Introduction to ACPI Based Memory Hot-Plug

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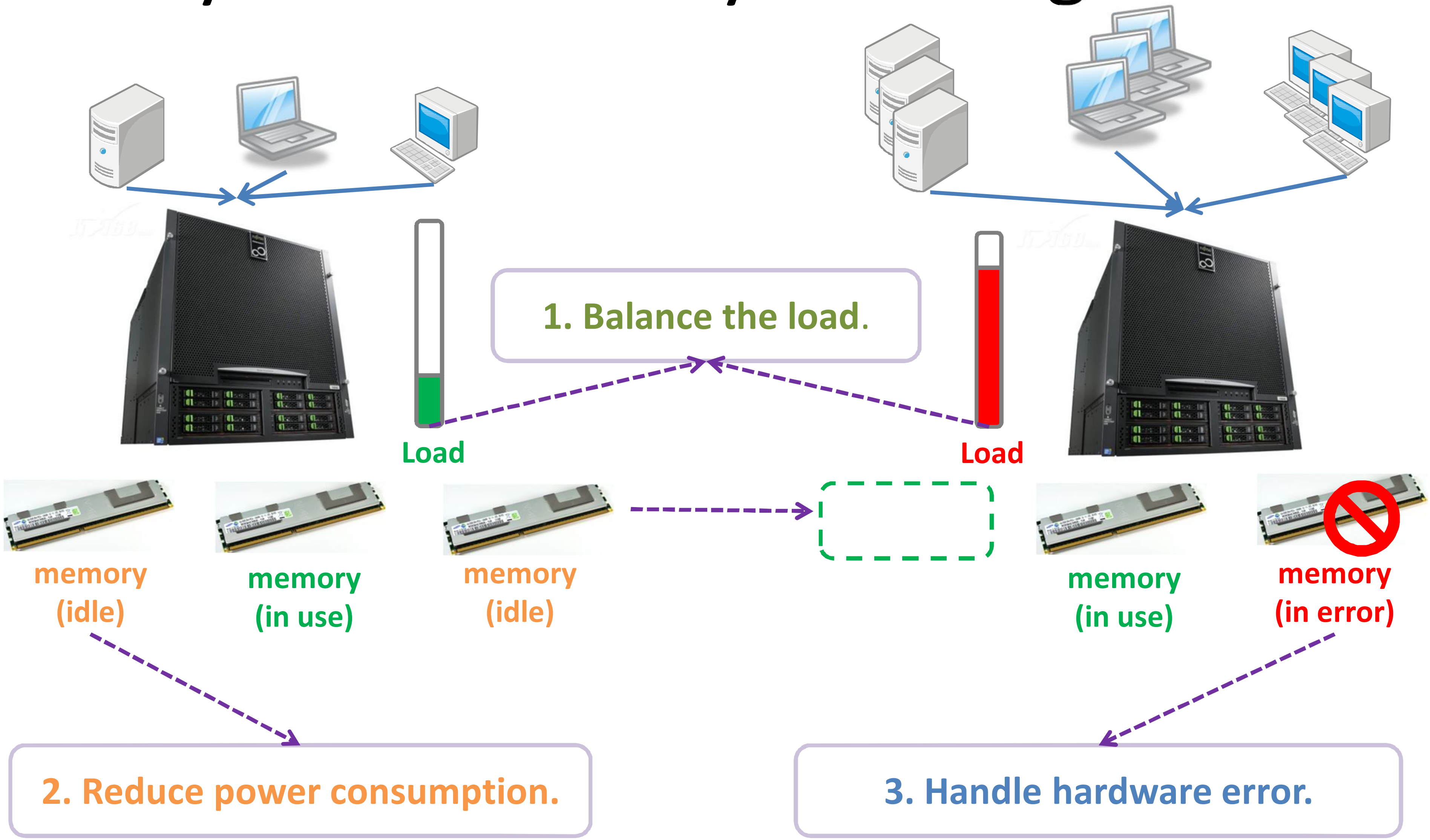
Agenda

1. Why need Memory Hot-Plug
2. ACPI & Memory Hot-Plug
3. Memory hot-add
4. Memory hot-remove
5. Movable node
6. Bootmem handling
7. Future work

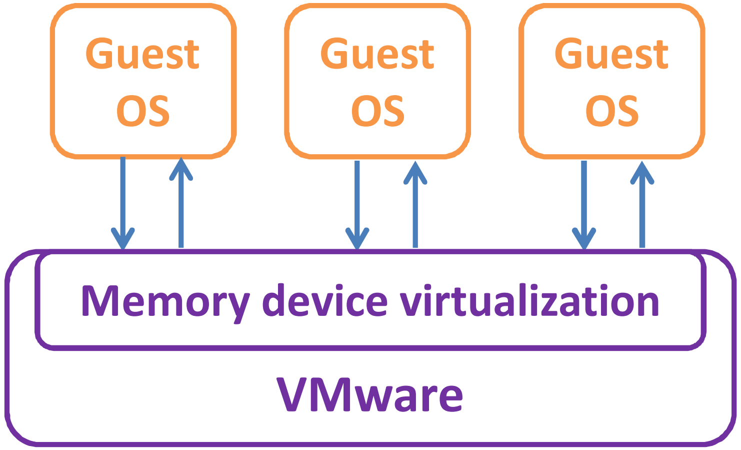
Why need memory Hot-Plug



Why need memory Hot-Plug

4. Guest OS should support memory hotplug.

- VMware supports virtual memory device hotplug for the virtual machine.
- The similar feature is being developped for KVM.



Firmware (ACPI BIOS)

+

Hardware (ACPI registers)

5. ACPI provides sufficient conditions

- With the help of ACPI, hardware and fireware are now able to support memory hotplug physically.

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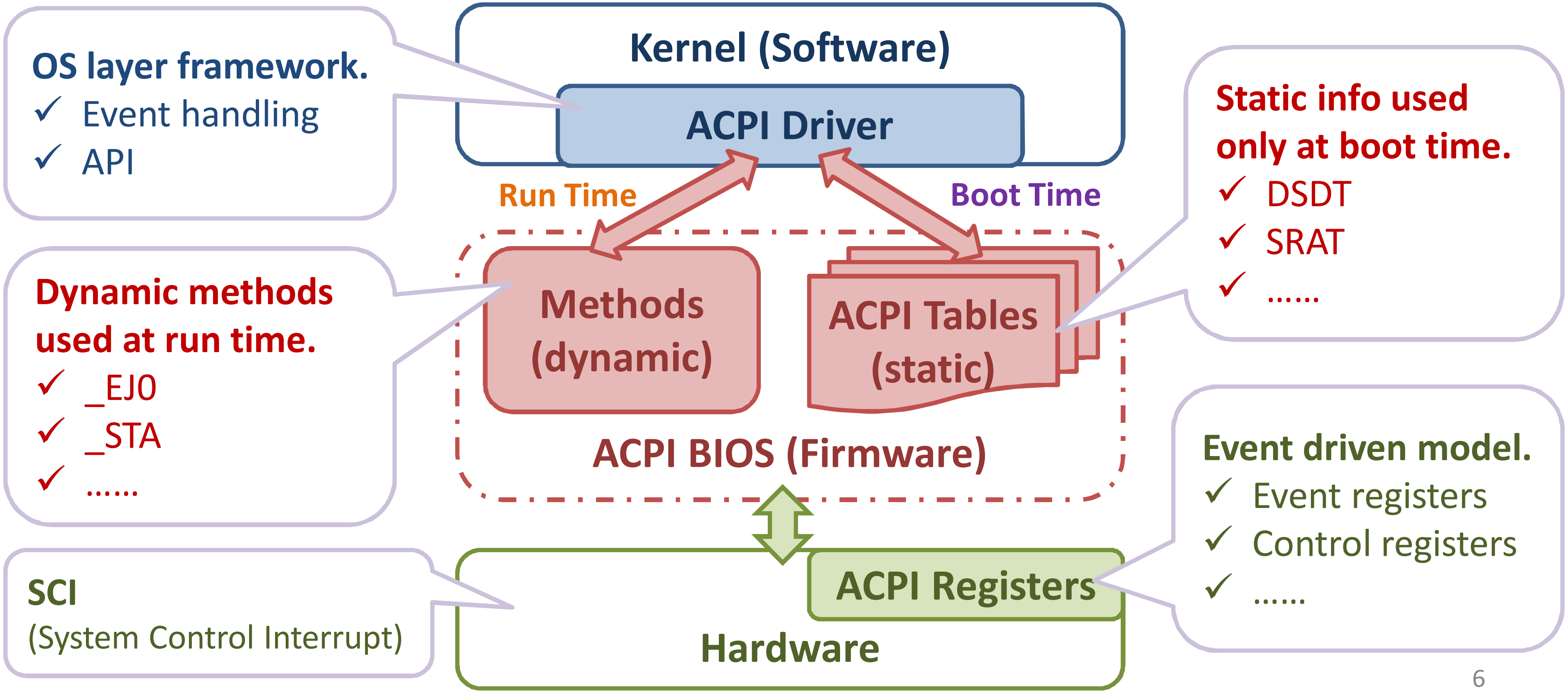
ACPI & Memory Hot-Plug

- ACPI: Advanced Configuration and Power Interface

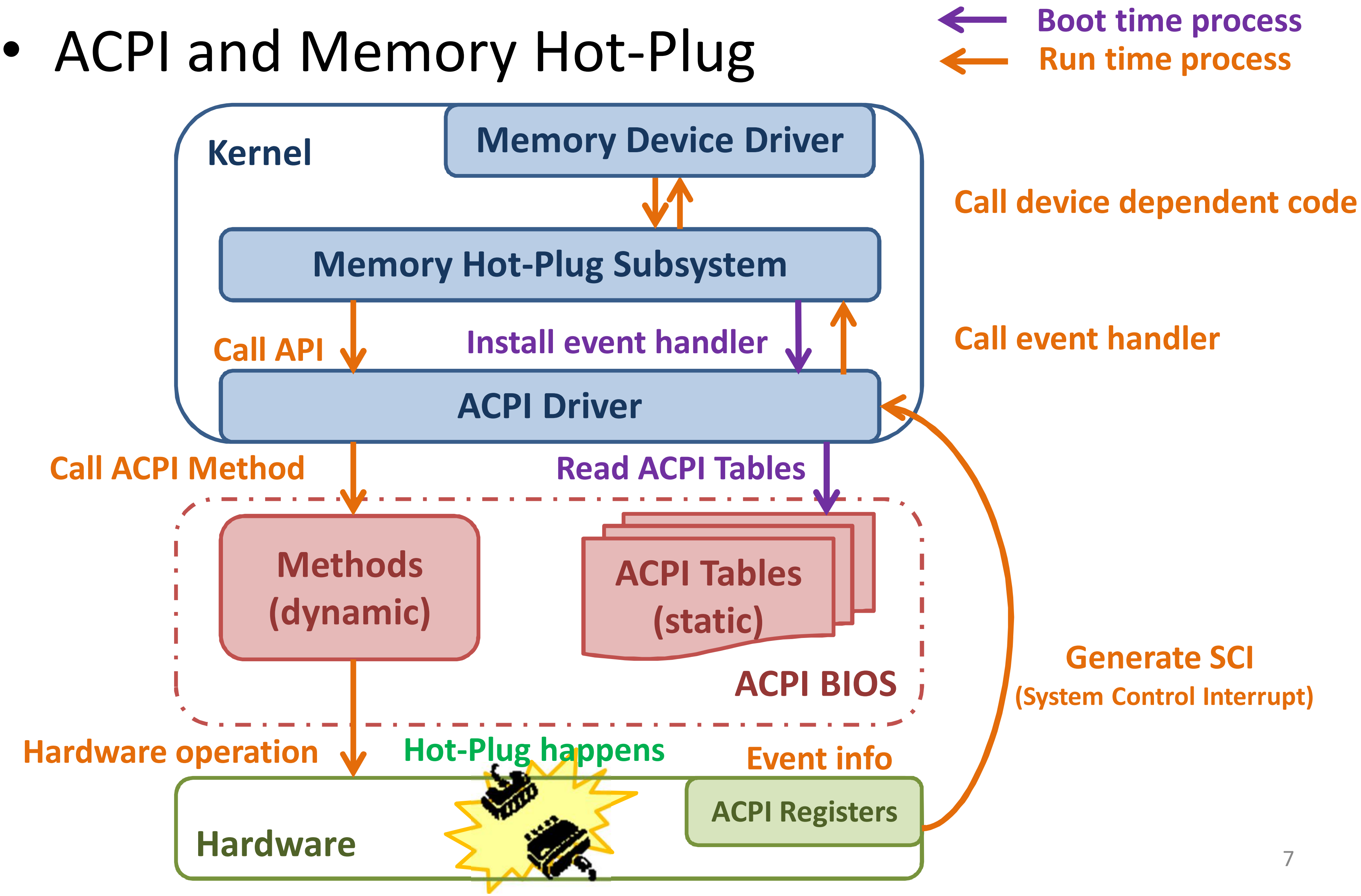
ACPI is an interface specification of Operating System-directed motherboard device configuration and Power Management.

