Linux Memory Management

What to Expect?

- W's of Memory Management?
- Memory Partitioning
- Memory Organization
- Memory Management in Linux
- Swapping

Why Memory Management?

- Transition from Uni-process → Multi-process
- Every process needs its own memory
  - Memory Division
- Program loaded to “any” available memory address
  - Relocation
- Independence / Non-interference between Processes
  - Protection
- Communication between Processes
  - Sharing
- Process Memory with Attributes (like read only for code)
  - Logical Organization
- Executing Programs bigger than available Memory
  - Physical Organization (Overlaying & Reusing)

What is Memory Management?

- Key task: Division of Memory
- Starting from the Division between
  - OS (Kernel)
  - Application (User)
- Others follow
  - Relocation, Protection, Sharing
  - Logical & Physical Organization
- May involve movement between primary & secondary

Memory Partitioning

- Two traditional division mechanisms
  - Segmentation: Unequal sized
    - Examples: Linear Allocation, Buddy System
  - Paging: Equal sized
    - Examples: 4K-Paged Allocation
- Examples in Linux
  - User-space malloc(): Segmentation
  - Slab sub-system: Paging

Pros & Cons

- Memory Fragmentation
  - External in Segmentation (gets worser)
  - Internal in Paging
- Space Efficiency
  - Segmentation: More meta but lesser allocation wastage
  - Paging: Negligible meta but significant allocation wastage
- Time Efficiency
  - Segmentation: Complex search & Storage Algorithm
  - Paging: Simple Algorithms

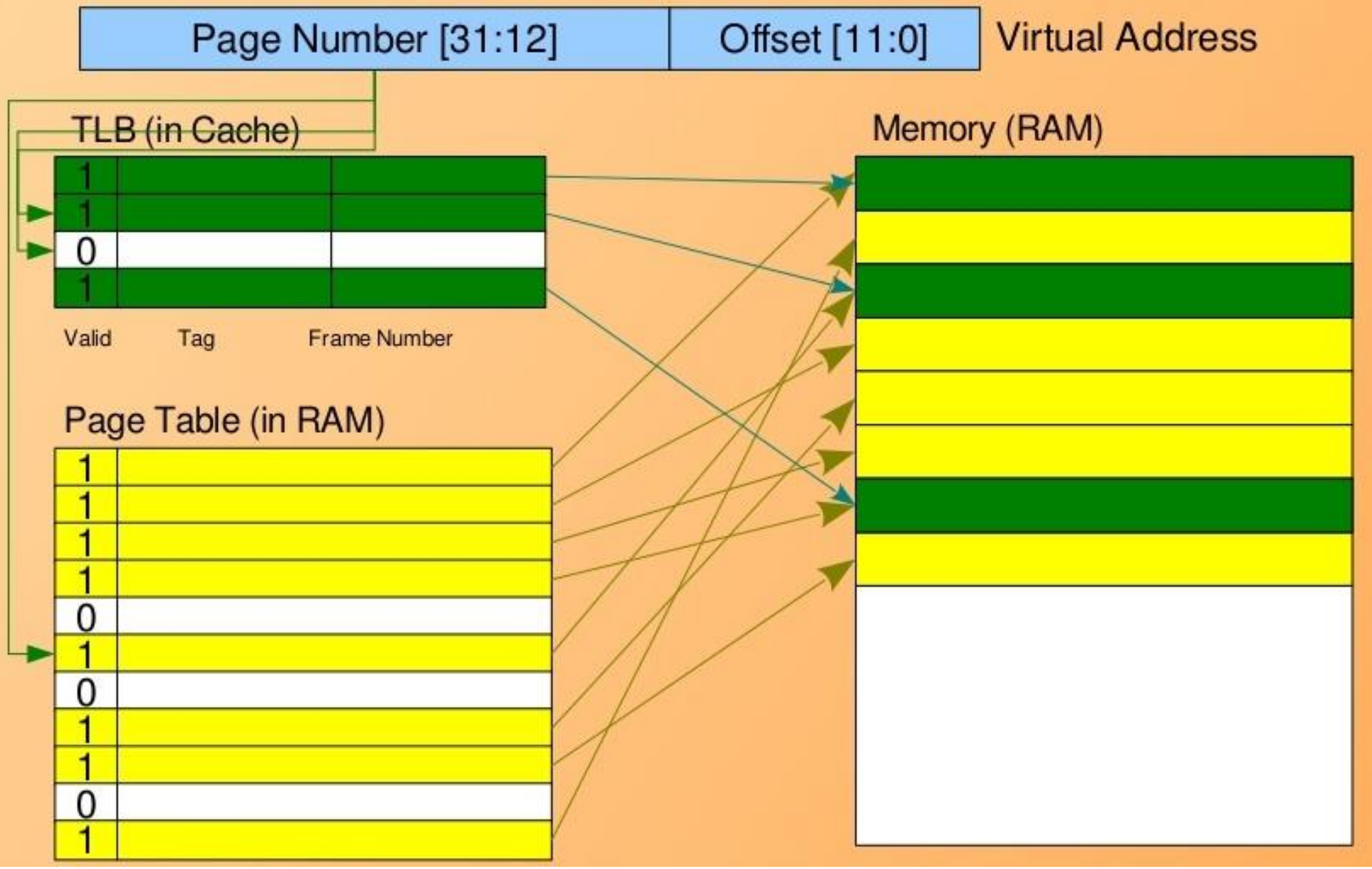
Memory Organization

- All other needs (Relocation, Protection, Sharing, ...)
  - Beautifully achieved by the concept of virtualization
- That is organizing the memory into
  - Physical & Virtual Address Spaces
  - And then using the virtual addressing for all purposes
- Both may use either Paging or Segmentation
- Best to use similar mechanisms
- Linux uses Paging for both with 4KiB/8KiB page size
- Virtualization can be achieved
  - Using special hardware called MMU
  - Using software MMU

Memory Organization ...

