The DragonBeam Framework:
Hardware-Protected Security Modules for In-Place Intrusion Detection

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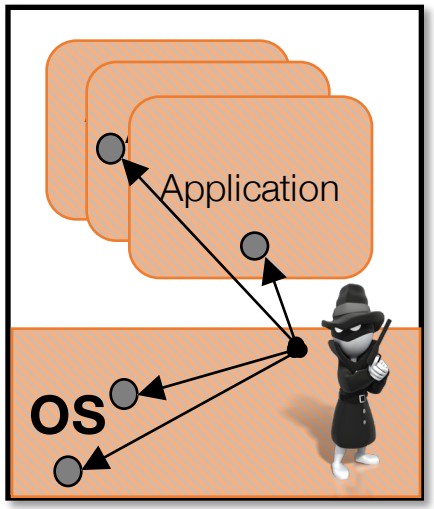
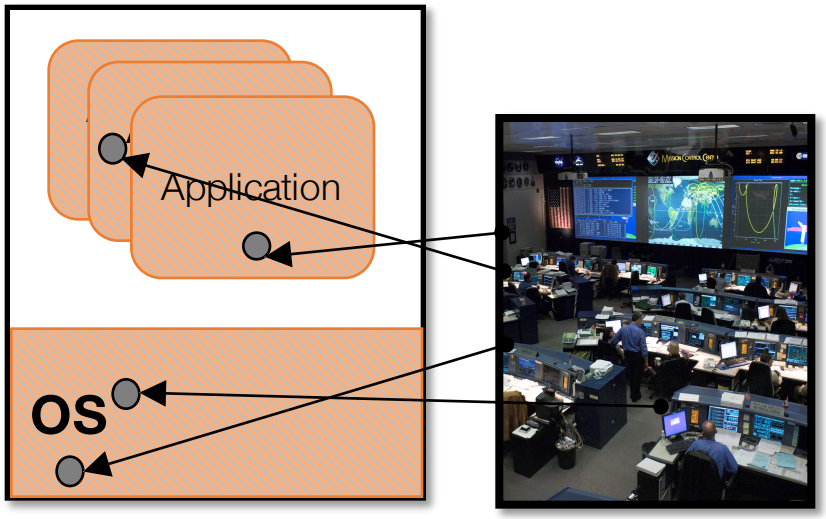
Security Monitoring

In-place Monitoring

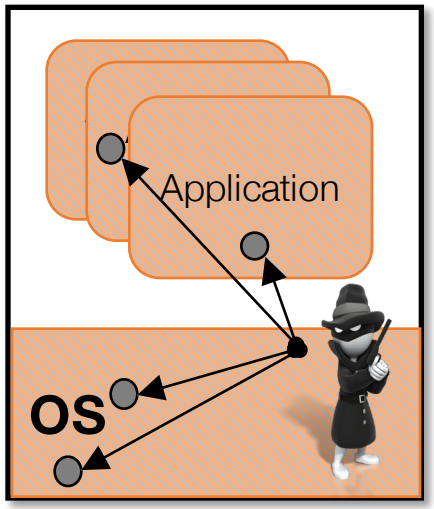


External Monitoring



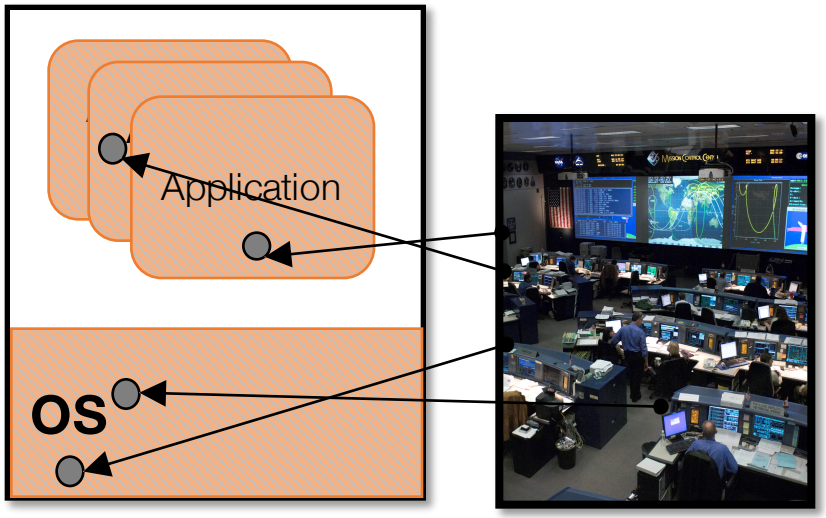
Security Monitoring

In-place Monitoring



Unsafety of the monitor

External Monitoring



Security Monitoring

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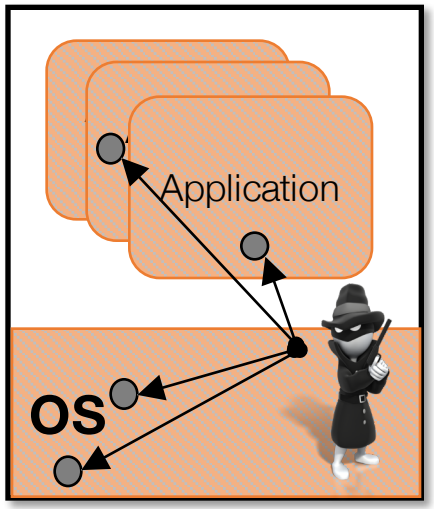

Unsafety of the monitor

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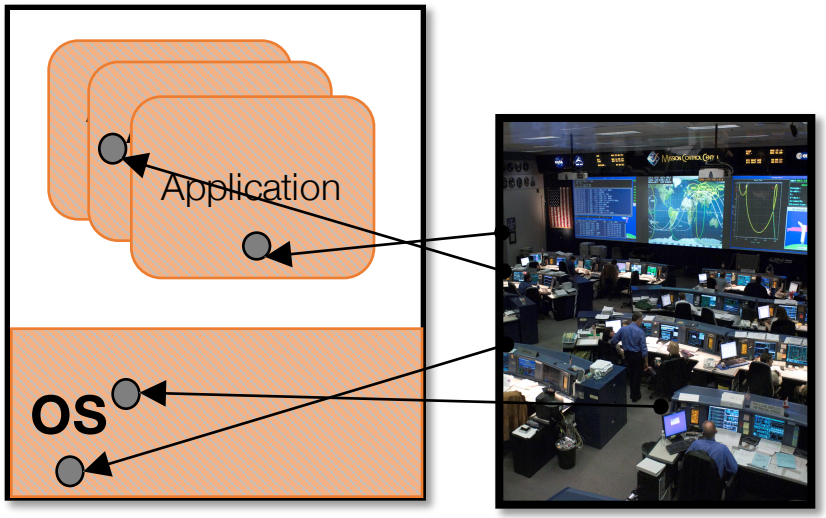
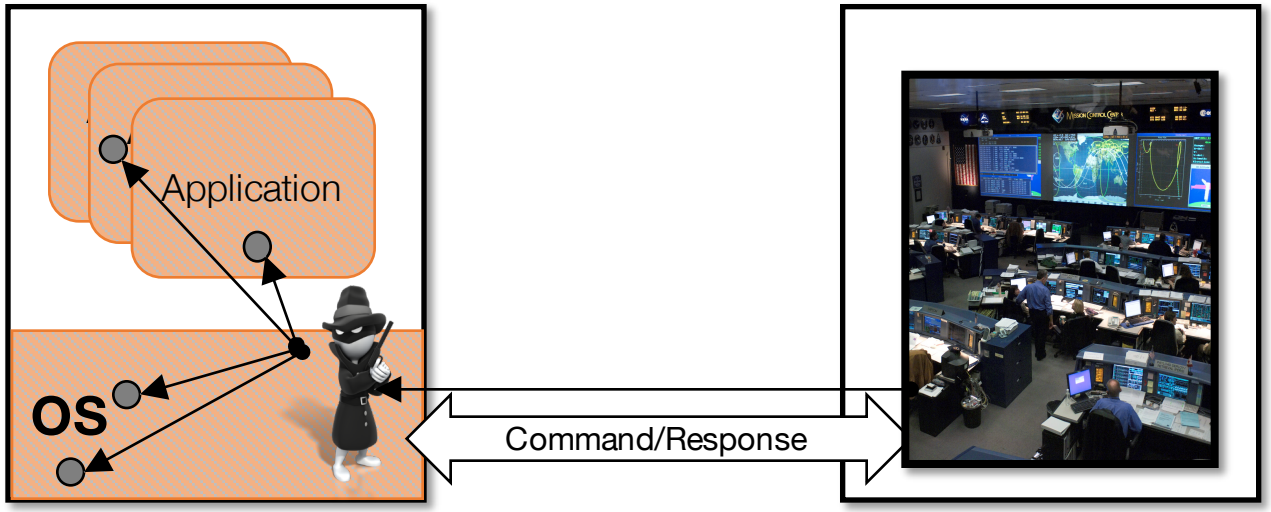


Semantic gap

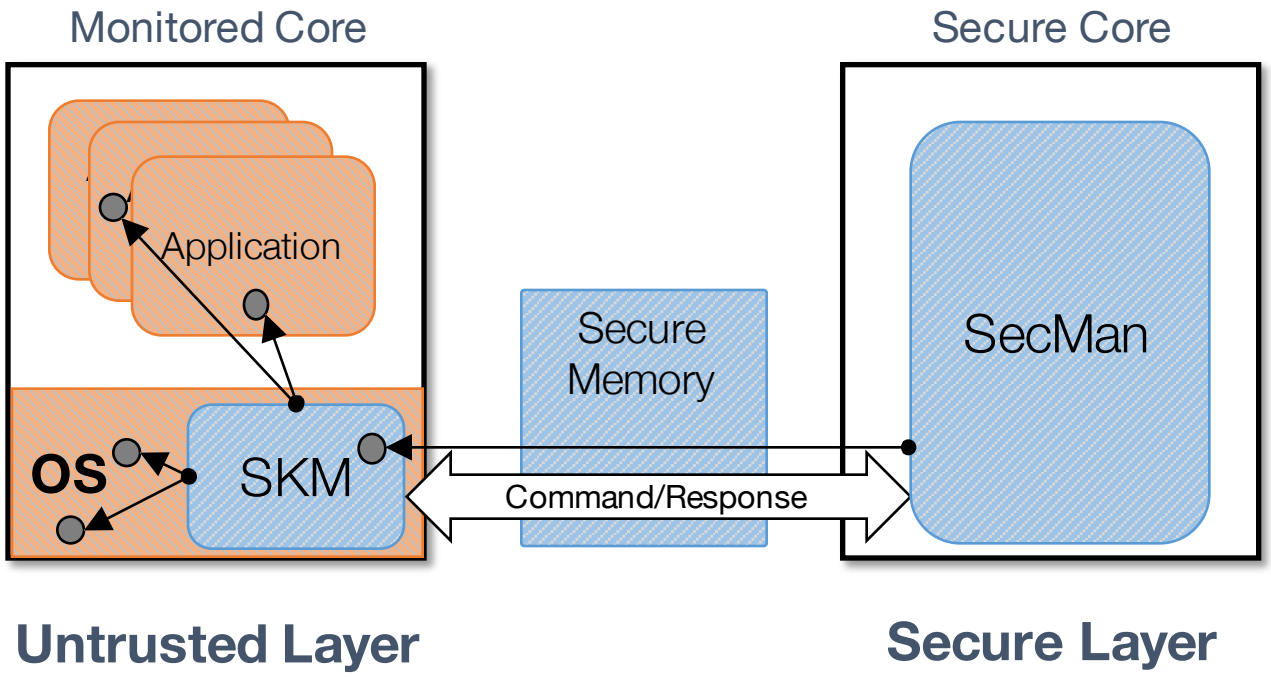
DragonBeam Framework



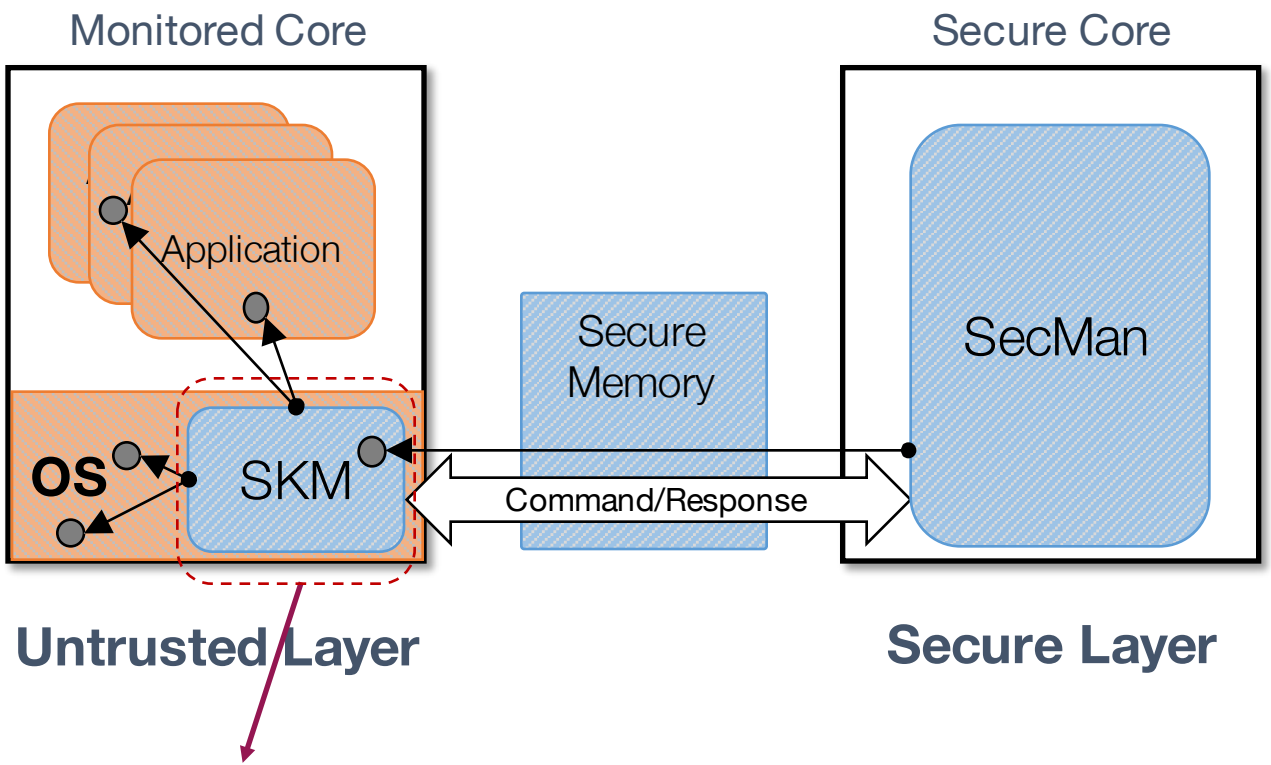
Untrusted Layer

Secure Layer

DragonBeam Framework



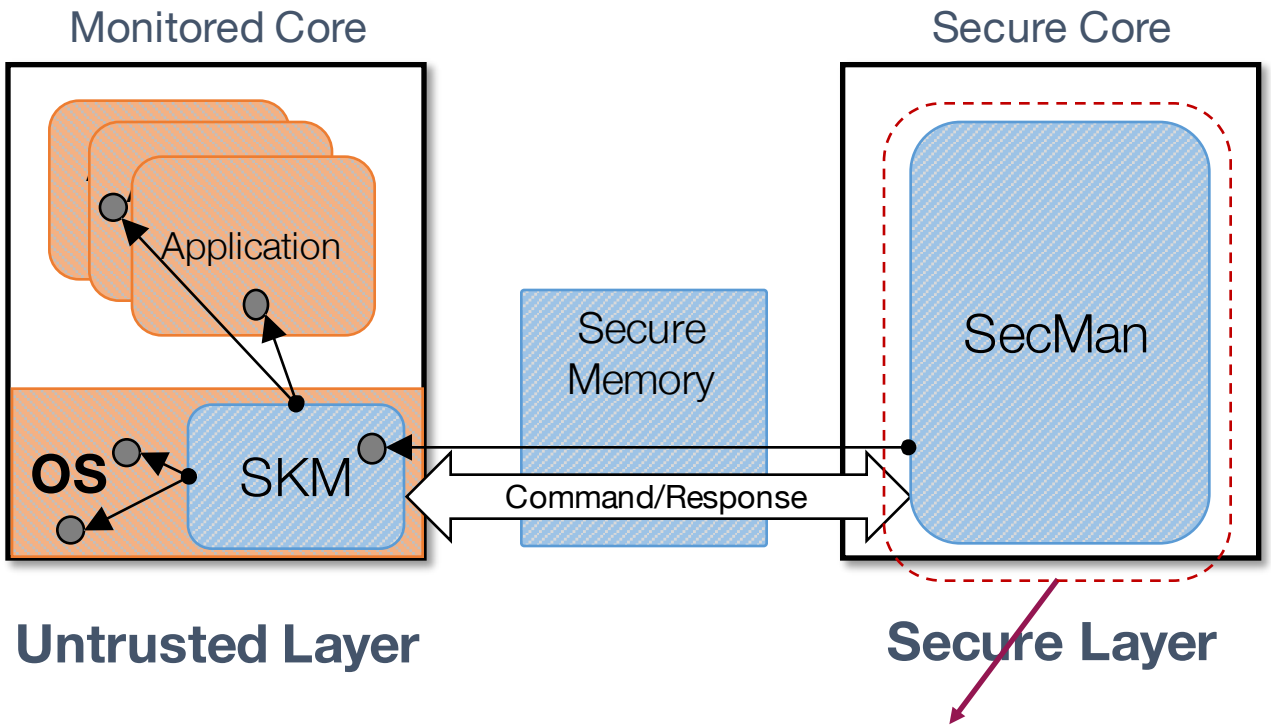
DragonBeam Framework



Secure Kernel Module

- Performs security monitoring operations
- Expands the observability
- Protected by Secure Core

