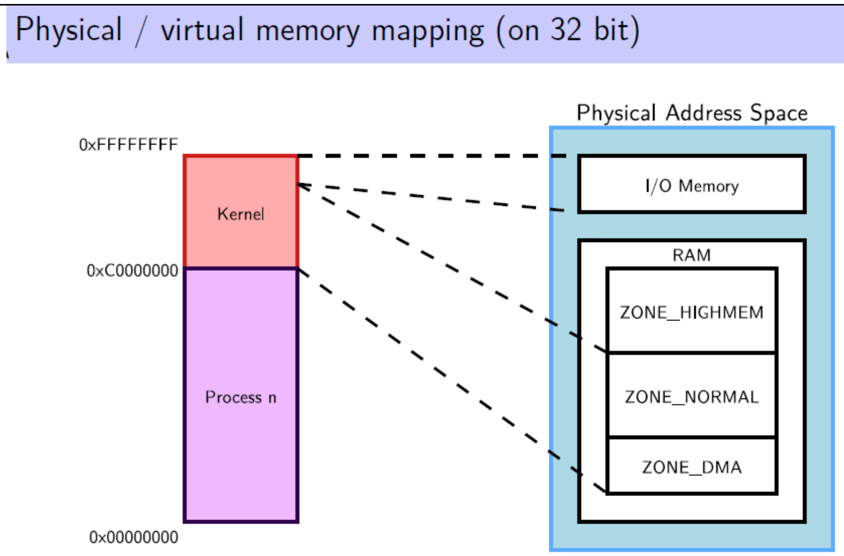
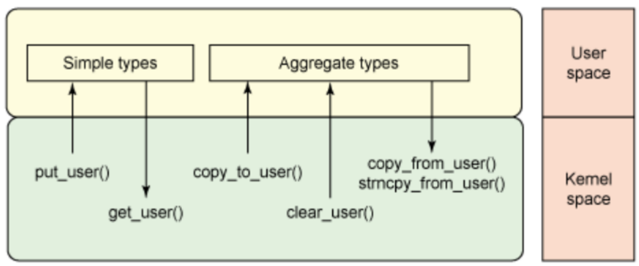
How GDB works	When a user inserts a breakpoint in a line of code, the debugger saves the opcode at that given location and replaces it with **0xCC (int 3).** The INT 3 instruction generates a special one byte opcode (CC) that is intended for calling the debug exception handle Downside of SW breakpoints is that debugger needs to be able to modify running program, which is not possible if program is running from read-only memory (quite common in embedded world).
Data center fabric	A data center fabric is a system of switches and servers and the interconnections between them that can be represented as a fabric. Cisco offering includes fabric management via Application Policy Infrastructure Controller (APIC) or Data Center Network Manager (DCNM)
Switch words	**Supervisor engine:** it is basically the control plane. **Line card:** data plane/responsible for packet forwarding **Fabric module:** It interconnects two different line-cards also supervisor card of the switch. **Fabric extender**: a line card connected using fabric has no capability to store a forwarding table or run any control plane protocols. They are fully managed as part of the parent switch and do not require independent software upgrades, config backups, or maintenance.
Virtual Memory Organization in 32-bit systems	 **Virtual Memory Organization in 32-bit systems** High 1GB reserved for kernel-space Next 3GB exclusive mapping available for each user space 4GB space is also configurable CONFIG_VMSPLIT_2G Because of hardware limitations, the kernel cannot treat all pages as identical. Some pages, because of their physical address in memory, cannot be used for certain tasks. Because of this limitation, the kernel divides pages into different zones. The kernel uses the zones to group pages of similar properties. Linux has to deal with two shortcomings of hardware with respect to memory addressing:

<table>
<tr>
<td></td>
<td>Some hardware devices are capable of performing DMA (direct memory access) to only certain memory addresses.

Some architectures are capable of physically addressing larger amounts of memory than they can virtually address. Consequently, some memory is not permanently mapped into the kernel address space.

Because of these constraints, there are three memory zones in Linux:

ZONE_DMA This zone contains pages that are capable of undergoing DMA.
ZONE_NORMAL This zone contains normal, regularly mapped, pages.
ZONE_HIGHMEM This zone contains "high memory," which are pages not permanently mapped into the kernel's address space.</td>
</tr>
<tr>
<td>copy_from_user</td>
<td>



The access_ok function

In a virtual memory environment, there’s no guarantee that the whole block of memory that you pass to write () is actually in RAM at the time. It (or part of it) could be a memory-m could be paged out.

When any data is passed to the kernel space from userspace, it is the responsibility of the kernel developer to make sure that everything is sanitized.

The copy_to_user function copies a block of data from the kernel into user space. This function accepts a pointer to a user space buffer, a pointer to a kernel buffer, and a length defined in bytes. After checking the ability to write to the user buffer (through access_ the page tables could change at any time, requiring the desired pages to be pinned into memory so that they could not be swapped out while being addressed.

If a kernel can handle page faults, there is perhaps no use (ignoring gory details like security for simplicity).

One of the additional things that copy_from_user does is disable SMAP . supervisor Mode Access Prevention) (if enabled) while accessing userspace memory. If SMAP is enabled, accessing userspace address is not allowed.</td>
</tr>
</table>

Definitions	**The root filesystem** is the top-level directory of the filesystem. It must contain all the files required to boot the Linux system before other filesystems are mounted. The "**sysroot**" is the location the cross compiler will look for header files and libraries. The sysroot directory acts as if it is the root of the system, **clangd** understands your C++ code and adds smart features to your editor: code completion compile errors, go-to-definition and more. **Electric Make® (”eMake”),** is a new Make version .You can invoke eMake interactively or through build scripts. Electric Accelerator is a software build accelerator that dramatically reduces software build times by distributing the build over a large cluster of inexpensive servers.
Yocto build	**Yocto Project**: A Linux Foundation project that acts as an umbrella for various efforts to improve Embedded Linux. **BitBake:** Bit Bake is a program written in the Python language. At the highest level, Bit Bake interprets metadata, decides what tasks are required to run, and executes those tasks. Similar to GNU Make, Bit Bake controls how software is built. GNU Make achieves its control through "make files". Bit Bake uses "recipes". **Metadata** is any data that describes other data. Document metadata gives information About a document such as the author, when it was created when it was last modified, and its size. In Yocto project – Metadata is collection of below items 1. Configuration (*.conf) :Drives the overall behavior of the build process 2. Recipes (*.bb) : Usually describe build instructions for a single package 3. Append files (*.bbappend) :Can add or override previously set values 4. Classes (*.bbclass) :Inheritance mechanism for common functionality . bbclass) are used to factorize recipe's code, to handle some general problems. For instance, handling example inherit logging

