SECURE PROGRAMMING OF RESOURCE CONSTRAINED DEVICES

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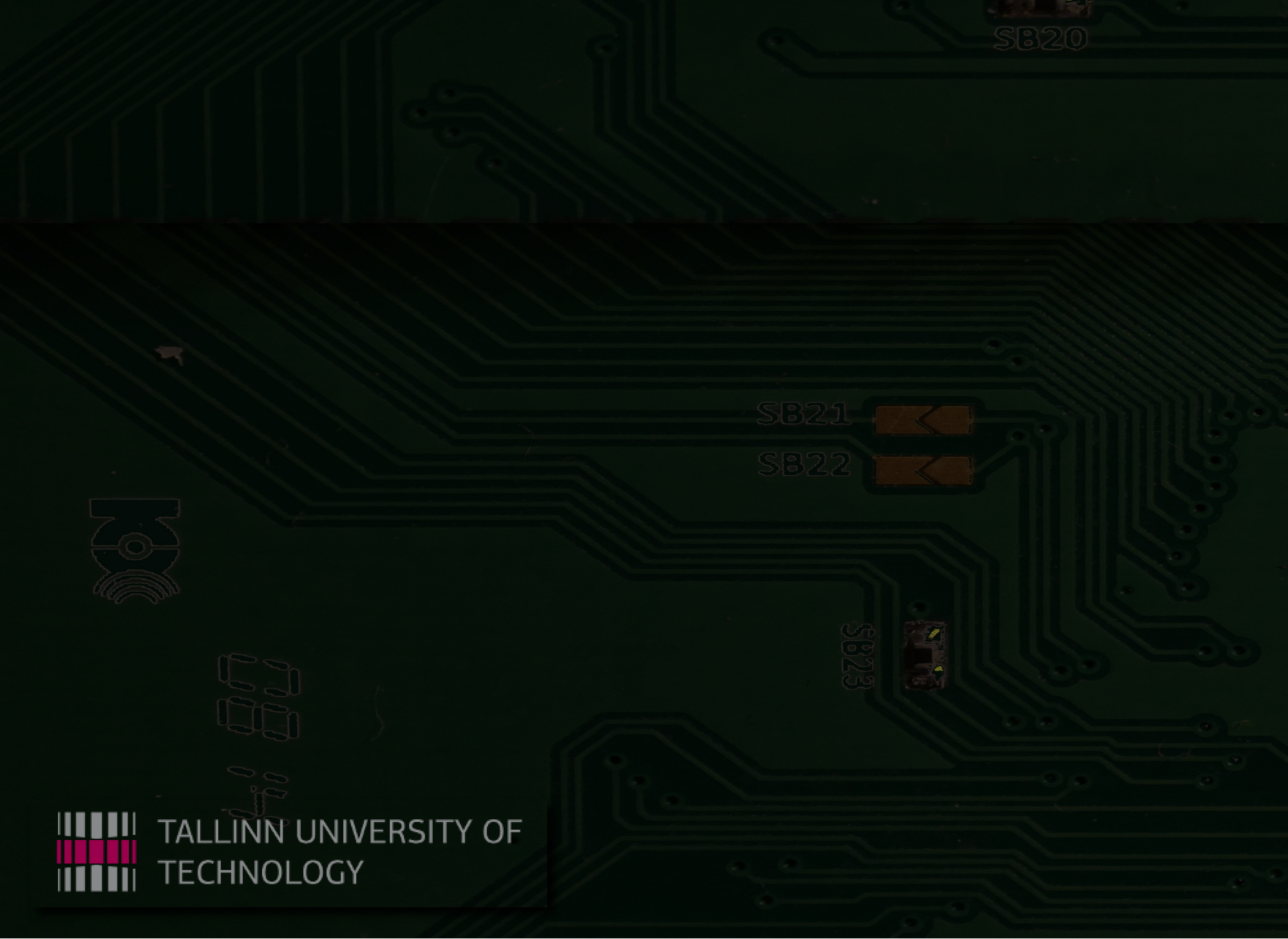

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AGENDA

1. Resource Constrained Devices
2. The Heartbleed vulnerability
3. The Rust Programming Language
4. Conclusion and recommendations

