fuzzing & exploiting wireless device drivers

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Agenda

- 802.11 fundamentals
- 802.11 fuzzing
- Virtual 802.11 fuzzing & live demonstration
- Kernel-mode exploits primer

introduction

About us

- We are two students from the **Technical University Vienna**
- Right now we ought to be working on our master theses at the **Secure Systems Lab @ TU Vienna**
- The work presented here is based on the results of a seminar paper we wrote during a collaboration between the **Secure Systems Lab** and **SEC Consult**
- **SEC Consult** also has a "Vulnerability Bonus Program" – for details see http://www.sec-consult.com or mail to vulnerabilities@sec-consult.com

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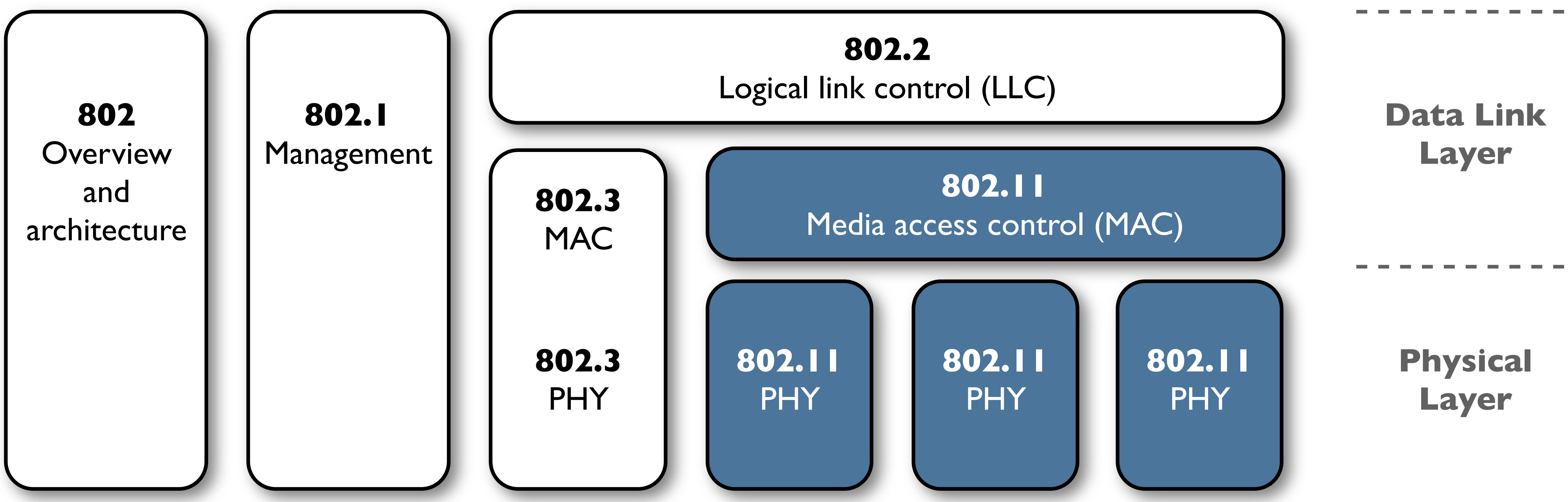
The playground

- Wireless networks have become a widely used means of communication. Compatible devices are included in most portable computers, mobile phones, etc.
- That means, there is an increasing number of mobile targets out there…
- What's more, the device drivers typically operate in supervisor-mode (i.e. in kernel-space), thus rendering vulnerabilities extremely dangerous.

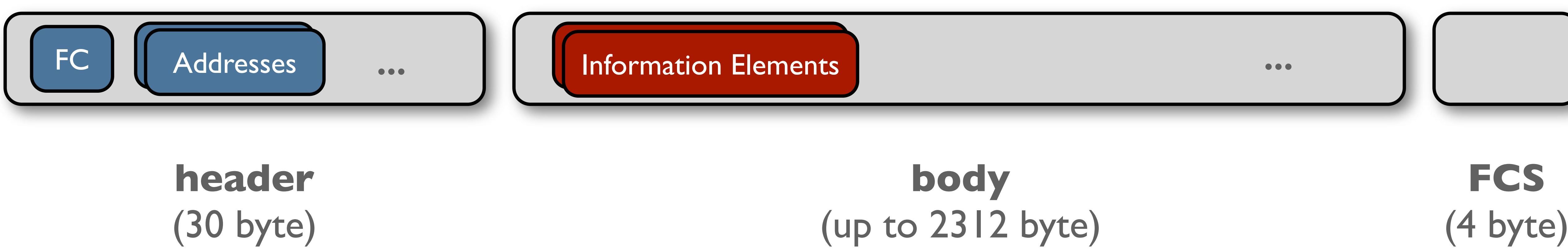
802.11 primer

The IEEE 802 Family



802.11 MAC frames

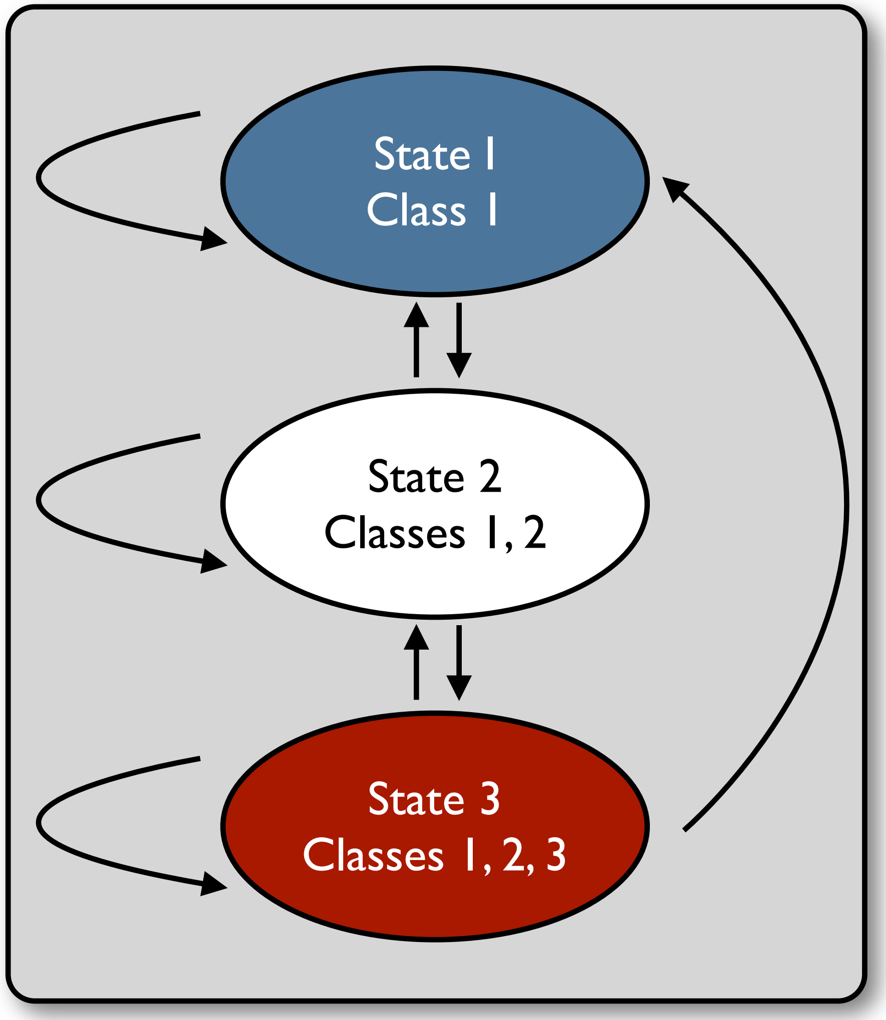
- Three types of frames: management, control and data frames
- Management frames used to advertise and connect to networks



802.11 states

Authentication

Association
or
Reassociation



DeAuthentication

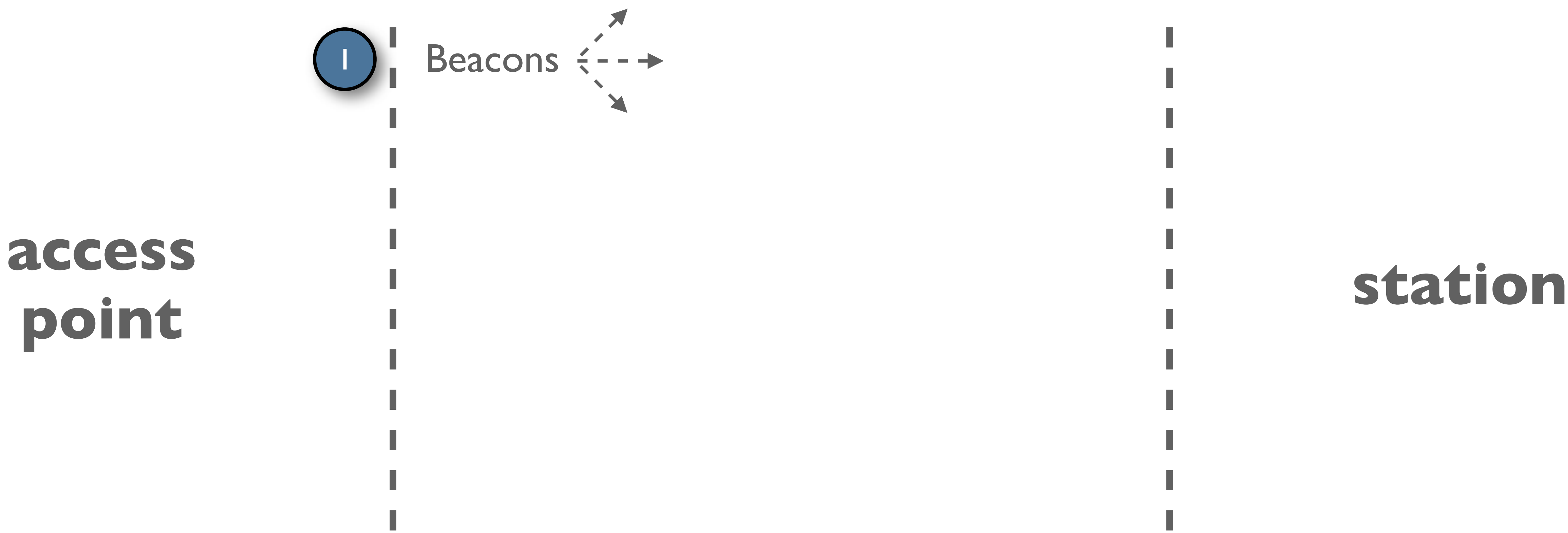
Disassociation

802.11 association

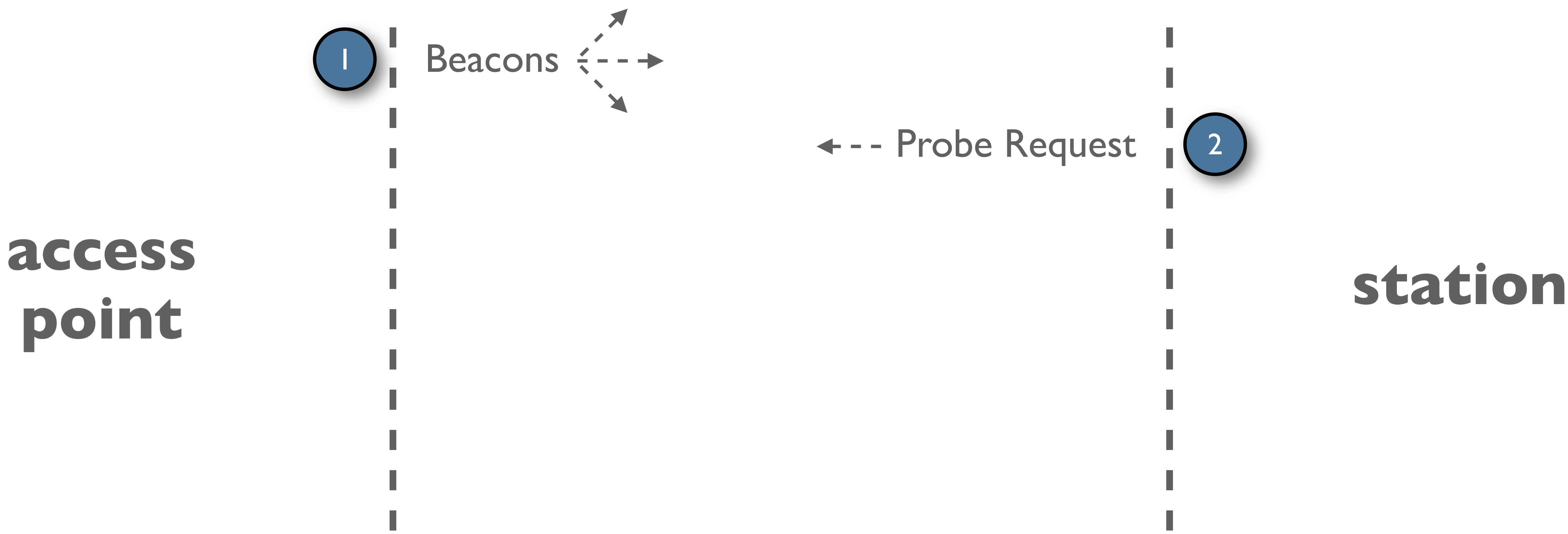
access point

station

802.11 association



802.11 association



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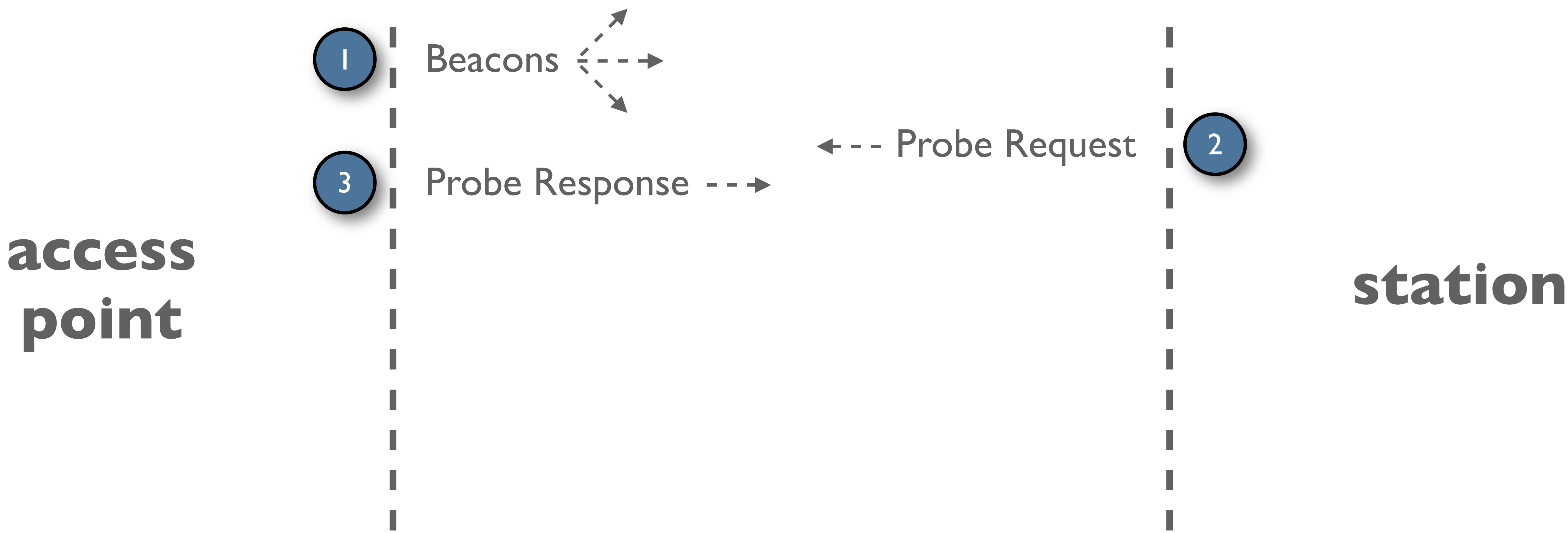

