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Predicate Abstraction Based Configurable Method for Data Race Detection in Linux Kernel

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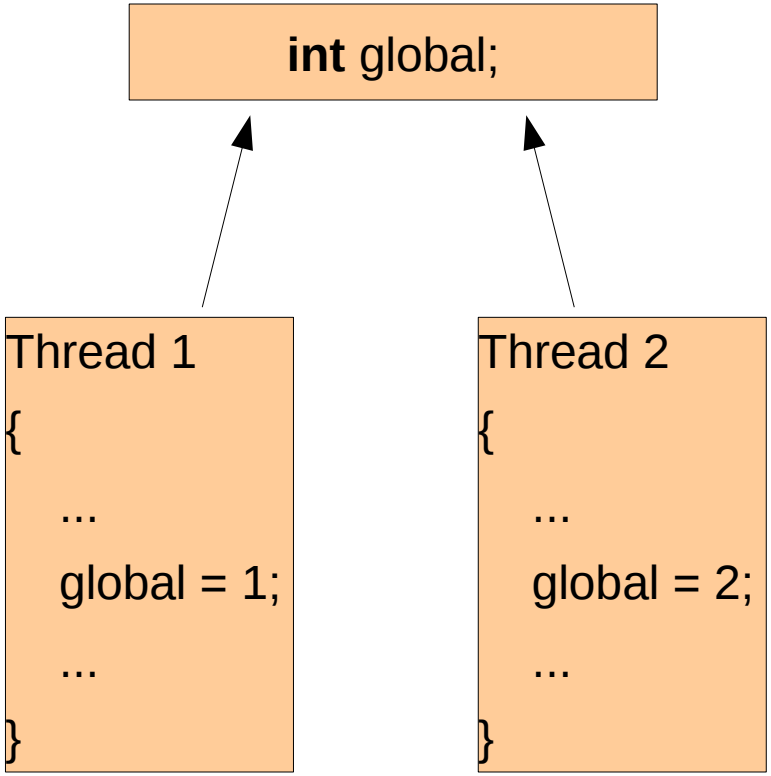
Race Condition



A situation, in which simultaneous accesses to the same memory location take place from several threads, one of the accesses is write

Real Data Race

drivers/net/wireless/marvell/libertas/libertas.ko

disconnect:

```
…
kfree_skb(priv->currenttxskb);
priv->currenttxskb = NULL;
priv->tx_pending_len = 0;
...
```

transmit:

```
spin_lock(&priv->driver_lock, flags)
if (priv->currenttxskb == NULL)
    return;
…
priv->currenttxskb->protocol =
eth_type_trans(priv->currenttxskb,
      priv->dev);
netif_rx(priv->currenttxskb);
…
spin_unlock(&priv->driver_lock,
flags)
```

Commit

author	Pavel Andrianov <andrianov@ispras.ru>	2016-06-15 11:34:03 (GMT)
committer	Kalle Valo <kvalo@codeaurora.org>	2016-06-29 15:46:56 (GMT)
commit	f52b041aed77592862c97726b98d78e8dccd72c9 (patch)	
tree	18e3a9e1f0401363f9c70b817965e505f9710d7d	
parent	6edc119ed3b5e860535d49852f8cc8e5be95538d (diff)	