-- ACPI Specification 5.0



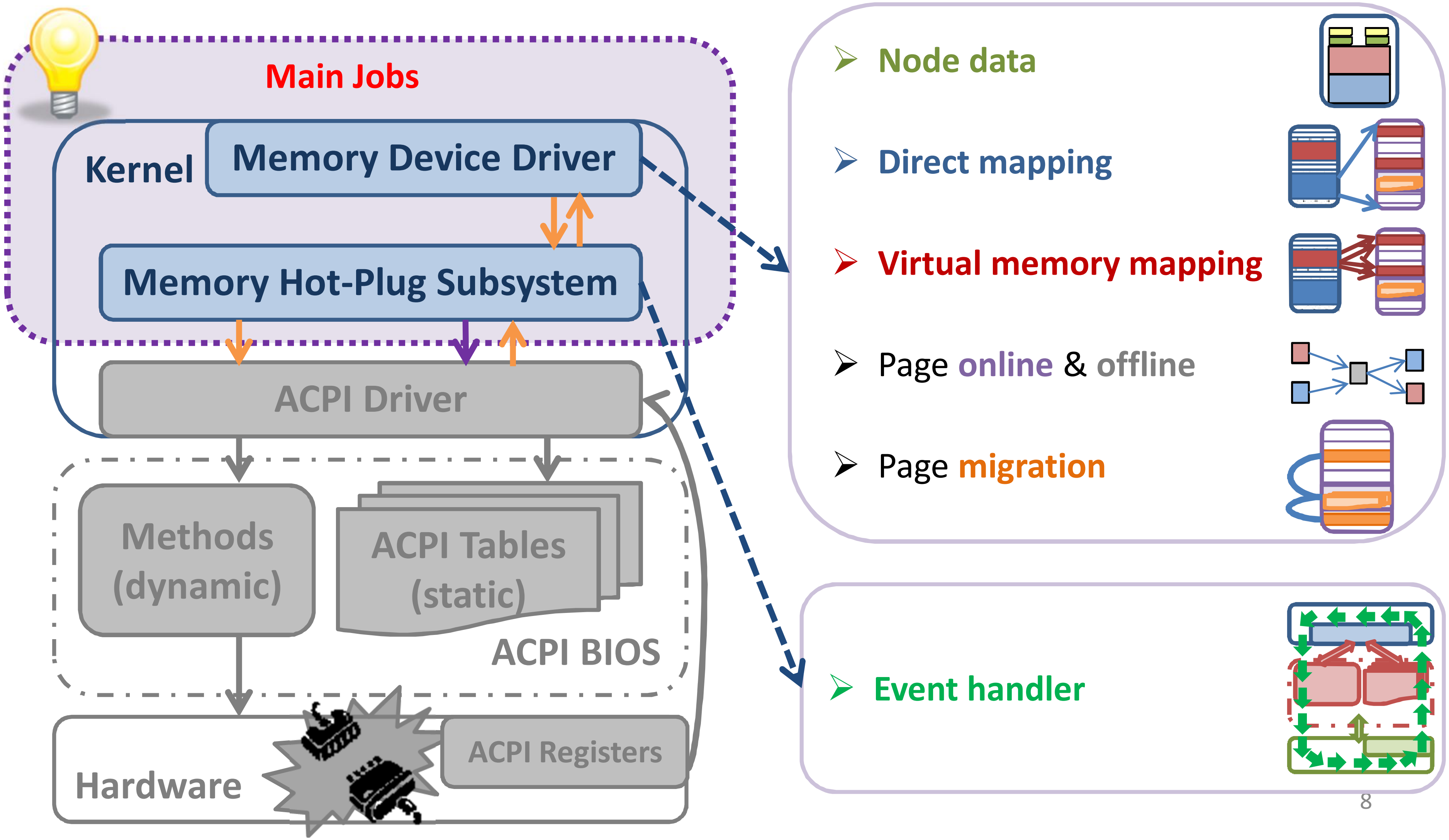
ACPI & Memory Hot-Plug

- ACPI and Memory Hot-Plug



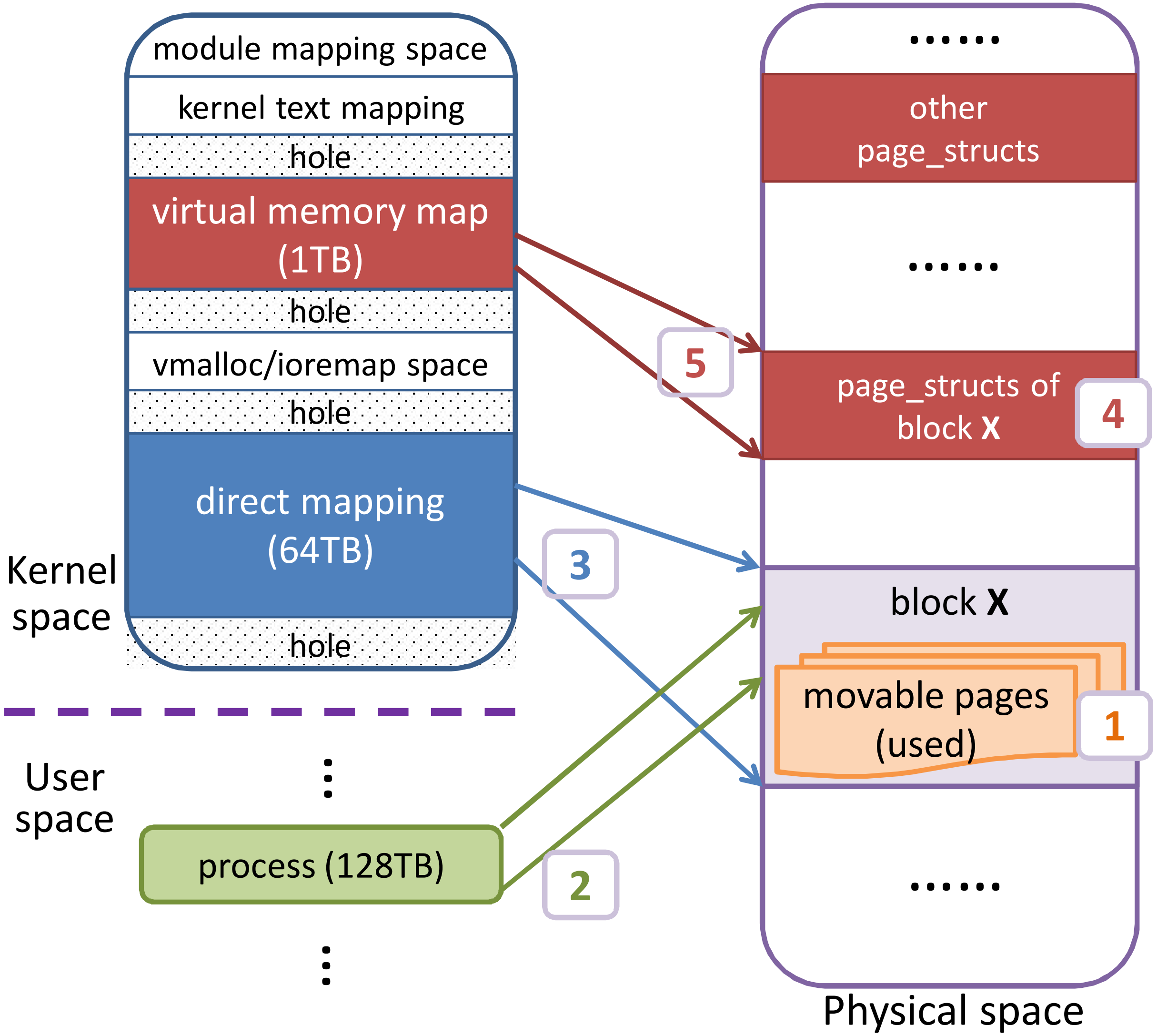
ACPI & Memory Hot-Plug

- Main jobs of Memory Hot-Plug



ACPI & Memory Hot-Plug

- Things associated with Memory Hot-Plug



1. Memory block to be hot-plugged.
2. User processes' pagetable.
3. Kernel direct mapping pagetable.
4. Virtual memory mapping pages.
5. Virtual memory mapping pagetable.

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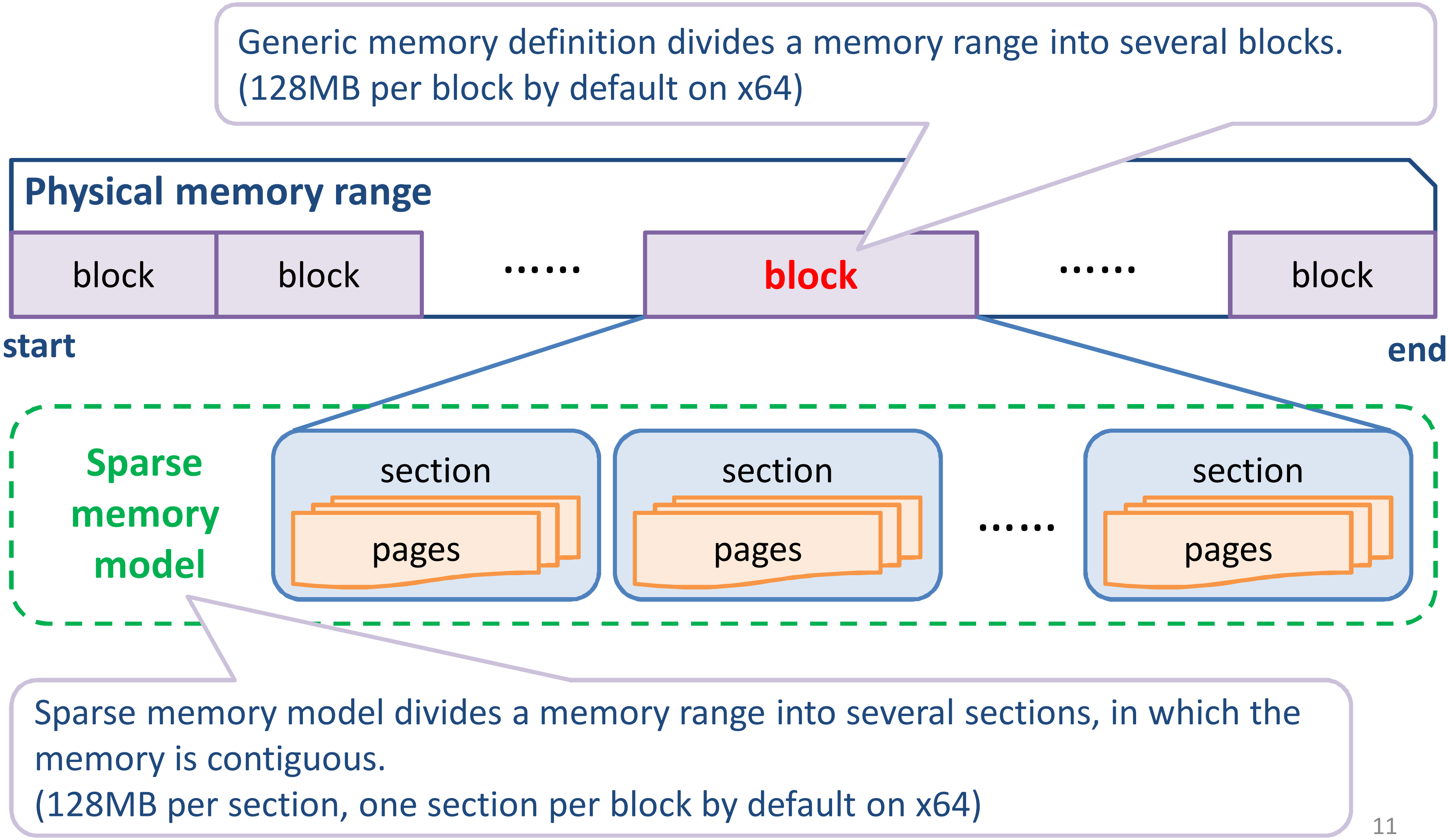
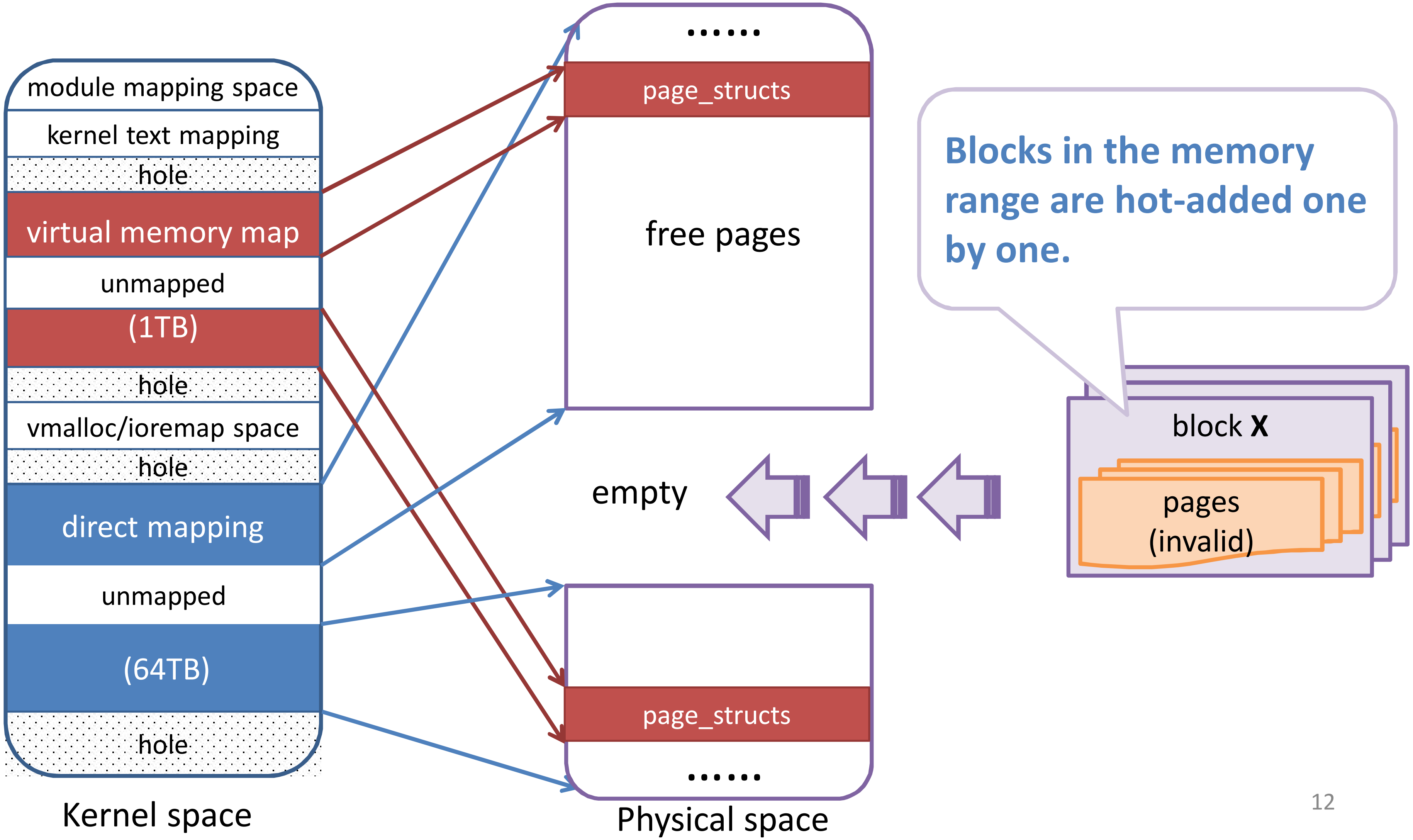
Memory hot-add

- Generic memory definition & sparse memory model



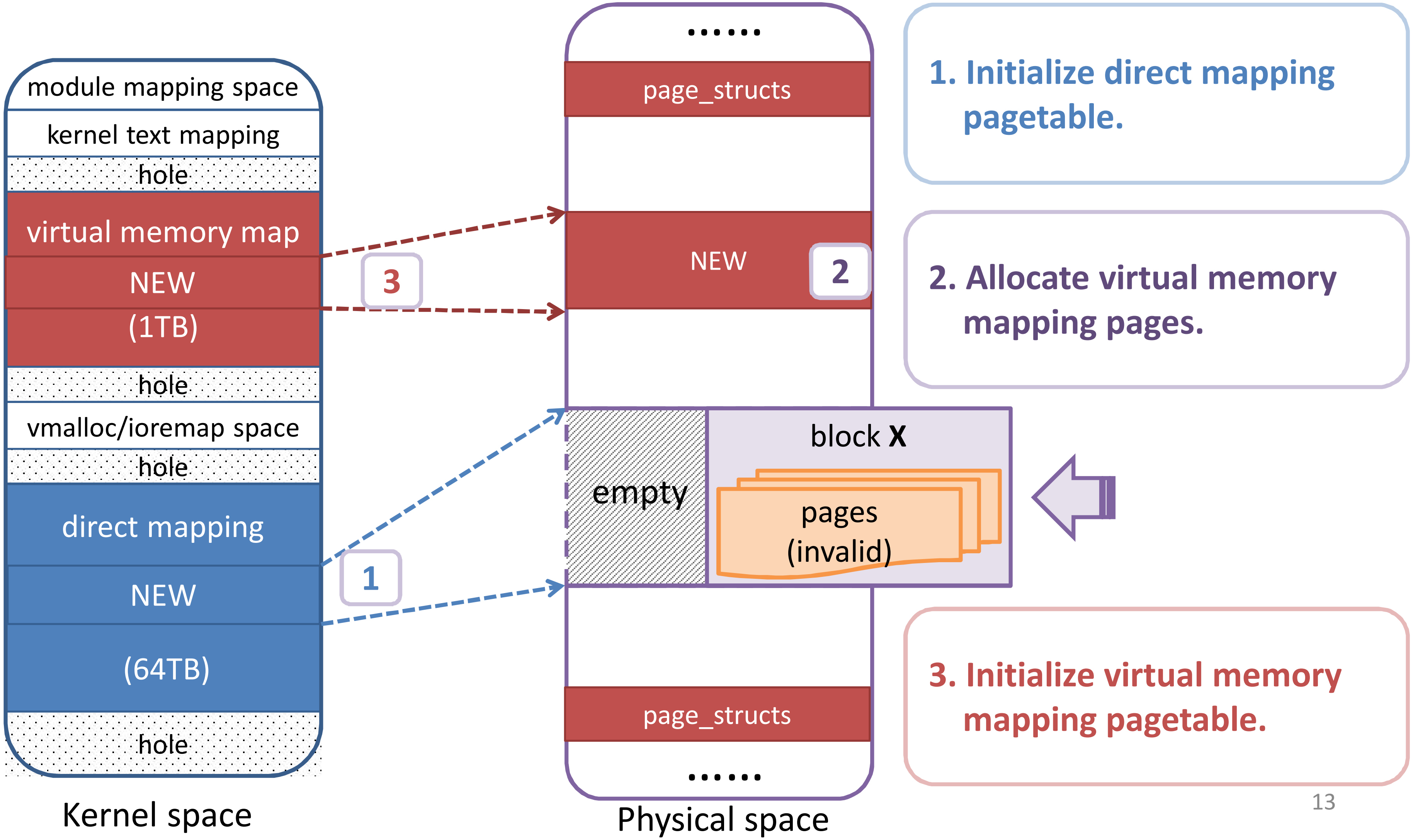
Memory hot-add

- Add memory (1)