Release Activity

Codename	Yocto Project Version	Release Date	Current Version	Support Level	Poky Version	BitBake branch
Gatesgarth	3.2	Oct 2020		Dev	24.0	1.48
Dunfell	3.1	April 2020	3.1.1	Long Term Stable	23.0	1.46
Zeus	3.0	October 2019	3.0.2	Stable	22.0	1.44
Warrior	2.7	April 2019	2.7.4	Community	21.0	1.42
Thud	2.6	Nov 2018	2.6.4	Community	20.0	1.40
Sumo	2.5	April 2018	2.5.3	EOL	19.0	1.38

bitbake-layers show-layers

Yocto provides the environment for compiling all the packages that are required to boot a board. It works on the meta layers. Under the meta layers, there are different different recipes for each package. Under these recipes, there are .bb files for each package. During compilation, these .bb files are used to get all the information about a package. This. files contain information like the License, URL to download the source code, what are the flags should pass at the time of configuration or compilation.

Yocto terms

1>**Poky** is the name of build system used by yocto

2> **Layer**: A collection of recipes. Typically, each layer is organized around a specific theme, e.g. adding recipes for building web browser software. Open Embedded-Core is a base layer of recipes, classes and associated files that is meant

3> All the artefacts generated are stored in the deploy folder.tmp/log/cooker will have all logs

4>**Recipe script:** Bit Bake Recipes, which are denoted by the file extension .bb, are the most basic metadata files. These recipe files provide Bit Bake with the following: version, existing Dependencies
how to compile .

1>Locate and download source code ,
2>Unpack source into working directory
3>Apply any patches Perform any necessary pre-build configuration
4>Compile the source code
5>Installation of resulting build artifacts in WORKDIR
6>Copy artifacts to sysroot ,Create binary package(s)

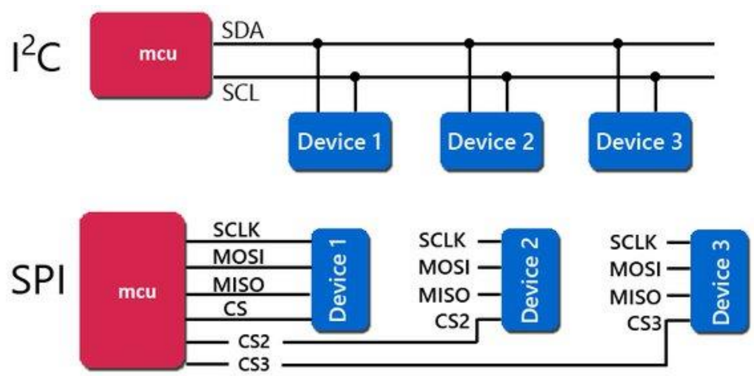
We have a bbappend file that supplies a set of patches. It currently has the unintended side-effect of patching both the native version used during the Yocto build process, and the eventual target version. How do I modify the recipe such that it only acts upon the target version?

	SRC_URI_append_class-target = " file://..." SRC_URI Where to obtain the upstream sources and which patches to apply (this is called “fetching”) **bitbake-layers create-layer ->**Use a new custom layer for modularity and maintainability. They all start with “meta-” by convention **Class files(.bbclass)** extension, contain information that is useful to share between metadata files. The BitBake source tree currently comes with one class metadata file called base. bbclass. You can find this file in the class’s directory. The base.bbclass is special since it is always included automatically for all recipes and classes. This class contains definitions for standard basic tasks such as fetching, unpacking, configuring (empty by default), compiling (runs any Makefile present), installing (empty by default) and packaging (empty by default). These tasks are often overridden or extended by other classes added during the project development process. **Append files**, which are files that have the .bbappend file extension, add or extend build information to an existing recipe file. **busybox_1.21.%. bbappend** That append file would match any busybox_1.21.x.bb version of the recipe. So, the append file would match the following recipe names: busybox_1.21.1.bb busybox_1.21.2.bb busybox_1.21.3.bb
NX-Linux (NXL)	NXL is a Linux Distribution for NXOS based on XE linux distro (Yocto Thud) with NXOS customizations including GCC 5.2 and Clang 7.0. We're based off of XELinux thud release. as of right now, we have a snapshot of their layers in our gitlab and are using that. Some of the layers XELinux uses come from yocto, XELinux may have made changes on top of those layers. No changes have been directly made to any of the layers coming from them. If any changes need to be made to the recipes, then there's a bbappend file in the meta-nx-linux layer, which we created and control. Layer information is on the build wiki page, and are locally cloned into our gitlab group. Following git repository mirrors are setup from XE sources - meta-open embedded, meta-virtualization, meta-security, scripts, meta-nx-Linux (Specific to NXOS for FOSS customizations Open-source packages should be sourced from the NX-Linux Distro
initramfs	initramfs, short for initial RAM filesystem, is a cpio archive of the initial filesystem loaded into memory after the kernel finishes initializing the system and before user-space begins the init process. The Linux kernel mounts the contents of initramfs as the initial root filesystem, before the real root (e.g. on your hard drive) is mounted. This initial root contains files needed to mount the real root filesystem and initialize your system—the most important bits being kernel modules.This feature is made up from a cpio archive of files that enables an initial root filesystem and init program to reside in kernel memory cache, rather than on a ramdisk, as with initrd filesystem initrd is for Linux kernels 2.4 and lower.

<table>
<tr>
<td>SPI or I2C? serial port Communication</td>
<td>

1. I2C is mainly half duplex, that is it uses only one line for sending and receiving data
2. I2C is mainly for master to many slaves' communication, you can connect up to 127 slave and one master to control them all
3. I2C can be used to read Temperature.

1. SPI is full duplex, that makes it faster at the same clock speed.
2. while SPI is designed to be a One Master to One Slave communication, adding another slave will cost you another hardware pin for chip select.
3. SPI can used Refresh a screen.