libertas: Add spinlock to avoid race condition

```
lbs_mac_event_disconnected may free priv->currenttxskb
while lbs_hard_start_xmit accesses to it.
The patch adds a spinlock for mutual exclusion.

Tested on OLPC XO-1 (usb8388) and XO-1.5 (sd8686) with v4.7-rc3.

Confirmed that lbs_mac_event_disconnected is being called on the
station when hostapd on access point is given SIGHUP.

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```
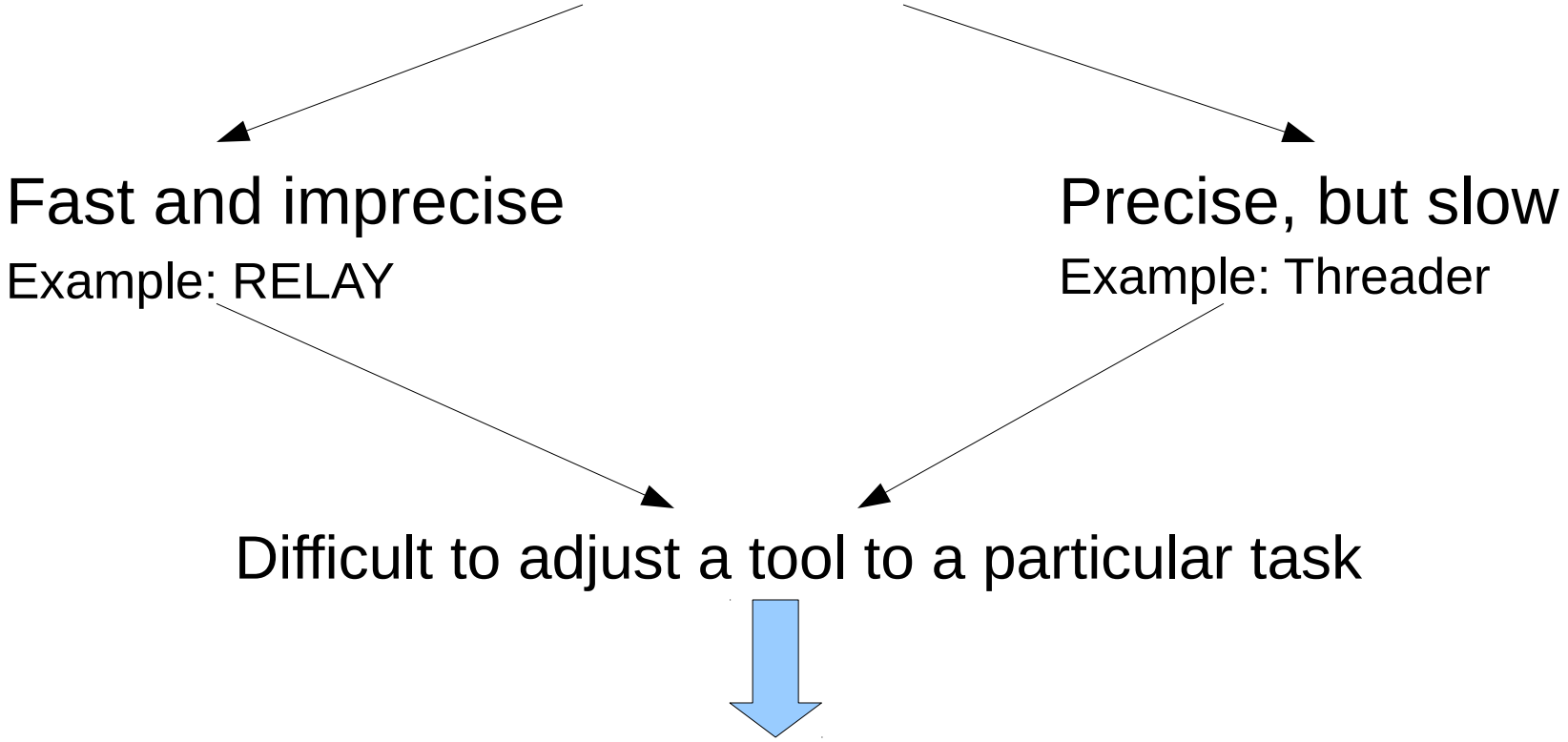

Motivation

- Concurrency bugs make up 20% of all across the file systems (*A Study of Linux File System Evolution*, FAST'13)
- Data race conditions make up 17% of all errors in the Linux kernel (*Analysis of typical faults in Linux operating system drivers,* Proceedings ISP RAN)

Other Tools


Fast and imprecise
Example: RELAY
Precise, but slow
Example: Threader
Difficult to adjust a tool to a particular task
Adjustable analysis?

Lockset Algorithm

Potential data race is a situation, when accesses to the same shared data occur with disjoint sets of locks from two parallel threads, one access is write.

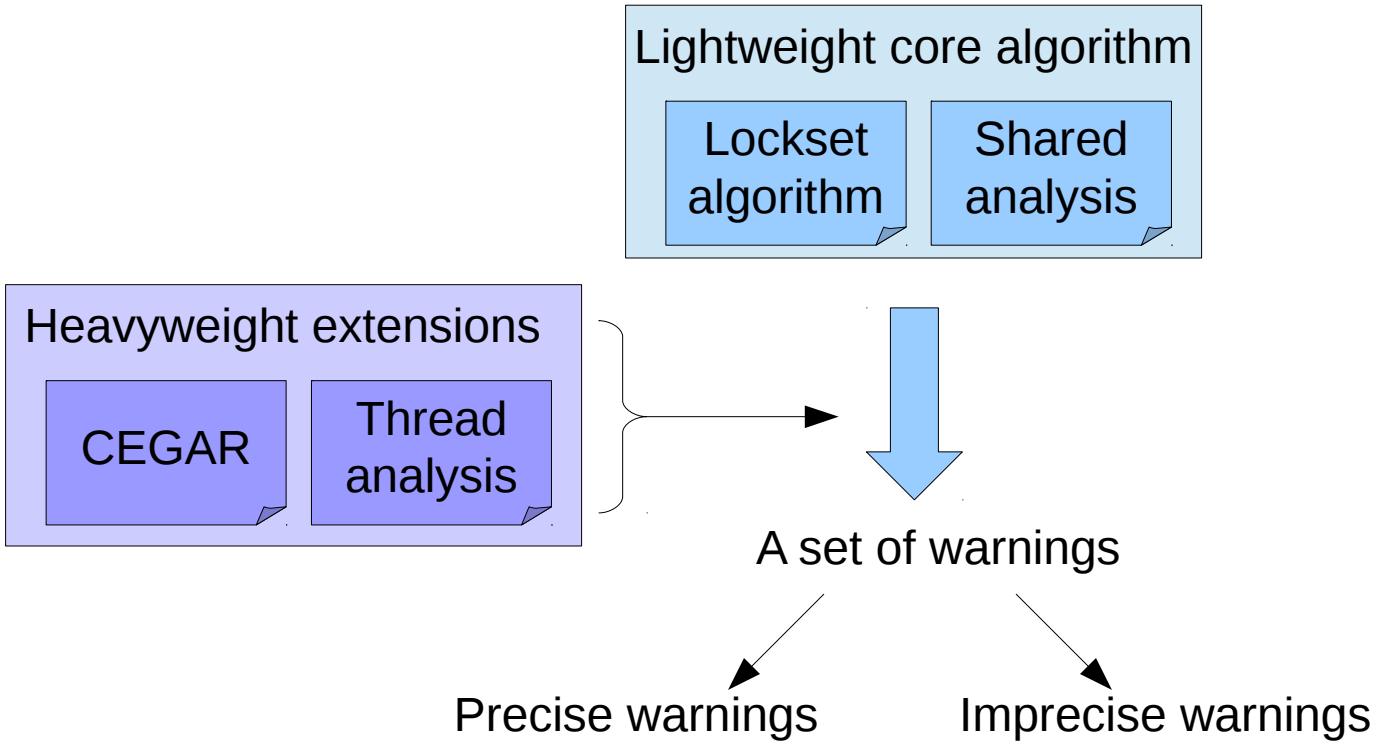
Potential Race Condition

```
...