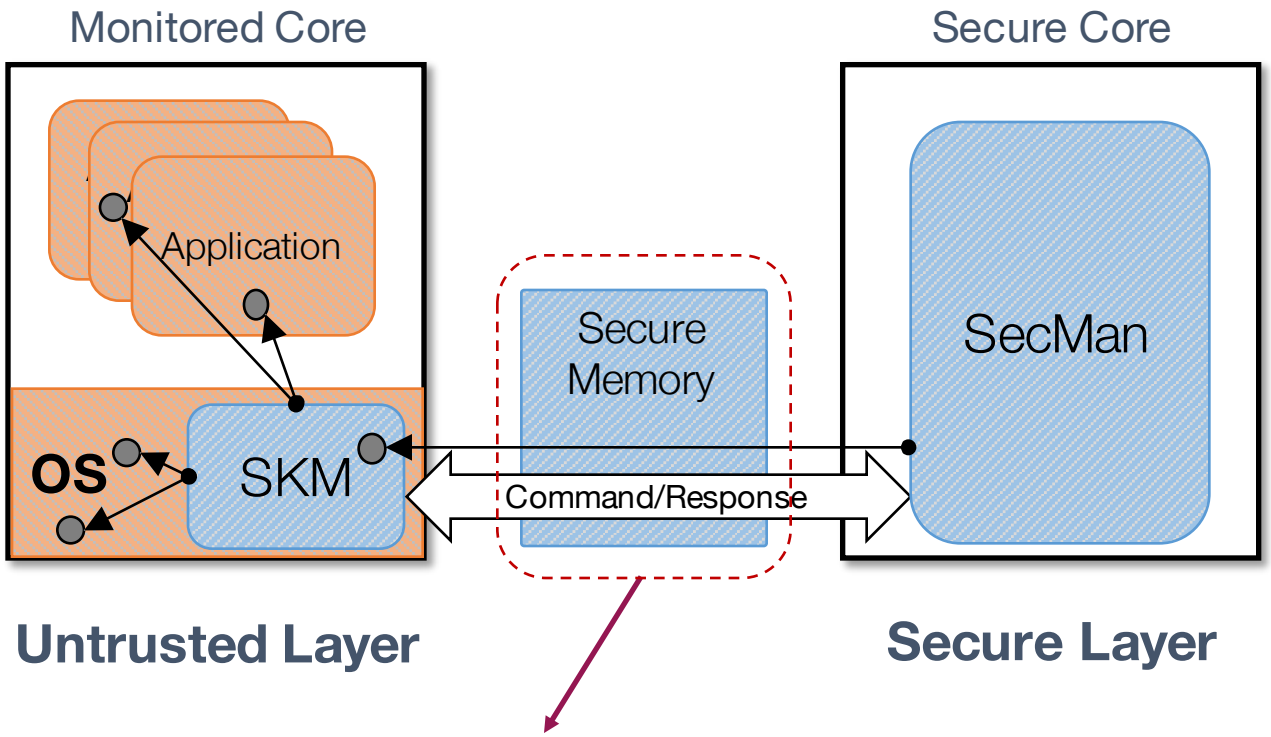
DragonBeam Framework



Secure Kernel Module Manager

- Commands SKM to perform security operations
- Analyzes monitored information
- Guarantees the integrity and the liveness of SKM

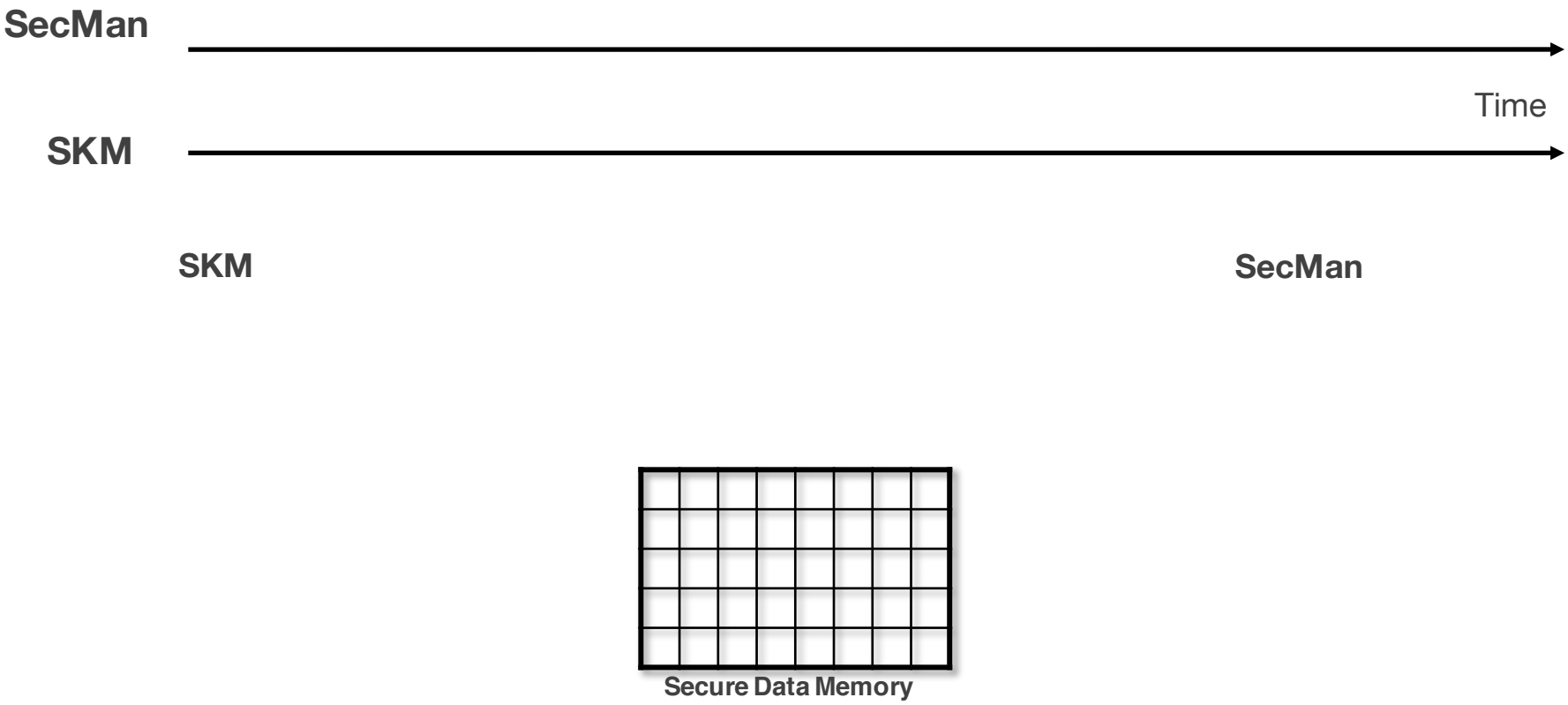
DragonBeam Framework



Secure Memory

- Secure communication channel between SKM and SecMan
  - Only accessible by SKM or Secure Core
- Also hosts SecMan code/data

Example Use Case



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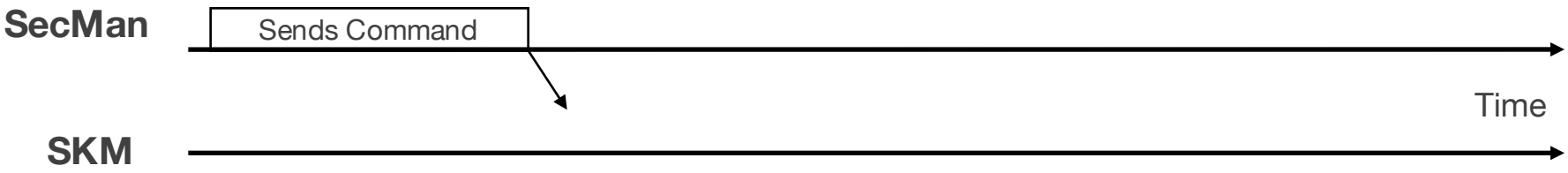
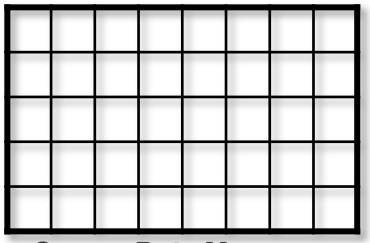


SKM

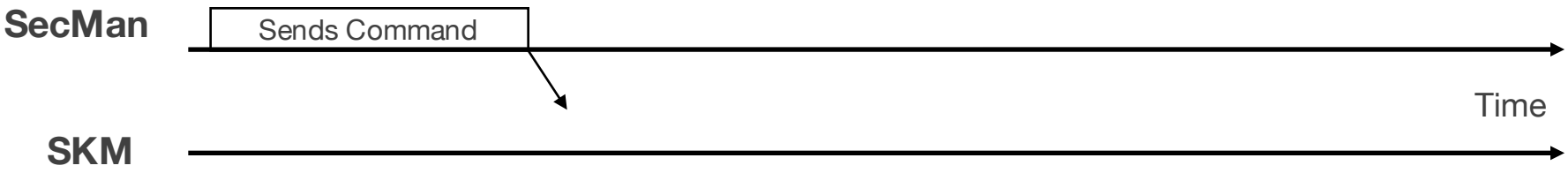
SecMan

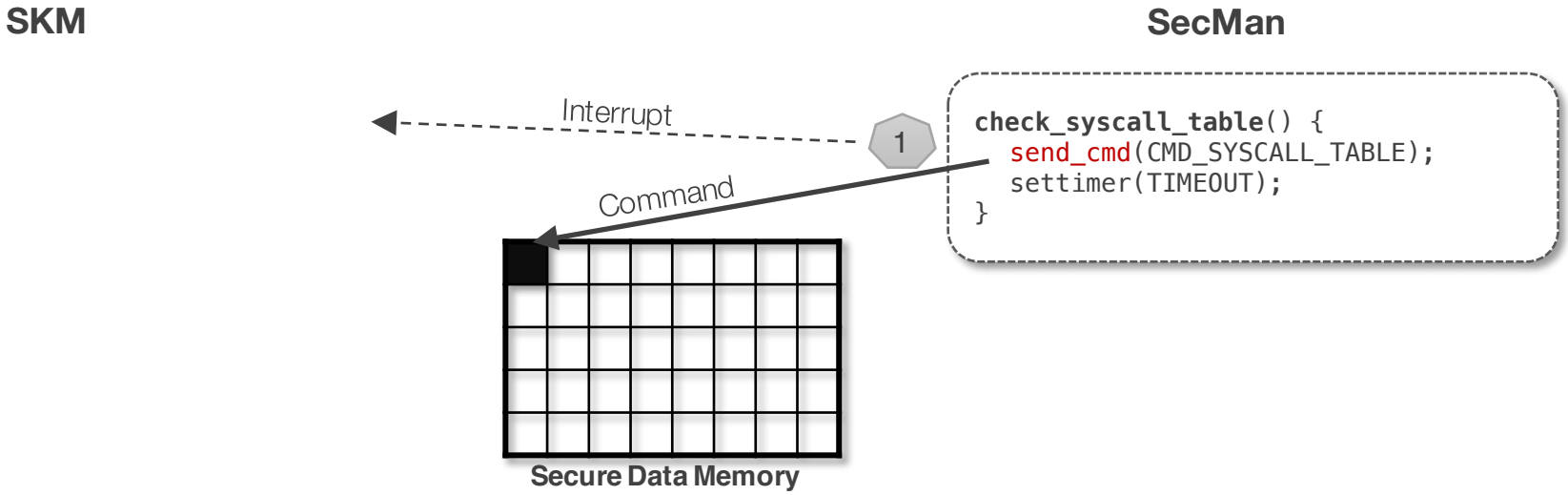
```
check_syscall_table() {
   send_cmd(CMD_SYSCALL_TABLE);
   settimer(TIMEOUT);
}
```



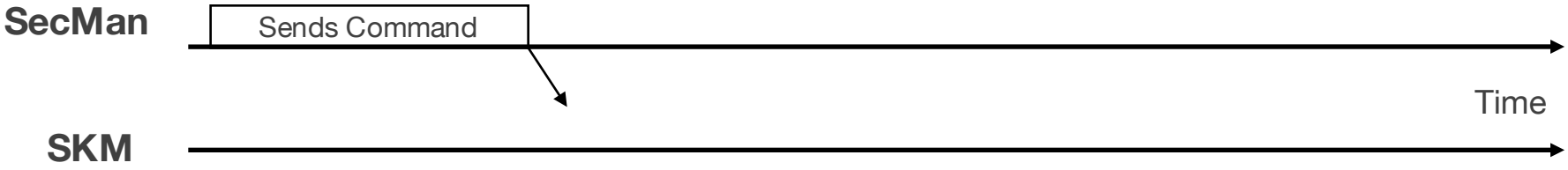
Secure Data Memory

Example Use Case





Example Use Case

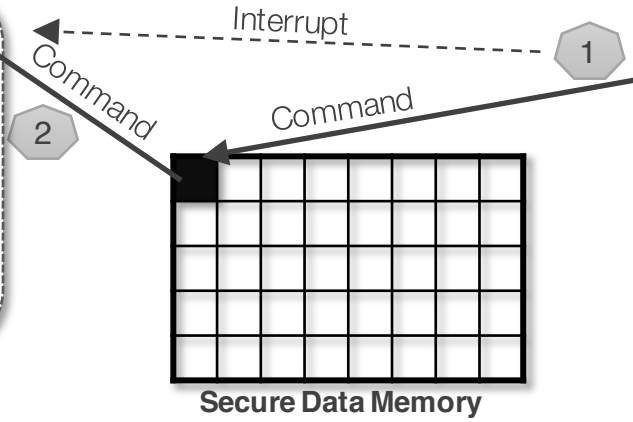


SKM

```
skm_ISR() {
   save sp;
   move sp to secure stack;
   switch (*CMD) {
      …
      case CMD_SYSCALL_TABLE:
         send_syscall_table();
         break;
      …
   }
   restore sp;
}
```

SecMan

```
check_syscall_table() {
   send_cmd(CMD_SYSCALL_TABLE);
   settimer(TIMEOUT);
}
```



