Preventing Kernel Hacks with HAKC

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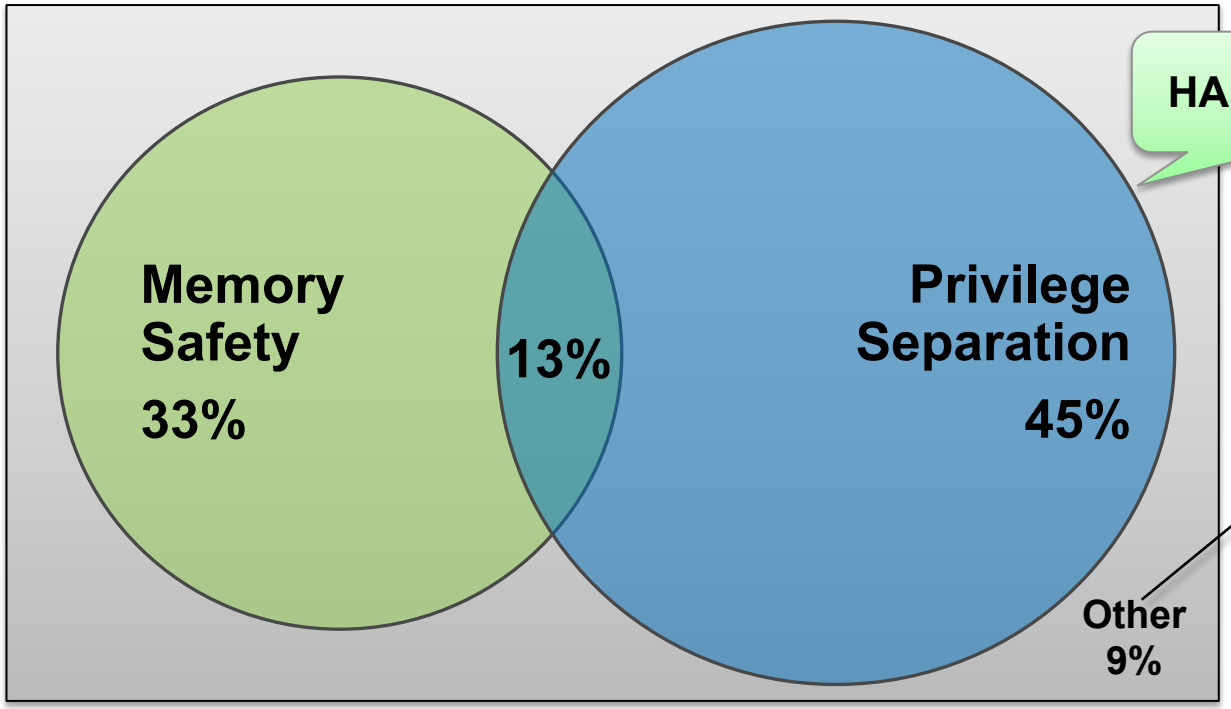
What is the Largest Class of OS Vulnerabilities?

We analyzed the past 5 years of vulnerabilities in Linux: 508 with *critical* or *high* severity



Other includes:

- **Race Conditions**
- **Integer Over/Underflow**
- **Logic bugs:**
  - **Missing checks**
  - **Buggy initialization**
  - **Buggy error handling**

