OPENED Tool for Managing eBPF Heterogeneity

[Microservices Observatory (microserviceobservatory.github.io)](https://microserviceobservatory.github.io)

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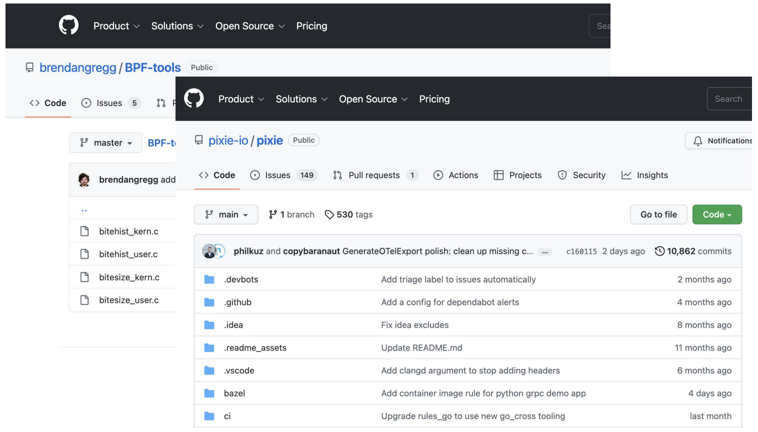
eBPF Programs are Monoliths

One Off Programs

Complex Codebase(s)



brendangregg / BPF-tools Public

master BPF-t

brendangregg add

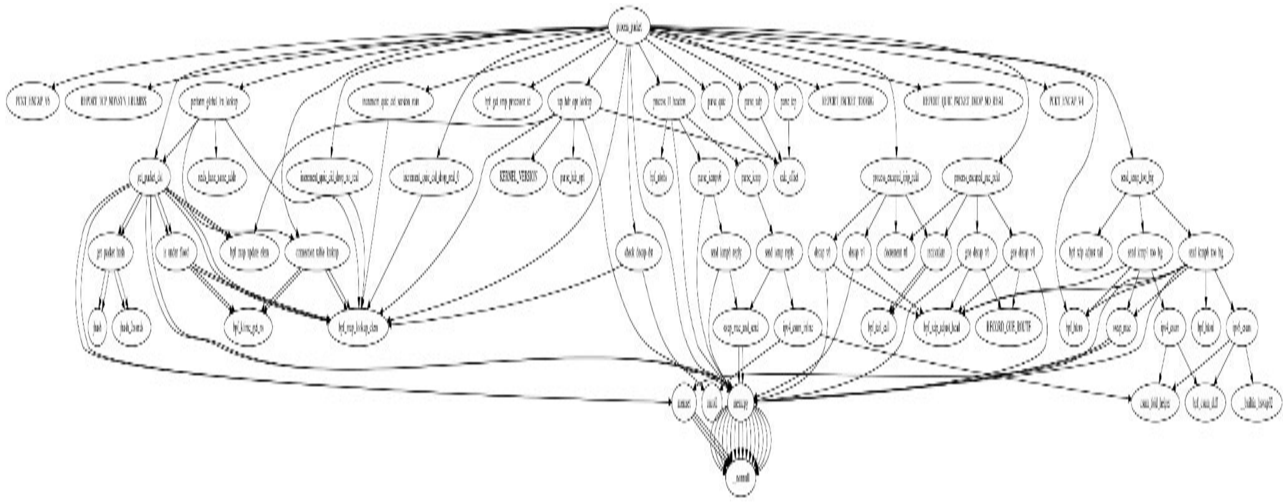
..
bitehist_kern.c
bitehist_user.c
bitesize_kern.c
bitesize_user.c

pixie-io / pixie Public

main 1 branch 530 tags

philkuz and copybaranaut GenerateOTelExport polish: clean up missing c... c160115 2 days ago 10,862 commits

.devbots	Add triage label to issues automatically	2 months ago
.github	Add a config for dependabot alerts	4 months ago
.idea	Fix idea excludes	8 months ago
.readme_assets	Update README.md	11 months ago
.vscode	Add clangd argument to stop adding headers	6 months ago
bazel	Add container image rule for python grpc demo app	4 days ago
ci	Upgrade rules_go to use new go_cross tooling	last month