RESOURCE CONSTRAINED DEVICES

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DEFINITION

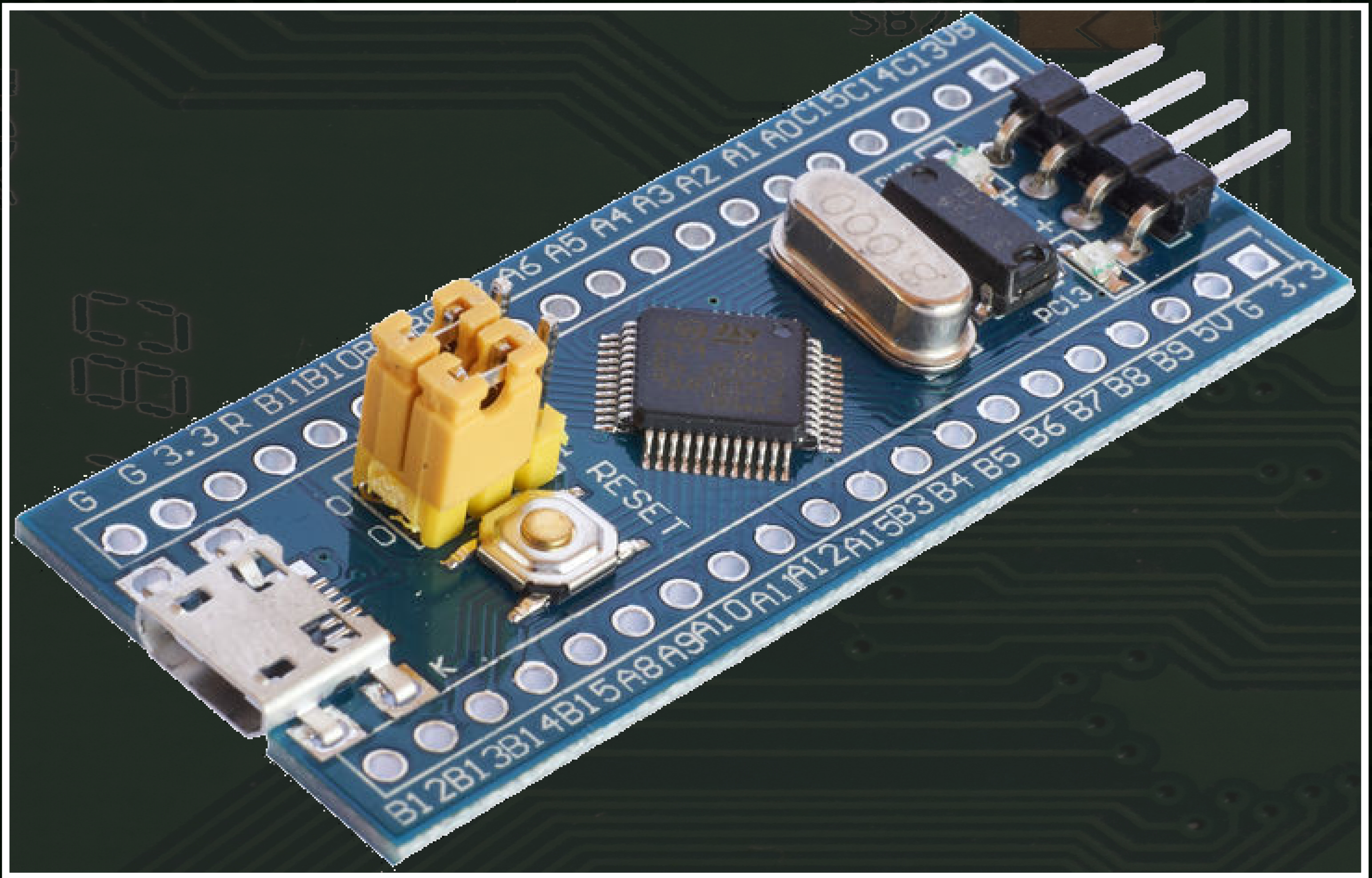
Resource constrained device

is a computer with very limited processing and storage capabilities, designed for low energy consumption.

Examples

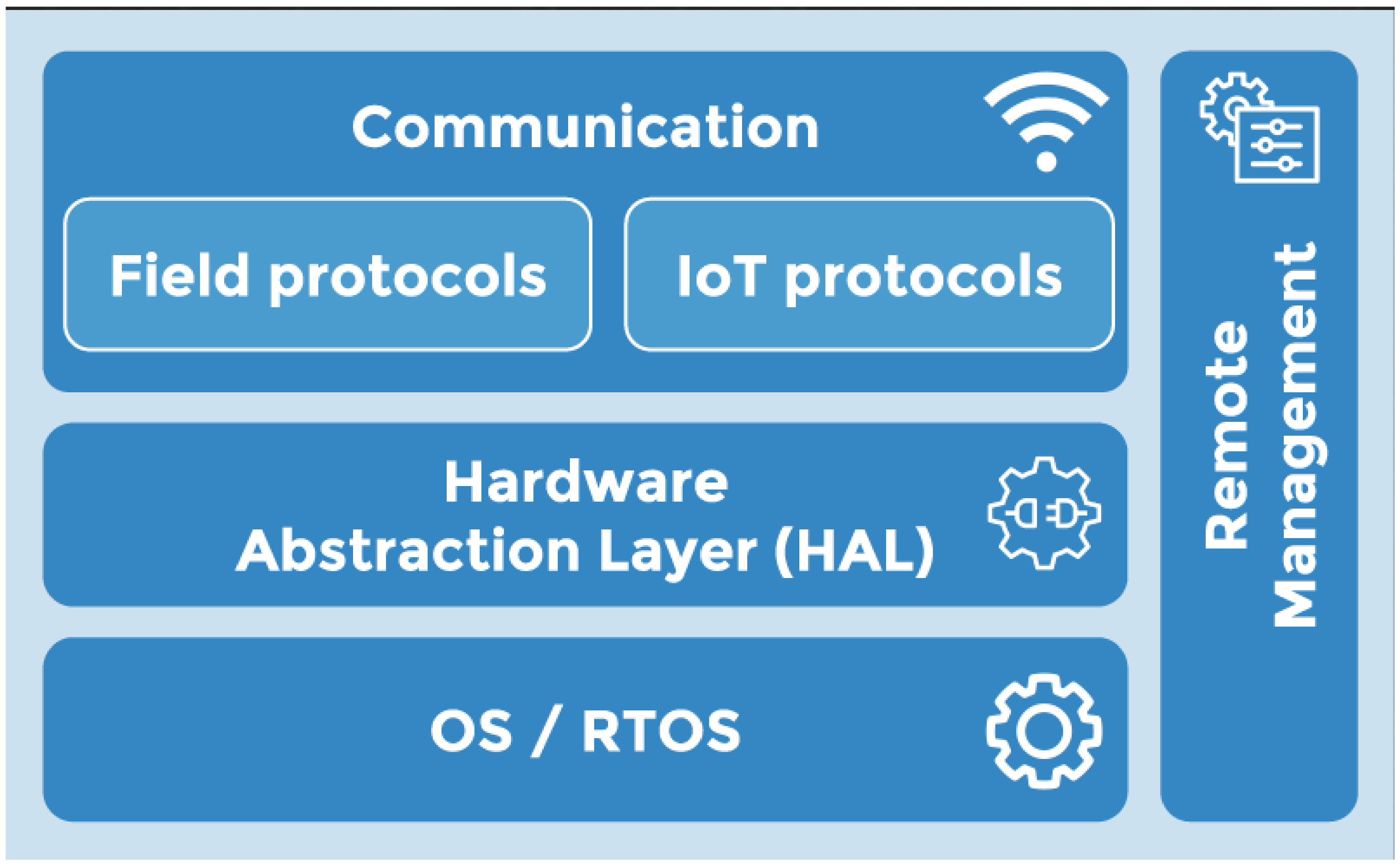
- Wireless Sensors
- The “Things” in the Internet of Things