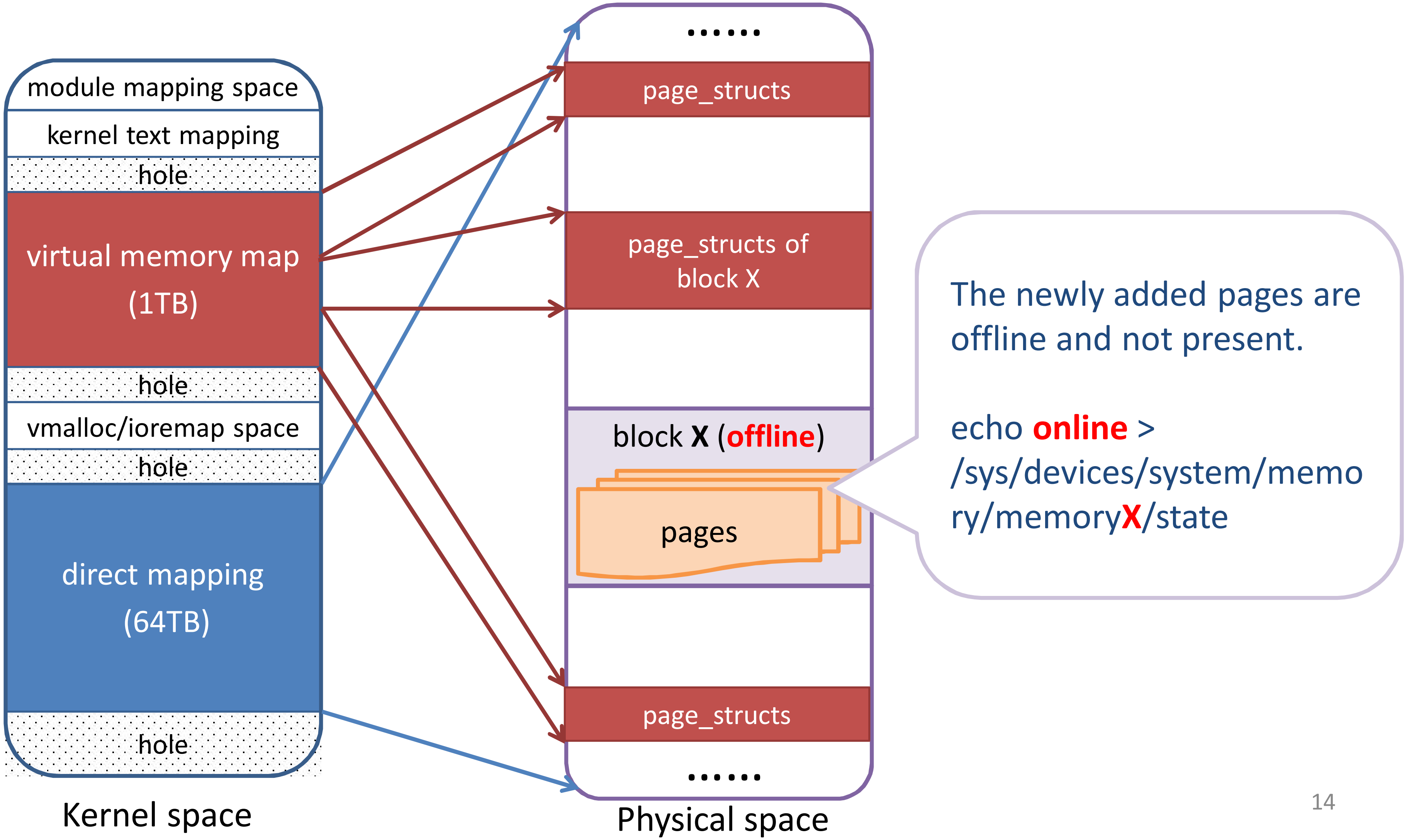
Memory hot-add

- Add memory (2)



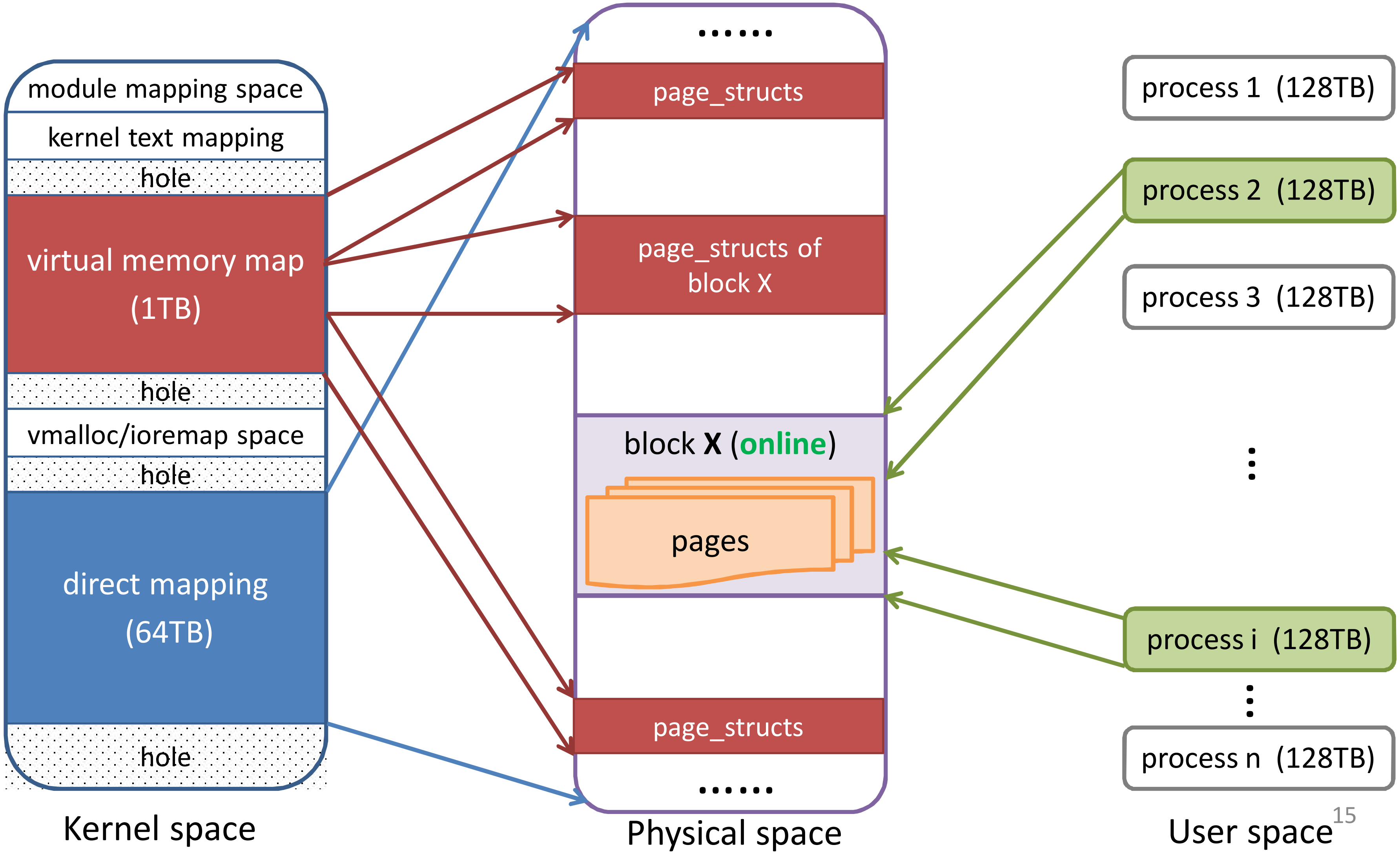
Memory hot-add

- Add memory (3)



Memory hot-add

- Online pages



Memory hot-add

- Configuration
  - mm/Kconfig

```
config MEMORY_HOTPLUG
    bool "Allow for memory hot-add“
    depends on SPARSEMEM || X86_64_ACPI_NUMA
    depends on HOTPLUG && ARCH_ENABLE_MEMORY_HOTPLUG
    depends on (IA64 || X86 || PPC_BOOK3S_64 || SUPERH || S390)
```

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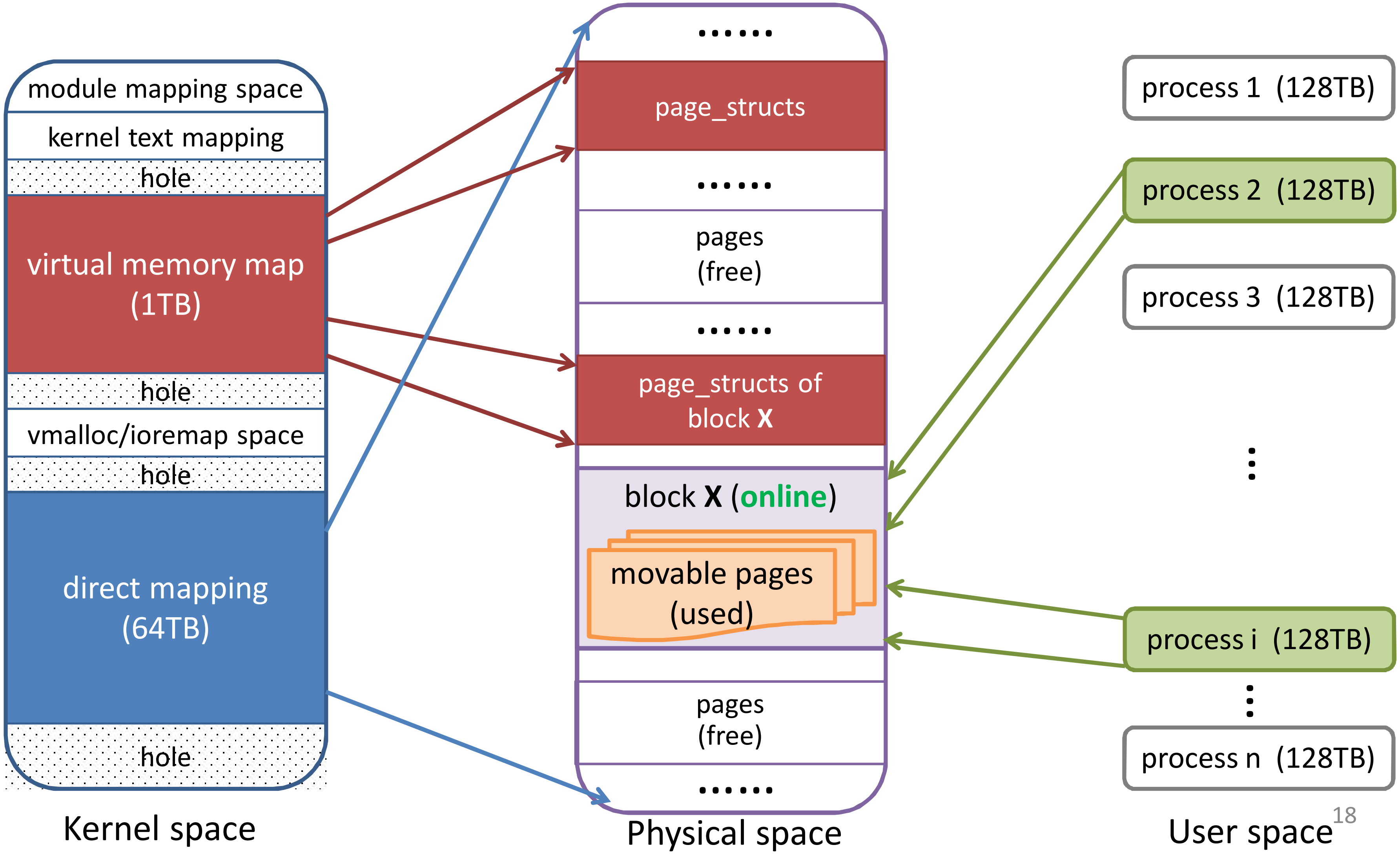
Memory hot-remove

- Remove memory (1)



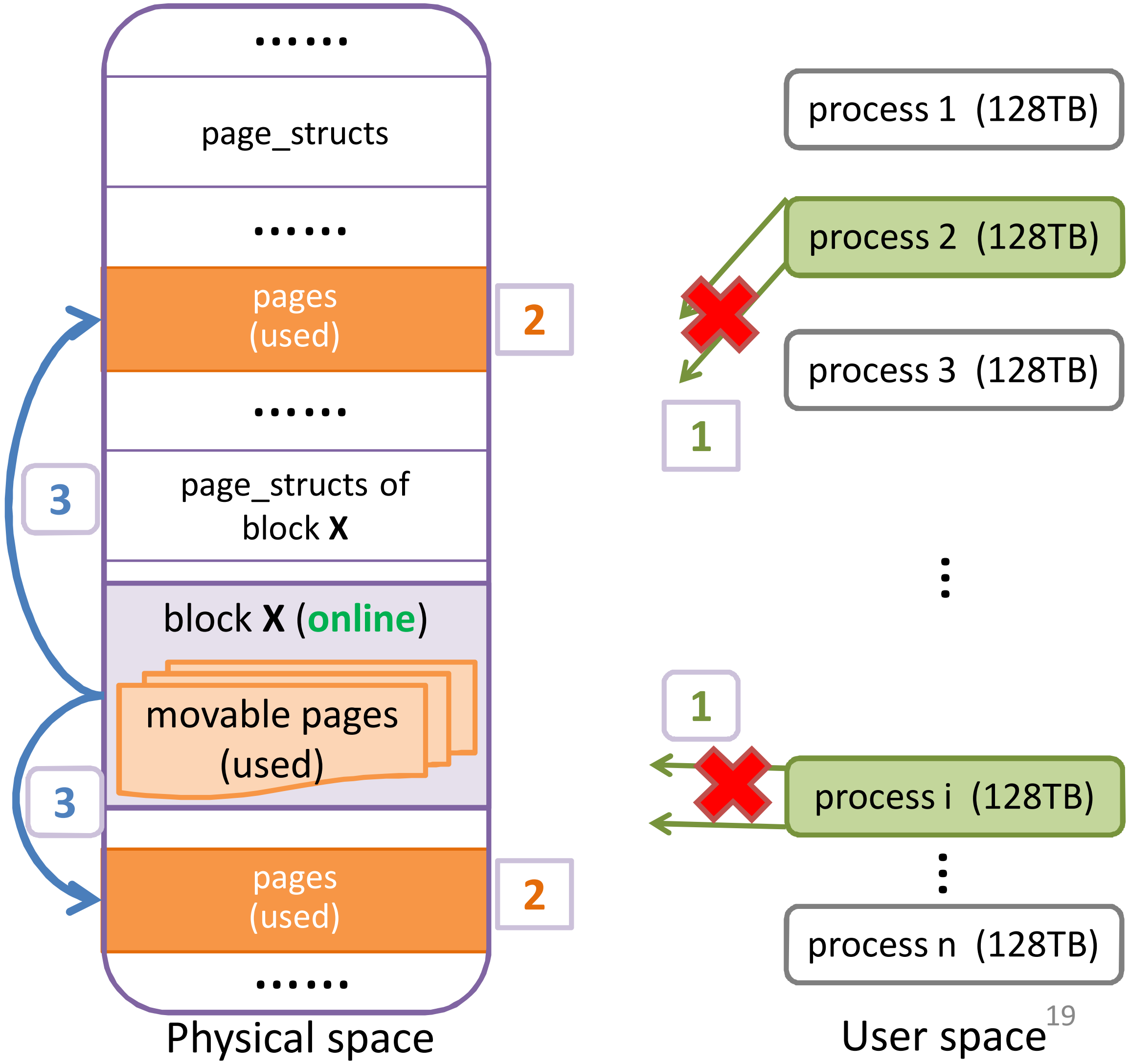
Memory hot-remove

- Remove memory (2)

1. Unmap user pages.
- Kernel will generate a page fault for each process who access these pages, and the process will wait till the migration is over.