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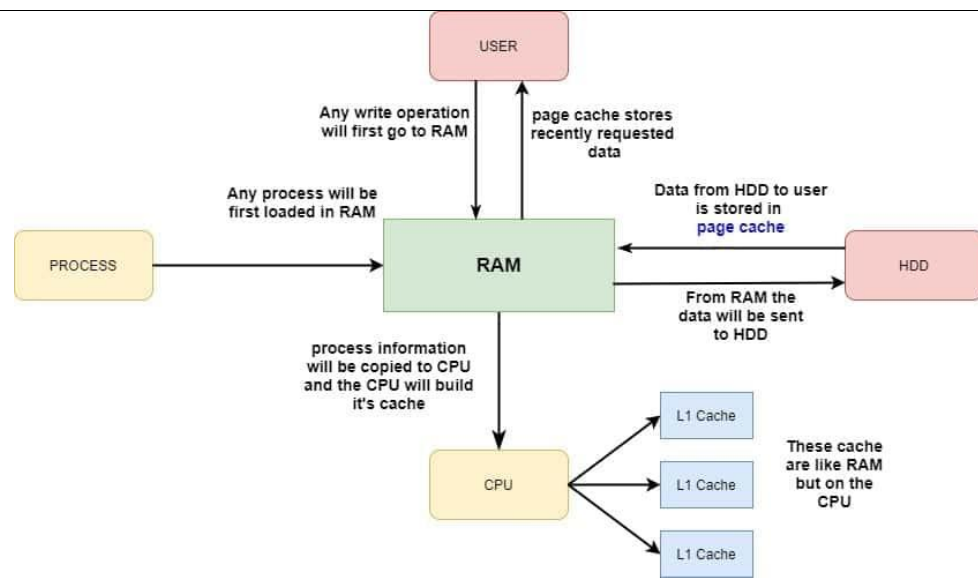
<tr>
<td>Kernel interview</td>
<td>



Dirty bit means data in cache is modified and the memory has stale copy.

kernel code has to supply its own library implementations (memcpy, crypto, tar No memory protection, oops. Never use floating point numbers in kernel code. Your code may need to run on low-end processor without a floating-point unit. Fixed stack (8 or 4 KB) size Unlike user space, no Swapping, don't used recursion

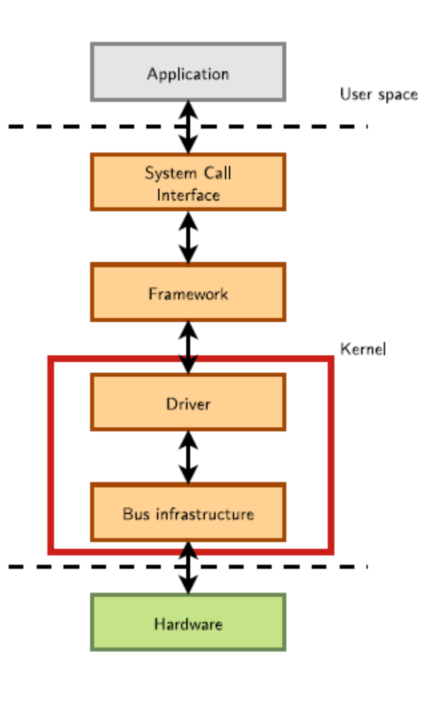
</td>
</tr>
</table>

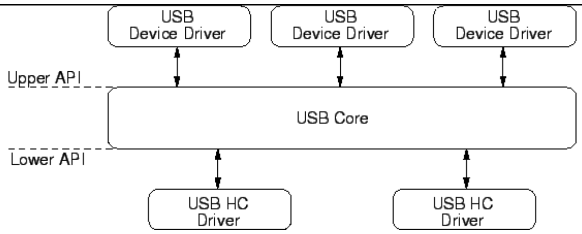
User mode driver- written using user space language Perl, propriety, cannot crash the kernel. can use floating-point computation. Potentially higher performance. Especially for memory-mapped Devices due to avoidance of system calls   UMD, drawback is Increased interrupt latency Less straightforward to handle interrupts

Many embedded architectures (x86,ppc) have lot of non-discoverable hardware (serial, Ethernet, I2C, Nand flash UART controllers, Ethernet controllers, SPI or I2C controllers, graphic or audio devices. Depending on the architecture, such hardware is either described in BIOS ACPI tables (x86), using C code directly within the kernel, or using a special hardware description language in a ***Device Tree***.Each node can have a number of properties describing various properties of the devices: addresses, interrupts, clocks, power, pin muxing, consumptions etc. At boot time, the kernel is given a compiled version, the Device Tree Blob, which is parsed to instantiate all devices described in the DT.

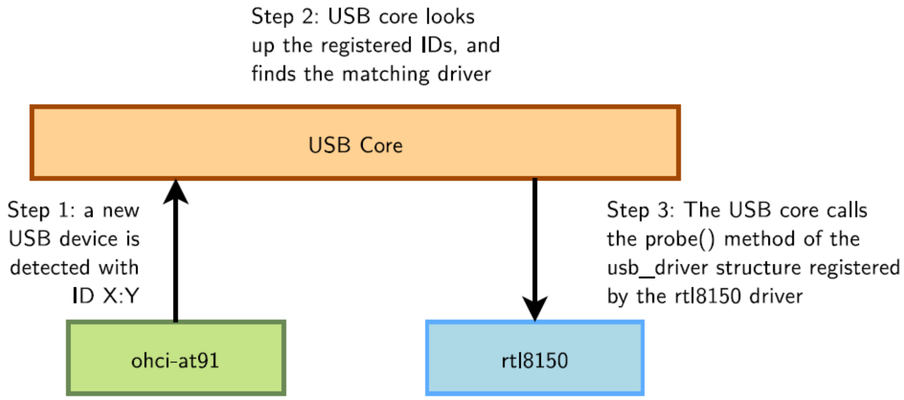
-

- The typical boot process is therefore:
  1. Load zImage at address X in memory
  2. Load <board>.dtb at address Y in memory
  3. Start the kernel with bootz X - Y
     The - in the middle indicates no *initramfs*