HARDWARE



Example: STM32F103C8T6 Blue-Pill

SOFTWARE ARCHITECTURE



Resource Constrained Device

SPECIAL REQUIREMENTS

meta-functional attributes

RESOURCE CONSTRAINED DEVICES ARE VULNERABLE

Attacks

Mirai (2016) / IoT reaper / IoTroop / Heartbleed (2014)

Causes

- RCD are as complex
- Internet connectivity does not generate excess profit.

  -> Devices are poorly configured and highly insecure
- C/C++ do not provide *memory and thread safety*

THE HEARTBLEED VULNERABILITY

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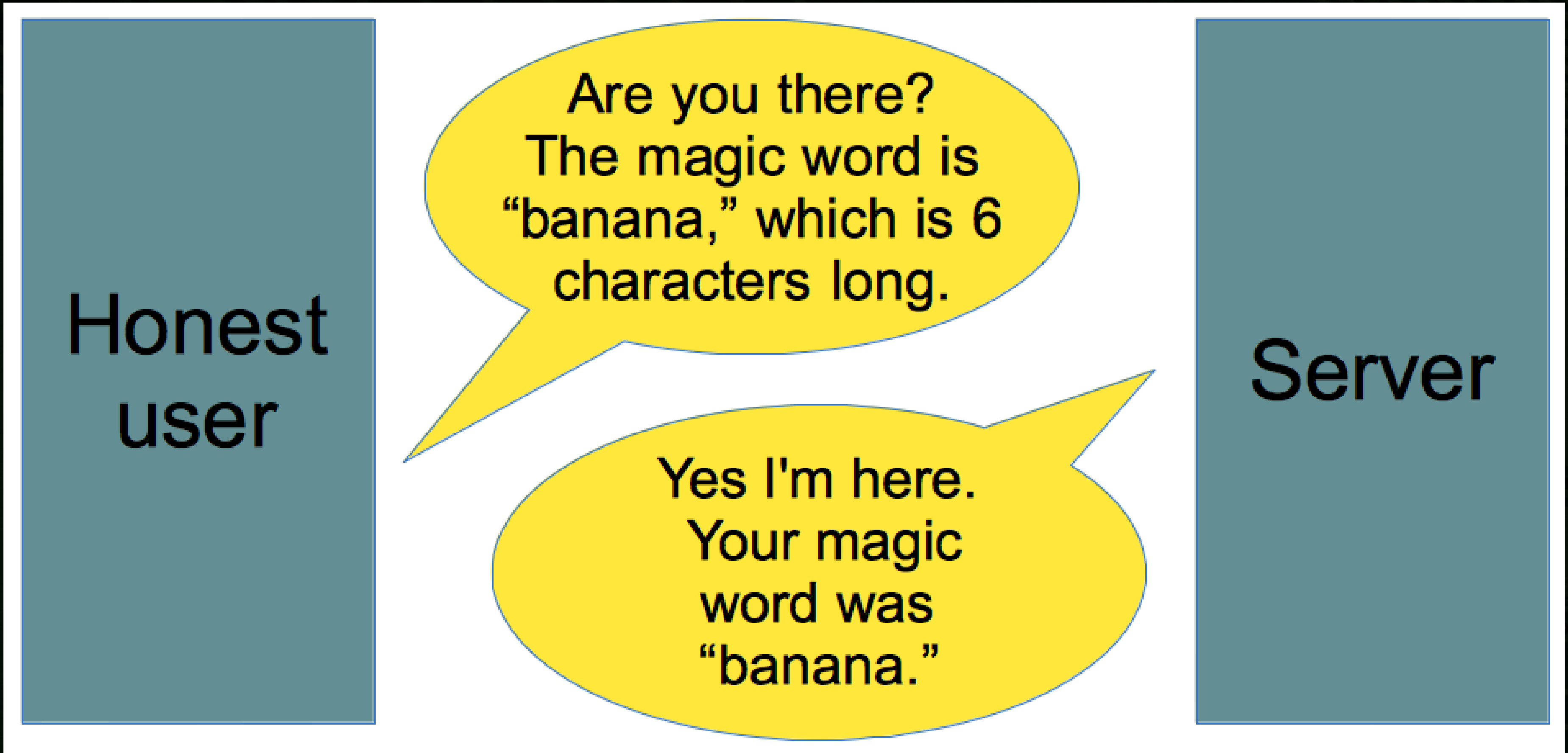
MEMORY SAFETY RELATED VULNERABILITIES

2/3 of all Linux kernel vulnerabilities are memory safety related.