Observability

Network Functions

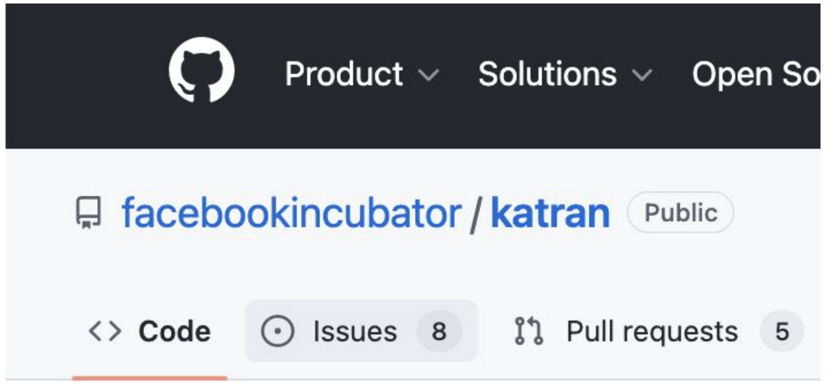
*Code from a Katran function

Implications of Monolith on Developer Productivity

Developing a new program

Find sub functionality on GitHub

Extracting and reusing functionality is non-trival

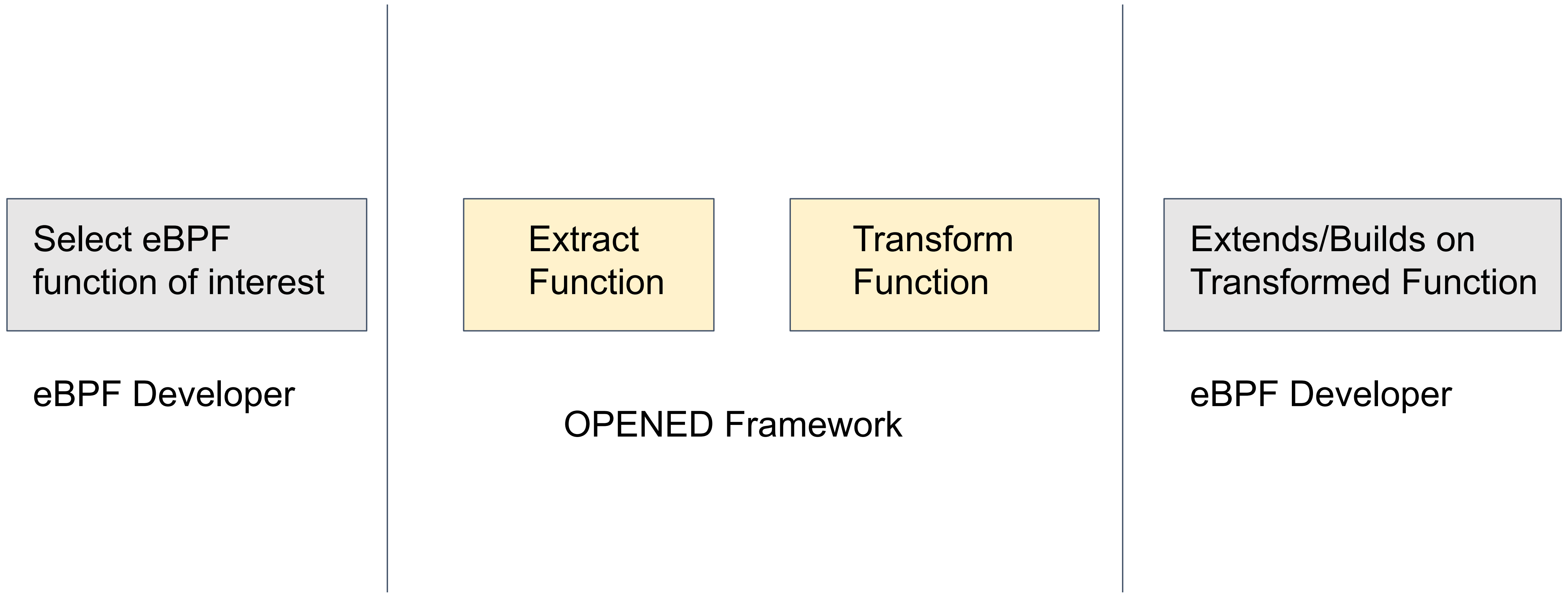


Step 1: Extract lines

Step 2: Identify + Extract Deps

Surprise Step 3: Rewrite for your target hookpoint

The OPENED Vision



OPENED Vision: Reduce time to new functionality development

- Automated extraction of relevant code

- Automated transformation of code