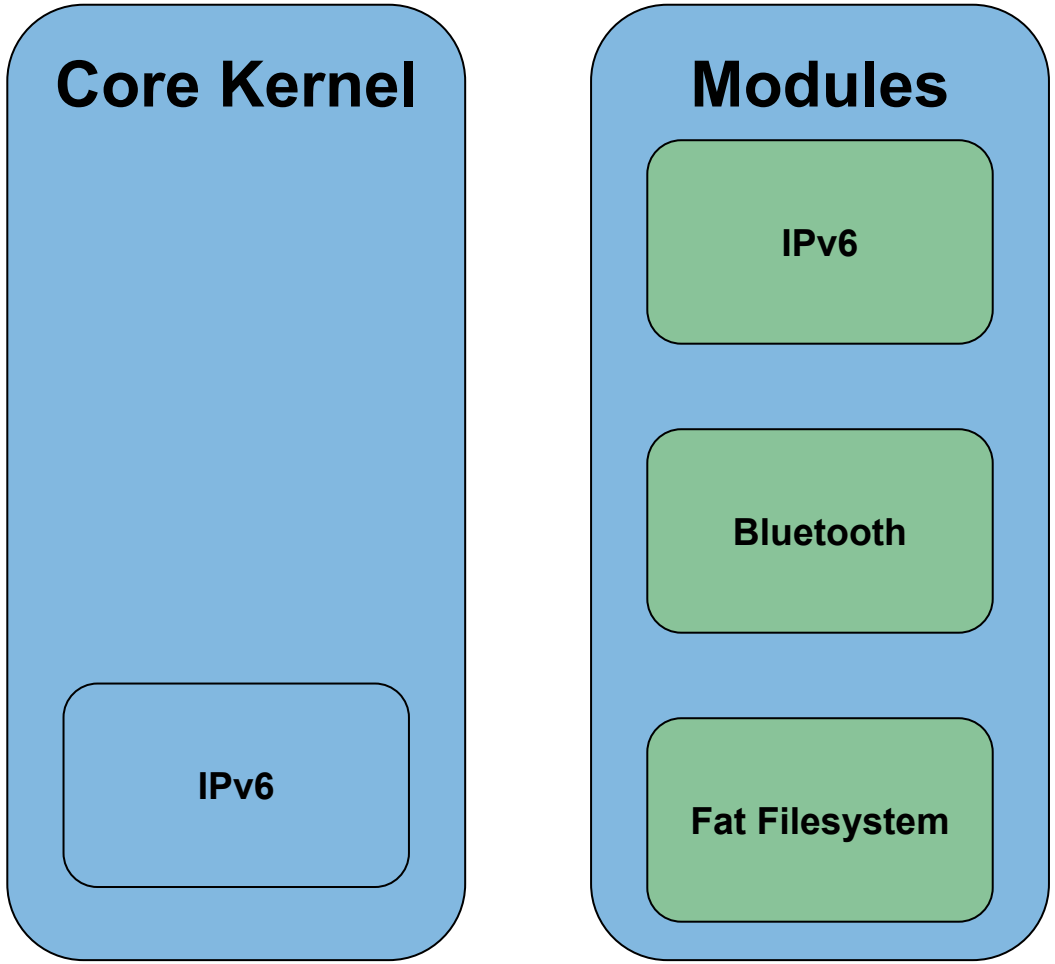
Privilege Separation mitigates the highest percentage of Linux CVEs.

What is HAKC?

- Hardware Assisted Kernel Compartmentalization (HAKC)
- Enforcement mechanism for compartmentalization policies
- Runs on bare metal without virtualization by using new hardware extensions
  - PAC computes a hash of a pointer and user-specified context
  - MTE colors an address range one of 16 colors
- HAKC restricts bugs to their compartments, which limits their reach

HAKC enforces ***compartmentalization*** to prevent the most common class of bugs.

Linux Today



Kernel CVE Example

```
void release(struct entry *e) {
    if(e->offset < OFFSET_MAX) {
        int *i = e->buffer + e->offset;
        e->cb(i);
        *i -= 1;
    }
}
```

