Extending Rust with Support for Zero Copy Communication

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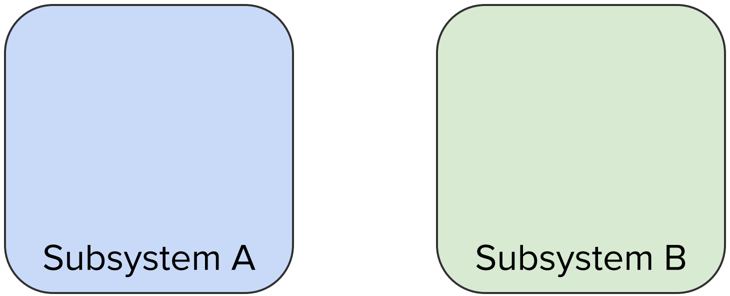
Language-Based Isolation



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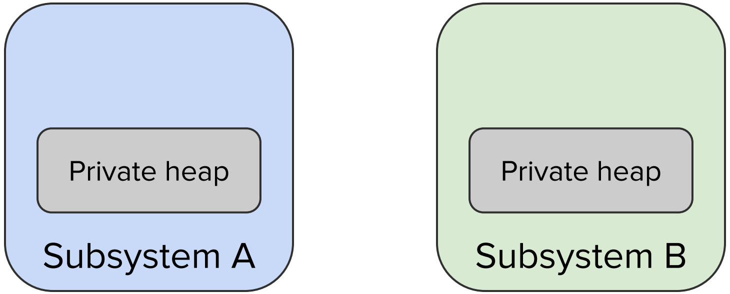

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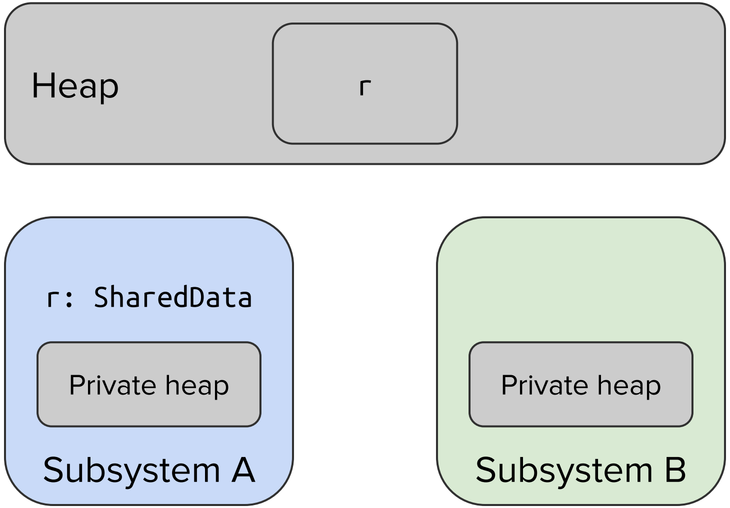

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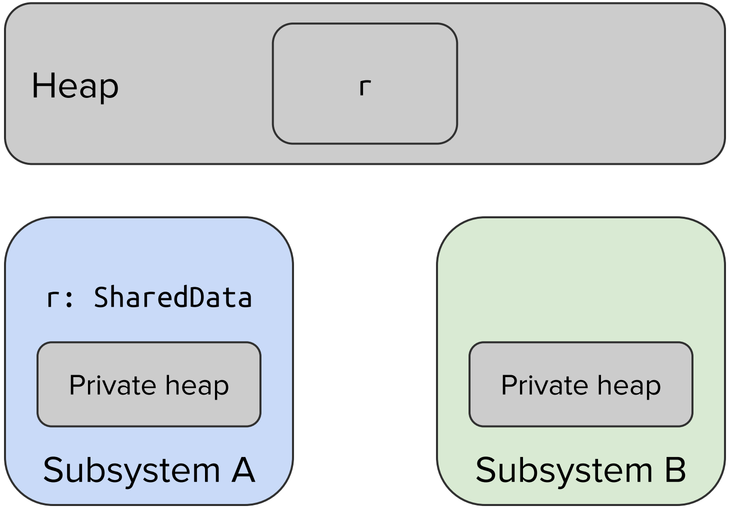
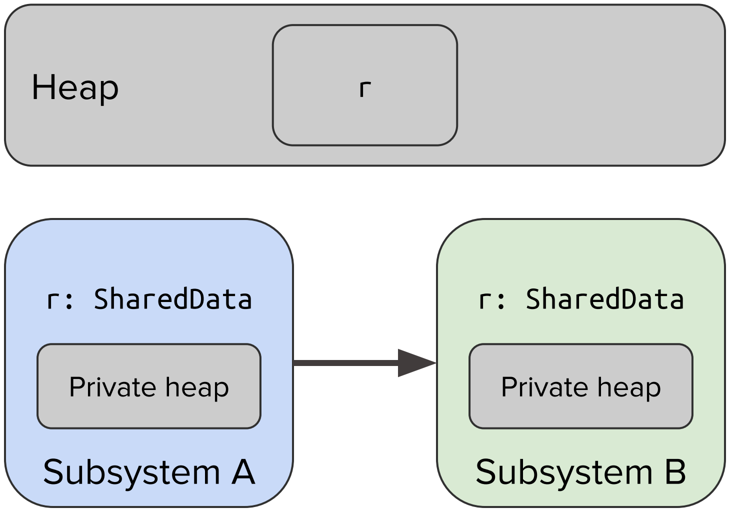


Language-enforced access control

Language-Based Isolation



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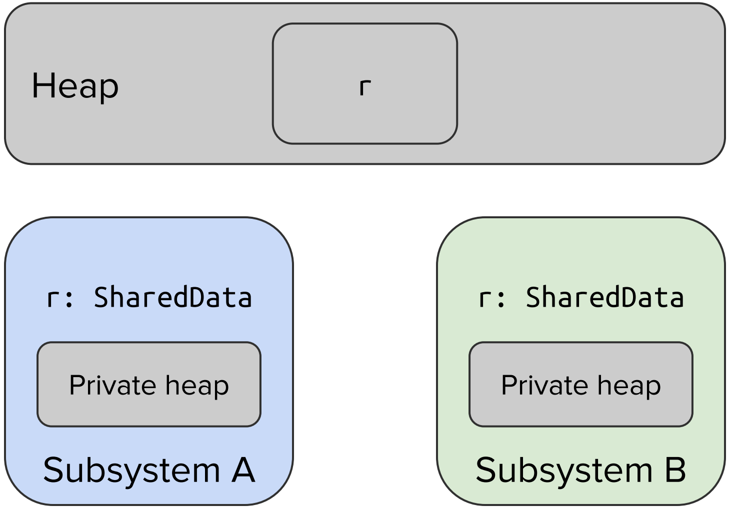

