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On-demand EventFS
to reduce Linux Tracer memory footprint

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Ajay Kaher (akaher@vmware.com)

Agenda

- Brief Introduction to Linux Tracer Events, Multiple instances of Tracer/Events

- Linux Tracer Memory Footprint

- On-demand Eventfs to improve ‘Tracer Memory Footprint’

- Code snippet of Eventfs APIs/Structure

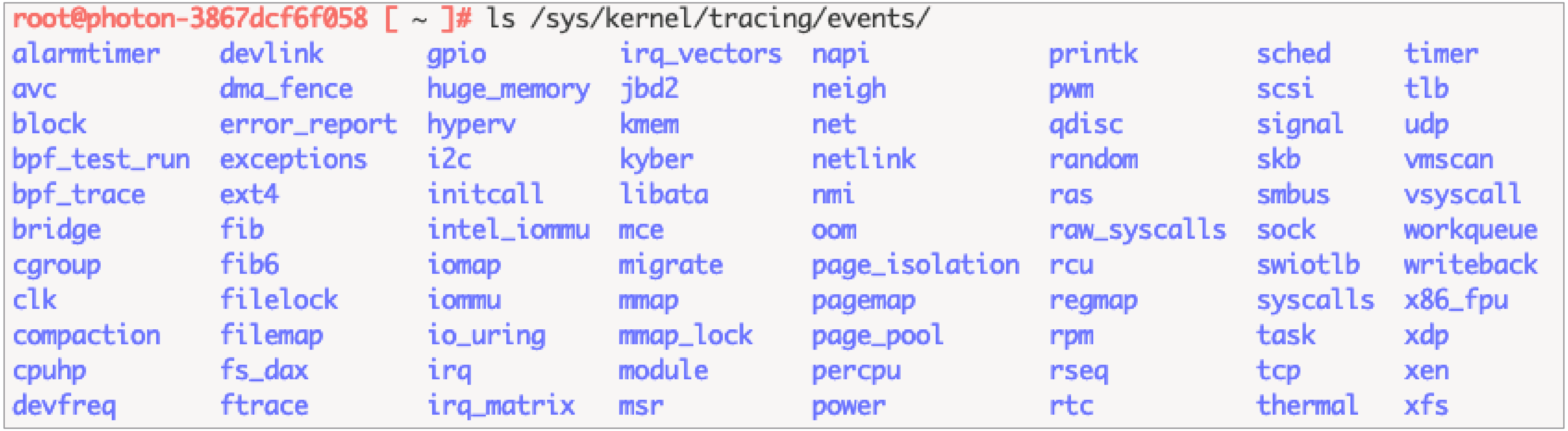
- Conclusion

- On going task, Suggestions/Feedback

Linux Tracing and Events hierarchy:

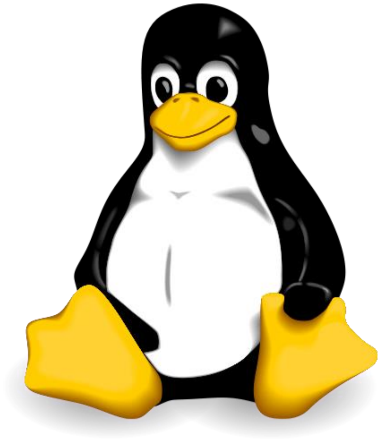
Linux Tracer is used for debugging and performance analysis of Kernel

Events Tracing Infrastructure:



```
root@photon-3867dcf6f058 [ ~ ]# ls /sys/kernel/tracing/events/
alarmtimer    devlink       gpio         irq_vectors  napi            printk        sched     timer
avc           dma_fence     huge_memory  jbd2         neigh           pwm           scsi      tlb
block         error_report  hyperv       kmem         net             qdisc         signal    udp
bpf_test_run  exceptions    i2c          kyber        netlink         random        skb       vmscan
bpf_trace     ext4          initcall     libata       nmi             ras           smbus     vsyscall
bridge        fib           intel_iommu  mce          oom             raw_syscalls  sock      workqueue
cgroup        fib6          iomap        migrate      page_isolation  rcu           swiotlb   writeback
clk           filelock      iommu        mmap         pagemap         regmap        syscalls  x86_fpu
compaction    filemap       io_uring     mmap_lock    page_pool       rpm           task      xdp
cpuhp         fs_dax        irq          module       percpu          rseq          tcp       xen
devfreq       ftrace        irq_matrix   msr          power           rtc           thermal   xfs
```

Multiple Instances of Tracing and Events



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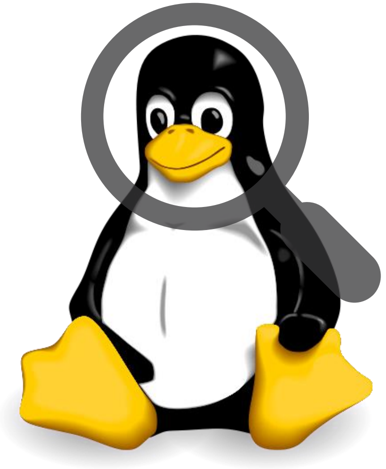

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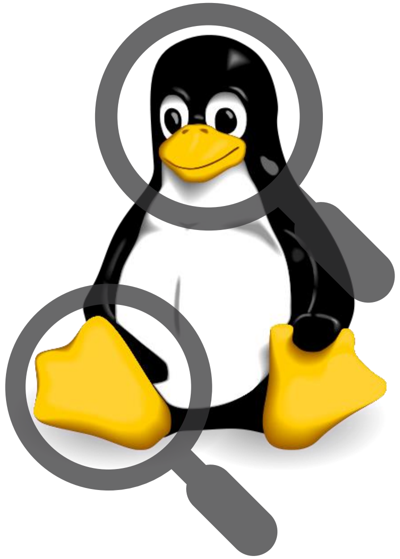

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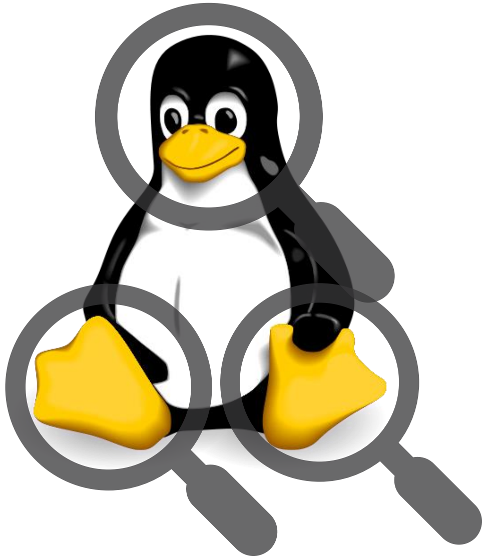
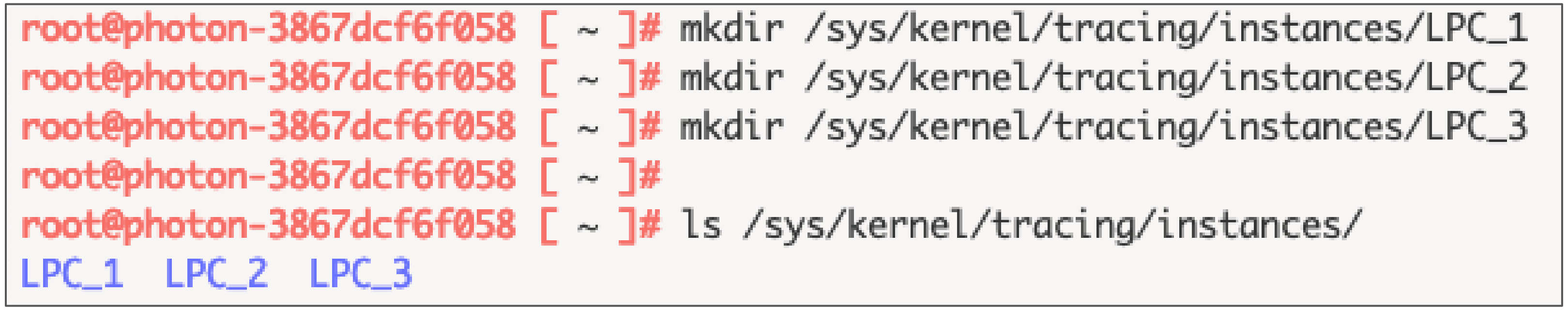
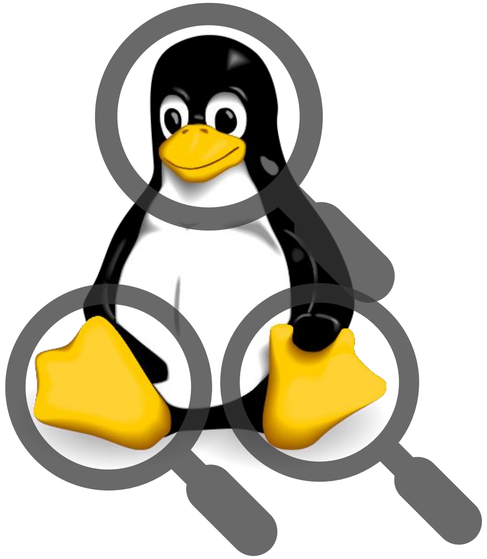


Multiple Instances of Tracing and Events

Linux tracer provides mechanism to have multiple instances of 'tracing'



```
root@photon-3867dcf6f058 [ ~ ]# mkdir /sys/kernel/tracing/instances/LPC_1
root@photon-3867dcf6f058 [ ~ ]# mkdir /sys/kernel/tracing/instances/LPC_2
root@photon-3867dcf6f058 [ ~ ]# mkdir /sys/kernel/tracing/instances/LPC_3
root@photon-3867dcf6f058 [ ~ ]#
root@photon-3867dcf6f058 [ ~ ]# ls /sys/kernel/tracing/instances/
LPC_1  LPC_2  LPC_3
```



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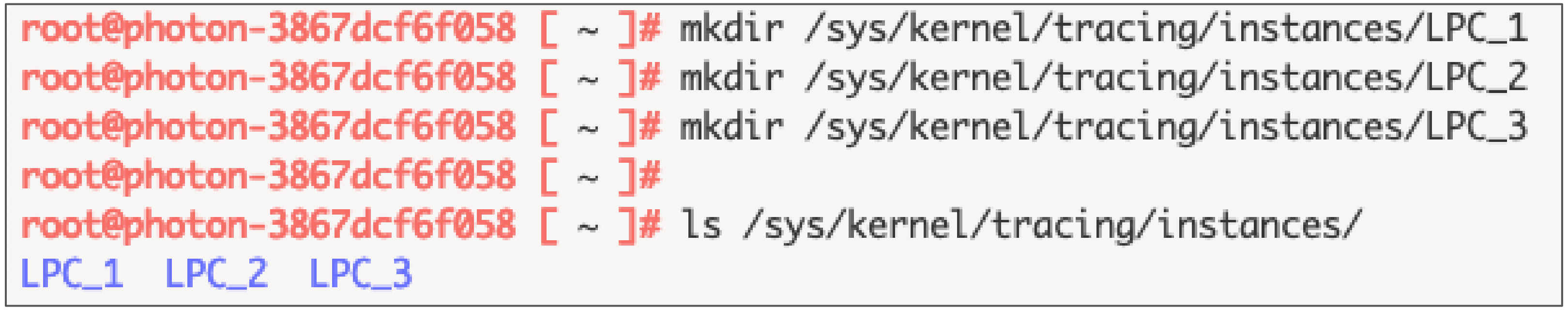

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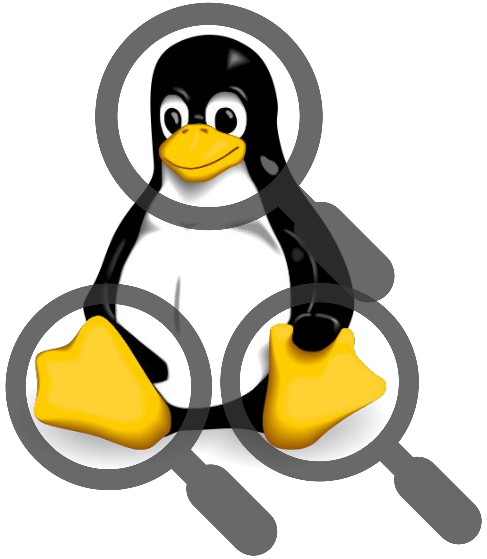
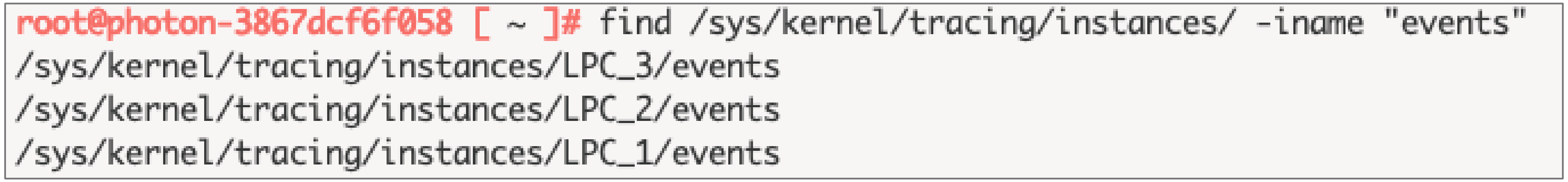