- Linux Kernels (>= 2.5.46) support both
  - Earlier kernels worked only with hardware MMU
  - uClinux used to be the solution for non-MMU processors & controllers
- Latest Intel, ARM, and most other architectures have in-built MMU
- Older x86, ARM7, and few such doesn't have a hardware MMU

Working of an MMU

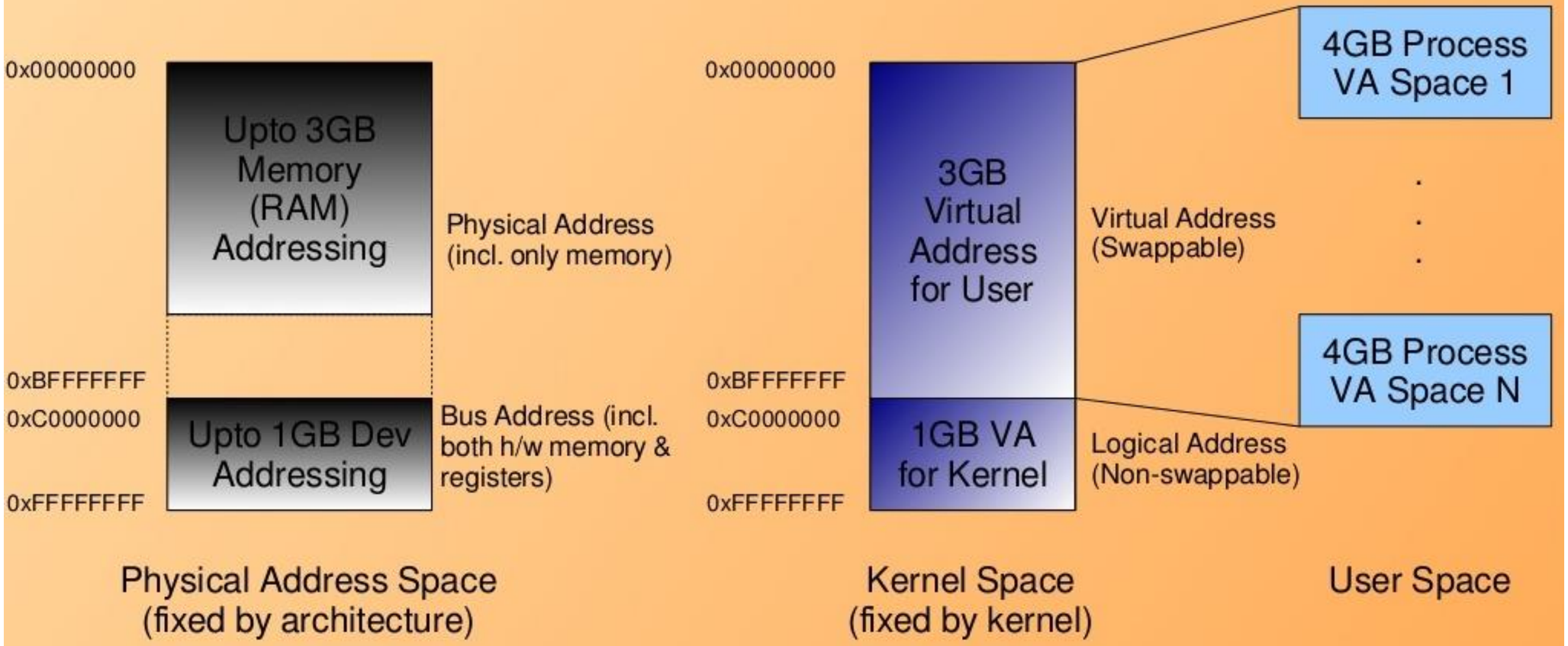


Memory Management in Linux

- In Linux, all these combined
  - User Space & Kernel Space
  - Memory Page Partitioning
  - Physical & Virtual Address Spaces
  - Device Addresses, Mapping & Access
- Takes the following form ...

Memory Organization in Linux

- An Example assuming 32-bit architecture



Linux Memory Manager

- Provides Access Control to h/w & memory resources
- Provides Dynamic Memory to kernel sub-system
  - Drivers
  - File Systems
  - Stacks
- Provides Virtual Memory to Kernel & User space
  - Kernel & User Processes run in their own virtual address spaces
  - Providing the various features of a Linux system
    - System reliability, Security
    - Communication
    - Program Execution Support

Swapping

- Optimizes primary & secondary memory usage
- Primary memory pages swapped out
  - When running out of memory
- Secondary memory pages swapped in
  - When needed back
- Linux maintains Page Cache in Primary Memory for
  - Code: Reloadable
  - Data: Unchanged vs Changed
  - Changed Data: Temporary (Dynamic) vs Persistent (Files)
- Linux uses Swap (raw) partition on Secondary Memory
- Related commands: mkswap, swapon/off

What all have we learnt?

- W's of Memory Management?
- Memory Partitioning
  - Segmentation & Paging
- Memory Organization
  - Physical & Virtual Addressing
  - Working of an MMU
- Memory Management in Linux
- Swapping & Swap Partition