Mitigating and Preventing Vulnerabilities with ELFbac

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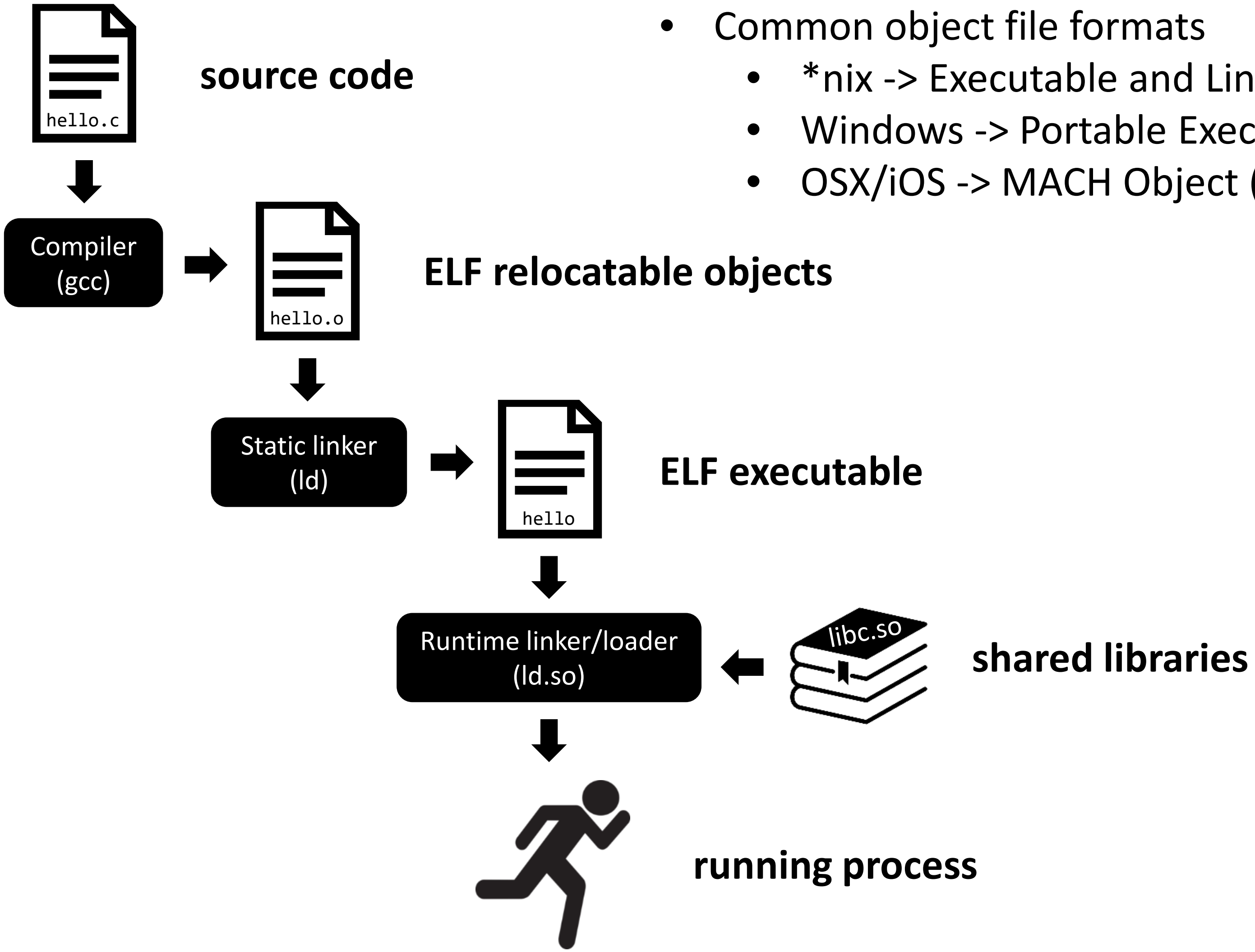
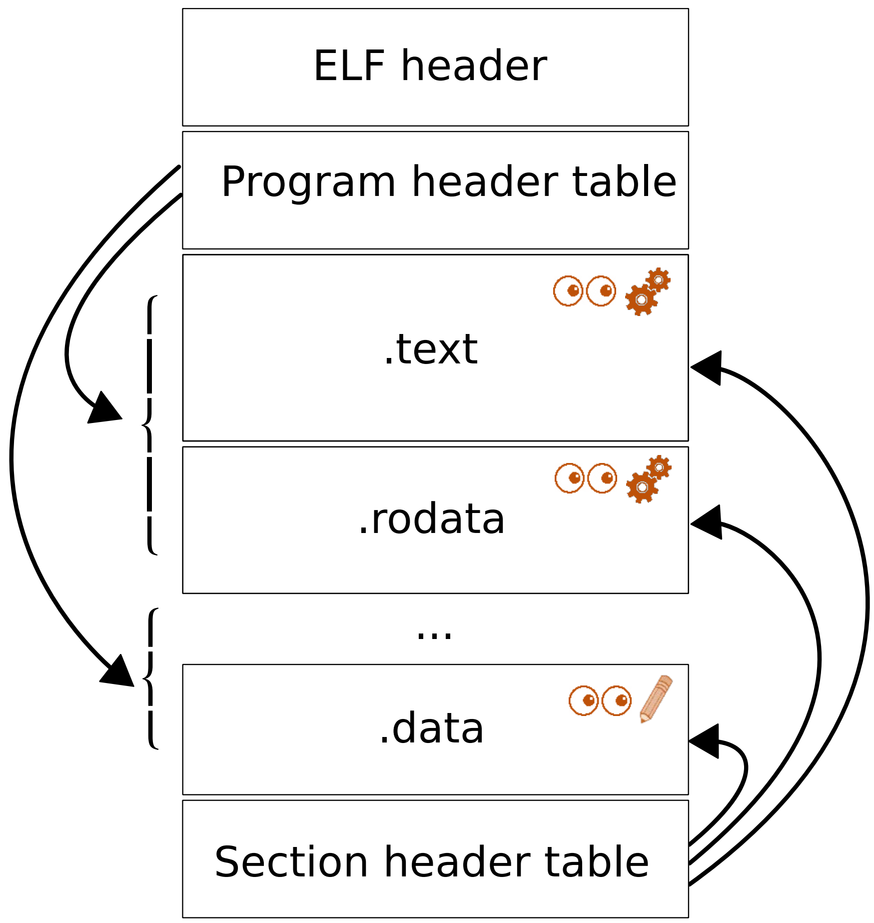
Code to Process