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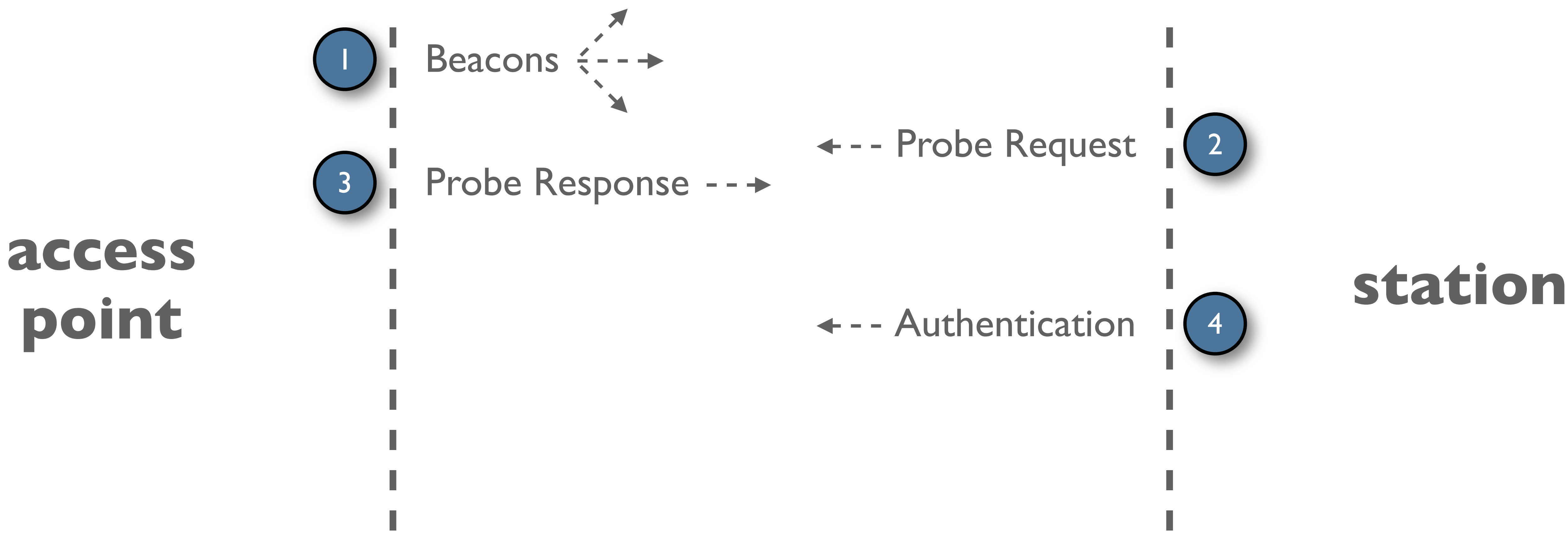

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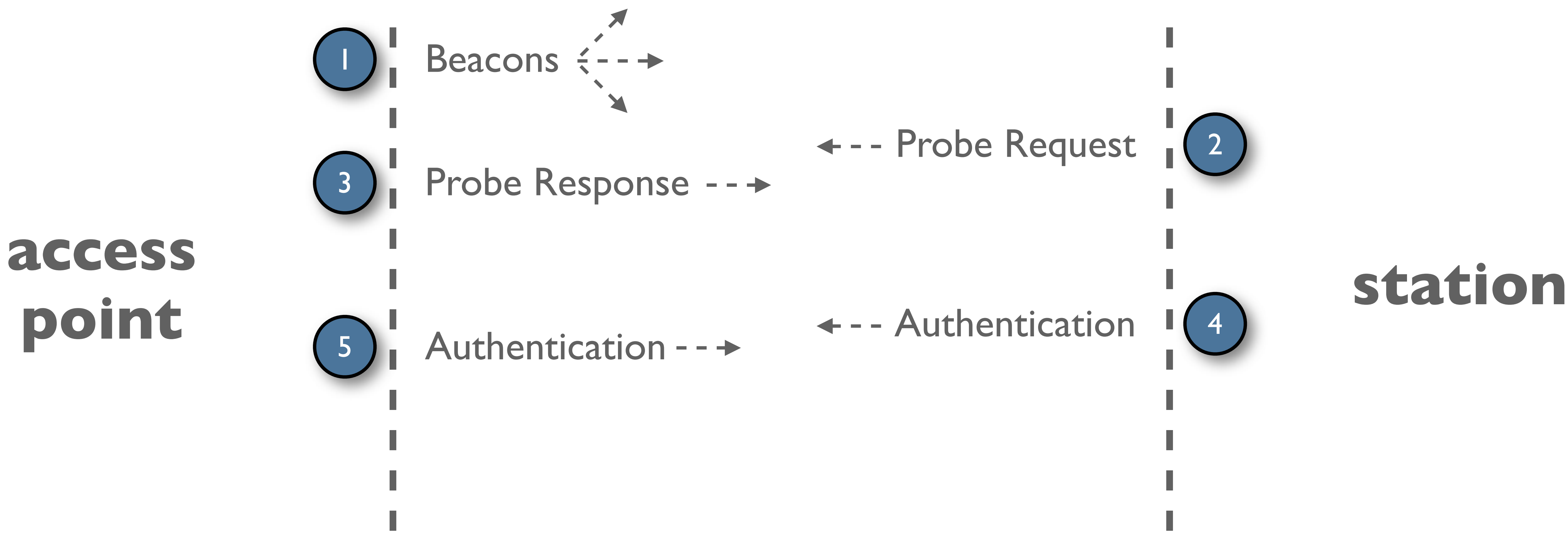

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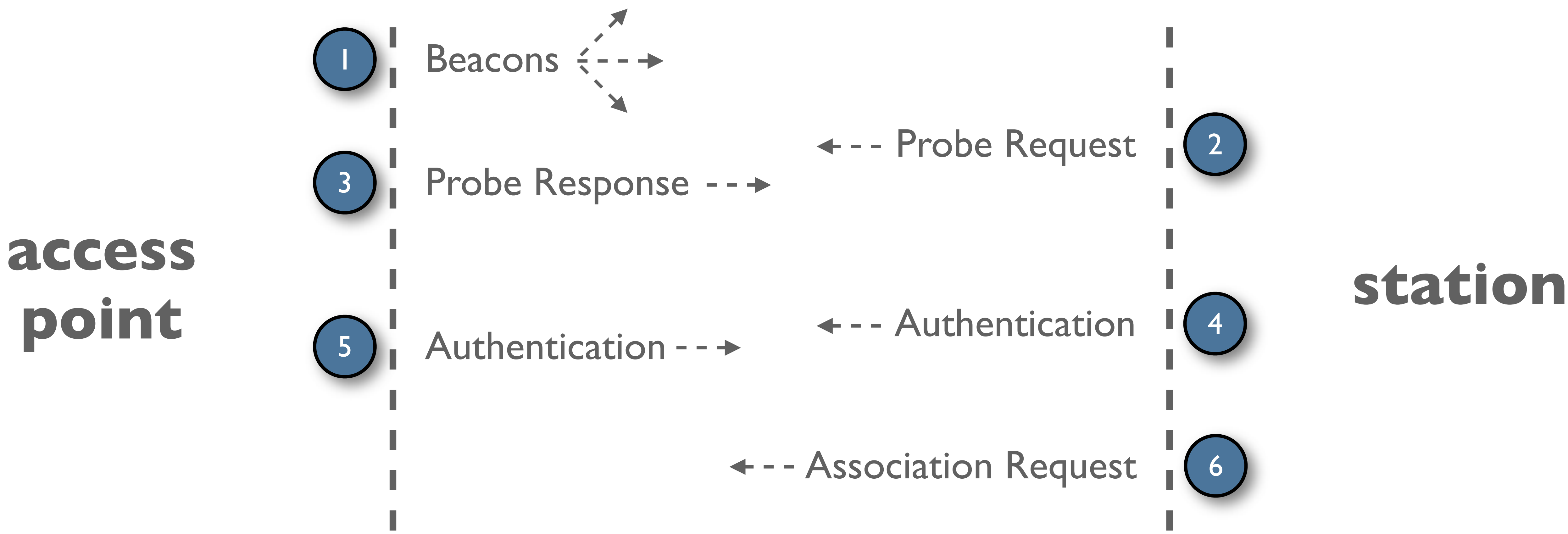

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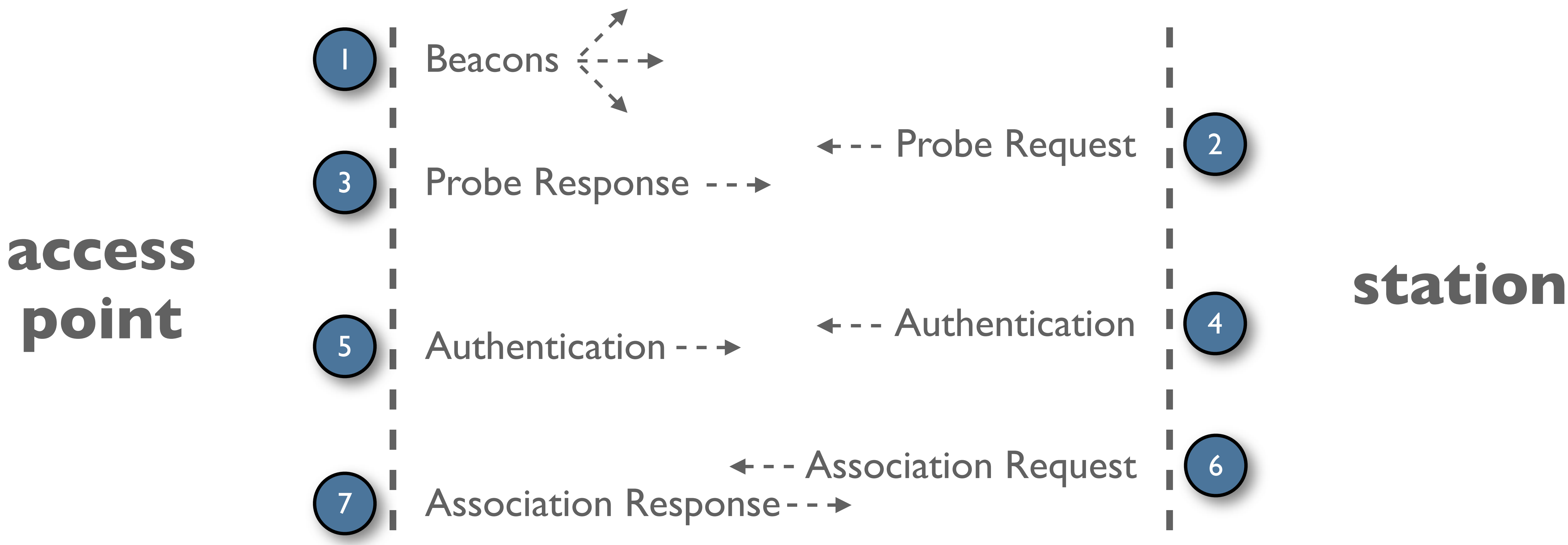

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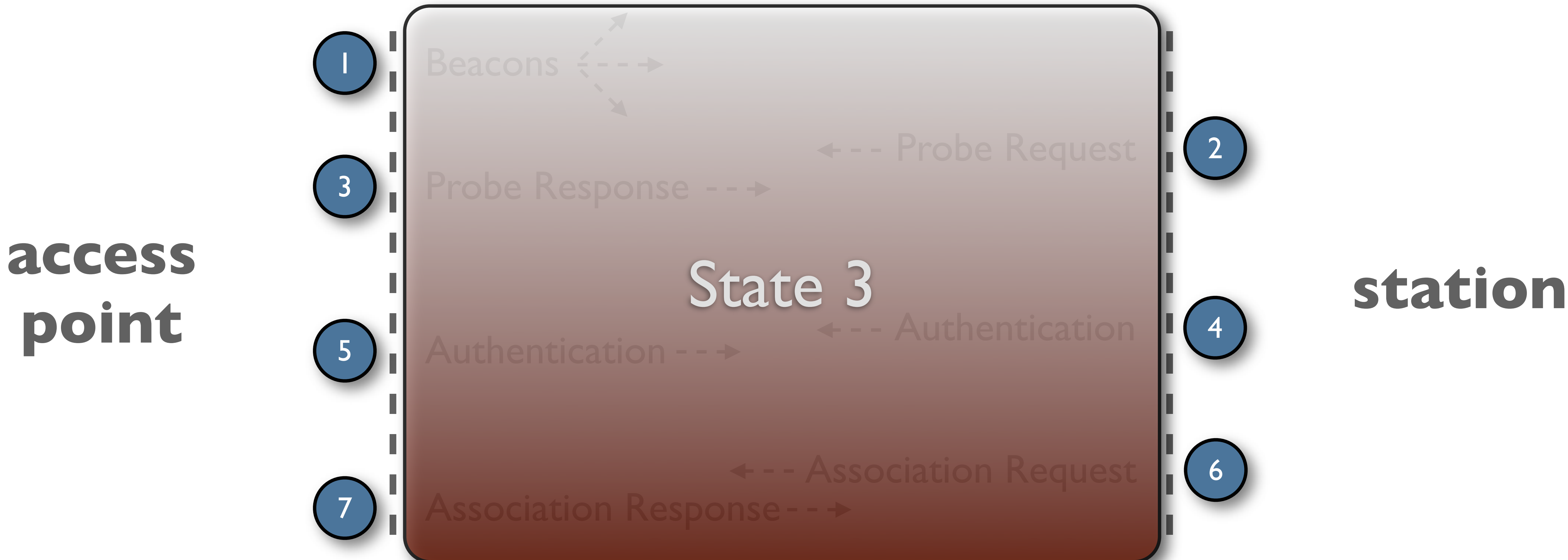