The USB core now knows the association between the vendor/product IDs



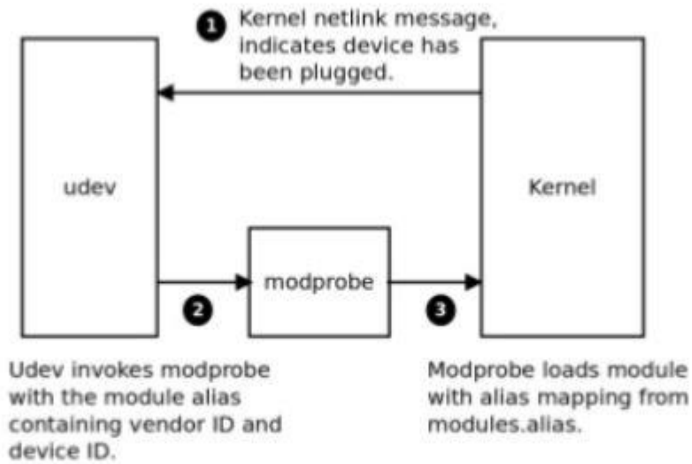
When a USB device is detected with id xxx USB Device controller try to find matching device driver and Called Probe function . The -probe() function is responsible for initializing the device , mapping I/O memory, registering the interrupt and registering it in the appropriate kernel

Slab allocation is a memory management mechanism intended for the efficient memory allocation of kernel objects. It eliminates fragmentation caused by allocations and deallocations. The technique is used to retain allocated memory that contains a data object of a certain type for reuse upon subsequent allocations of objects of the same type. Slab is the original, available since Linux kernel version 2.2.
Slub is the next-generation replacement default since Linux kernel since 2.6.23.
SLOB (Simple List Of Blocks) is a memory allocator optimized for embedded systems with Low memory footprint

Modules are dynamic plugin, stored as a separate file in the filesystem so no possible With Module reduce boot time and image size, signed modules

Amongst the non-discoverable devices, a huge family are the devices that are directly part of a system-on-chip: UART controllers, Ethernet controllers, SPI or I2C controllers, graphic or audio devices, etc. In the Linux kernel, a special bus, called the **platform bus** has been created to handle such devices.it works like any other bus (USB, PCI), enumerated statically instead of being discovered dynamically

udev (userspace /dev) Udev is the device manager for the Linux 2.6 kernel that creates/removes device nodes in the /dev directory dynamically. It is the successor of devfs and hotplug. It runs in userspace, and the user can change device names using Udev rules.



A very important UNIX design decision was to represent most system objects as Files. It allows applications to manipulate all system objects with the normal file API (open, read, write, close, etc.)So, devices had to be represented as files to the applications
ls -l /dev/ttyS0 /dev/tty1 /dev/sda /dev/sda1 /dev/sda2 /dev/sdc1 /dev/zero

Example C code that uses the usual file API to write data to a serial port

```
int fd;
    fd = open("/dev/ttyS0", O_RDWR);
    write(fd, "Hello", 5);
    close(fd);
```

Within the kernel, all block and character devices are identified using a *major* and a *minor* number. The *major number* typically indicates the family of the device. The *minor number* allows drivers to distinguish the various devices they manage. Most major and minor numbers are statically allocated

1. Dmesg - kernel keeps its messages in a circular buffer

2. CONFIG_COMPAT is a config flag. 64 bit kernel supports for 32 bit emulation

3. Modern SoCs (System on Chip) include more and more hardware blocks pins are Multiplexed

4. three types of devices: - network, block(usb,harddisk) ,serial and others (graphics) all block and character devices are identified using a major and a minor number. – represent as file

	5. "Zero-copy" describes computer operations in which the CPU does not perform the task of copying data from one memory area to another. 6. Kmalloc calls slab page is usually 4K, but can be 8k 16k,PIO - IN and OUT instructions 7. Kernel pre-emption, if enabled, causes the kernel to switch from the execution 8. Mutex - The kernel's main locking primitive. It's a binary lock , mutex_trylock Use mutexes in code that is allowed to sleep -not in spinlock 9. Spinlocks cause kernel pre-emption to be disabled on the CPU executing them, No sleeping, several variants like Doesn't disable interrupts, Disables software interrupts, but not hardware ones 10. lock-free algorithms -rcu lock, atomic instructions 11. Some device controllers embedded their own DMA controller, DMA deals with physical addresses But the DMA does not access the CPU cache, so one needs to take care of cache coherency (cache content vs. memory content).
interrupt handler	Each device must register its interrupt handler. whenever an interrupt occurs the OS does the most important part of handler "upper half" to respond to interrupt, create a data structure containing device specific data called "**lower half**" for later processing when CPU becomes available. This way interrupt handlers can be used in Bottom halves are required because as we know when ISR executes, it disables all other interrupts on running processor and same interrupt on all processors. To increase the response time and throughput of the system, we need to finish ISR as soon as possible. Acknowledge the interrupt to the device (otherwise no more interrupts will be generated, or the interrupt will keep firing repeatedly

choice of different bottom half implementations

	Softirqs	Tasklets	Work Queues
Execution context	Deferred work runs in interrupt context.	Deferred work runs in interrupt context.	Deferred work runs in process context.
Reentrancy	Can run simultaneously on different CPUs.	Cannot run simultaneously on different CPUs. Different CPUs can run different tasklets, however.	Can run simultaneously on different CPUs.
Sleep semantics	Cannot go to sleep.	Cannot go to sleep.	May go to sleep.
Preemption	Cannot be preempted/scheduled.	Cannot be preempted/scheduled.	May be preempted/scheduled.
Ease of use	Not easy to use.	Easy to use.	Easy to use.
When to use	If deferred work will not go to sleep and if you have crucial scalability or speed requirements.	If deferred work will not go to sleep.	If deferred work may go to sleep.

The softirqs handlers are executed with all interrupts enabled. They are executed once all interrupt handlers have completed, before the kernel resumes scheduling processes,

The number of softirqs is fixed in the system, so softirqs are not directly used by drivers, but by complete kernel subsystems (network, etc.)

HI_SOFTIRQ and TASKLET_SOFTIRQ are used to execute tasklets,Example usage of softirqs – I

Work queues typically be used for background work with can be scheduled.

Linux memory

swap: The primary function of swap space is to substitute disk space for RAM memory when real RAM fills up and more space is needed.

Using **ramfs or tmpfs** you can allocate part of the physical memory to be used as a partition. partition and start writing and reading files like a hard disk partition. Since you'll be reading and writing to vivthe RAM, it will be faster.

Non-Uniform Memory Access is a computer memory design used in multiprocessing, where the memory access
time depends on the memory location relative to the processor.