- Common object file formats
  - *nix -> Executable and Linkable Format (ELF)
  - Windows -> Portable Executable (PE)
  - OSX/iOS -> MACH Object (MACH-O)



Sections & Segments

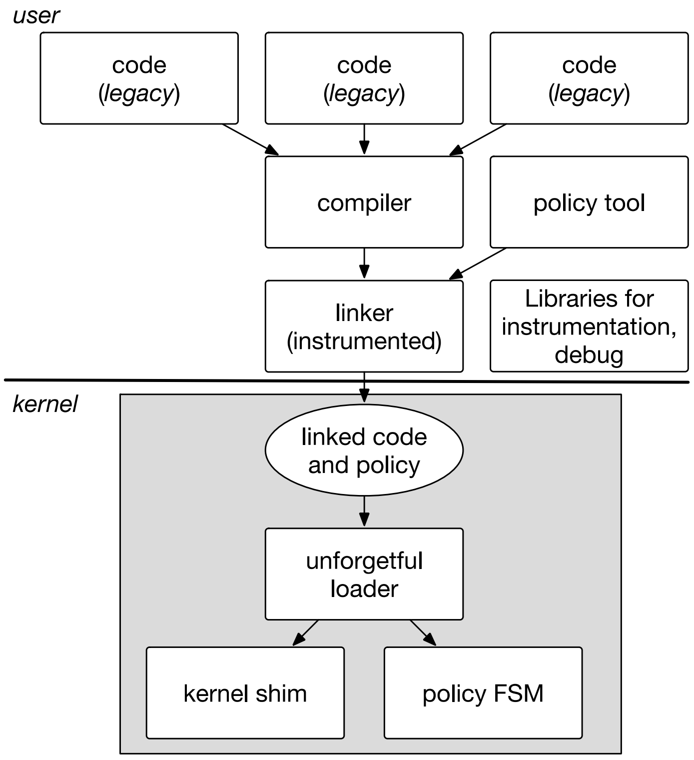
- Executable and Linkable Format (ELF) files contain the code and data for a given executable, as well as metadata necessary for the creation of a process address space.
- Sections contain the code and data of a program.
  - Each section defines semantically distinct units of code and data
- Segments are groupings of sections.
  - Segments are loaded at runtime into the process address space
  - Segments define the permissions of memory sections



Programmer intent is discarded in the packing of sections into segments!