802.11 fuzzing

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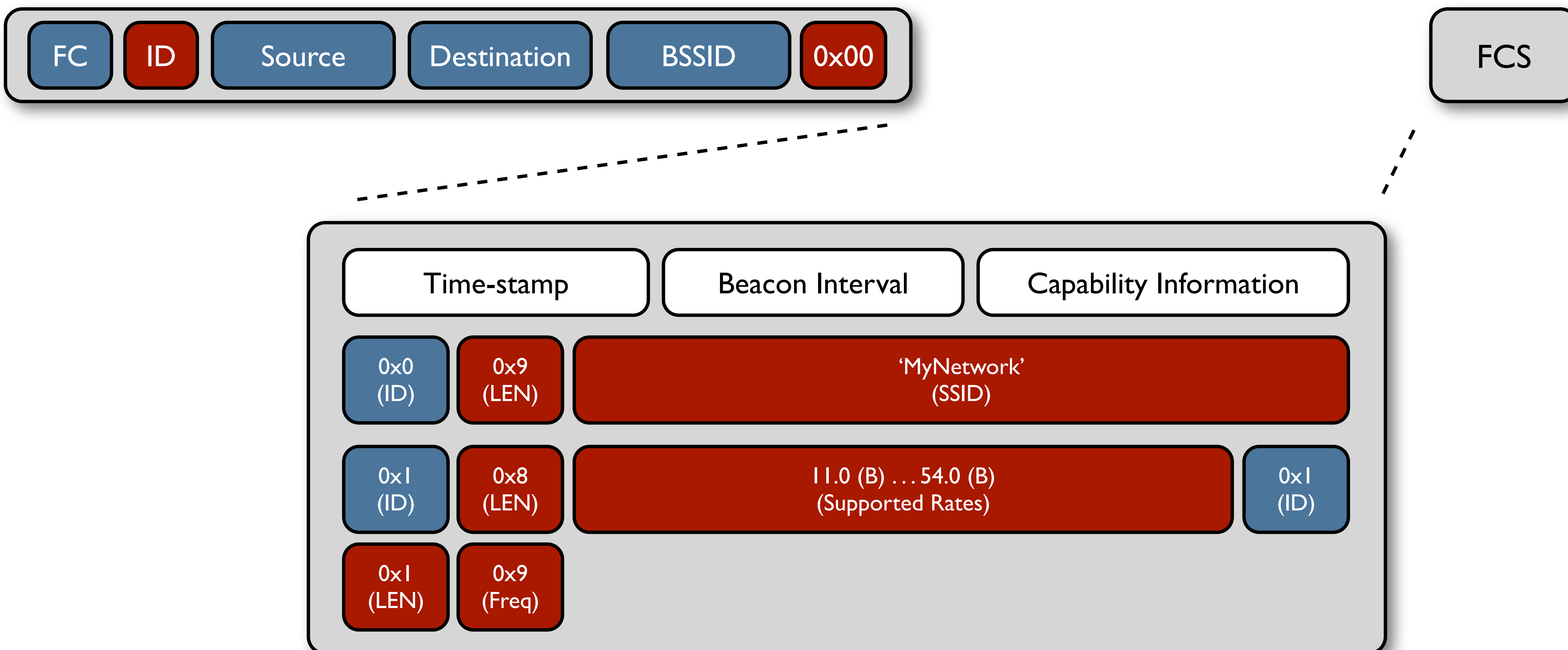
802.11 fuzzing issues

- Fuzzers must be aware of frequency channels, BSSIDs, states, modes, and data link encryption (filtering may take place at hardware level!)
- Response time and timing of replies is critical (e.g., because of reply windows or channel hopping)
- Overload, interference, packet corruption may occur
- Attacker and target must be co-ordinated and target must be continuously monitored

What to fuzz?

- Some Information Elements (IE) follow type-length-value pattern
- Type and length fields have fixed size, the value field's size is variable (potential overflow)

Example: a beacon frame



virtual 802.11 fuzzing

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A novel approach

- Requirements
  - Eliminate timing contraints
  - Replace unstable wireless medium
  - Allow guaranteed delivery
  - Support advanced target monitoring
- Solution
  - Move target into a virtual environment!

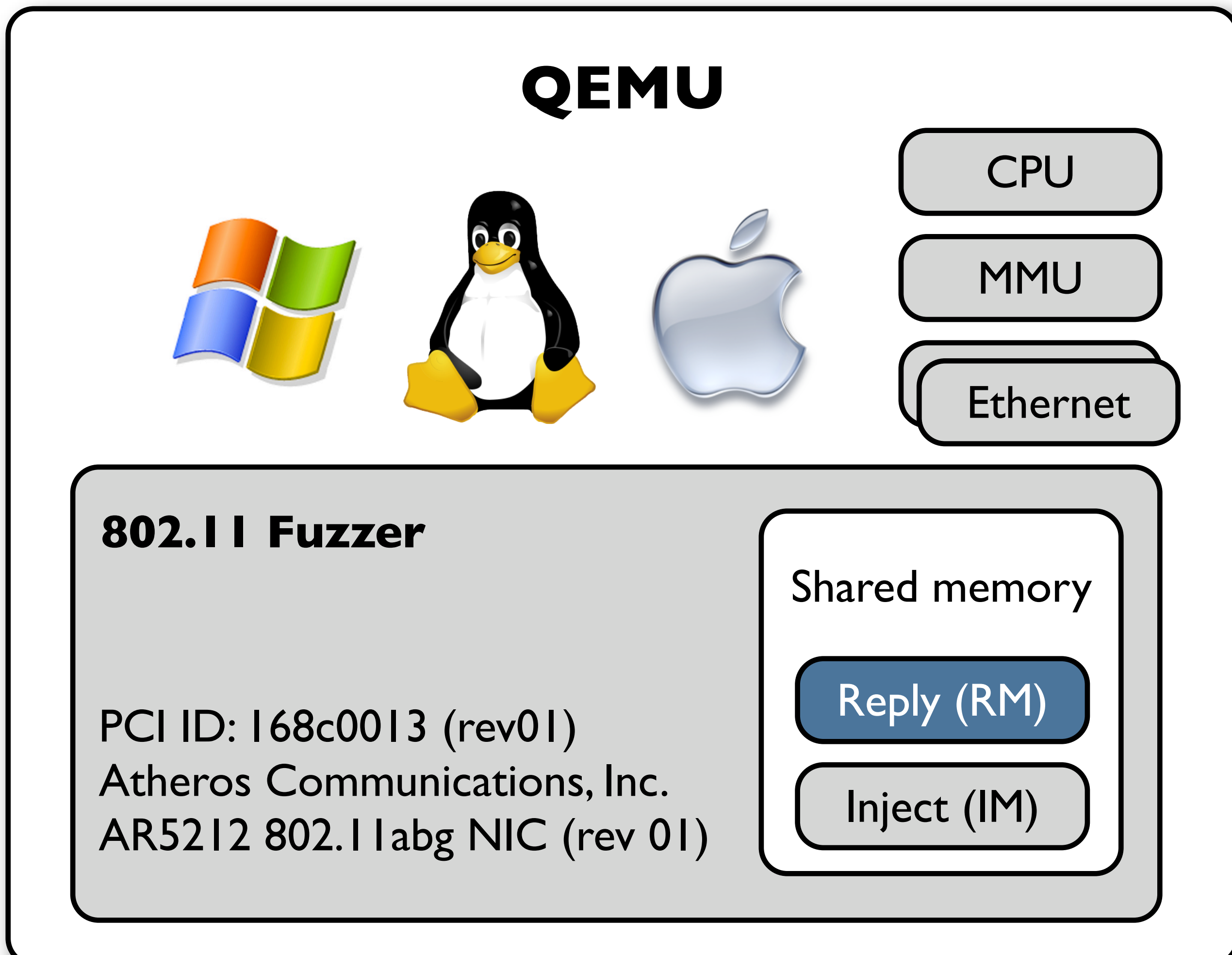
Advantages

- Virtual wireless device (software) replaces network hardware
- High-level IPC instead of live frame-injection
- CPU of virtual machine can be interrupted and stopped if necessary
- Guest OS monitoring at low-level (system restart, console output, etc.)
- Drastically simplifies complexity of fuzzing process

Our solution

- Develop a fuzzing "framework" on the basis of Fabrice Bellard's QEMU (optional ethernet card can be added via command-line option)
- Modular design
  - packets read from outgoing queue are copied to shared memory
  - connected modules are notified via semaphores
  - packets are read from shared memory and copied to incoming queue

System overview



- Dumper (RM): store outgoing packets
- Listener (RM): display outgoing packets
- Injector (IM): inject arbitrary packets
- Stateless fuzzer (IM): reply directly
- Access point (RM & IM)
- Stateful fuzzer (RM & IM): AP and fuzzer

Access Point module

- Broadcasts beacon frames
- Responds to incoming probe requests
- Supports complete Open System Authentication
- Responds to incoming association requests
- Features minimum implementation of ICMP
- Full logging of 802.11 traffic
- But words can only say so much…

Stateful fuzzer module

- Initially, the fuzzer behaves like an access point module, broadcasting valid beacons and responding to probe requests
- Once authentication is complete, it is possible to fuzz the target in state 2, e.g. transmit fuzzed association response frames
- See it yourself…

fuzzing results

Results

- We have developed a "framework" for 802.11 fuzzing using QEMU
- So far the framework supports fuzzing in all three states of a target in managed mode
- A simple fuzzer using the framework and old versions of the MadWifi driver detected known vulnerabilities
- A previously undocumented vulnerability was also found!

The vulnerability

- Our fuzzer detected a flaw in the MadWifi implementation
- A beacon frame with a specially crafted Extended Supported Rates information element crashes Linux when scanning for available networks
- Sadly (uh, is deepsec blackhat?), no remote code execution possible (but DoS)
- Recently published by SEC Consult & TU Vienna and fixed since 0.9.3.3

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kernel-mode exploits

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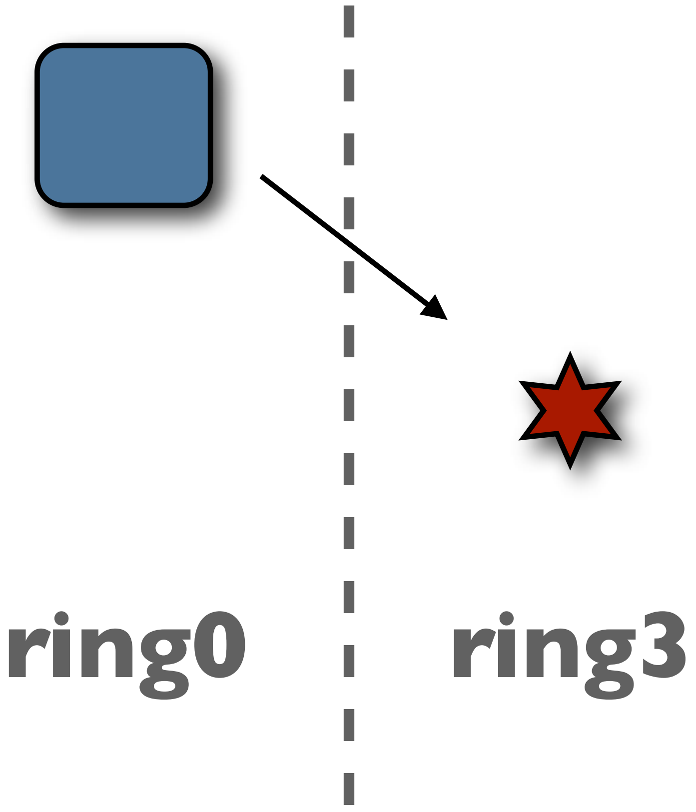
- How can they be exploited (remotely)?
- How generic are these exploits?