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Zero copy communication

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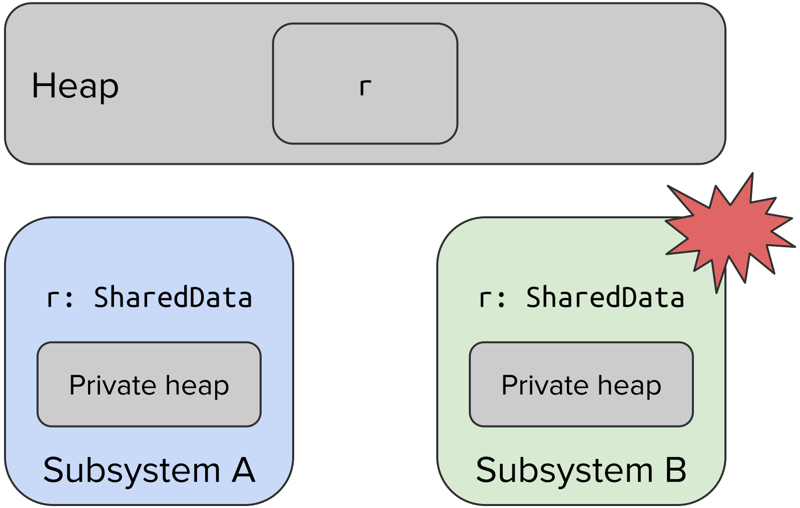

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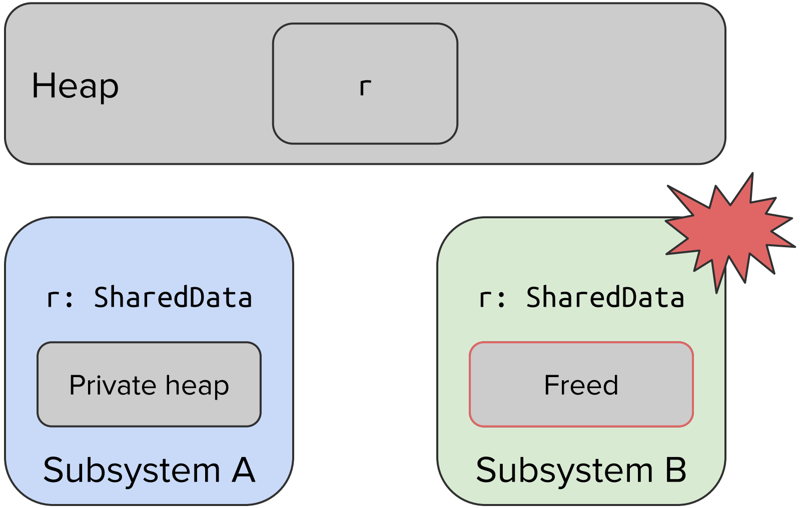

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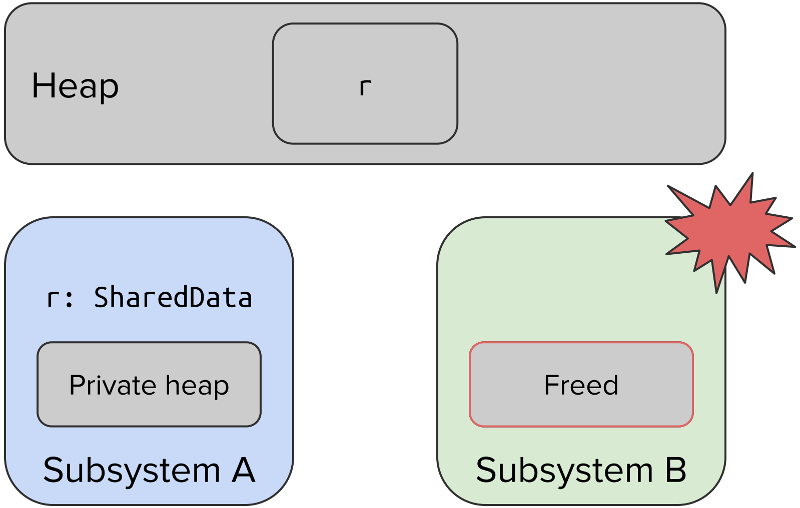
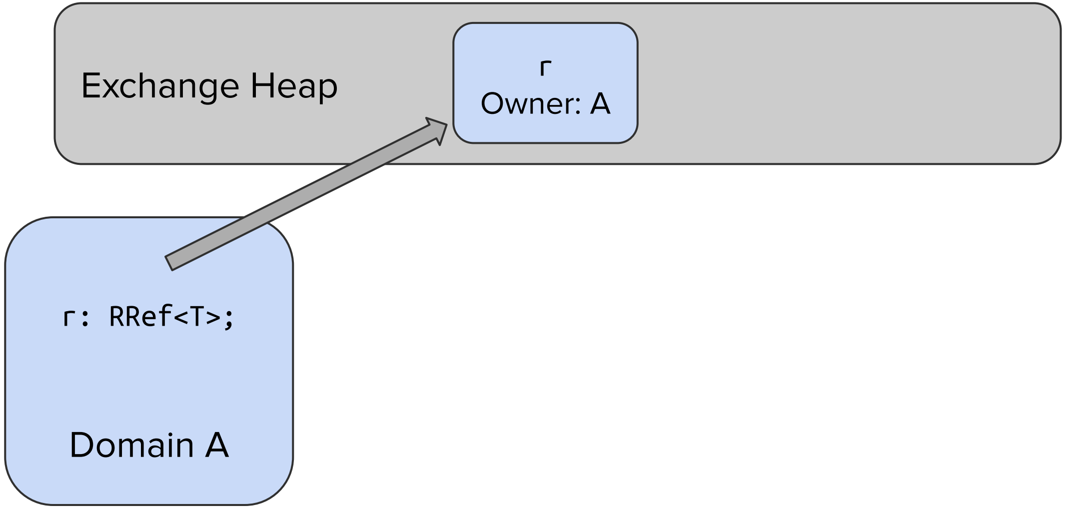