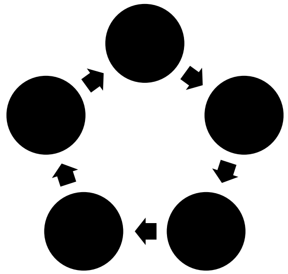
ELF-Based Access Control

- Goal: Reclaim the programmer intent discarded by a "forgetful" loader
- Code is annotated, compiled, and linked with ELFbac policy
- An "unforgetful", ELFbac-aware, loader builds the process address space with the policy, creating the desired isolation
- An ELFbac-aware kernel enforces the policy during runtime



ELFbac Policy Creation

- Policy is as a Finite State Machine.
  - States define a particular abstract phase of program execution driven by a given section of code, e.g., input parsing, network code, or cryptographic code
  - Transitions between states are achieved via memory accesses ("data transitions") and function calls ("call transitions")
- ELFbac policy is defined via linker scripts in simple JSON.
  - Defining custom sections, their access controls, and any intersectional relationships
  - Semantic policies, e.g., "input data can only be read by parsing functions"
- Code is annotated to use the policy via compiler pragmas:
  - `__attribute__ ((section (". inputs"))) int debug_flag = 0;`

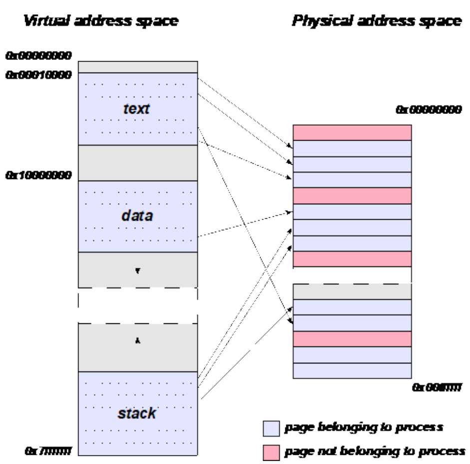


```
"name": "Parse",
"sections" : [{
    "name": "inputs",
    "description": "*(. .data.secret) ", "flags": rw }
]
```

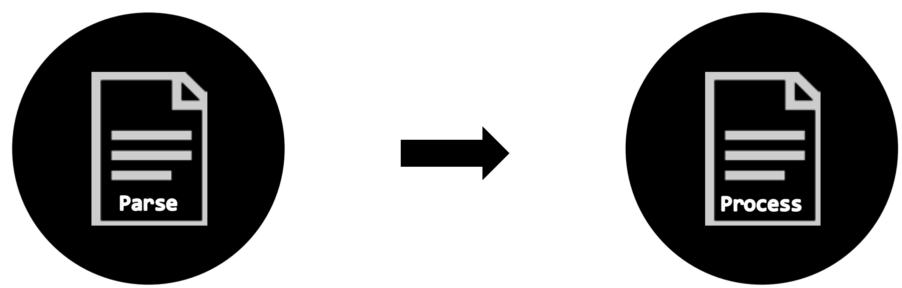
```
"call_transitions": [ {
    "from": "Parse",
    "to": "Calculate",
    "address": "GoToCalculate()" }]
```

ELFbac Policy Enforcement

- Replaces the kernel's view of a process' virtual memory context with a diversified collection of "shadow" contexts, each representing a single policy state.
  - Each shadow context only maps those regions of memory that can be accessed in the current state according to the policy.
  - Achieved through Page Tables and Virtual Memory mappings.
- Policy violations (unintended memory accesses or function calls) are trapped, leading to error handling code or ultimately a segmentation fault.