Allocating kernel memory (buddy system and slab system)

The main drawback in buddy system is internal fragmentation as
larger block of memory is acquired then required.

cat/proc/buddyinfo displays as follows:
Node 0, Zone DMA 0 4 5 4 4 3 ...
Node 0, Zone Normal 1 0 0 1 101 8 ...
Node 0, Zone highmem 2 0 0 1 1 0 ...

static memory allocation linux kernel : boottime by driver reserve contagious memory
A second strategy for allocating kernel memory is known as slab allocation. It eliminates fragmentation caused by allocations and deallocations. A slab is made up of one or more physically contiguous pages. `cat /proc/slabinfo`

Linux Scheduling Policy

Linux supports real-time scheduling out of the box. There is a misconception that Linux has to be patched to provide support for real-time scheduling. The only issue is that the scheduling latencies may not satisfy the hard real-time requirements of critical applications. There are patches that try to address this, like the CONFIG_PREMPT_RT patch

We have two categories of scheduling policies. Normal and real-time. Real-time scheduling policy has two sub-types, round-robin and first-in first-out, identified by SCHED_RR and SCHED_FIFO.The **sched_setscheduler()** system call set scheduling policy of thread to real Time SCHED_FIFO ,SCHED_RR .

SCHED_FIFO and SCHED_RR priorities allow priorities from 1 to 99. SCHED_OTHER, which is the default supports only the value of 0. In case of SCHED_FIFO, for tasks of the same priority, the currently running task has to yield before the next one can run .
Tasks of the same priority when running with RR_SCHEDULING will get an equal interval run.

Default Priority is 20 with nice value 0

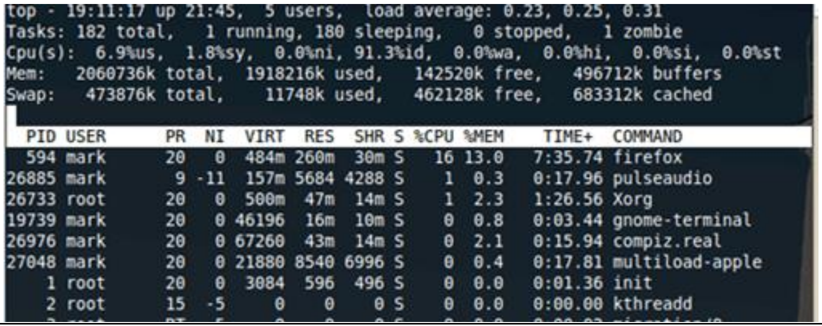
Linux Kernel implements two separate priority ranges –

- **The nice value range** is -20 to +19 where -20 is highest, 0 is default/

Nice value: minus 20 to plus 19; larger (+19) nice correspond to lower priority.

- Real-time priority: 0 to 99; higher real-time priority values correspond to

a greater priority. **PR = 20 plus nice ,**
0 is default nice priority of process



```
top - 19:11:17 up 21:45,  5 users,  load average: 0.23, 0.25, 0.31
Tasks: 182 total,   1 running, 180 sleeping,   0 stopped,   1 zombie
Cpu(s):  6.9%us,  1.8%sy,  0.0%ni, 91.3%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Mem:   2060736k total,  1918216k used,   142520k free,   496712k buffers
Swap:   473876k total,    11748k used,   462128k free,   683312k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
  594 mark      20   0  484m 260m  30m S   16 13.0   7:35.74 firefox
26885 mark       9 -11  157m 5684 4288 S    1  0.3   0:17.96 pulseaudio
26733 root      20   0  500m  47m  14m S    1  2.3   1:26.56 Xorg
19739 mark      20   0 46196  16m  10m S    0  0.8   0:03.44 gnome-terminal
26976 mark      20   0 67260  43m  14m S    0  2.1   0:15.94 compiz.real
27048 mark      20   0 21880 8540 6996 S    0  0.4   0:17.81 multiload-apple
    1 root      20   0  3084  596  496 S    0  0.0   0:01.36 init
    2 root      15  -5     0    0    0 S    0  0.0   0:00.00 kthreadd
```

<table>
<tr>
<td>Packet journey</td>
<td>
The high-level path a packet takes from arrival to socket receive buffer is as follows:

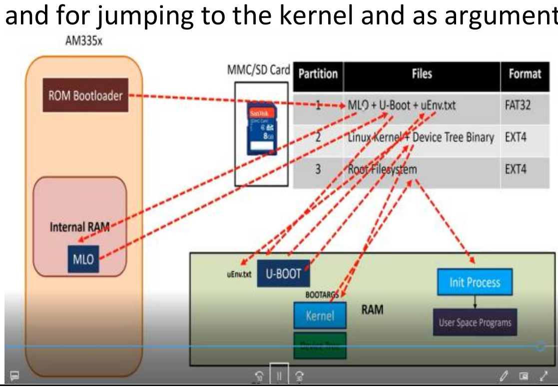
Driver is loaded and initialized.

Receive Side
1. Packet arrives at the NIC from the network.
2. Packet is copied (via DMA) to a ring buffer in kernel memory.
3. Hardware interrupt is generated to let the system know a packet is in memory.
4. Data that was DMA’d into memory is passed up the networking layer as an ‘skb’ for more processing.
5. Tapping in eth layer (tcp dump), net filter in ip layer, state machine in tcp layer later queue to socket and copy to application and invoke poll.
6. Tcp maintain state machine, fragmentation and assembly
7. Skb and packet memory is free after socket read and copy to user memory

send side
1. skb is allocated in TCP layer and enqueue in write queue, empty space in beginning of skb. Mac or neighbor discover if not cached, ipl layer net filter on send side
2. Add Checksum before sending it. Nic does frame checksum on both recv and send side ,nic checksum offload

3. Modern nic has more hardware queue (faster) , in recv side packet belong to same Stream Goes to same queue useful in SMP

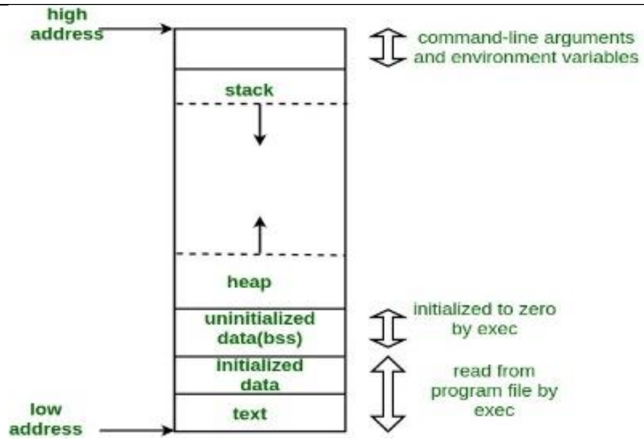
NAPI = New API, Principe: when the network traffic exceeds a given threshold (”budget”), Disable network interrupts and consume incoming packets through a polling function, instead of processing each new packet with an interrupt.