Language-enforced access control

Zero copy communication

RedLeaf



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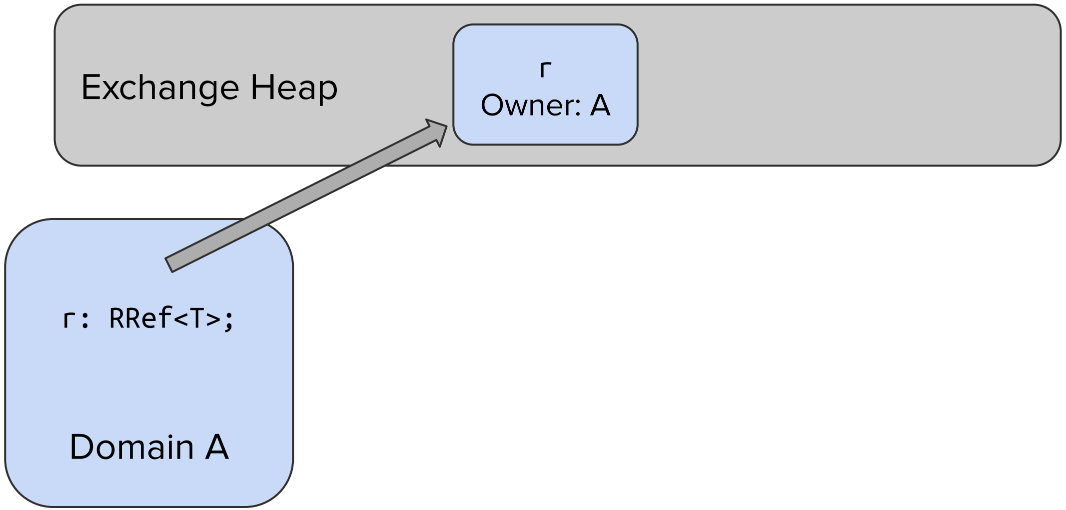
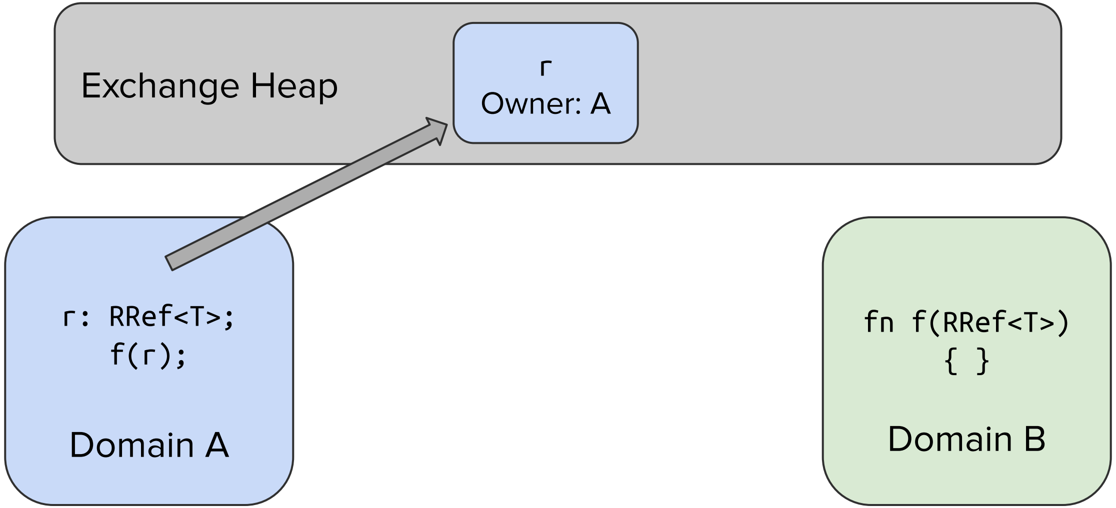


RRef: Single ownership shared data

RedLeaf



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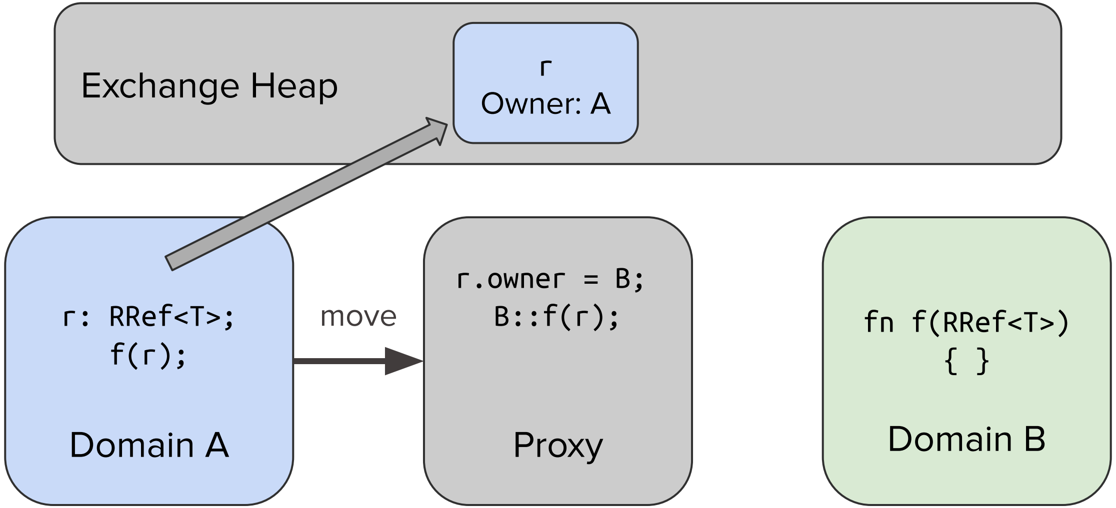

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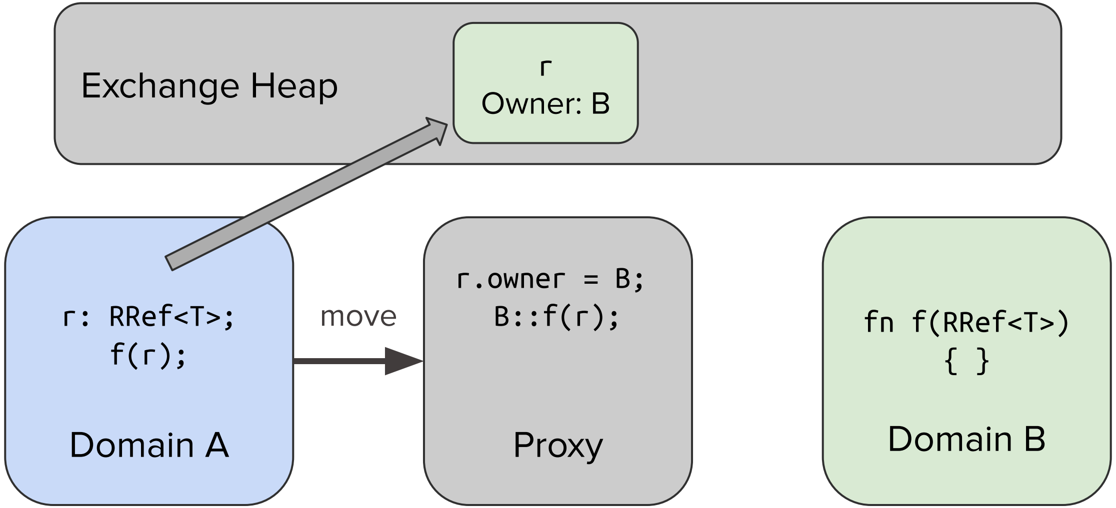