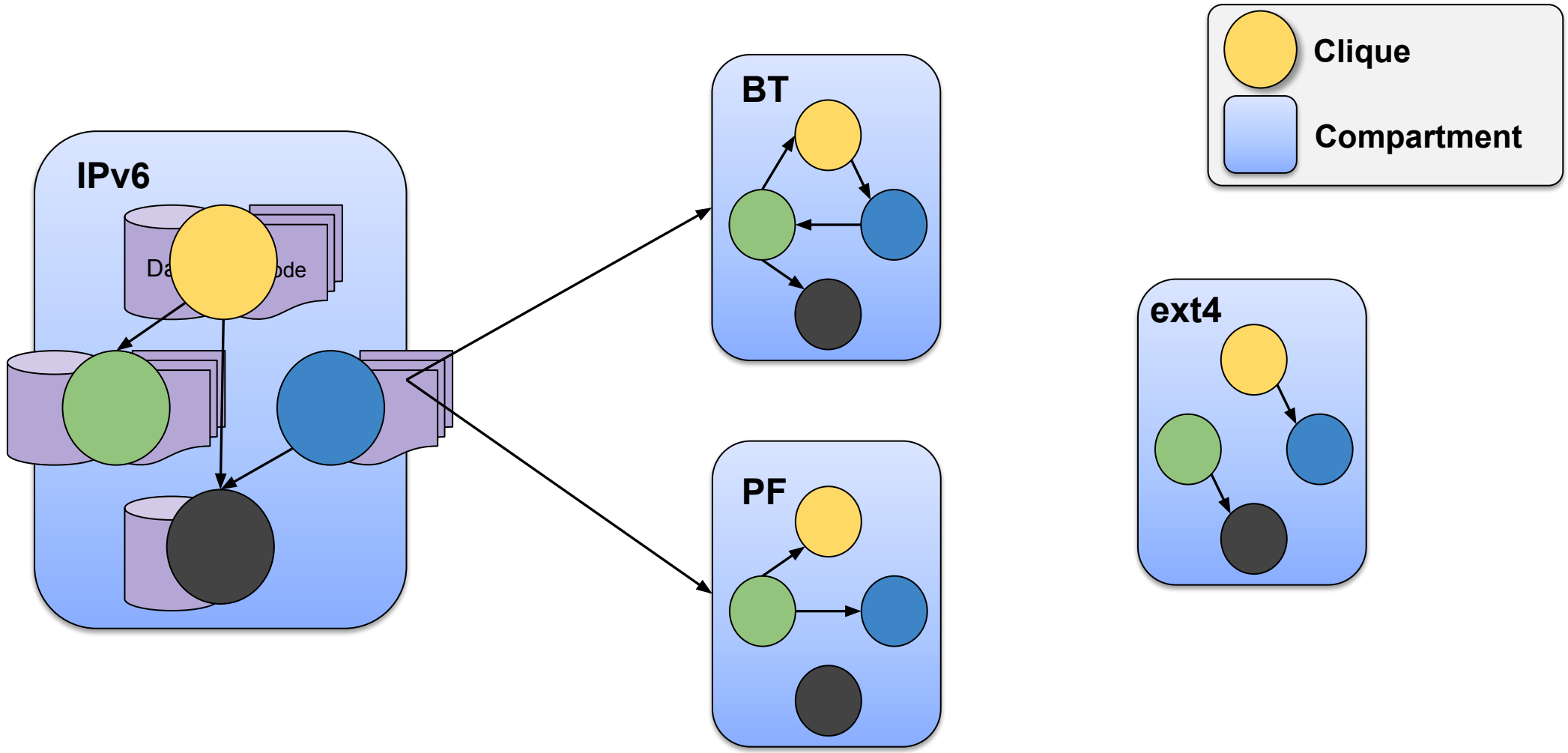
Attacker controlled

Missing lower bound check!

i is any arbitrary kernel data

- Adapted from CVE-2016-4997

How Does HAKC Work?



