FirmFuzz: Automated IoT Firmware Introspection and Analysis

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Internet of Things

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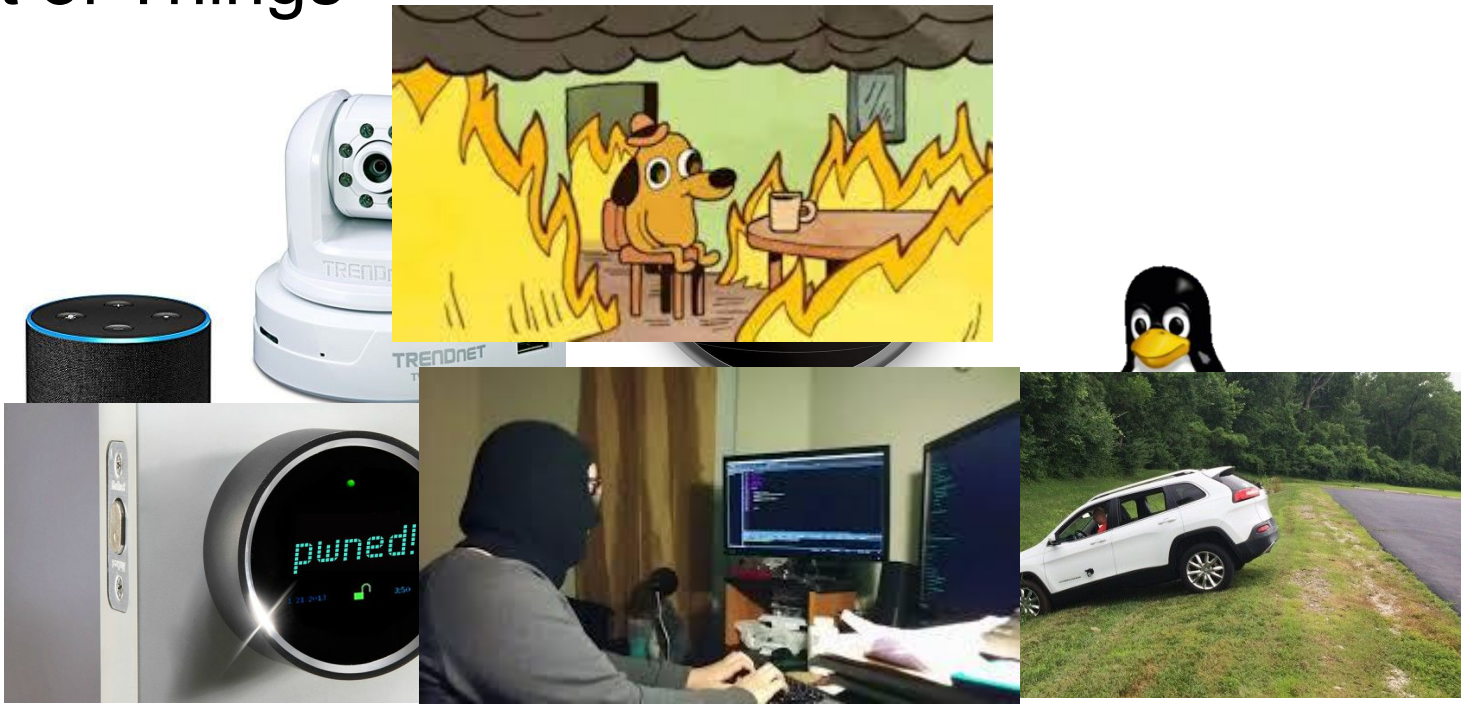
- 233 CVE’s assigned from Jan 2018 - Nov 2019