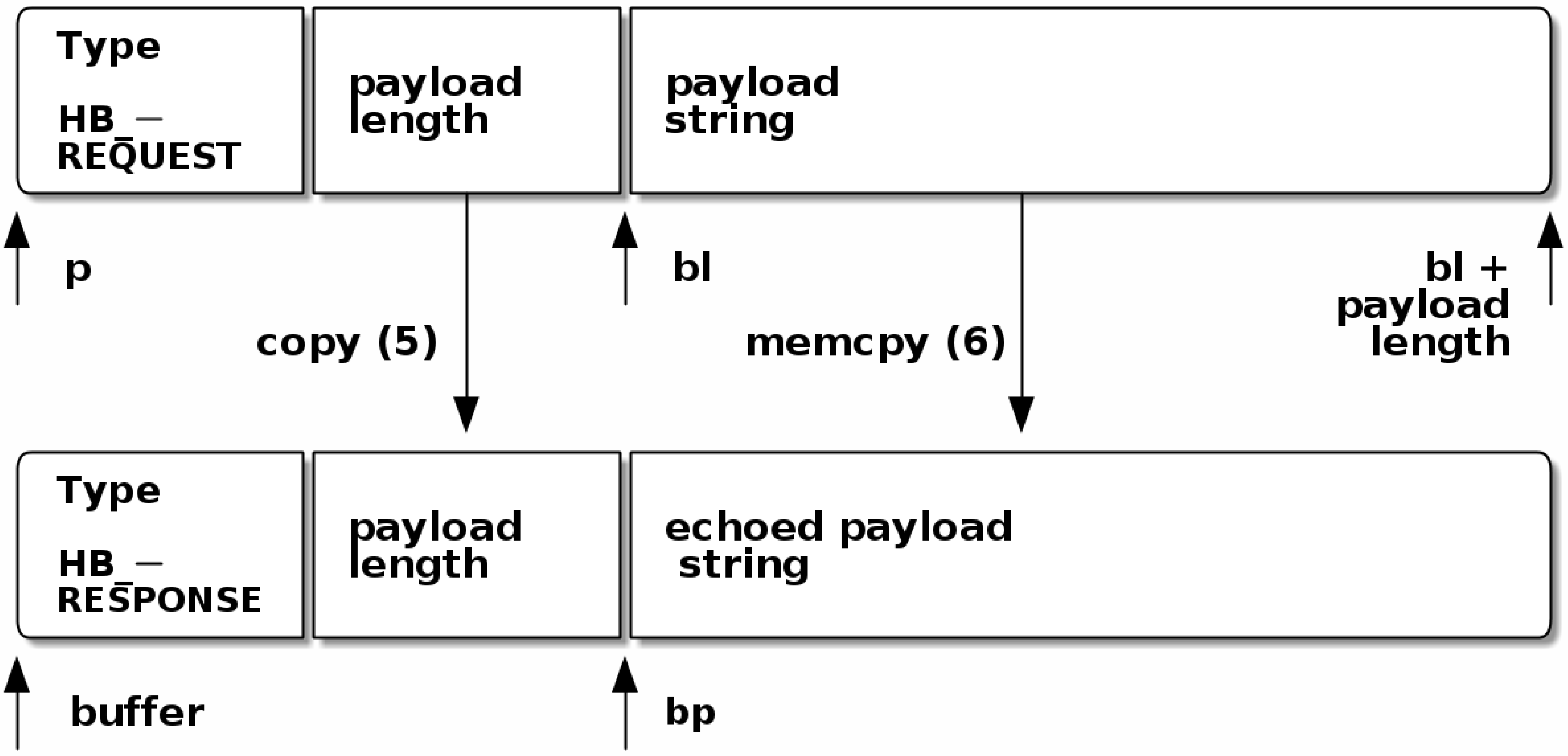
CWE ID	Name
120	Buffer Copy without Checking Size of Input
125	Out-of-bounds Read
126	Buffer Over-read
122	Heap-based Buffer Overflow
401	Memory Leak