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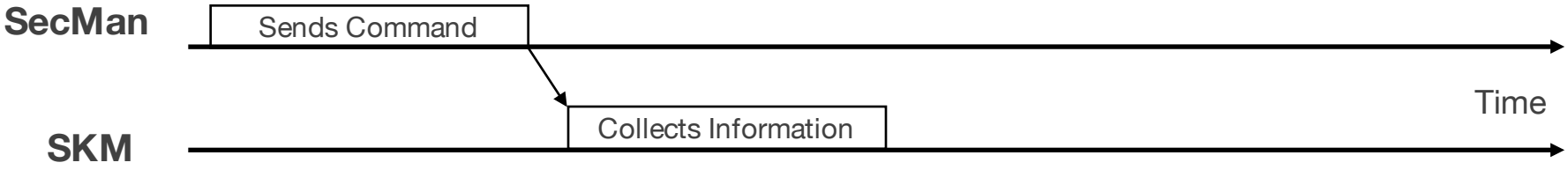
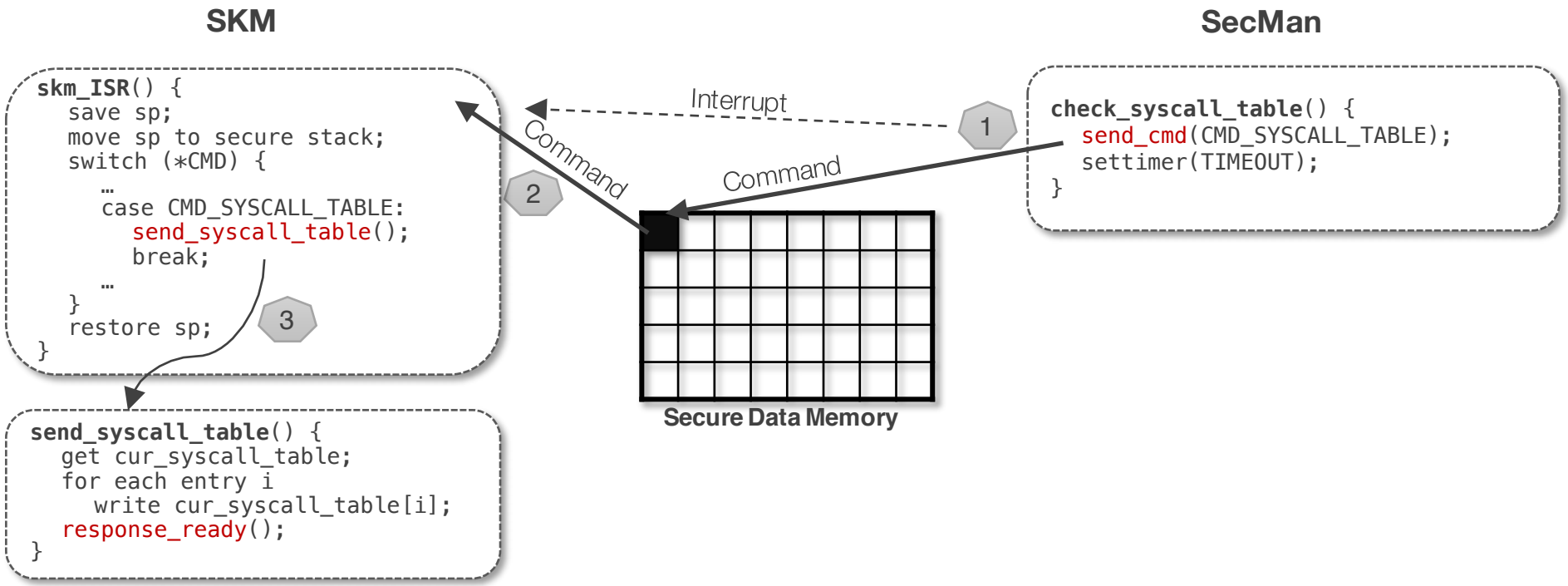
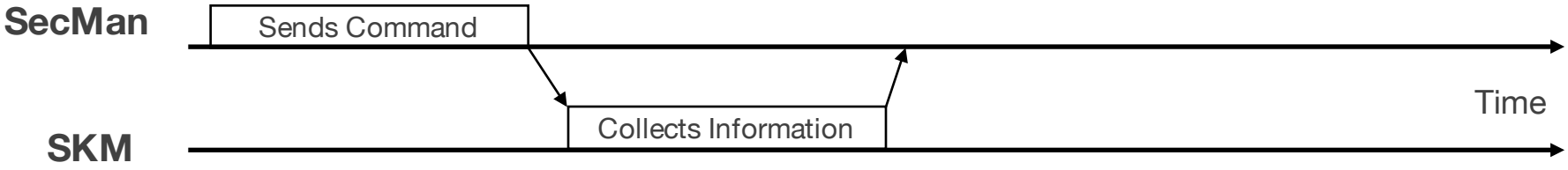
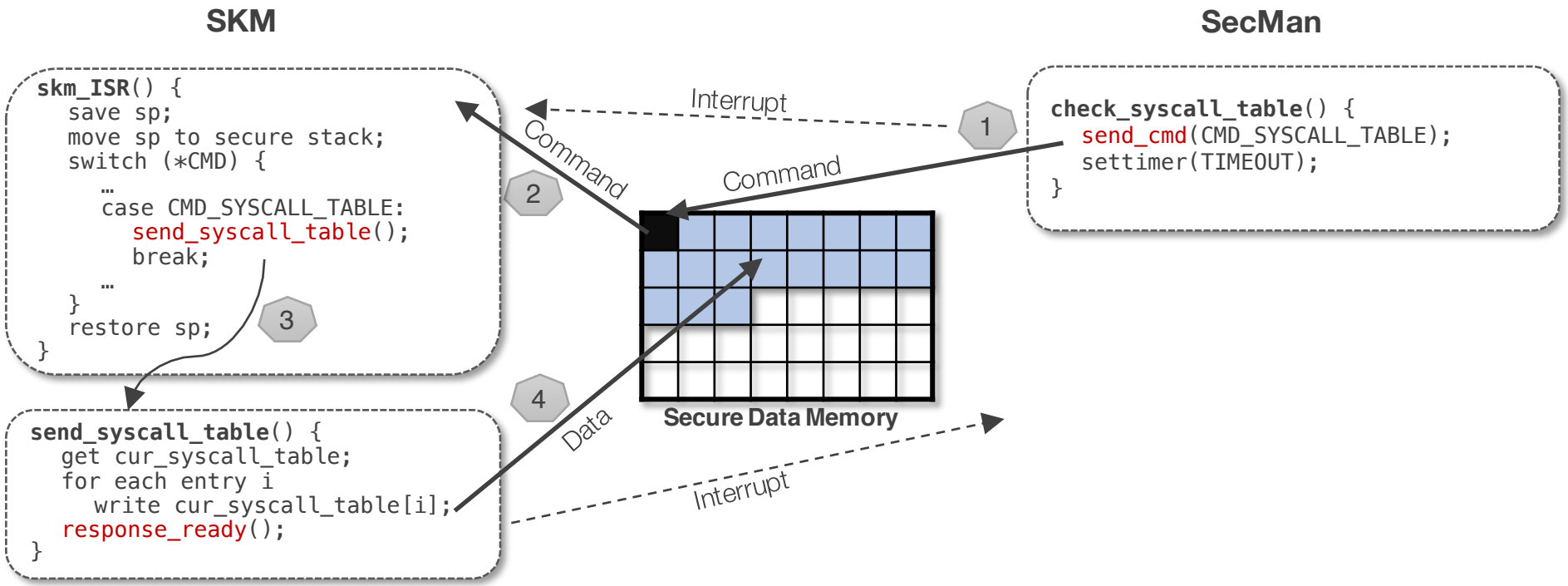




Example Use Case





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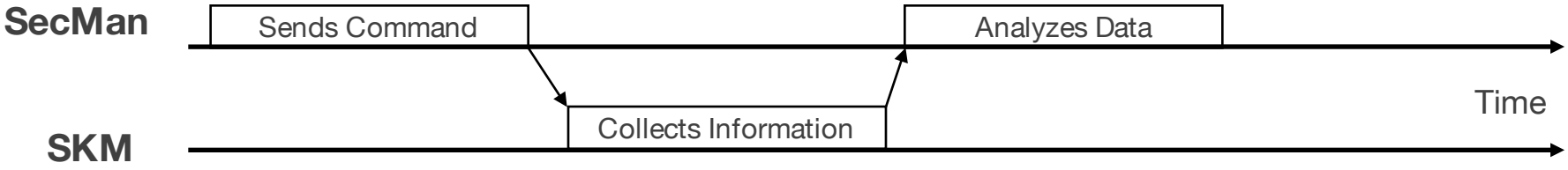
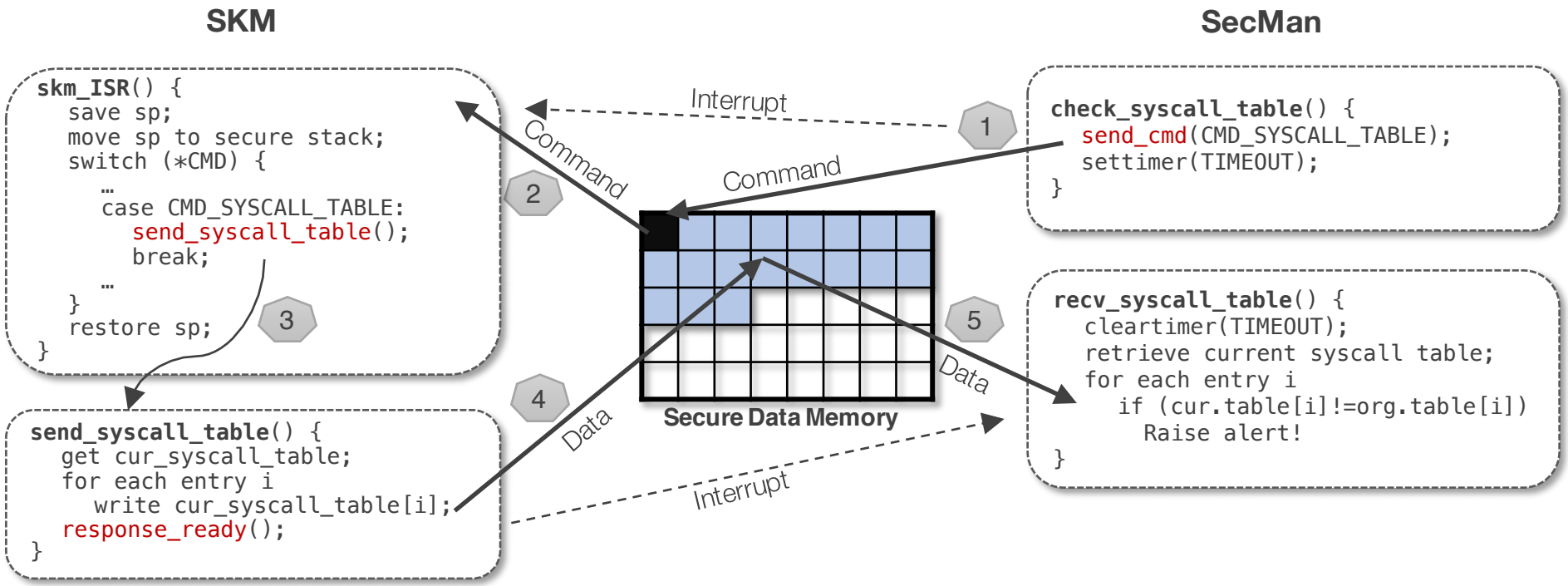
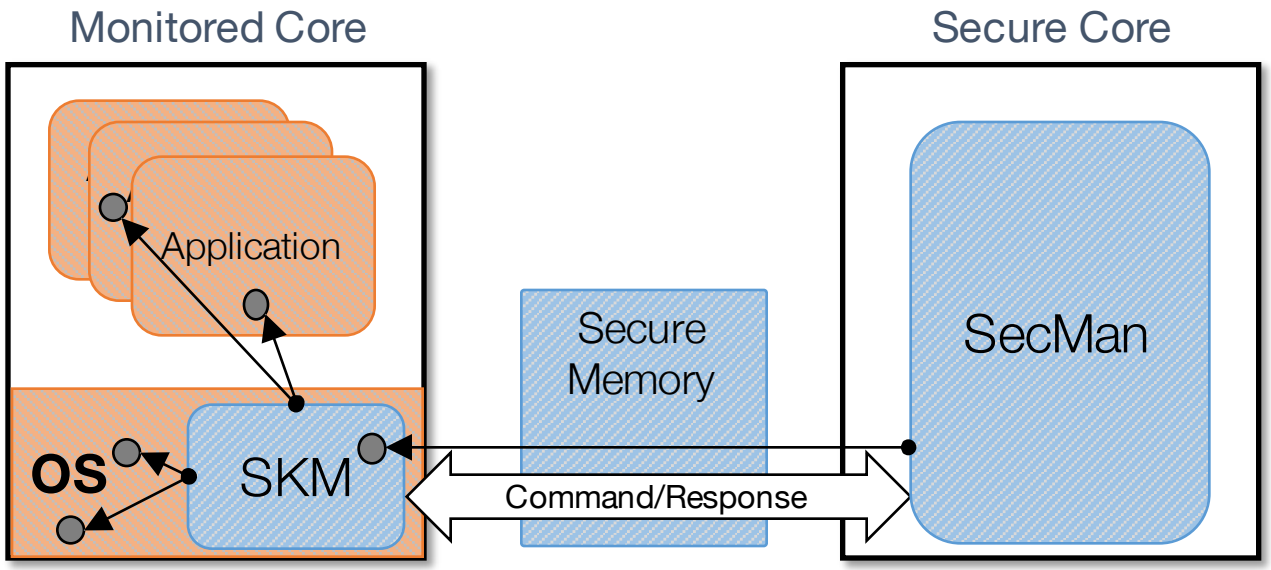




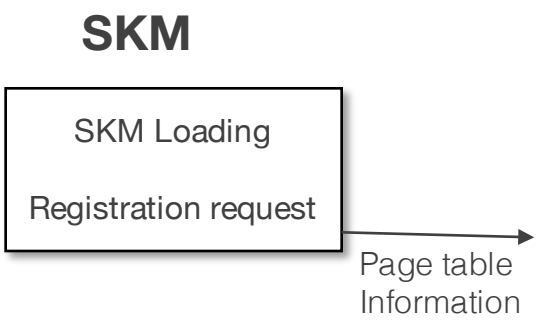
Challenges

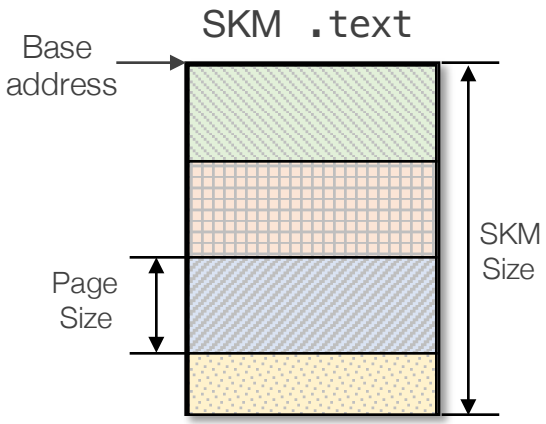


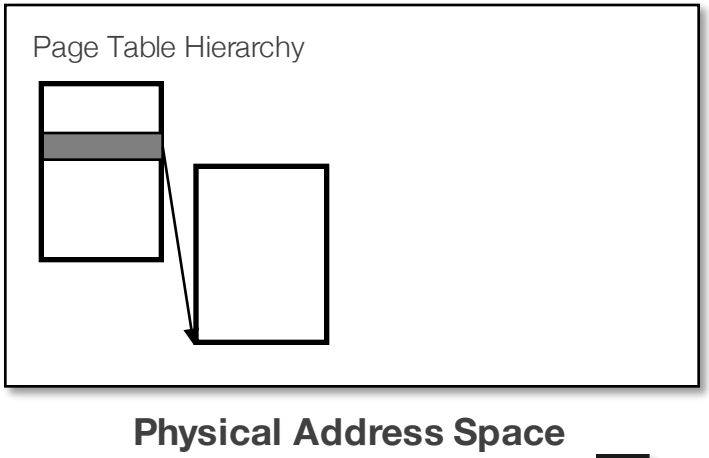
- SKM identification
- Secure memory access control
- SKM integrity and liveness guarantee

SKM Registration

- **Requested by SKM, verified by SecMan**
  - Calculates a hash of SKM's code
  - Directly from physical frames