Process View



Kernel View

CREDC

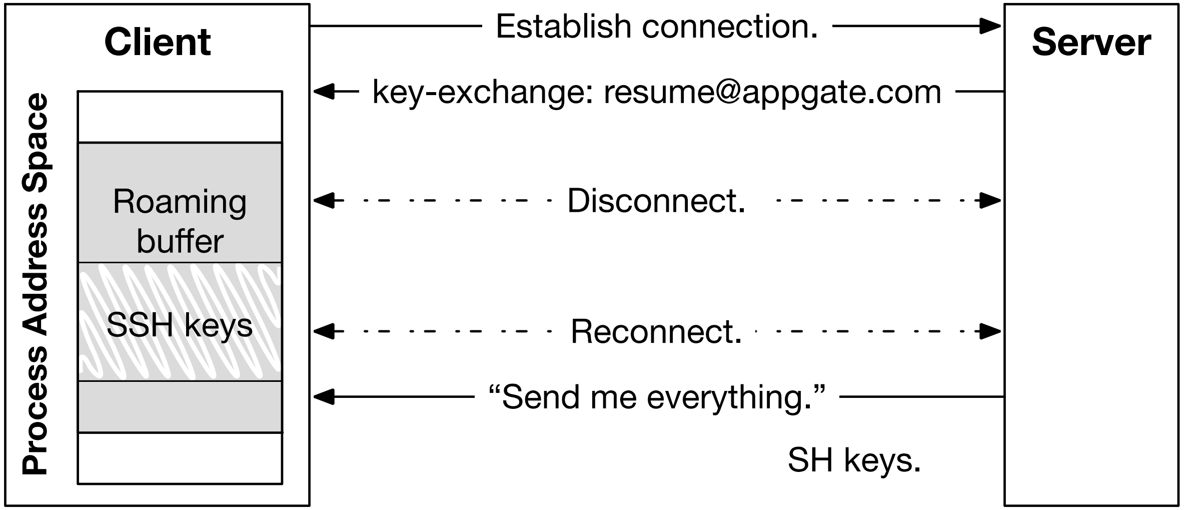
OpenSSH is Ubiquitous

- Most popular implementation of the Secure Shell (SSH) network protocols
  - Used to securely connect to and manage remote devices

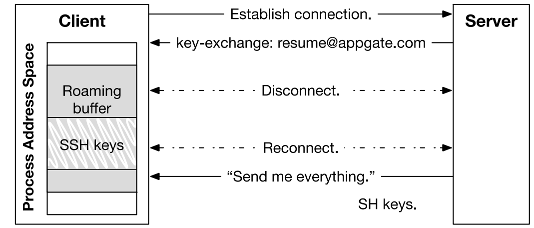
"The company believes that its optional access to the Linux operating system through a secure shell (SSH) will be of particular interest to OEMs."

Roaming in OpenSSH

- In version 5.4, released in 2010, the OpenSSH client introduced an experimental and undocumented "roaming" feature.
- The purpose of roaming was to allow the resumption of suspended sessions, e.g., in the case of unexpected network termination.
- In 2016, CVE-2016-0777 disclosed an information leak present in the implementation of OpenSSH's roaming feature.

