STORAGE INDUSTRY SUMMIT

Convergence of Storage and Memory Developing the Needed Ecosystem

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Persistent Memory in Linux

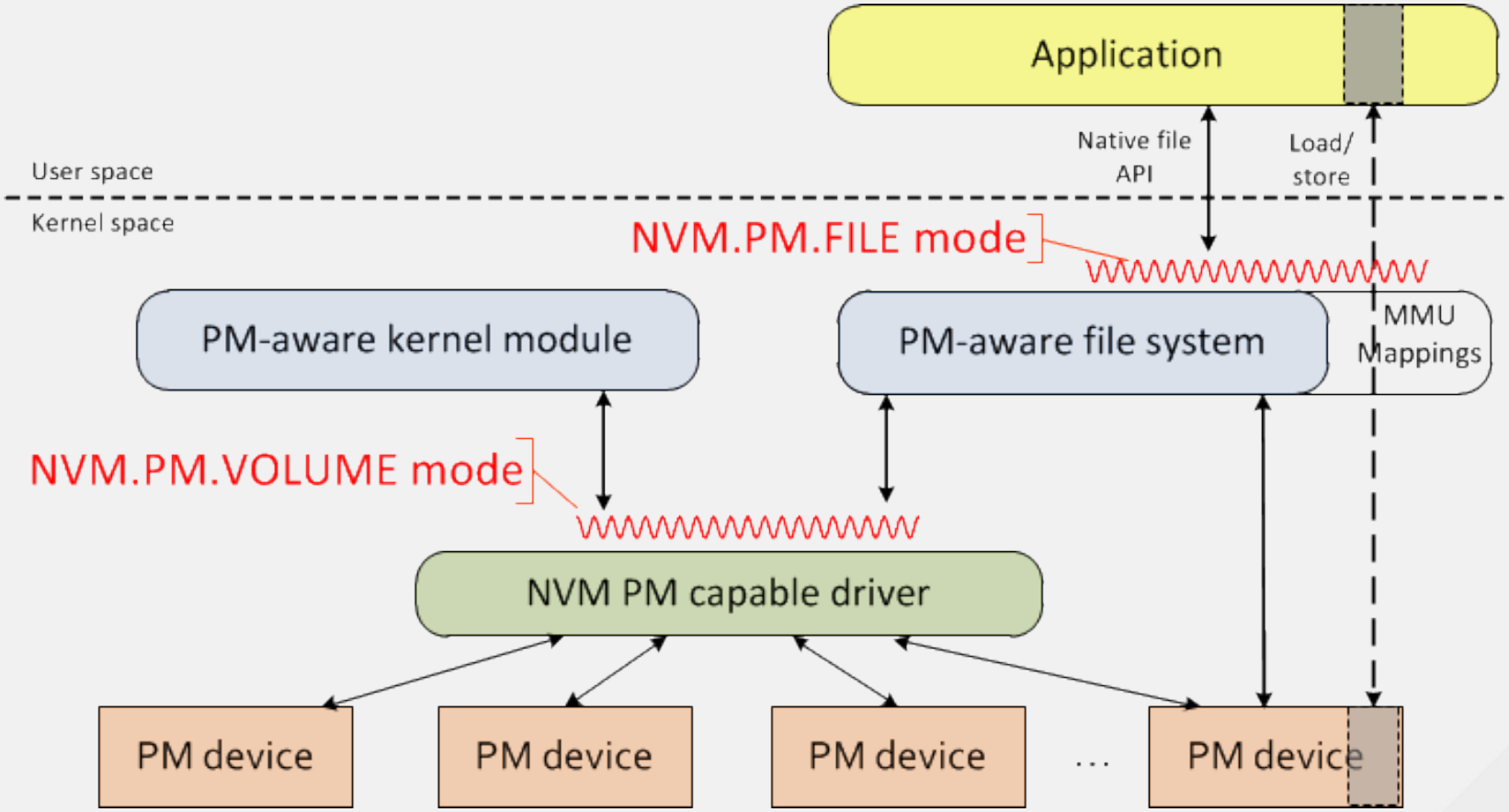