  - Enable moving code between hook-points
  - Enable moving code between programs

- Developer-first automation
  - Extraction + Transformation guided by developer choices

Road Map

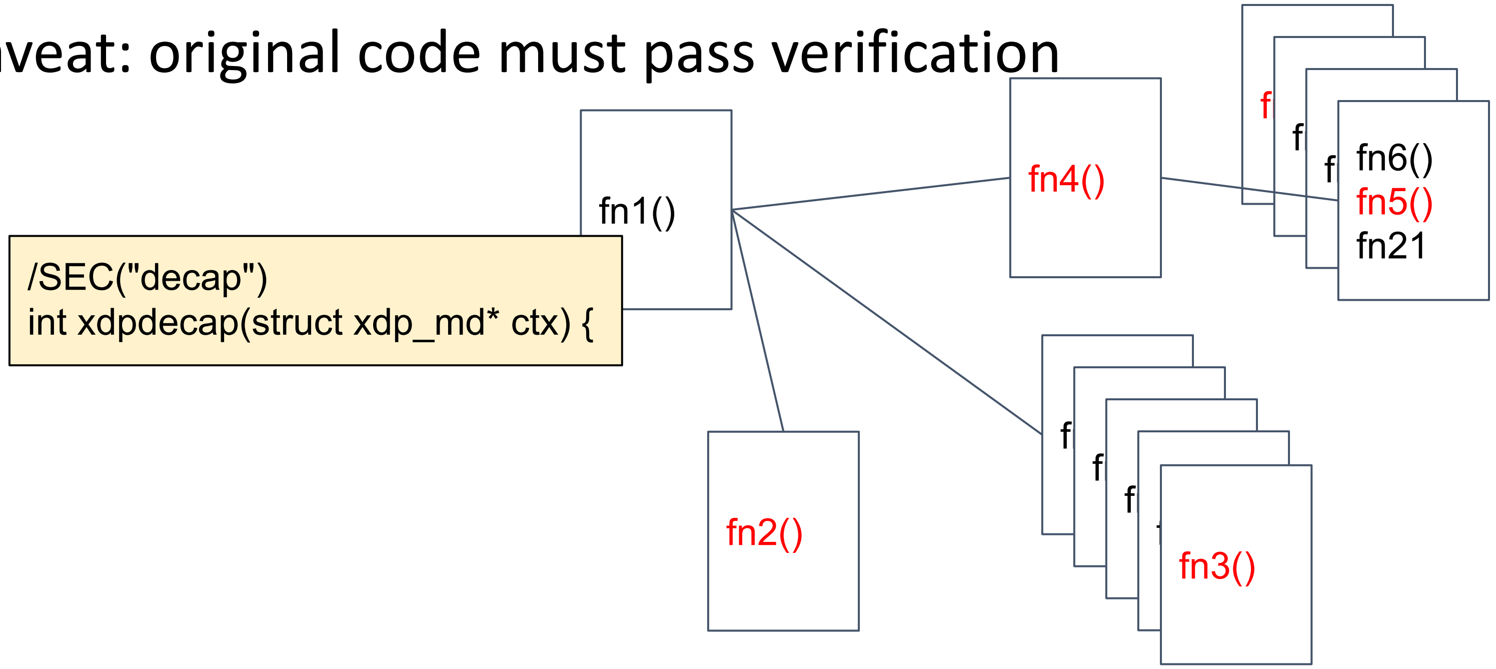
Extraction

- Transformation
- Demo
- Call to Arms

Extraction

Extract eBPF func as an independently loadable module

- Identify all dependencies of the eBPF function
  - Dependencies: function call graph, Maps & associated structures, header files
  - Extract relevant dependencies while
    - Ensuring correctness and minimizing technical debt
- Caveat: original code must pass verification