THE HEARTBEAT TLS EXTENSION 1



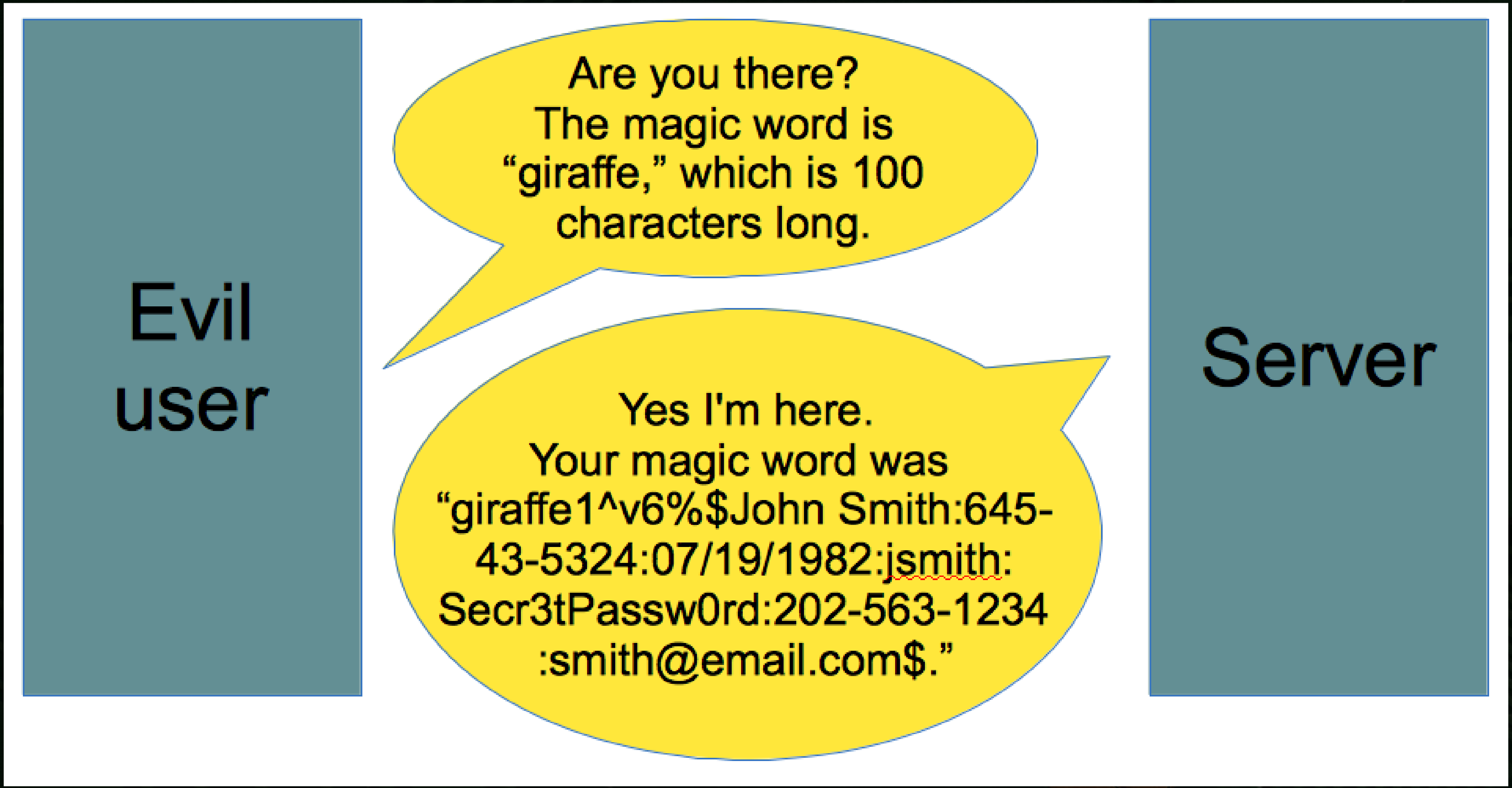
TLS Heartbeat protocol

THE HEARTBEAT TLS EXTENSION 2



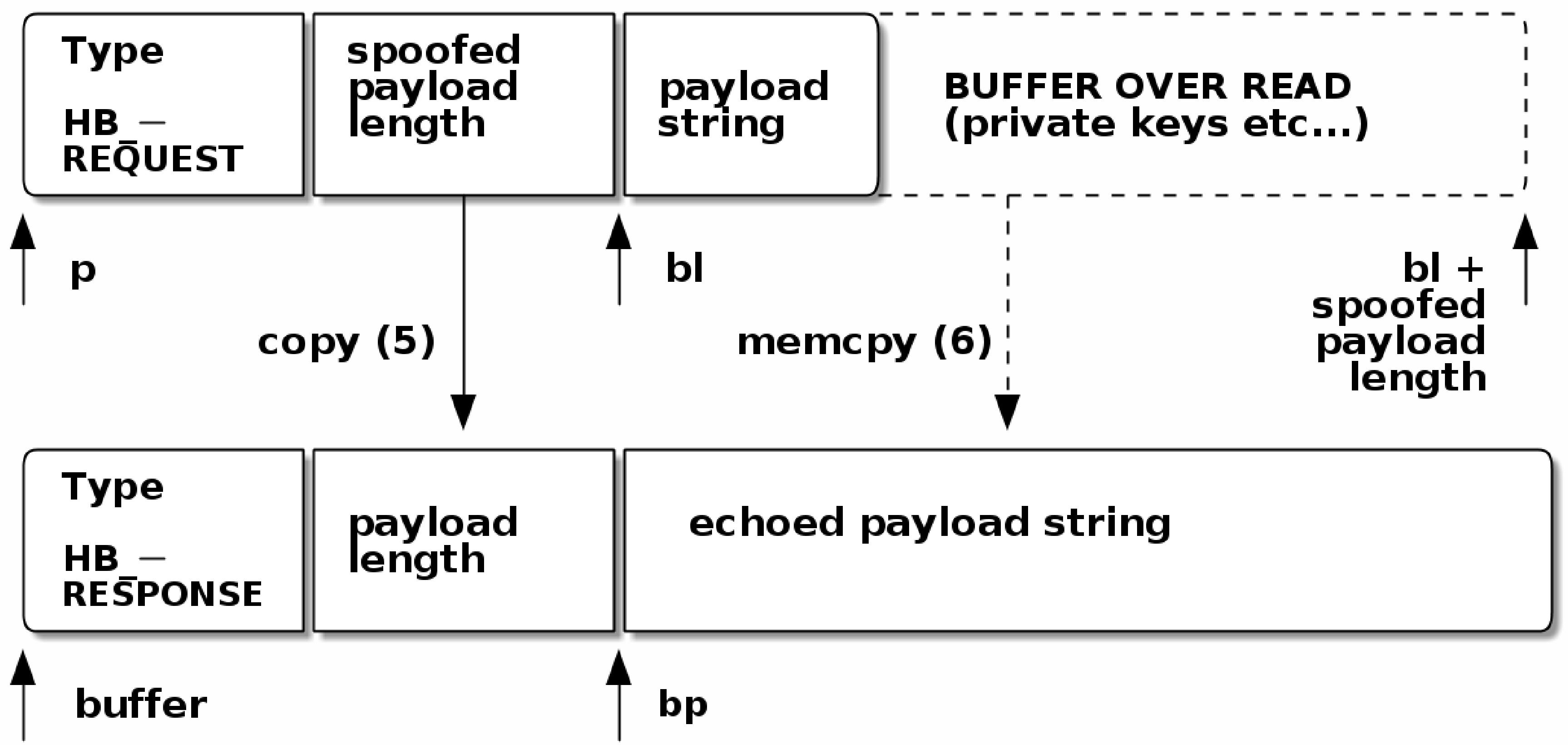
TLS Heartbeat protocol

THE HEARTBLEED VULNERABILITY 1



Heartbleed vunerability

THE HEARTBLEED VULNERABILITY 2



VULNERABLE C CODE

```c
unsigned char *p = &s->s3->rrec.data[0], *pl;
unsigned short hbtype;
unsigned int payload;
unsigned int padding = 16;

hbtype = *p++;      //<1>
n2s(p, payload);    //<2>
pl = p;

//... folded lines ...

if (hbtype == TLS1_HB_REQUEST)
        {
        unsigned char *buffer, *bp;
        Cint r;

        buffer = OPENSSL_malloc(1 + 2 + payload + padding); //<3>
```

THE RUST PROGRAMMING LANGUAGE

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FEATURES

- guaranteed memory safety
- zero-cost abstractions
- threads without data races

References: Firefox 57, Maidsafe, Parity-Bitcoin-Client

COULD HEARTBLEED HAVE HAPPENED WITH RUST?

```
fn tls1_process_heartbeat (s: Ssl) -> Result<(), isize> {
  const PADDING: usize = 16;