SNIA SSSI | SOLID STATE STORAGE

AGENDA

- Software Architecture
- Status
- Getting Started with PMEM

SOFTWARE ARCHITECTURE

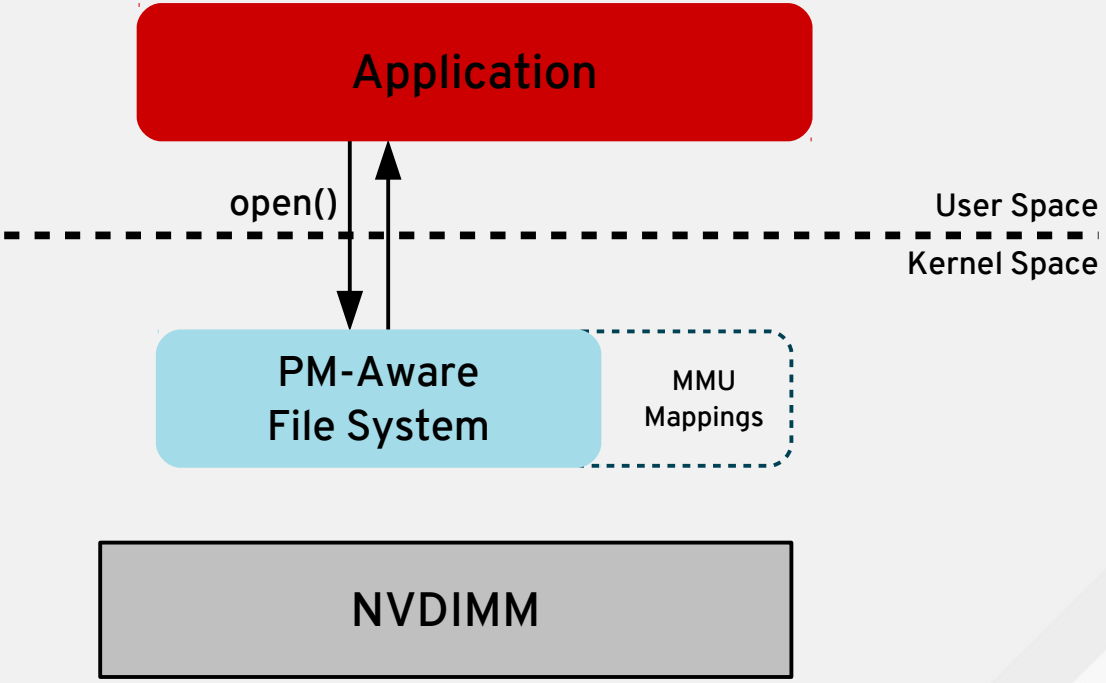
NVM.PM MODES