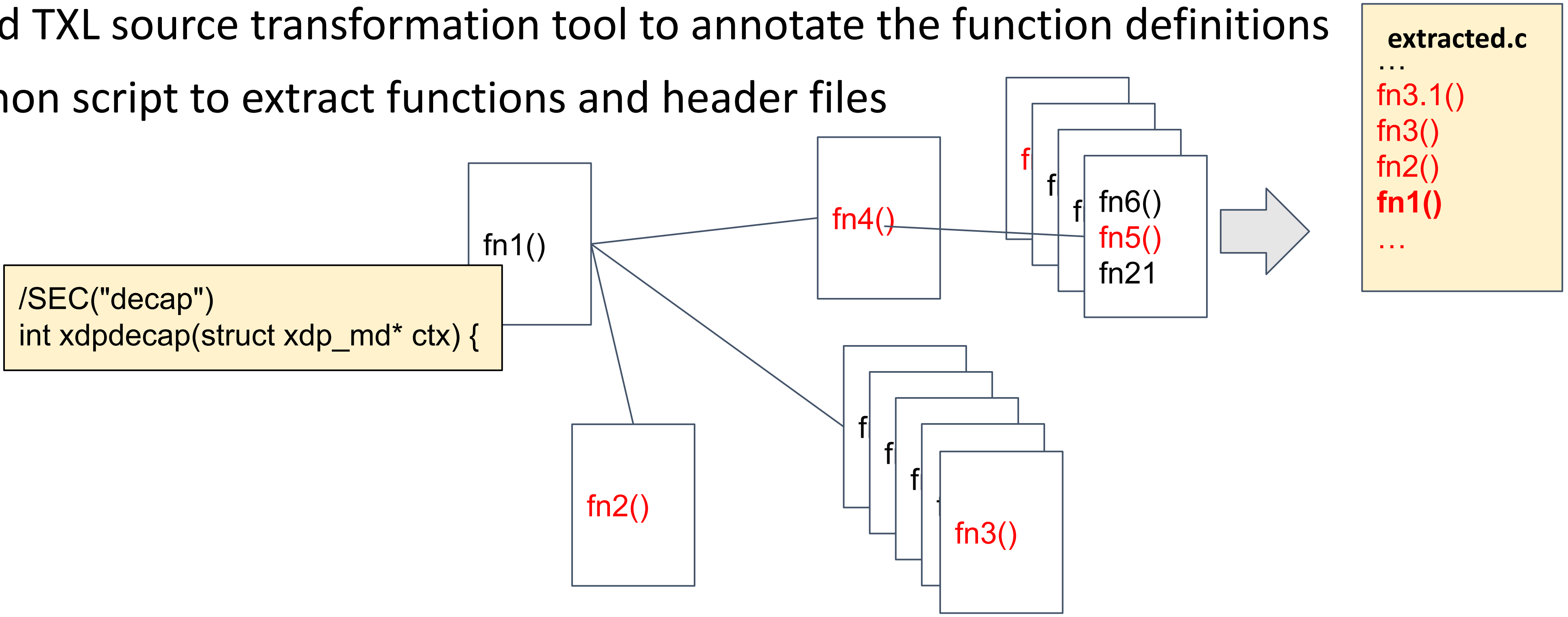


Challenge: Dependency Extraction

Function Dependencies

- Extended codequery tool[1],
  - Recursively identify function call graph
  - Uses cscope and ctags and sqlite internally
- Used TXL source transformation tool to annotate the function definitions
- Python script to extract functions and header files

```
/* Extracted from
 /root/github/demo_lpc/
codequery/katran/decap_kern.c  startLine: 223
endLine: 247 */
SEC("decap")
int xdpdecap(struct xdp_md* ctx) {
```