  let p = s.s3.rrec;
  let hbtype:u8 = p[0];
  let payload:usize = ((p[1] as usize) << 8) + p[2] as usize; // <1>

  let mut buffer: Vec<u8> = Vec::with_capacity(1+2+payload+PADDING);
  buffer.push(TLS1_HB_RESPONSE);
  buffer.extend(p[1..1+2].iter().cloned());                    // <2>
  buffer.extend(p[3..3+payload].iter().cloned());              // <3>

  let mut rng = rand::thread_rng();                            // <4>
  buffer.extend( (0..PADDING).map(|_|rng.gen::<u8>())
        .collect::<Vec<u8>>() );
```

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HEARTBLEED EXPLOIT PACKAGE

```
let s: Ssl = Ssl {
    s3 : Rrec{
            rrec:  &[TLS1_HB_REQUEST, 1, 1, 14, 15, 16, 17,
                     18, 19, 20, 21, 22, 23, 24, 25, 26, 27,
                     28, 29, 30, 31, 32]
    }
};
tls1_process_heartbeat(s).unwrap();
}
```

SYSTEM RESPONSE AFTER HEARTBLEED ATTACK

```
thread '<main>' panicked at 'assertion failed:
index.end <= self.len()',
Process didn't exit successfully:
`target/release/heartbeat` (exit code: 101)
```