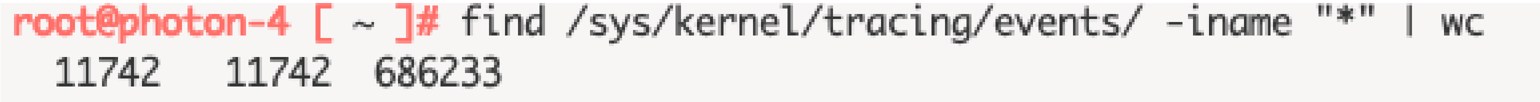
Each tracing instance have individual events directory known as 'Events Tracing Infrastructure'



```
root@photon-3867dcf6f058 [ ~ ]# find /sys/kernel/tracing/instances/ -iname "events"
/sys/kernel/tracing/instances/LPC_3/events
/sys/kernel/tracing/instances/LPC_2/events
/sys/kernel/tracing/instances/LPC_1/events
```

Problem Statement: Linux Tracer Memory Footprint

- 'Events Tracing Infrastructure' contains lot of files/directories (although depending upon the Kernel config)



```
root@photon-4 [ ~ ]# find /sys/kernel/tracing/events/ -iname "*" | wc
  11742   11742  686233
```

- 'Events Tracing Infrastructure' has 11742 files/directories = ~ 9 MB

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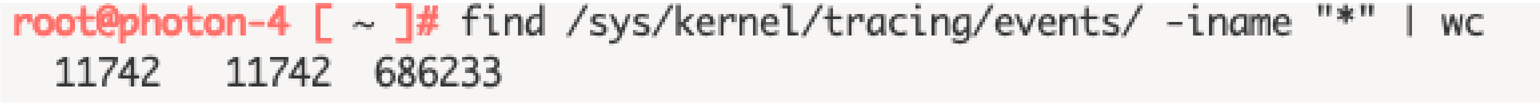

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Linux Tracer

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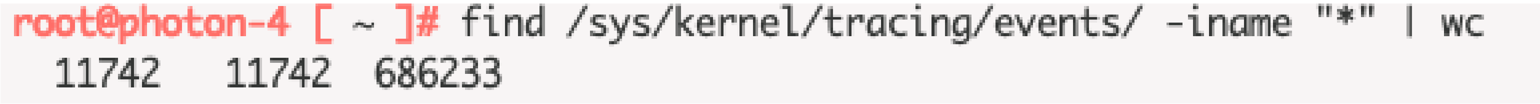

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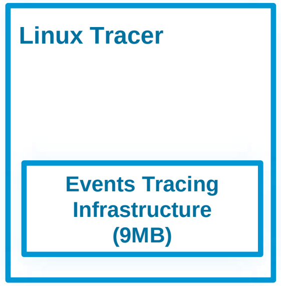

Linux Tracer

Events Tracing Infrastructure (9MB)

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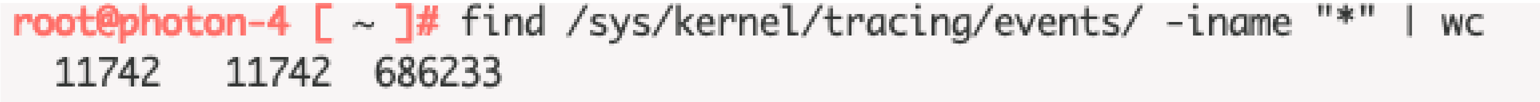

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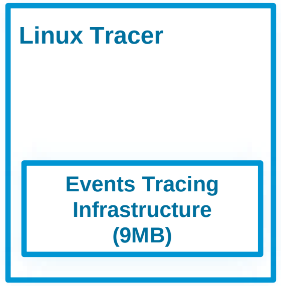

1st Instance

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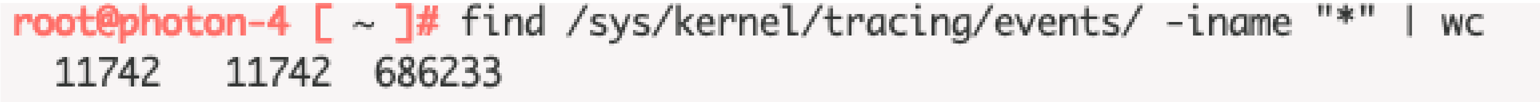

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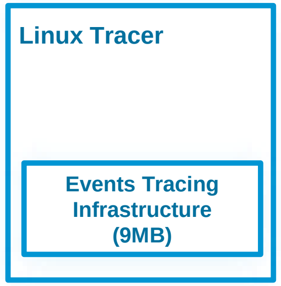

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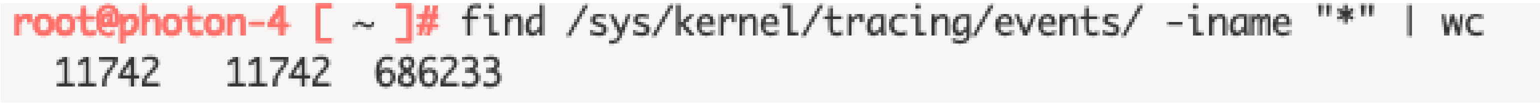

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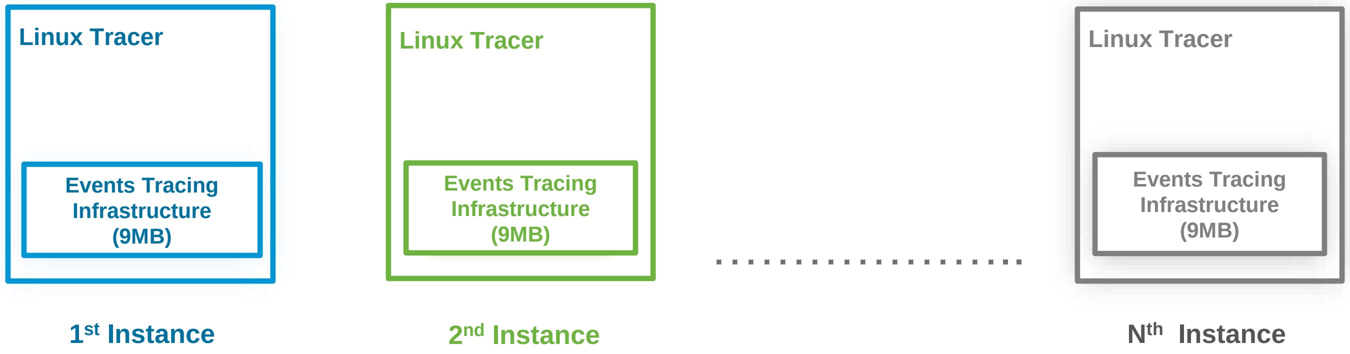
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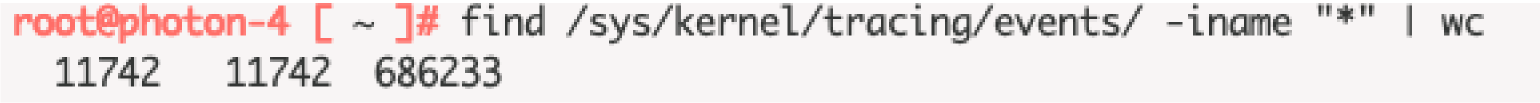

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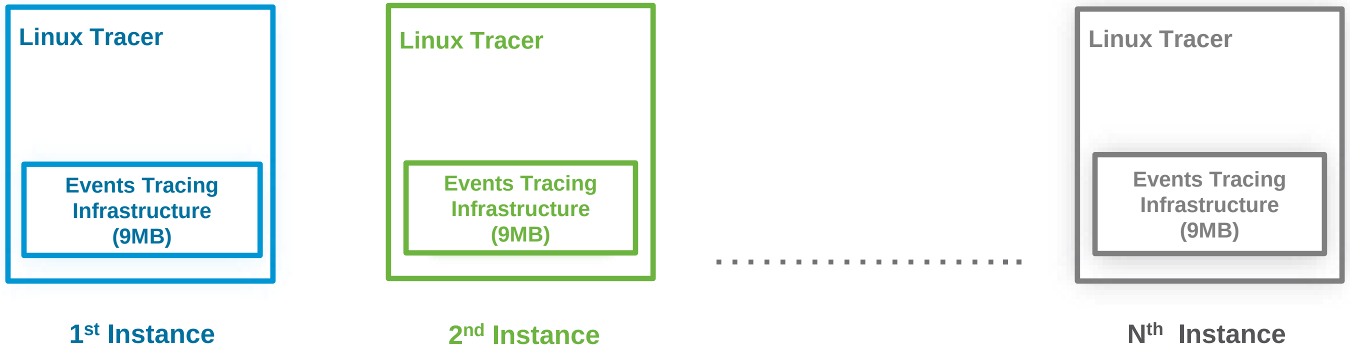

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Goal: Reduce memory footprint of 'Events Tracing Infrastructure'

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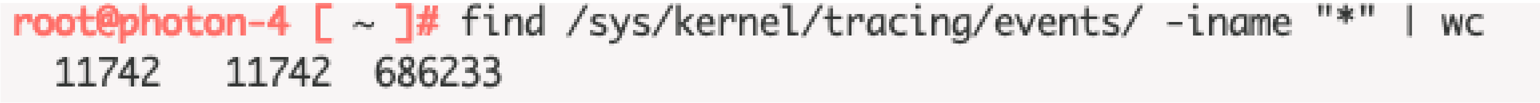

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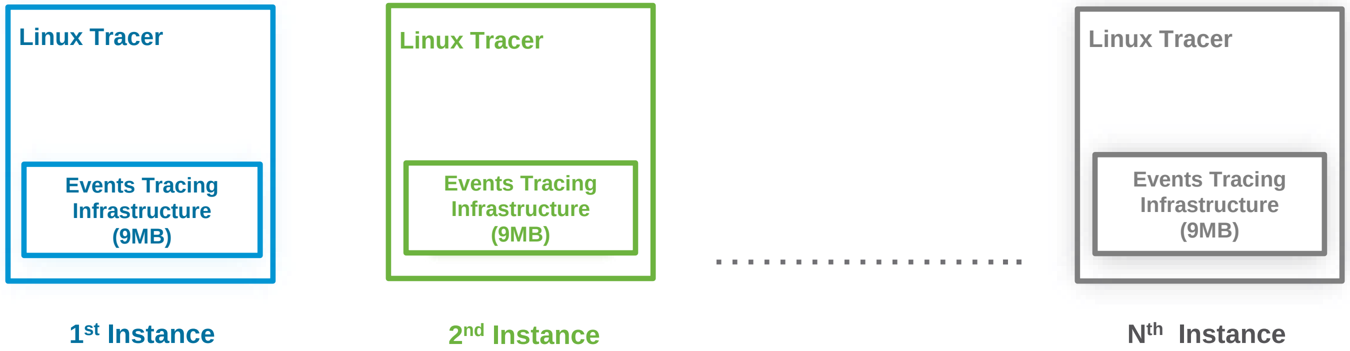
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1st Instance
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…………………
Linux Tracer
Events Tracing Infrastructure (9MB)
Nth Instance

Goal: Reduce memory footprint of 'Events Tracing Infrastructure'

Target: 75% reduction in memory footprint of Events

Solution: On-demand Eventfs to improve ‘Tracer Memory Footprint’

- Instead of inode and dentry structure, just keep the meta-data of files/directories.
- On-demand use the meta-data to create the files/directories and delete them if no longer requires.