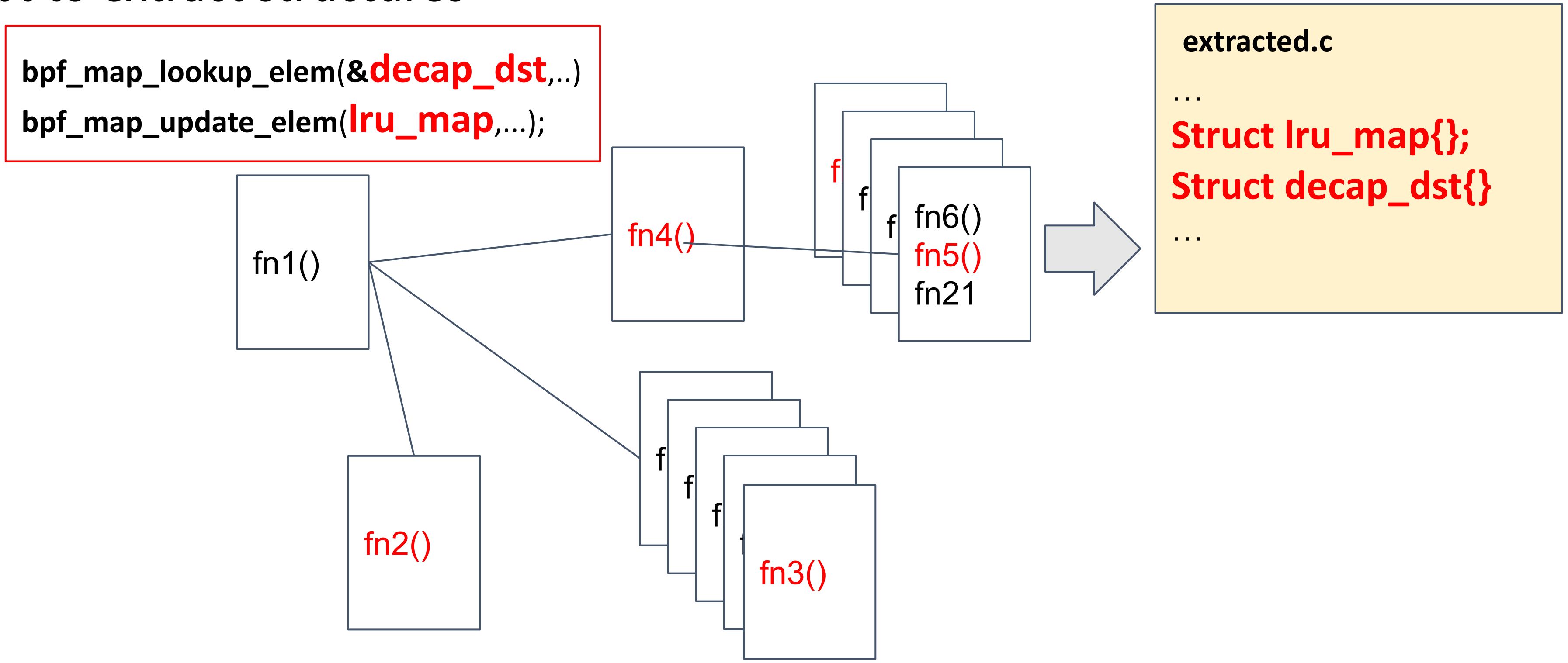


```
/SEC("decap")
int xdpdecap(struct xdp_md* ctx) {
```

Challenge: Dependency Extraction

Map Definitions

- eBPF specific method of tracking bpf_map_update/lookup_elem while parsing call flow graph
- TXL code transformation tool toannotate maps and other data structures needed
- Python script to extract structures



```
bpf_map_lookup_elem(&decap_dst,..)
bpf_map_update_elem(lru_map,...);
```

```
extracted.c
…
Struct lru_map{};
Struct decap_dst{}
…
```