*a = 1;
...
```

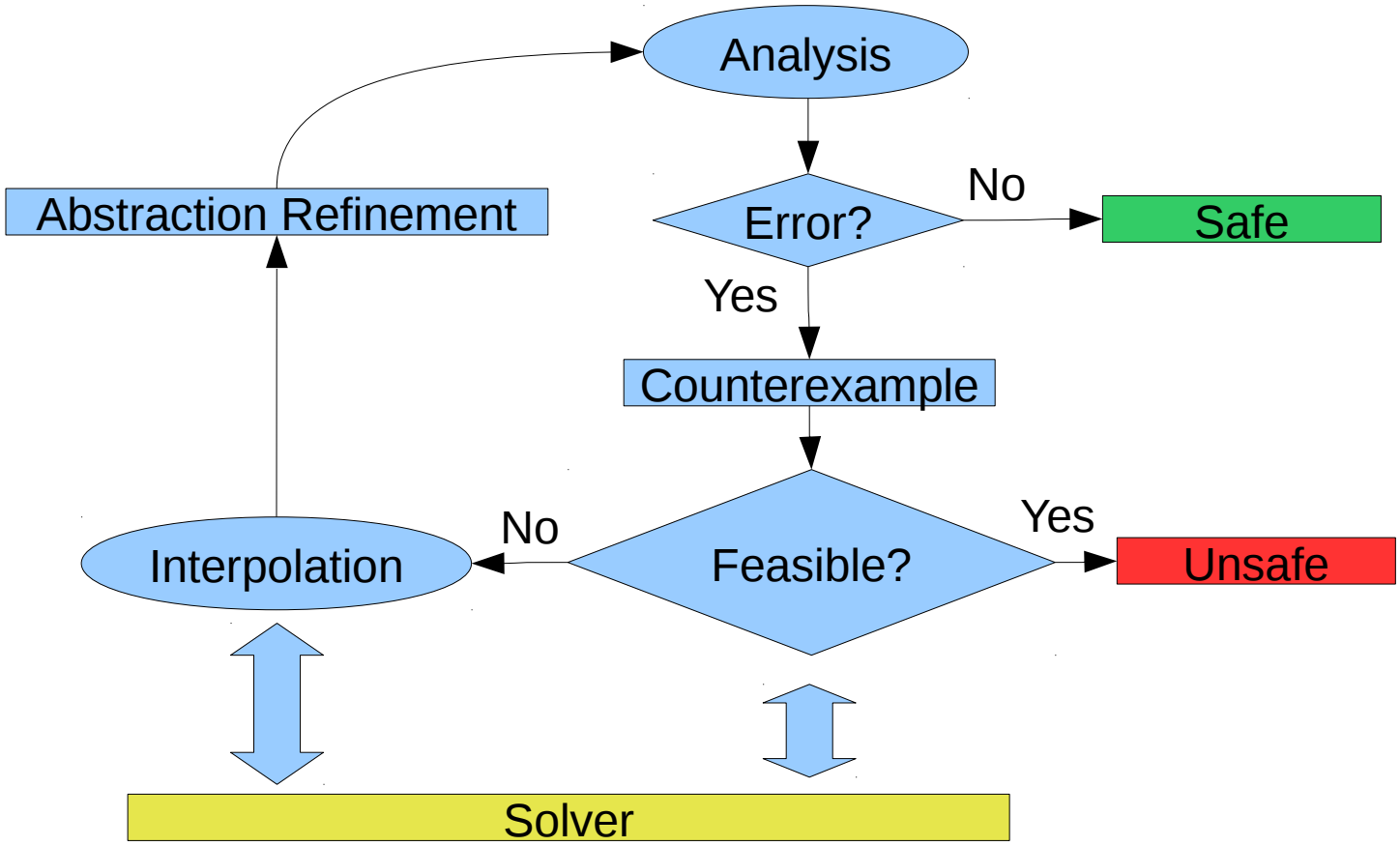
```
...
mutex_lock();
*a = 1;
mutex_unlock();
...
