Jetset: Targeted Firmware Rehosting for Embedded Systems

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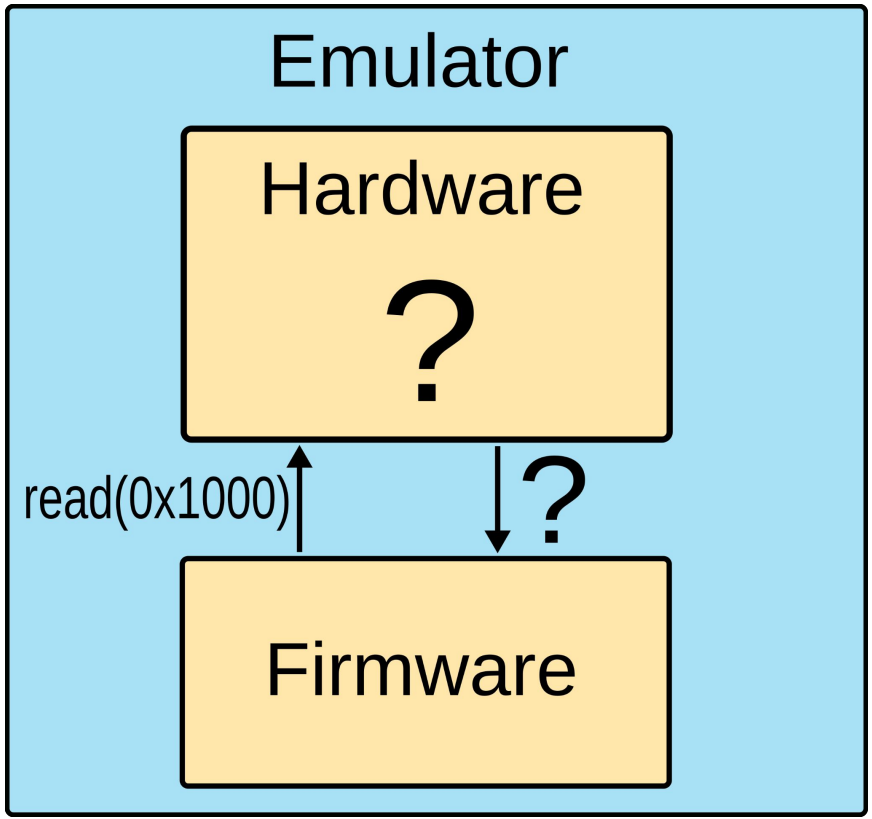
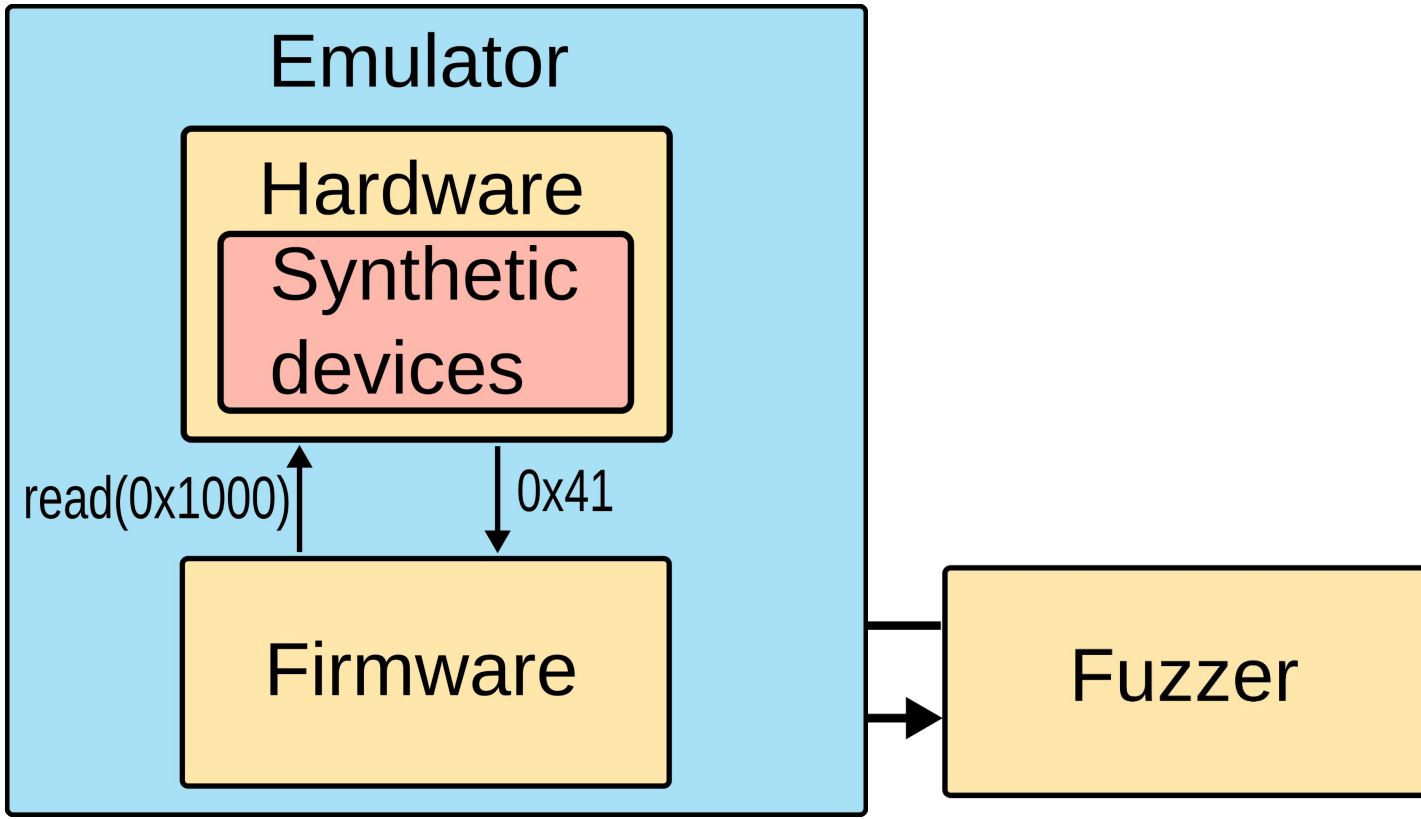
Embedded systems are hard to analyze