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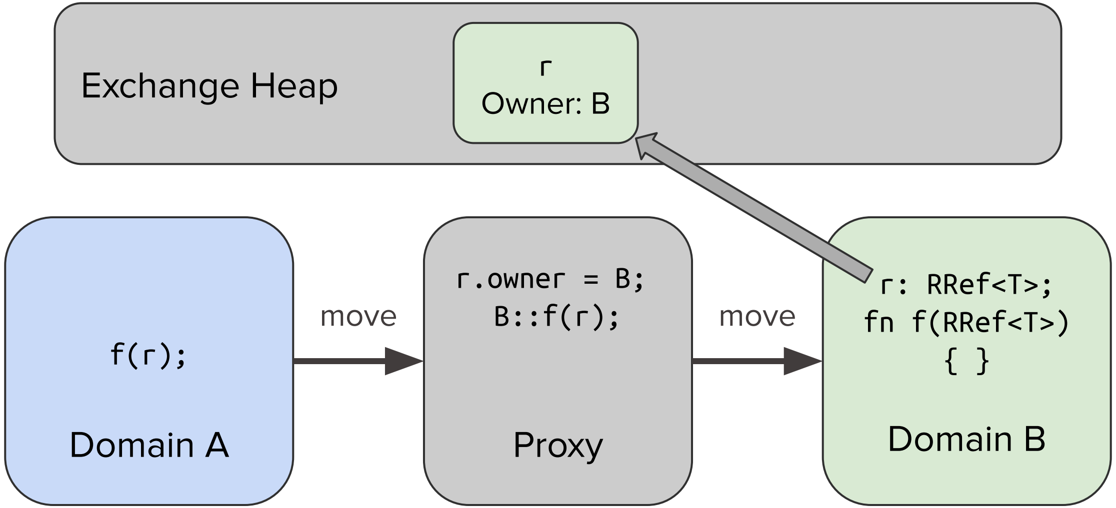

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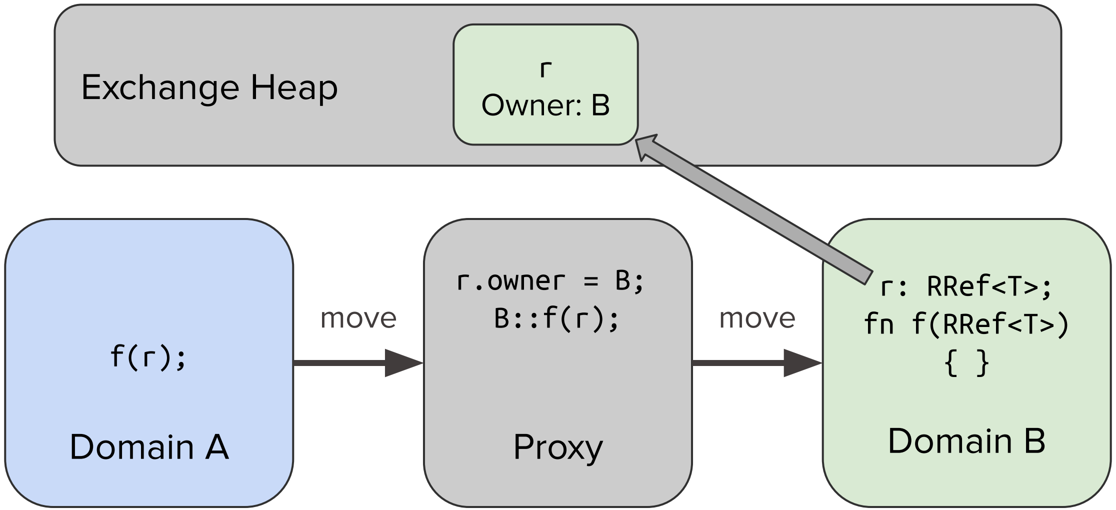
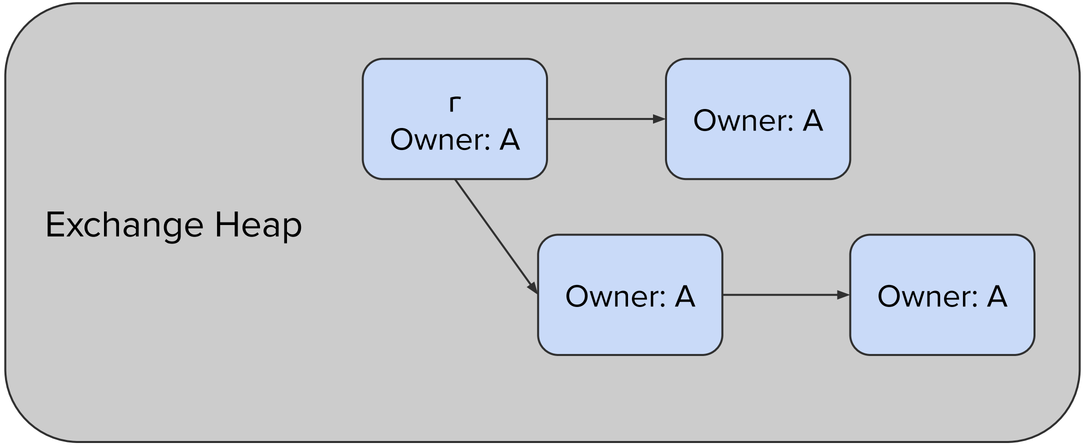


RRef: Single ownership shared data

Ownership update upon IPC

Nested RRefs



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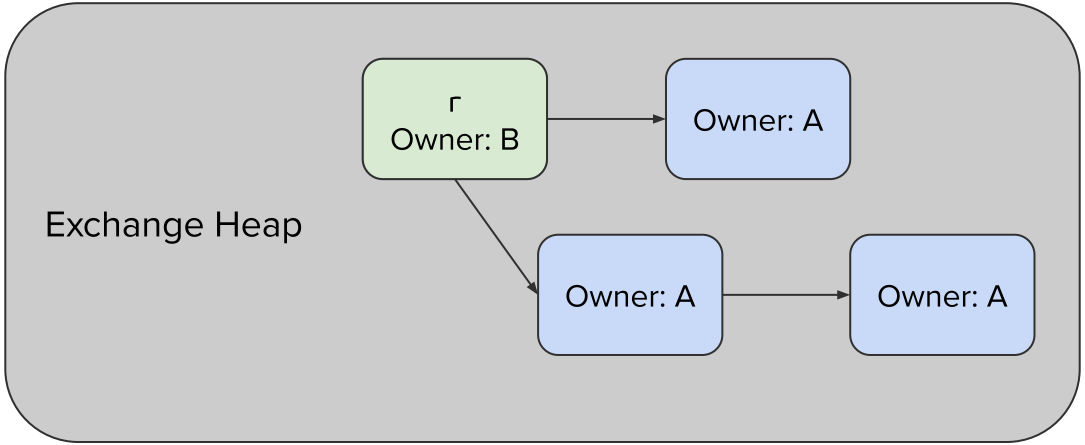