source: NVM Programming Model Specification

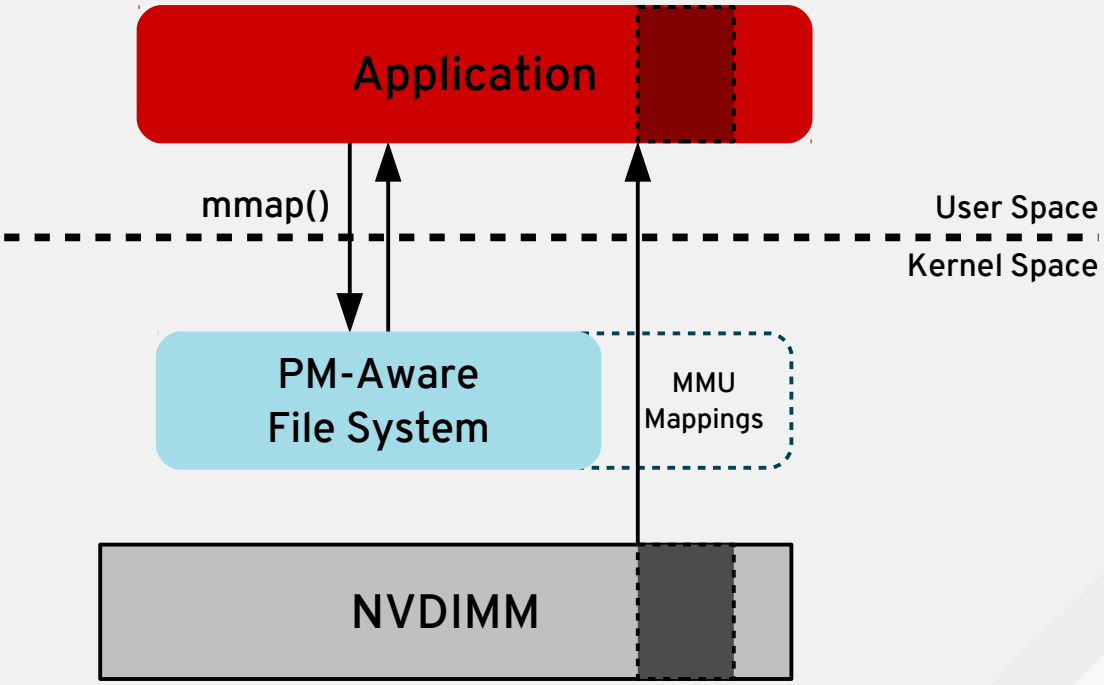
APPLICATION VIEW

- Step 1: open()



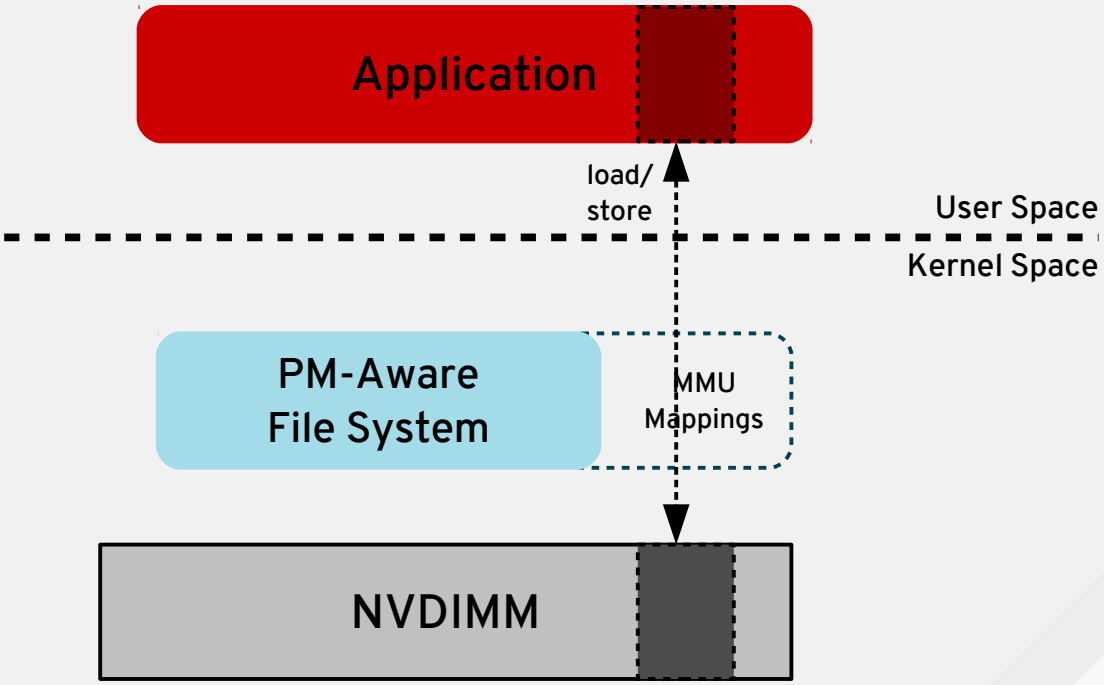
APPLICATION VIEW

- Step 1: open()
- Step 2: mmap()