```

- A disjoint set of synchronization primitives
- The same shared data
- Accesses from different threads, which can be executed simultaneously
- Real (reachable) paths

Method overview



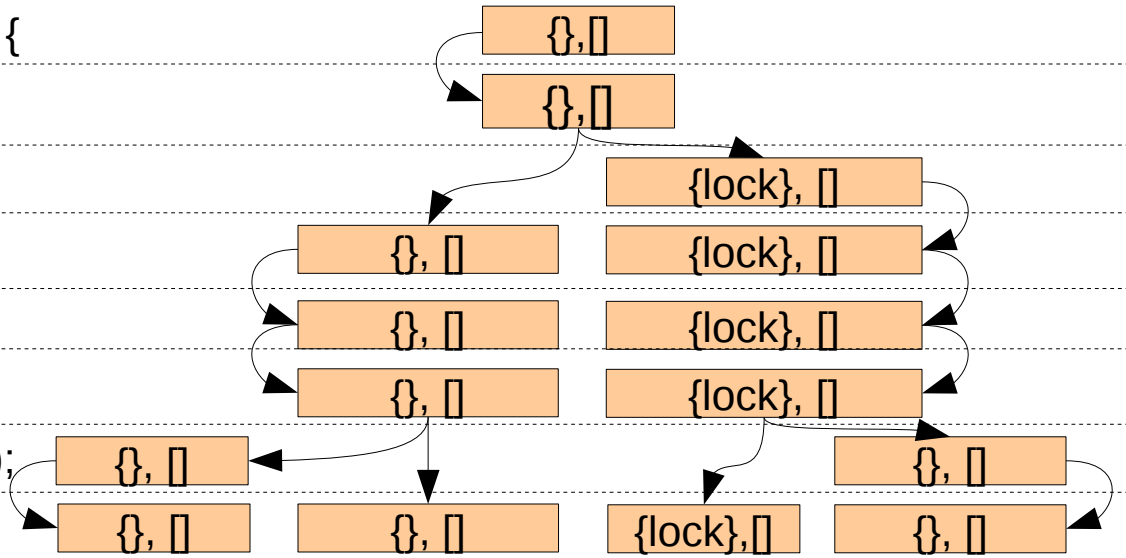
Counter Example Guided Abstraction Refinement



Reachability analysis

based on predicate abstraction

```
int global;
int func(int var) {
        if (var) {