incoming network data frames are distributed among multiple CPUs if packet steering is enabled or if the NIC has multiple receive queues.
</td>
</tr>
<tr>
<td>UBOOT</td>
<td>
U-Boot is both a first stage and second-stage bootloader. If there are size constraints, U-Boot may be split into stages: U-Boot performs both first-stage (e.g., configuring memory controllers and SDRAM) and second-stage booting. ,
U-Boot Linux booting requires its boot commands to explicitly specify the physical memory addresses as destinations for copying data (kernel, ramdisk, device tree, etc.) and for jumping to the kernel and as arguments for the kernel


</td>
</tr>
</table>

Linux booting facts	Hot plug is the addition of a component to a running computer system without significant interruption to the operation of the system. Hot plugging a device does not require a restart of the system.
Synchronization mechanisms inside Linux kernel	**Critical Region:** A critical section is a piece of code which should be executed under mutual exclusion. Suppose that two threads are updating the same variable which is in parent process's address space **Atomic operation:** This is the very simple approach to avoid race condition or deadlock. Atomic operators are operations, like add and subtract, which perform in one clock cycle (uninterruptible operation). and another that operates on individual bits. All atomic functions are inline functions. **Semaphore**: This is another kind of synchronization mechanism which will be provided by the Linux kernel. When some process is trying to access semaphore, which is not available, semaphore puts process on wait queue (FIFO) and puts task on sleep. That's why semaphore is known as a sleeping lock. After this processor is free to jump to another task which is not requiring this semaphore. As invoked. There two flavors of semaphore is present.Basic semaphore **Reader-Writer Semaphore** **Semaphore** puts a task on sleep. So, the semaphore can be only used in process context. Interrupt context cannot sleep. Operation to put task on sleep is time consuming(ov semaphore is suitable for lock which is holding for long term. A code holding a semaphore can be preempted. It does not disable kernel preemption. After disabling interrupts from some tasks, semaphore should not acquire. Because task would sleep if it failed to acquire the semaphore, at this time the interrupt has been disabled and current task cannot be scheduled out. **Semaphore wait list is FIFO in nature**. So, the task which tried to acquire semaphore first will be waken up from wait list first.. Semaphore can be acquired/release from any proce **Spin-lock**: This is special type of synchronization mechanism which is preferable to use in multi-processor (SMP) system. Basically, its a busy-wait locking mechanism until the lock is available. In case of unavailability of lock, it keeps thread in light loop and keep checking the availability of lock. Spin-lock is not recommended to use in single processor system. If some procesq_1 has acquired a lock and other process_2 is trying to acquire lock, in this case process 2 will spins around and keep processor core busy until it acquires lock. process_2 will create a deadlock, it dosent allow any other process to execute because loop by semaphore. Couple of observations about nature of spinlocks: 1. Spinlocks are very much suitable to use in interrupt(atomic) context because it doesn't put process/thread in sleep. 2. In the uni processor environment, if the kernel acquires a spin lock, it would **disable preemption first** ; if the kernel releases the spin lock, it would enable

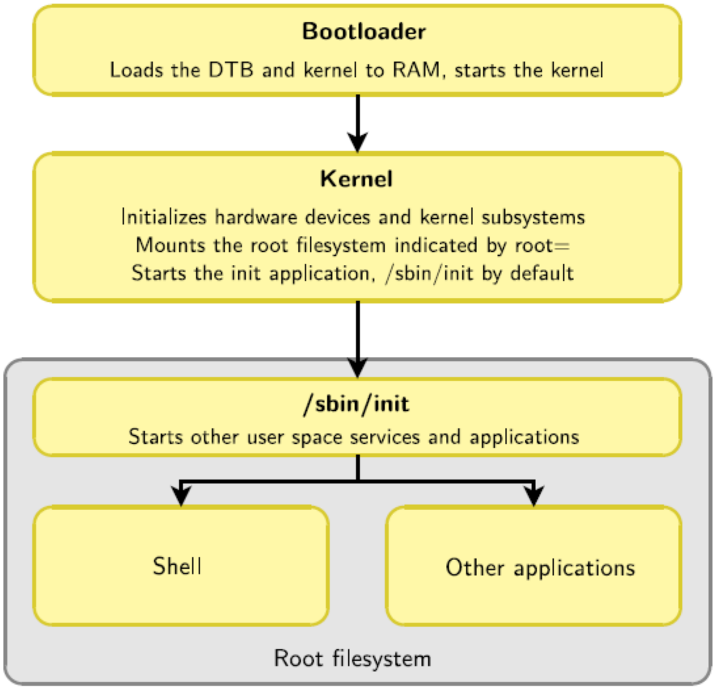
	preemption. This is to avoid dead lock on uni processor system 3. Spin-locks is not recursive. A thread may call lock on a recursive mutex repeatedly. Ownership will only be released after the thread makes a matching number of calls to unlock 4. Special care must be taken in case where spinlock is shared b/w interrupt handler and thread. Local interrupts must be disabled on the same CPU(core) before acquiring spin-lock. In the case where interrupt occurs on a different processor, and it spins on the same lock, does not cause deadlock because the processor who acquire lock will be able to release the lock using the other core. 5. When data is shared between two tasklet, there is not need to disable interrupts because tasklet dose not allow another running tasklet on the same processor. There two flavors of spin-lock is present. Basic spin-lock Reader-Writter Spin-lock With increasing the level of concurrency in Linux kernel read-write variant of spin-lock is introduces. This lock is used in the scenario where many readers and few writers are present Any reader will not get lock until writer finishes it. **Sequence Lock**: This is very useful synchronization mechanism to provide a lightweight and scalable lock for the scenario where many readers and a few writers are present. Sequence lock maintains a counter for sequence. When the shared data is written, a lock is obtained and a sequence counter is incremented by 1. Write operation makes the sequence counter value to odd and releasing it makes even.