Challenge: Dependency Extraction

Multiple declaration of dependencies (both maps & functions)

```
{#funcName,count,[FileName,lineNumber]}
.....
increment_quic_cid_version_stats,1,[<dir...>/balancer_kern.c,445]
increment_quic_cid_drop_no_real,1,[<dir...>/balancer_kern.c,460]
process_l3_headers,2,[<dir...>/balancer_kern.c,158],[<dir...>/decap_kern.c,34]
increment_quic_cid_drop_real_0,1,[<dir...>/balancer_kern.c,470]
process_encaped_ipip_pckt,2,[<dir...>/balancer_kern.c,340],[<dir...>/decap_kern.c,85]
parse_udp,1,[<dir...>/pckt_parsing.h,76]
REPORT_PACKET_TOOBIG,2,[<dir...>/introspection.h,32],[<dir...>/introspection.h,40]
.....
```

Annotated Function Call Graph

Preserve MACRO Definitions during Extraction

Identify and propagate preprocessor guards into extracted code

balancer_kern.c

```
#ifdef GLOBAL_LRU_LOOKUP

__attribute__((__always_inline__)) static inline bool
reals_have_same_addr(
   struct real_definition* a,
           struct real_definition* b) {
  ...
  ...
}

__attribute__((__always_inline__)) static inline int
perform_global_lru_lookup(
   struct real_definition** dst,
   struct packet_description* pckt,..){
   ...
   ...
}

#endif // GLOBAL_LRU_LOOKUP
```

extracted.c

```
#ifdef  GLOBAL_LRU_LOOKUP
/* Extracted from balancer_kern.c  startLine: 261 endLine: 277 */
__attribute__((__always_inline__)) static inline bool
reals_have_same_addr(
   struct real_definition* a,
   struct real_definition* b) {
  ...
  ...
}
#endif
#ifdef  GLOBAL_LRU_LOOKUP
/* Extracted from balancer_kern.c  startLine: 279 endLine: 337 */
__attribute__((__always_inline__)) static inline int
perform_global_lru_lookup(
   struct real_definition** dst,
   struct packet_description* pckt,..){
   ...
}

#endif // GLOBAL_LRU_LOOKUP
```

Challenge: Minimize Code Debt

- Maintain ordering between definitions and invocations
- Propagate license into newly created c file (with extracted code).
- Identify and copy relevant current directory includes into extraction site.
  - Introduce preprocessor guards in new header files
- Rewrite Makefiles (currently Manual).

```
#include balancer_const.h”
```

```
#IFDEF  BALANCER_CONST_ OPF

#include balancer_const.h”

#ENDIF
```

Road Map

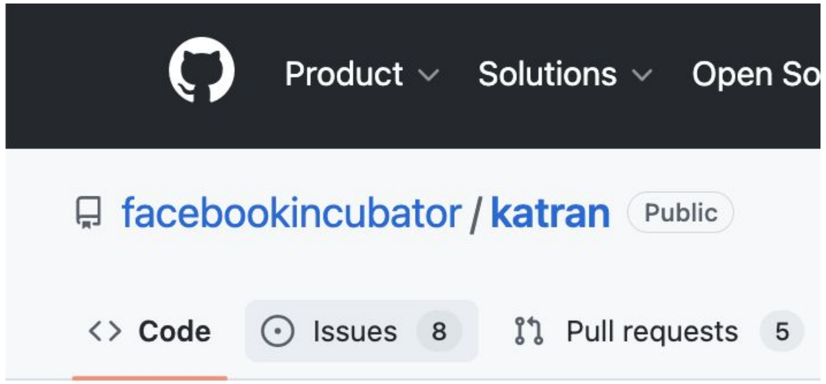
- Extraction
- **Transformation**
- Demo
- Call to Arms