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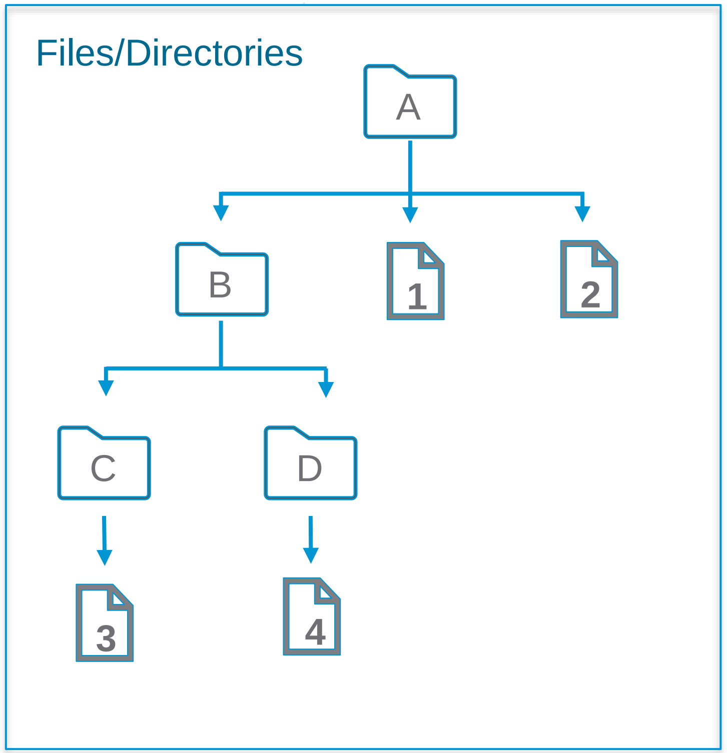

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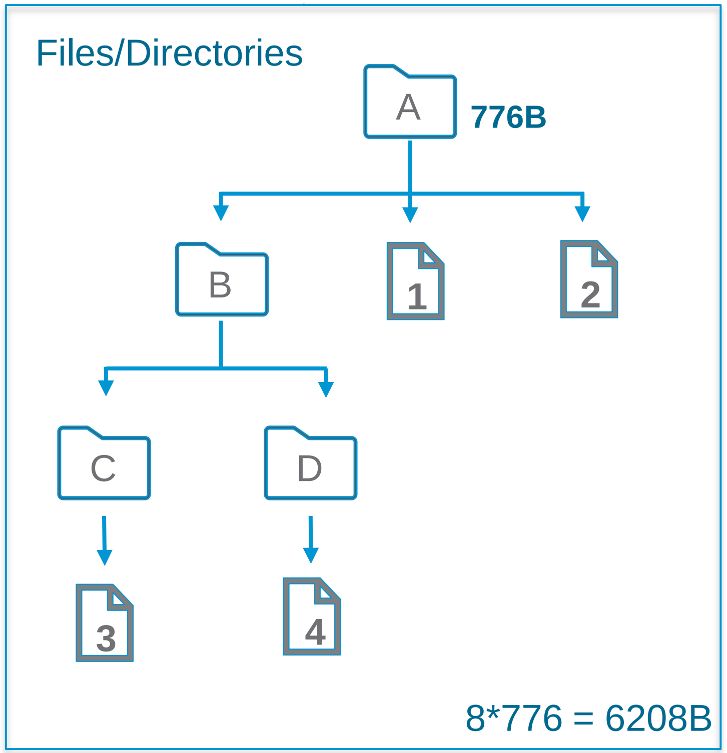

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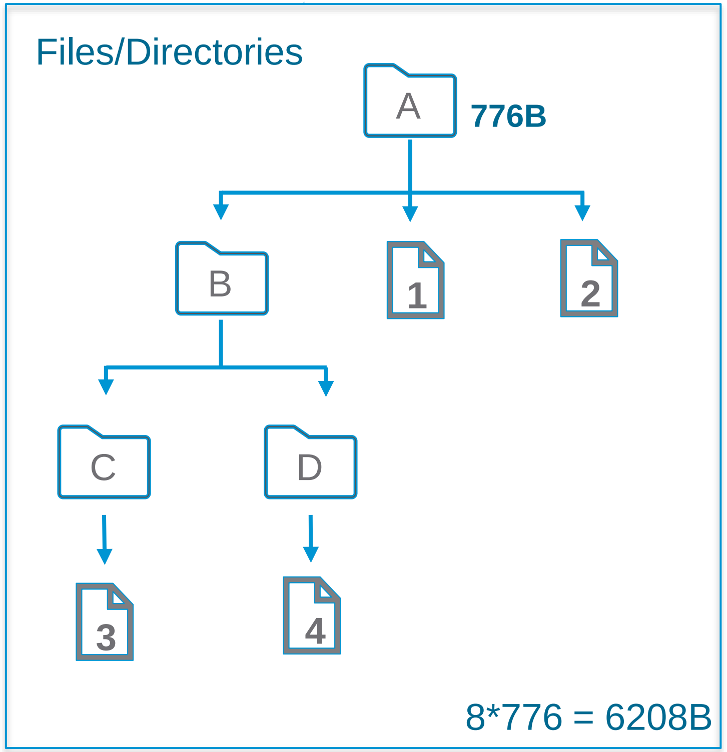

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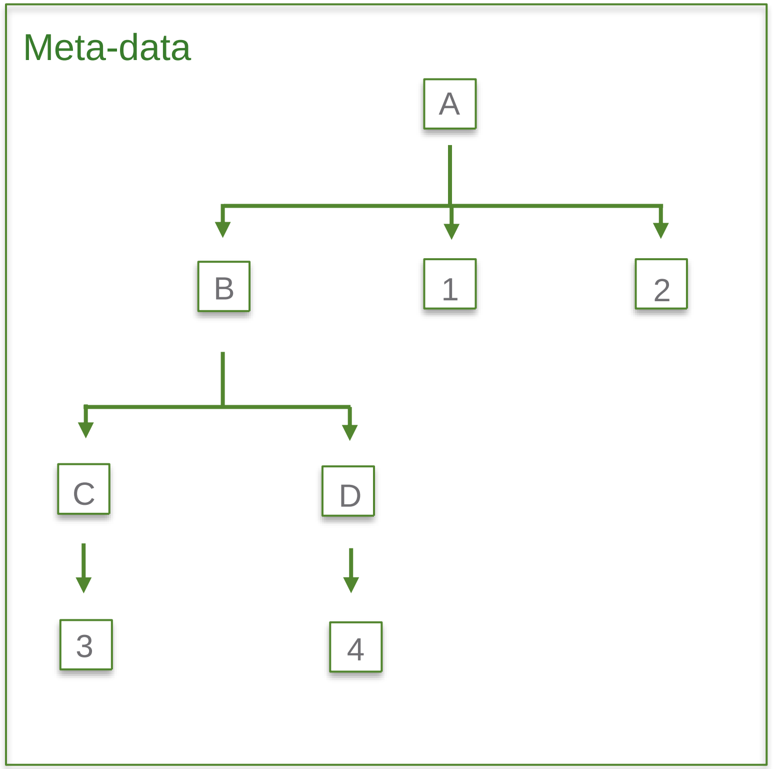

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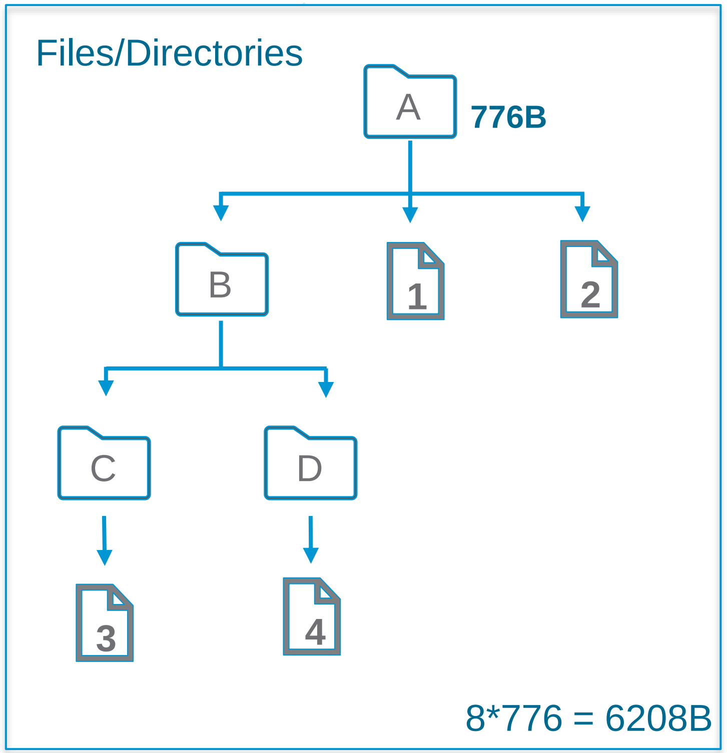

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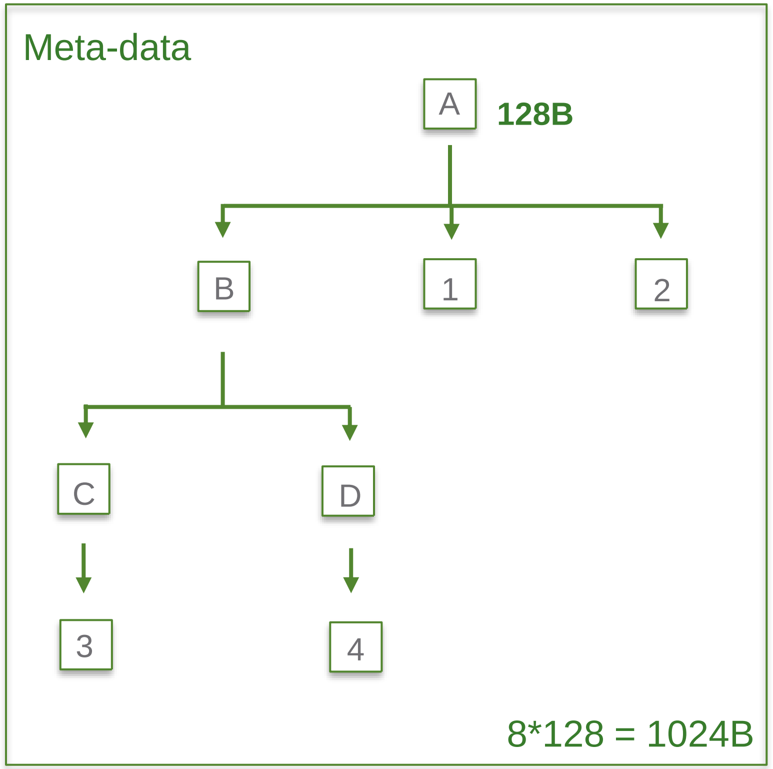

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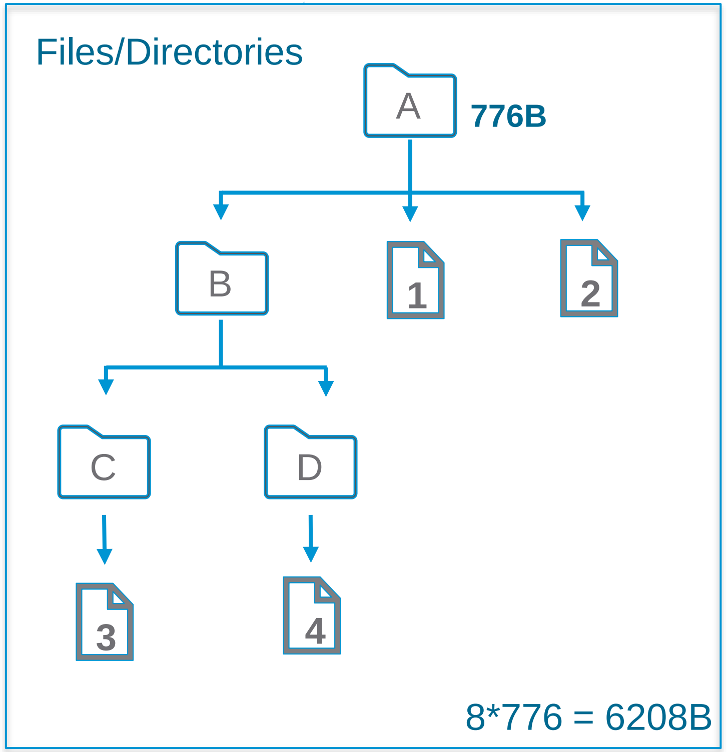

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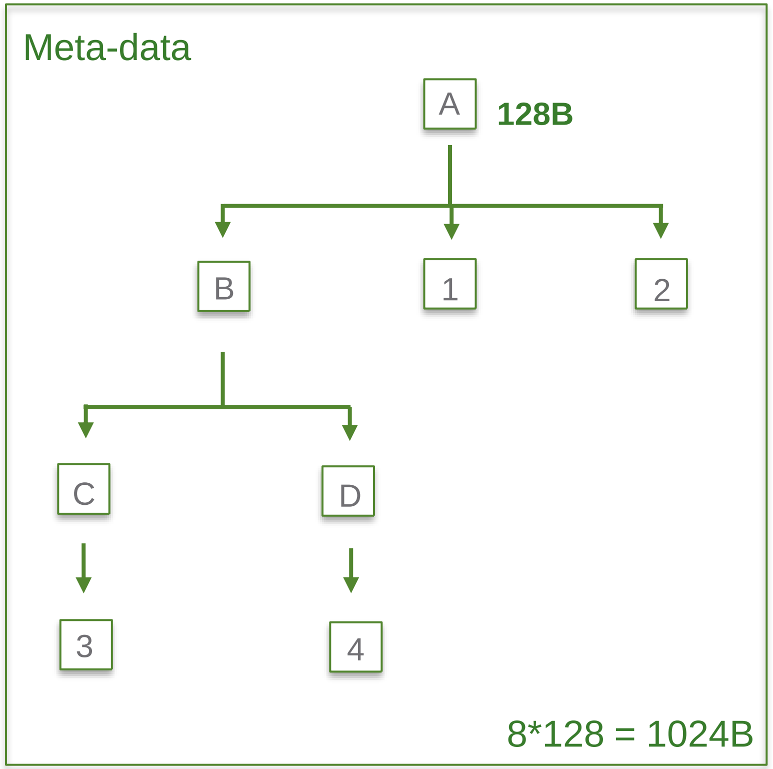

