mmuse: Memory management of persistent memory in userspace

Giving userspace control over dynamic virtual machine guest memory to survive kexec

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Agenda

Live update

Live update of hypervisor via kexec:
serialise -> kexec -> deserialise -> run

Persist guest memory and state across live update (kexec).

Different to snapshot/restore: full restart of userspace process; new VMM binary! Only preserve guest.

Objective: Make live update properly supported! Starting with memory.

Live update memory management

Memory "use cases:"

- Basic case: fixed allocation at launch.
- Memory overcommit: dynamic allocation/reclaim incl swap
- Deliver faults to userspace for post-copy LM.
- Keep DMA running during kexec: IOMMU persistent pgtables
- Pass through slice of PCI BAR
- Side-car VM: carve out portion of memory to run another VM.

Options considered

Fully kernel management persistence: Traditional kernel-driven allocations. Kernel state passed from old to new kernel. Like pkram[1] RFC; think `tempfs` with persistence.
State can be passed similar to Xen breadcrumbs.
Pros: fast, Cons: complex state hand over.

Filesystem with userspace control: Filesystem backed by non-kernel managed memory: hard split of persistent vs ephemeral.
Provide privileged userspace process the ability to control memory mappings (`pg_offset` to `PFN`) of files.
Store arbitrary file types: memory, state, pgtables, etc.

[1] https://lwn.net/Articles/851192/

Suggestion: filesystem with userspace control

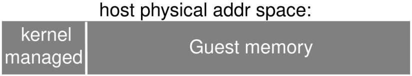
Idea floated at LSF/MM earlier this year:
https://lwn.net/Articles/895453/

Suggesting userspace filesystem. Justification:

- Avoid complexity of passing and re-hydrating state.
- Avoid attempting to expose allocation policies and things like swap to persistent memory.
- Allow userspace policy and implementation to develop freely.

Proposal: "mmuse" fs (mem mgmt in userspace)

- Carve out persistent memory by `mem=` cmdline param:



- Mount `mmuse`, setting backing file to something with access to the carved out memory: `/dev/mem`, `DAX` device, etc.
- Control process: own persistent memory, create files, program allocations into kernel via file ioctls.
- Client process (QEMU): use those allocation in non-privileged way: just open the file.

Example: Set up filesystem and backing memory. Mount:

```
mount -t mmuse guest-memory /mnt/guest-memory
```

Initially admin file for control process:

```
ls -l /mnt/guest-memory/
-rw-rw---- 1 root root   0 Aug  4 00:00  admin
```

Set backing to /dev/mem:

```
int admin_fd = open("/mnt/guest-memory/admin")
int devmem_fd = open("/dev/mem")
ioctl(admin_fd, SET_BACKING_FD, devmem_fd)
```

Example: Programming a mapping from backing memory to a file:

```
dst_fd = open("/mnt/guest-memory/dom123_0_3GiB");
struct mmuse_mapping mapping = {
  .dst = dst_fd,
  .src_start = 100 * GiB,
  .size = 3 * GiB,
  .dst_start = 0,
  .granulaity = GIGANTIC_PAGE // lvl 3 -> 1 GiB
};
ioctl(admin_fd, MAP_MEMORY_RANGE, &dst_fd);
```

When client processes mmaps that file it would get backing memory, faulting in 1 GiB PTEs.
Control process would replay after live update.

To persist or not to persist?

Should the filesystem preserve state internally across kexec: files, mappings, etc. Or should userspace re-drive filesystem state? Userspace need to know state anyway, so ought to be able to re-drive.

Advantage of persisting: 1) faster restore on LU, 2) kernel can consume files early.

Advantage of not persisting: No need for memory for pmem for metadata. Generally simpler.

Suggest: no persist at first, retrofit when more stable.

Discussion and Questions

Work so far:
Fairly complete proof of concept implemented. Not LKML worthy yet, but could be!

Open floor for questions/comments.

Some ideas for feedback:

- Are we re-inventing or overcomplicating this?
- Other use-cases than live-update?
- Other ideas to solve this which we should look at?
- Should we add `mmuse` to linux?

Backup slides

Backup slides.

Example: heirarchy using one mmuse file as backing memory for another:

```
int source_fd = open("/mnt/guest_memory/dom:123_memory")

mount -t mmuse dom:123_memory /mnt/dom:123_memory
int admin_fd = open("/mnt/dom:123_memory/admin")

ioctl(admin_fd, SET_BACKING_FD, source_fd)
```

Use case: hand over large chunk of memory to guest VMM. That VMM can carve it up for sidecar VMs.

Example: memory overcommit

Memory overcommit: reclaim a chunk of memory currently assigned to a file:

```
struct mappings = {
  .dst = dst_fd,
  .src_start = (100 << 30),
  .dst_start = 0,
  .size = (16 << 20)
}
ioctl(admin_fd, UNMAP_MEMORY_RANGE, &dst_fd);}
```

Use case: hand over large chunk of memory to guest VMM. That VMM can carve it up for sidecar VMs.