- On standard platforms, tools can take advantage of standard I/O interface
- Analysis tools like fuzzing and dynamic RE “just work”
- Embedded systems may have nonstandard (or unique) I/O interfaces

Testing firmware



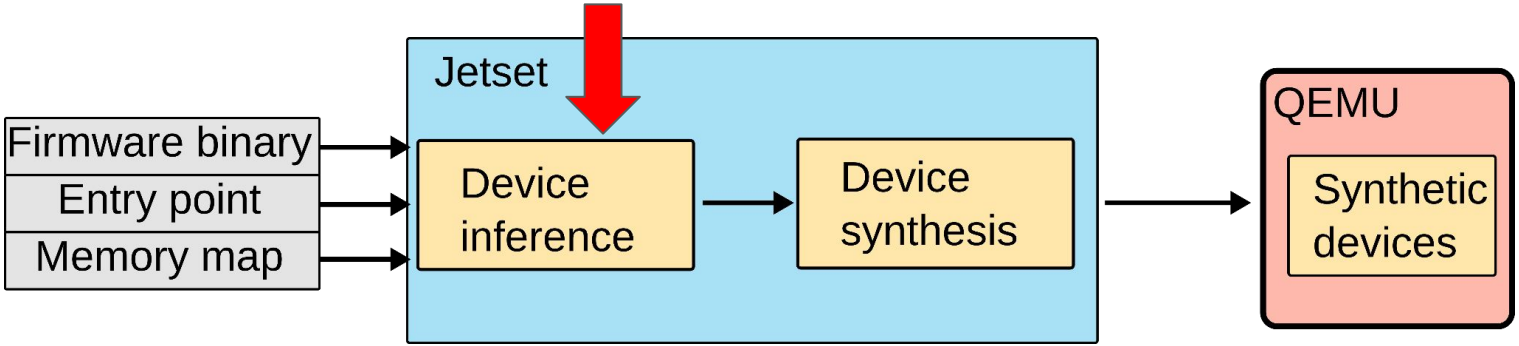
Firmware rehosting



A targeted approach to rehosting

- Key Insight: Firmware implicitly encodes expected hardware behavior
- What values need to be read from the device to read the boot point?
- Goal: Generate HW device that guides firmware towards the boot point

Jetset: targeted firmware rehosting



Searching for a boot path

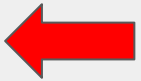
- Jetset uses a guided-DFS to find a path to the boot point

Example: initializing UART and USB

```
USB:
       ...



UART:
       ...



FINISH_BOOT:
       ...


call print_boot_msg
```

Example: initializing UART and USB

```
USB:
      mov ebx, [0x1000]; usb_present
      cmp ebx, 0;
      je UART;
      call init_usb
UART:
      mov ebx, [0x2000]; uart_present
      cmp ebx, 0
      je FINISH_BOOT
      call init_uart
FINISH_BOOT:
      mov ebx, [0x400000]; all_ok
      cmp ebx, 0
      je FAIL
call print_boot_msg
```