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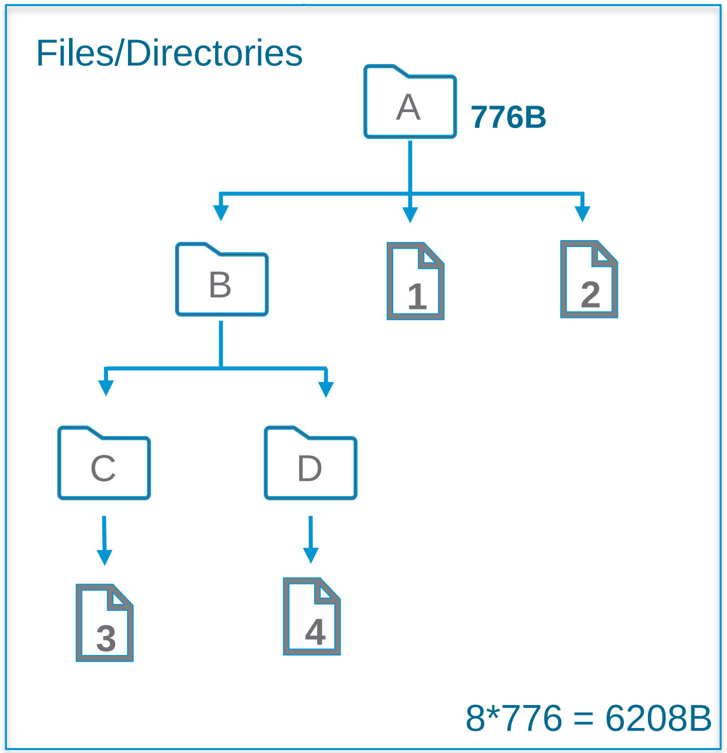

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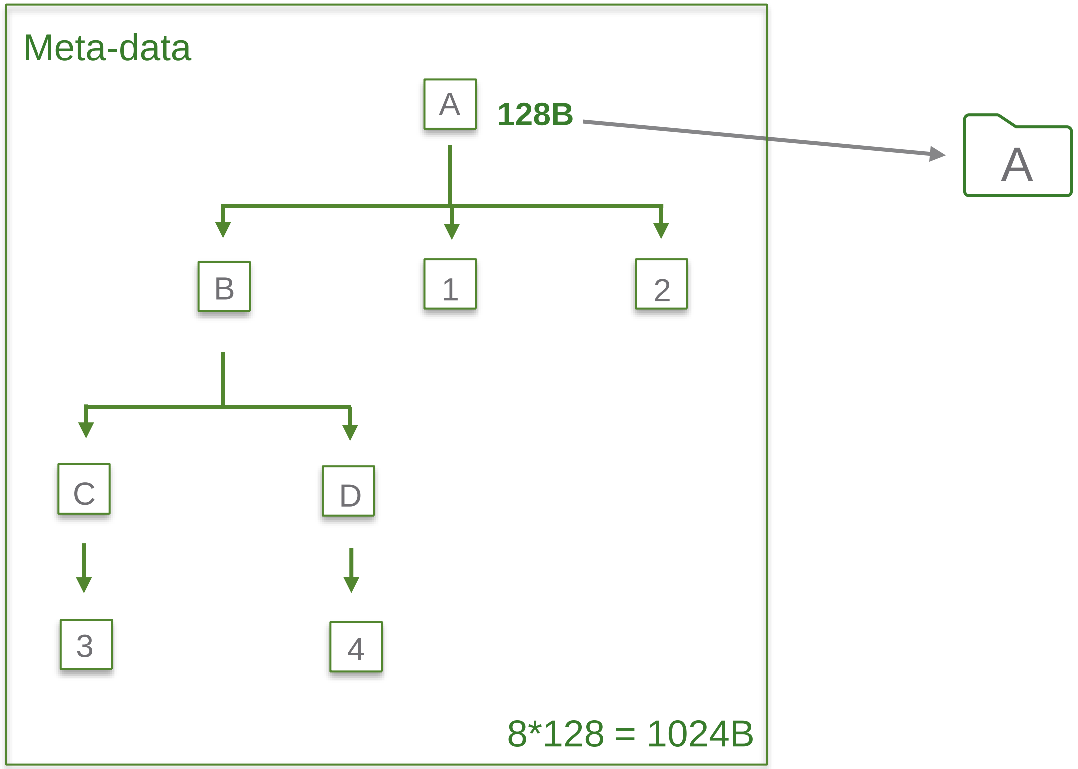

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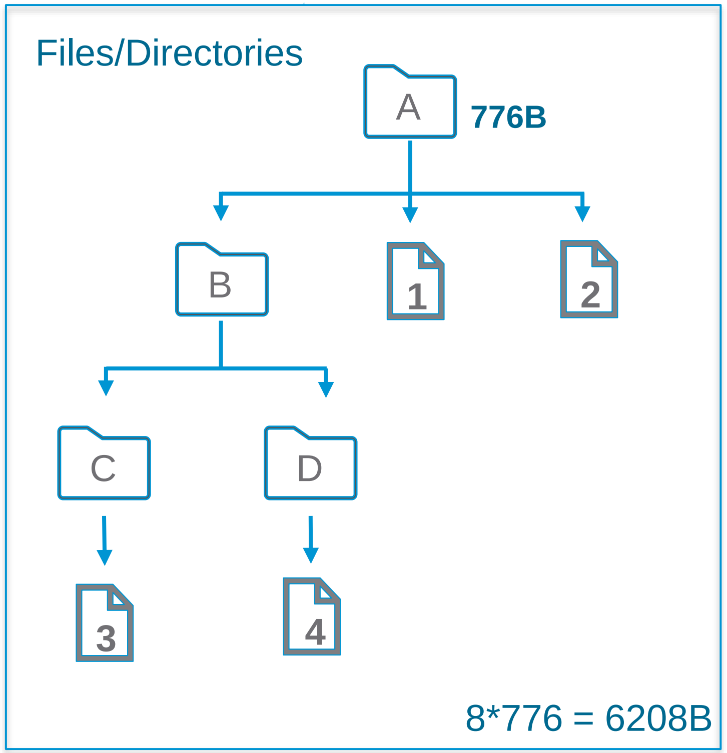

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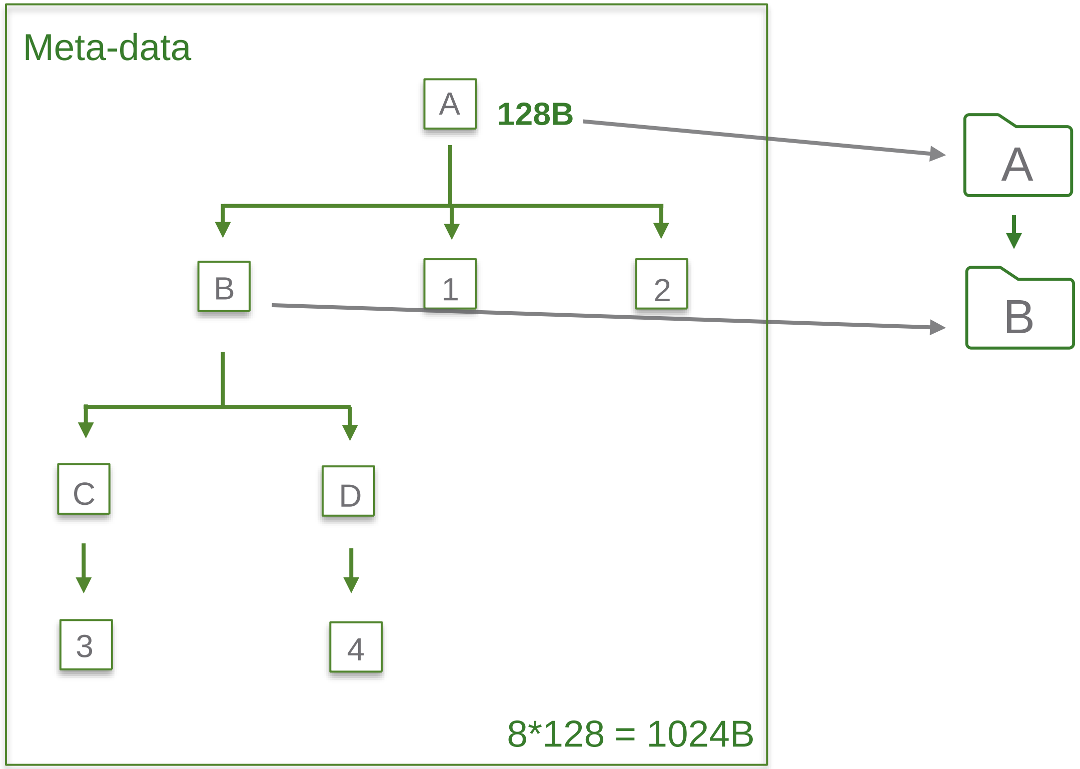

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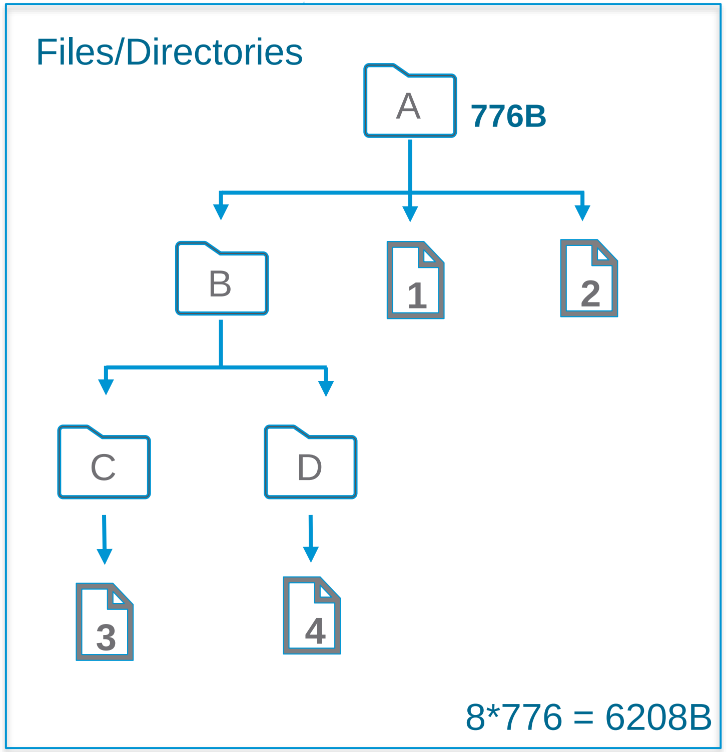

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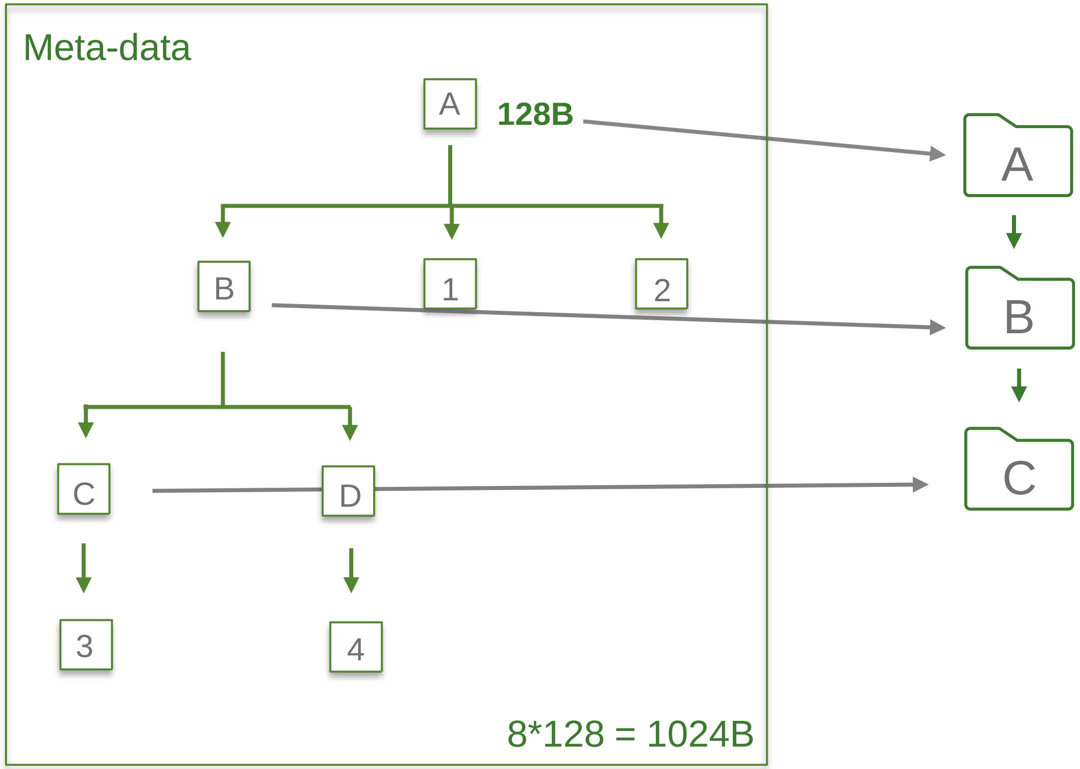