Implications of Monolith on Developer Productivity

Developing a new program

Find sub functionality on GitHUB

Extracting and reusing functionality in non-trival



Step 1: Extract lines

Step 2: Identify + Extract Deps

Surprise Step 3: Rewrite for your target Hookpoint

Nuances of Hookpoint Transformation

- Code written for one hookpoint does not port to another trivially
  - Different Header files, Actions, Information source & Helper functions
- Some capabilities are hookpoint specific , e.g., bpf_redirect_maps
- However, some capabilities are overlapping, e.g., access to 5-tuple
    - Even if expressed differently [They are portable]

***Talk to us for more transformation use cases**

Our Solution for Hookpoint Transformation

- Code written for one hookpoint does not port to another trivially
  - Different Header files, Actions, Information source & Helper functions
- Some capabilities are hookpoint specific , e.g., bpf_redirect_maps
- However, some capabilities are overlapping, e.g., access to 5-tuple
    - Even if expressed differently [They are portable]
- Database of domain specific functionality mapping between hookpoints
  - Currently working only for XDP ⇒ TC
  - Transformation rules written in using Coccinelle and TXL
- Report error, if transformation is unknown

***Talk to us for more transformation use cases**

Transformation*

- Porting Header files is trivial
  - Include/Exclude headers e.g., #include <linux/pkt_cls.h> for XDP⇒TC

- Porting Actions is straightforward, E.g.,
  - DROP and PASS are transformable
    - XDP_DROP ⇒ TC_ACT_SHOT
    - XDP_PASS ⇒ TC_ACT_OK
  - XDP_TX is hookpoint specific, and does not port, report Error

```
rule replaceXDP_DROP
      replace [token]
        XDP_DROP
      by
        TC_ACT_SHOT
end rule

rule replaceXDP_PASS
      replace [token]
        XDP_PASS
      by
        TC_ACT_OK
end rule
```

TXL Rule snippet

***Talk to us for more transformation use cases**

Transformation*

Porting information source is straightforward,

- (If available) Replace with information source
    - [XDP]eth- >h_proto ⇒ ctx->protocol [TC]
    - [XDP] vlan_hdr->h_vlan_TCI ⇒ ctx->vlan_tci [TC]

```
@replaceethproto@
identifier p,c,fn;
type t;
struct ethhdr *e;
@@
t fn(struct __sk_buff *ctx){
...
-  e->h_proto
+ ctx->protocol
...
}
```

Coccinelle Rule snippet

***Talk to us for more transformation use cases**

Transformation*

Porting helper functions is non-trivial

- Simple: static transformation rules, E.g.,
  - bpf_redirect() ports from XDP to TC with FLAG set to ingress
- Complex: developer must introduce new rules based on intended use
  - bpf_xdp_adjust_head(E1,E2) ⇒ bpf_skb_adjust_room(E1,E2, BPF_ADJ_ROOM_MAC, BPF_F_ADJ_ROOM_ENCAP_L3_IPV4/IPV6)

```
@replacexdpadjust@
expression E1,E2;
@@
- bpf_xdp_adjust_head(E1,E2)
+bpf_skb_adjust_room(E1,E2,BPF_
ADJ_ROOM_MAC,BPF_F_ADJ_ROO
M_ENCAP_L3_IPV4)
```

Coccinelle Rule snippet

***Talk to us for more transformation use cases**

Current Prototype

- Extraction: 1448-LoC
  - 251 LoC TXL[1] (Grammar specification)
  - 547 Extended Codequery[3]
- Transformation: 200-LoC
  - 74 LoC in Coccinelle[2]
  - 68 LoC in TXL
- Extracted and transformed functions within Meta’s Katran, Mizar, Suricata, Cloudflare’s XDP_drop

