Kexec Handover and Live Update

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What is Live Update?

High level overview

Building blocks

Upstream status

Future work

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What is Live Update?

- It's NOT: live patching, live migration.
- Updates the kernel or hypervisor with minimal disruption for underlying workloads.
- Most commonly used for hypervisors.
- Can also be used by other workloads to reduce kernel patching downtime.
- Multiple cloud providers working together to upstream it.

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Live update flow

- The system is in normal state.
- The system software starts the live update process.
- Serializes state keeping VMs active but with limited capabilities.
- Pauses VMs and does final serialization.
- Loads and next kernel and hands over the serialized data.
- Next kernel deserializes the data.
- Resumes VM, returning normal operation.

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- In “serialization” part, mention the role of system software and kernel.
- Note the similarities to live migration.

What gets preserved?

- VM metadata
- VM memory
- Passthrough devices
- IOMMU mappings

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- Complex feature, not easy to do it in one go.
- Upstreaming as a set of building blocks instead.

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Kexec Handover (KHO)

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- Provides mechanism to mark memory as preserved.
- Makes sure preserved memory does not get used by the next kernel.
- Passes this information over kexec.

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- Explain that it is not possible to preserve user memory using this.
- But it can be used for non-liveupdate cases as well, like `reserve_mem` for example.

KHO: Memory preservation

```c
int kho_preserve_folio(struct folio *folio);
int kho_unpreserve_folio(struct folio *folio);
struct folio *kho_restore_folio(phys_addr_t phys);
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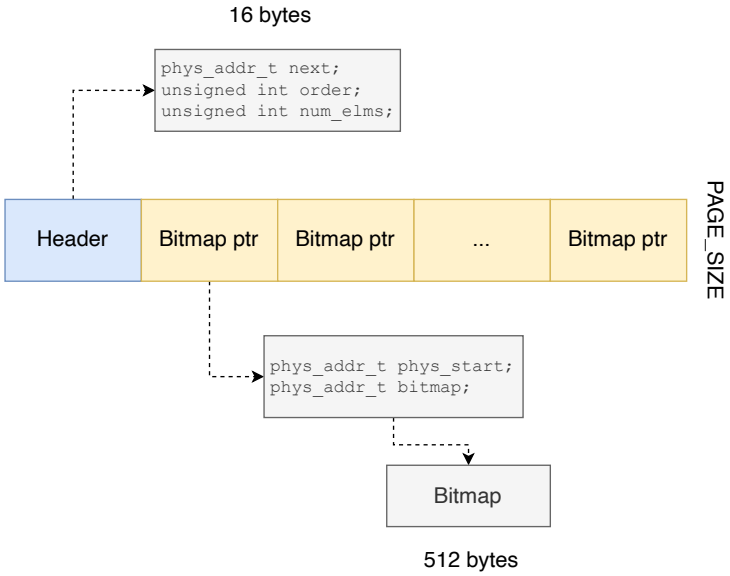

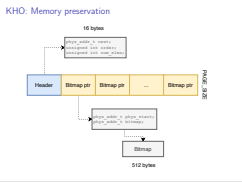

KHO: Booting up

- Pre-reserved scratch area for early boot.
- Passing KHO metadata: setup data on x86, chosen node in FDT on arm64.

```
struct kho_data {
        __u64 fdt_addr;
        __u64 fdt_size;
        __u64 scratch_addr;
        __u64 scratch_size;
} __attribute__((packed));
```

```
chosen {
        linux,kho-fdt = <...>;
        linux,kho-scratch = <...>;
};
```


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- Mention that kexec image and all early boot allocations go in scratch.
- Mention that chosen node gets set at kexec load time.

KHO: Booting up

- On early boot, only allocate from scratch.

```
enum memblock_flags choose_memblock_flags(void)
{
        if (kho_scratch_only)
                return MEMBLOCK_KHO_SCRATCH;
        [...]
}
```

- After early boot, mark preserved pages as reserved and turn off scratch-only mode
- Reserved pages don't get released to buddy allocator.

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Live Update Orchestrator (LUO)

- LUO provides a way for userspace to control the live update process.
- Allows marking which resources to preserve.
- Provides a state machine to co-ordinate all the components.
- API is exposed through a set of IOCTLs.

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- Allows marking which resources to preserve.
- Provides a state machine to co-ordinate all the components.
- API is exposed through a set of IOCTLs.

- Can't preserve everything since too much state.
- Mention that this is the next layer since it lets userspace actually do stuff.
- Maybe mention that `/dev/liveupdate` can only be opened once and that luod must control it?

LUO: States

```
struct liveupdate_ioctl_set_event {
        __u32           size;
        __u32           event;
};
```

- `LIVEUPDATE_PREPARE`: Normal -> Prepared
- `LIVEUPDATE_FREEZE`: Prepared -> Frozen
- `LIVEUPDATE_FINISH`: Updated -> Normal
- `LIVEUPDATE_CANCEL`: Prepared -> Normal

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- Explain all the states.
- FREEZE: Sent from `reboot(2)`.

LUO: File Descriptors

- Userspace can pass in supported file descriptors to LUO to mark them for preservation.
- Not any arbitrary FD, only FDs for supported file types.

```
struct liveupdate_ioctl_fd_preserve {
        __u32                   size;
        __s32                   fd;
        __aligned_u64           token;
};
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LUO: File Descriptors
- Userspace can pass in supported file descriptors to LUO to mark them for preservation.
- Not any arbitrary FD, only FDs for supported file types.
struct liveupdate_ioctl_fd_preserve {
__u32 size;
__s32 fd;
__aligned_u64 token;
};

- Give some examples of FDs in Linux: memfd, sockets, VFIO, IOMMUFD, KVM, etc.
- Mention some properties that can change with restore FDs, taking memfd as example.
- Mention that the token can be used to identify the FD after reboot.

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- Mention that not much work done on this so use cases and usage model still unclear.

Memory File Descriptor (memfd)

- memfd attaches a file descriptor to anonymous memory.
- State preserved: memory contents, size and position.
- After preserve, cannot add or remove pages from the memfd.
- Limitations: no sparseness, no swap.

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- Mention that memfd is the first user of LUO.
- Mention that pages are pinned and holes are filled.

memfd: preservation format

```
/ {
        pos = <0x...>;
        size = <0x...>;
        folios = [array of memfd_luo_preserved_folio]
};
```

```
struct memfd_luo_preserved_folio {
        u64 foliodesc;
        u64 index;
};
```

- Foliodesc: bottom 12 bits for flags, rest for PFN.

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- Explain why we use FDT.

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Upstream status

- KHO is in mainline. See `kernel/kexec_handover.c` and `include/linux/kexec_handover.h`.
- LUO v4 sent out few days ago. Patch posting. It is starting to stabilize and is on path to upstream soon.
- memfd support will get merged with the LUO patches.
- RFCs for PCI, VFIO, IOMMU out.

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- Implementing luod.
- Improving performance for reboots.
- Defining a mechanism for kernels to negotiate versions to enable rollback and roll forward to a wider set of kernels.
- Testing and validation.

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