Memory Layout of C Programs	 **From low to high memory** **1 Text Segment:** contains executable instructions. **2. Data Segment:** contains global & static variables 3. heap goes up 4. stack goes down
Mutex V/s Semaphore	1> In mutexes has an ownership property, only the thread that took the lock has the key. Only that thread alone can release the lock. Binary semaphores doesn't have an ownership property, as any thread can take the key to open the lock. 2)A semaphore is a generalized mutex. In lieu of single buffer, we can split the 4 KB buffer into four 1 KB buffers (identical resources). A semaphore can be associated with these four buffers. The consumer and producer can work on different buffers at the same time.
Dockers	A software container is a way to bundle and isolate processes (software) running on a server. Virtual machines and containers differ in several ways, but the primary difference is that containers provide a way to virtualize an OS so that multiple workloads can run on a single OS instance. With VMs, the hardware is being virtualized to run multiple OS instances. Docker is an open source project that makes it easier to create, deploy and run Applications in containers .The applications are packaged in a docker container which contains all the dependencies (libraries, packages) that are needed to deploy the application. By using docker, an application can be easily moved around from the developer's laptop, into the testing environment and finally into production. Podman, new in Red Hat Enterprise Linux 7.6 Beta, can replace the docker CLI, allowing you to run standalone (non-orchestrated) containers ...

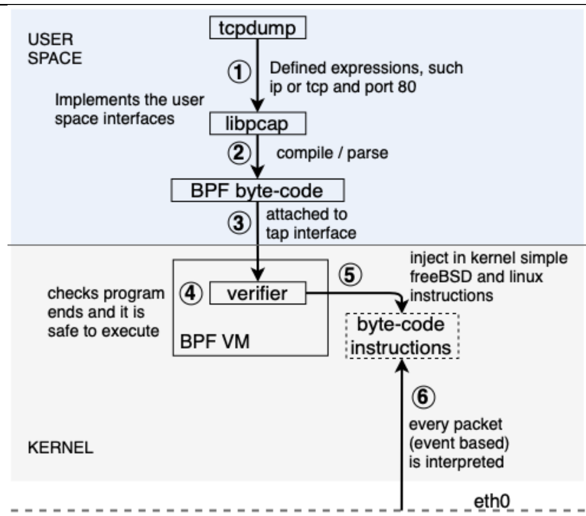
Docker/ Kubernetes	Docker is what enables us to run, create and manage containers on a single host Kubernetes can then allow you to automate container provisioning, networking, load-balancing, security and scaling across all these nodes from a single command line or dashboard. A collection of nodes that is managed by a single Kubernetes instance is referred to as a **Kubernetes cluster**. Now, why would you need to have multiple nodes in the first place? The two main motivations behind it are: 1. To make the infrastructure more robust: Your application will be online, even if 2. some of the nodes go offline, i.e, High availability. 3. To make your application more scalable: If workload increases, simply spawn more 4. containers and/or add more nodes to your Kubernetes cluster. Kubernetes automates the process of scaling, managing, updating and removing containers. In other words, it is a container orchestration platform. While Docker is at the heart of the containerization, it enables us to have containers in the first place. Differences Between Kubernetes and Docker In principle, Kubernetes can work with any containerization technology. **Kubernetes pods** :A Kubernetes pod is a group of containers that are deployed together on the same host. If you frequently deploy single container s, you can generally replace the word "pod" with "container" and accurately understand the concept. **Docker** is a run time engine running on your computer. It's a daemon that is in charge of containers start, stop on that single computer. So Docker is about managing works within a single machine. **Kubernetes is kind of a cluster management software**. It is a group of daemons that is in charge of a cluster of machines. Though there is a single daemon (kubelet) running on an individual machine, the kubelet by itself does not have much value on the table; it is these group of kubelets (along with kubernetes controllers that control them) make decisions about the whole cluster. So k8s is about managing works for a cluster of machines.
ASLR	Address space layout randomization (ASLR) is a memory-protection process for operating systems (OSes) that guards against buffer-overflow attacks by randomizing the location where system executables are loaded into memory. The success of many cyberattacks, particularly zero-day exploits, relies on the hacker's ability to know or guess the position of processes and functions in memory. ASLR is able to put address space targets in unpredictable locations. If an attacker attempts to exploit an incorrect address space location, the target application will crash, stopping the attack and alerting the system.

	ASLR works alongside virtual memory management to randomize the locations of different parts of the program in memory. Every time the program is run, components (including the stack, heap, and libraries) are moved to a different address in virtual
Object Size Checking (OSC)	Object Size Checking (OSC) leverages a builtin compiler technique to determine buffer overflows in C/C++ code. various optimization passes enabled with -O2
xspace	Making the stack (and heap) non-executable provides a high degree of protection against many types of buffer overflow attacks for existing programs. is that execution occurs in the code section, which is neither stack nor heap.
Reader-writer lock	When a writer is writing the data, all other writers or readers will be blocked until the writer is finished writing. Readers–writer locks are usually constructed on top of mutexes and condition variables, or on top of semaphores.
STACK	**Key Differences Between Stack and Heap Allocations** 1. In a stack, the allocation and deallocation is automatically done by whereas, in heap, it needs to be done by the programmer manually. 2. Memory shortage problem is more likely to happen in stack whereas the main issue in heap memory is fragmentation. 3. Stack is not flexible, the memory size allotted cannot be change
OS concept	Page Fault: A page is a fixed-length block of memory that is used as a unit of transfer between physical memory and external storage like a disk, and a page fault is an interrupt (or exception) to the software raised by the hardware when a program accesses a page that is mapped in address space, but not loaded in physical memory.
DMA	Direct Memory is a feature which provides direct access (read/write) to system memory without interaction from the CPU. using “DMA Controller”
STACK protection	in a multi-threaded environment, there can be multiple stacks in a process. One threat to the stack is malicious program input, which can overflow a buffer and overwrite stack pointers, simple method GCC, you use -fstack-protector-all.
vmalloc	vmalloc allocates virtually contiguous memory space (not necessarily physically contiguous), while kmalloc allocates physically contiguous memory (also virtually contiguous). Most of the memory allocations in Linux kernel are done using kmalloc, due to the following reasons: On many architectures, hardware devices don’t understand virtual address. Therefore, their device drivers can only allocate memory using kmalloc. kmalloc has better performance in most cases because physically contiguous memory region is more efficient than virtually contiguous memory. interval of time.