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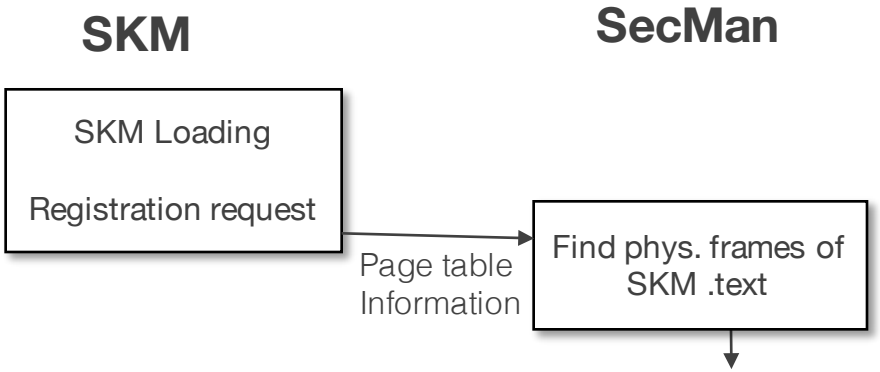

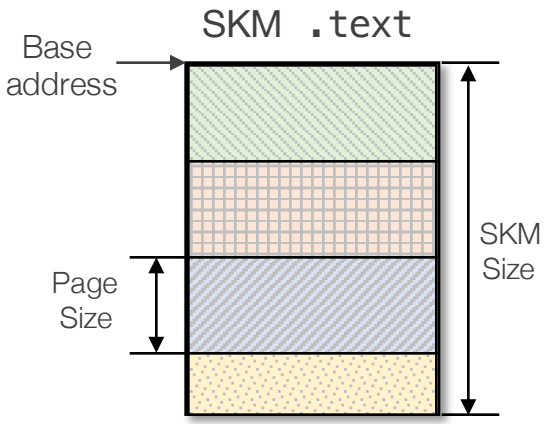

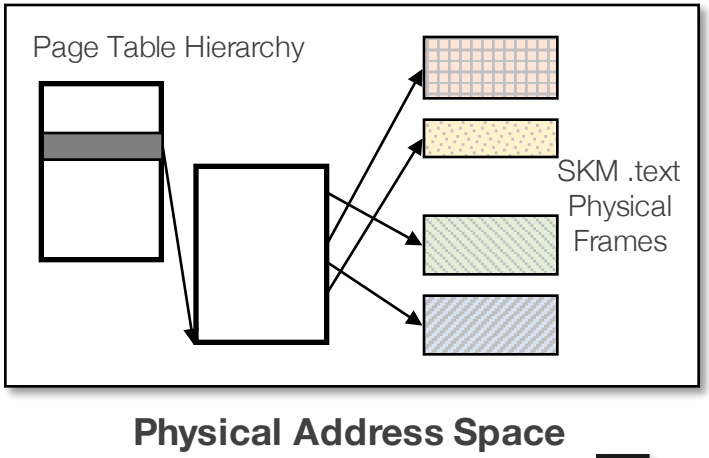

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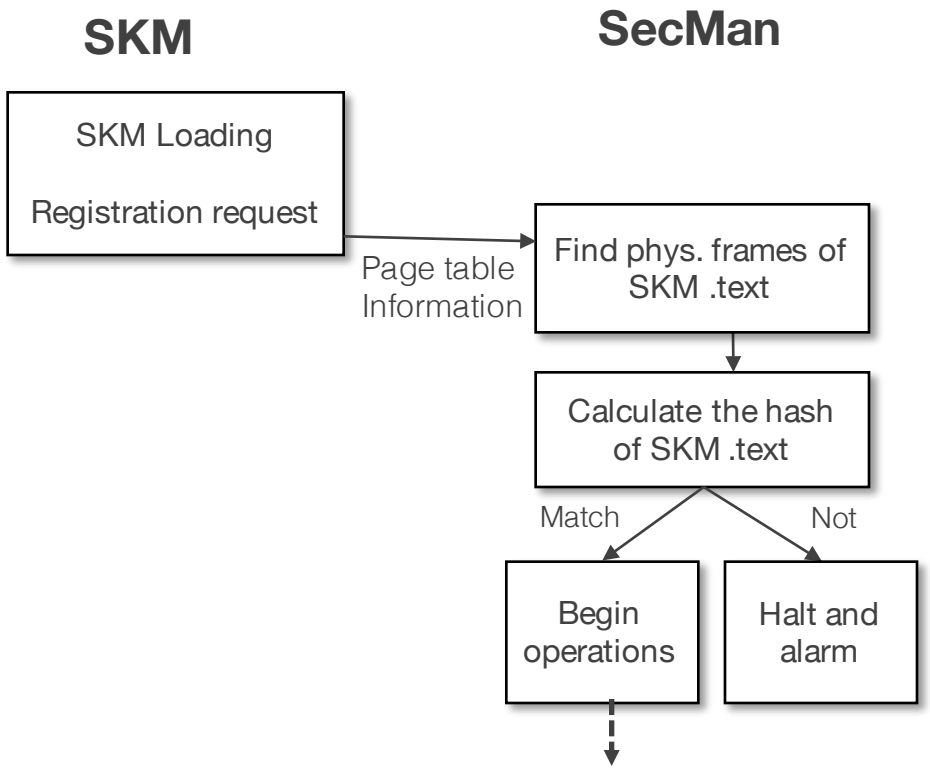
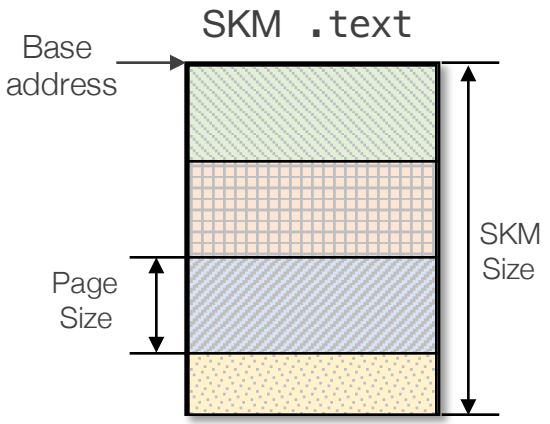
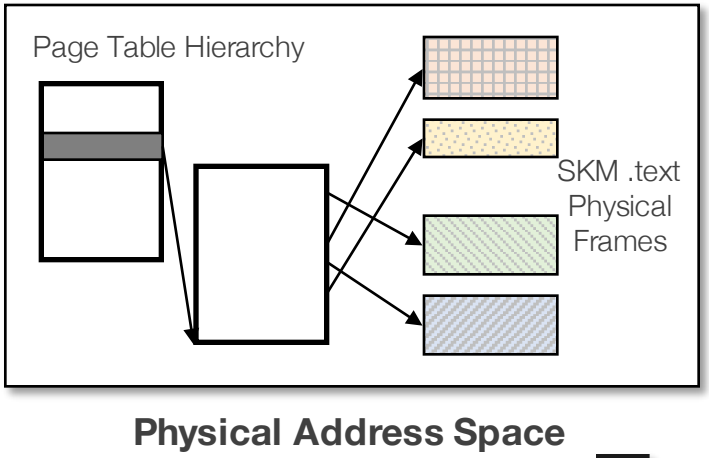
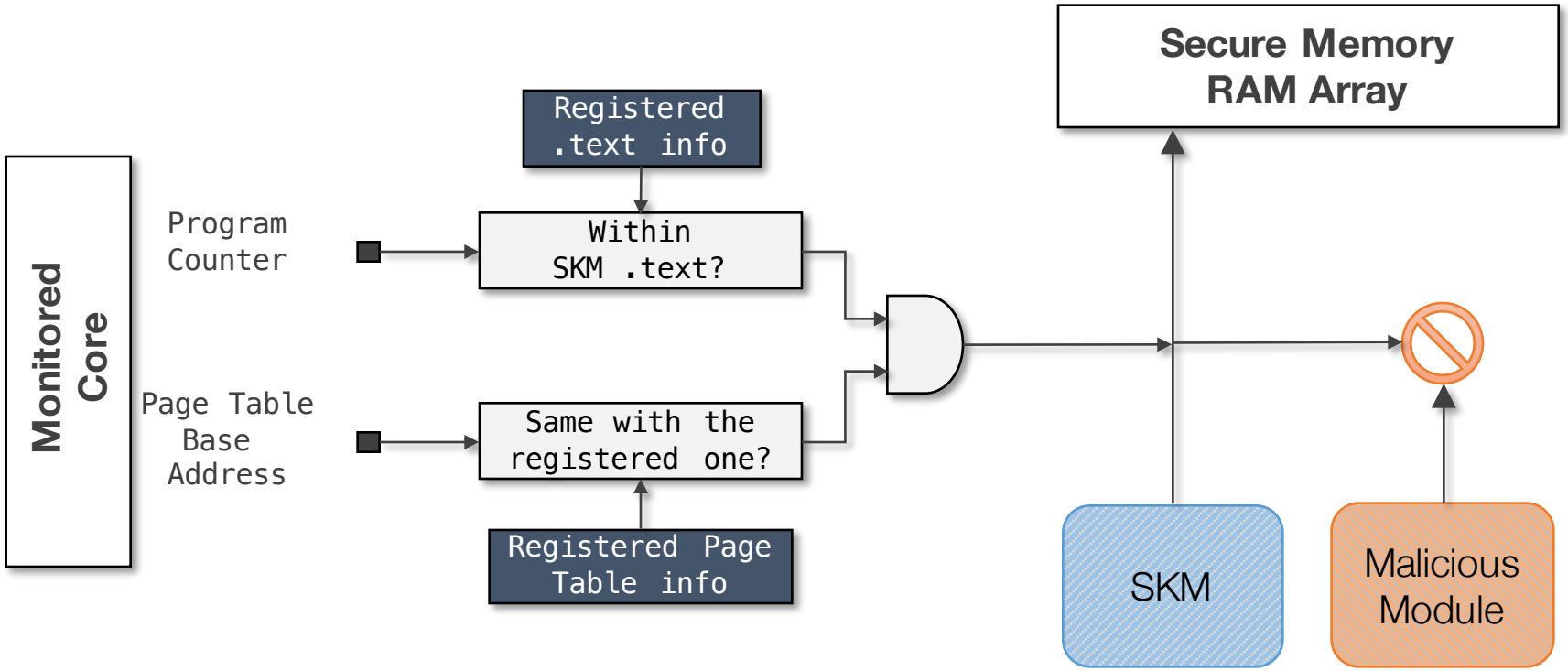






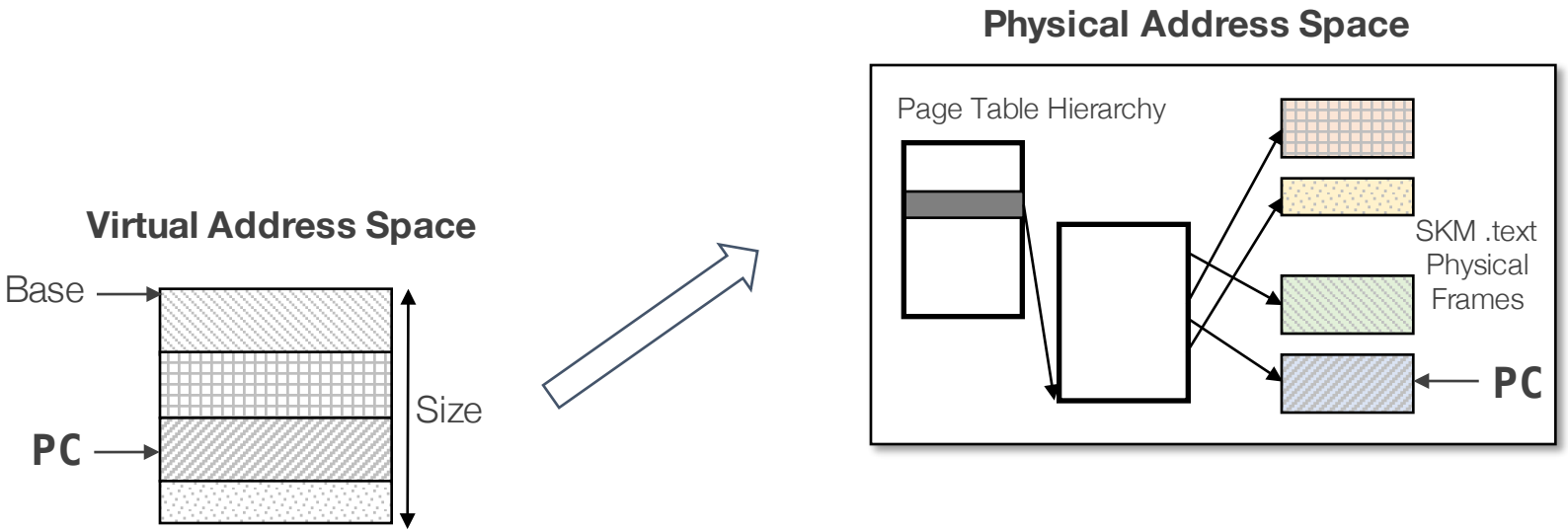
Secure Memory Access Control

- **Who initiated memory transaction?**
  - Use the current program counter and page mapping information