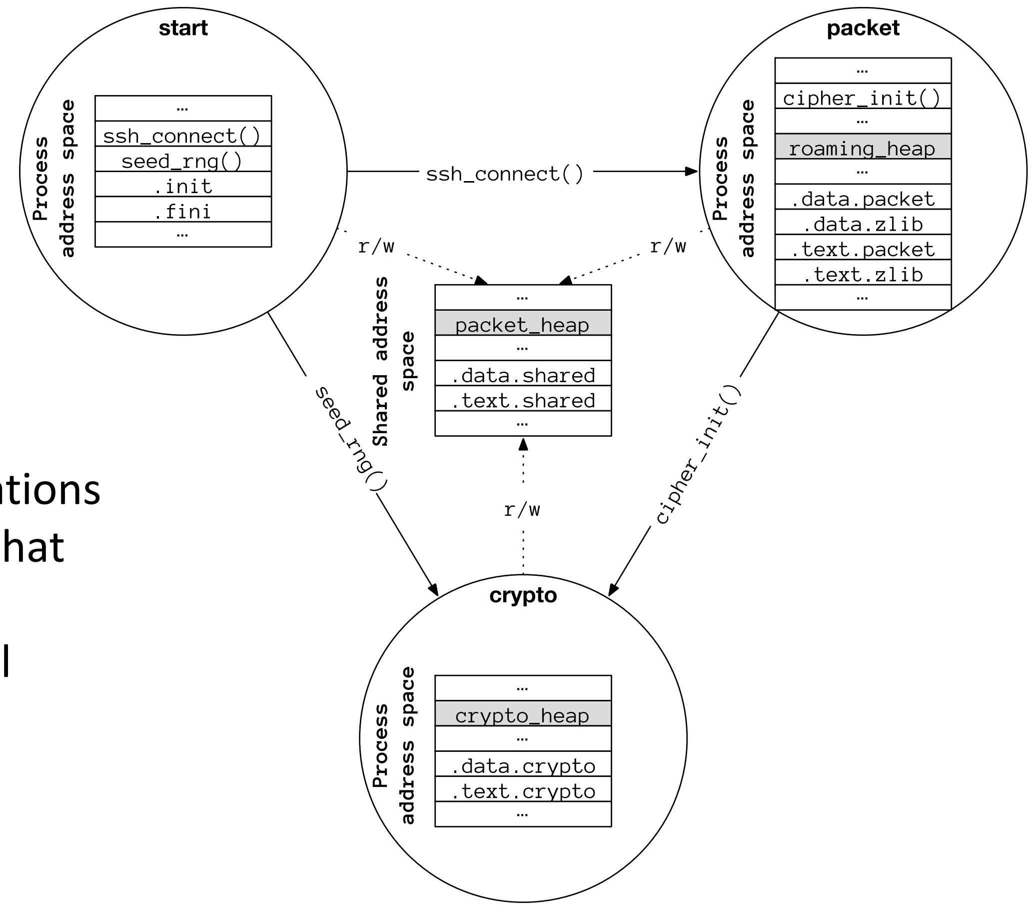


Mitigating the Roaming Bug



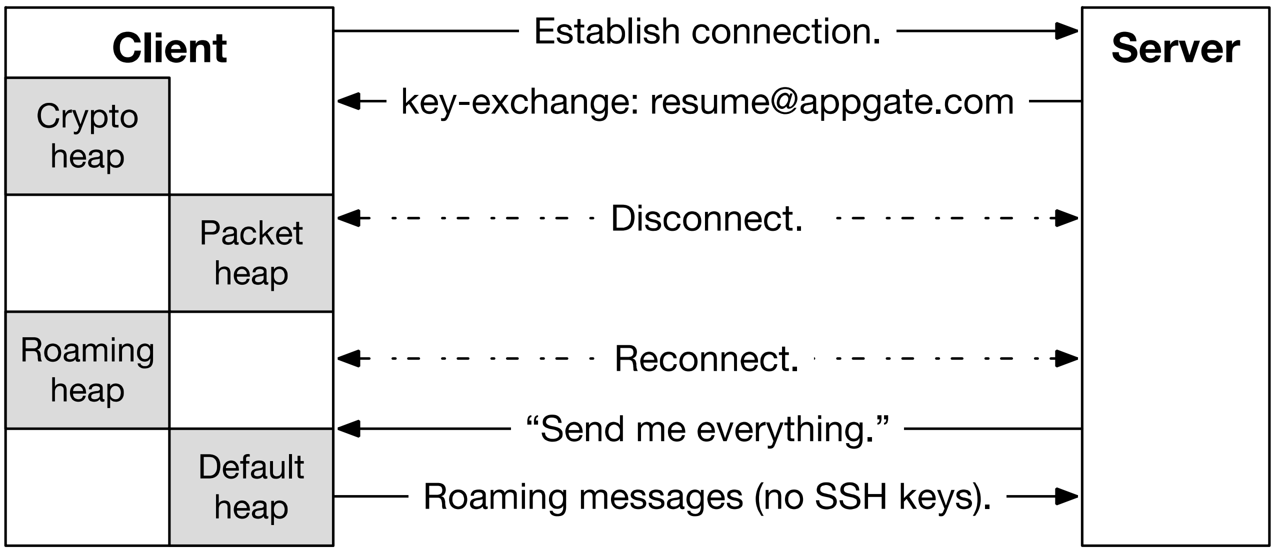
- Goal: Use ELFbac to isolate the memory regions used to store cryptographic keys and the roaming buffer.

In total, 27 annotations in 4 files were all that was necessary to achieve the critical isolation.



ELFbac Policy FSM

Execution with Mitigation



Demo

Conclusions

- Programmer intent is a crucial part of software security
- ELFbac allows a programmer to codify intent into enforceable policy
- Were ELFbac to have been used in OpenSSH, this bug would never have occurred
- ELFbac is as flexible and robust as a software's modularity
  - More modular -> more easily isolated

Future Work

- Policy creation relies largely on codebase familiarity and intuition…
- Performance can be a problem…
- Multiple policies in a single executable…
- Where does ELFbac fit with the IoT and ICS…
- Mitigating Spectre…?

Thanks!

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