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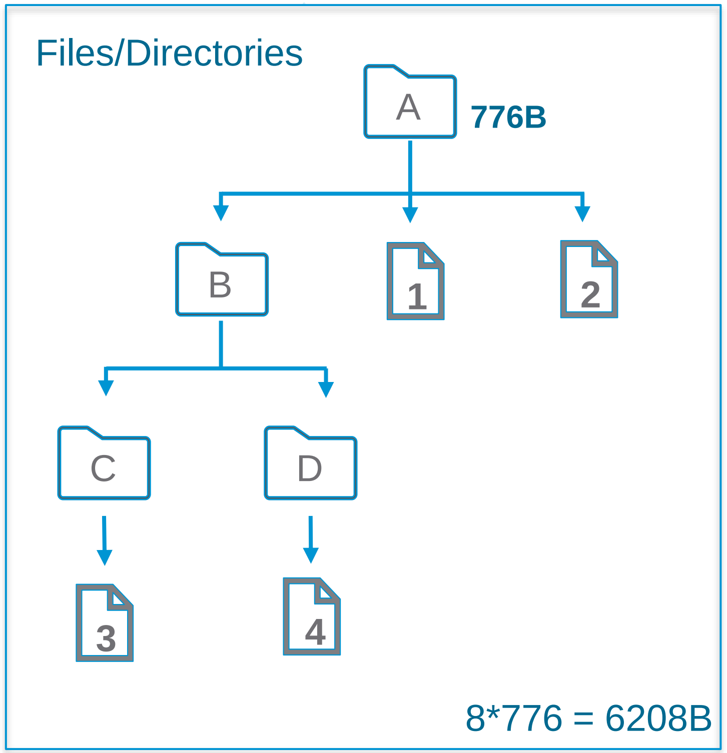

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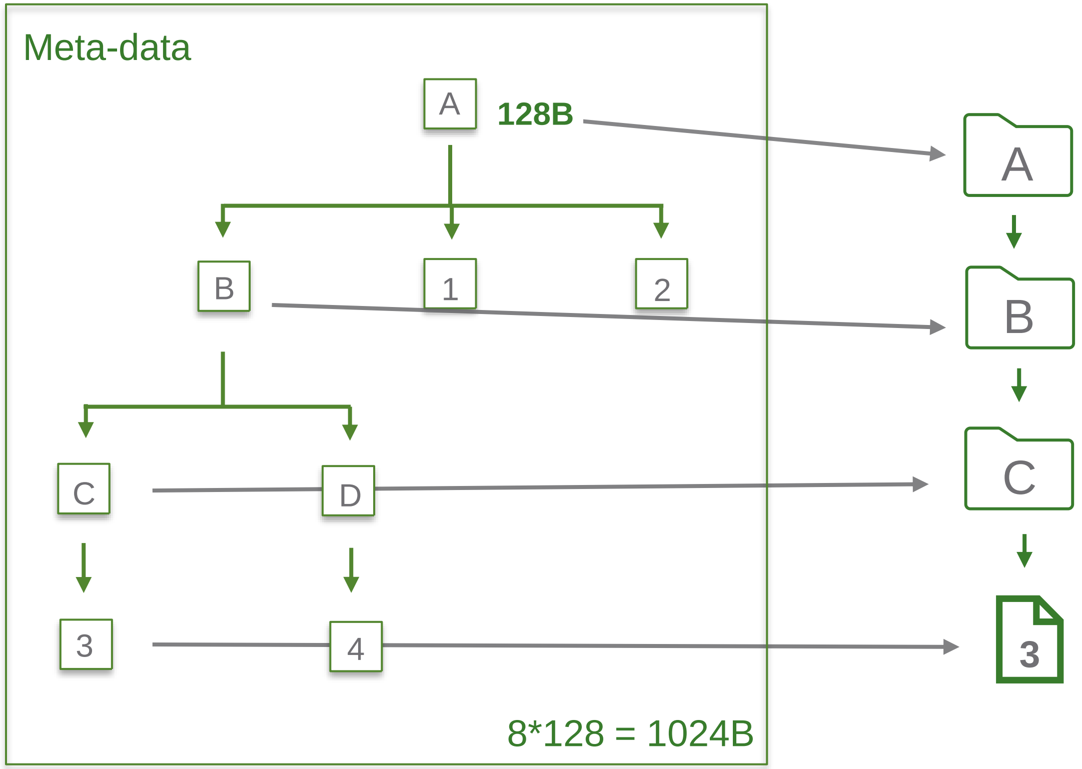

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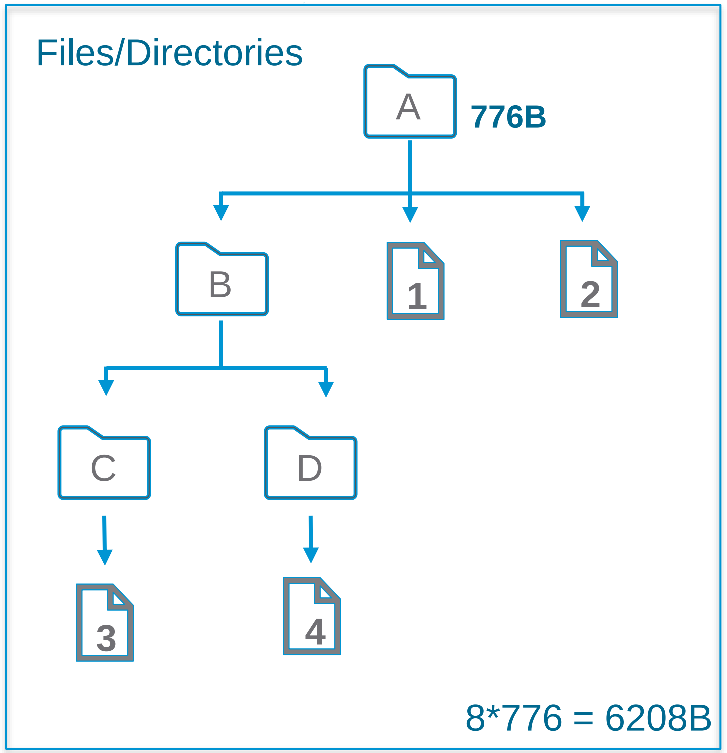

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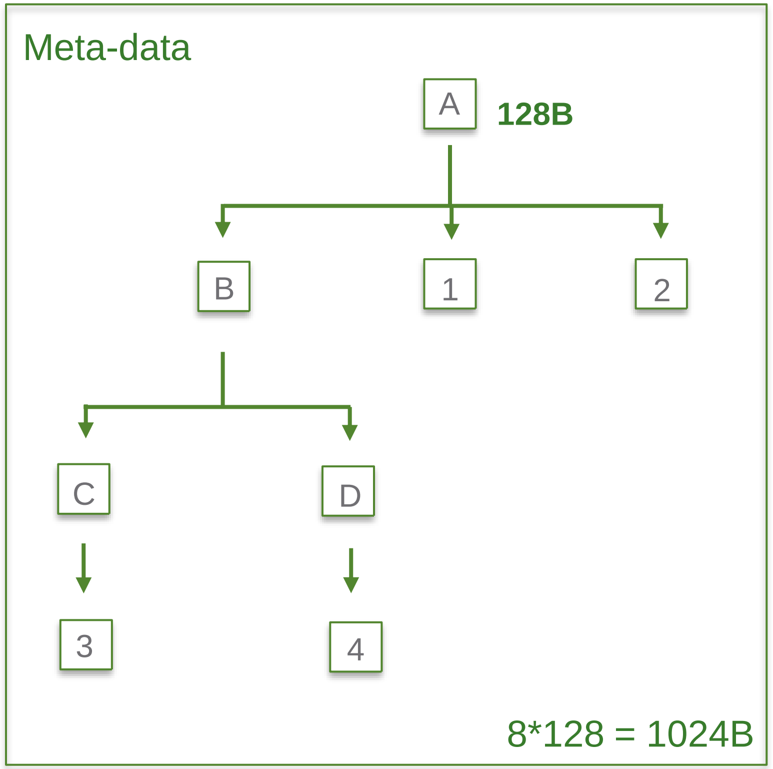

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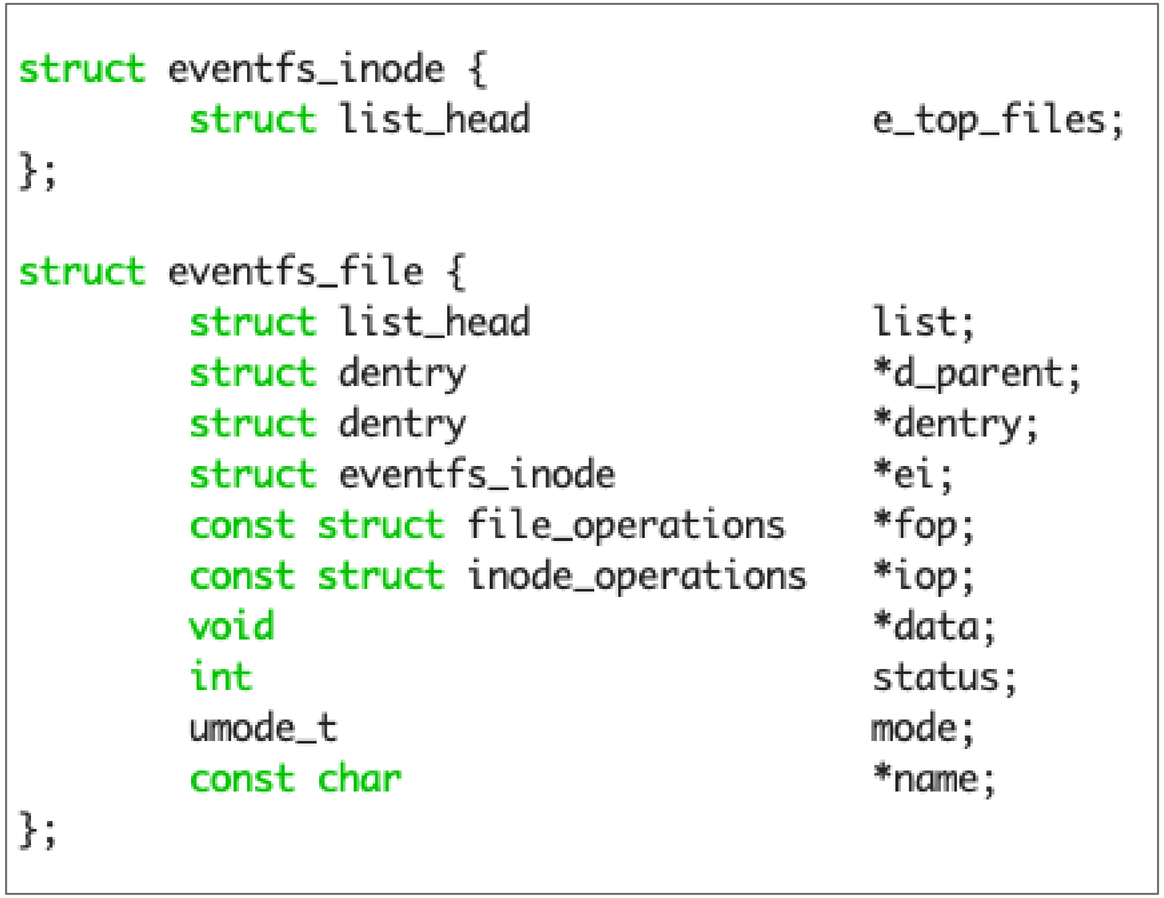
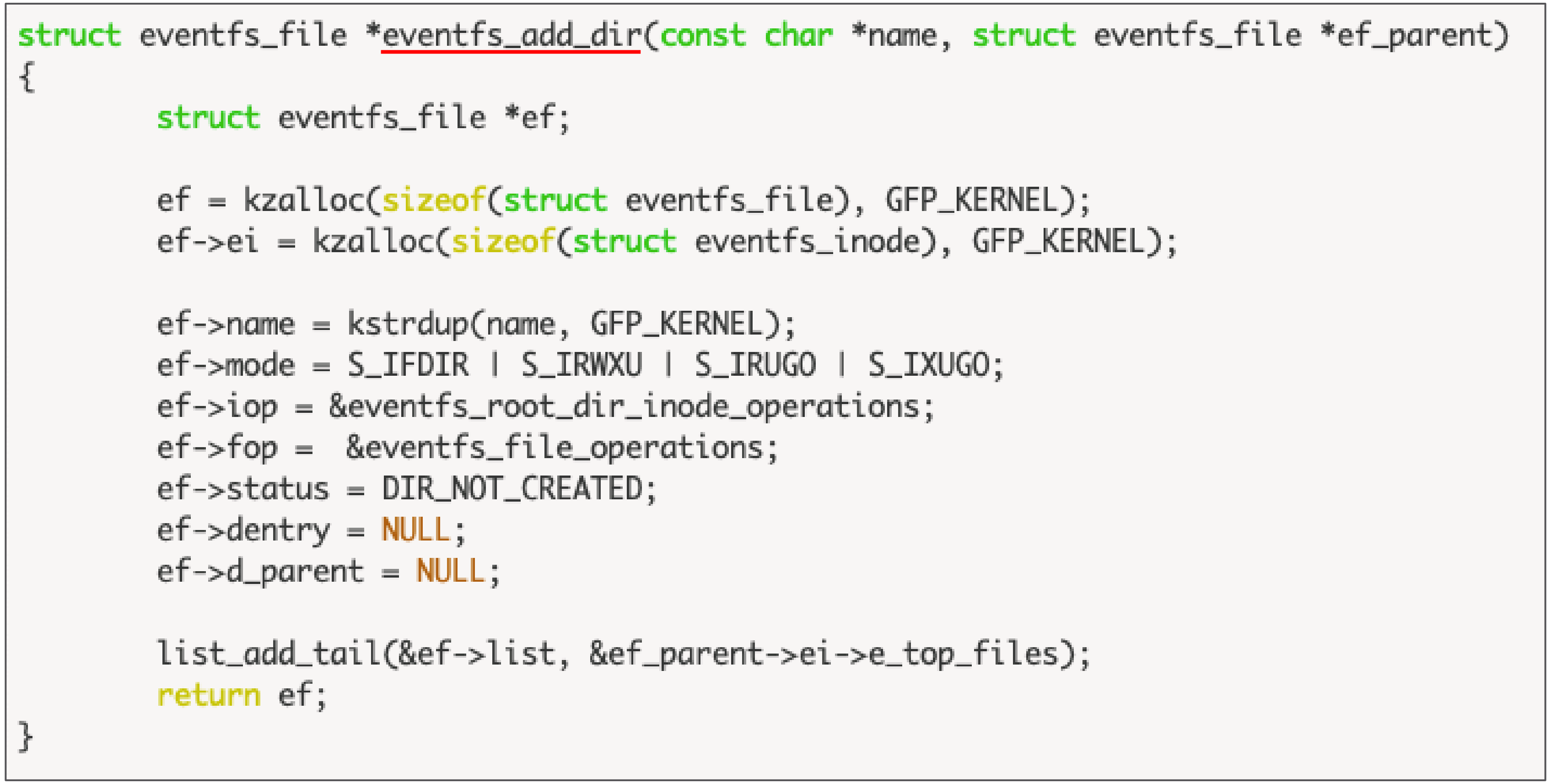
Eventfs: Metadata Structures - eventfs_inode, eventfs_file



```
struct eventfs_inode {
        struct list_head                 e_top_files;
};

struct eventfs_file {
        struct list_head                 list;
        struct dentry                    *d_parent;
        struct dentry                    *dentry;
        struct eventfs_inode             *ei;
        const struct file_operations     *fop;
        const struct inode_operations    *iop;
        void                             *data;
        int                              status;
        umode_t                          mode;
        const char                       *name;
};
```