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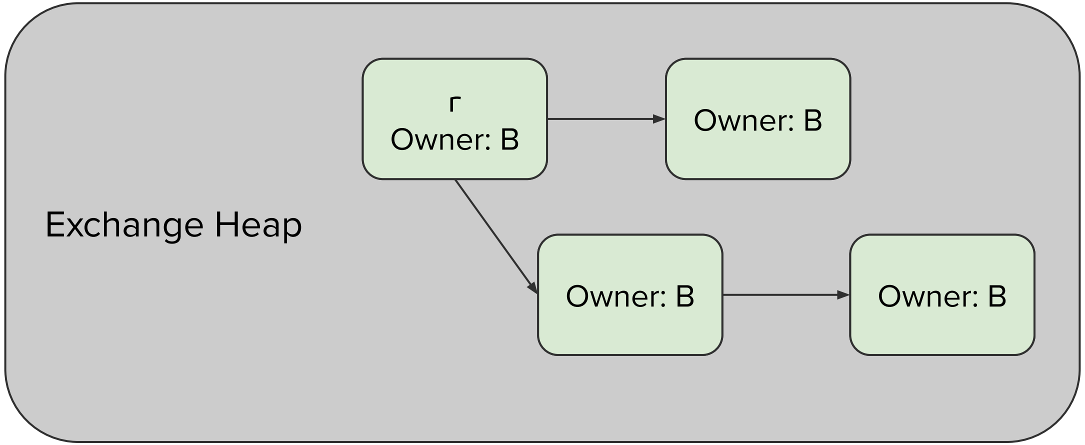
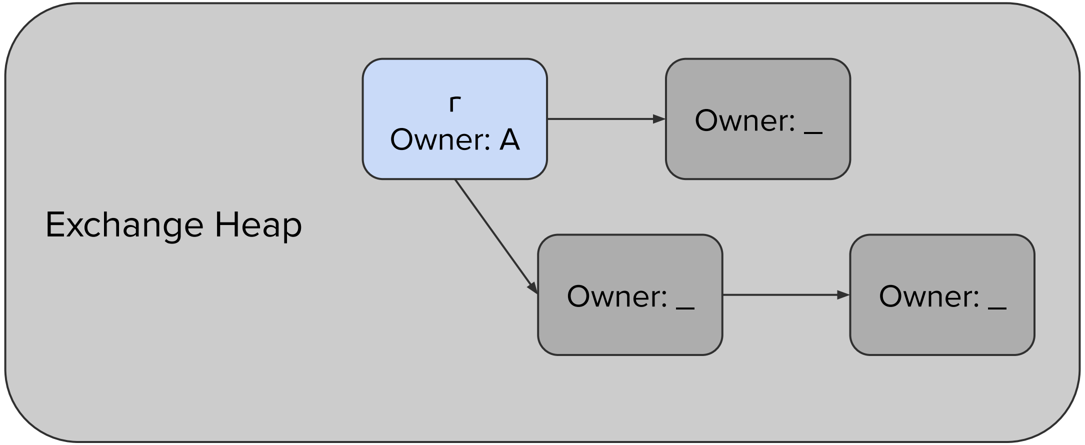


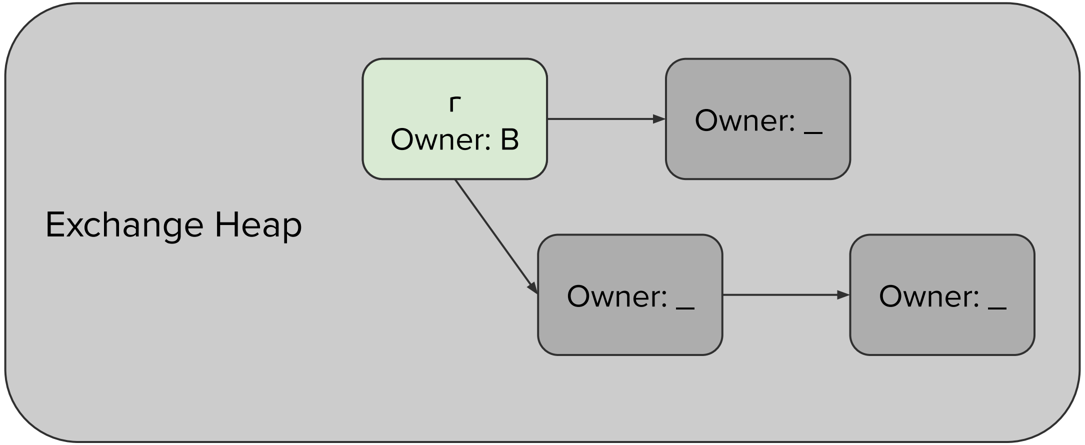
Costly ownership updates

Nested RRefs



Better idea: Track ownership at **roots** only

Nested RRefs



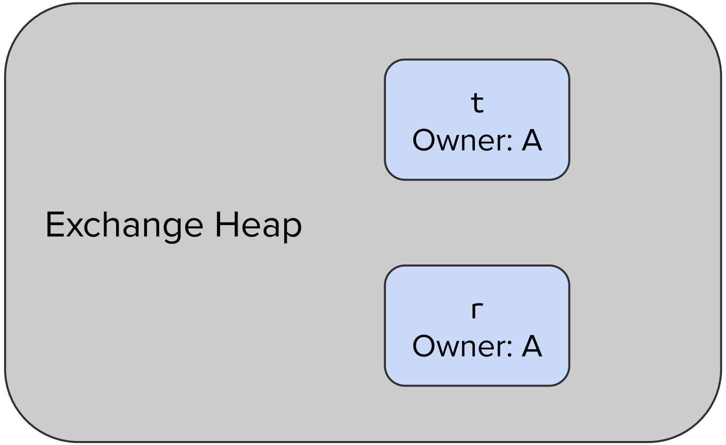
Better idea: Track ownership at **roots** only

Problem: Maintaining “Bottomness”

```
struct T {
    r: RRef<i32>,
}

fn move_in(mut t: RRef<T>) {
    let r = RRef::new(1);


}
```



Problem: Maintaining "Bottomness"

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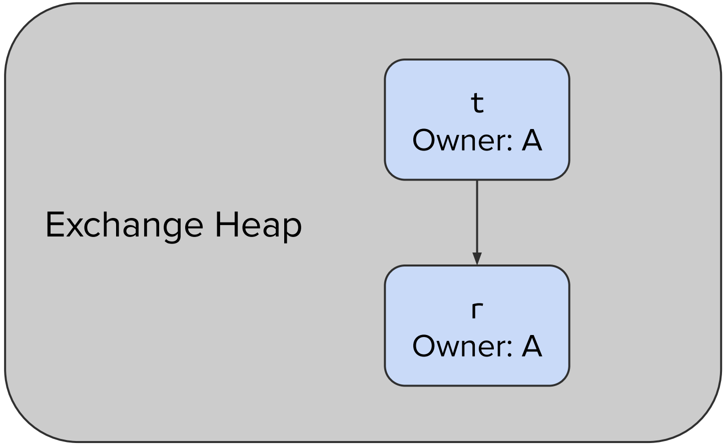