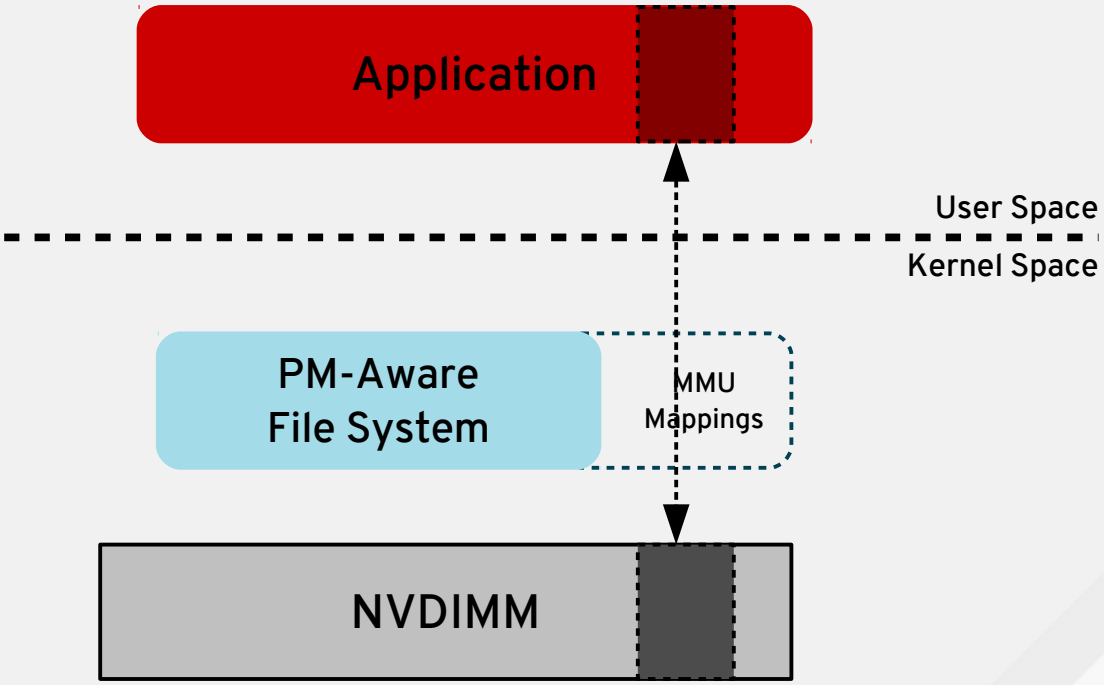
APPLICATION VIEW

- Step 1: open()
- Step 2: mmap()
- Step 3: ???