NULL / user-space dereference



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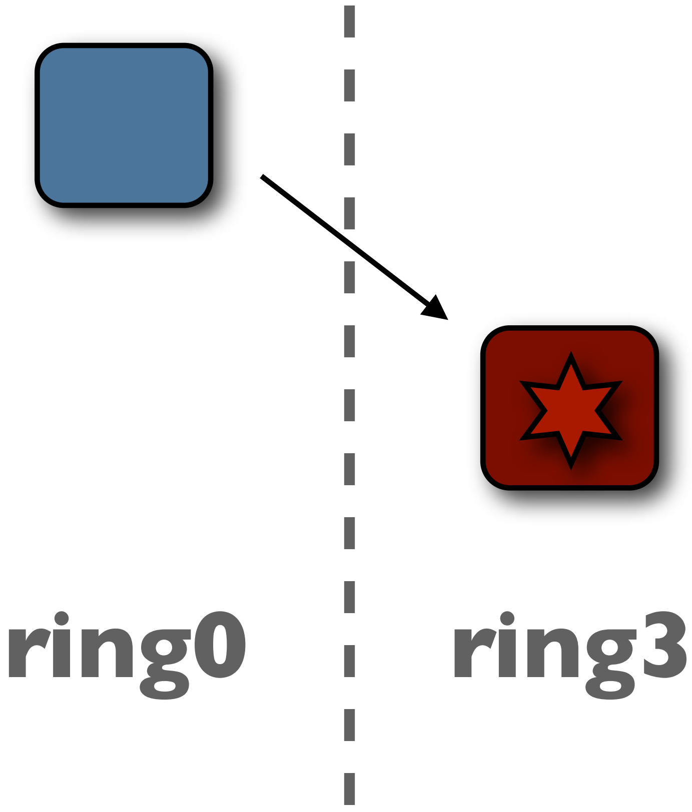

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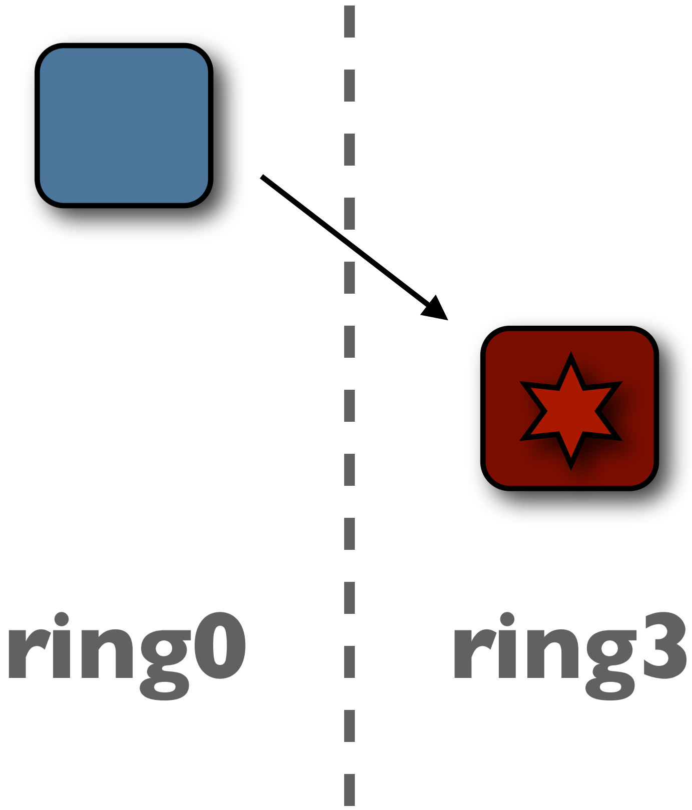


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foo = kmalloc(size, GFP_KERNEL);
/* if kmalloc fails, foo will be NULL */
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/* later on... */
foo->data->value = some_value;
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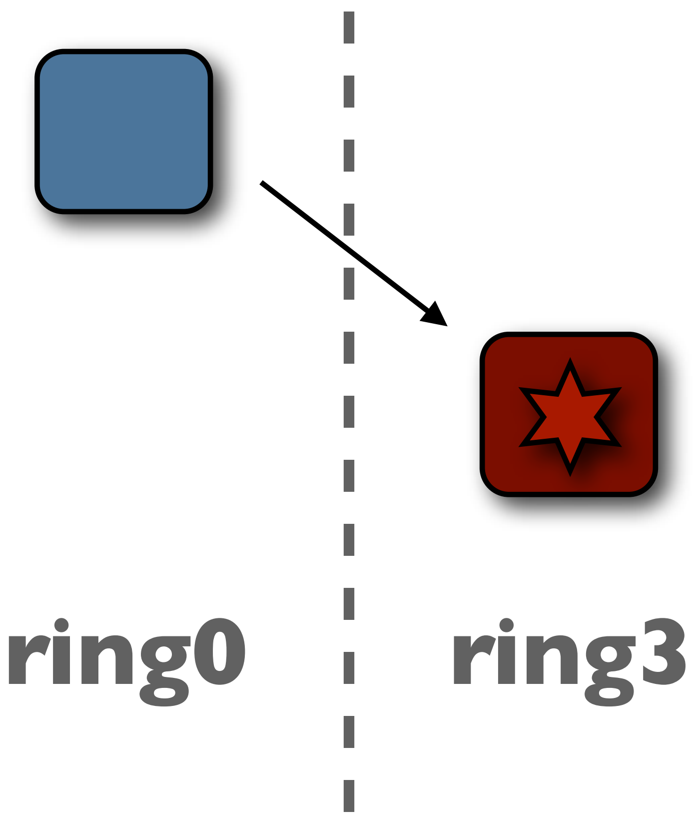


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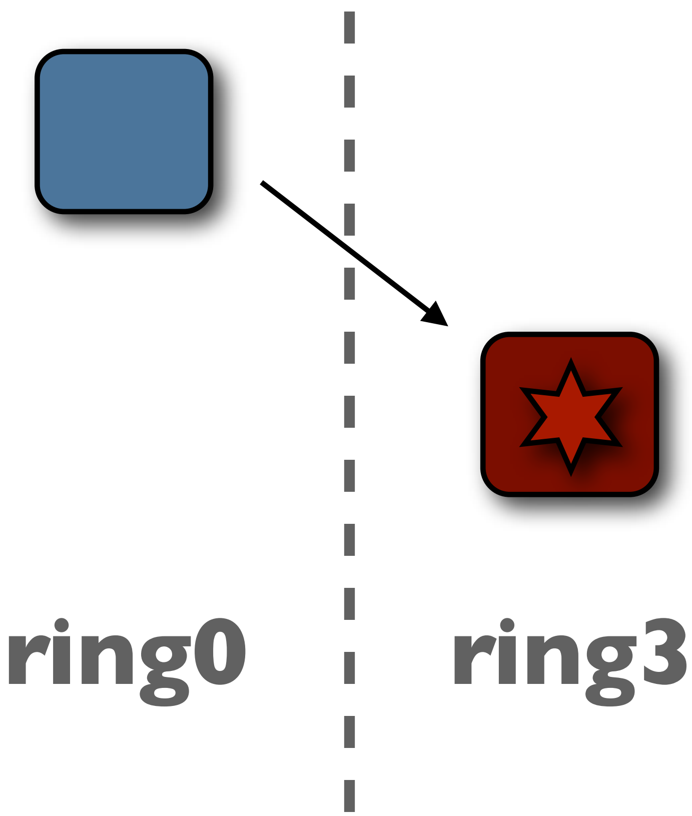


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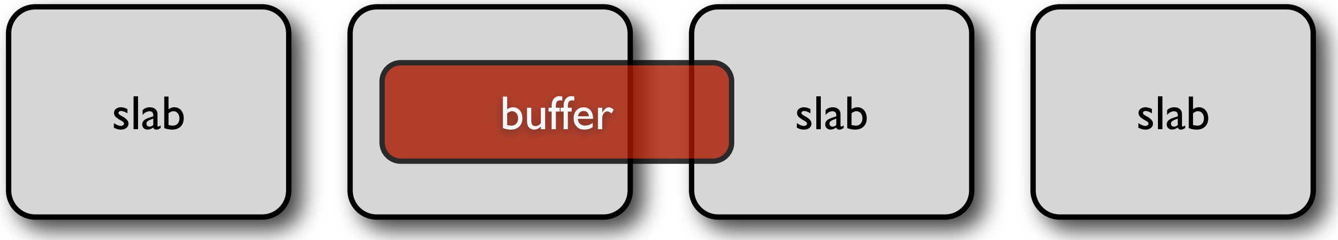

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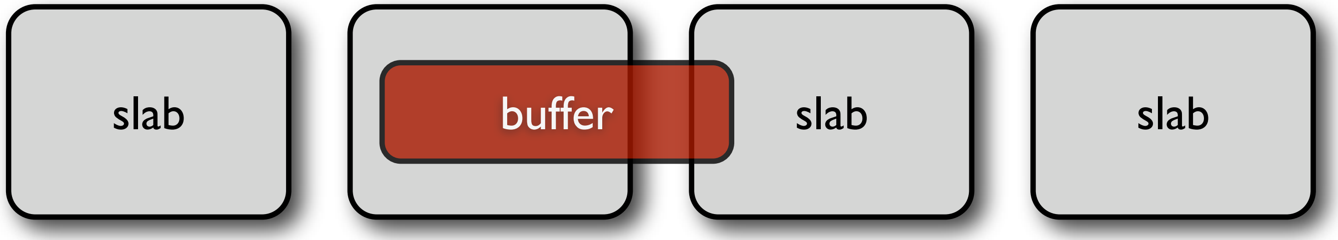
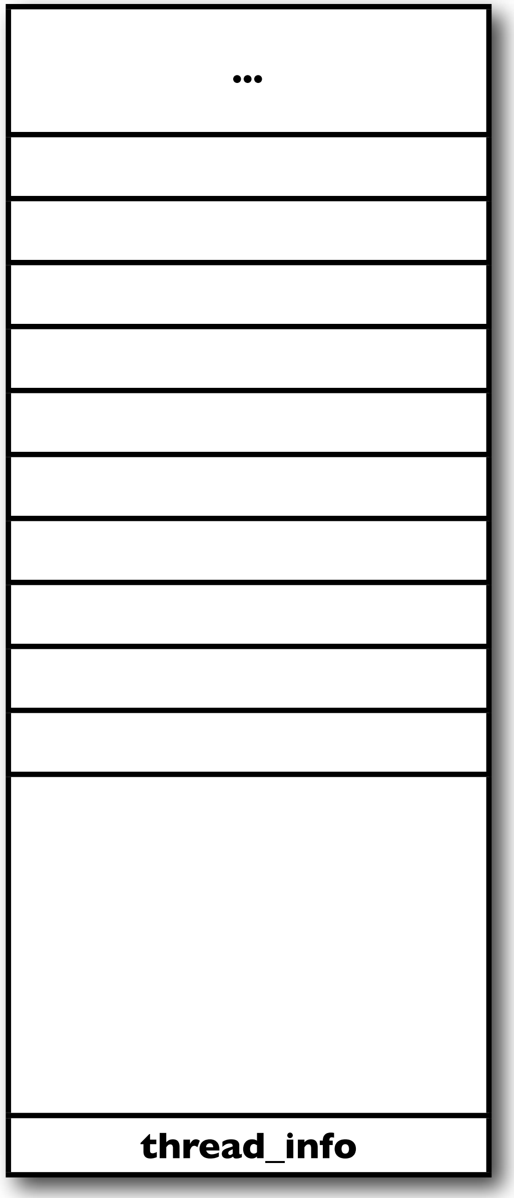


- If we know the contents of the adjacent slab, we might be able to overwrite a pointer and thus create a pointer dereference exploit, or similar scenario.

Stack overflows

- Typically, kernel stack is 4k or 8k.
- Otherwise similar to user stack exploits: overwrite saved return address with buffer address.
- How do we know where to jump to? And how do we know the location of the saved return address?



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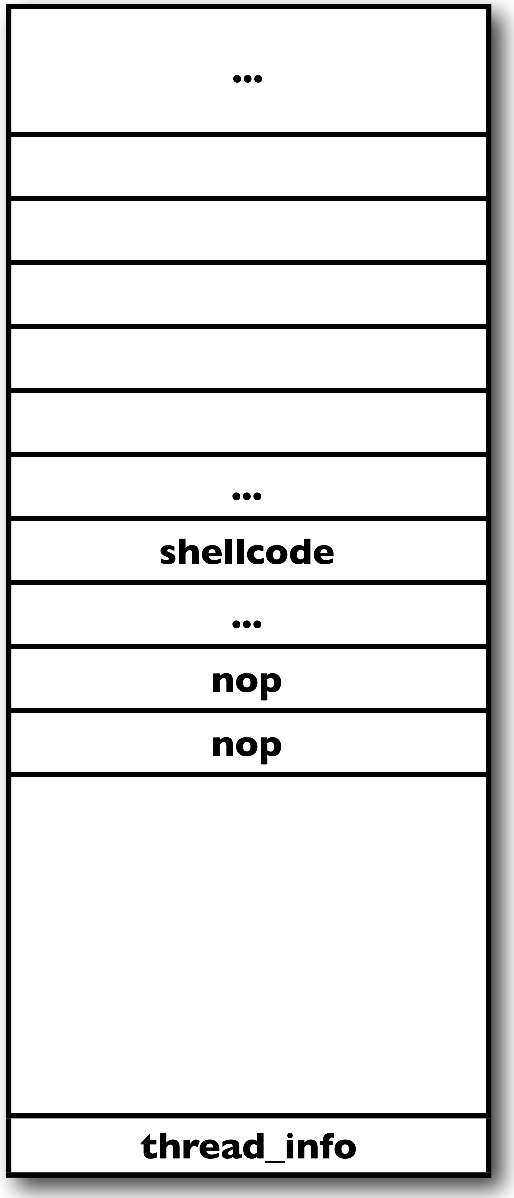

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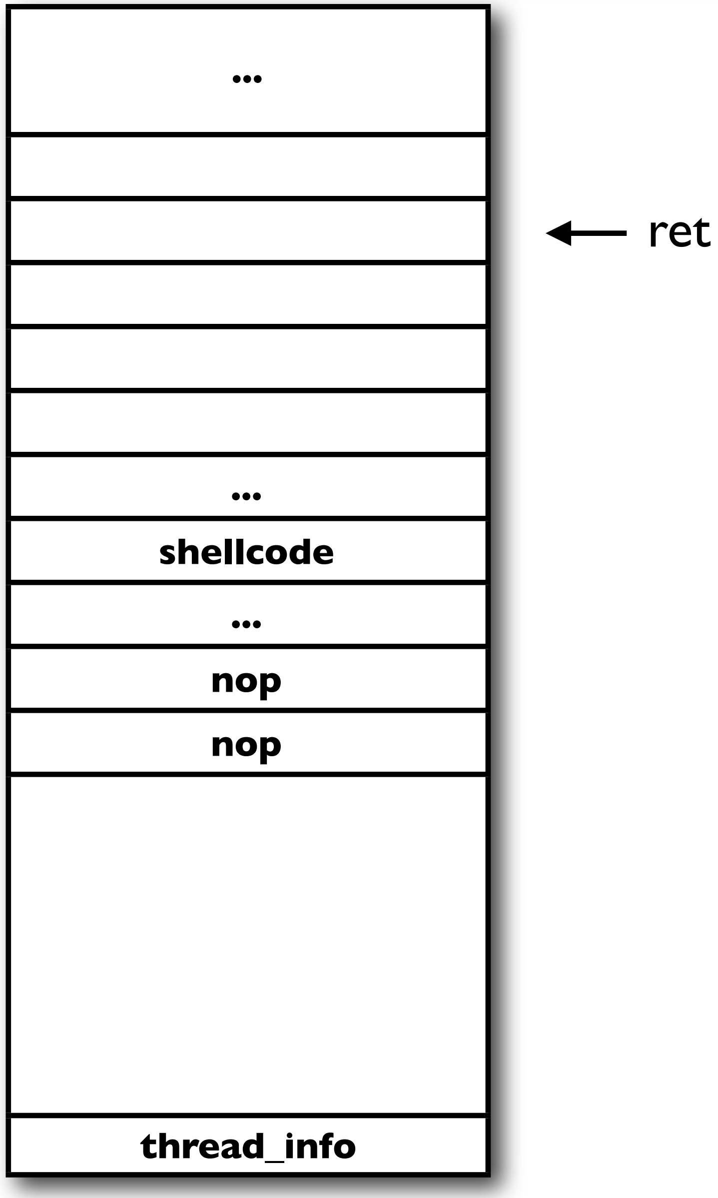