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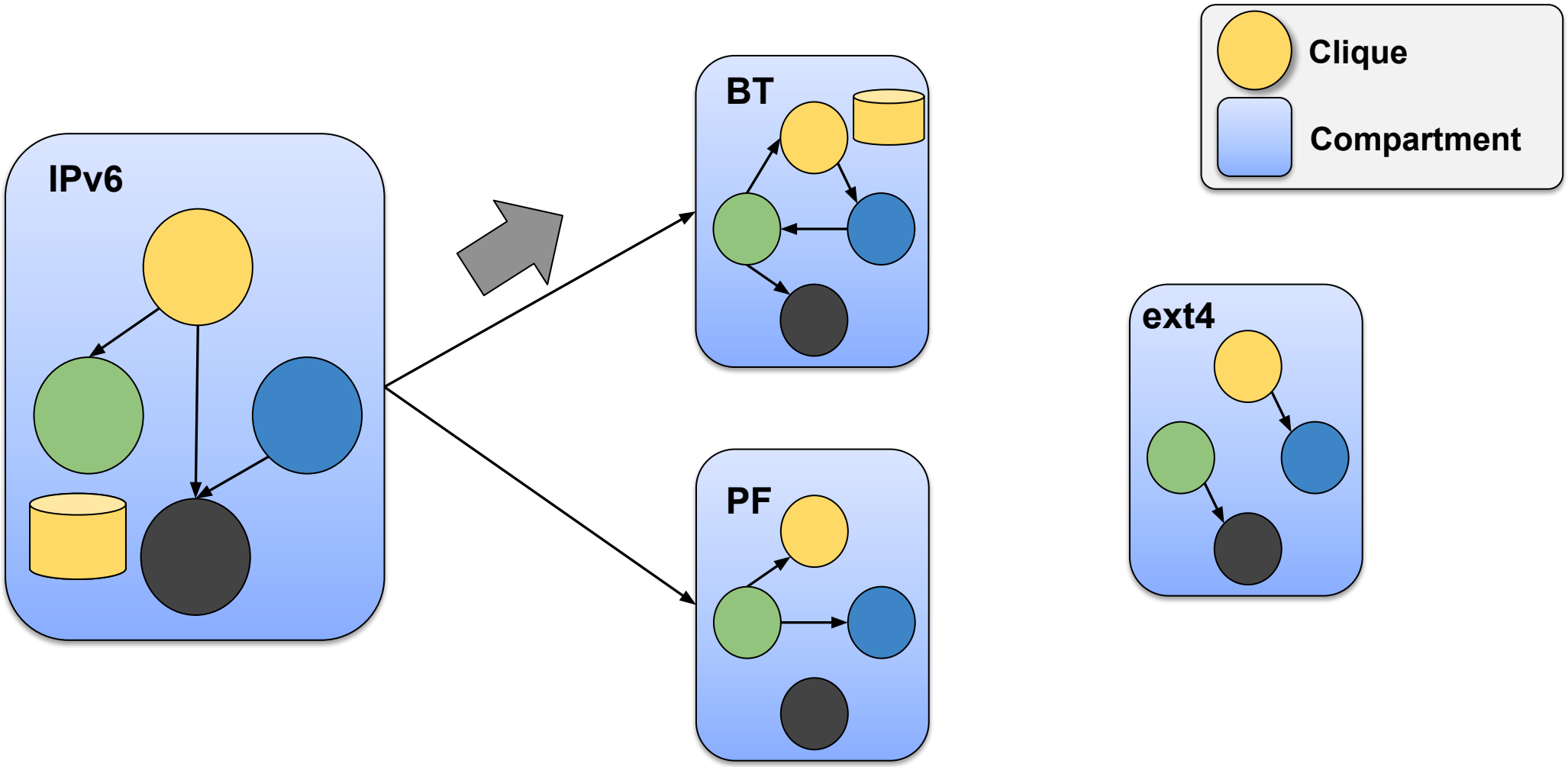