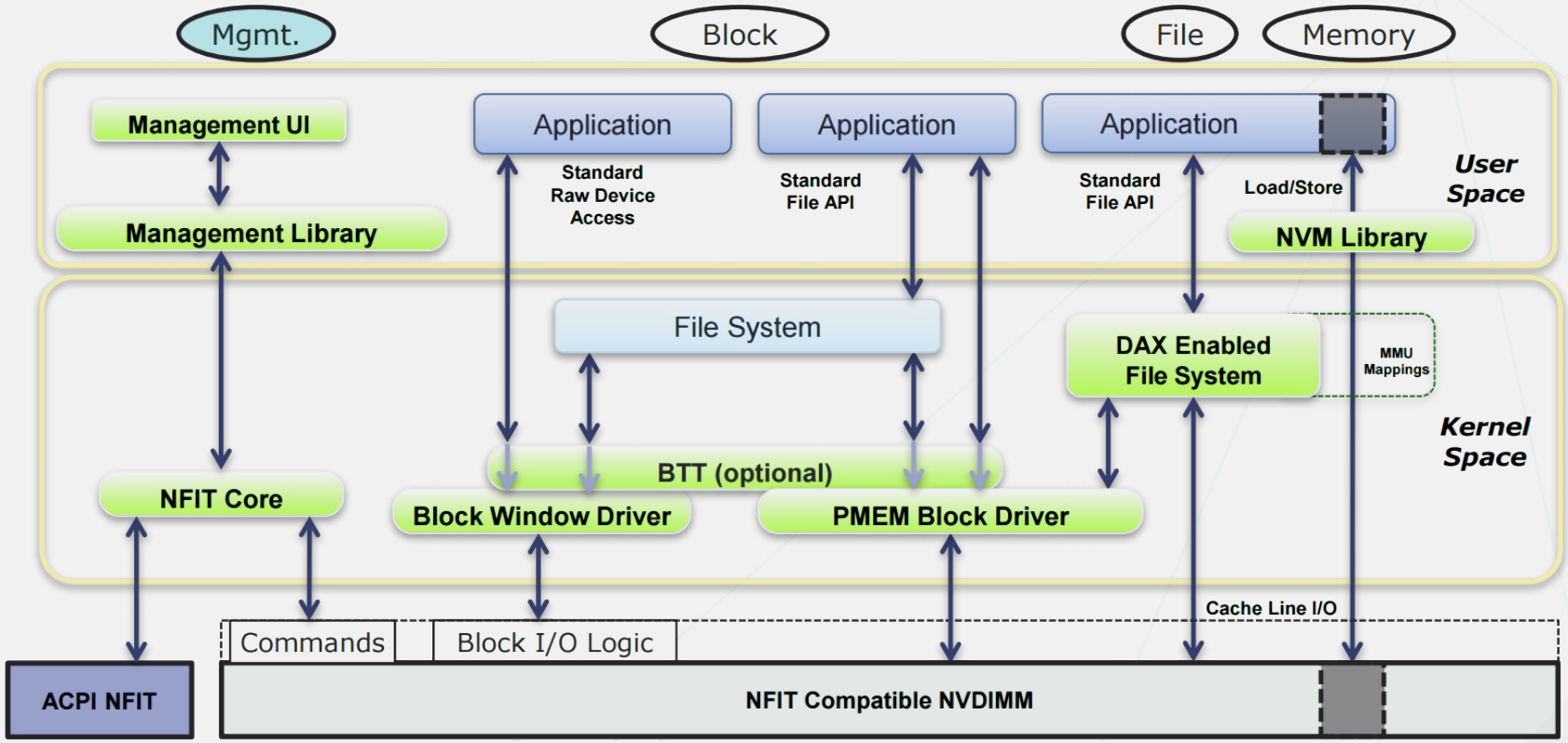


APPLICATION VIEW

- Step 1: open()
- Step 2: mmap()
- Step 3: ???
- Step 4: **PROFIT!!!**



NVDIMM SOFTWARE ARCHITECTURE



source: http://pmem.io/documents/NVDIMM_Namespace_Spec.pdf

NVM.PM.FILE ACTIONS

- Implemented by kernel
  - Map
  - Sync
- Implemented in userspace
  - Optimized_flush
  - Optimized_flush_and_verify

POSIX READ/WRITE WITH DAX

- Bypasses the Page Cache
- Synchronous

POSIX READ/WRITE WITH DAX

- Bypasses the Page Cache
- Synchronous

Still suffers from torn sectors!

ERROR HANDLING

- 2 cases to handle
  - Machine checks
  - Known bad “blocks”

MACHINE CHECK EXCEPTIONS

- Goal: Turn MCEs into SIGBUS
- Not recoverable on all platforms (or in all cases)

KNOWN BAD BLOCKS

- Address Range Scrub
- Stored per block device

STATUS

SUBSYSTEMS ADDED/MODIFIED

IN SUPPORT OF NVDIMMS

- ACPI
- Device Drivers
- Architecture code (e.g. x86)
- Block Layer
- VFS
- File Systems (ext4, xfs)
- Memory Management

NON-KERNEL COMPONENTS

- QEMU, libvirt, virt-manager
- Libraries (nvml, libndctl)
- Kexec
- Anaconda (installer)
- Smartmontools
- Management utilities

WHAT WORKS?

Kernel

- NVDIMM driver core
  - NFIT parsing, pmem driver, nd_blk, btt
- DAX support (experimental)
  - 4k + 2MB pages
  - Ext4, xfs
- Bad block tracking **infrastructure**
- Core dump filtering

WHAT IS MISSING?

Kernel

- DAX
  - fsync/msync
  - 1GB page support in file systems
  - Error handling
- Management utilities

GETTING STARTED

TRYING OUT PMEM

- Kernel configurations
- Making and mounting a file system
- Testing the programming model

TRYING OUT PMEM

Kernel Configuration

```
CONFIG_ZONE_DEVICE=y
CONFIG_X86_PMEM_LEGACY_DEVICE=y
CONFIG_X86_PMEM_LEGACY=m
CONFIG_ACPI_NFIT=m
CONFIG_LIBNVDIMM=m
CONFIG_BLK_DEV_PMEM=m
CONFIG_ND_BLK=m
CONFIG_ND_CLAIM=y
CONFIG_ND_BTT=m
CONFIG_BTT=y
CONFIG_ND_PFN=m
CONFIG_NVDIMM_PFN=y
```