Secure Memory Access Control

- **What if attacker modifies SKM's page mapping?**



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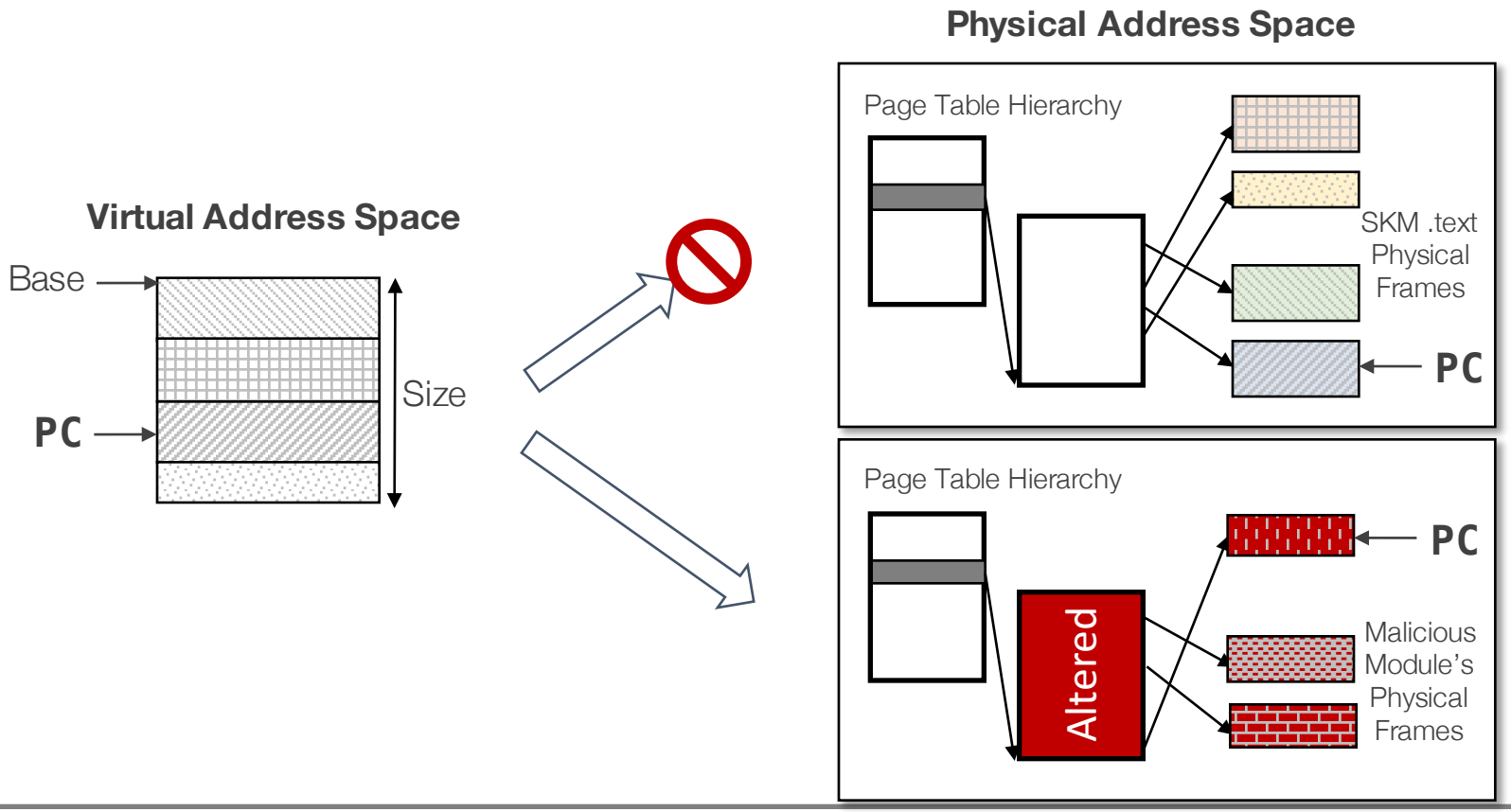
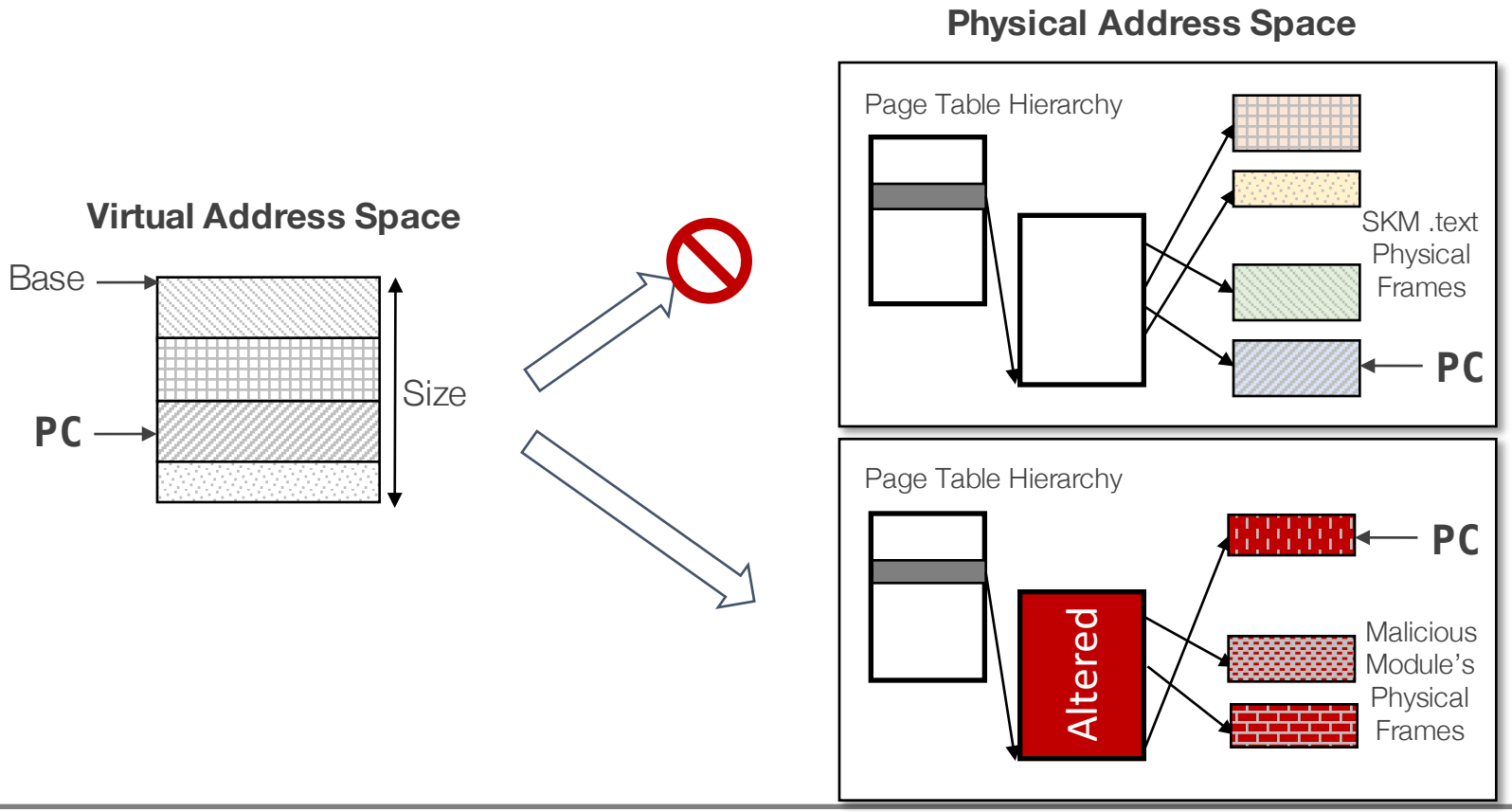


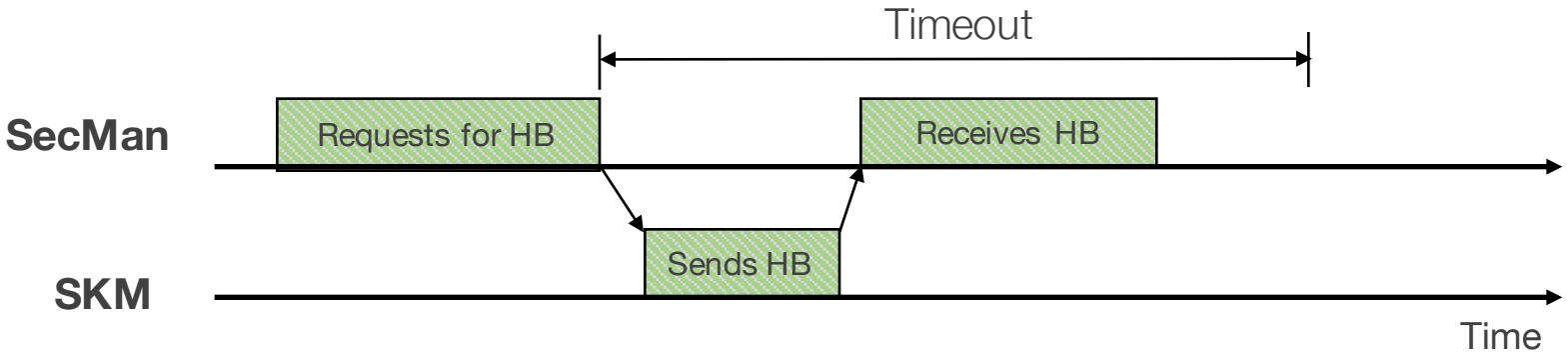
Secure Memory Access Control

- **What if attacker modifies SKM's page mapping?**
  - **Solution**: Regularly translate virt-to-phys address and verifies SKM .text hash



Heartbeat and Hashing

- **Heartbeat**
  - Checks if SKM is alive
  - Only SKM can respond



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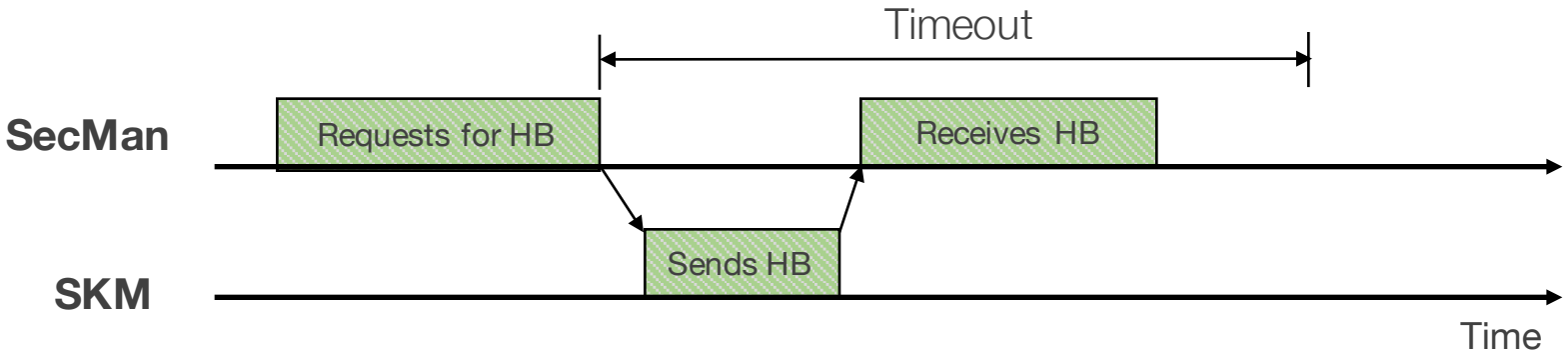
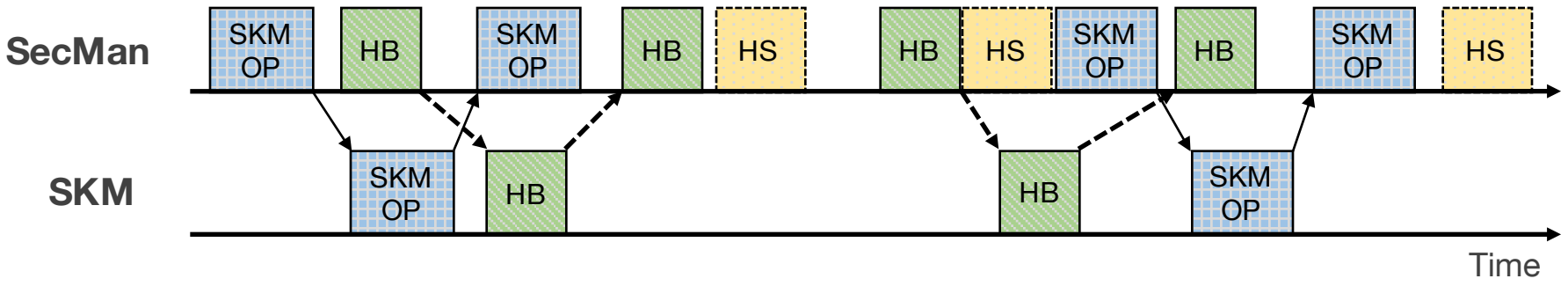


- **SKM .text hashing**
  - Checks if SKM's code and page mapping have not been altered

Random Check Intervals

- To prevent TOCTTOU (Time Of Check To Time Of Use) attacks
- Attacker *cannot guess* the pattern of checks

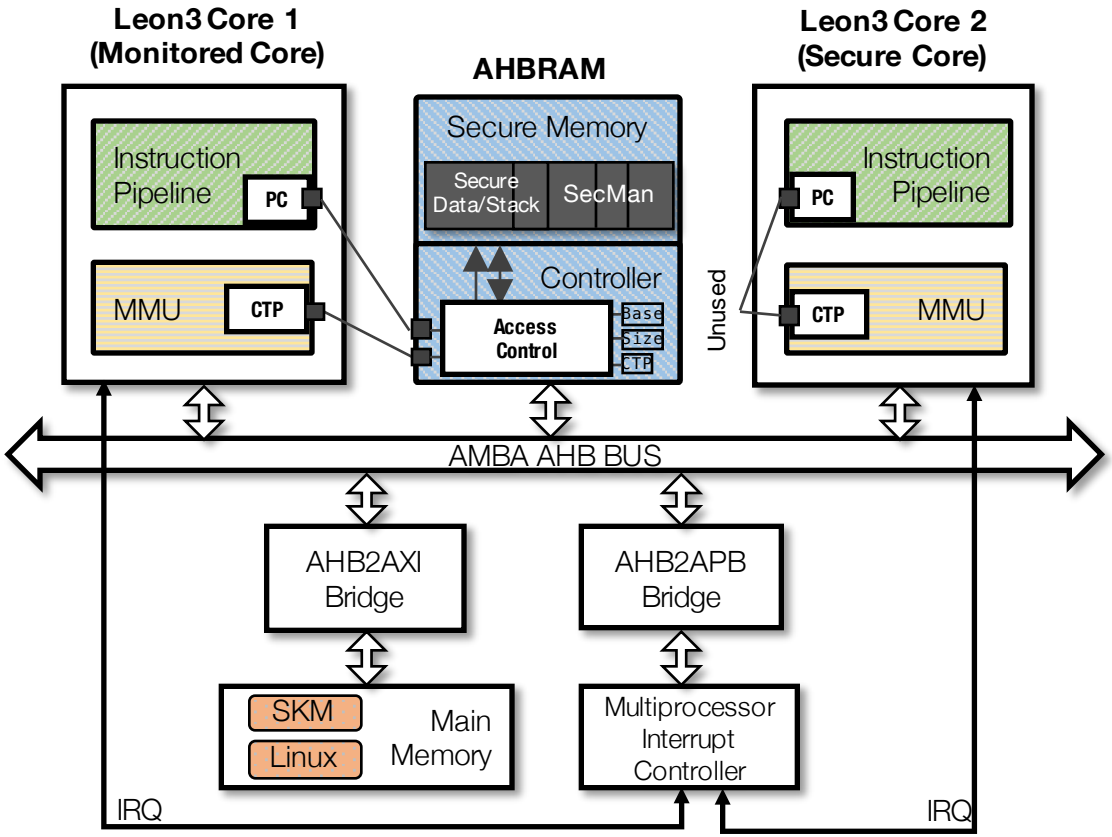


SKM OP **SKM Operation** (Send/Response/Analysis)

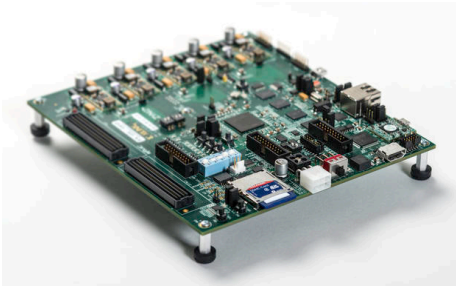
HB **Heartbeat** (Request/Send/Receive)

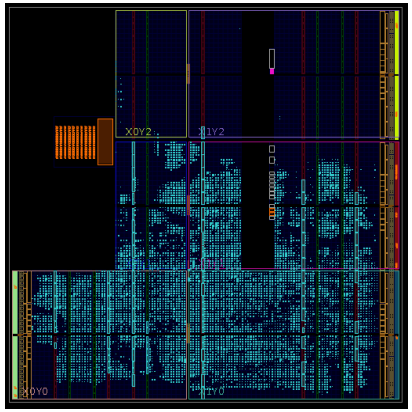
HS **Hashing** SKM .text

Implementation



- Leon3 processor on Xilinx ZC702 FPGA
  - SPARC V8, soft-core
  - 83.3 MHz
  - 256 MB





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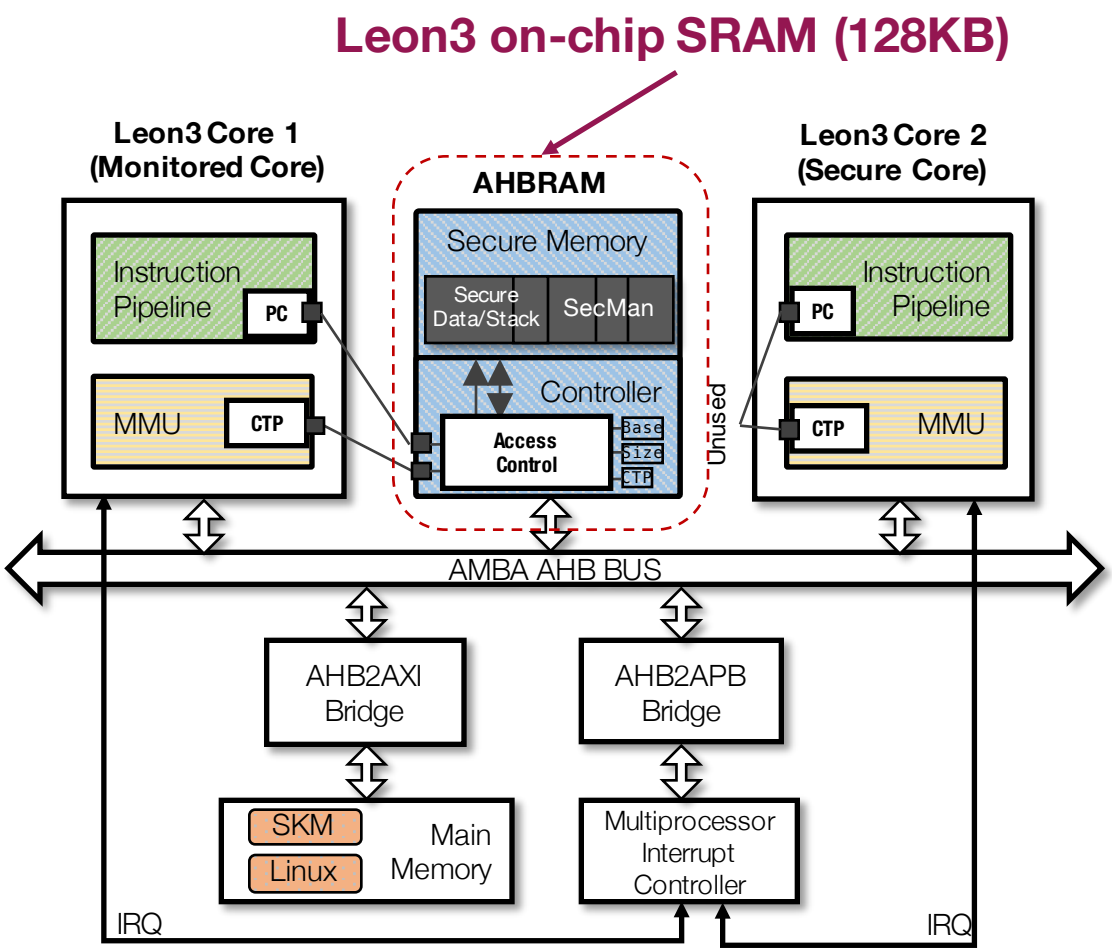