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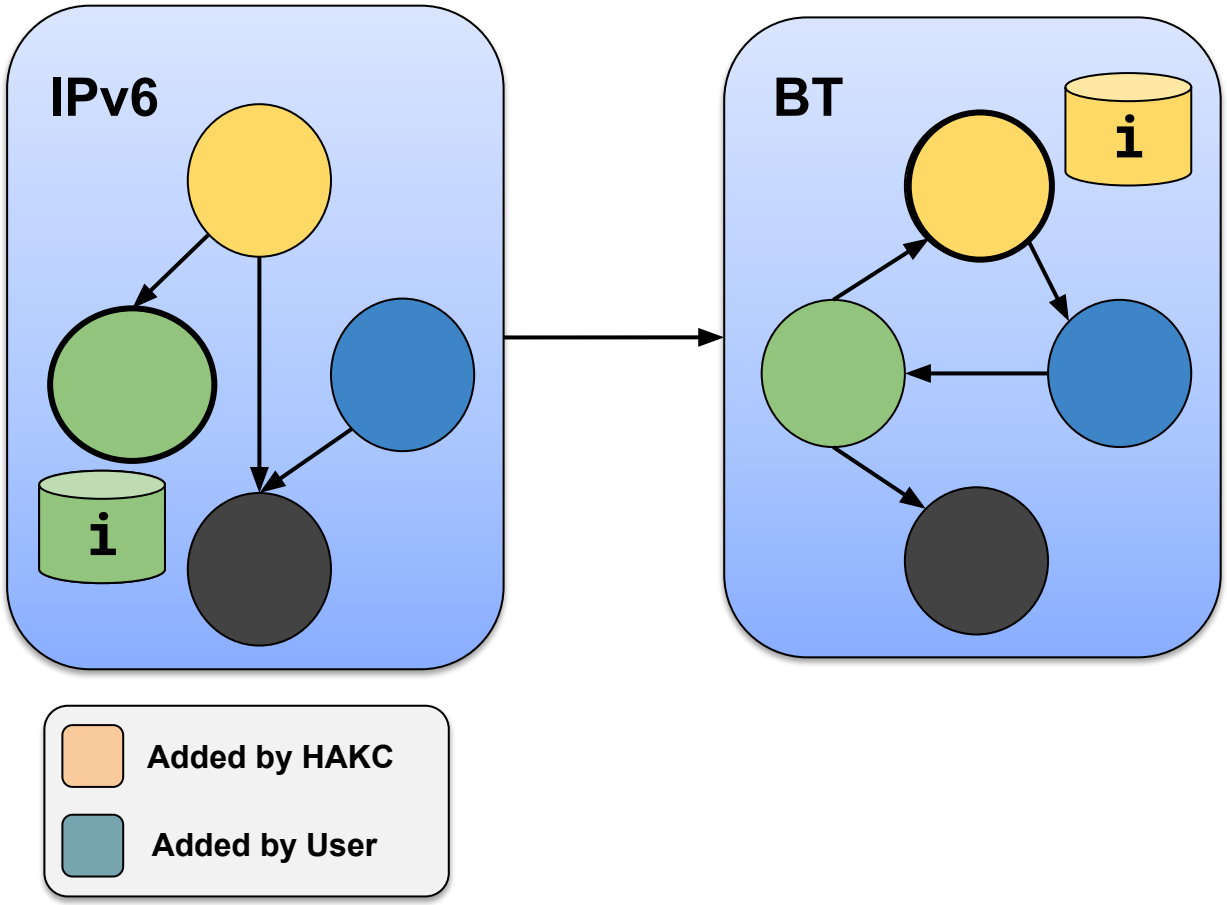



```
void release(struct entry *e) {
  if(e->offset < OFFSET_MAX) {
    int *i = e->buffer + e->offset;
```