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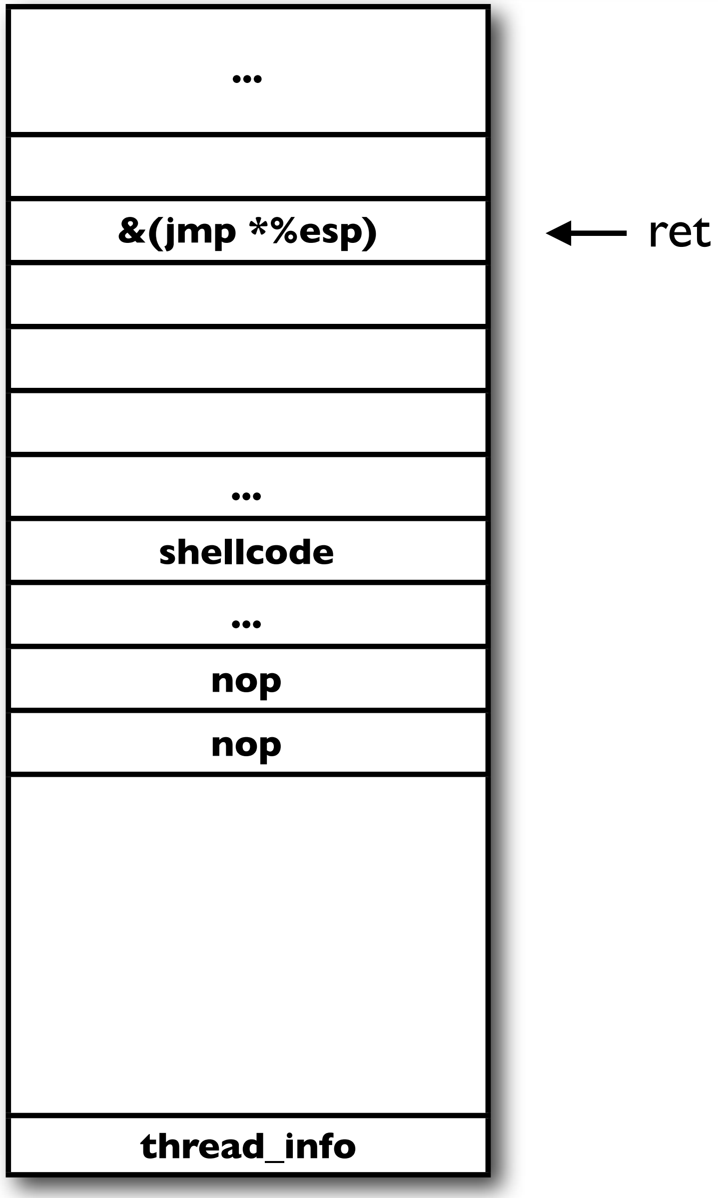

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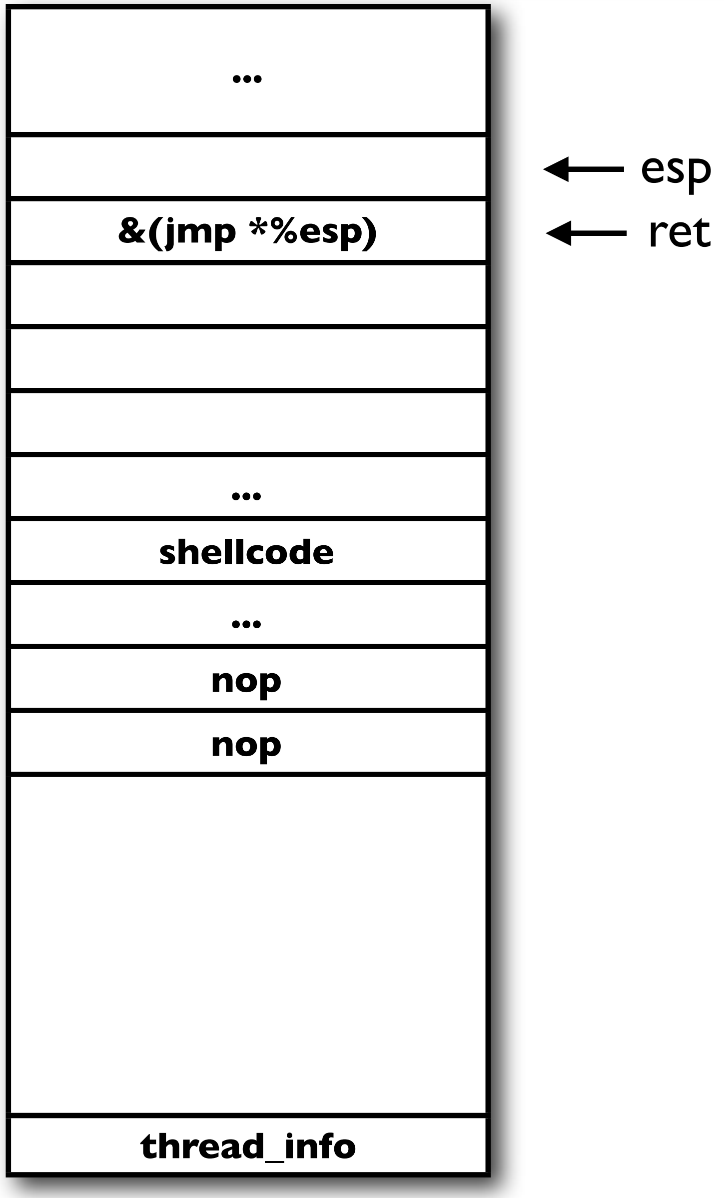

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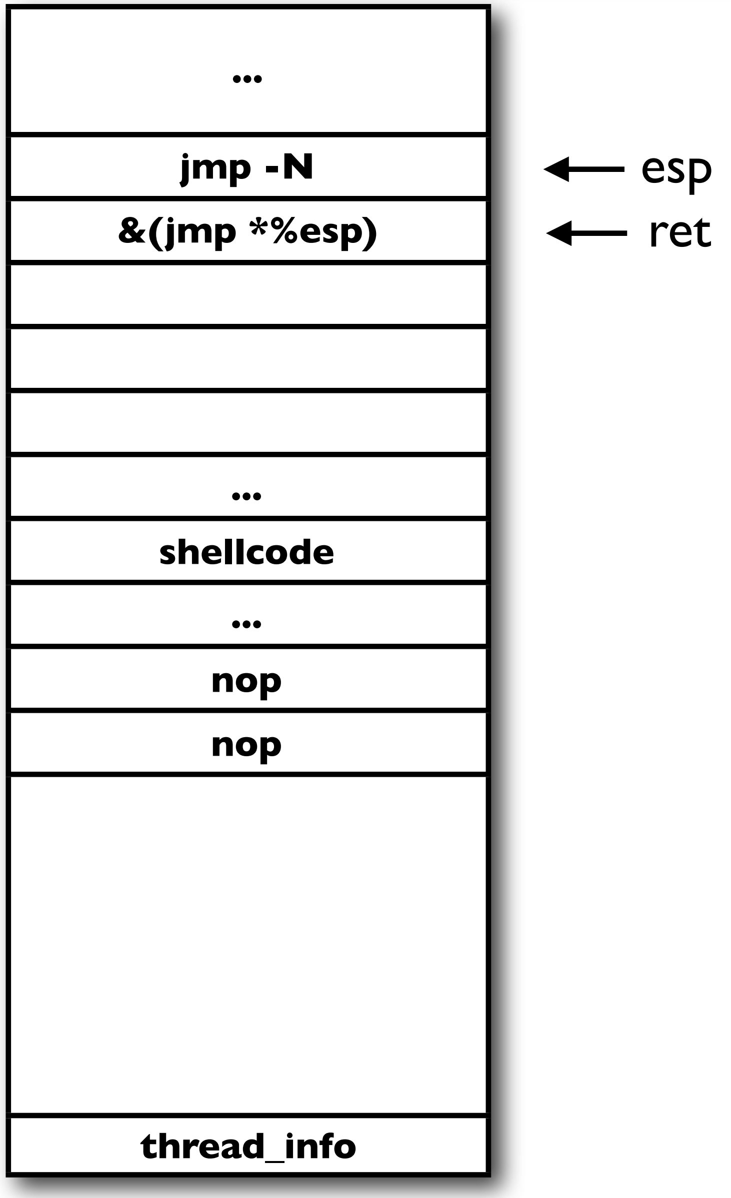

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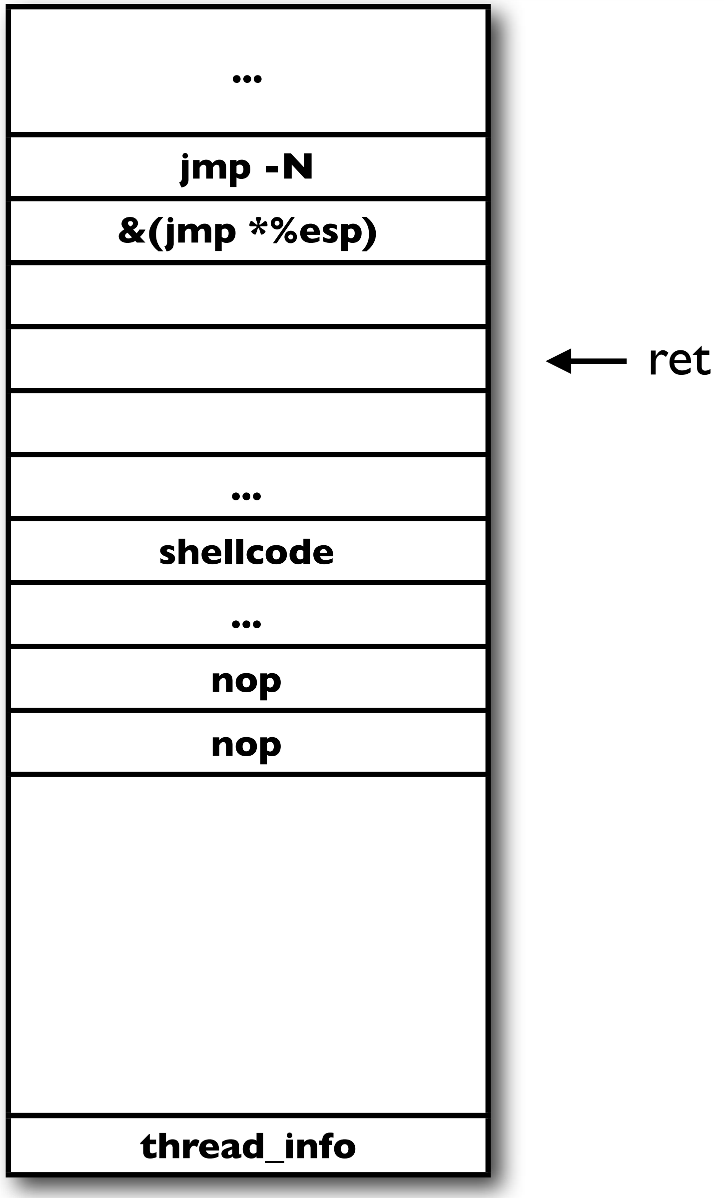

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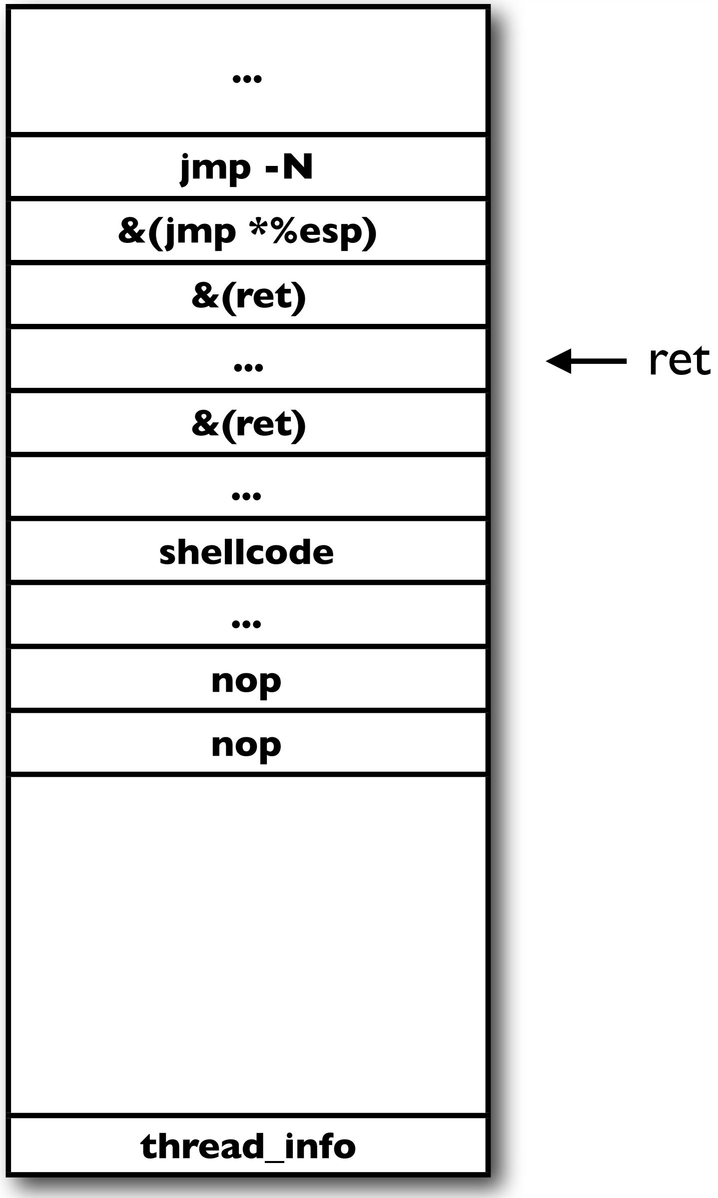