Eventfs: Add files and directories



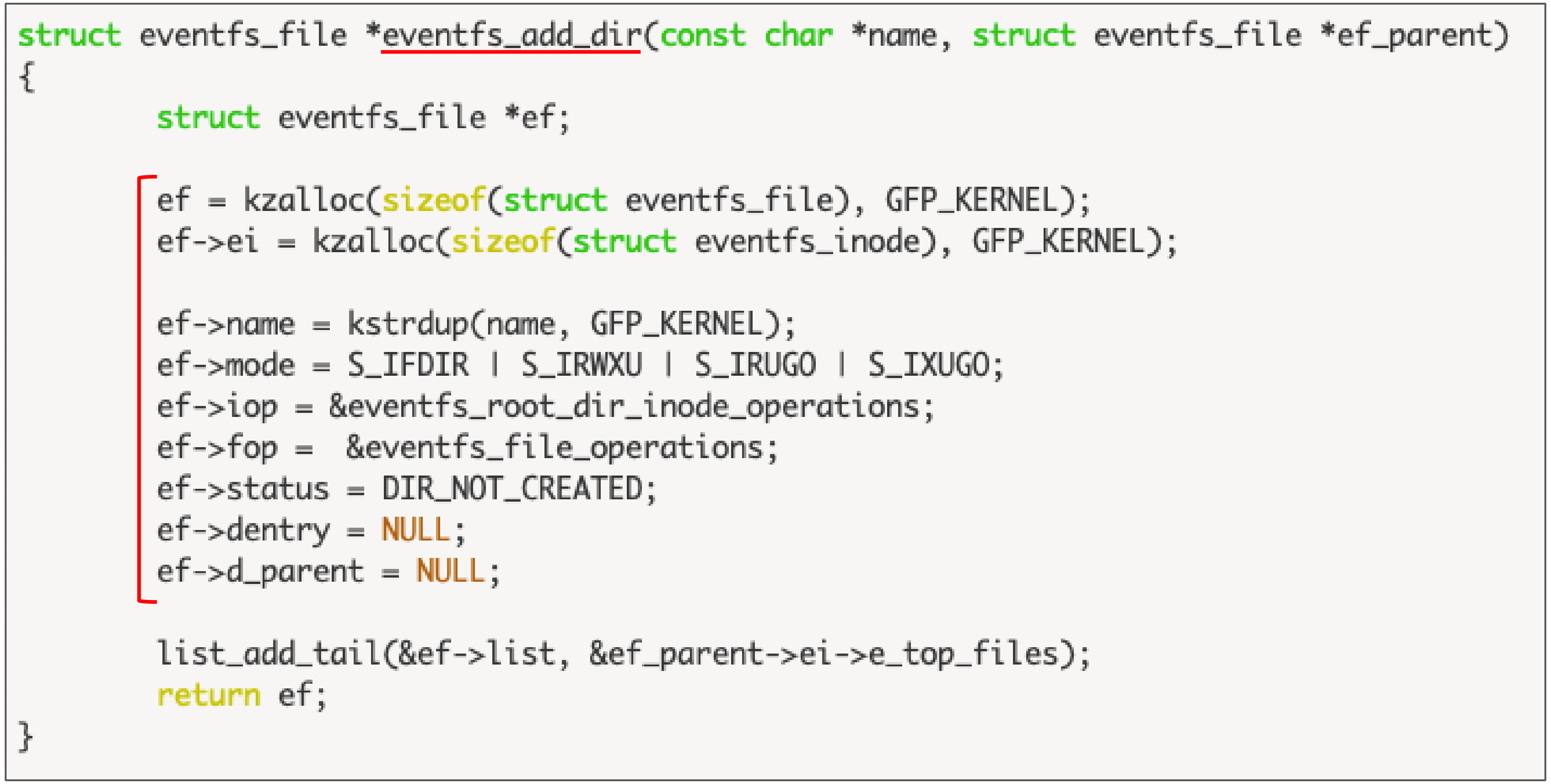
```
struct eventfs_file *eventfs_add_dir(const char *name, struct eventfs_file *ef_parent)
{
        struct eventfs_file *ef;

        ef = kzalloc(sizeof(struct eventfs_file), GFP_KERNEL);
        ef->ei = kzalloc(sizeof(struct eventfs_inode), GFP_KERNEL);

        ef->name = kstrdup(name, GFP_KERNEL);
        ef->mode = S_IFDIR | S_IRWXU | S_IRUGO | S_IXUGO;
        ef->iop = &eventfs_root_dir_inode_operations;
        ef->fop =  &eventfs_file_operations;
        ef->status = DIR_NOT_CREATED;
        ef->dentry = NULL;
        ef->d_parent = NULL;

        list_add_tail(&ef->list, &ef_parent->ei->e_top_files);
        return ef;
}
```

Eventfs: Add files and directories



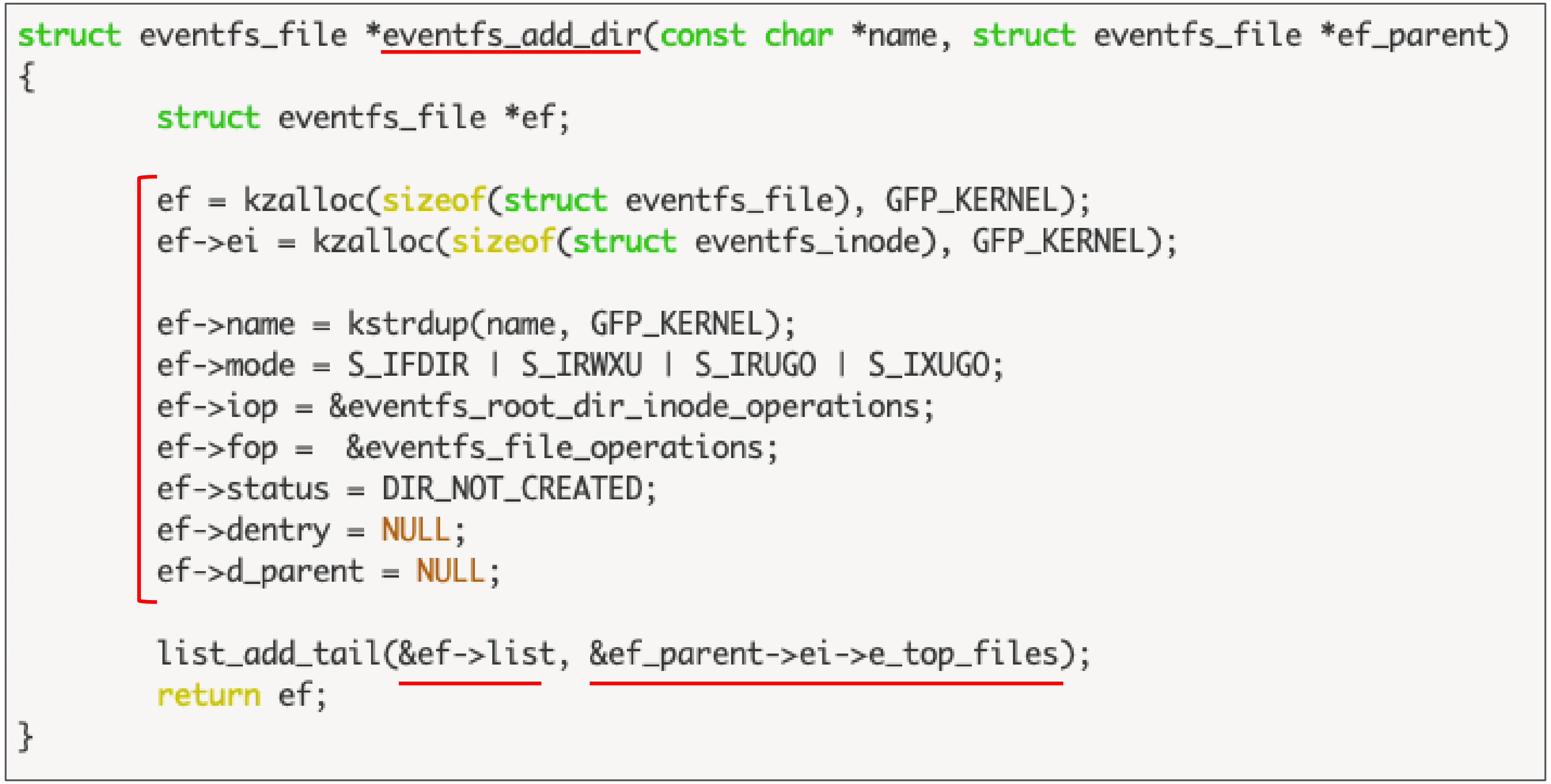
```
struct eventfs_file *eventfs_add_dir(const char *name, struct eventfs_file *ef_parent)
{
        struct eventfs_file *ef;

        ef = kzalloc(sizeof(struct eventfs_file), GFP_KERNEL);
        ef->ei = kzalloc(sizeof(struct eventfs_inode), GFP_KERNEL);

        ef->name = kstrdup(name, GFP_KERNEL);
        ef->mode = S_IFDIR | S_IRWXU | S_IRUGO | S_IXUGO;
        ef->iop = &eventfs_root_dir_inode_operations;
        ef->fop =  &eventfs_file_operations;
        ef->status = DIR_NOT_CREATED;
        ef->dentry = NULL;
        ef->d_parent = NULL;

        list_add_tail(&ef->list, &ef_parent->ei->e_top_files);
        return ef;
}
```