2. Allocate new pages.

3. Copy data from old pages to new pages.



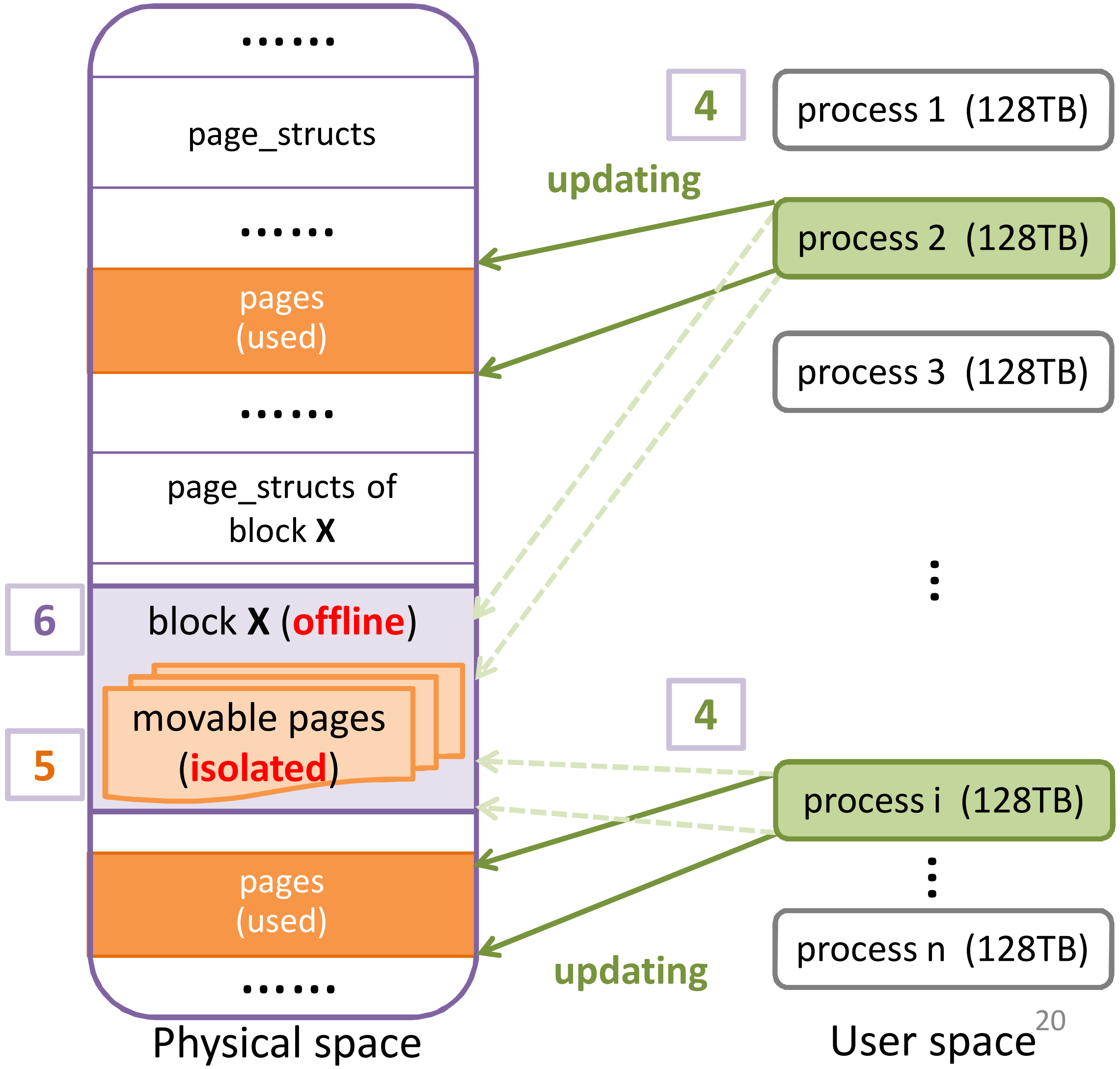
Memory hot-remove

- Remove memory (3)

4. Update user processes' pagetable.
- **Also wake up all the processes waiting for these pages.**

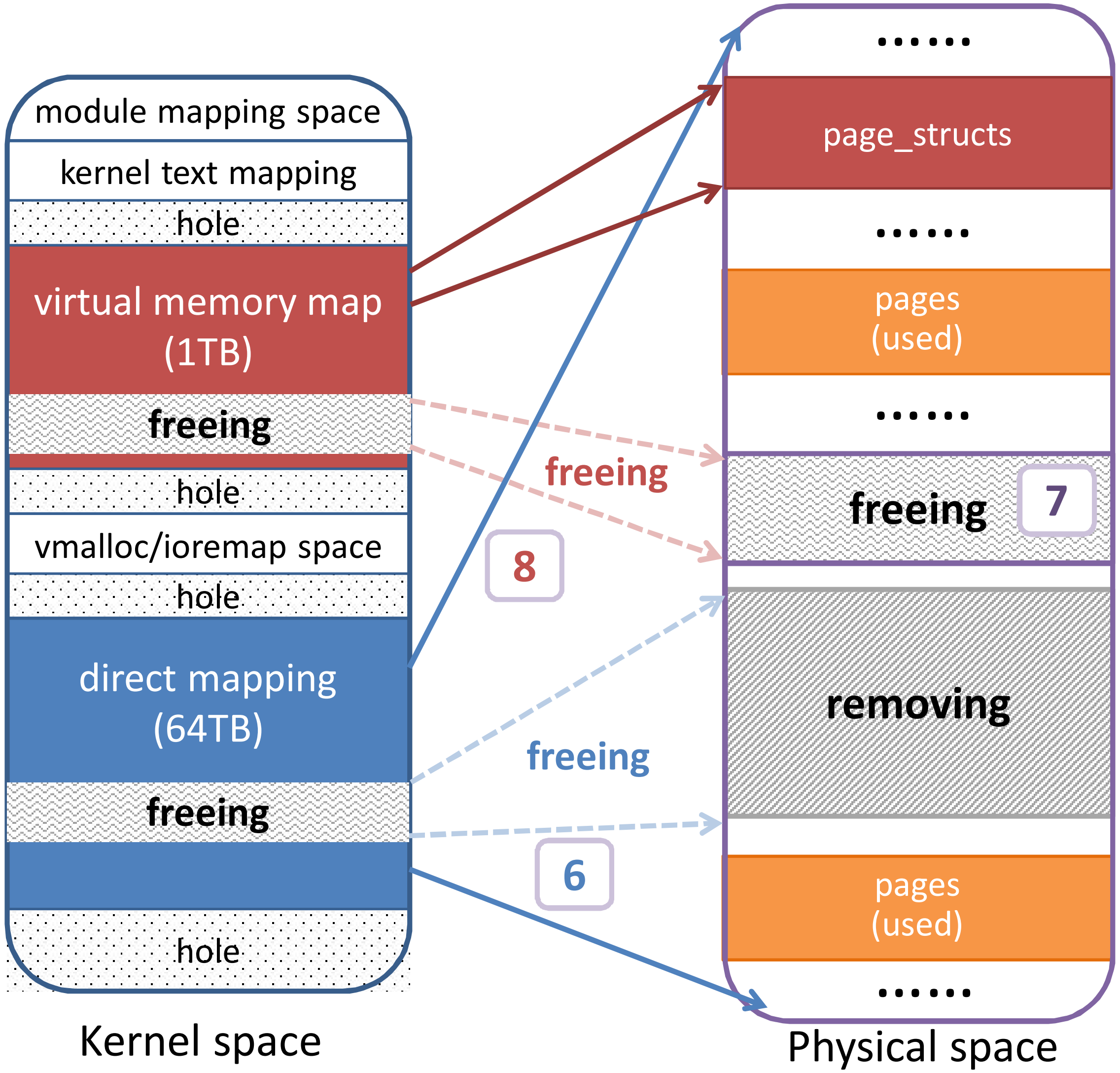
5. Isolate old pages.
- **Pages are not in the buddy system, and won't be allocated to anyone.**

6. Set the block state to offline.



Memory hot-remove

- Remove memory (4)



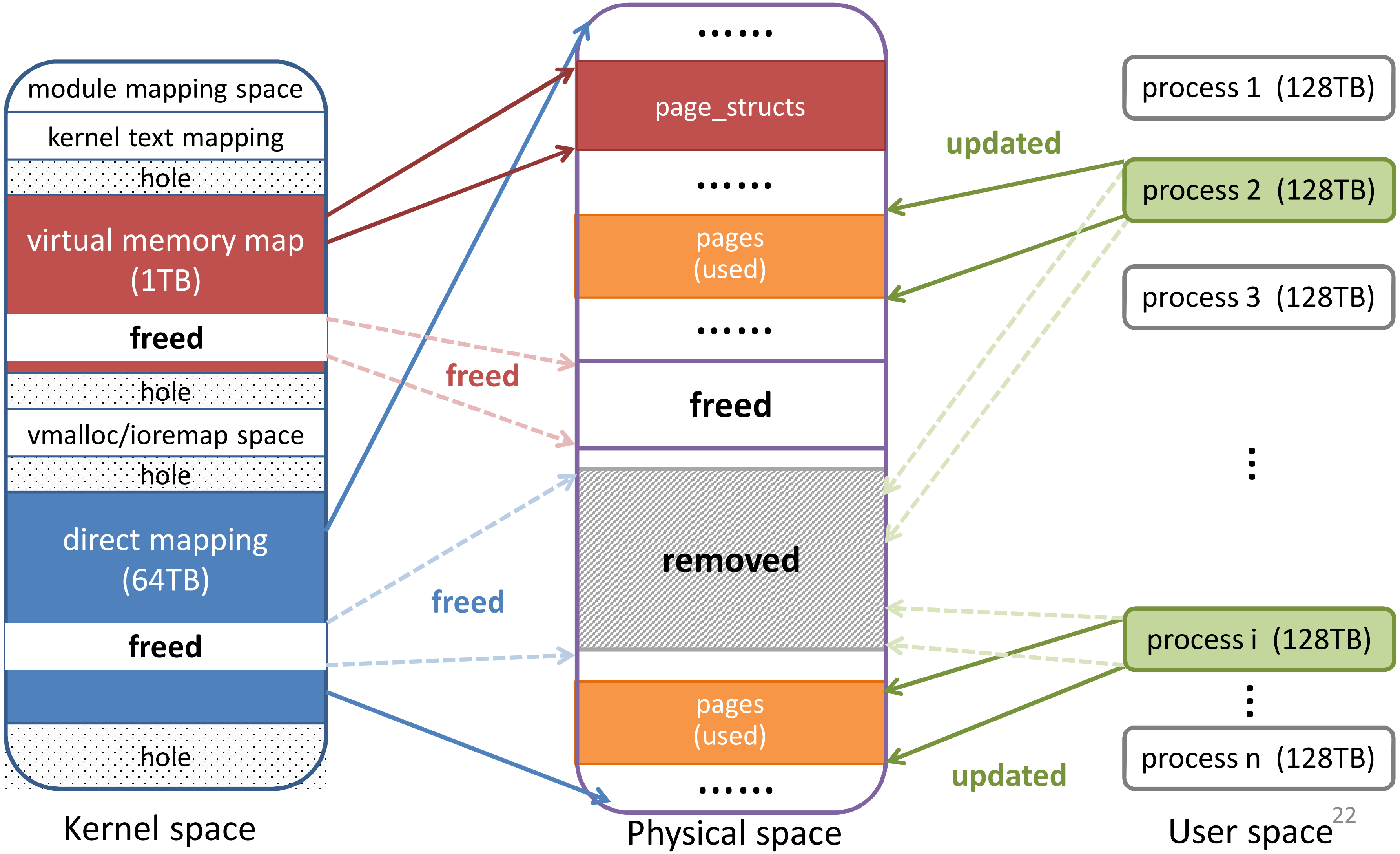
6. Free kernel direct mapping pagetable.

7. Free virtual memory mapping pages.

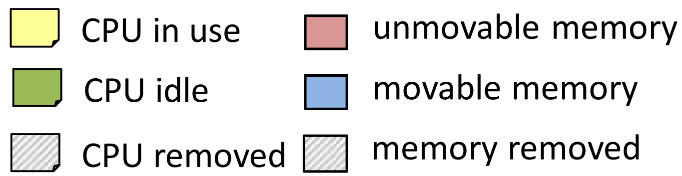
8. Free virtual memory mapping pagetable.

Memory hot-remove

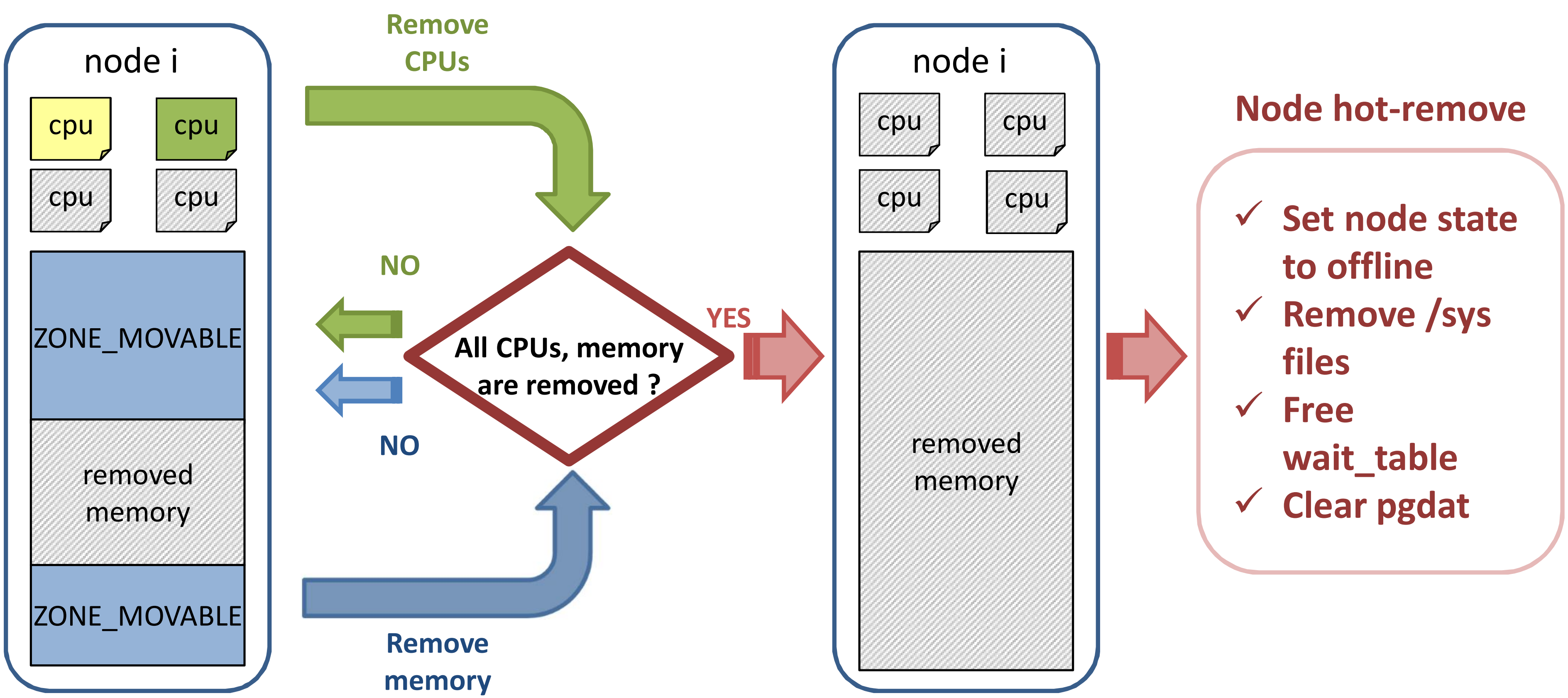
- Remove memory (5)