HAKC Data Check for i

HAKC Compartment Transition Check

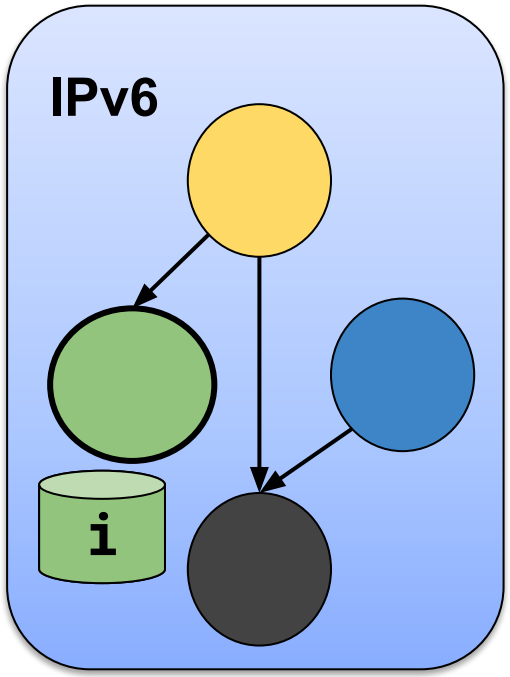
HAKC Data Ownership Transfer to e->cb

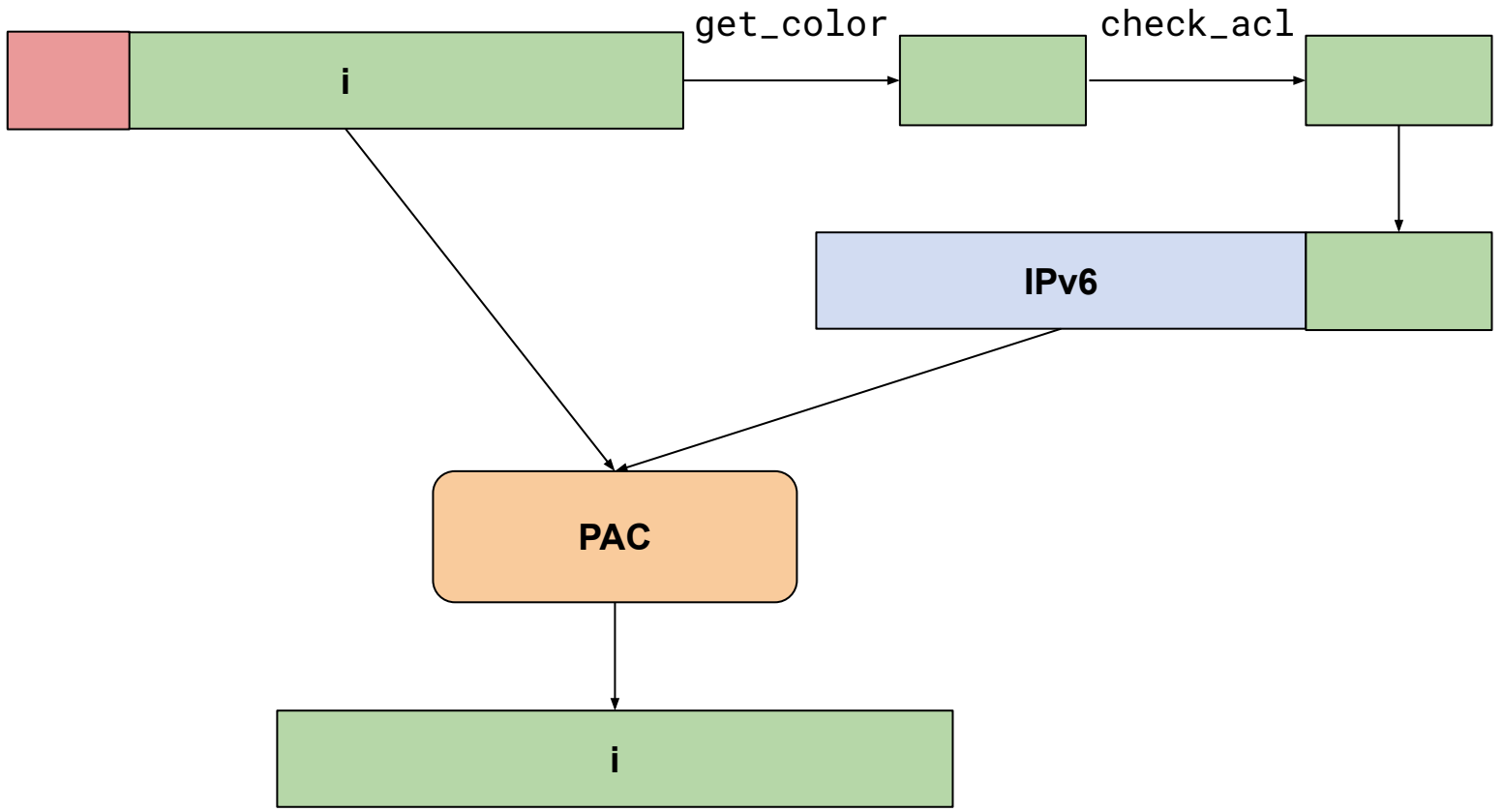
```
    e->cb(i);
```

HAKC Data Ownership Reversal

```
    *i -= 1;
  }
}
```

HAKC Checks

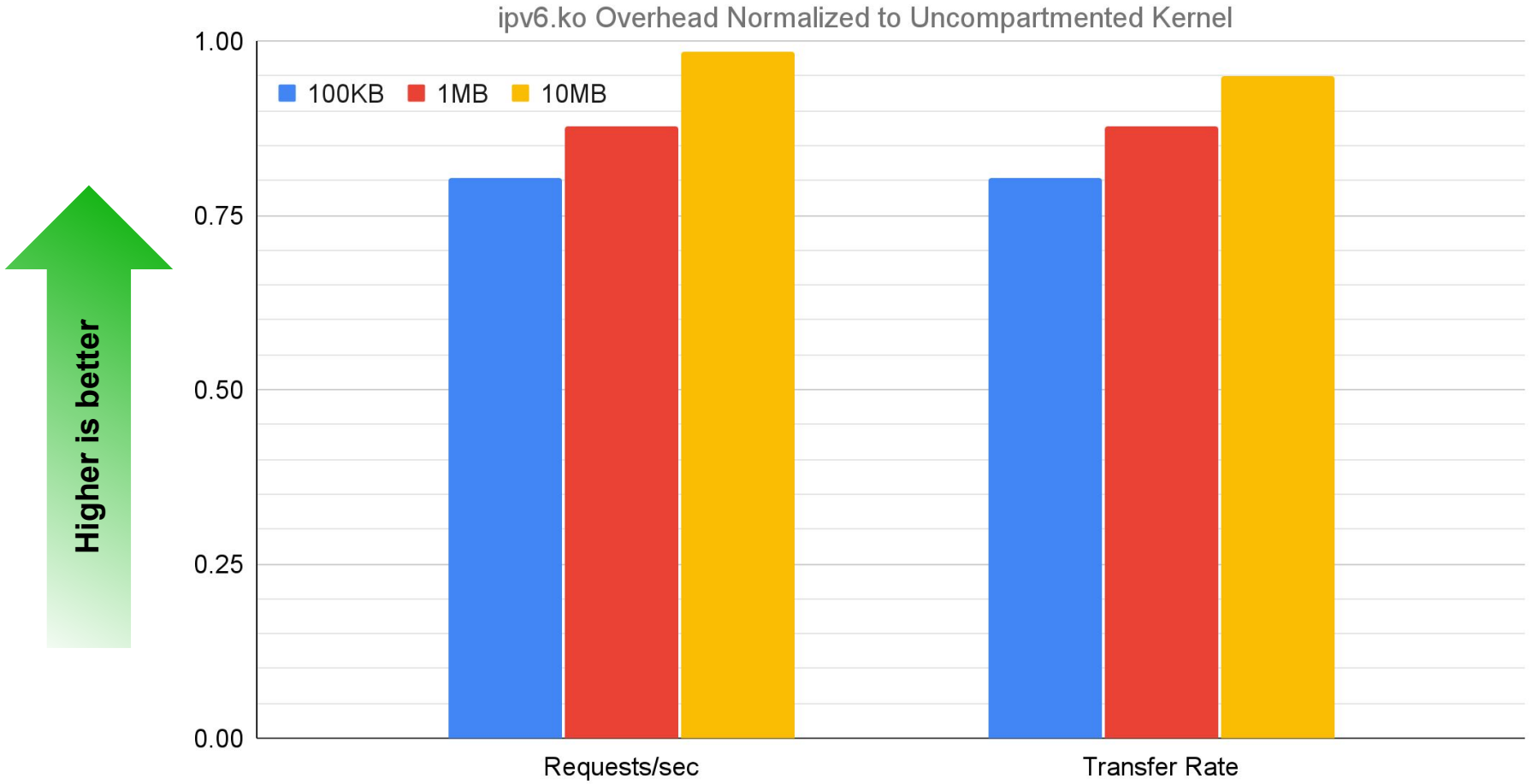




HAKC Experimental Results

- Compartmentalized the IPv6 and one of the packet filtering modules
- Measured the performance using Apachebench
- User simulation study browsing popular websites

Single Module Apachebench Overhead



HAKC imposes a low performance overhead of ≤ 20%.