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struct T {
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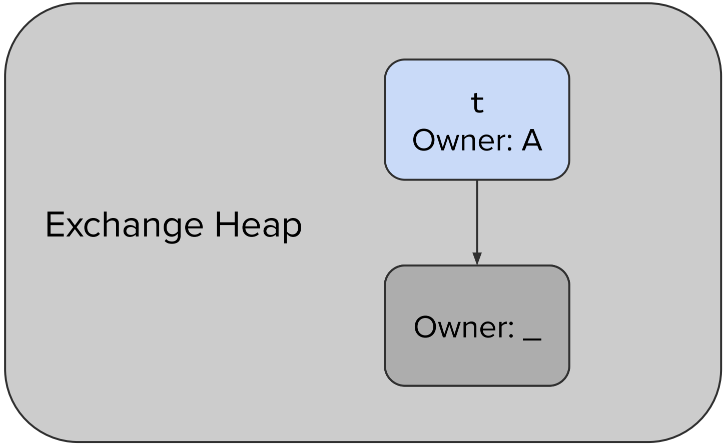
fn move_in(mut t: RRef<T>) {
    let r = RRef::new(1);
    t.r = r;
    mark_bottom(&mut t.r);
}
```



Assignment Analysis

Static analysis: Did nesting change?

```
t.r = r;
mark_bottom(&mut t.r);
```

Codegen: Update ownership

Composite Types

```
struct T {
    r: RRef<E>,
}

enum E {
    Zero,
    One(RRef<i32>),
    Two(RRef<i32>, RRef<i32>),
}
```

```
fn move_in(mut t: RRef<T>, r: RRef<E>) {
    t.r = r;







}
```

Composite Types

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struct T {
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```

```
fn move_in(mut t: RRef<T>, r: RRef<E>) {
    t.r = r;
    match t.r {
        E::One(ref mut r) => mark_bottom(r),




    }
}
```

Composite Types

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struct T {
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```
fn move_in(mut t: RRef<T>, r: RRef<E>) {
    t.r = r;
    match t.r {
        E::One(ref mut r) => mark_bottom(r),
        E::Two(ref mut r1, ref mut r2) => {
            mark_bottom(r1);
            mark_bottom(r2);
        },

    }
}
```

Composite Types

```
struct T {
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}

enum E {
    Zero,
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fn move_in(mut t: RRef<T>, r: RRef<E>) {
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    match t.r {
        E::One(ref mut r) => mark_bottom(r),
        E::Two(ref mut r1, ref mut r2) => {
            mark_bottom(r1);
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        },
        _ => {},
    }
}
```

Dynamic decision making

Mutable Borrows

```
struct T {
    r: RRef<i32>,
}

fn move_in(mut rt: RRef<T>) {
    let t = &mut *rt;



}
```

Borrow **from** RRef

Mutable Borrows

```
struct T {
   r: RRef<i32>,
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fn move_in(mut rt: RRef<T>) {
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Borrow **from** RRef

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struct T {
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fn move_in(mut t: T) {
    let t = &mut t;
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Borrow **without** RRef

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Borrow **from** RRef

```
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fn move_in(mut t: T) {
    let t = &mut t;
    let r = RRef::new(1);
    t.r = r;
    // no need to mark bottom
}
```

Borrow **without** RRef

Analysis loses **locality**

Interprocedural Analysis

```
struct T {
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fn move_in(t: &mut T) {
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Interprocedural Analysis

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RRef moved into
t @ t.r

```rust
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Crash Cleanup Safety

```
t.r = r;
mark_bottom(&mut t.r);
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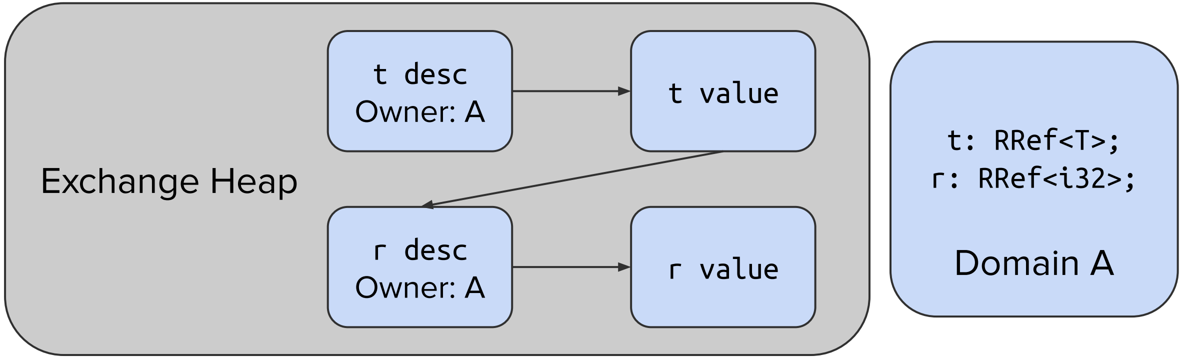
Crash Cleanup Safety

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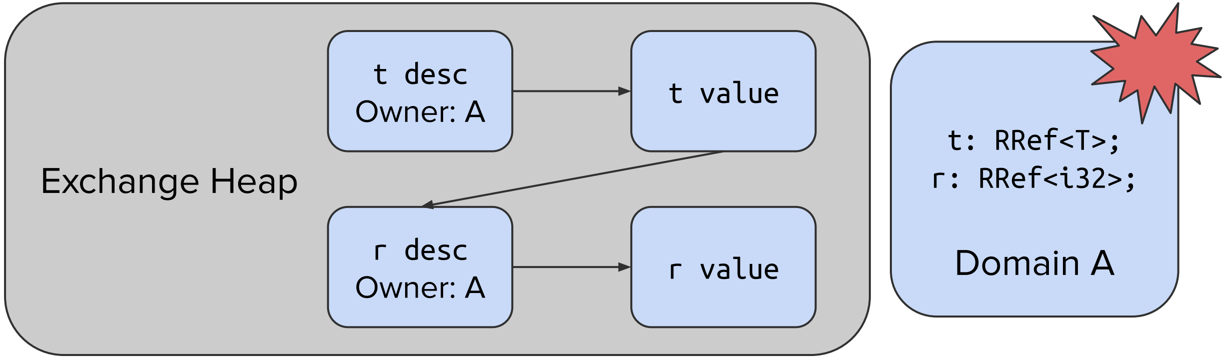