[1] http://txl.ca/

[2] https://coccinelle.gitlabpages.inria.fr/

[3]https://github.com/ruben2020/codequery

Road Map

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- Transformation
- **Demo**
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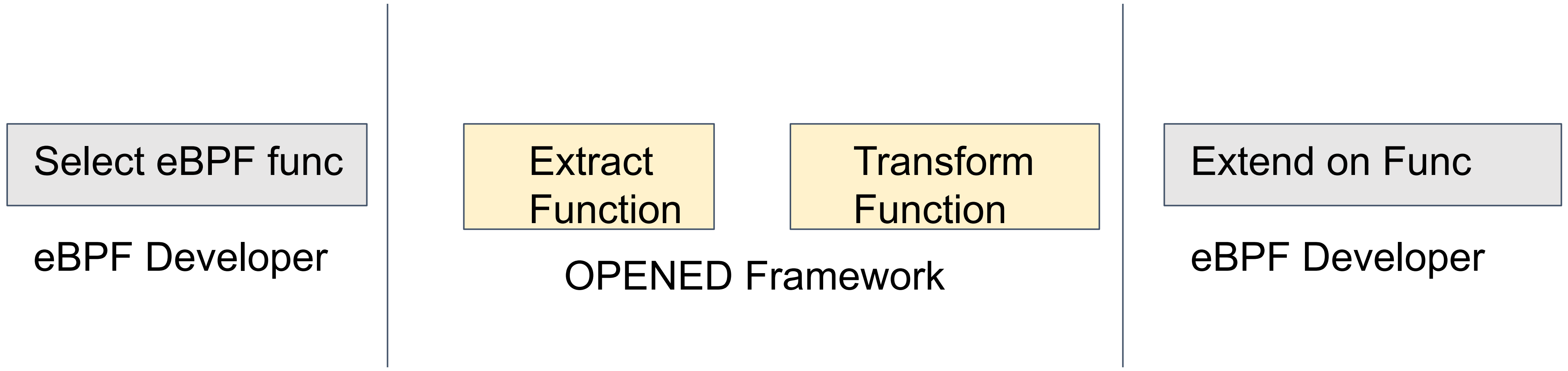
DEMO

Road Map

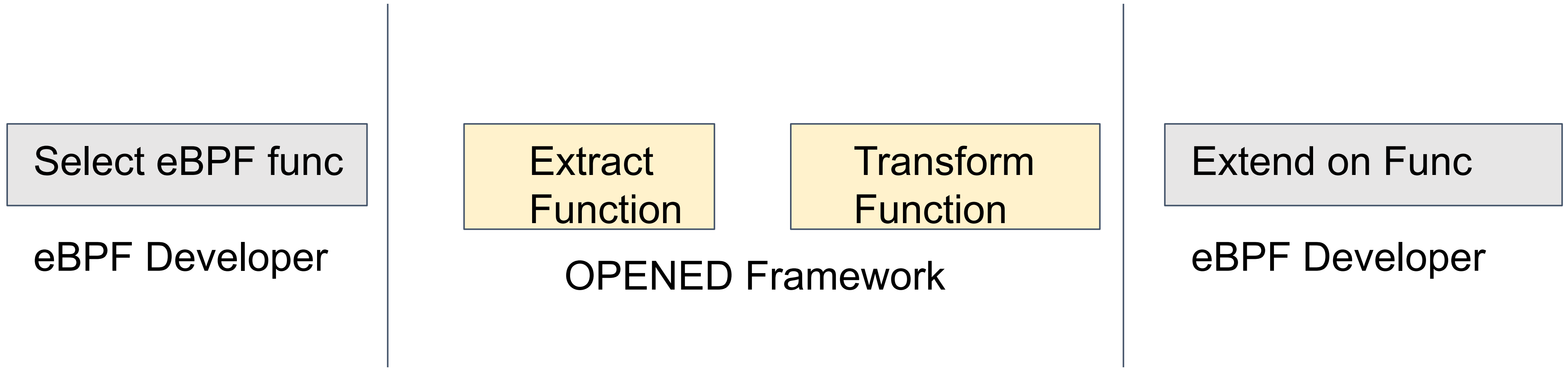
- Extraction
- Transformation
- Demo
- **Call to Arms**

Future Plans



- Decompose convert open source programs into L3AF/Polycube/BPFD modules
- Expand the set of supported transformation rules
- Improve usability of our framework

Join the OPENED Community (DevTools for Supporting Modular eBPF Programs)



Join Us!

Submit your use cases for programs to be decomposed

[Microservices Observatory (microserviceobservatory.github.io)](microserviceobservatory.github.io)