Memory hot-remove



- Post work: automatically remove the node



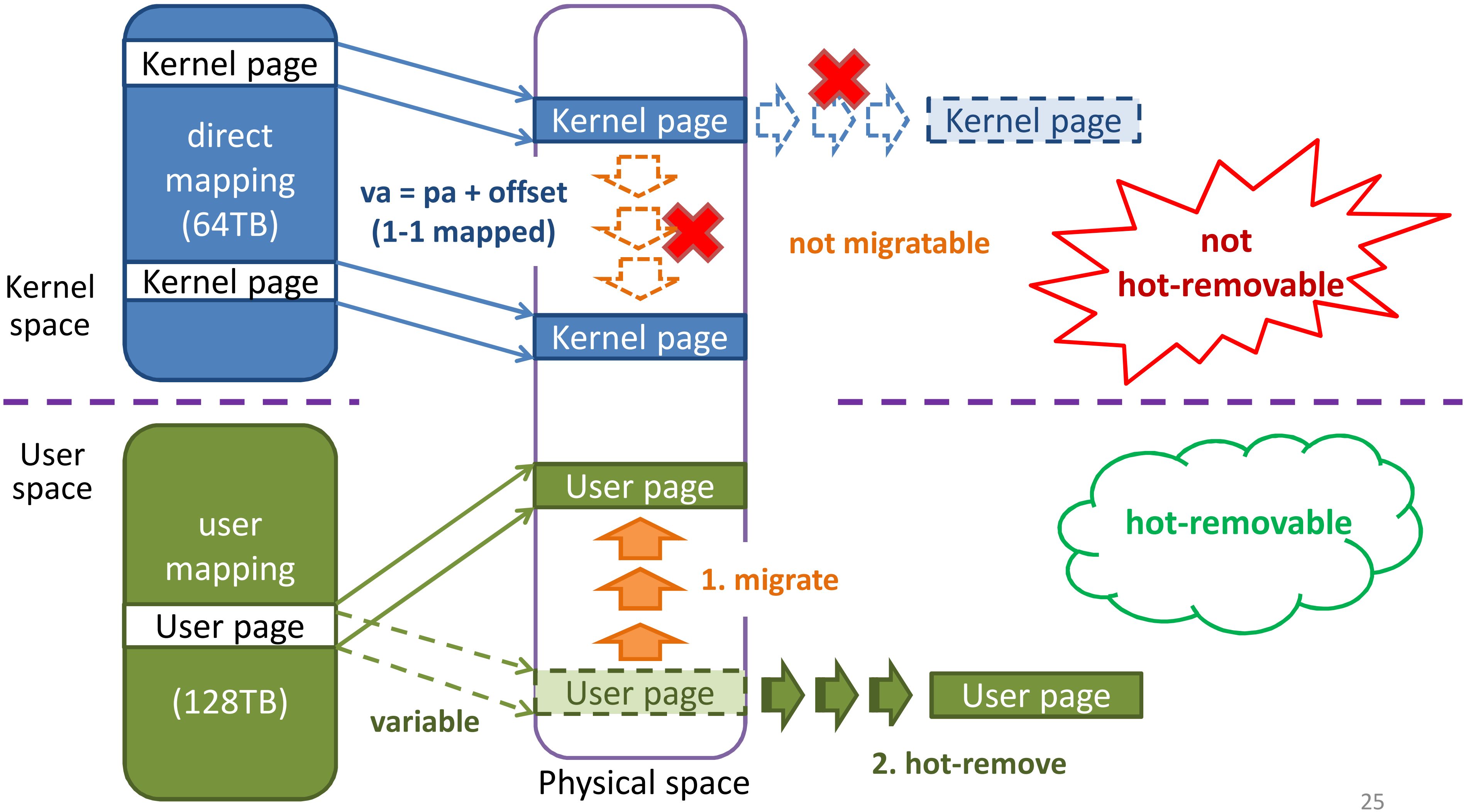
Memory hot-remove

- Merged into Linux 3.9
- Configuration
  - mm/Kconfig

```
config MEMORY_HOTREMOVE
	bool "Allow for memory hot remove"
	select MEMORY_ISOLATION
	select HAVE_BOOTMEM_INFO_NODE if X86_64
	depends on MEMORY_HOTPLUG && ARCH_ENABLE_MEMORY_HOTREMOVE
	depends on MIGRATION
```

Memory hot-remove

- Kernel pages cannot be hot-removed



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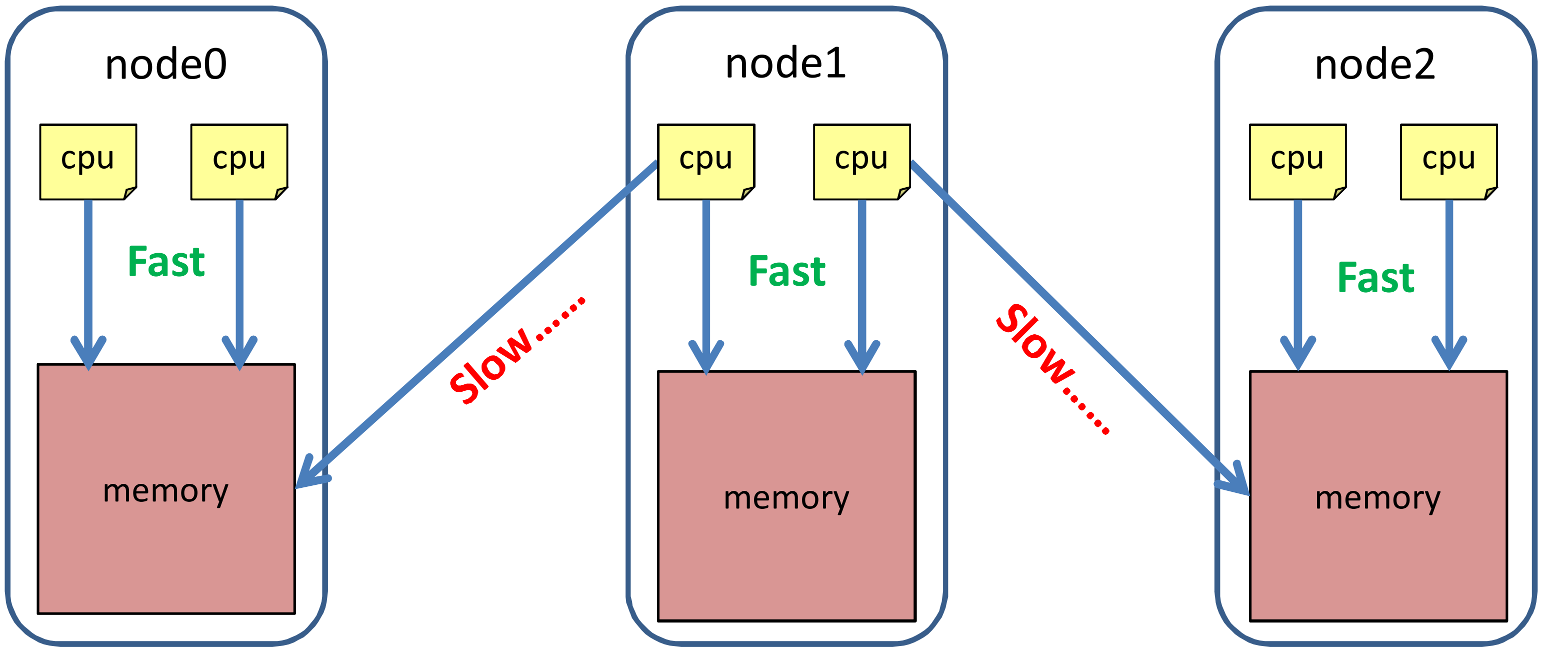
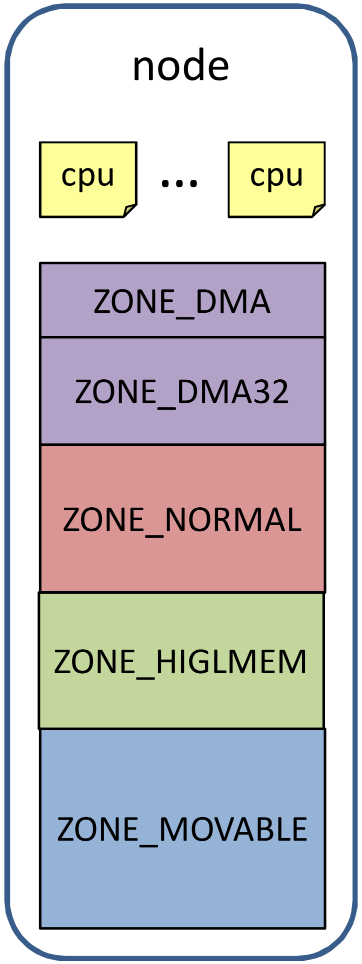
Movable node

- NUMA: Non-Uniform Memory Access
  - A node consists of a set of CPUs and memory.
  - CPUs access memory in the same node faster.
  - Meaningful in 64bits platform only. 32bits platform has only one node.



Movable node

- Zone: Different types of memory in a node



ZONE_DMA / ZONE_DMA_32 (64bits only): used for DMA.

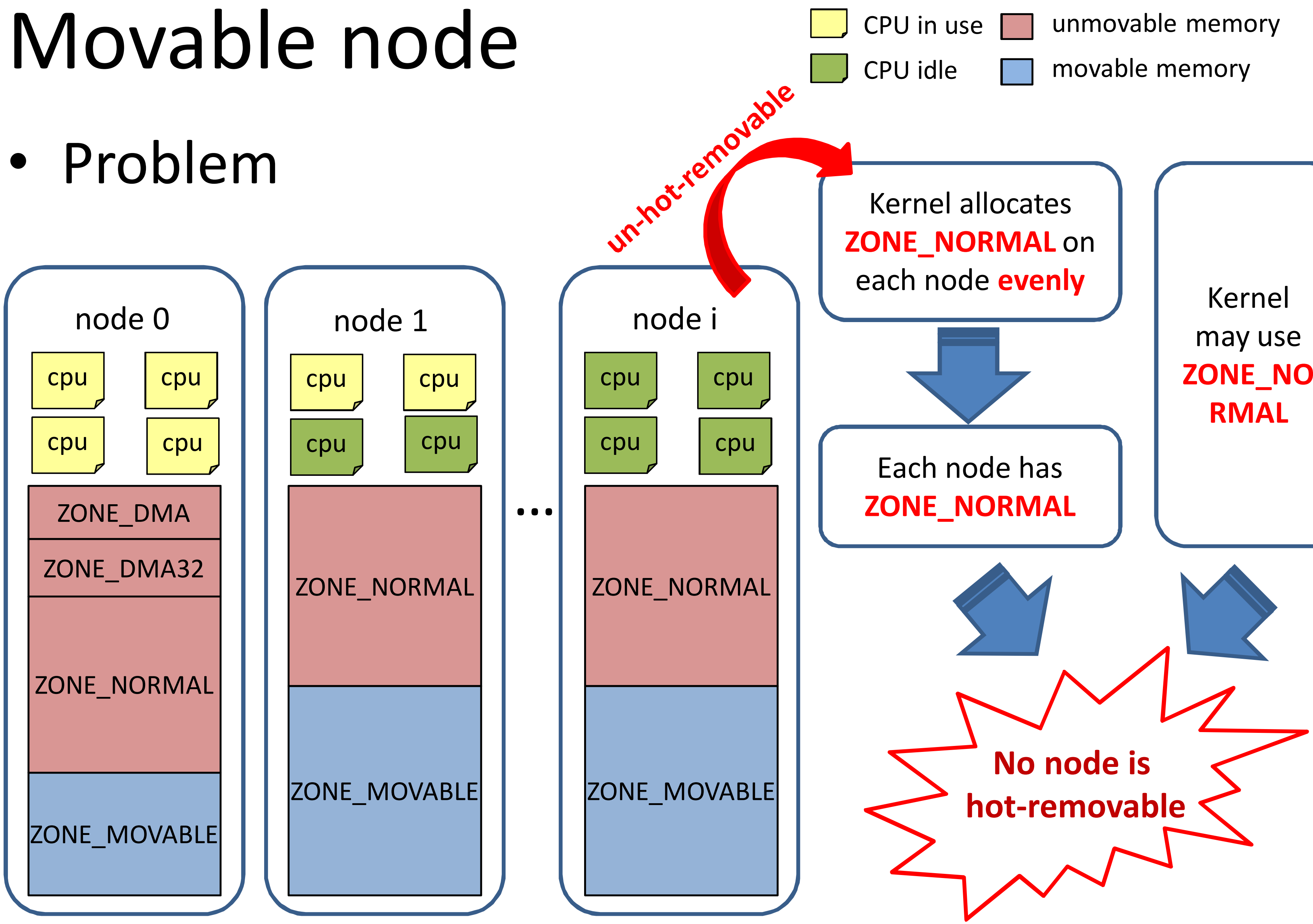
ZONE_NORMAL: Memory directly mapped, used by kernel and user space.

ZONE_HIGHMEM: For 32bits kernel to access memory not directly mapped.

ZONE_MOVABLE: Memory can be migrated. (user space only)