            lock();
        }
        global++;
        if (var) {
            unlock();
        }
}
```



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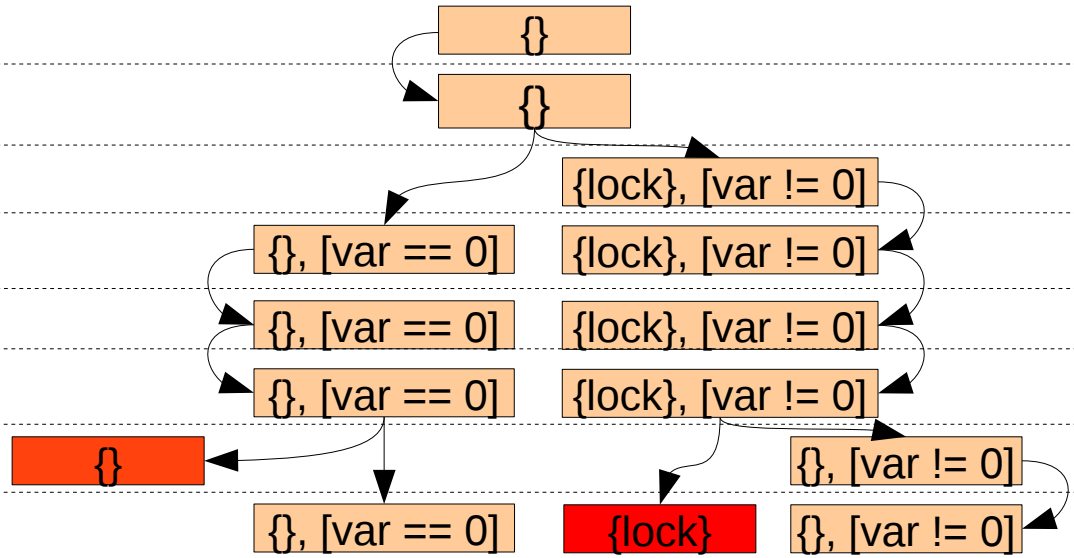
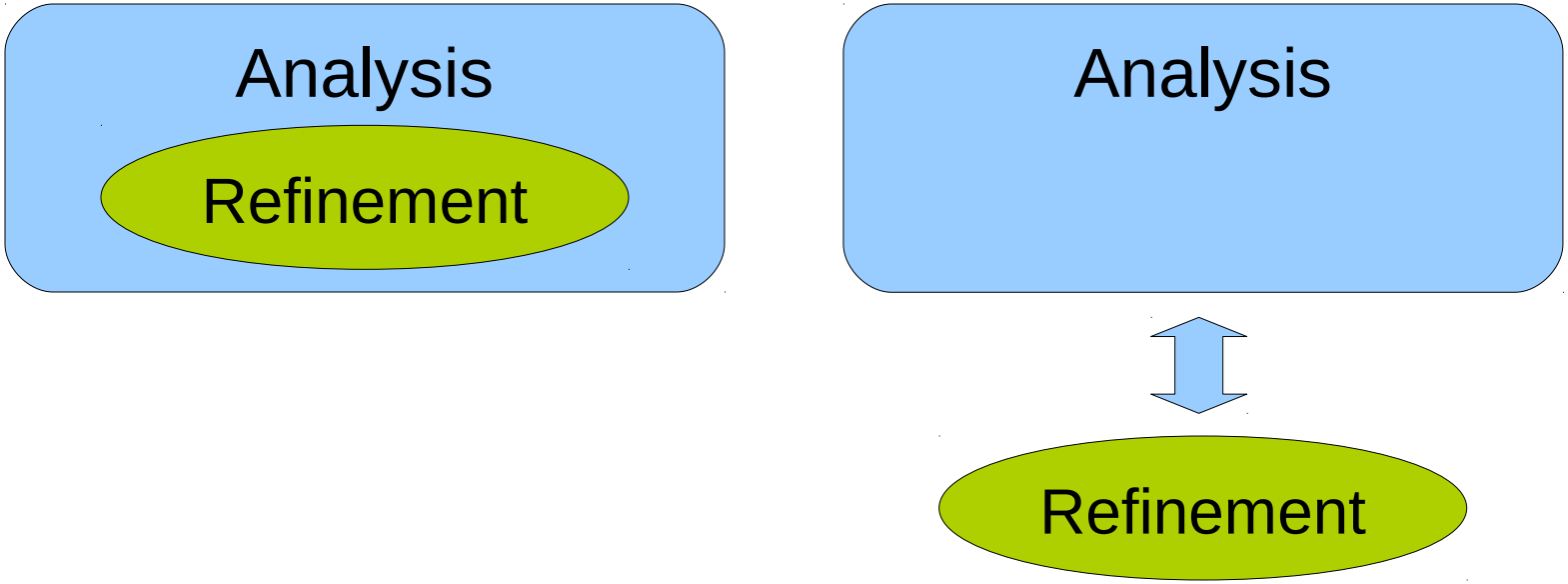
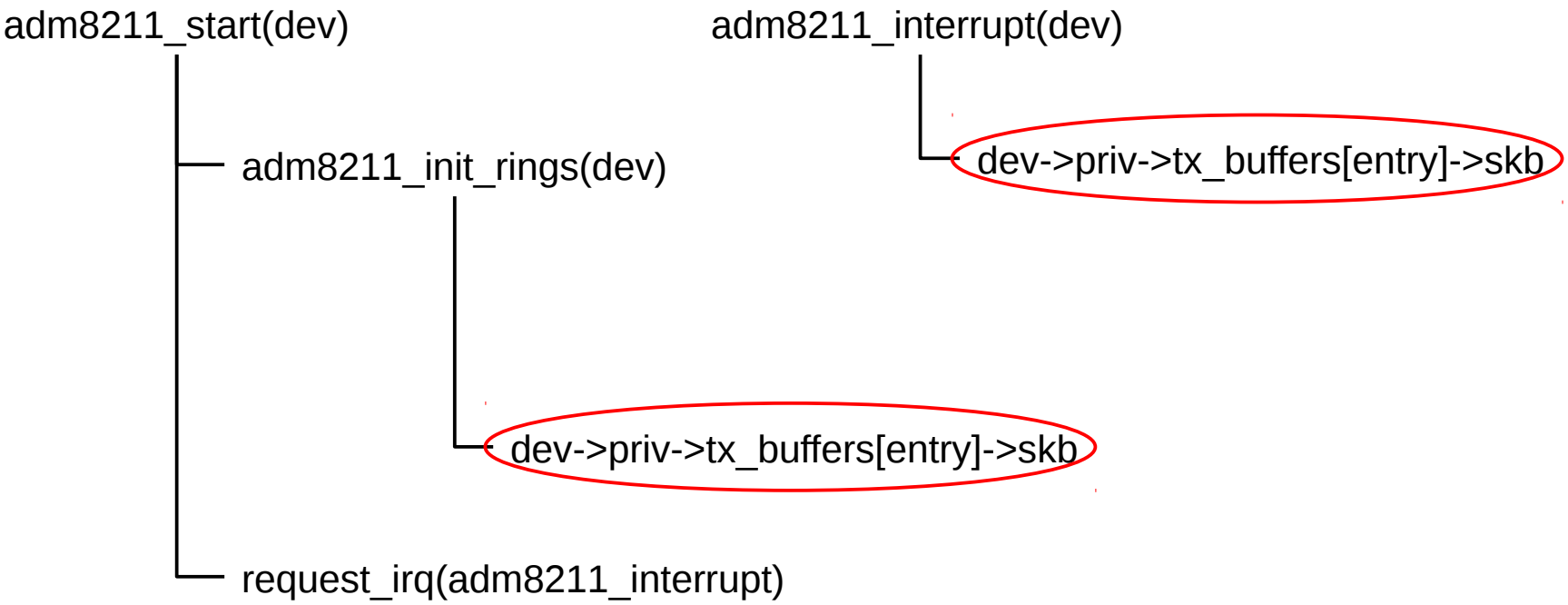


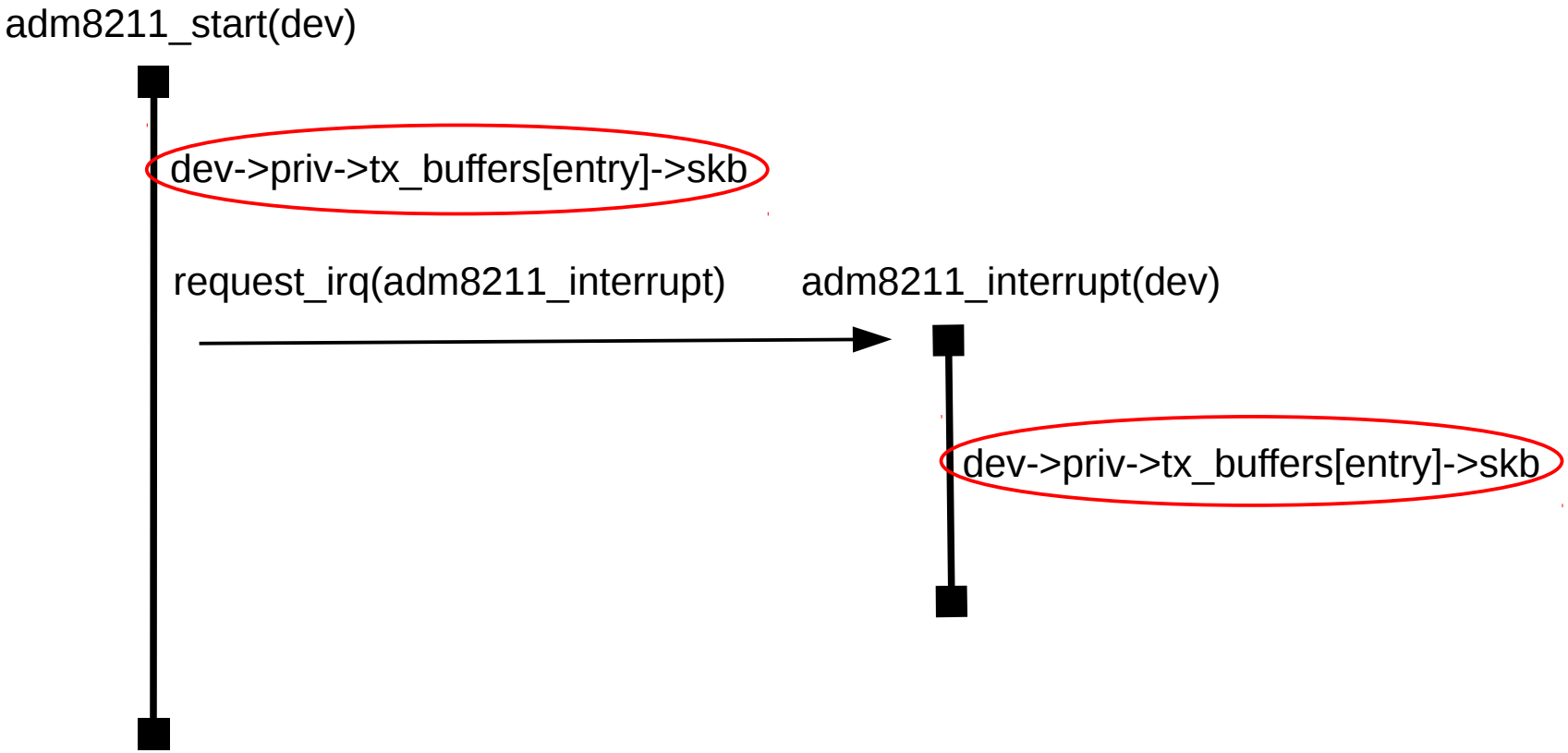
Two Ways of Refinement



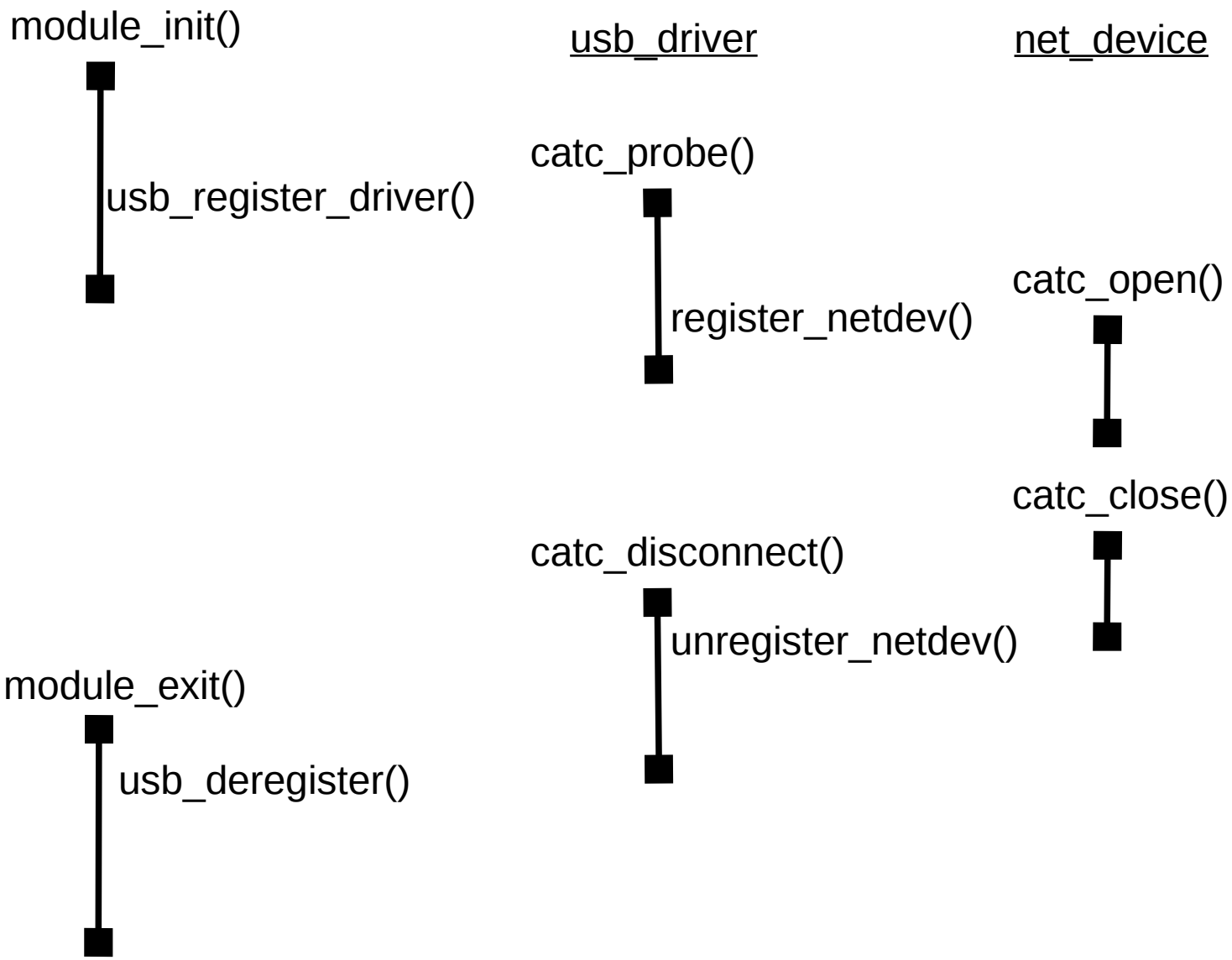