Eventfs: Add files and directories



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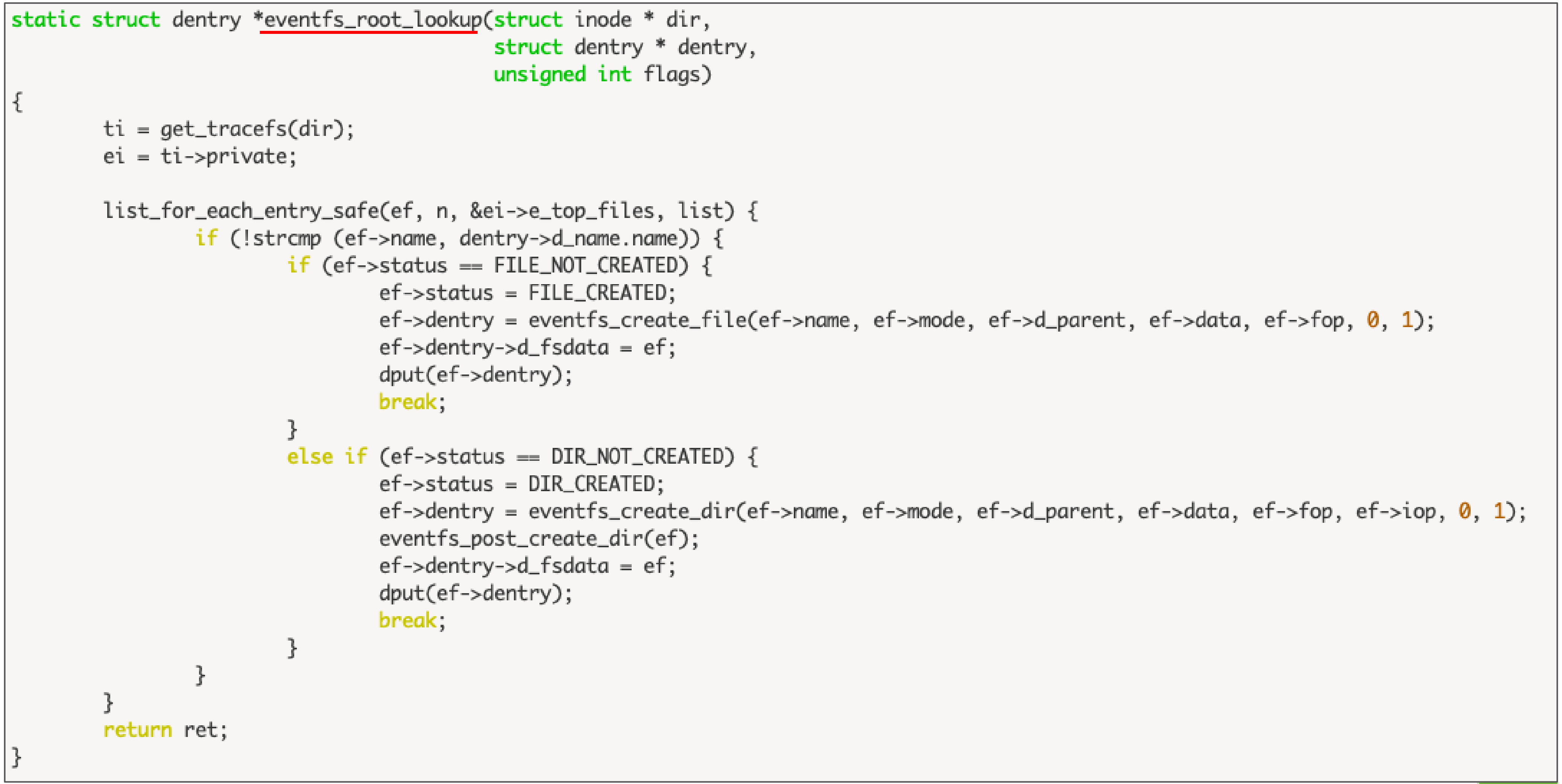
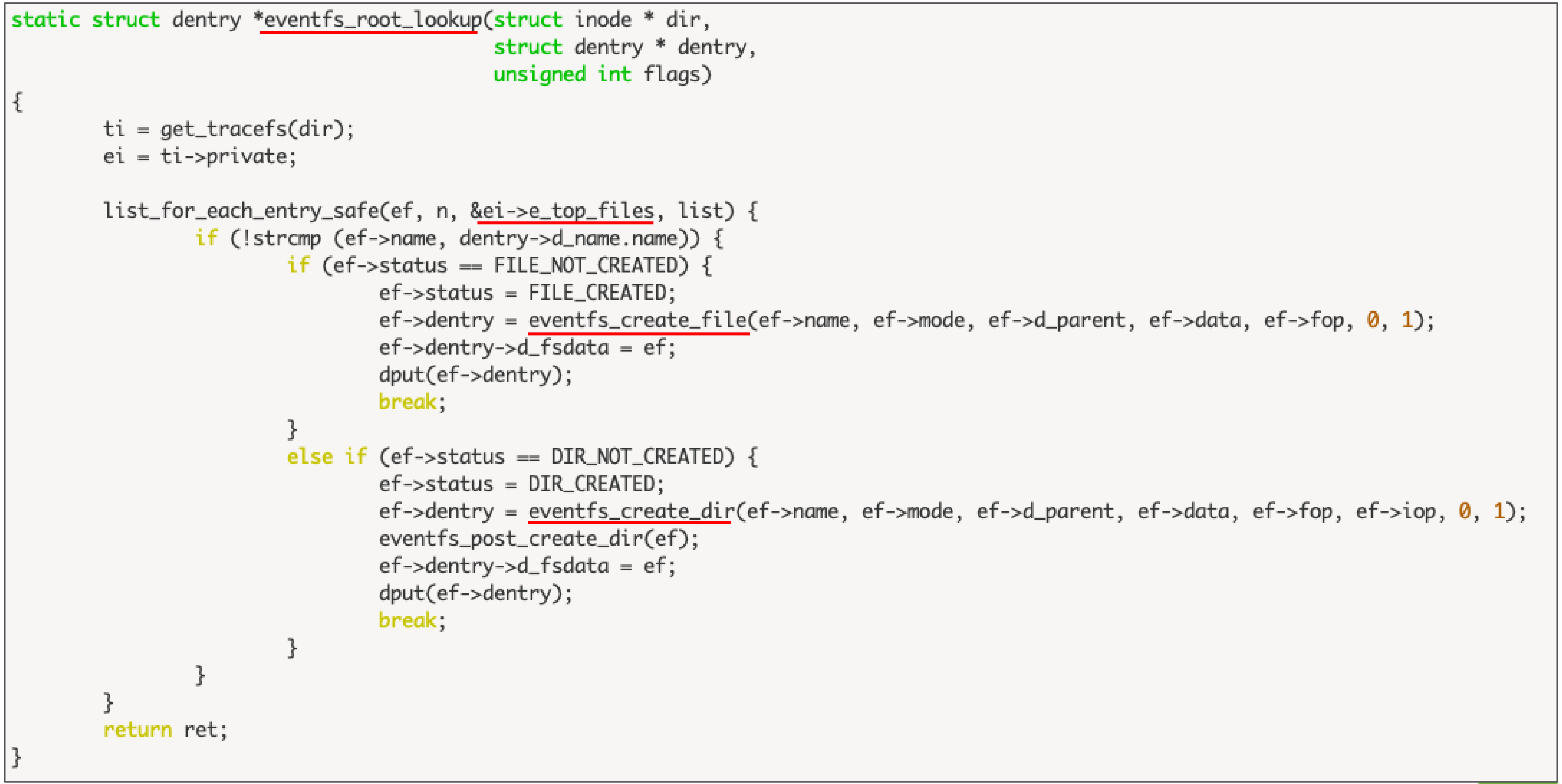
Eventfs: lookup and open



```
static struct dentry *eventfs_root_lookup(struct inode * dir,
                                          struct dentry * dentry,
                                          unsigned int flags)
{
        ti = get_tracefs(dir);
        ei = ti->private;

        list_for_each_entry_safe(ef, n, &ei->e_top_files, list) {
                if (!strcmp (ef->name, dentry->d_name.name)) {
                        if (ef->status == FILE_NOT_CREATED) {
                                ef->status = FILE_CREATED;
                                ef->dentry = eventfs_create_file(ef->name, ef->mode, ef->d_parent, ef->data, ef->fop, 0, 1);
                                ef->dentry->d_fsdata = ef;
                                dput(ef->dentry);
                                break;
                        }
                        else if (ef->status == DIR_NOT_CREATED) {
                                ef->status = DIR_CREATED;
                                ef->dentry = eventfs_create_dir(ef->name, ef->mode, ef->d_parent, ef->data, ef->fop, ef->iop, 0, 1);
                                eventfs_post_create_dir(ef);
                                ef->dentry->d_fsdata = ef;
                                dput(ef->dentry);
                                break;
                        }
                }
        }
        return ret;
}
```

Eventfs: lookup and open



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                }
        }
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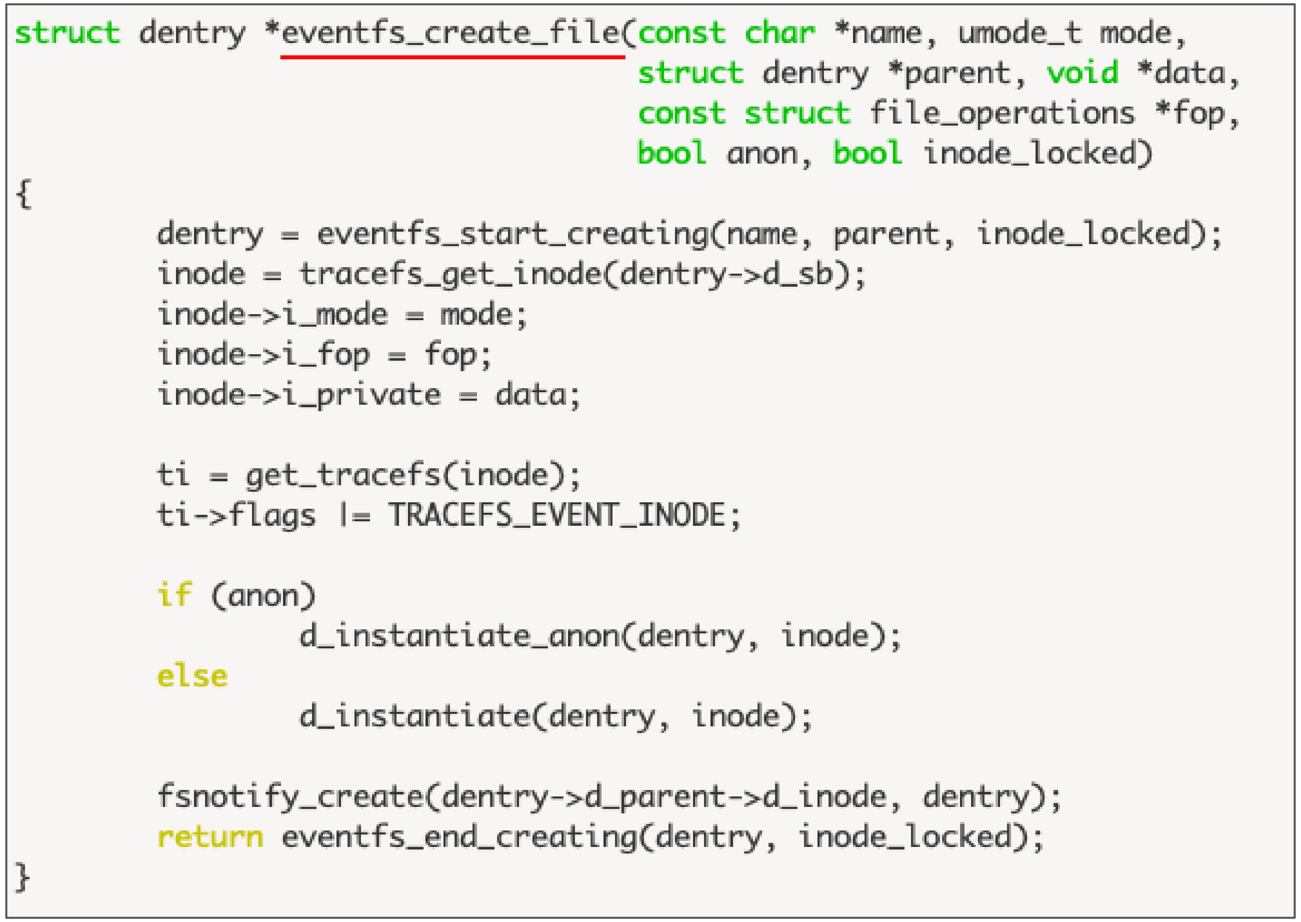
```

Eventfs: create file or directory



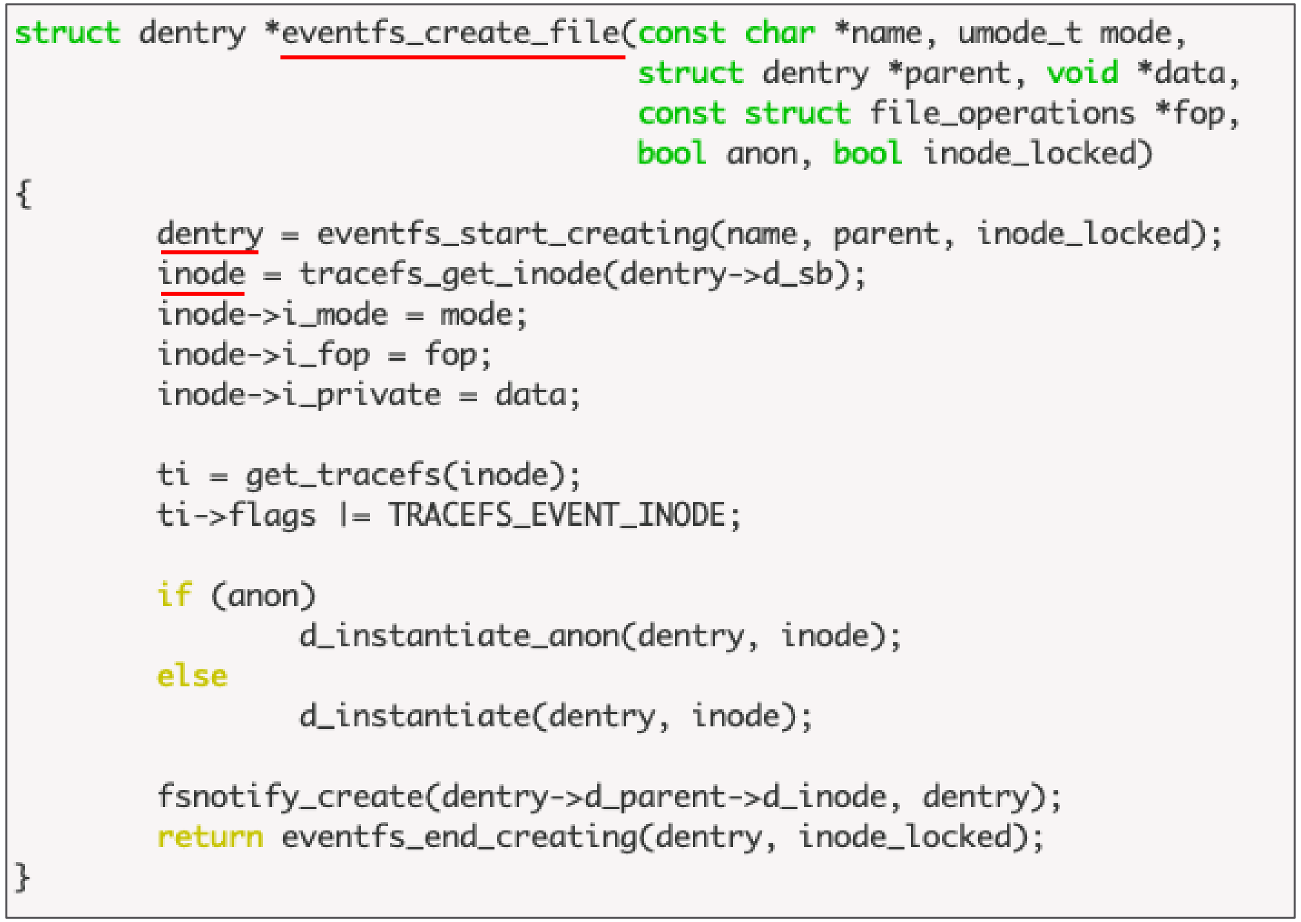
```
struct dentry *eventfs_create_file(const char *name, umode_t mode,
                                   struct dentry *parent, void *data,
                                   const struct file_operations *fop,
                                   bool anon, bool inode_locked)
{
        dentry = eventfs_start_creating(name, parent, inode_locked);
        inode = tracefs_get_inode(dentry->d_sb);
        inode->i_mode = mode;
        inode->i_fop = fop;
        inode->i_private = data;