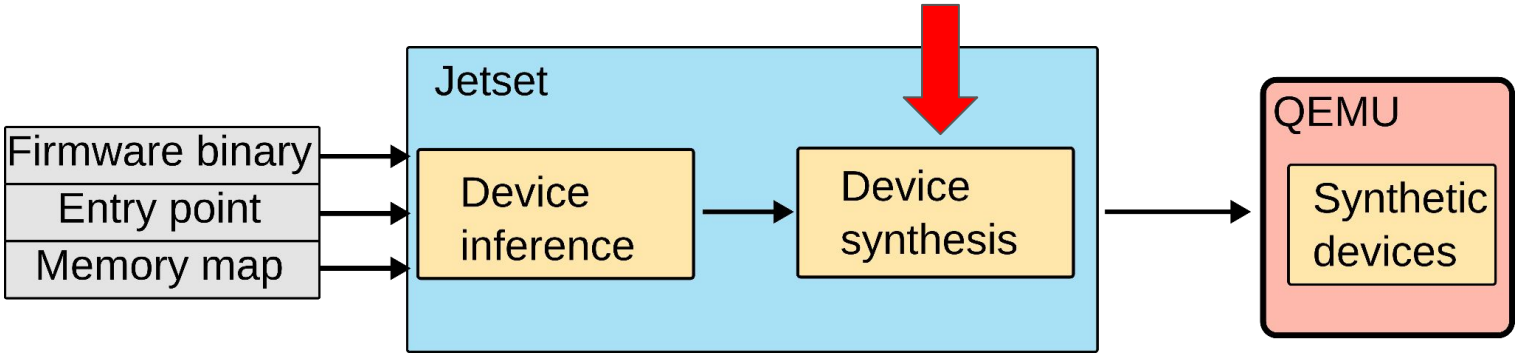


Example: initializing UART and USB

```
USB:
      mov ebx, [0x1000]; usb_present
      cmp ebx, 0;
      je UART;
      call init_usb
UART:
      mov ebx, [0x2000]; uart_present
      cmp ebx, 0
      je FINISH_BOOT
   9: call init_uart
FINISH_BOOT:
   4: mov ebx, [0x400000]; all_ok
      cmp ebx, 0
      je FAIL
call print_boot_msg
```

Backtrack!

Jetset: targeted firmware rehosting



Generating device models

- Use SMT solver to generate satisfying trace that replays successful path

Example: Generating device models for UART and USB

```
USB:
      mov ebx, [0x1000]; usb_present
      cmp ebx, 0;
      je UART;
      call init_usb
UART:
      mov ebx, [0x2000]; uart_present
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      je FINISH_BOOT
      call init_uart
FINISH_BOOT:
      mov ebx, [0x400000]; all_ok
      cmp ebx, 0
      je FAIL
call print_boot_msg
```
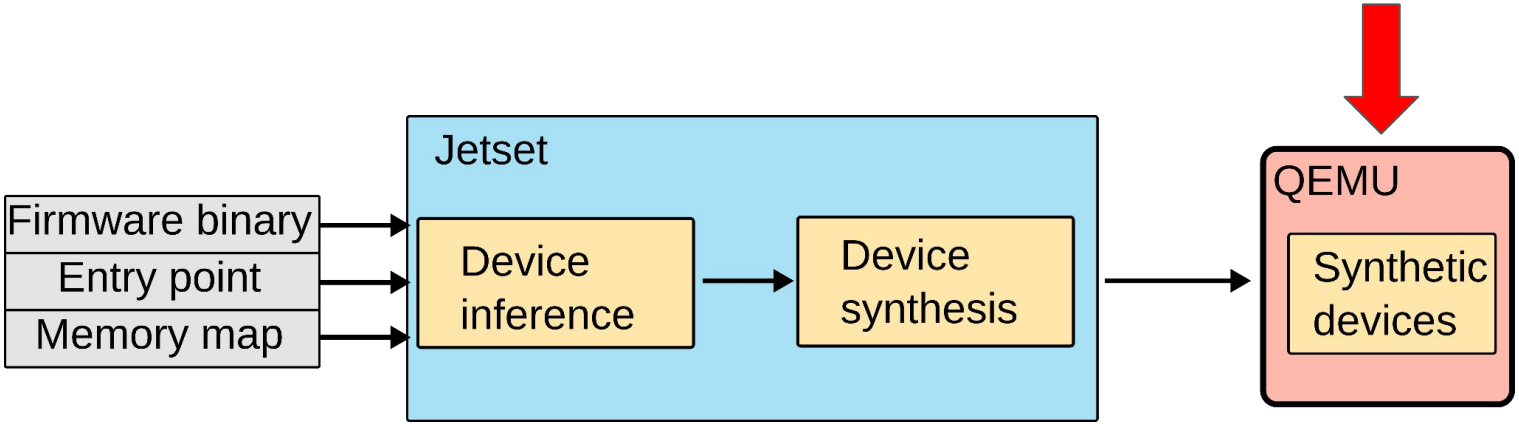

```
Traces:
0x1000: 0x0
```

Jetset: targeted firmware rehosting



Evaluation: generating device models for realistic firmware

- 13 firmware targets (4 original, 9 from previous work)
- 3 different architectures (ARM, i386, m68k-coldfire)
- 4 operating systems: Linux, VRTX, RIOT, Arduino (+ 4 bare metal)
- Average synthesis time ~14 minutes (one subject took 2 hours 34 minutes)

Evaluation: using generated models for dynamic analysis

- We used Jetset's generated models to fuzz CMU-900 and RPi2
- Found (not remotely exploitable) privilege escalation bug in the CMU-900
- Fuzzed syscall handlers of RPi2, to check that emulation had correct behavior

Summary

- Jetset uses directed symbolic execution to generate emulators for firmware
- Technique tested against several architectures and operating systems
- We used Jetset to find a bug in an otherwise untestable piece of firmware

https://jetset.aerosec.org