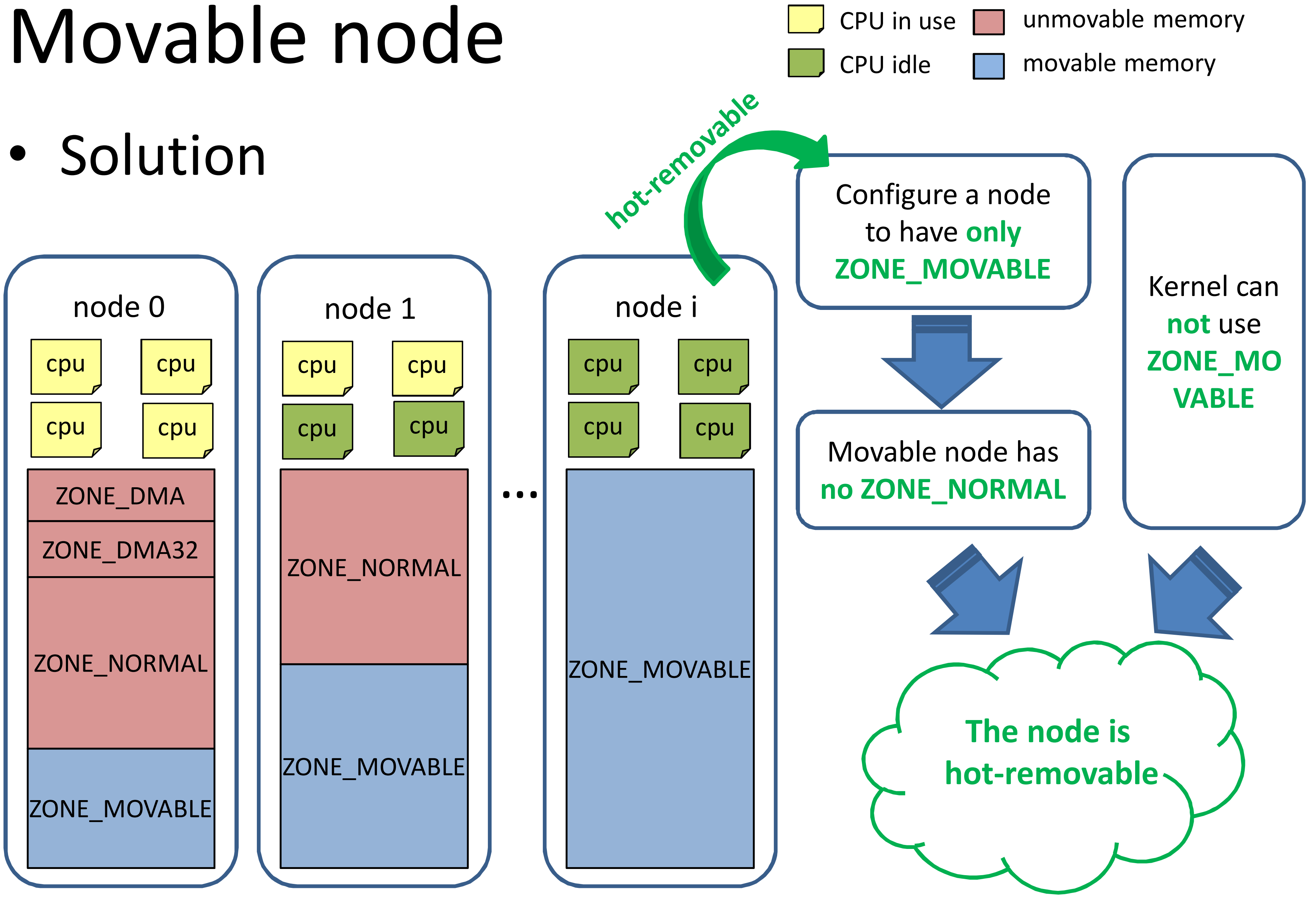
Movable node

- Problem



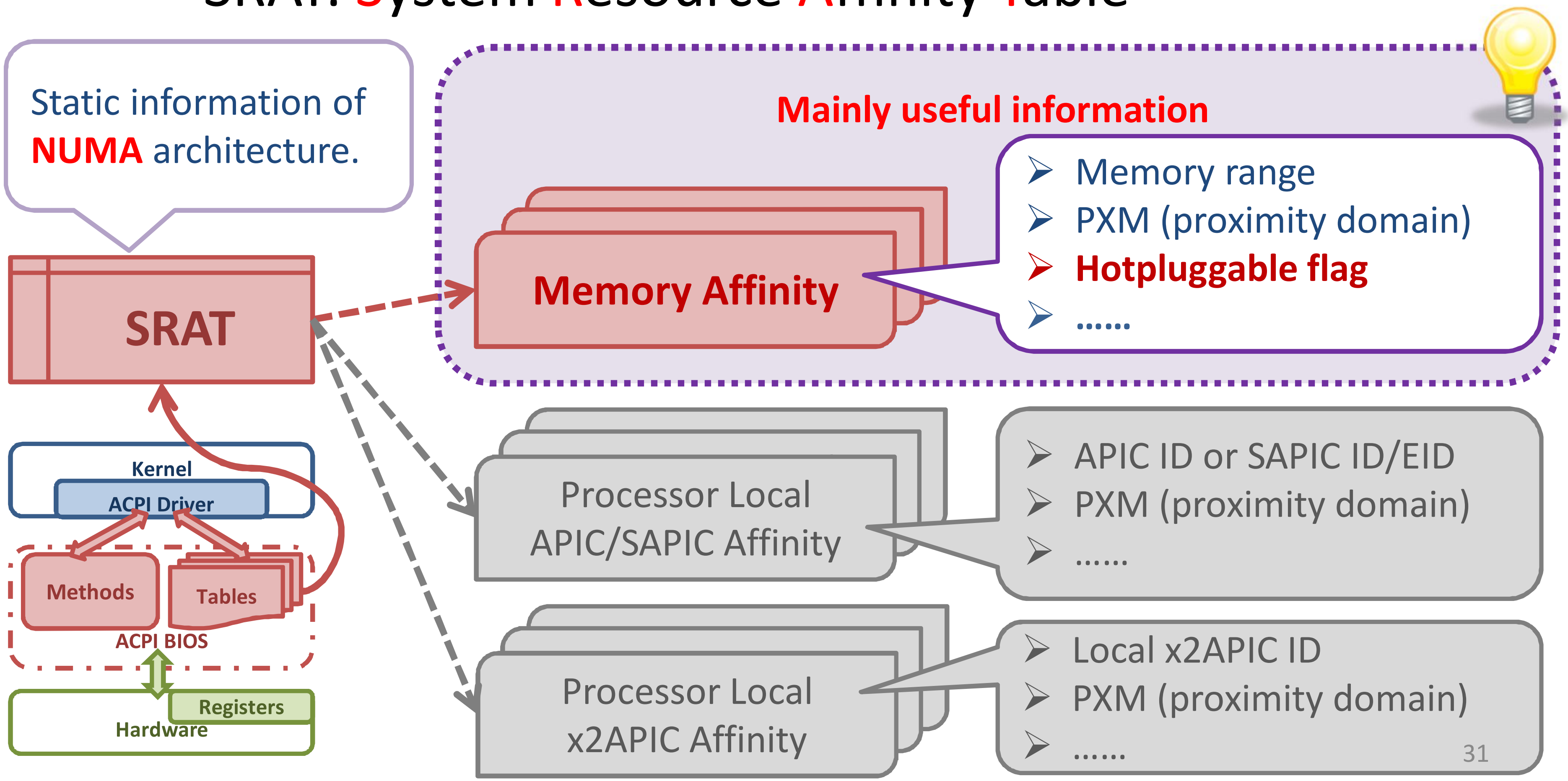
Movable node

- Solution



Movable node

- Static configuration
  - SRAT: System Resource Affinity Table



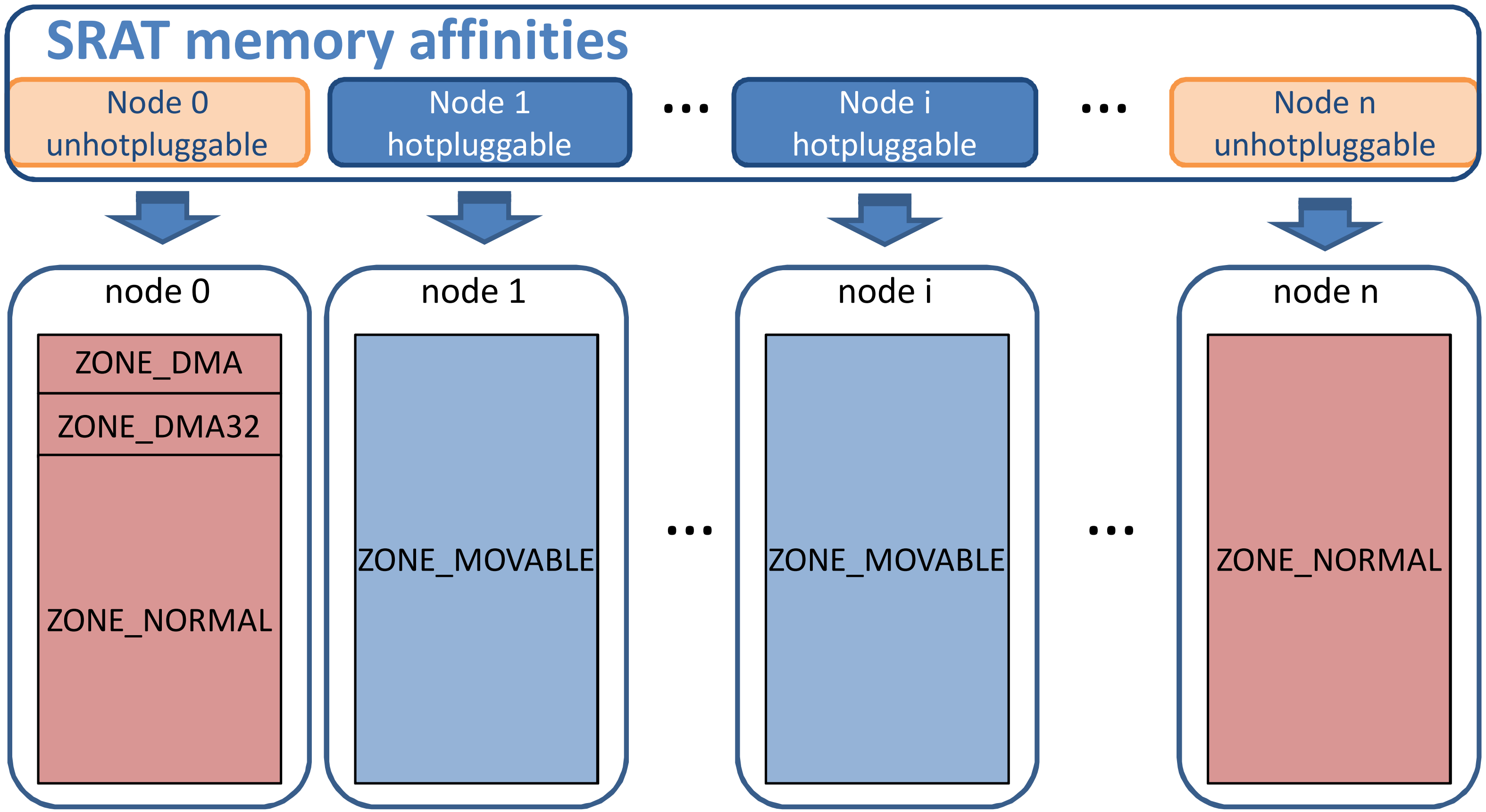
Movable node

unmovable memory
movable memory

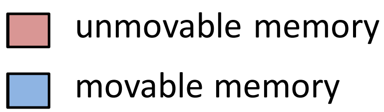
- movablecore = **acpi**

(New)

- **Use SRAT to arrange ZONE_MOVABLE.**
- **Only for memory hotplug users.**
- **Still being pushing.**

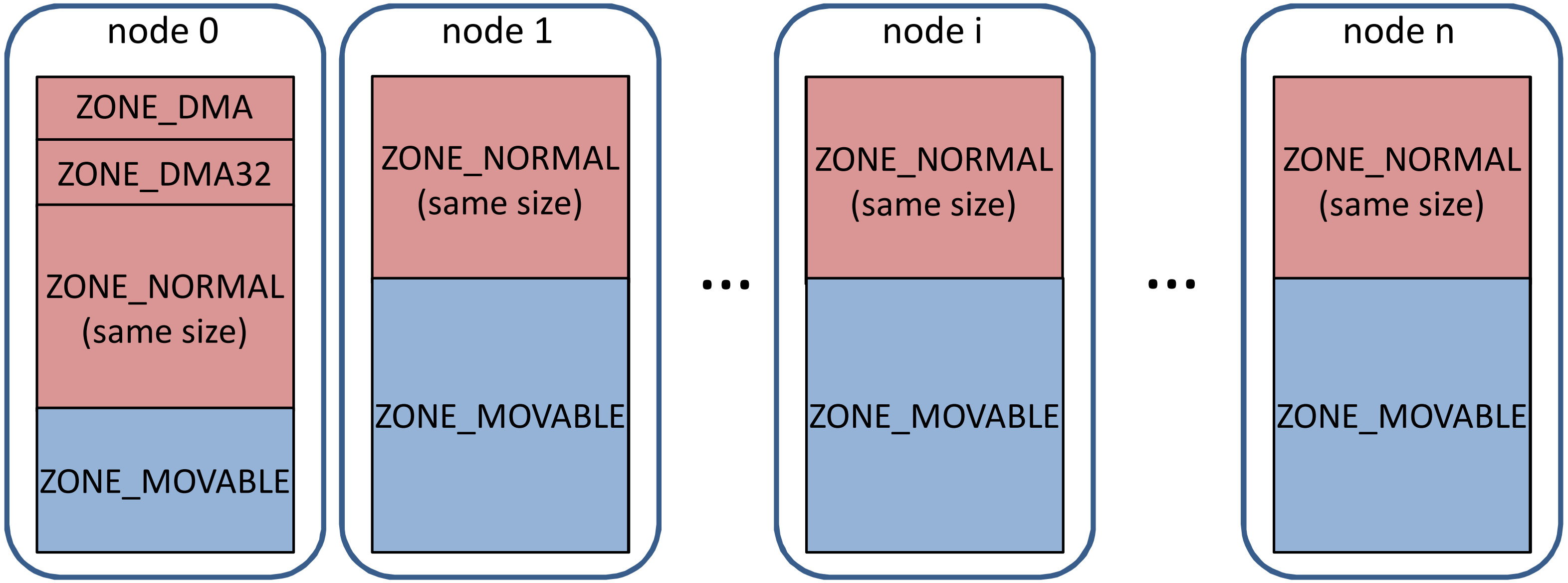


Movable node



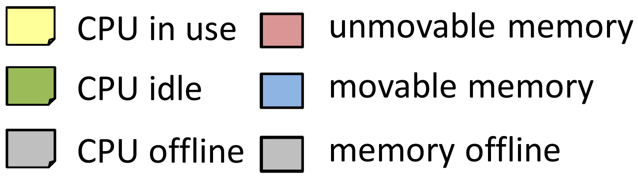
- The old way (no performance lost)
  - kernelcore / movablecore = nn {G|M|K}   (**Old**)

- **Allocate ZONE_MORMAL in each node evenly.**
- **For regular users.**

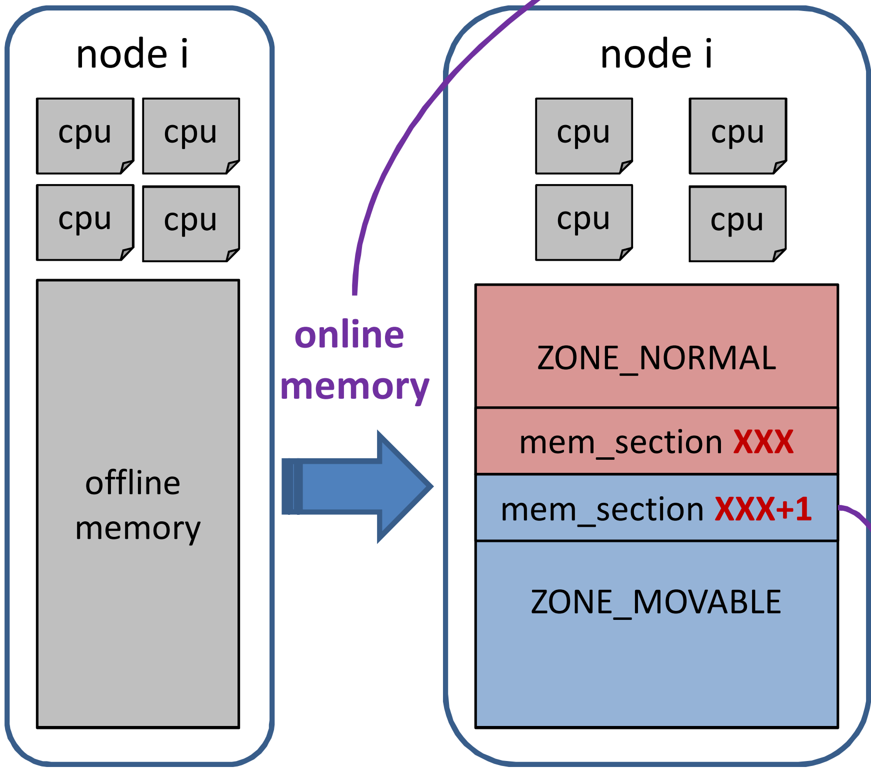


Movable node

- Dynamic configuration

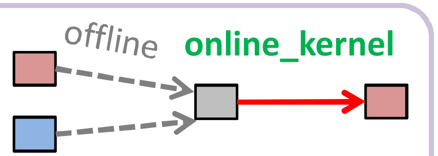


offline and online again

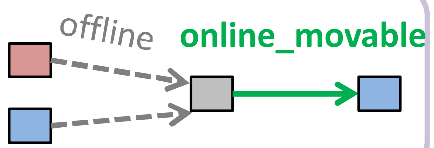


echo **COMMAND** > /sys/devices/system/node/nodei/memory**XXX**/state

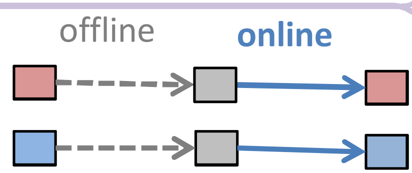
1. **online_kernel (NEW)**
   Set to ZONE_NORMAL.



2. **online_movable (NEW)**
   Set to ZONE_MOVABLE.