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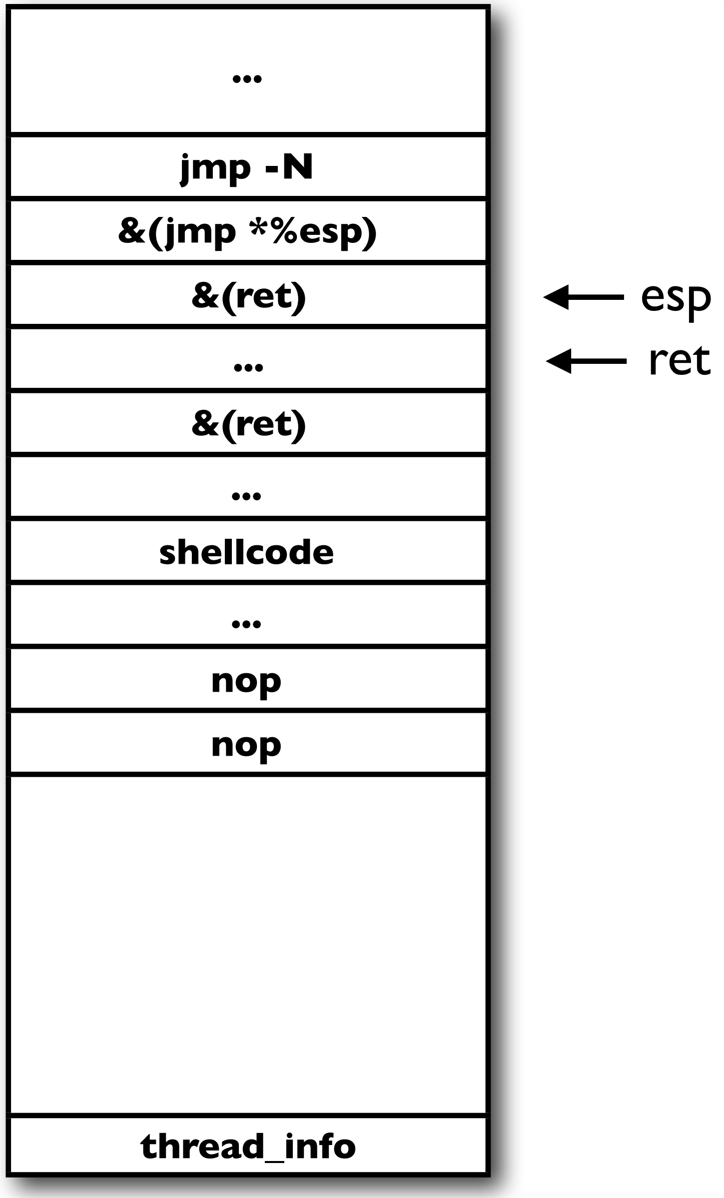

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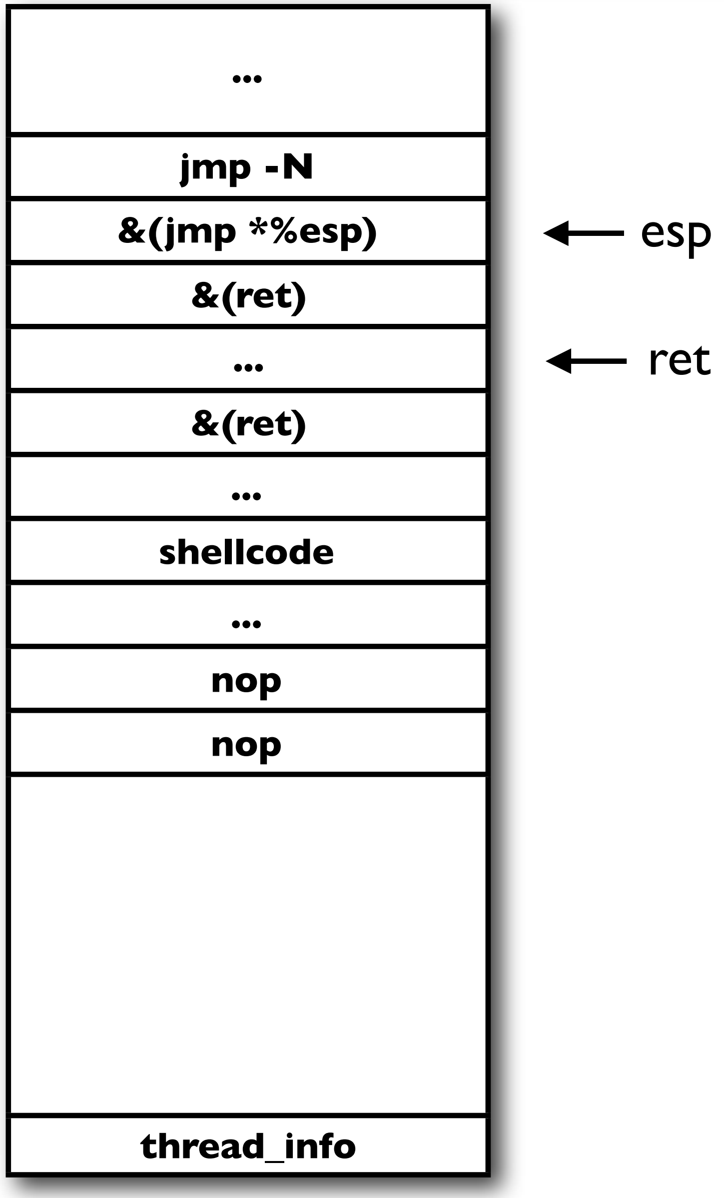

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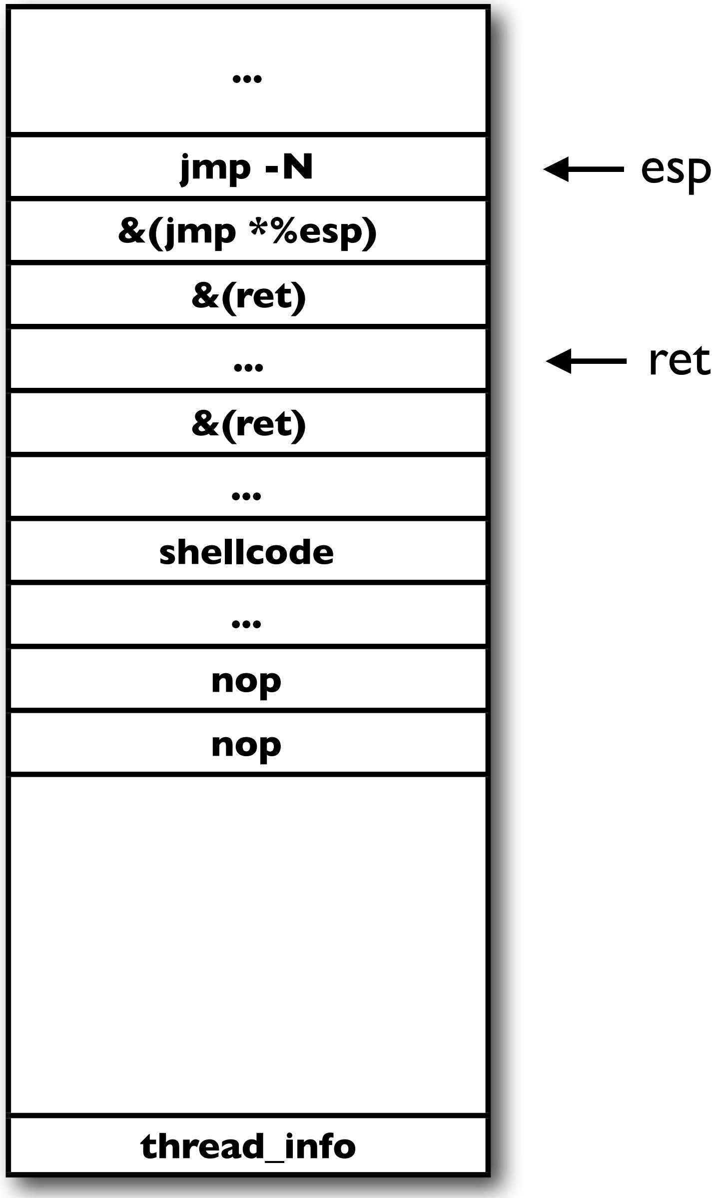
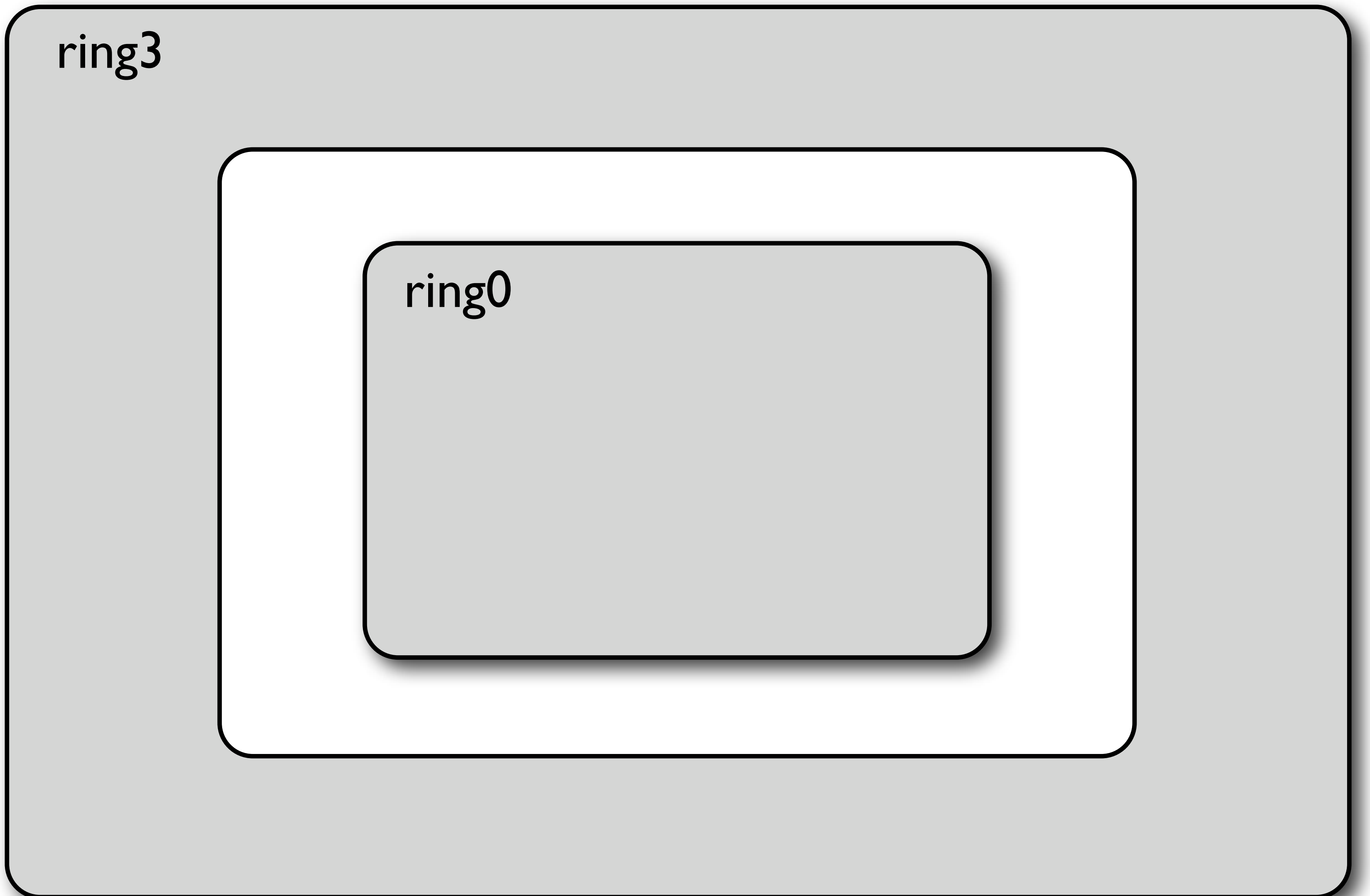


Inside ring0, now what?



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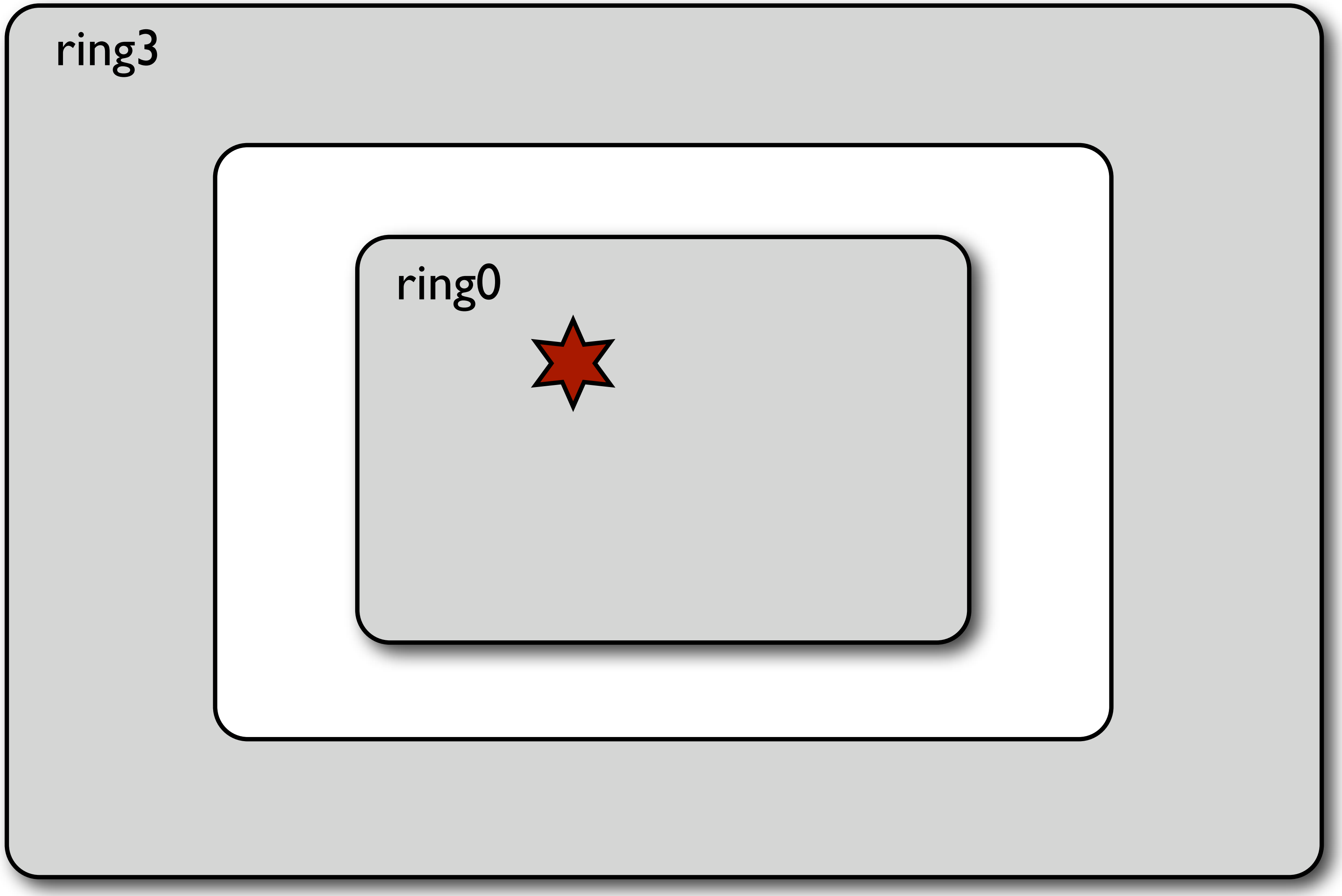