Internet of Things



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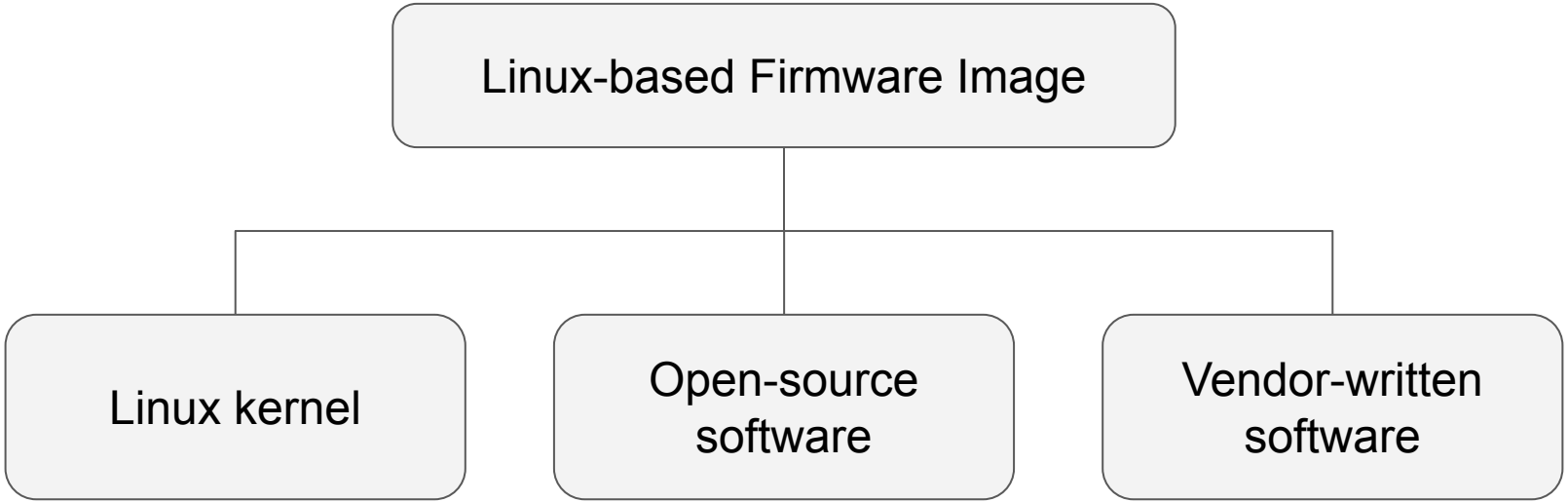
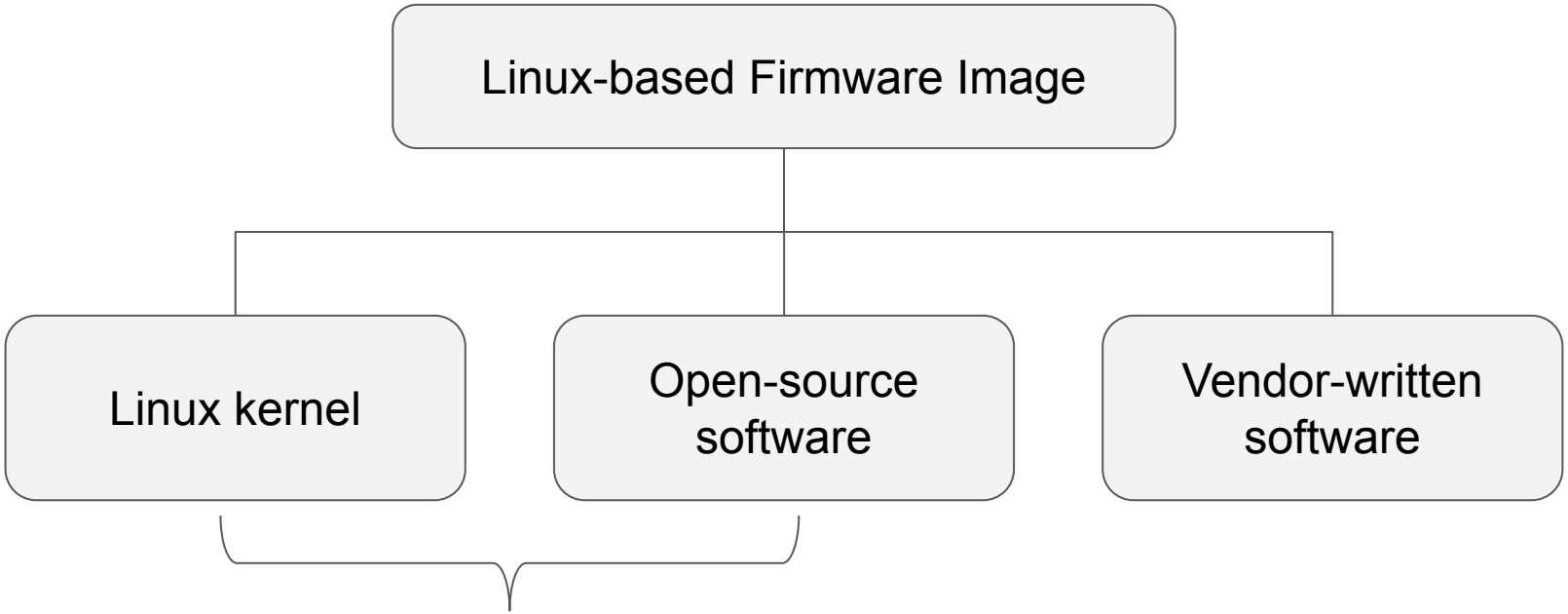
Fuzz Target


Linux-based Firmware Image
Linux kernel
Open-source software
Vendor-written software