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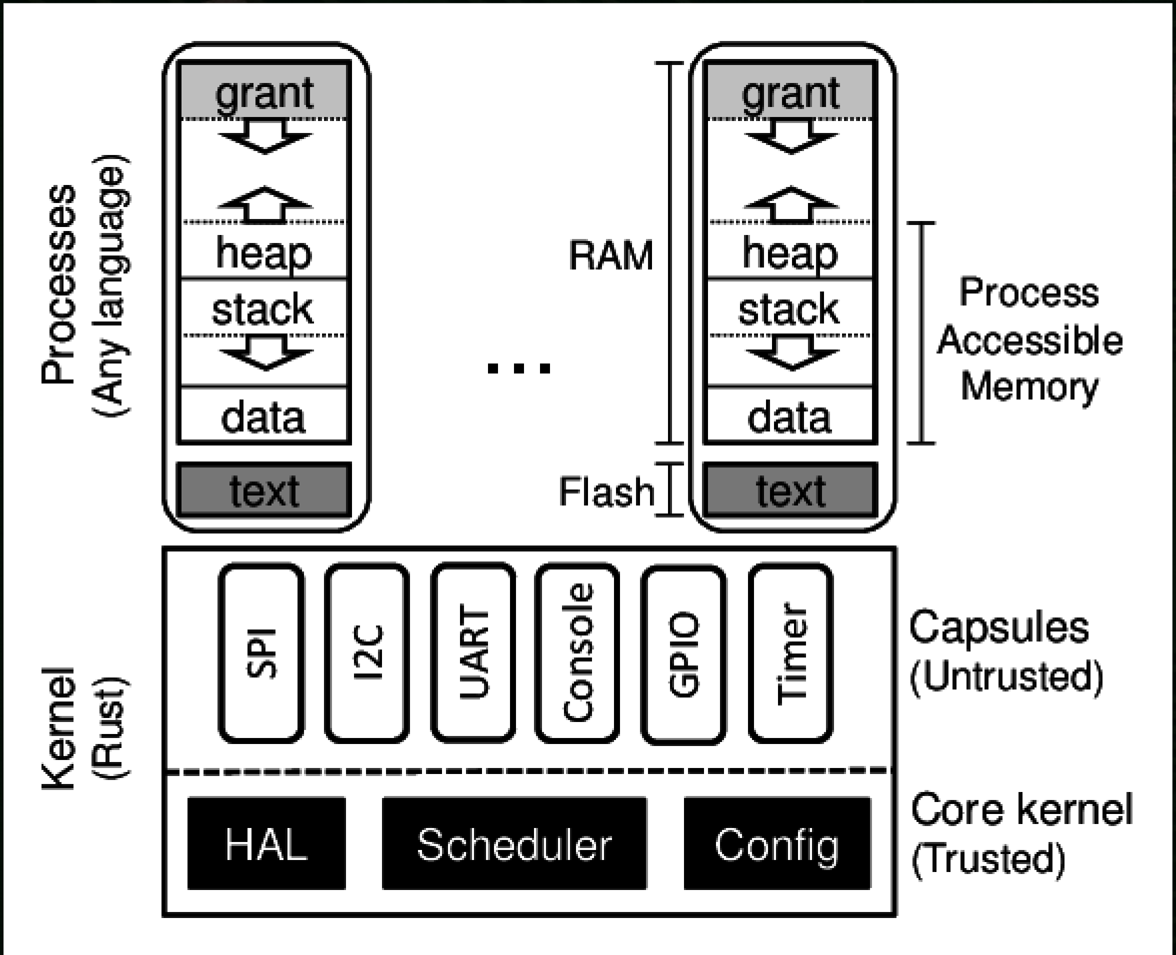
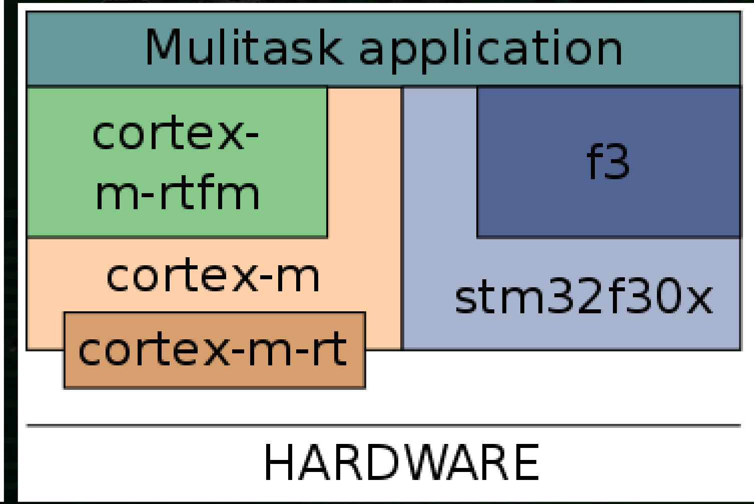
RESOURCE SHARING IN RUST

Resource sharing type	Aliasing	Mutation	Example
move ownership	no	yes	`let a = b`
shared borrow	yes	no	`let a = &b`
mutable borrow	no	yes	`let a = &mut b;`