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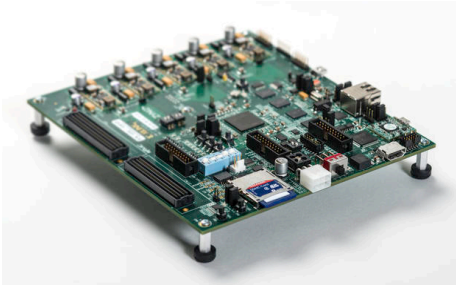

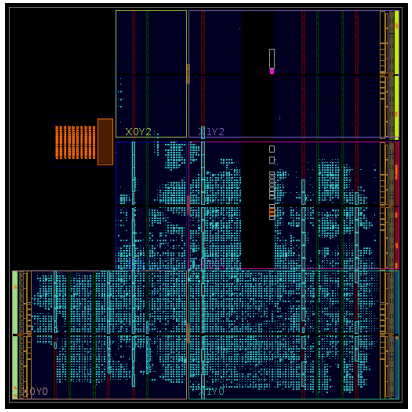

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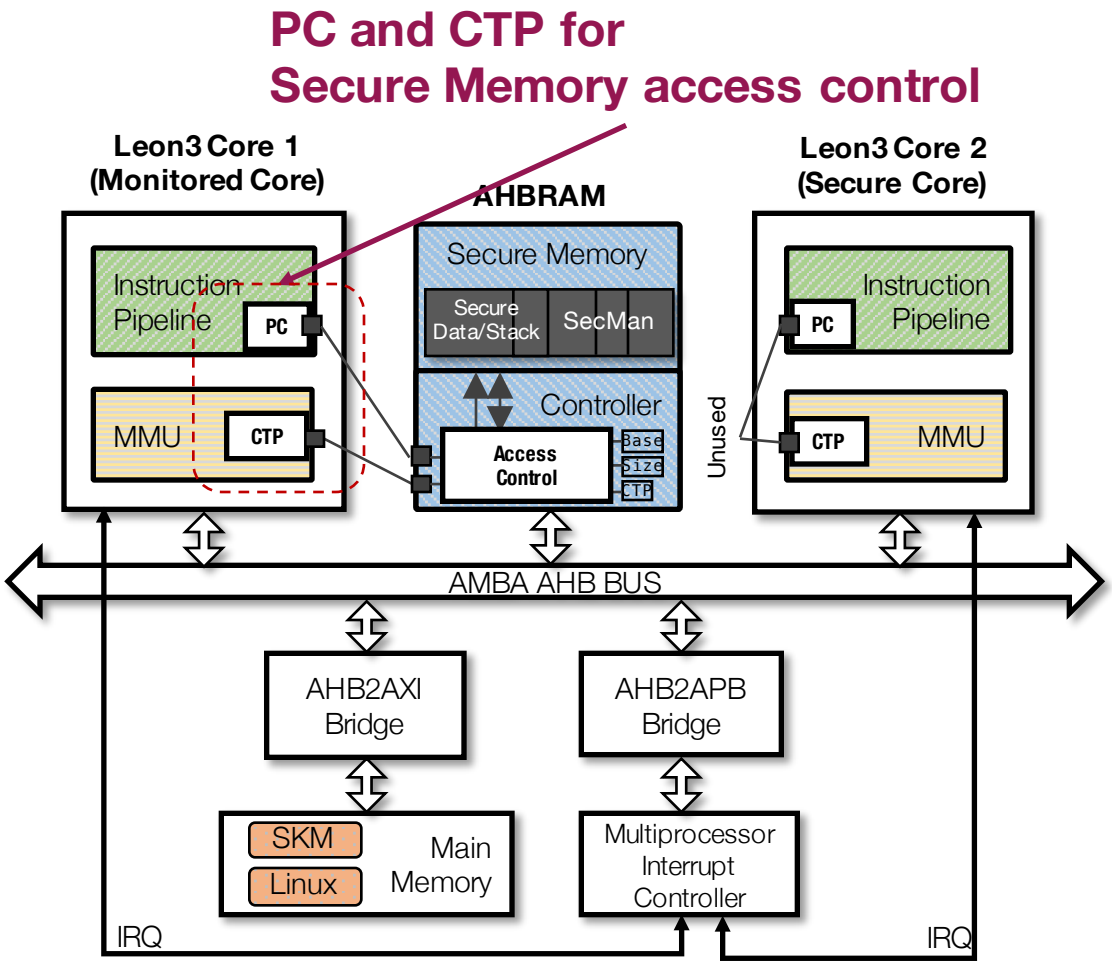

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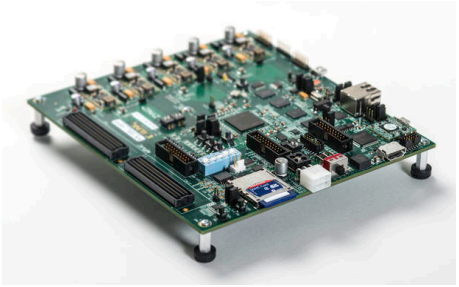

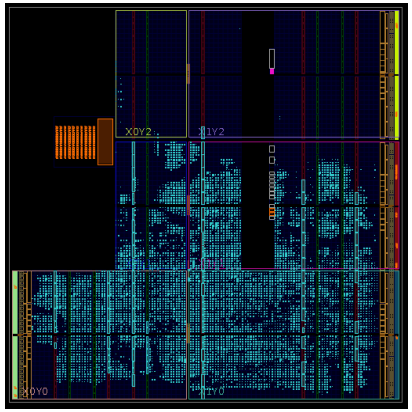

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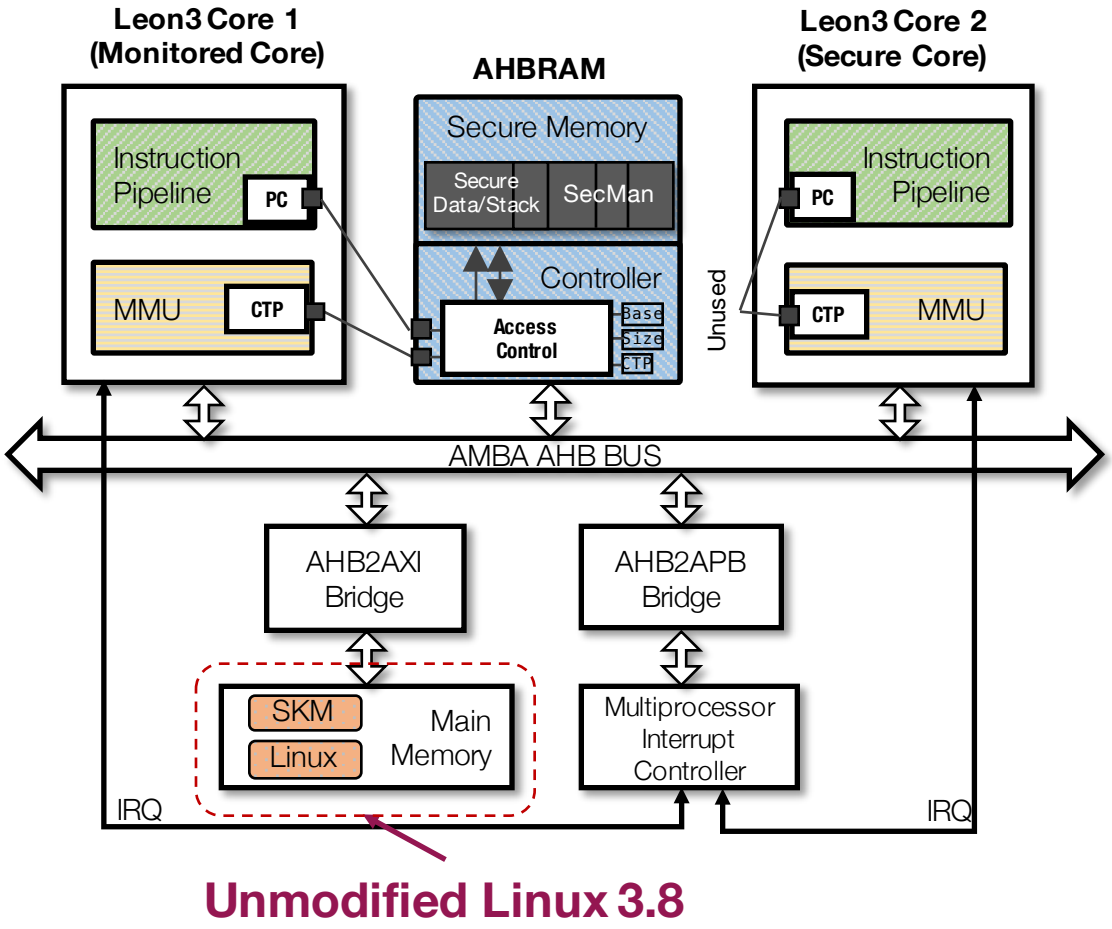

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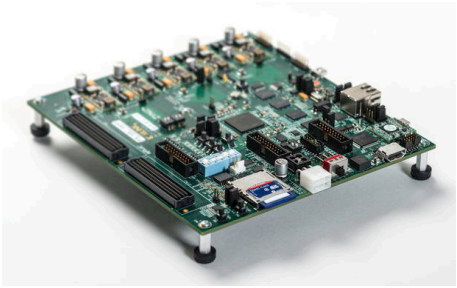

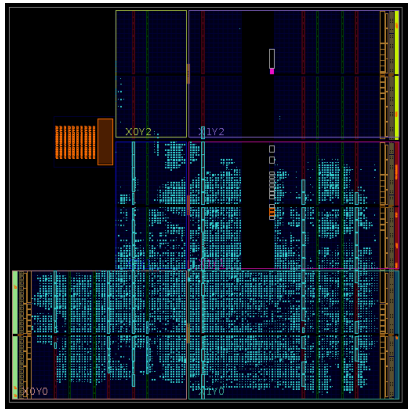

Evaluation – Use Cases

1) System call table integrity check
2) Hidden module detection

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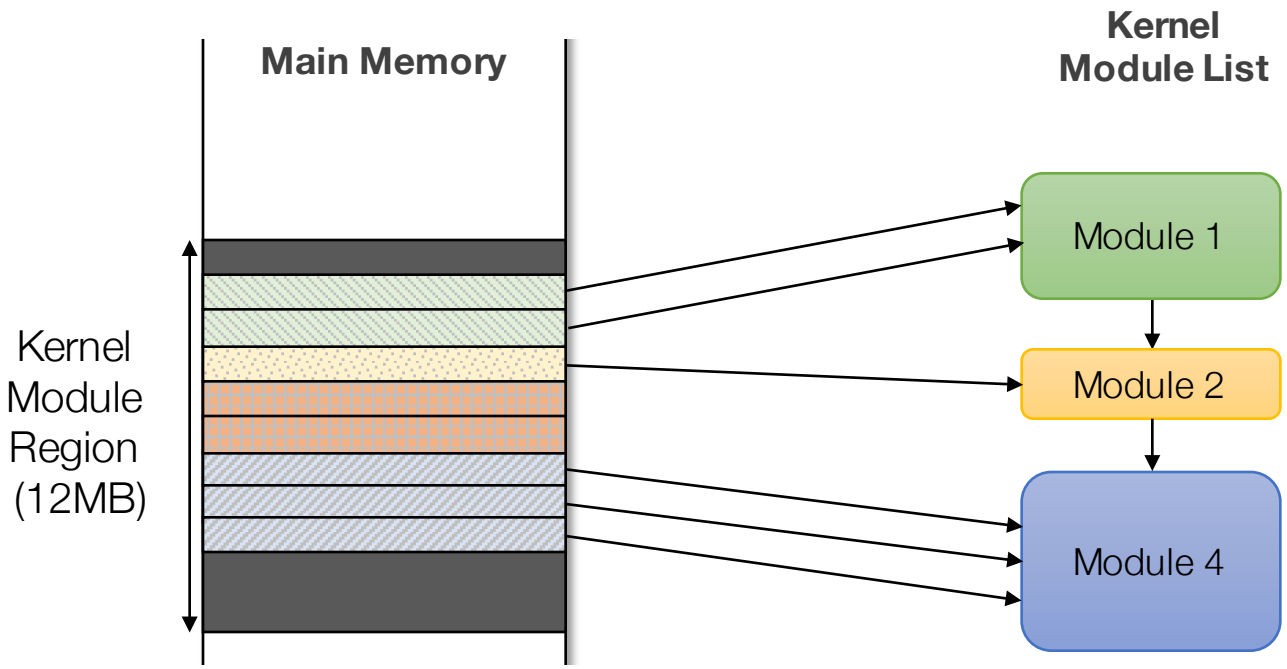
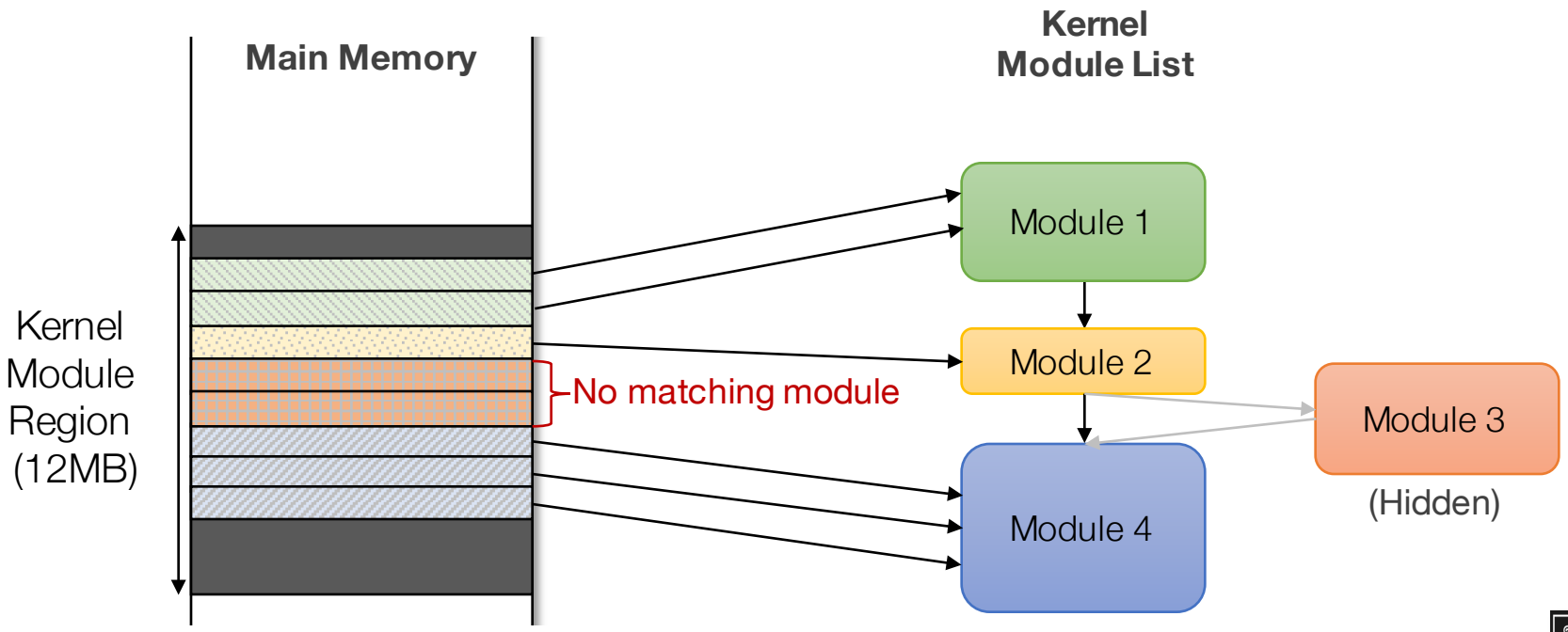