Fuzz Target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Vendor-written software
Can be independently analyzed

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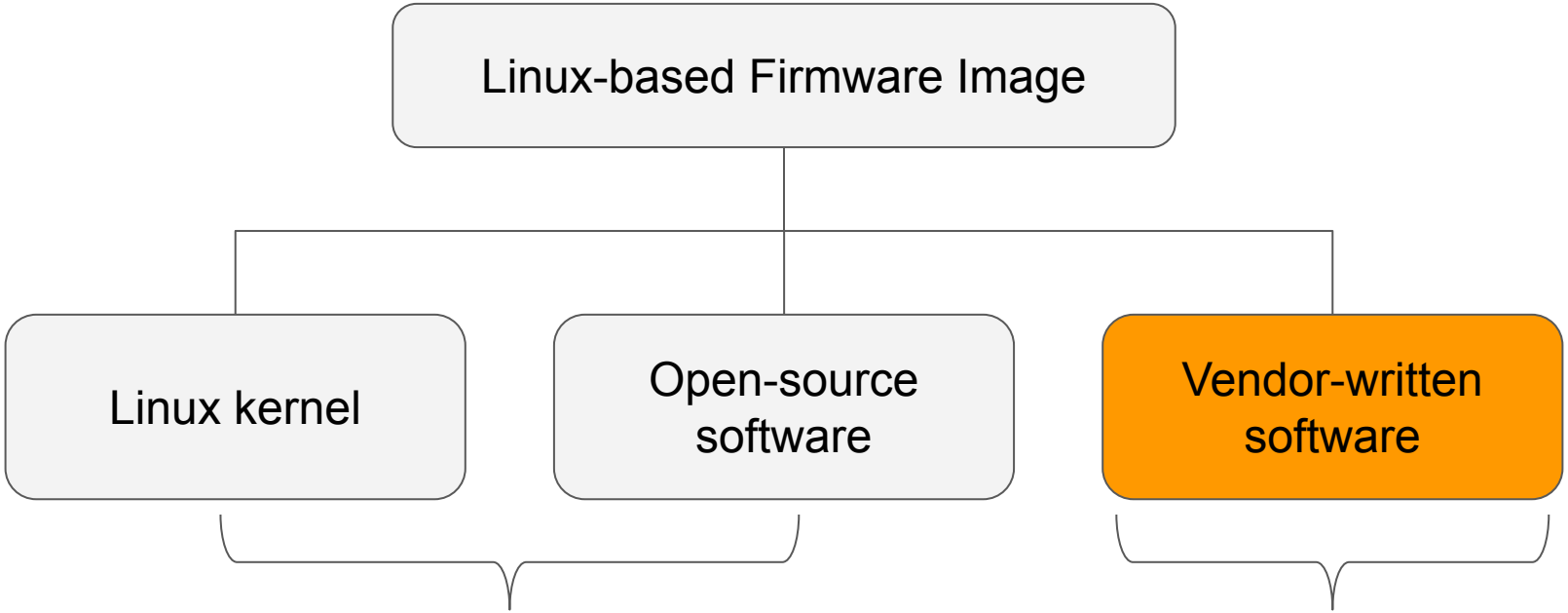
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~~Open-source~~
~~Openly analyzed~~