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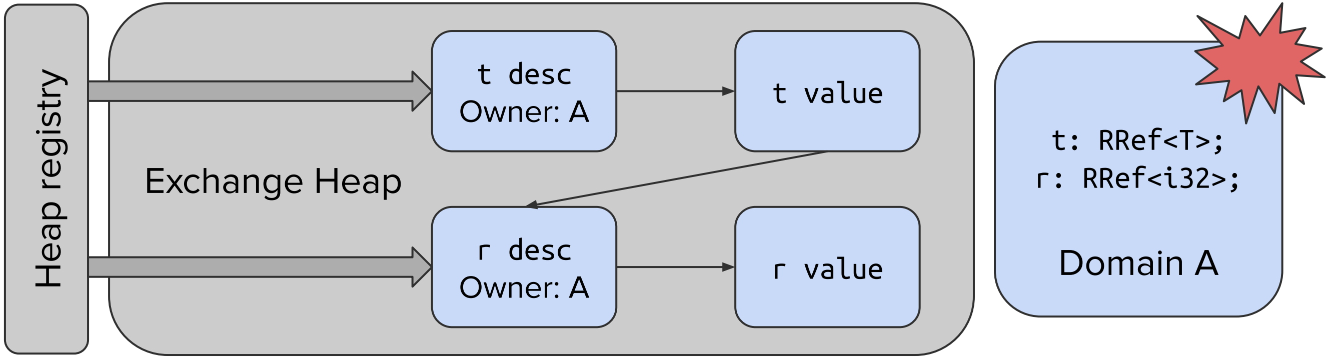


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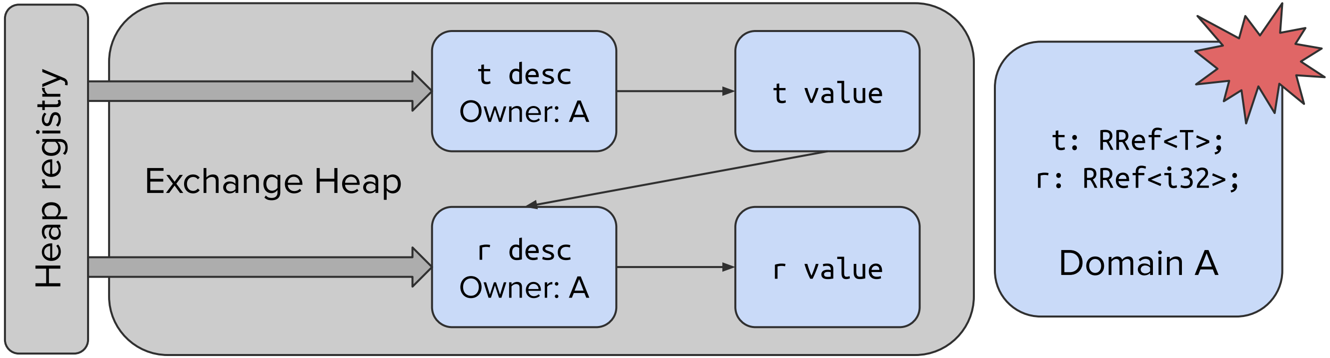


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t.r = r;
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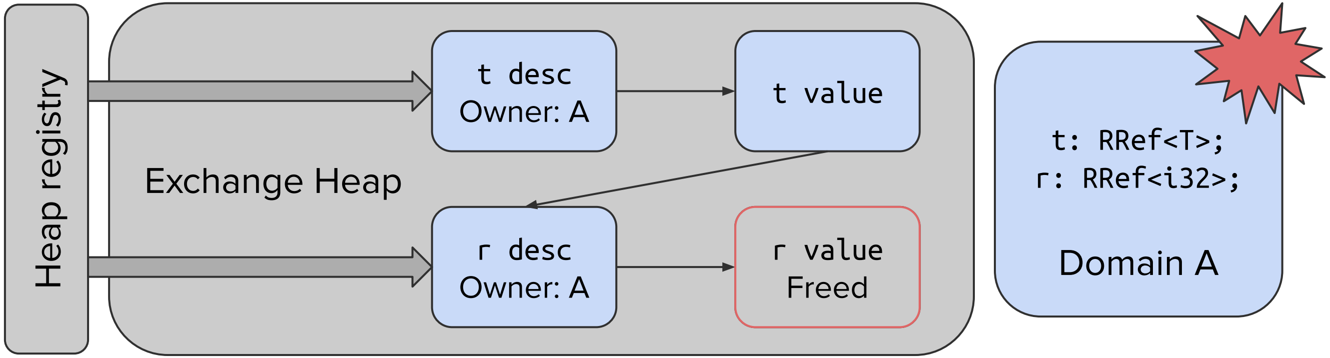
Two pass cleanup

Crash Cleanup Safety




```
t.r = r;
mark_bottom(&mut t.r);
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Two pass cleanup

Crash Cleanup Safety: Selective Drop

```rust
impl<T> Drop for RRefDesc<T> {
    fn drop(&mut self) {
        if !crashed() || self.is_bottom() {
            self.reclaim_and_drop_value();
        }
    }
}
```

Crash Cleanup Safety: Selective Drop

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impl<T> Drop for RRefDesc<T> {
    fn drop(&mut self) {
        if !crashed() || self.is_bottom() {
            self.reclaim_and_drop_value();
        }
    }
}
```