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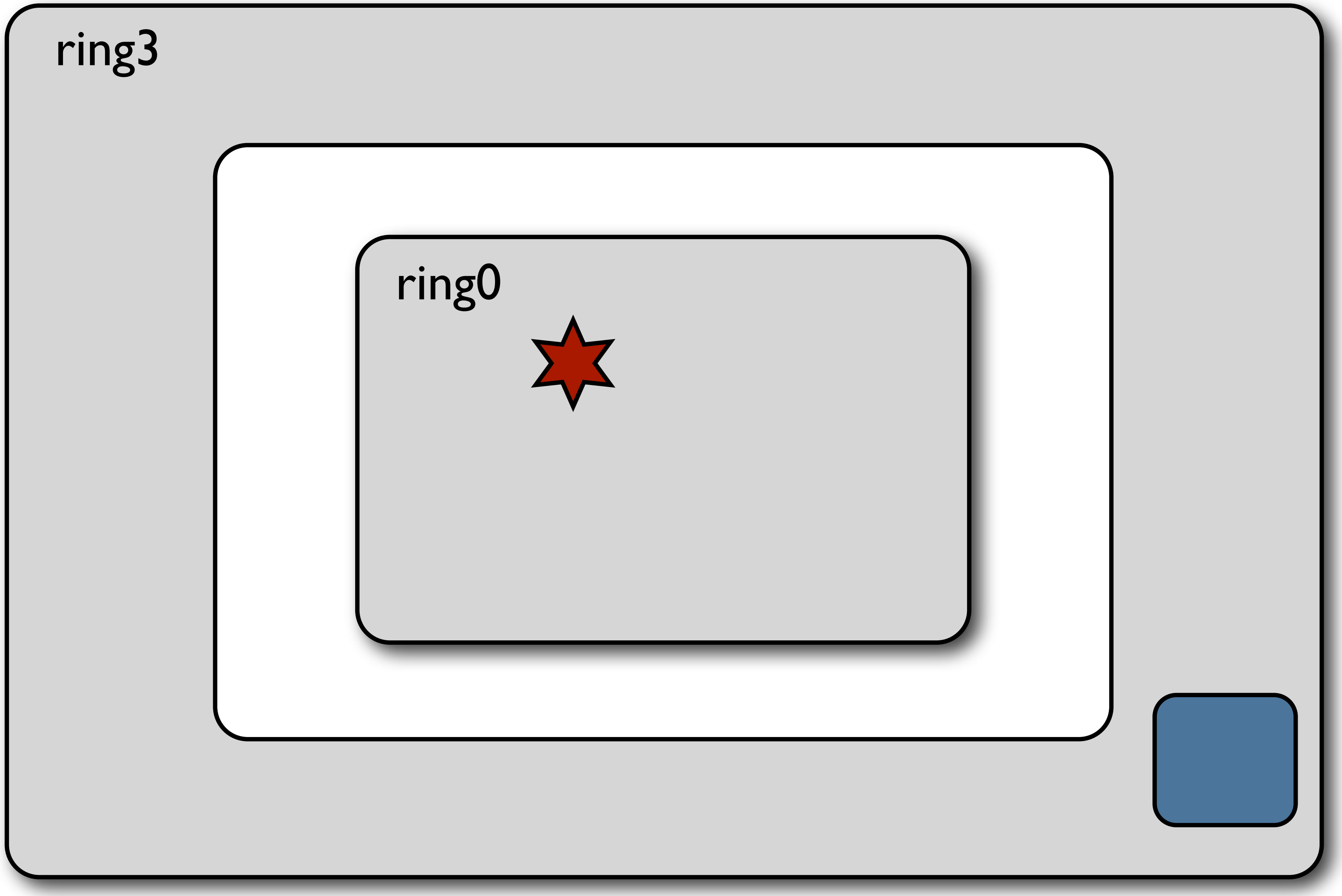

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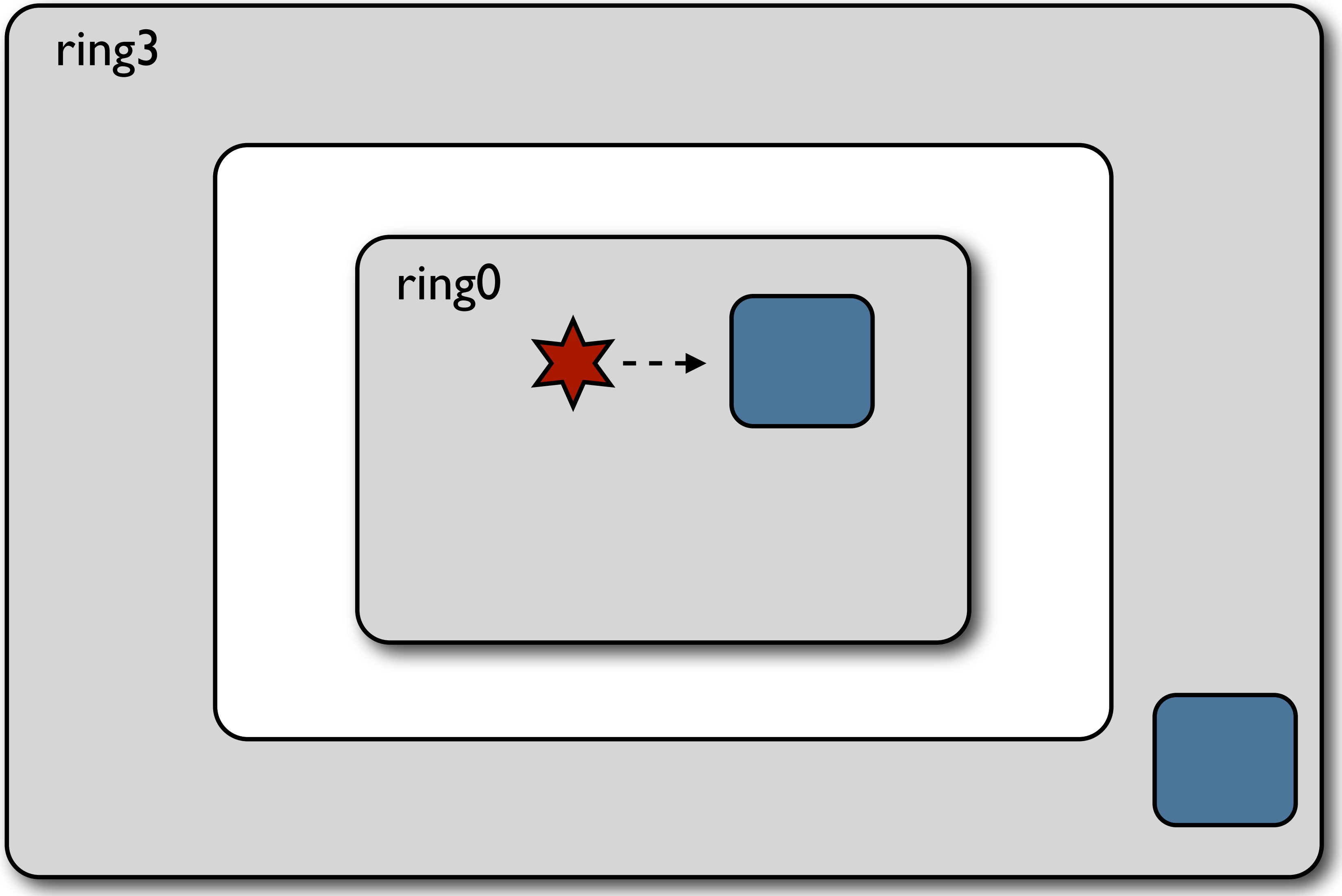

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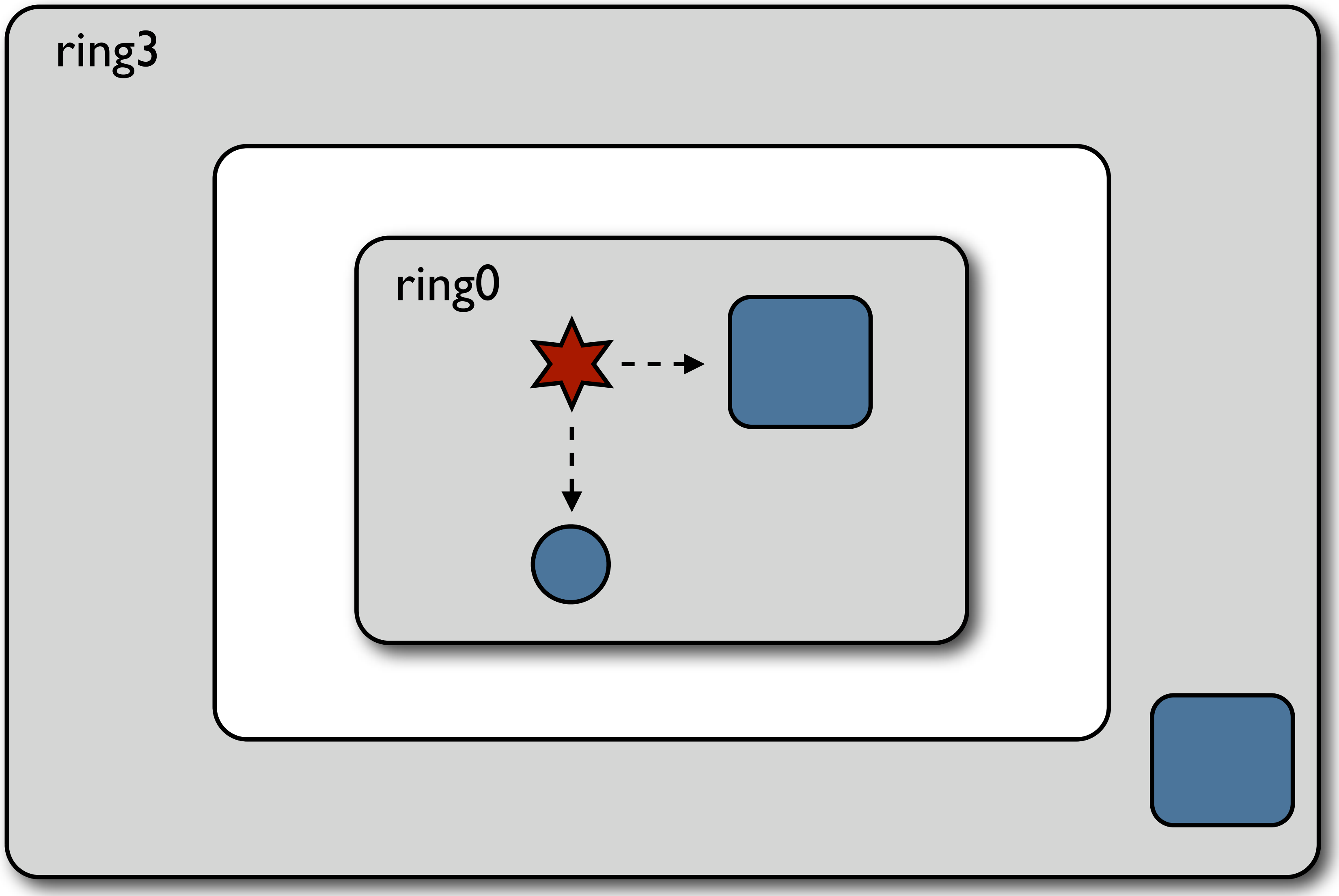