        ti = get_tracefs(inode);
        ti->flags |= TRACEFS_EVENT_INODE;

        if (anon)
                d_instantiate_anon(dentry, inode);
        else
                d_instantiate(dentry, inode);

        fsnotify_create(dentry->d_parent->d_inode, dentry);
        return eventfs_end_creating(dentry, inode_locked);
}
```

Eventfs: create file or directory



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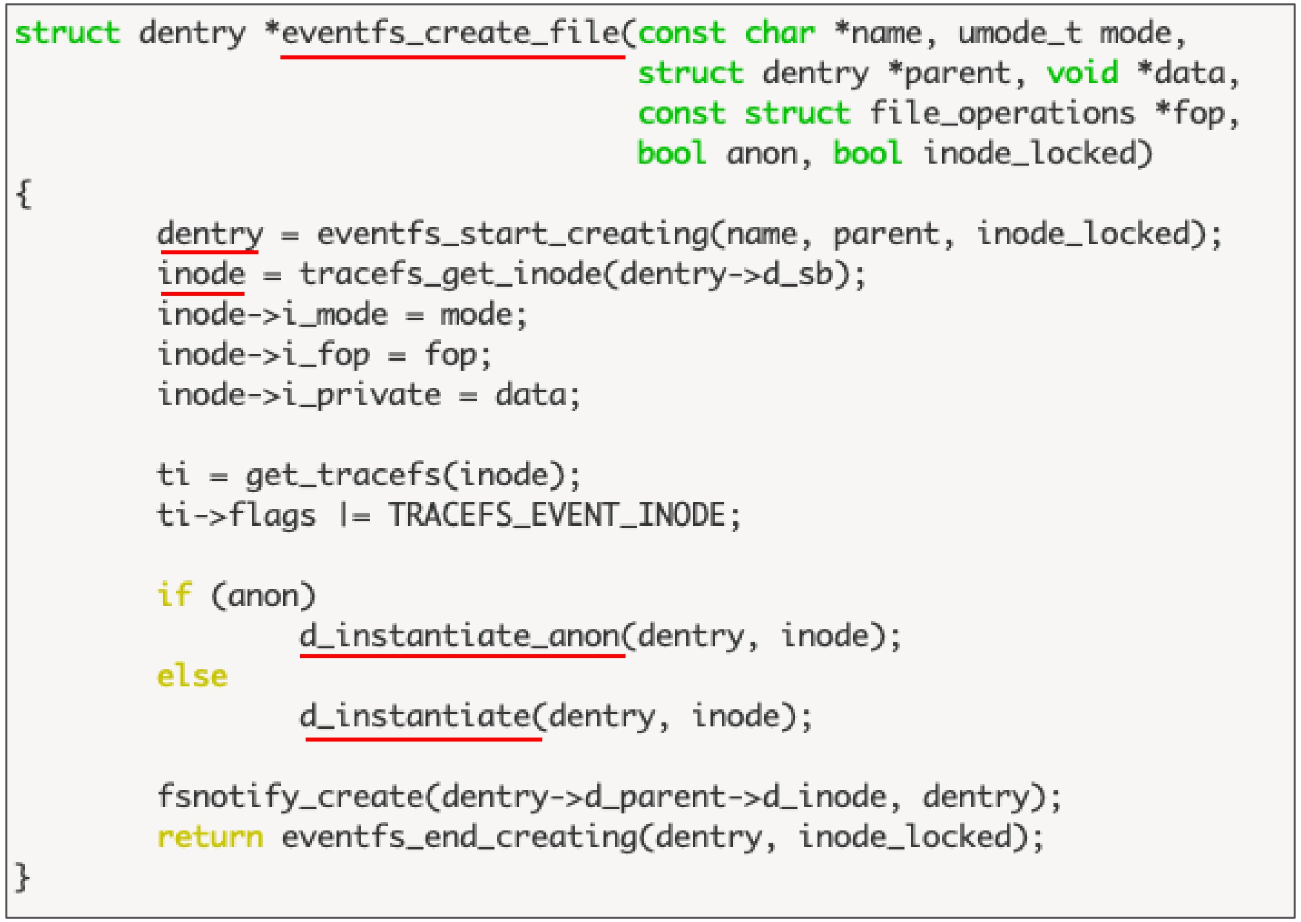

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Conclusion: Events Infrastructure memory footprint

Note: Following readings are from Linux Kernel v5.12, events directory is having 11742 files/directories and 8 CPUs

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Tracefs:

On-demand Eventfs:

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Tracefs:

Theoretical values

inode + dentry	584 + 192 = 776B

On-demand Eventfs:

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eventfs_inode + eventfs_file + name	80 + 16 + 32 = 128B

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Files/Dirs in ‘events’	776 * 11742 = ~ 9MB

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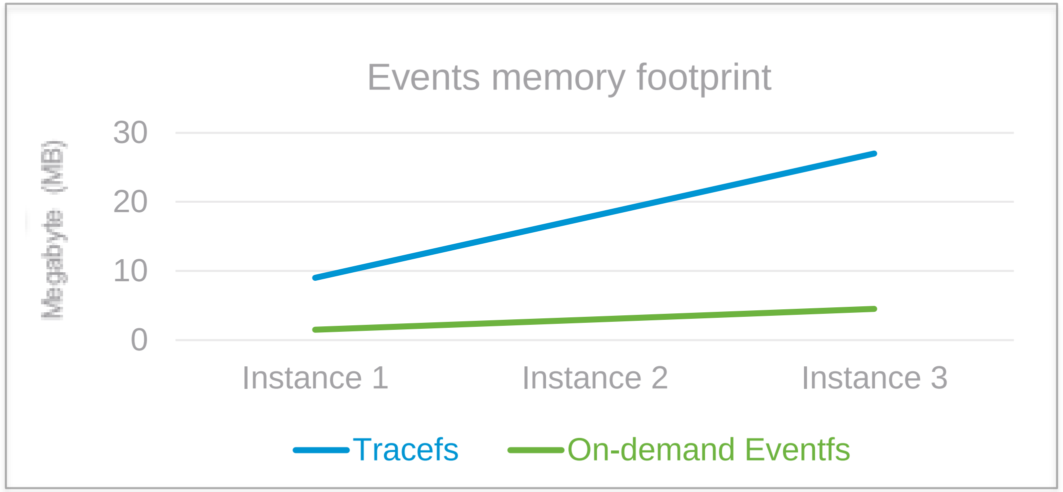

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Practical values

Events Infrastructure	~ 9MB

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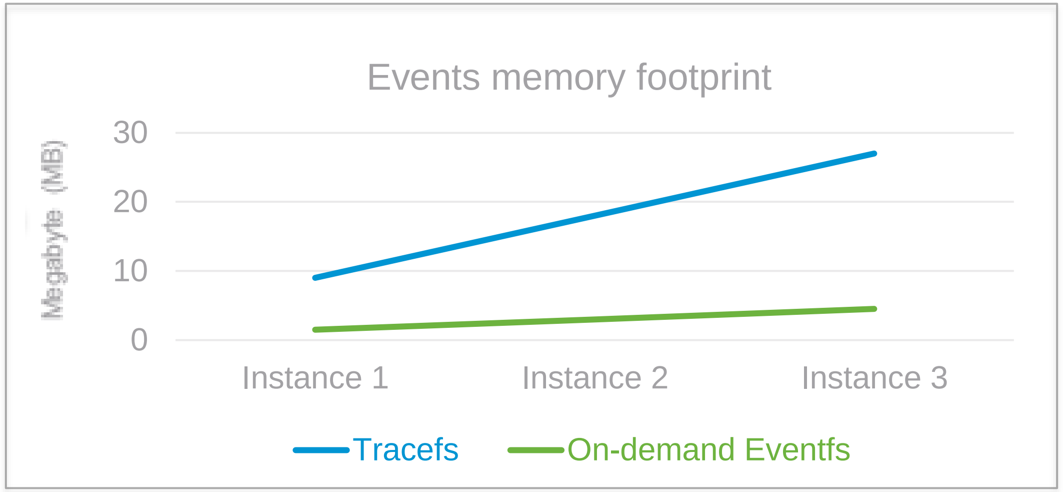

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Practical values

Events Infrastructure	~ 9MB

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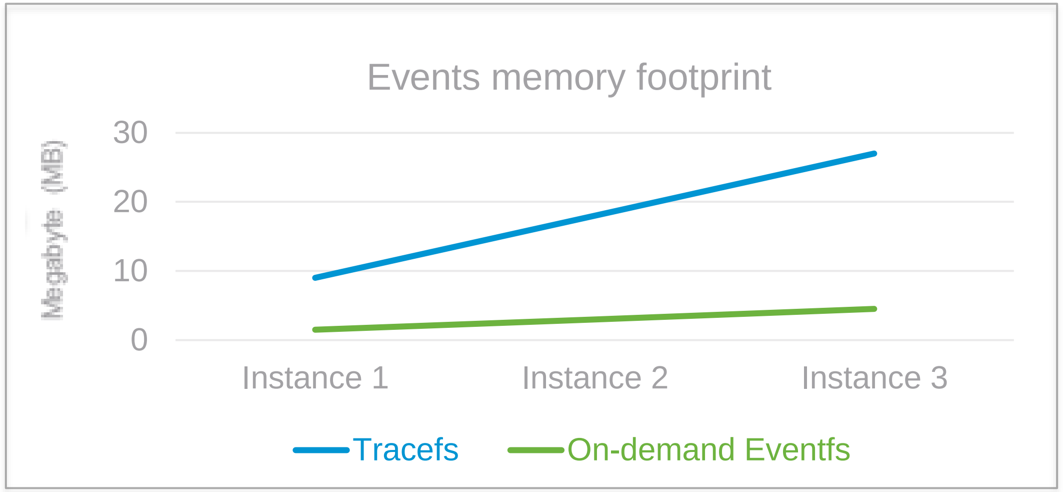
eventfs_inode + eventfs_file + name	80 + 16 + 32 = 128B
Files/Dirs in ‘events’	128 * 11742 = ~ 1.5MB

Practical values

‘Events Infrastructure’	~ 6MB



On going task:

- Analyzing why practical values are not matching with theoretical values.
- Enhance ‘On-Demand Eventfs’ to have one copy of Meta-data for Multiple Instances of Tracer.

Suggestions / Feedback:

- Is this the correct way to dynamically create files/directories?
- Any better approach to improve memory footprint of Linux Tracer.

Thanks