… or just use Fedora

TRYING OUT PMEM

Device Nodes

Kernel Parameter Added

- memmap=16G!16G

```
# ls /dev/pmem*
/dev/pmem0

# fdisk -l /dev/pmem0

Disk /dev/pmem0: 16 GiB, 17179869184 bytes,
33554432 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

TRYING OUT PMEM

Making and mounting a file system

```
# mkfs -t xfs -d su=1g,sw=1 /dev/pmem0
# mount -t xfs -o dax /dev/pmem0
```

OR

```
# mkfs -t ext4 /dev/pmem0
# mount -t ext4 -o dax /dev/pmem0
```

NOTE: Inconsistent behavior

- ext4 fails if DAX unavailable
- xfs logs a message

Using DAX

```
int
main(int argc, char **argv)
{
     int         fd;
     void       *addr;
     struct stat st;

     fd = open(argv[1], O_RDWR);
     fstat(fd, &st);
     addr = mmap(0, st.st_size, PROT_READ|PROT_WRITE, MAP_SHARED, fd, 0);

...
```

Using DAX

Verifying PMEM Was Allocated

```
/proc/self/smaps:

7fc173c6b000-7fc17a06b000 rw-s 00000000 103:00
2097155                   /mnt/nvm/testfile
Size:             102400 kB
Rss:                   0 kB
Pss:                   0 kB
Shared_Clean:          0 kB
Shared_Dirty:          0 kB
Private_Clean:         0 kB
Private_Dirty:         0 kB
Referenced:            0 kB
Anonymous:             0 kB
AnonHugePages:         0 kB
Shared_Hugetlb:        0 kB
Private_Hugetlb:       0 kB
Swap:                  0 kB
SwapPss:               0 kB
KernelPageSize:        4 kB
MMUPageSize:           4 kB
Locked:                0 kB
VmFlags: rd wr sh mr mw me ms mm hg
```

Using DAX

Verifying PMEM Was Allocated

```
        char *caddr = addr;

        FILE *fp;
        fp = fopen("/proc/self/smaps", "r");

        while (fgets(line, PROCMAXLEN, fp) != NULL) {
                static const char vmflags[] = "VmFlags:";
                static const char mm[] = " mm";

                /* check for range line */
                if (sscanf(line, "%p-%p", &lo, &hi) == 2) {
                        if (needmm) {
                                /* last range matched, but no mm flag found */
                                break;
                        } else if (caddr < lo) {
                                /* never found the range for caddr */
                                break;
                        } else if (caddr < hi) {
                                /* start address is in this range */
...
```

Using DAX

Verifying PMEM Was Allocated

```
        size_t rangelen = hi - caddr;

        /* remember that matching has started */
        needmm = 1;

        /* calculate remaining range to search for */
        if (len > rangelen) {
                len -= rangelen;
                caddr += rangelen;
        } else {
                len = 0;
        }
}
```

Using DAX

Verifying PMEM Was Allocated

```
        } else if (needmm && strncmp(line, vmflags,
                        sizeof (vmflags) - 1) == 0) {
                if (strstr(&line[sizeof (vmflags) - 1], mm) != NULL) {
                        if (len == 0) {
                                /* entire range matched */
                                retval = 1;
                                break;
                        }
                        needmm = 0;     /* saw what was needed */
                } else {
                        /* mm flag not set for some or all of range */
                        break;
                }
        }
}

fclose(fp);
```

… or just use nvml

… or just use nvml

(which is the source of the above stole^wborrowed code)

SUMMARY

- BTT for legacy applications
- PMEM devices for modified applications or applications that are resilient to torn sectors
- NVM.PM.FILE.MAP can be used today with a Fedora kernel
- NVM.PM.FILE.SYNC is coming soon

REFERENCES

- Upstream NVDIMM mailing list:
  - https://lists.01.org/mailman/listinfo/linux-nvdimm
- NVDIMM wiki, includes pointers for getting started:
  - https://nvdimm.wiki.kernel.org/
- pmem.io, includes blog posts, reference materials, and nvml:
  - http://pmem.io
- NVDIMM Namespace Specification (label format, etc):
  - http://pmem.io/documents/NVDIMM_Namespace_Spec.pdf
- SNIA NVM Programming Model Specification:
  - http://www.snia.org/tech_activities/standards/curr_standards/npm

redhat.

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