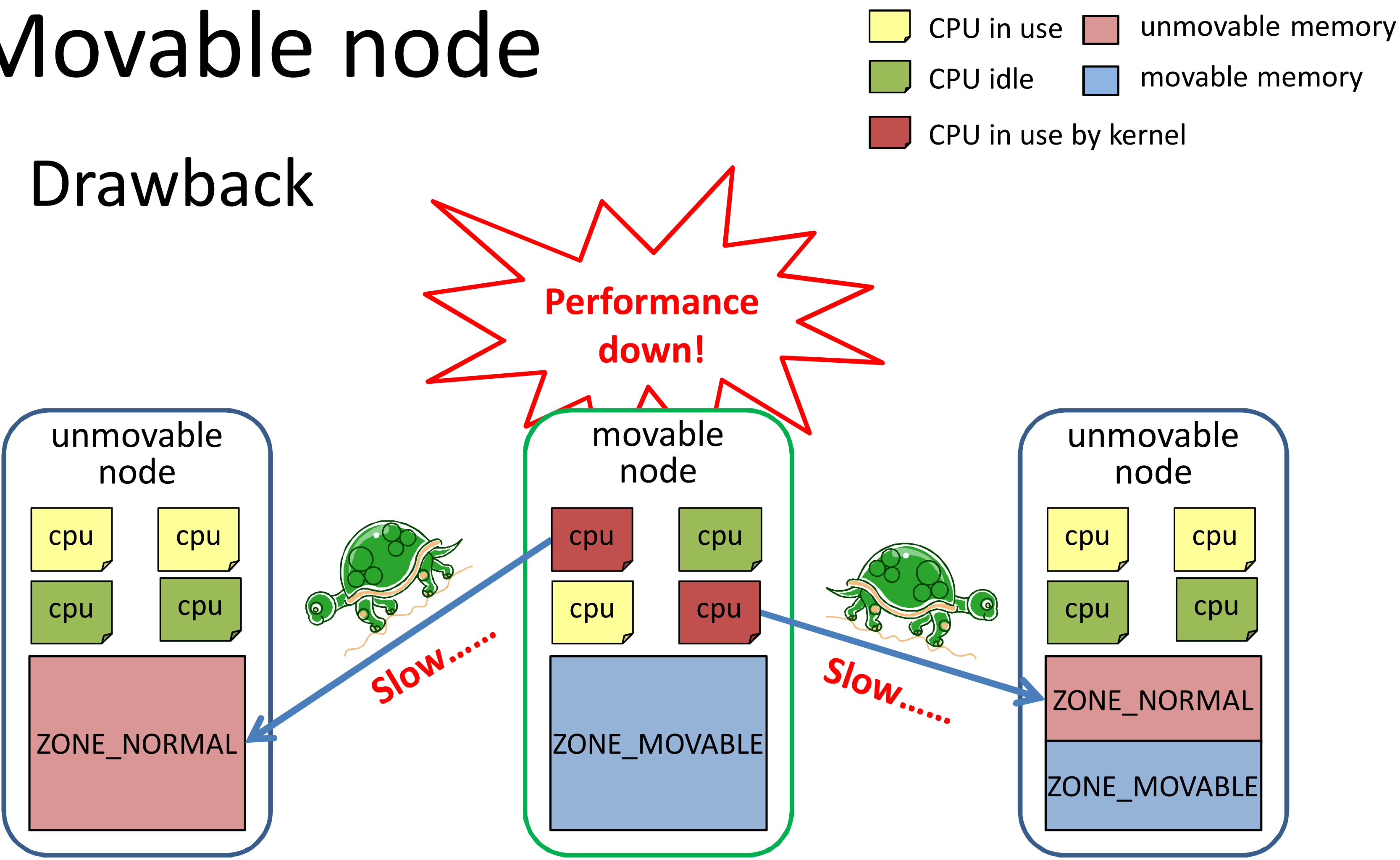
3. **online (Improved)**
   Keep the previous state.
   (ZONE_NORMAL for the first time)



Rule: **ZONE_MOVABLE** should always be after **ZONE_NORMAL**, never overlaps.

Movable node

- Drawback



No good enough way to solve this problem now.

Movable node

- Merged into Linux 3.8
- Configuration
  - mm/Kconfig

```
config MOVABLE_NODE
	boolean "Enable to assign a node which has only movable memory"
	depends on HAVE_MEMBLOCK
	depends on NO_BOOTMEM
	depends on X86_64
	depends on NUMA
	default n
```

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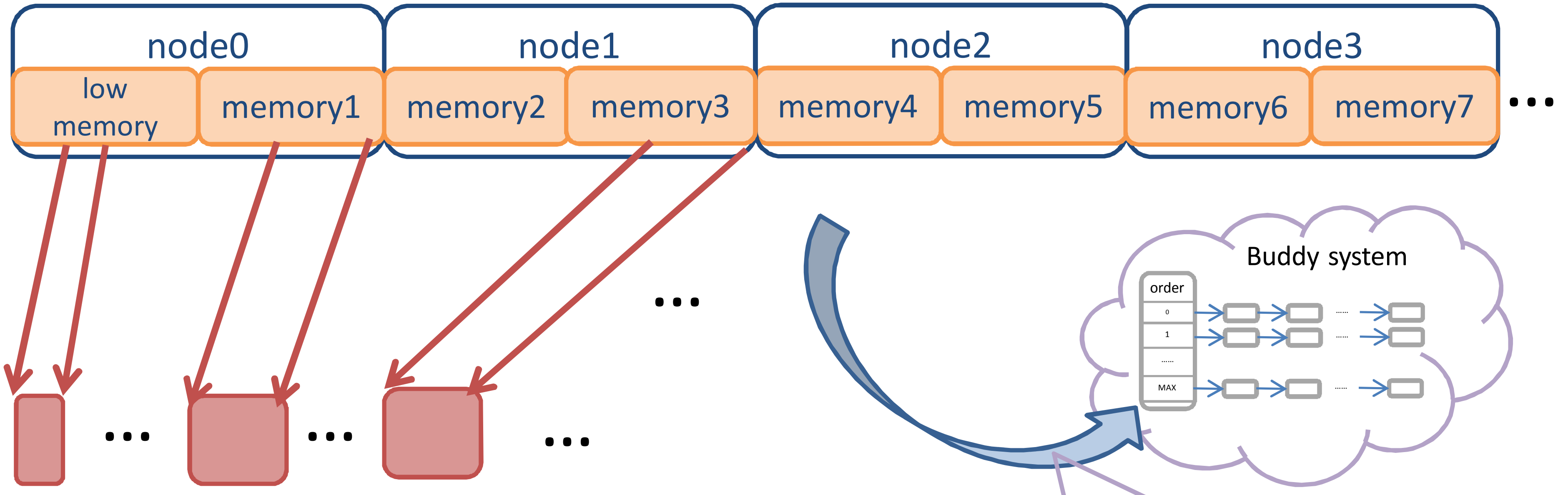
Bootmem handling

- Memblock: A bootmem allocator
  - Consists of two arraies

memblock.memory[]: All the present memory in the system.

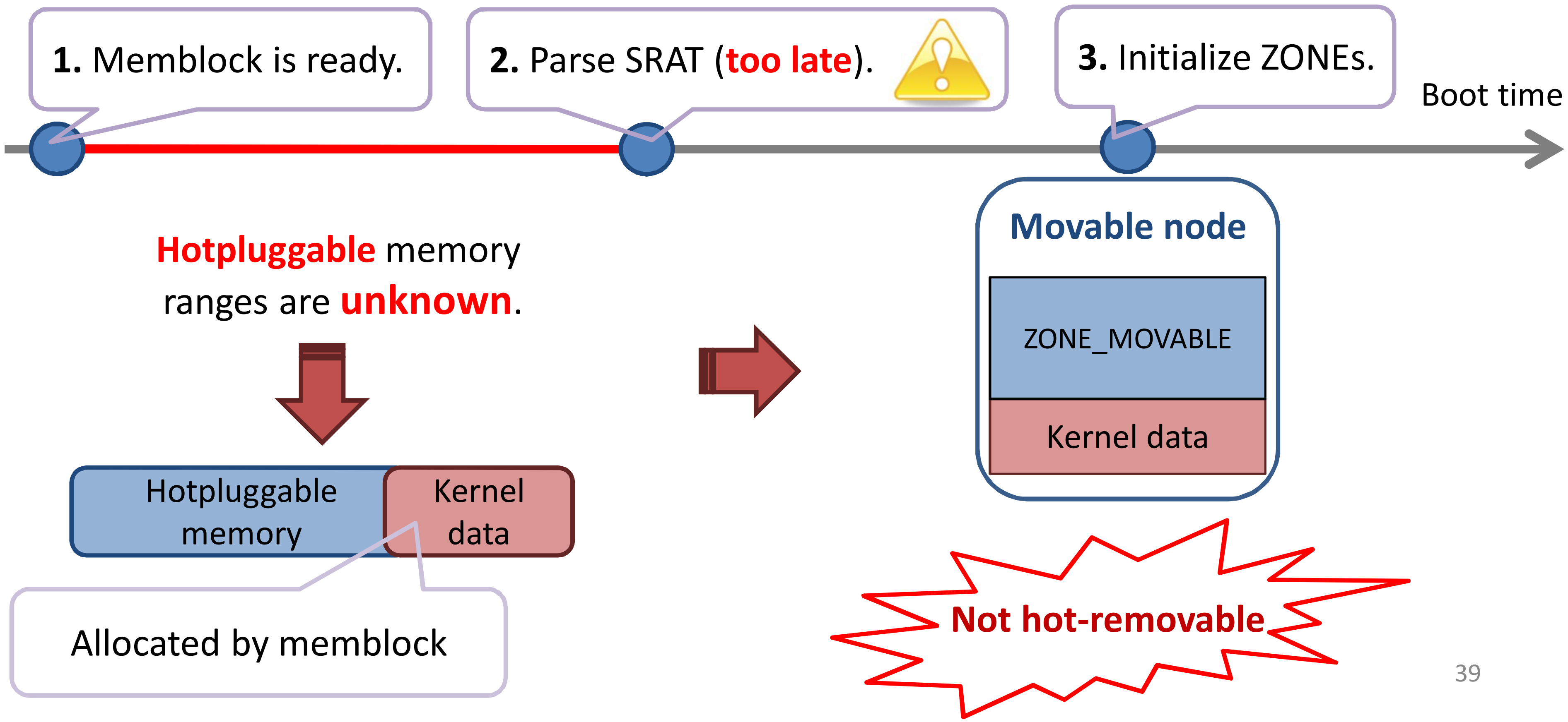


memblock.reserve[]: Allocated memory.

Free unused memory to buddy system at last.

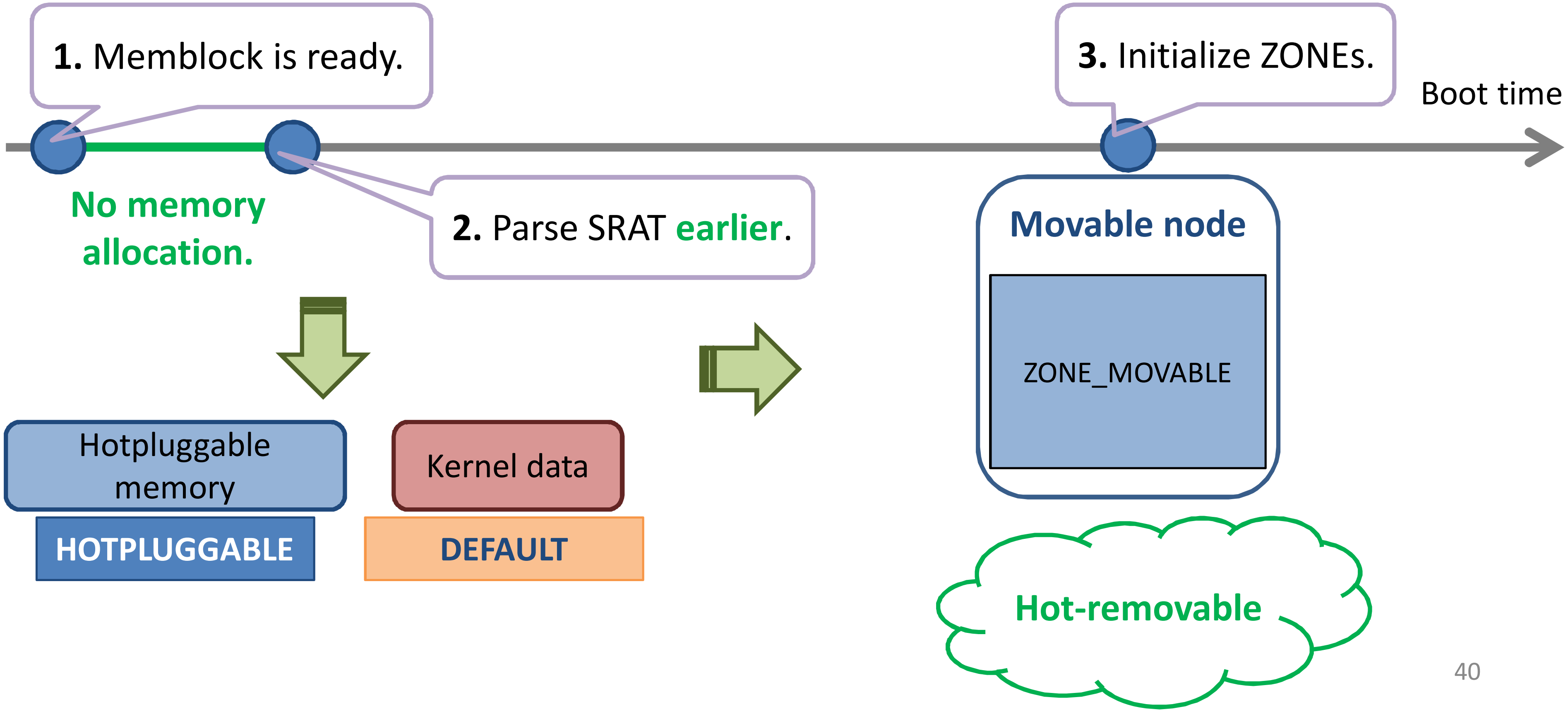
Bootmem handling

- Problem at boot time
  - Bootmem allocator memblock may allocate **hotpluggable** memory for kernel at boot time.