Deep Analysis

Challenges

Solutions

Deep Analysis

Challenges

Syntactically legal input generation

Solutions

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Solutions

Utilize the web API

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Fine-grained vulnerability monitoring	

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Challenges	Solutions
Syntactically legal input generation	Utilize the web API
Fine-grained vulnerability monitoring	Monitor injection into runtime environment
Device-independent dynamic analysis	Full-system emulation of firmware image

FirmFuzz Design

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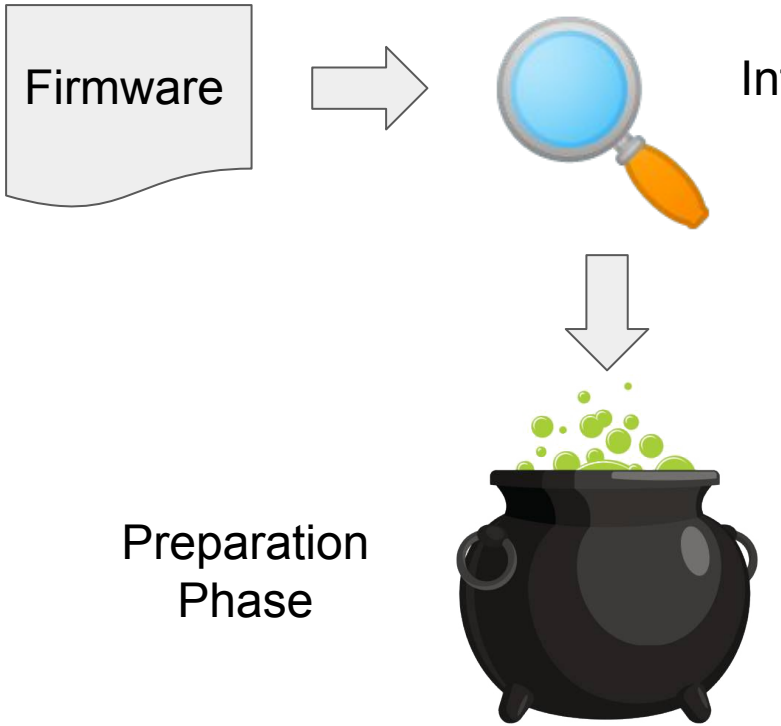
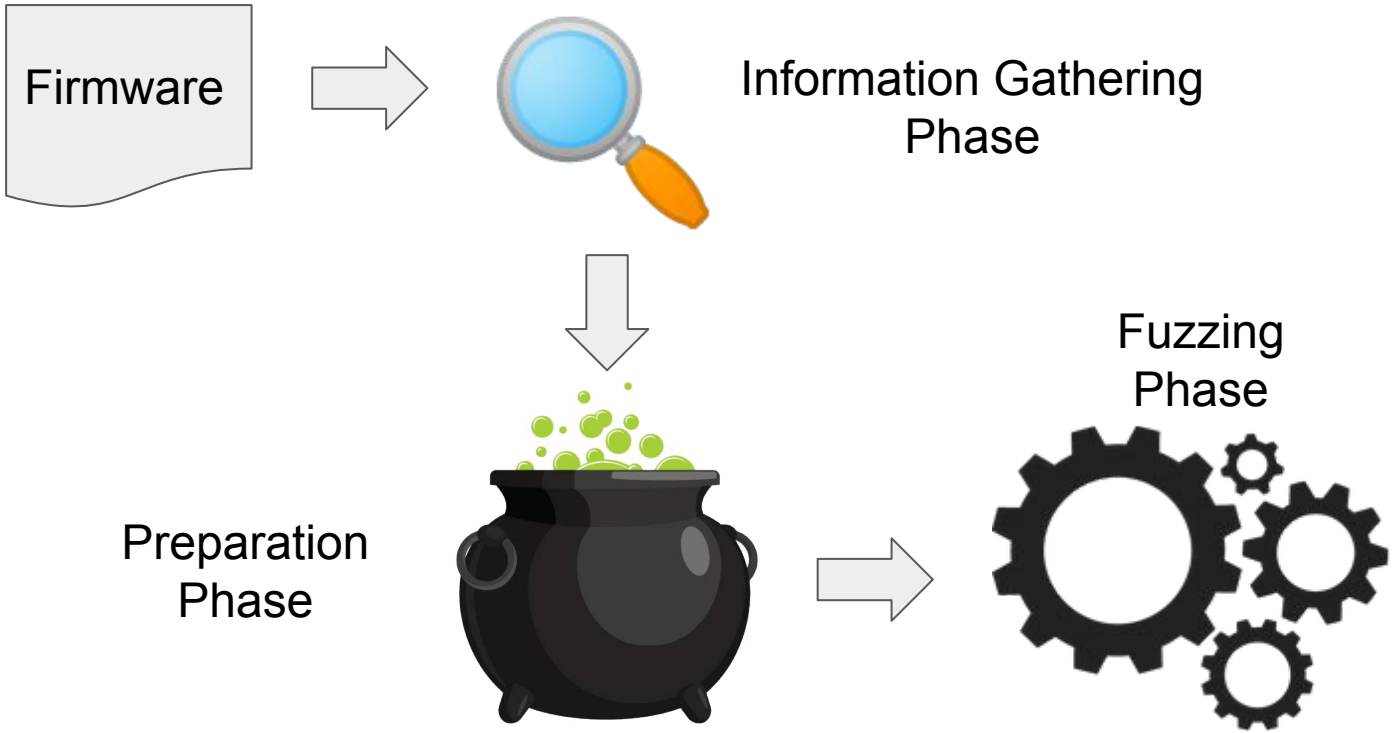
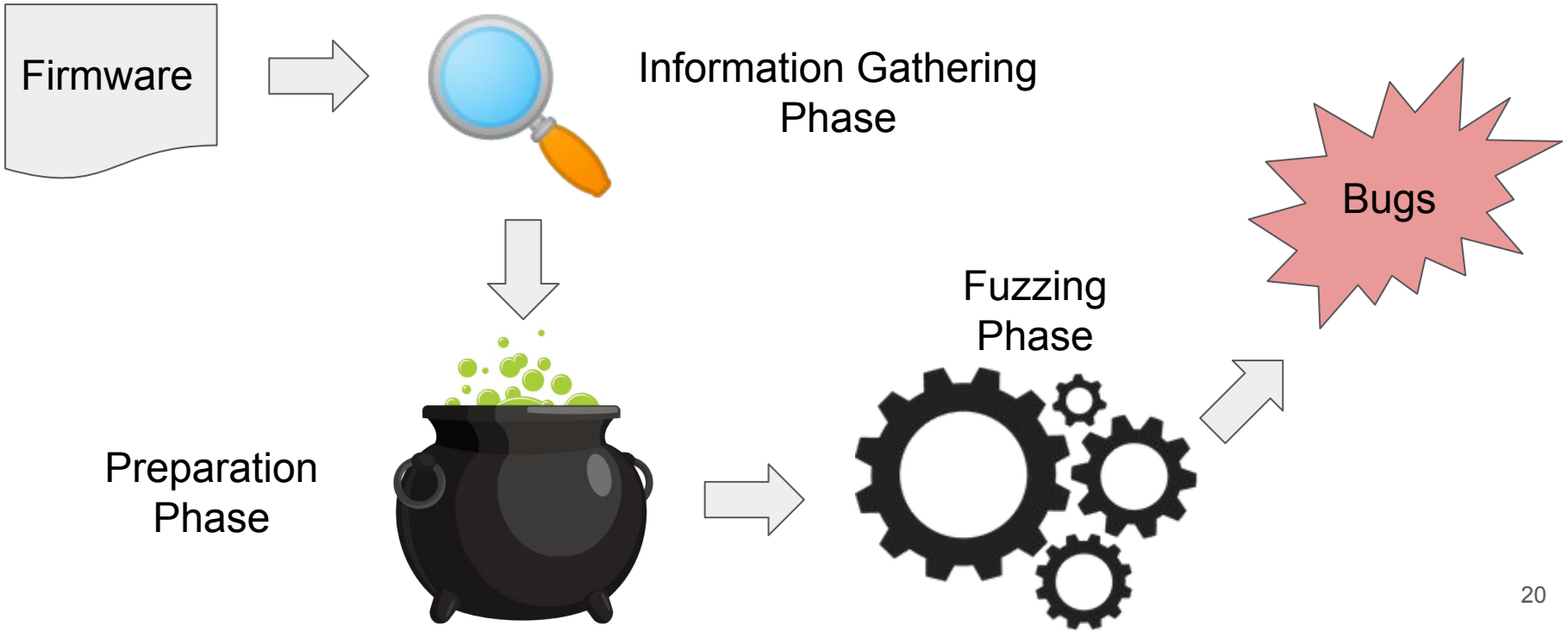