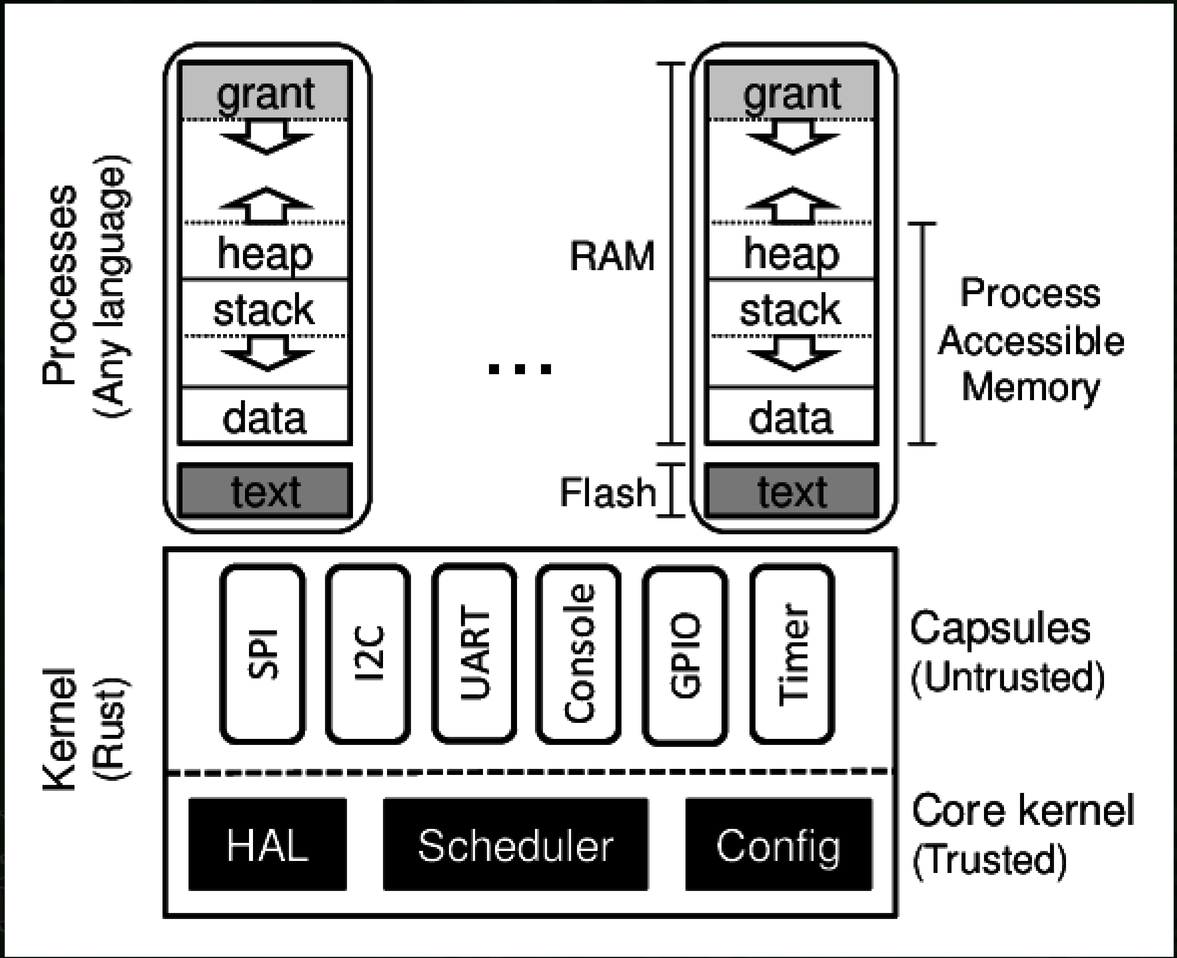
RUST OPERATING SYSTEMS





TockOS versus RTFM

TOCK-OS



TockOS architecture

TOCK-OS PRIMITIVES

```
struct App {
    count: u32,
    tx_callback: Callback,
    rx_callback: Callback,
    app_read: Option<AppSlice<Shared,u8>>,
    app_write: Option<AppSlice<Shared,u8>>,
}
pub struct Driver {
    app: TakeCell<App>,
}

new_app () {
    ...
    driver.app.map(|app| {app.count = app.count + 1});
}
```

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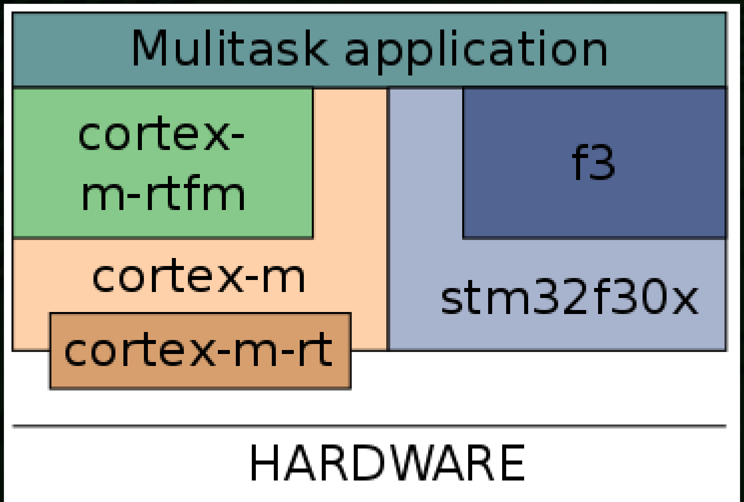
REAL TIME FOR THE MASSES



RTFM architecture

RTFM PRIMITIVES

```
threshold.raise(
    &SHARED, |threshold| {
        let shared = SHARED.access(priority, threshold);
        shared.mode.set(Mode::Bounce)
    }
);
```

RUST IN EMBEDDED SYSTEMS

Challenges

- secure concurrency
  - (lightweight) threads
  - interrupt driven
- “zero zero” cost abstractions
- yet only few drivers available
- yet only few platforms are supported
- no `std`-library

CONCLUSION AND RECOMMENDATION

LIMITATIONS

Rust for Resource Constrained Devices:
Technology is mature, ready for production.

- only few drivers are available
- only few platforms are supported

Doable, typical amount of lines of code 10k
(vs Linux Kernel 4.14: 25 Mio lines)

OPPORTUNITIES

Rust eradicates memory safety related vulnerabilities, improves systematically the security of

- field sensors
- *consumer IoT*

Contribute to **F**ree and **O**pen **S**ource **S**oftware.

THANK YOU!

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REFERENCES

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