Kernel mode	Kernel mode ----------- Enter using interupt/Trap 1. Access to privileged instructions --> CPU control instructions (CLI, STI, HLT, WAIT, LOCK, ...) --> IN, OUT (direct hardware access) 2. Full access to physical memory (RAM) User mode ---------- 1. Restricted instruction set 2. No direct hardware access 3. No access to entire physical memory (RAM) 4. Memory access only by virtual addresses (Virtual memory) 5. Memory access can happen via demand-paging
How system call works	1. Application program makes a system call by invoking wrapper function in C library 2. This wrapper functions makes sure that all the system call arguments are available to trap-handling routine 3. Generally, a stack is used to pass these arguments to wrapper function. But the Kernel looks into specific registers for these arguments. Hence the wrapper function also takes care of copying these arguments to specific registers 4. Each system call has a unique call number which is used by kernel to identify which system call is invoked? The wrapper function again copies the system call number into specific CPU registers 5. Now the wrapper function executes trap instruction (int 0x80). This instruction causes the processor to switch from 'User Mode' to 'Kernel Mode' 6. The code pointed out by location 0x80 is executed (Most modern machines use sysenter rather than 0x80 trap instruction) 7. In response to trap to location 0x80, kernel invokes system_call() routine which is located in assembler file arch/i386/entry.S (also called handler) 8. This **handler saves register values** onto kernel stack and does some validations like verifying system call number etc. 9. A map of system call number as key and the appropriate system call as value exists. This After proper validations, the service routine performs required actions like modify values at addresses specified in arguments or transfer data between user memory and kernel memory. After all these actions, service routine returns status of execution to the system_call routine 10. Now the handler restores register values from kernel stack and places the system call return value on the stack 11. Thus handler is returned to wrapper function, simultaneously returning processor to user mode 12. Just in case if the return value of system call service routine indicated an error, then wrapper function sets 'errno' a global variable and then returns to caller providing integer return value that indicates the status of execution

Linux booting	 **Stage 1** When a system is booted, Processor executed a code from a well-known location known as BIOS (Basic Input Output System) which is stored in flash memory of motherboard. Its Job is to find the boot device (floppy/hard disk, cd). When boot device is detected, it passes control to first stage bootloader. A master boot record (often shortened as MBR) is a kind of boot sector stored on a hard disk drive or other storage device that contains the necessary computer code to start the boot process. **Stage 2** FIRST stage boot loader is loaded into the RAM and executed. This Boot Loader is 512 bytes in size with 64 bytes partition table). Its job is to find the SECOND order Boot Loader (grub) and load it into RAM and passed control to 2nd stage bootloader. **Stage 3** Grub1 is is embedded in an MBR (size issue). Grub2 is knowledge about the Linux file system (ext2,ext3) Grub2 copy the Linux kernel image into the RAM using /boot/grub/grub.conf.. **Step 4 Kernel stage** Kernel is in compressed **cpio format** file present in /boot directory . Mounts the root file system as specified in the “root=” in grub.conf

	grub> root (hd0,0) grub> kernel /vmlinuz-i686-up-4GB root=/dev/hda9 grub> boot kernel /vmlinuz-i686-up-4GB root=/dev/hda9 - Specifies the kernel location which is inside the /boot folder. This location is related to the root(hd0,0) statement.The root partition is specified according to the Linux naming convention (/dev/hda9/) initrd/ Initramfs is used by kernel as temporary root file system until kernel is booted and thereal root file system is mounted. It also contains necessary drivers compiled inside,which helps it to access the hard drive partitions, and other hardware. insmod for loading kernel modules, and lvm (logical volume manager tools). Initramfs/intrd is an image file in /boot containing the basic root file system with all Kernel modules. The kernel then Mount this image file as a starting memory-based root file system. The kernel then starts to detect the system's hardware. The root file system on disk takes over from the memory. The boot process then starts INIT (SYSTEMD) **Step 5 INIT** The kernel, once it is loaded in step 4, it finds init in sbin (/sbin/init) and executes it. The first thing init does is reading the initialization file, /etc/inittab. The program init is the process with process ID 1.
Hardware Security	**Secure Boot** is a security standard developed by members of the PC industry to help make sure that your PC boots using only software that is trusted by the PC manufacturer. When the PC starts, the **Bios checks the signature of each piece of boot software**, including drivers and the operating system. If the signatures are good, the PC boots, and the Bios gives control to the operating system or else it would halt the boot up process and thrown error. A **Trusted Platform Module (TPM)** is a hardware chip on the computer's motherboard that stores cryptographic keys used for encryption. Once enabled, the Trusted Platform Module provides full disk encryption capabilities. It becomes the "root of trust" for the system to provide integrity and authentication to the boot process. It keeps hard drives locked/sealed until the system completes a system verification, or authentication check. The TPM includes a unique RSA key burned into it, which is used for asymmetric encryption. generate, store, and protect other keys used in the encryption and decryption process. A hardware security module (HSM) are external devices connected to a network using TCP/IP.encryption capabilities by storing and using RSA keys.
ebpf	eBPF is a revolutionary technology with origins in the Linux kernel that can run sandboxed programs in an operating system kernel. It is used to safely and efficiently **extend the capabilities of the kernel** without requiring changing kernel source code or load kernel modules.

<table>
<tr><td></td><td>

First BPF use case: tcpdump</td></tr>
<tr><td>DPDK</td><td>DPDK (Data Plane Development Kit) is a framework (under the Linux Foundation) comprised of various userspace libraries and drivers for fast packet processing. Originally developed by Intel to run on x86 based CPUs, DPDK now supports other CPU types. DPDK leverages existing Intel Processor technologies like SIMD instructions (Singles Instruction Multiple Data), Huge-pages memory, multiple Memory channels and Caching to provide acceleration with its own libraries.

Though DPDK uses a number of techniques to optimise packet throughput, how it works (and the key to its performance) is based upon Fast-Path and PMD.

Fast-Path (Kernel bypass) - A fast-path is created from the NIC to the application within user space, in turn, bypassing the kernel. This eliminates context switching when moving the frame between user space/kernel space. Additionally, further gains are also obtained by negating the kernel stack/network driver, and the performance penalties they introduce.

Poll Mode Driver - Instead of the NIC raising an interrupt to the CPU when a frame is received, the CPU runs a poll mode driver (PMD) to constantly poll the NIC for new packets. However, this does mean that a CPU core must be dedicated and assigned to running PMD.</td></tr>
<tr><td>KSM</td><td>KSM (kernel samepage merging) is a Linux kernel feature that allows share identical memory pages among different process or virtual machines on the same server.

User kernel tracing with ftarce to get back trace
https://blog.selectel.com/kernel-tracing-ftrace/</td></tr>
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