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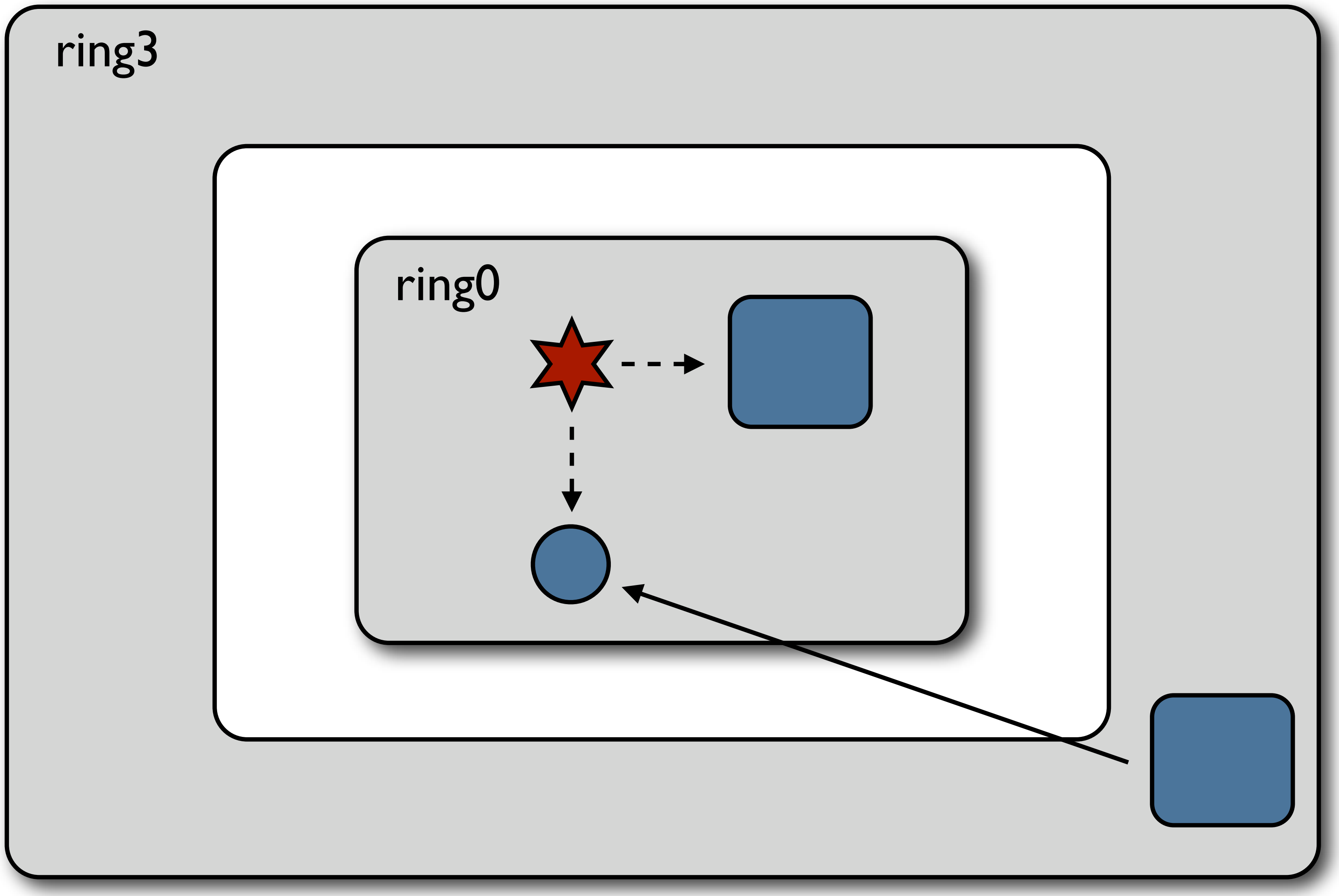

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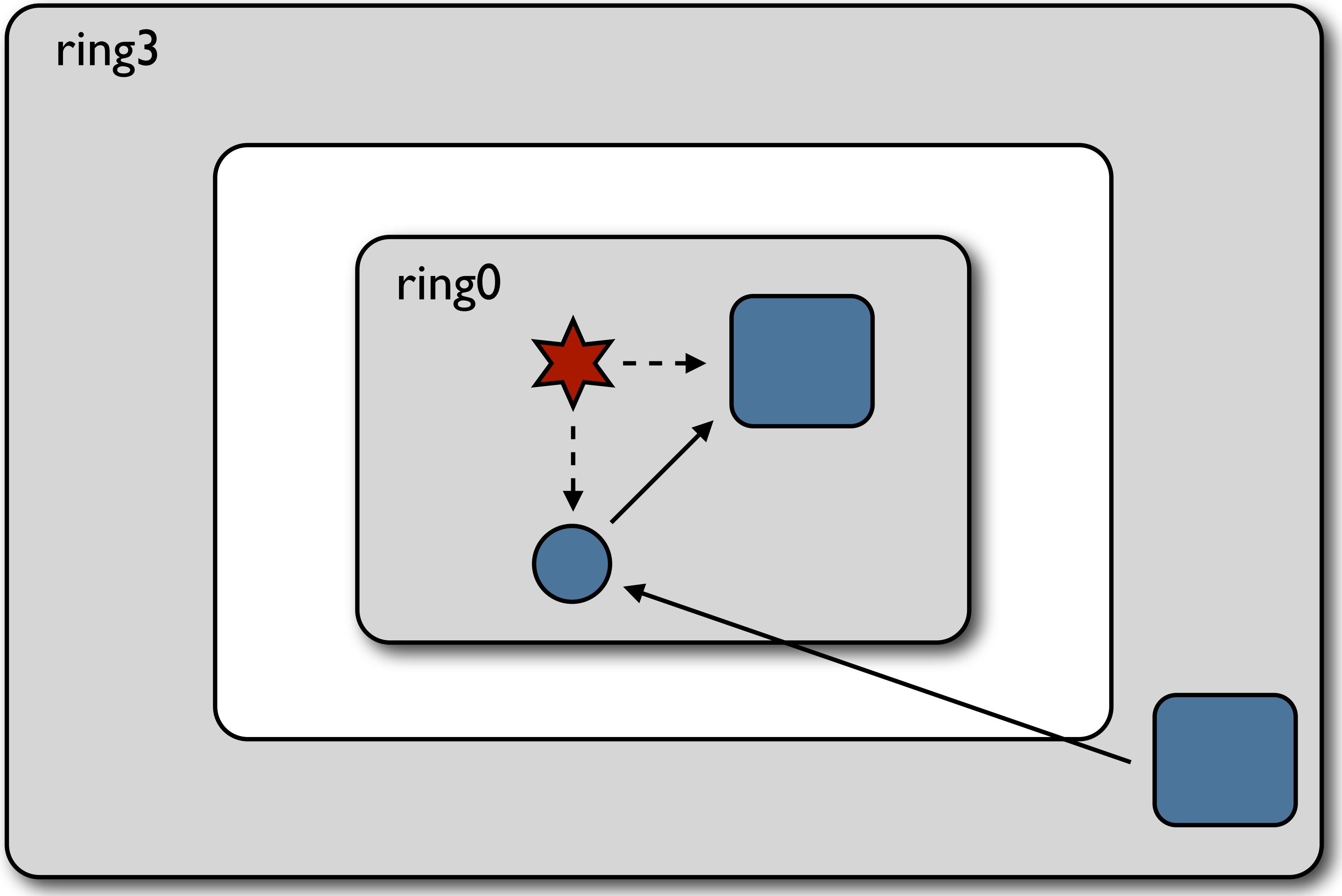

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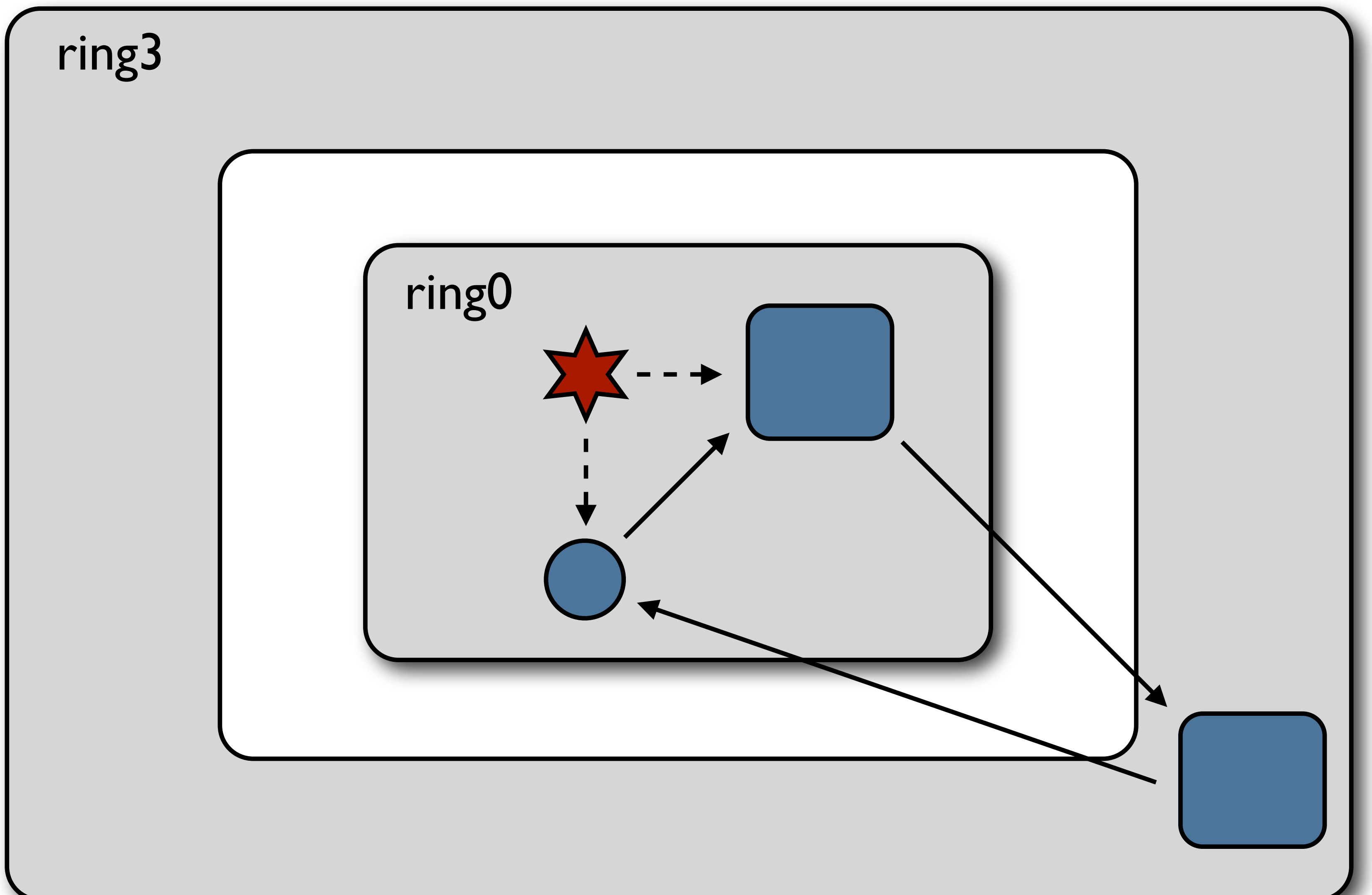
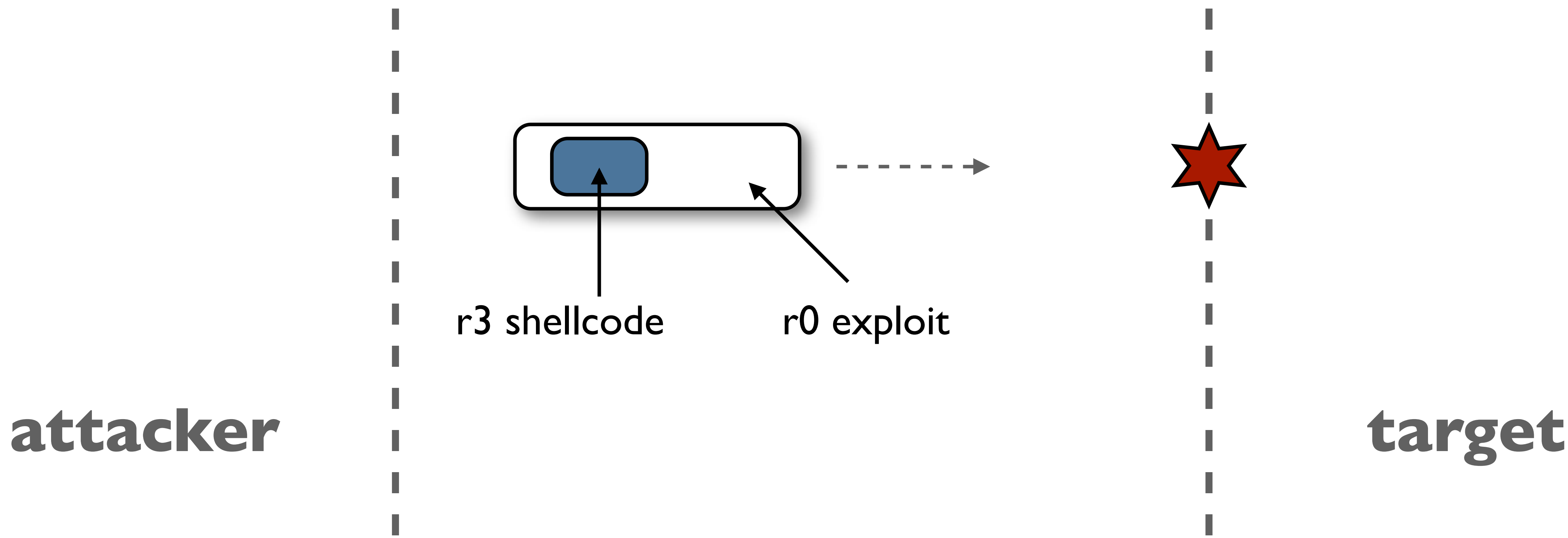


Return to ring3!



Metasploit's approach

- Migration (not implemented yet)
- Stager
- Recovery
- Stage (regular ring3 payloads)

Migration

- The goal of this step, is to transition to a state where the ring0 payload can be executed in a safe manner.
- On Windows it may be necessary to adjust the current IRQL. On Linux, it may be necessary to cleanly get out from an interrupt or softirq.
- May coincide with the stager component.

Stager

- Copy the ring0 or ring3 to a suitable location
  - We may only be able to access currently loaded pages
  - Space between kernel stack and thread_info
  - Unused entries in the IDT
- Install hook that will execute the payload in the desired context
  - Interrupt handlers
  - System call handlers (how do we find the system call table?)

Recovery

- If the system crashes after the stager has finished, we haven't accomplished anything
- We need to recover from the exploit and leave the system in a safe state
- Recovery depends on the situation:
  - Restore registers (but we smashed the stack…)
  - Enable interrupts or preemption
  - Release spinlocks

Stage

- Ideally, the stage is simply a ring3 shellcode
- Depending on the migration / stager we may have a two-level stage
  - Copy ring3 payload to user-space (in context of a user-mode process)
  - Adjust process privileges ;-)
  - Set process saved instruction pointer or some function pointer to payload
  - We hooked the sys_execve system call and replaced the command to be executed

conclusion

Conclusion

- Fuzzing 802.11 live on the air is a cumbersome and time-consuming process due to the limitations and requirements of the wireless medium
- Moving the fuzzer and the target into an emulated environment dramatically speeds up and simplifies the process!
- Every kernel vulnerabilities is a story of its own, but some generalizations are still possible

references & tools

Fabrice Bellard. "QEMU, a Fast and Portable Dynamic Translator" USENIX 2005 Annual Technical Conference

sgrakkyu & twiz. "Attacking the Core: Kernel Attacking Notes" Phrack 0x0c, 0x40, #0x06

QEMU
http://www.qemu.org

Christopher Kruegel
Engin Kirda
http://www.seclab.tuwien.ac.at

Bernhard Müller
http://www.sec-consult.com

kudos & respect

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vielen dank