch to use QAT/IAX compression or DSA diff during live migration using a prediction based on the compression ratio history and diff ratio history

Q & A

Disclaimers

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