FirmFuzz Design



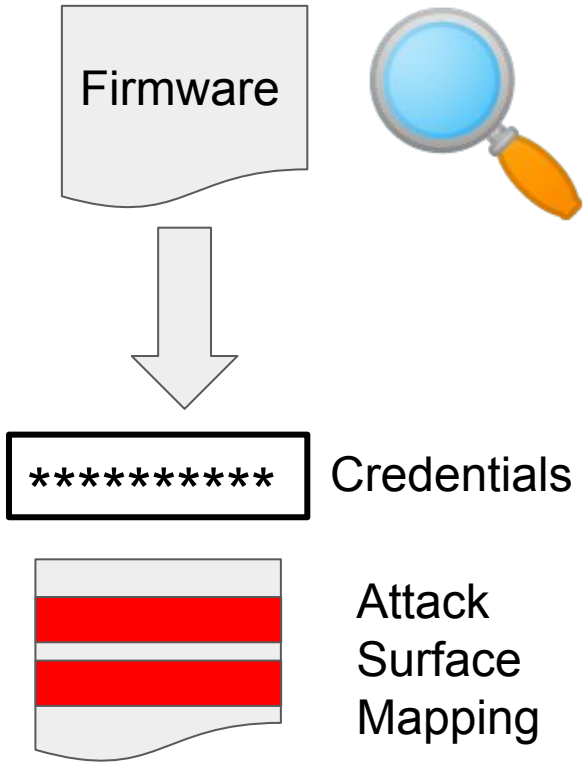
FirmFuzz Design



Information Gathering Phase

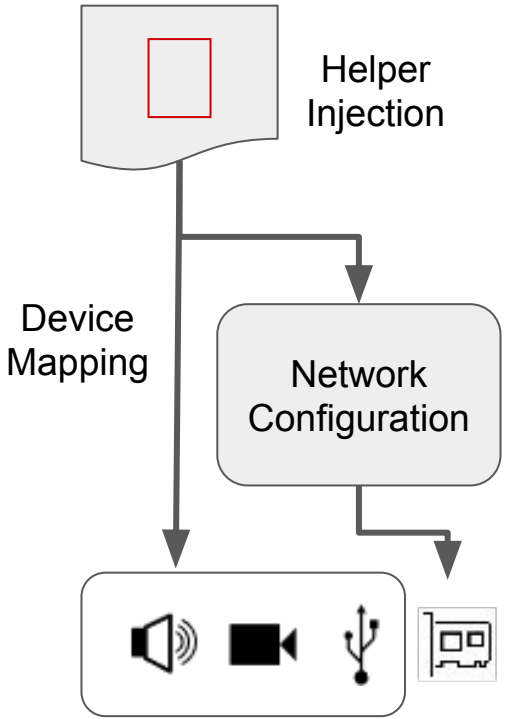
- Discover authentication credentials
  - Increase fuzzer coverage

- Static analysis of PHP scripts
  - Find inputs for vulnerable code paths
  - Perform taint analysis to build input constraints



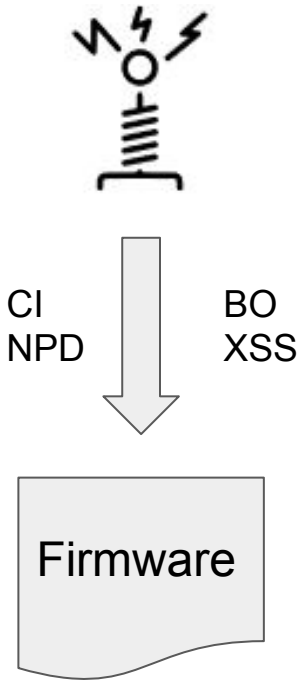
Preparation Phase

- Helper injection
  - Allows FirmFuzz to perform fine-grained vulnerability monitoring
    - CI — Helper binaries
    - BO, NPD — Exception handling mechanism of the kernel
    - XSS — Host-side monitoring
- Peripheral mapping
  - Firmware may require unsupported peripherals during runtime
  - FirmFuzz automatically creates mappings to a *fake* peripheral
- Network configuration
  - FirmFuzz logs interactions with the kernel networking interface
  - Creates an appropriate virtual network configuration