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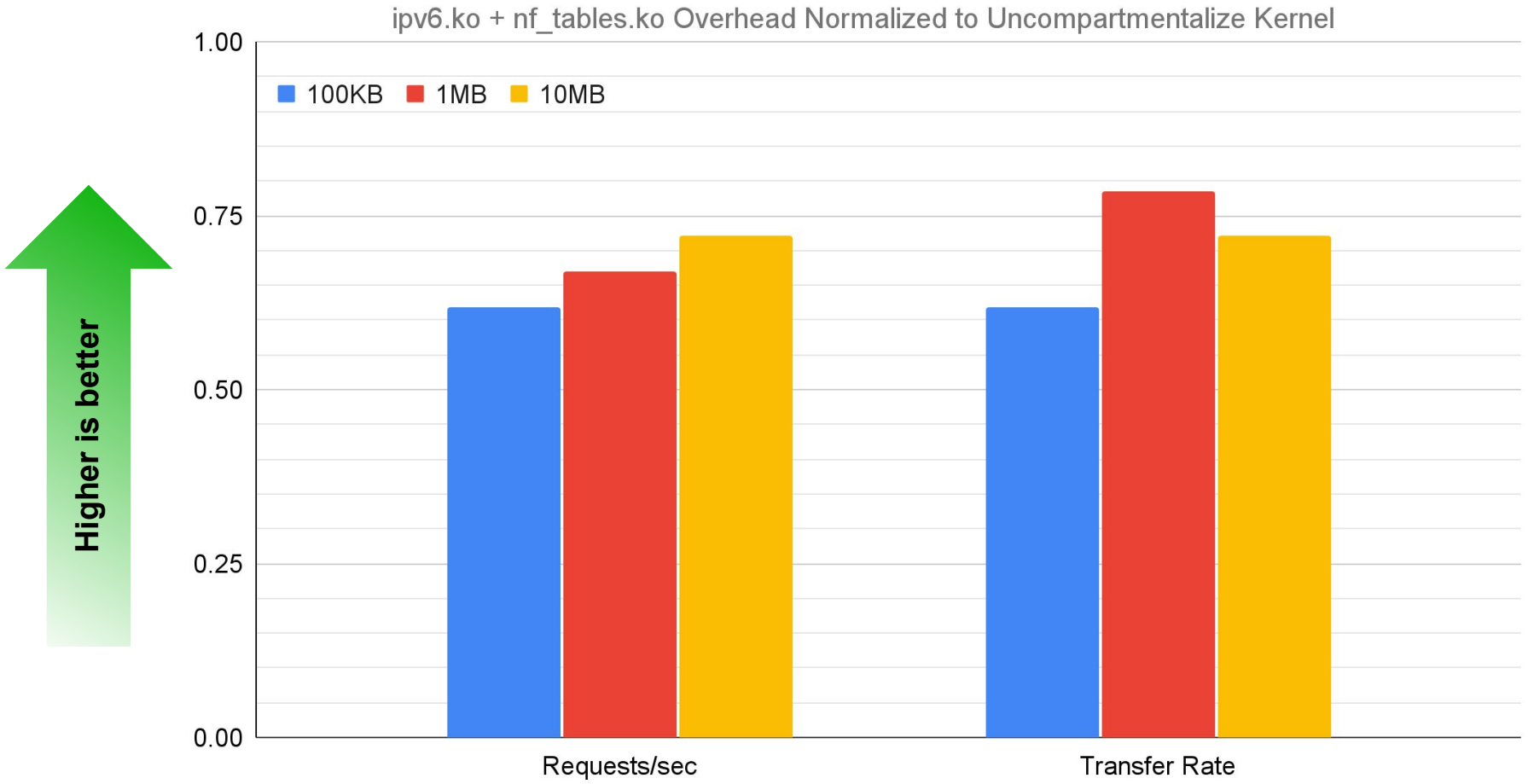
Multiple Module Apachebench Overhead



Overhead increases linearly with Compartment count in the worst case.

User Browsing Overhead

Website	Load Time Delta (s)	Stdev (s)
linkedin.com	-0.47	0.065
hdfcbank.com	-0.12	0.085
google.cn	-0.068	0.086
bing.com	-0.087	0.13
investing.com	38	62
okezone.com	-11	20
cnn.com	-9.8	15
yahoo.com	-4.9	15

HAKC Load time is
1.19 ± 4.34s slower

Users browsing the internet with a HAKC protected IPv6 module will notice no difference.

HAKC Summary

- Novel two-level enforcement mechanism for arbitrary compartmentalization policies
- By utilizing new hardware extensions, HAKC does not require any virtualization layer or trusted monitor
- HAKC enforces compartments that provide strong protection for data and control-flow at low overhead
- Available at https://github.com/mit-ll/HAKC
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  - Twitter: @unbound_brewer