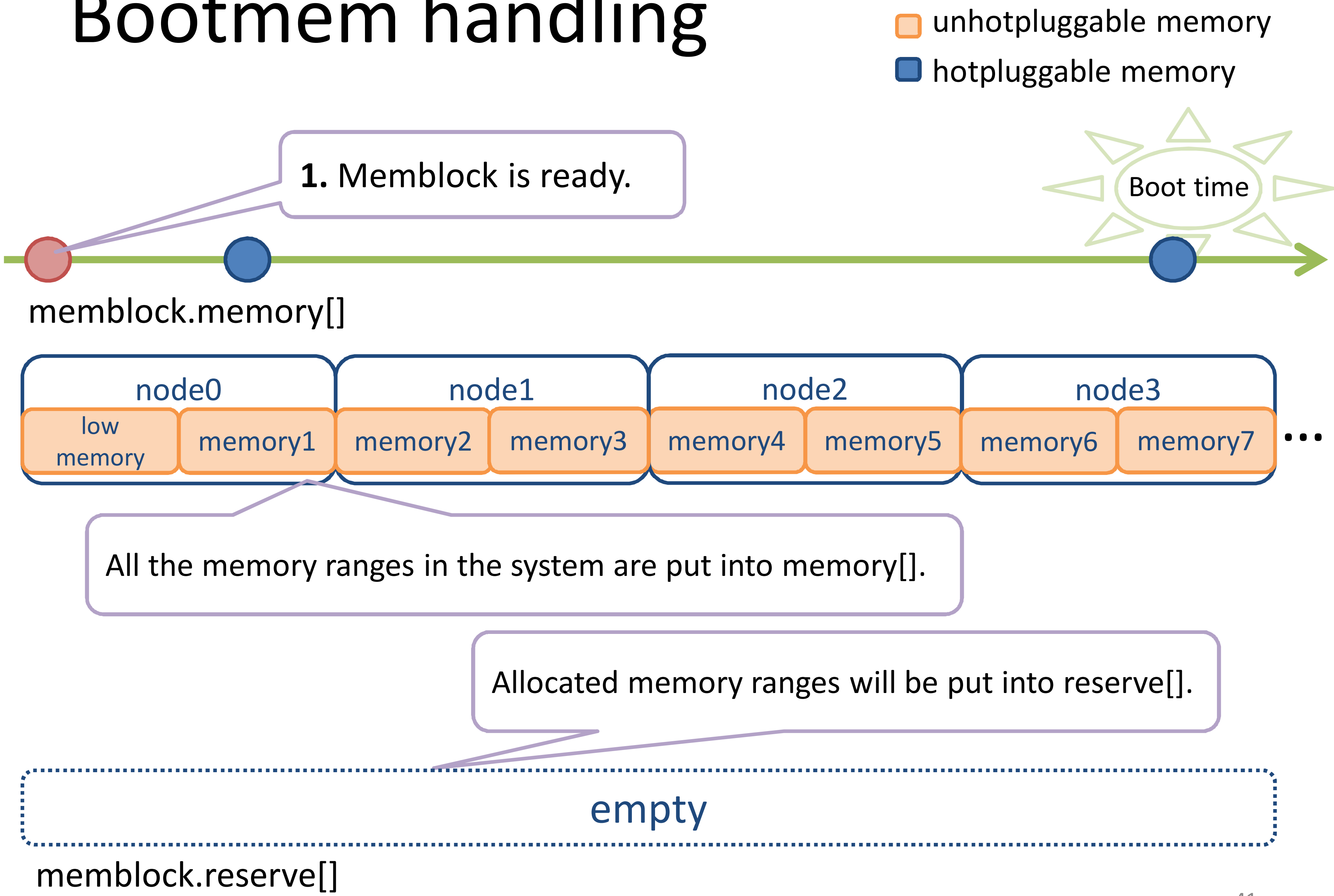


Bootmem handling

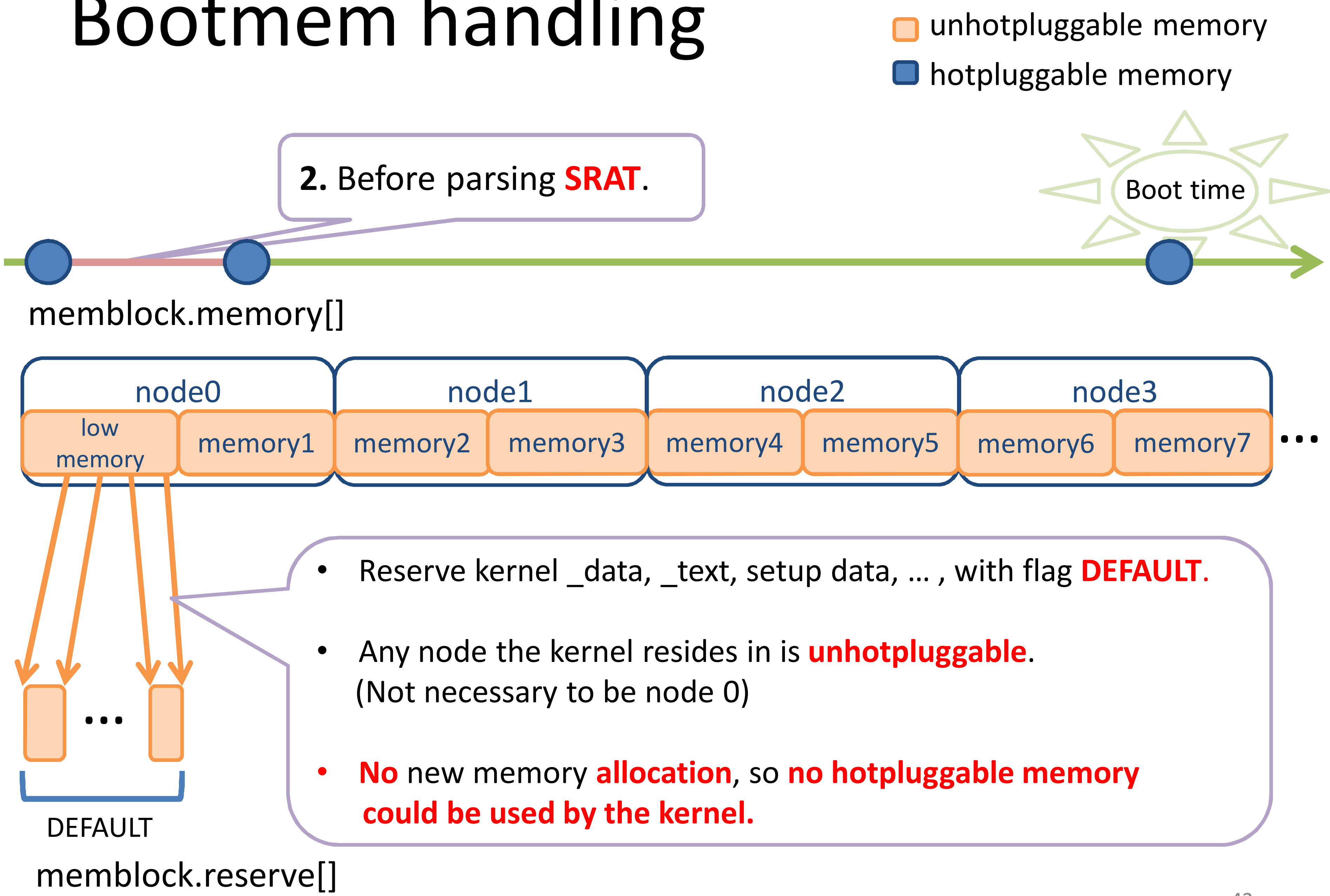
- Solution
  1. Parse SRAT **earlier**, before memblock starts to work.
  2. Introduce flags into memblock, and reserve hotpluggable memory with a special **flag** in memblock.



Bootmem handling

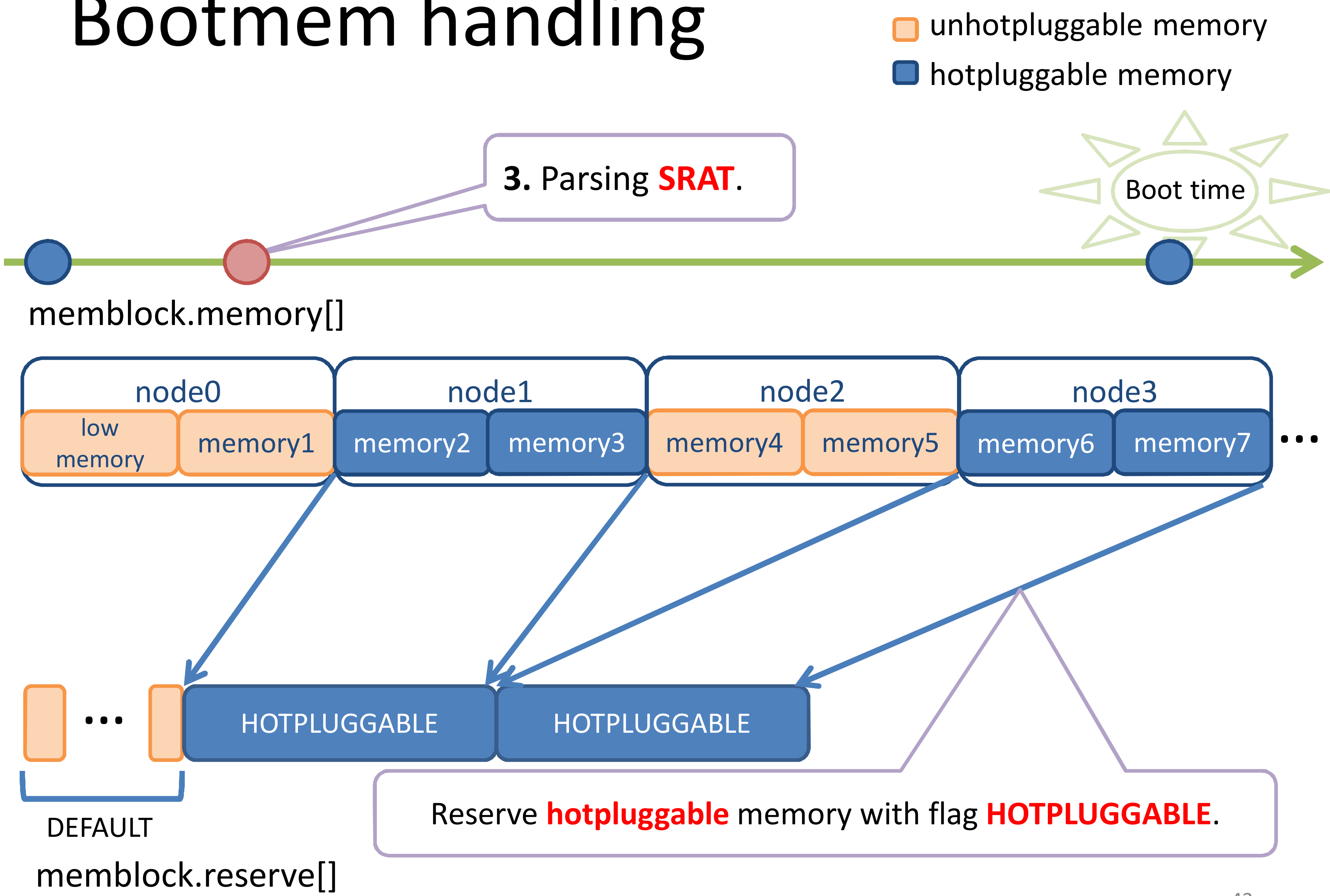


Bootmem handling

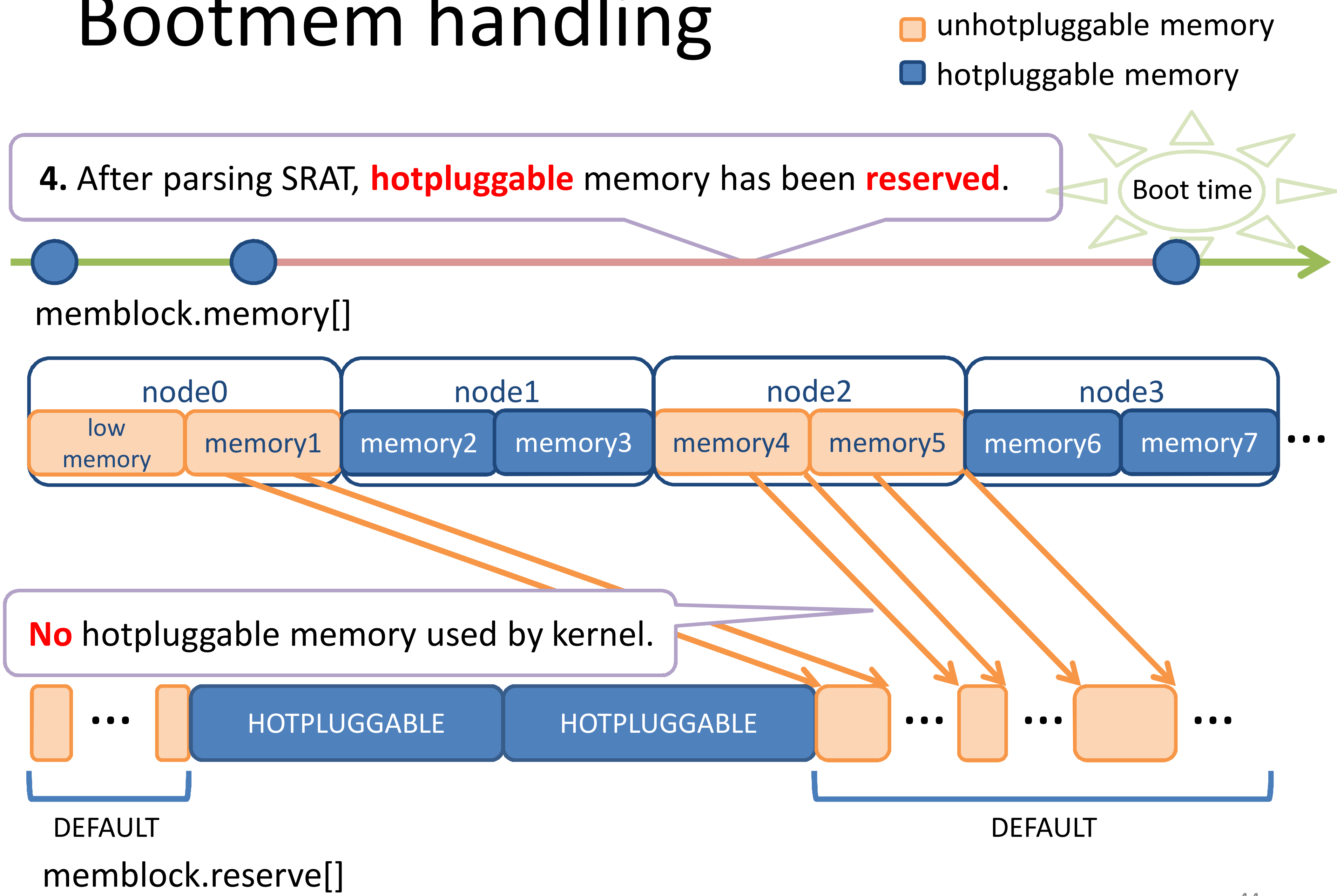


- Reserve kernel _data, _text, setup data, … , with flag **DEFAULT**.
- Any node the kernel resides in is **unhotpluggable**.
  (Not necessary to be node 0)
- **No** new memory **allocation**, so **no hotpluggable memory could be used by the kernel.**

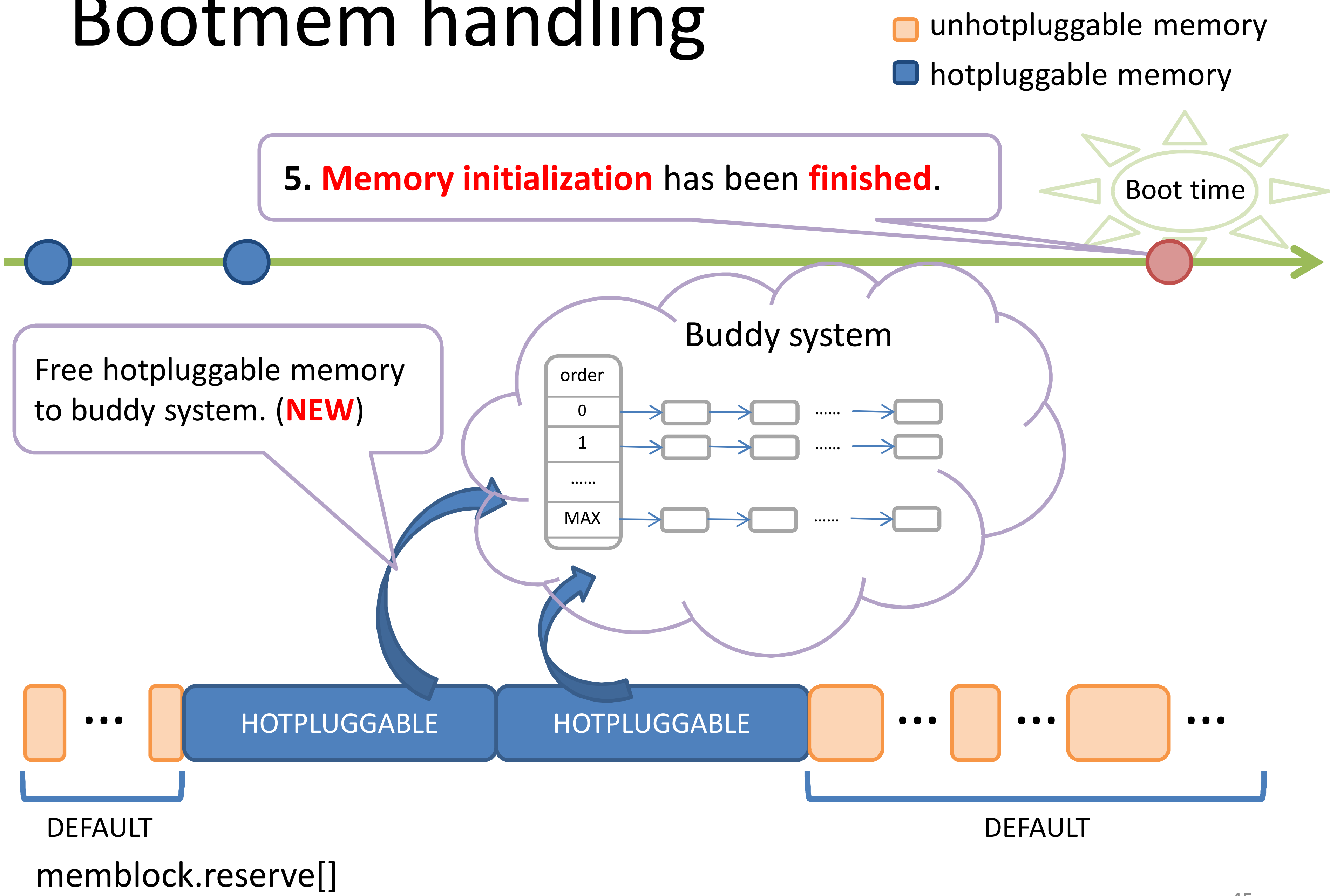
Bootmem handling



Bootmem handling



Bootmem handling



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Future work

- Node local pagetable and vmemmap.
  - Improve performance.
- Migrate user pages pinned in memory.
  - For those who pin pages for a long time.
- User space tools, like libnuma and numactl.
  - A library of functions.
  - Commands.

Thank you!
Q&A

Movable node

- Performance tests

Alloc: 40% down

Read: 33% down

Write: 12% down