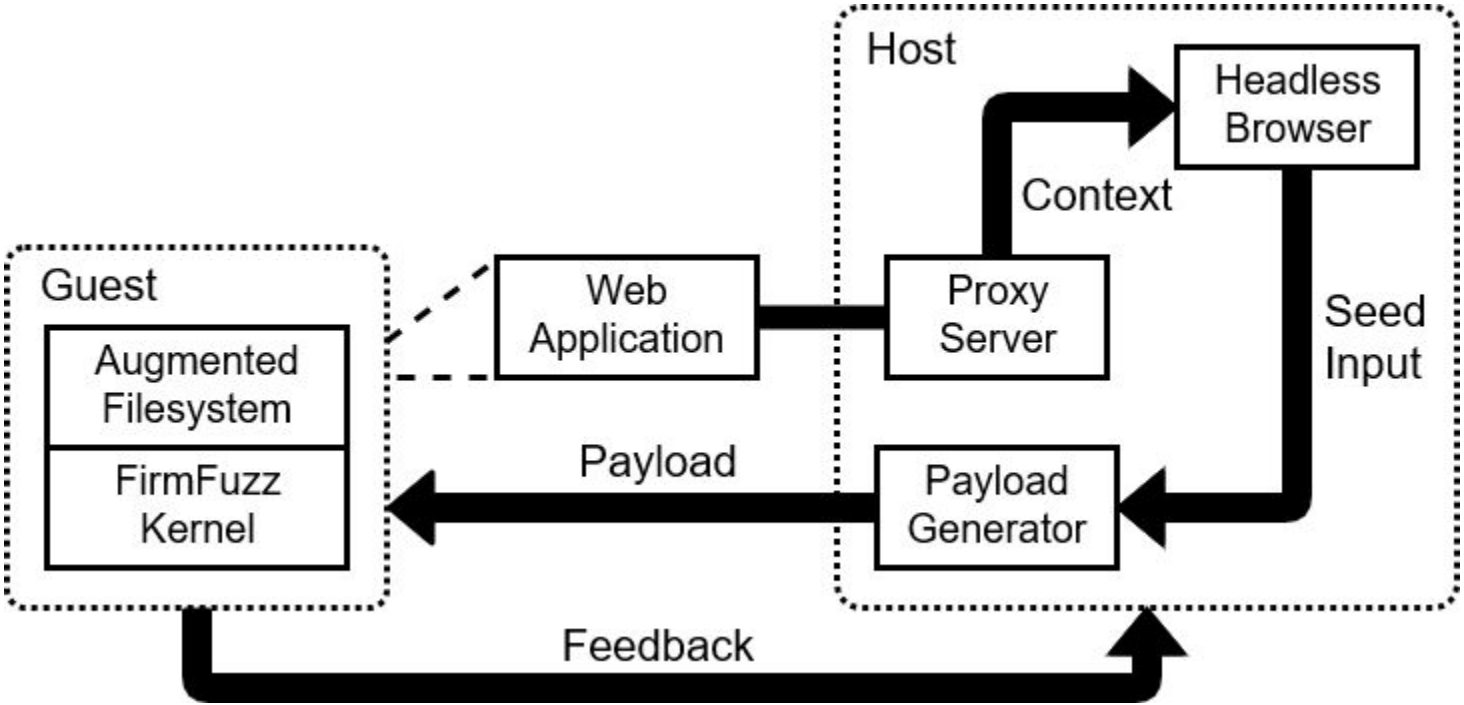


Fuzzing Phase

- Syntactically legal input generation
  - Use headless browser for interaction with web API
- Deterministic vulnerability detection
  - Leverage runtime monitors for vulnerability detection
- Fuzzing side-effects elimination
  - Use snapshots to revert firmware to a consistent state
- Payload delivery
  - Bypass web API validation checks by generating raw requests



Fuzzing Workflow



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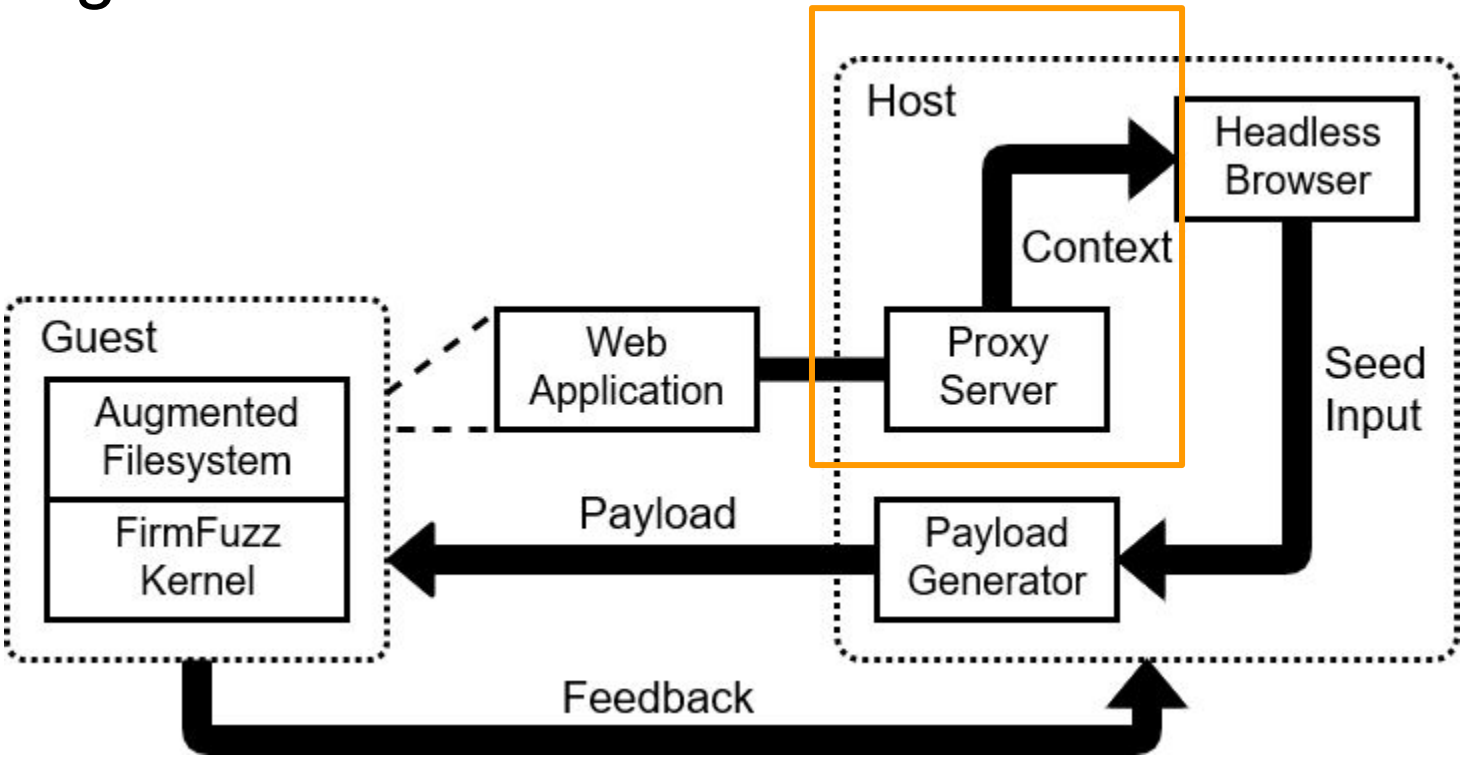