Evaluation – Use Cases

1) System call table integrity check
2) Hidden module detection



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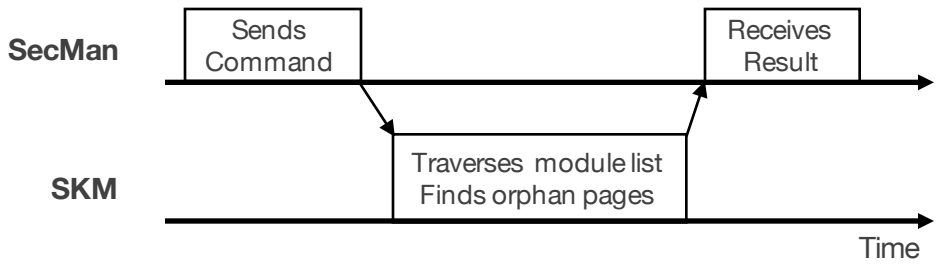
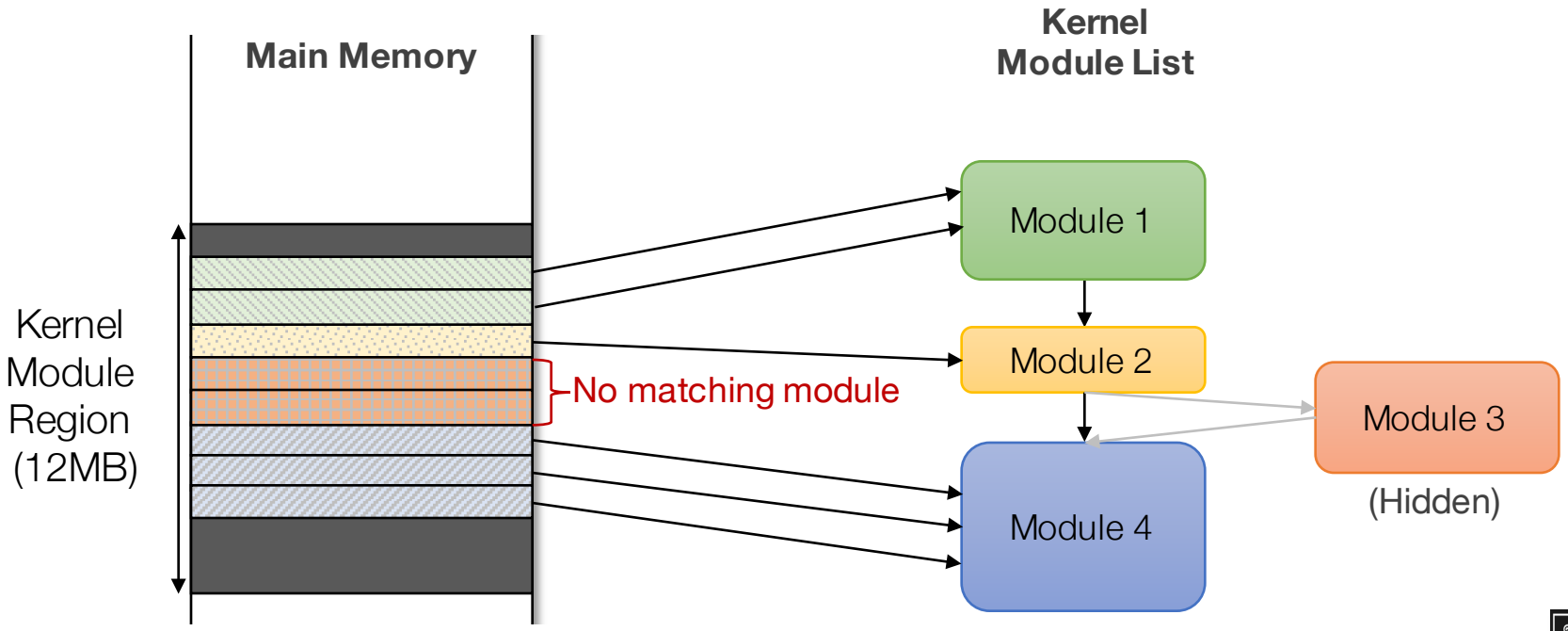
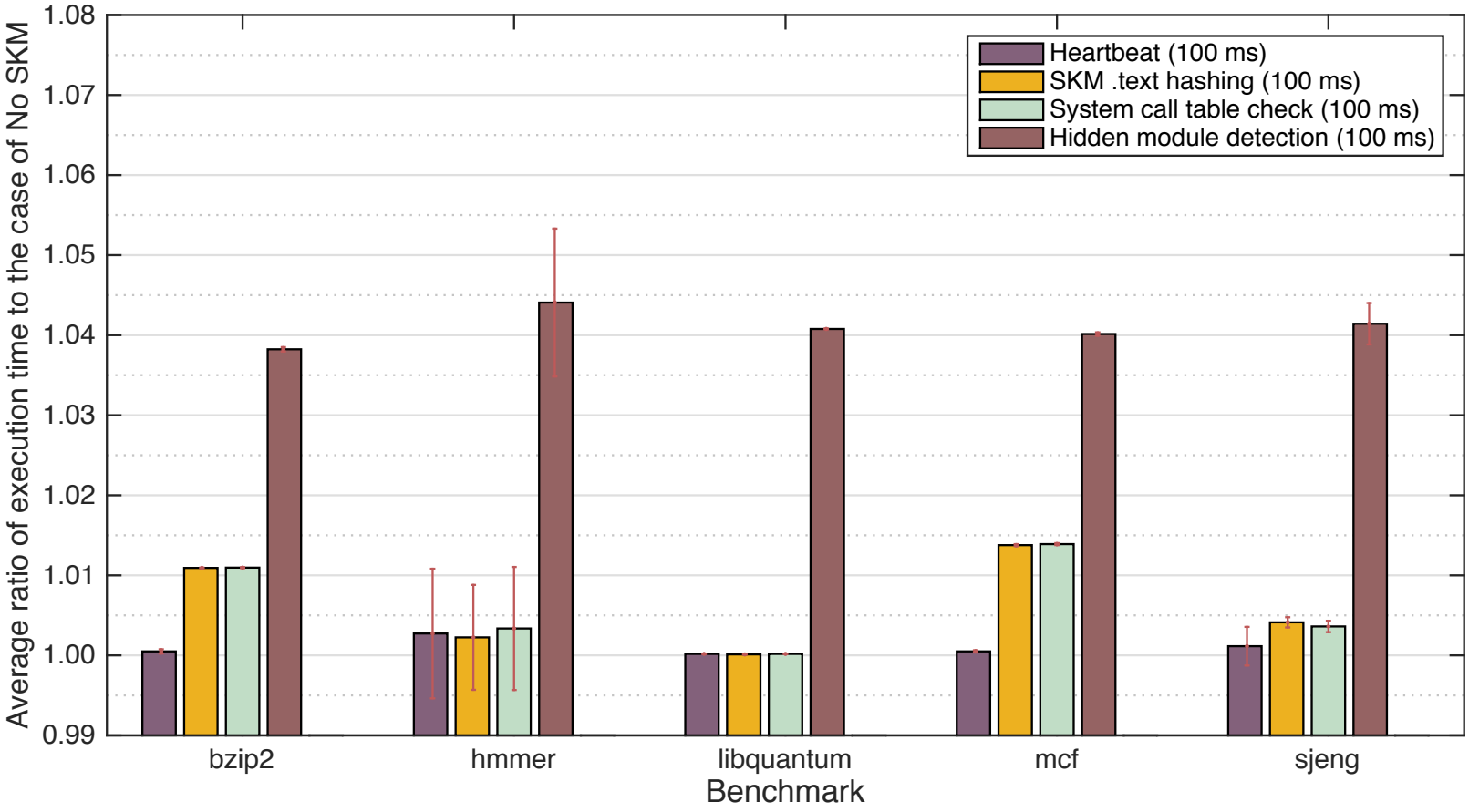




Evaluation – Performance Overhead

- SPEC Benchmarks on the monitored core



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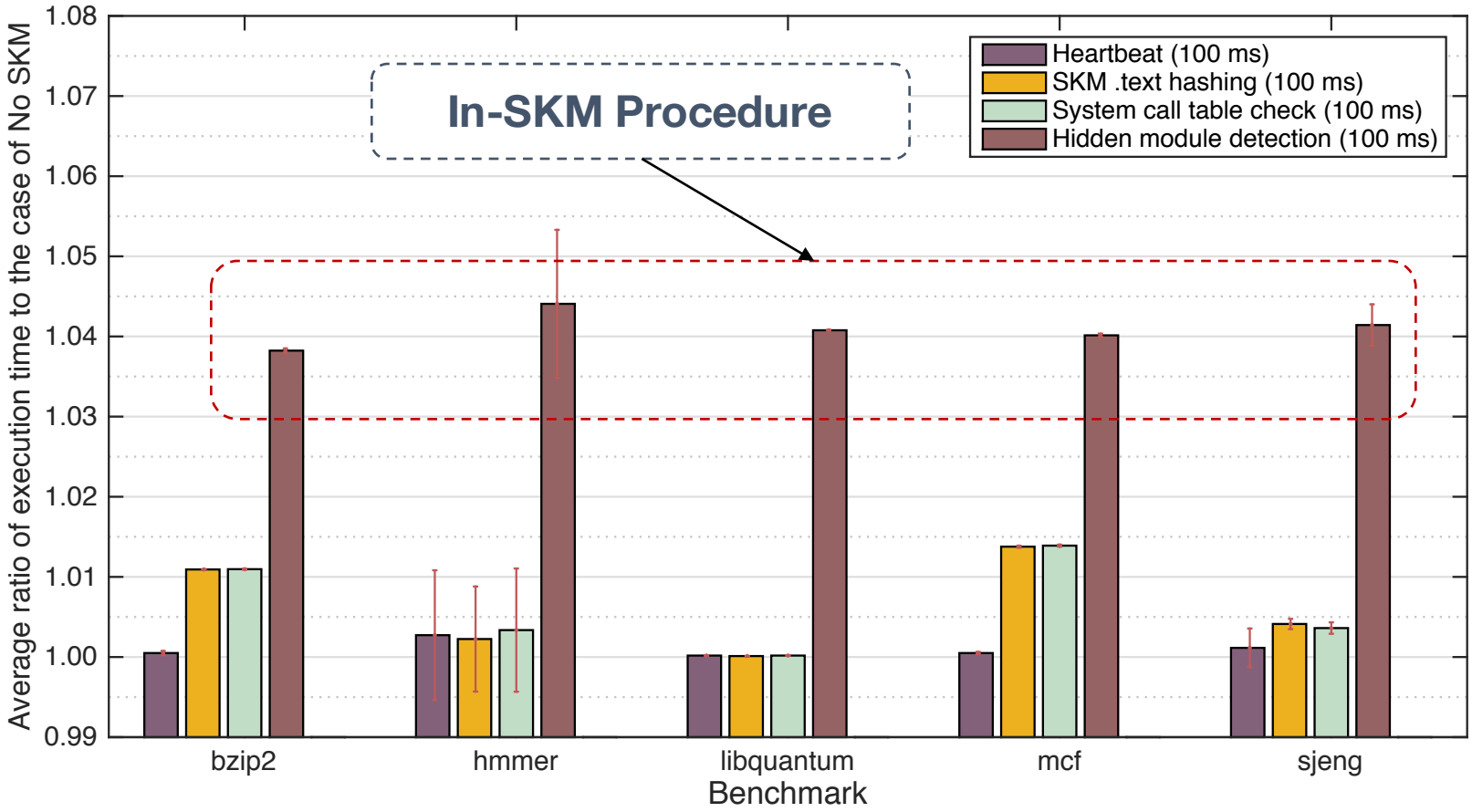

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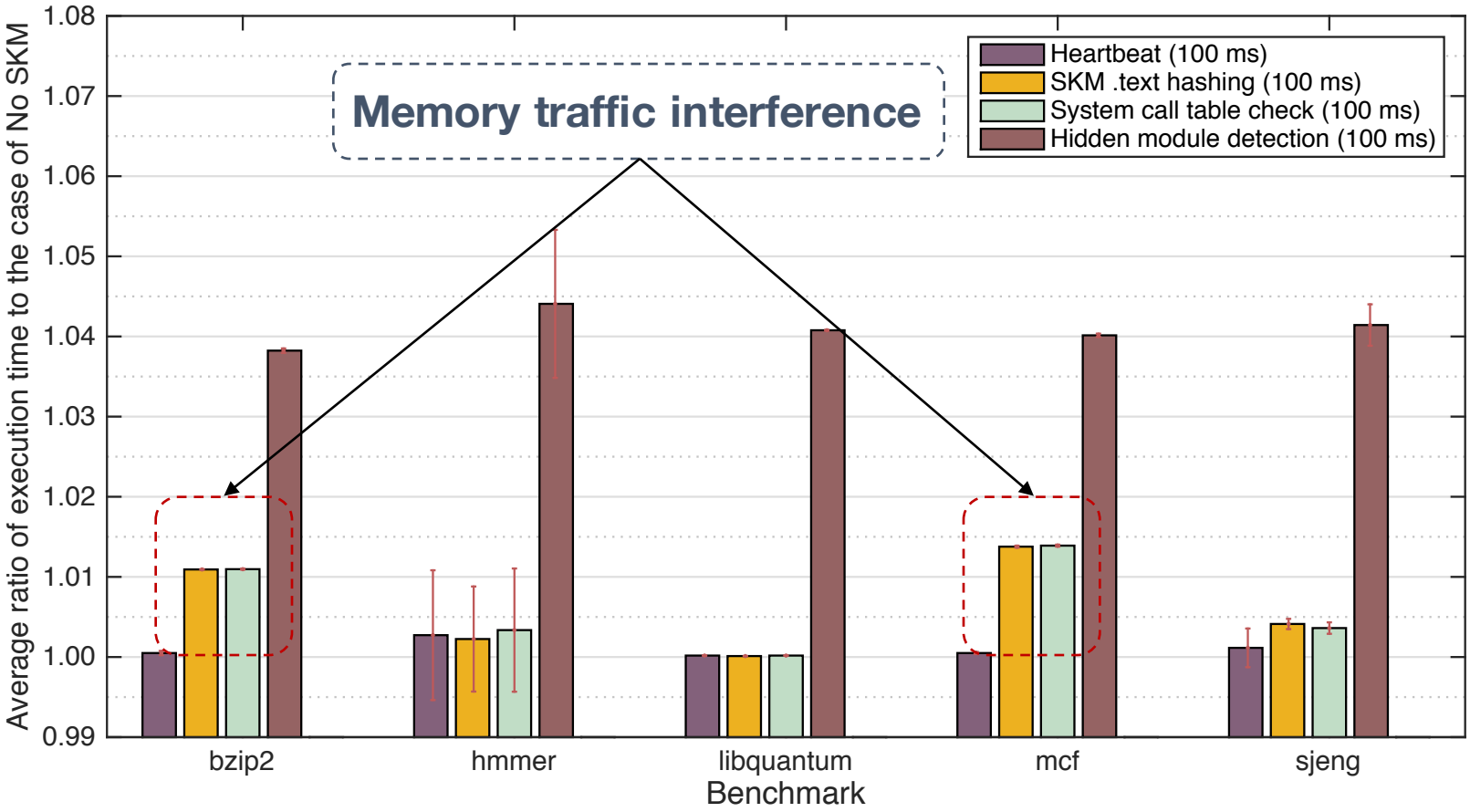