`!crashed()`

False

Crash Cleanup Safety: Selective Drop

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        if !crashed() || self.is_bottom() {
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        }
    }
}
```

`!crashed()`

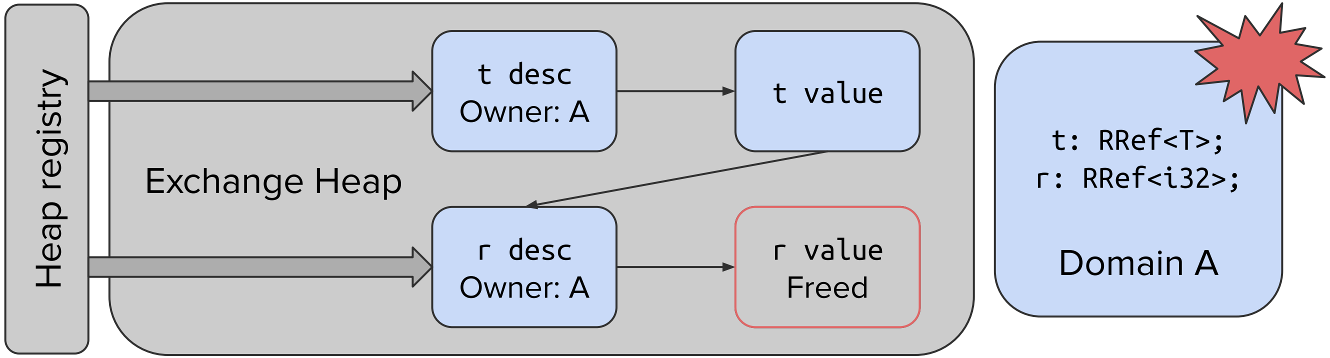
False

`self.is_bottom()`

False

No double free

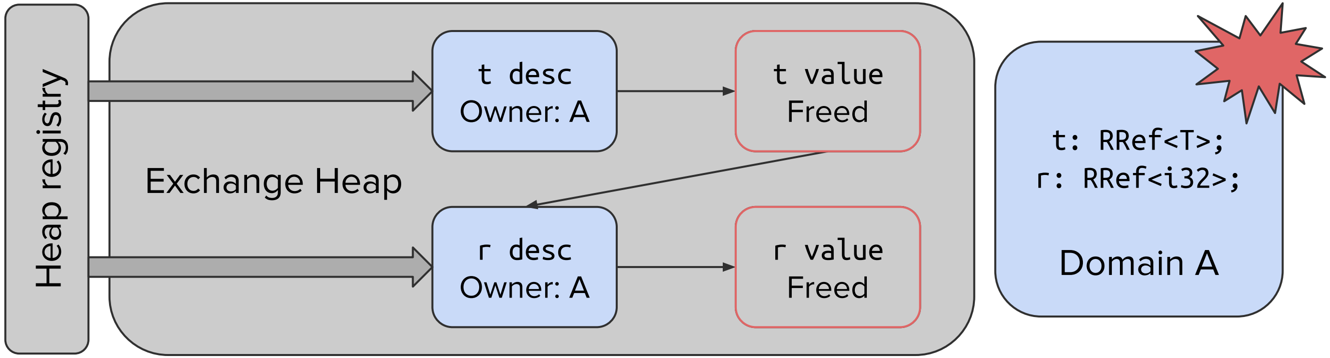
Crash Cleanup Safety



Two pass cleanup

Selective drop

Crash Cleanup Safety



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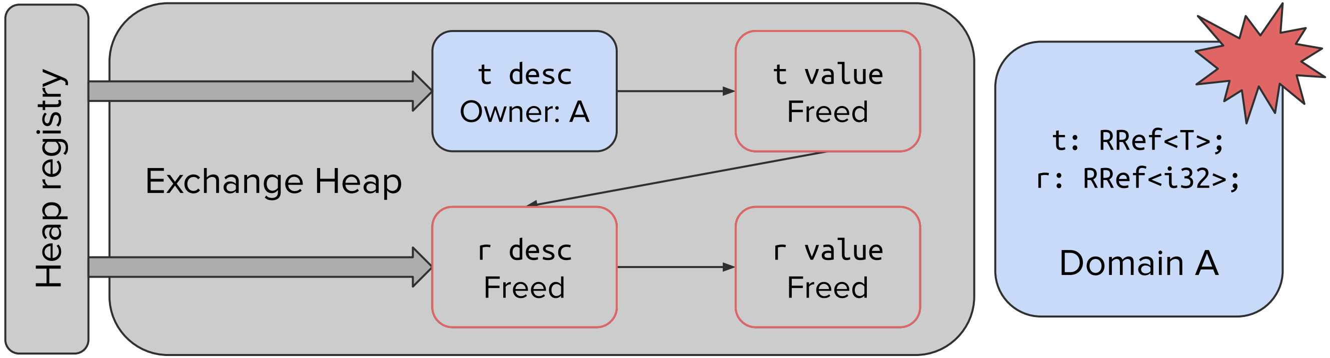

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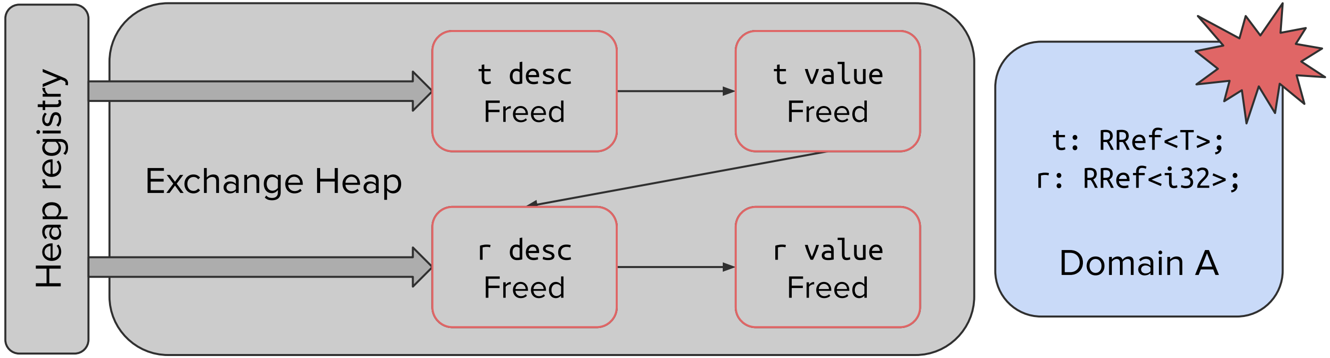
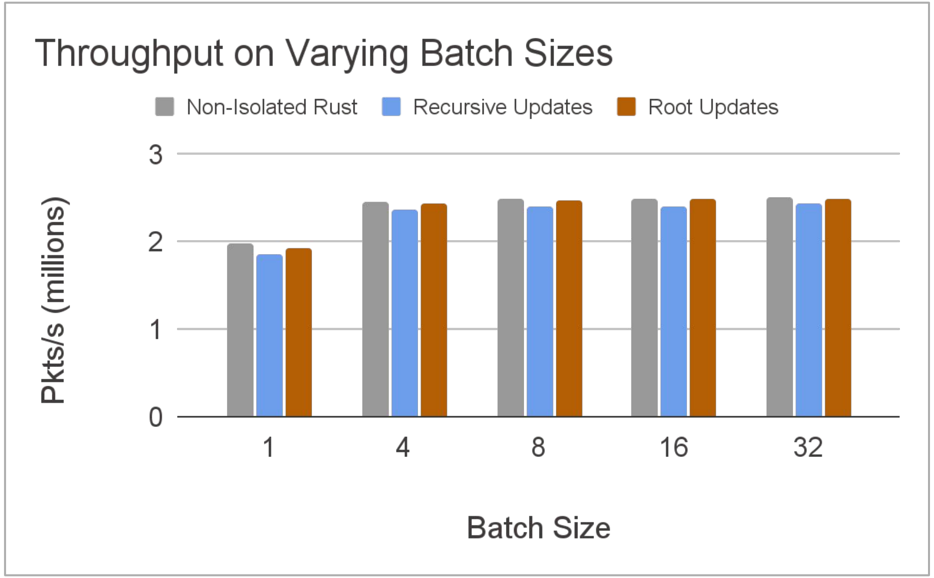


Two pass cleanup

Selective drop

Evaluation: Network Functions

- Relative to normal Rust, compare:
  - Linear updates (naive)
  - Root updates (our analysis)
- Naive proxy: **4%** overhead
- Our analysis: **1%** overhead



Conclusion

Zero copy communication in language-based isolation

enabled by

Static analysis to ensure correct nested data ownership

Thank You!