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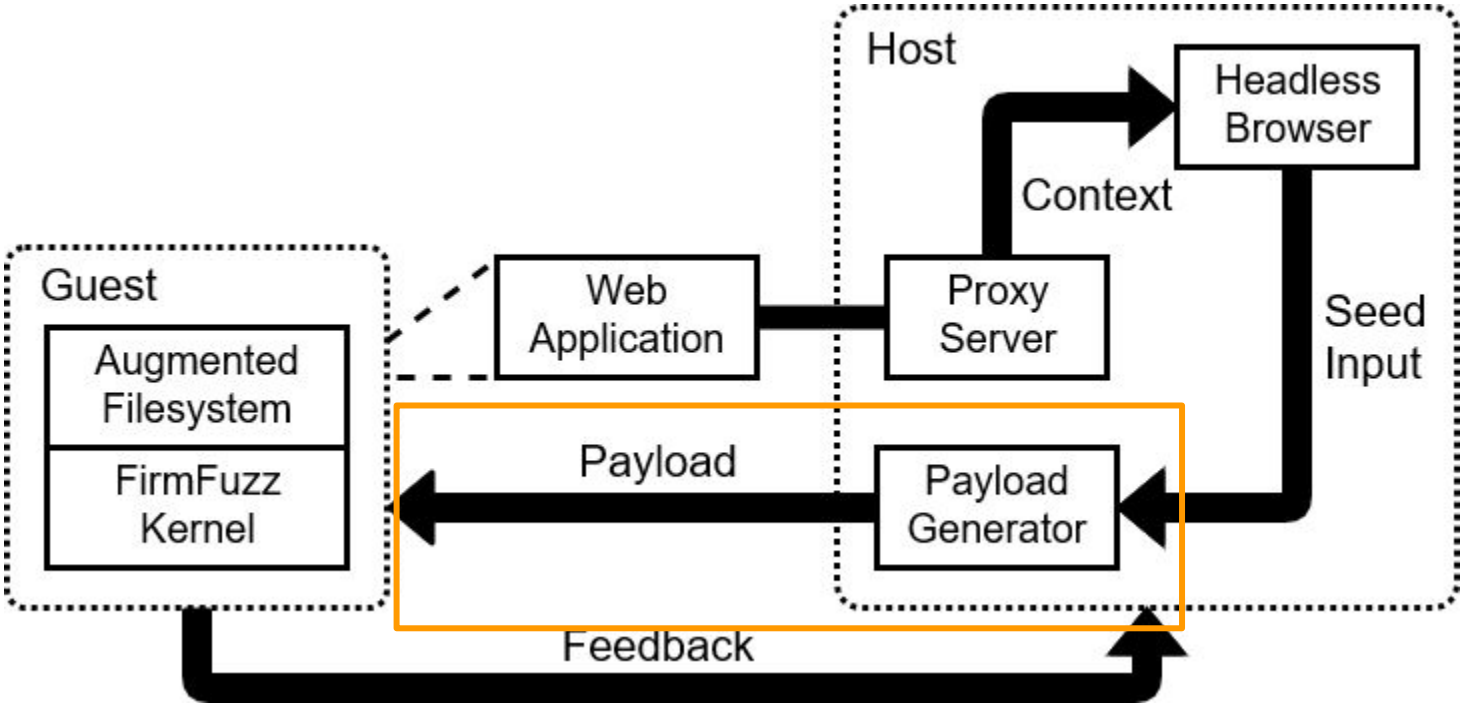

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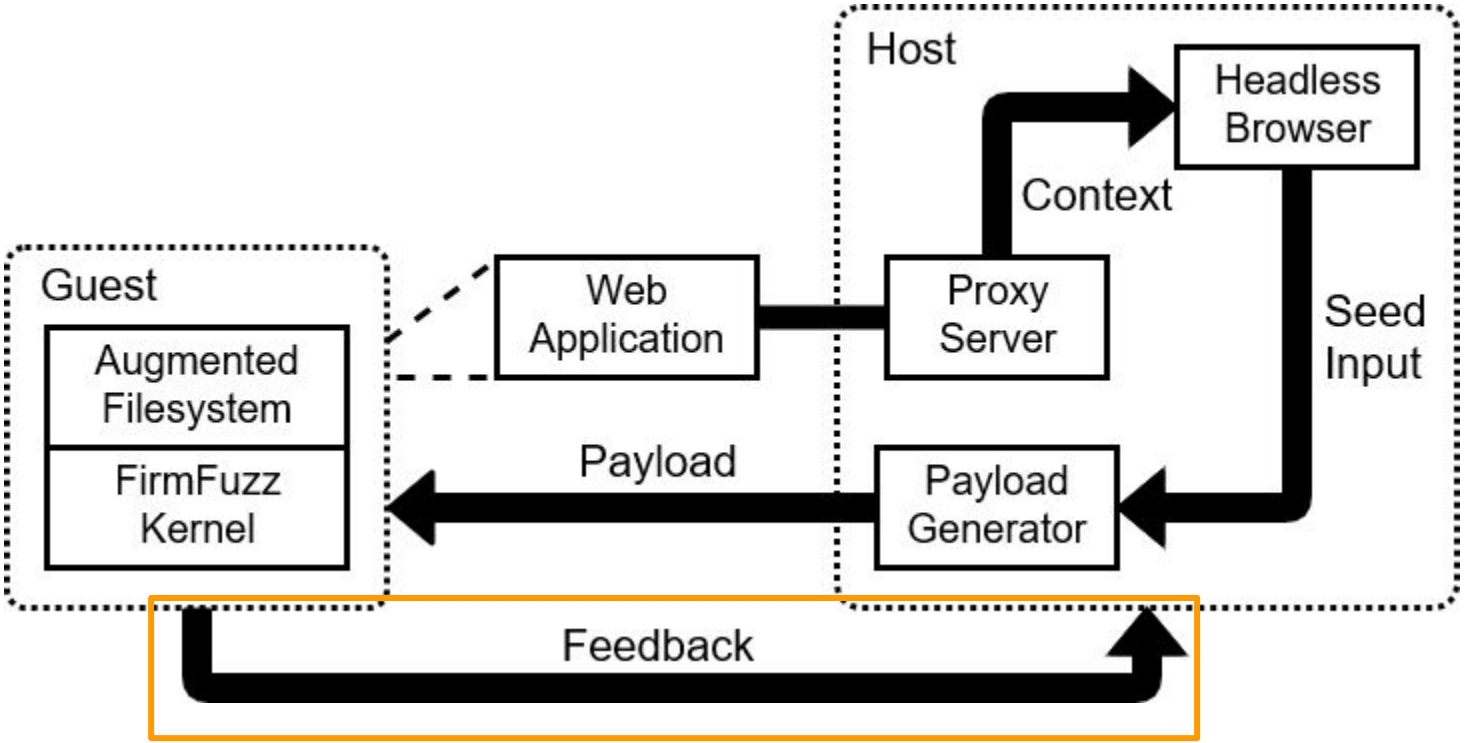