Example of False Alarm



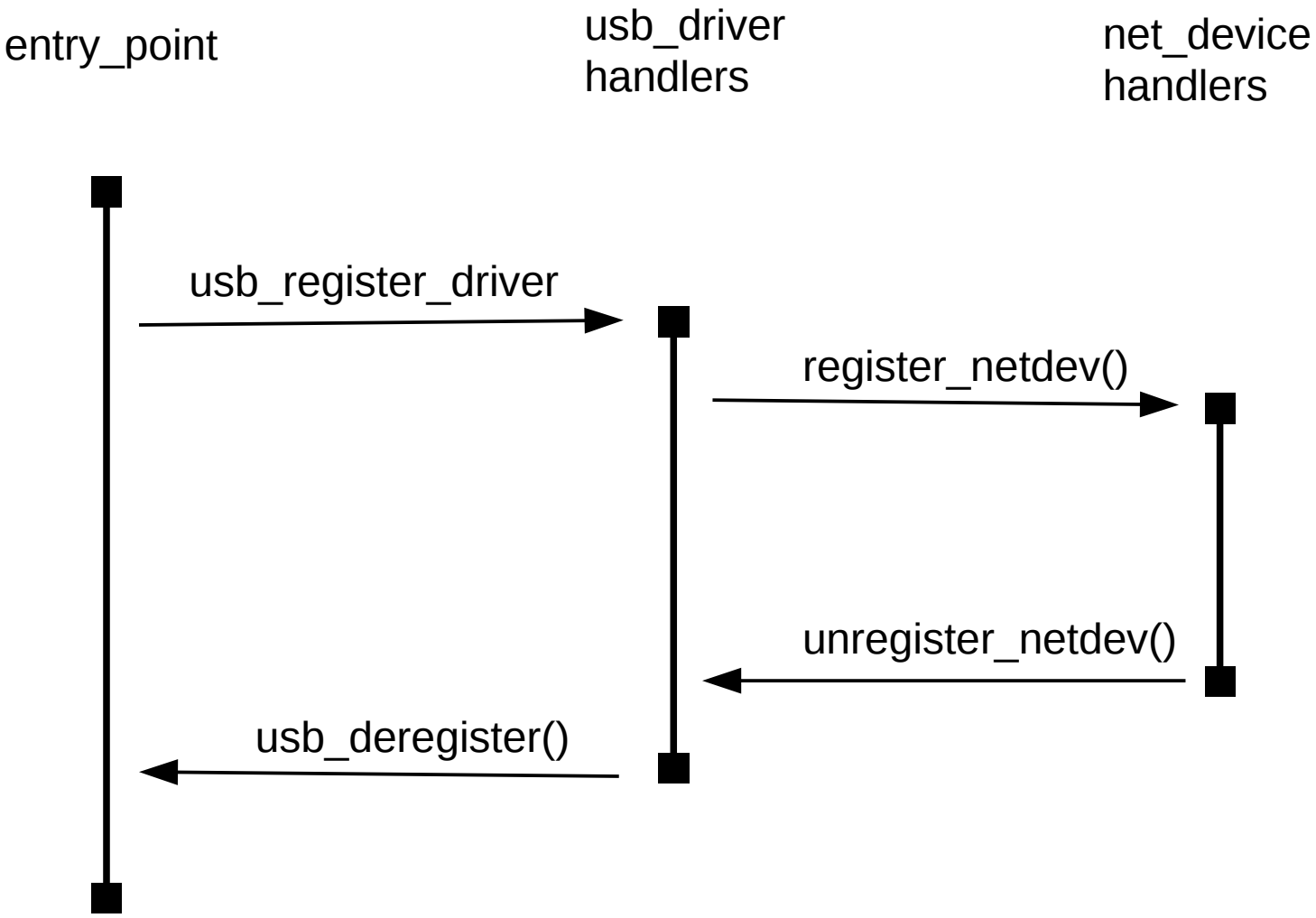
Example of False Alarm



Example of Linux Driver

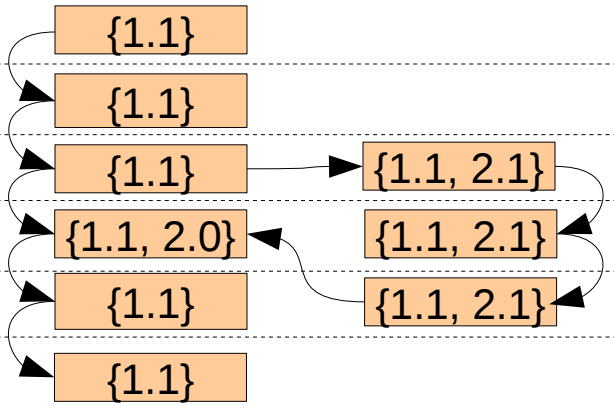


Example of Model



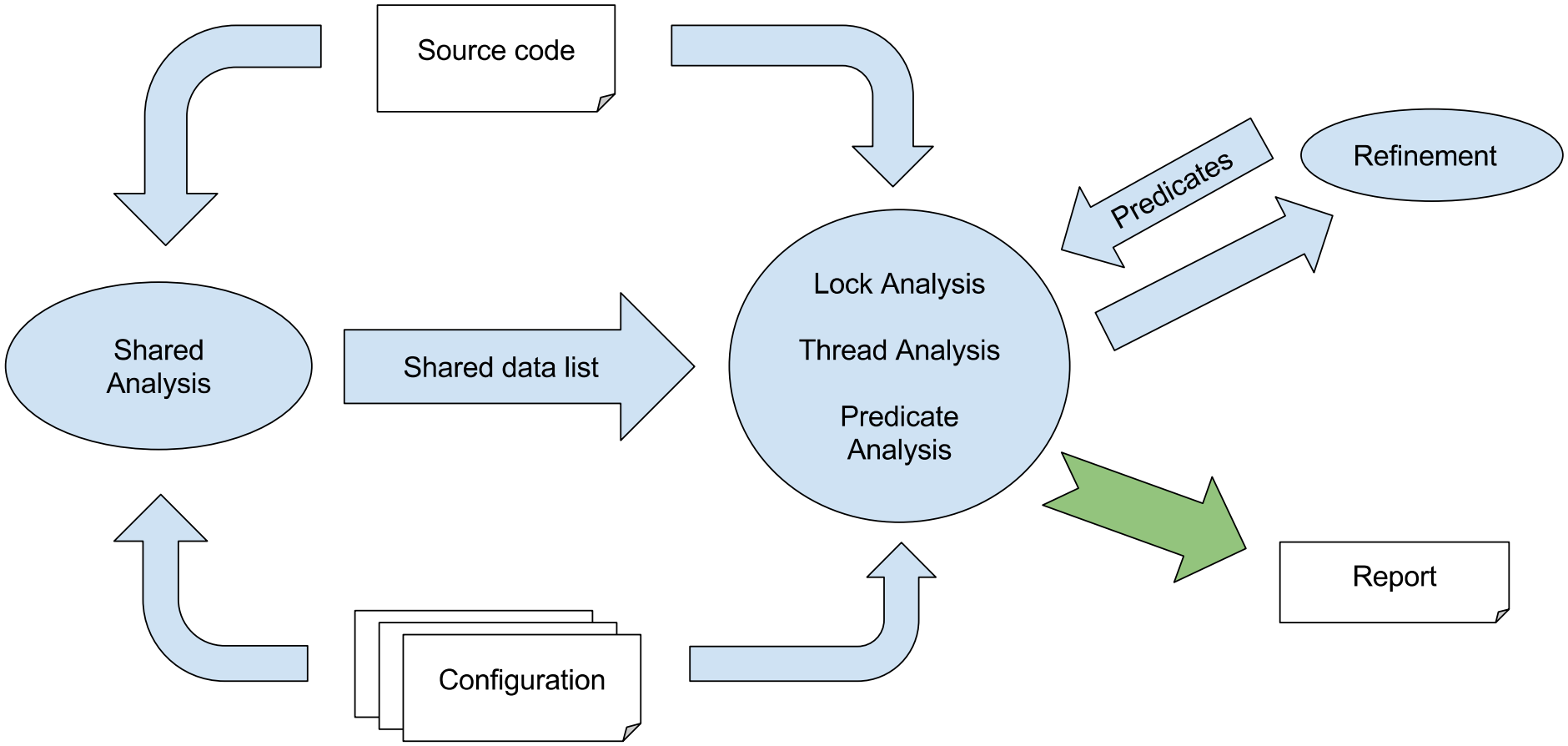
Thread Analysis

```
int global;
Int start() {
    global = 0;
    pthread_create(&thread, .., worker, ..);
    pthread_join(&thread);
    result = global;
}
```




```
int worker() {
        global++;
}
```

Method Overview



Results

113 modules of OS Linux 4.5-rc1 subsystem drivers/net/wireless/

	Unsafes	Unknowns	Safes	Time, h	Memory, Gb
+ Threads, + Refinement	5	61	51	3.2	8.1
- Threads, + Refinement	6	67	44	4.1	4.0
+ Threads, - Refinement	27	57	49	2.3	8.2
- Threads, - Refinement	186	54	43	2.1	3.5

2219 warnings at drivers/

- 2219 warnings = 270 unsafe drivers
  - 55% - imprecision of environment model
  - 10% - simple memory model
  - 10% - operations with lists
  - 10% - other inaccuracies in our analysis
  - 15% - true races
- 290 true warnings = 32 bugs

Conclusion

- Flexible adjustment of the balance between resources and accuracy
- Applicable to industry projects
- Real race conditions are found

Thank you!

Questions?