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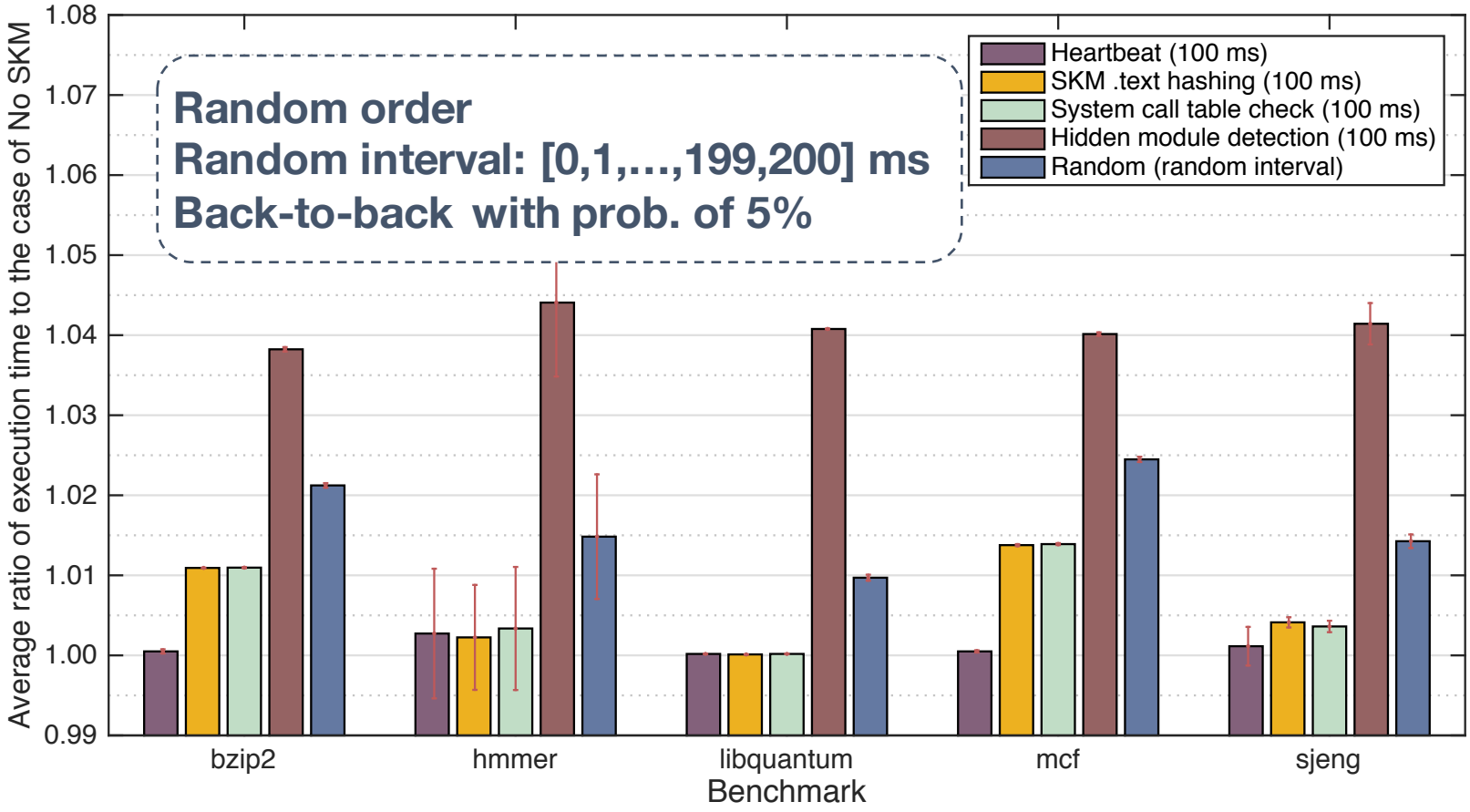
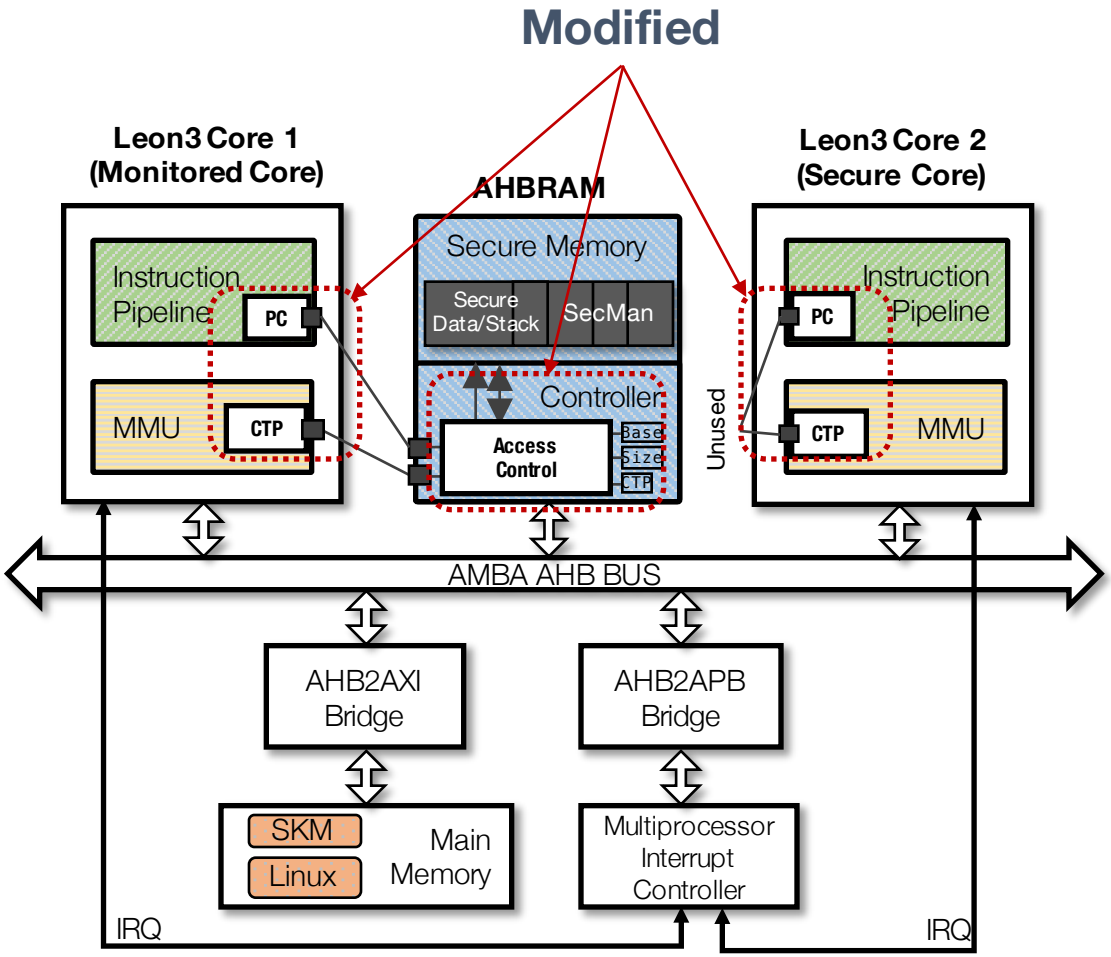
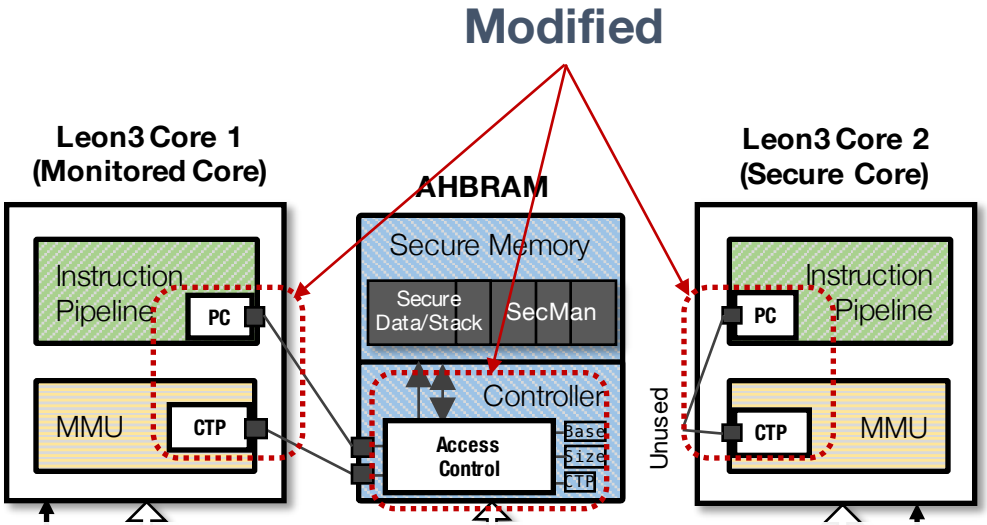


Evaluation – Hardware Cost



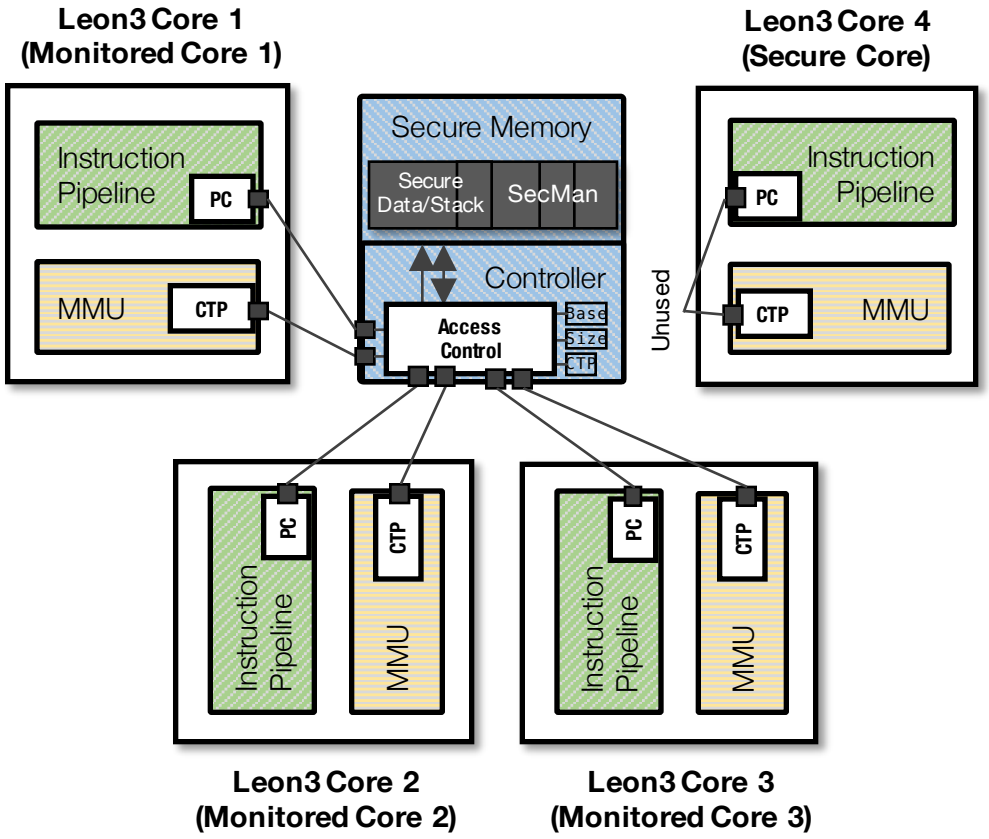
Evaluation – Hardware Cost



Resource	Original	W/ DragonBeam	Δ
Registers	10258	10356	0.96%
Look-up Tables	19482	19511	0.15%

Extension to Multiple Monitored Cores

- Extended to quad-core
- Works only for SMP
  - Single SKM



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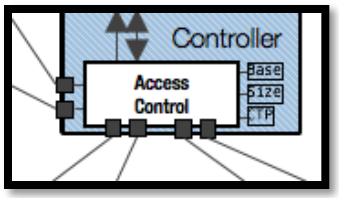
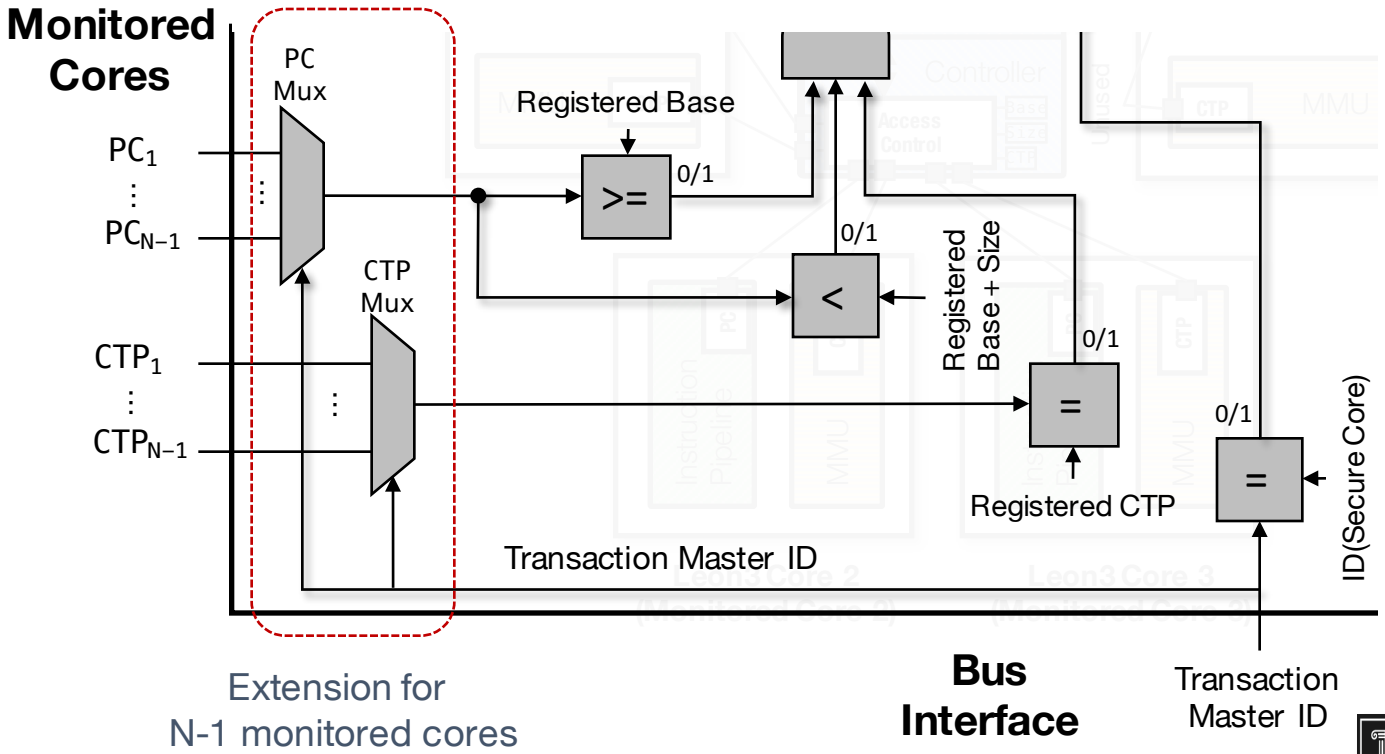




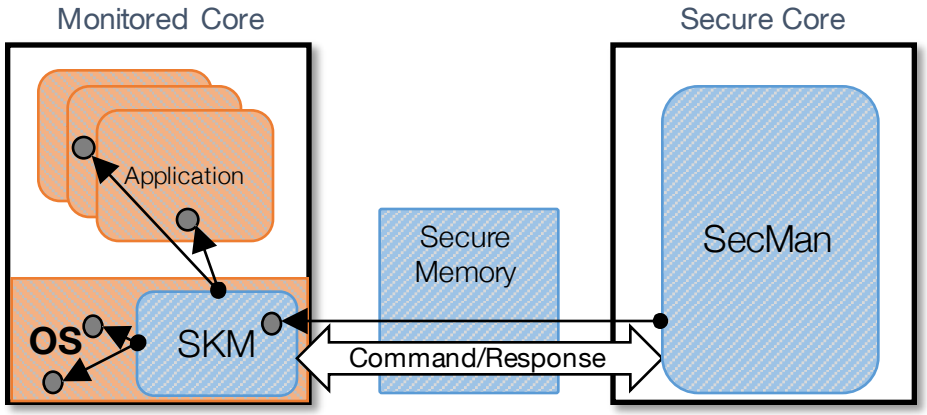
Extension to Multiple Monitored Cores

- Extended to quad-core
- Works only for SMP
  - Single SKM

	Resource	Original	W/ DragonBeam	
Dual Core	Registers	10258	10356	0.96%
	Look-up Tables	19482	19511	0.15%
Quad Core	**Registers**	**18932**	**19029**	**0.51%**
	Look-up Tables	**37777**	**37835**	**0.15%**

Conclusion

- **DragonBeam Framework**
  - HW/SW framework for trusted security monitoring
    - Bootstrap trust into SW layer from trusted HW
    - Multicore-based
  - Expanded observability due to in-place monitoring
    - Secure "Kernel Module"
  - Allows for customized security modules to system developers



Thank you