Evaluation

- Analyzed 6427 firmware images scraped from three vendors
- Found 7 vulnerabilities across 6 different devices
- Average runtime for the fuzzing phase was 16.7 minutes

Firmware Image Breakdown

Vendor	**Network Inferred**	**Fuzzed (Unique Devices)**	**Unique Web UI**
TRENDnet	26	6 (5)	2
Netgear	162	20 (17)	3
D-Link	15	6 (5)	1
Total	203	32 (27)	6

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Sharp drop-off between network inferred and fuzzed images

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High reusability of web interfaces between different devices

Comparison Against Existing Work

Number	Vulnerability	CVE-ID	FirmFuzz	Web vulnerability scanners	Firmadyne
1	CI	CVE-2018-19239	✔	×	×
2	XSS	-	✔	✔	×
3	BO	CVE-2018-19242	✔	×	×
4	BO	-	✔	×	×
5	BO	CVE-2018-19240	✔	×	×
6	BO	CVE-2018-19241	✔	×	×
7	NPD	-	✔	×	×

Conclusion

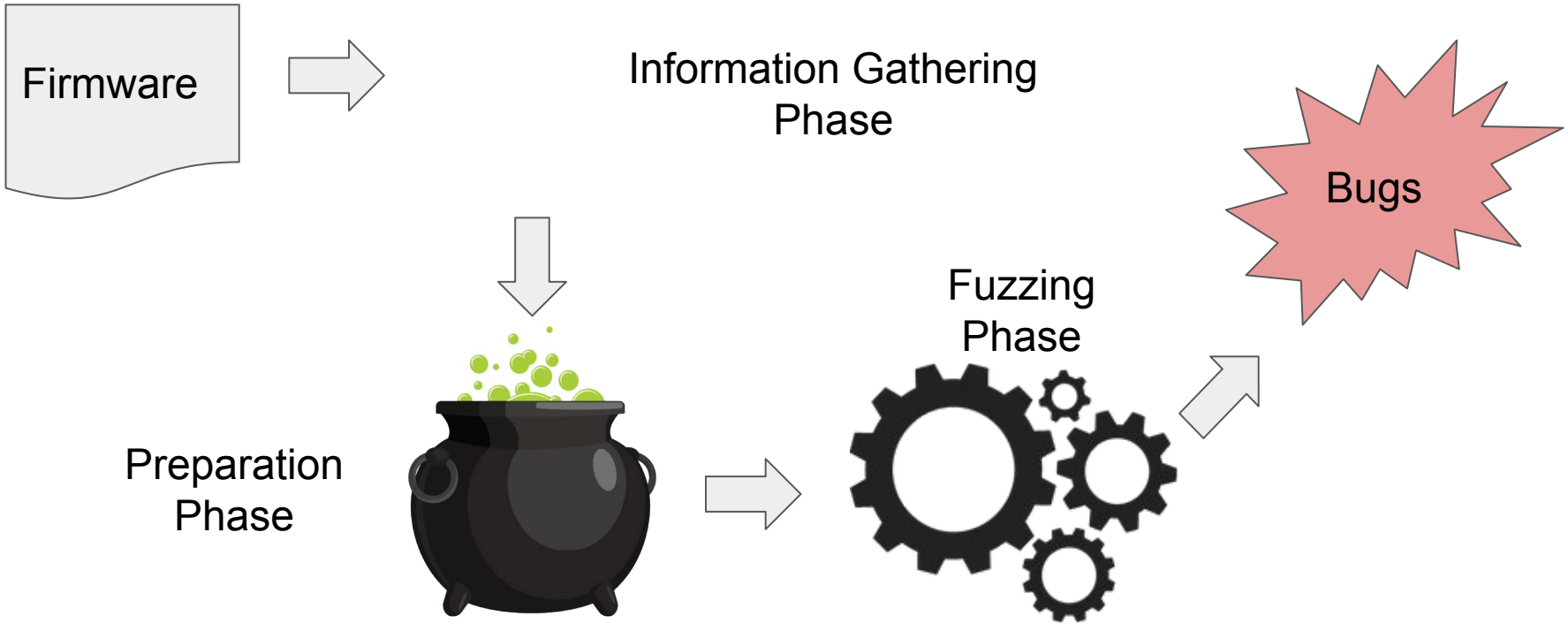
- We presented FirmFuzz, an automated dynamic analysis framework for finding deep vulnerabilities

- A generational fuzzer that leverages runtime monitors to aid the vulnerability discovery

- We found seven unknown vulnerabilities across six different devices

Questions ?

hexhive



Source code: https://github.com/Hexhive/Firmfuzz