Distributed Actor System in Rust

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About me

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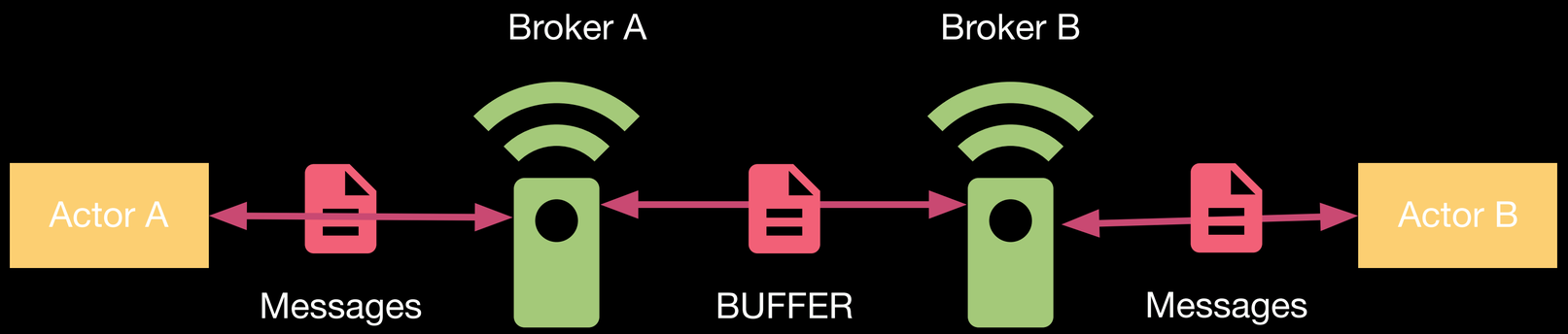
This talk is *not* about

- Details of full featured actor system
- Comparison with other popular actor systems (*Actix*, etc.)
- Feature introduction of any crate

This talk is about

- How to solve common problems when building an actor system in Rust
  - Compilation-stable type id
  - Proc macros
  - Specialization
  - *Tick*-Based actor system



The Type-id Problem

The Type-id Problem

- Messages need to be encoded into buffers (`Vec<u8>`) so they could be transferred in a network
- How could a receiver actor recover the type information of a message?

Give each message payload type a *Type Id*

```rust
pub struct Message {
    /// Indicating the type of payload
    pub type_uid: TypeId,
    /// The receiver's address info
    pub recv: RawId,
    /// Payload is encoded into a buffer (type erased)
    pub payload: Vec<u8>
}
```

Trait std::any::Any

1.0.0 [−][src]

[+] Show declaration

[−] A type to emulate dynamic typing.

Most types implement `Any`. However, any type which contains a non-`'static` reference does not. See the module-level documentation for more details.

Required methods

-] `fn get_type_id(&self) -> TypeId`

└ ▶  This is a nightly-only experimental API. (`get_type_id` #27745)

Gets the `TypeId` of `self`.

Type id

- Type ID needs to be stable across the network, or it could lead to decoding error
- We could not use std::any::TypeId
  - It generates different type ids with each compilation
  - Network could be running software from different compilations

Proc Macro to the Rescue

- Get the ident of target struct payload
- Save the ident + id combo to a local file
- Read the file on next compilation to recover the type id

```rust
pub trait UniqueTypeId {
    fn type_uid() -> TypeId;
}
```

```rust
pub struct TypeId {
    pub t: u64
}
```

```rust
#[derive(UniqueTypeId)]
pub struct StartTaskRequest {
    pub task_id: u64,
    pub sender: Option<RawId>
}
```

The payload struct we need to assign a unique type id to

```rust
quote::quote! {
    impl #impl_generics UniqueTypeId for #ident #ty_generics #where_clause {
        fn type_uid() -> TypeId {
            let mut t = #id;
            TypeId { t }
        }
    }
}
```

Load id from local file

types.toml

```
18  ResetTaskRequest=17
19  StartTaskRequest=18
20  PluginDeployRequest=19
21  ClusterPluginsInfo=20
22  ClusterTaskStatus=21
23  ResourceConfigUpdate=22
24  TaskStatus=23
```

Type Id

- Once we get a stable type id, we could use it to erase / recover type information for networking
  - T ———(serialization)——— Vec<u8>
  - &[u8] ——— (Type Id matching deserialization) ——— T

This is more or less similar to *Reflection* in Java

```rust
if message.type_id == PayloadA::type_id() {
    let payload_a = PayloadA::deserialize(&message.payload);
    // Handle this message ...
} else if message.type_id == PayloadB::type_id() {
    let payload_b = PayloadB::deserialize(&message.payload);
    // Handle this message...
} else {
    // More possibilities
}
```

You still need to match against all types !

Solve it with proc macros (again…)

```rust
pub trait Actor: ActorLifecycle + Any {
    /// Return current actor's id
    fn id(&self) -> &RawId;
    /// Return a mutable ref of current actor's id
    fn id_mut(&mut self) -> &mut RawId;
    /// All-in-one handler for messages
    fn handle_message(&mut self, message: &Message);
}
```

```rust
#[derive(Actor)]
struct SampleActor {
    id: RawId
}
```

```rust
impl #impl_generics Actor for #name #ty_generics #where_clause {
    fn id(&self) -> &RawId {
        &self.id
    }
    fn id_mut(&mut self) -> &mut RawId {
        &mut self.id
    }
    fn handle_message(&mut self, m: &Message) {
        handle_message!(self, m #(, #ident_msg_types )*)
    }
}
```

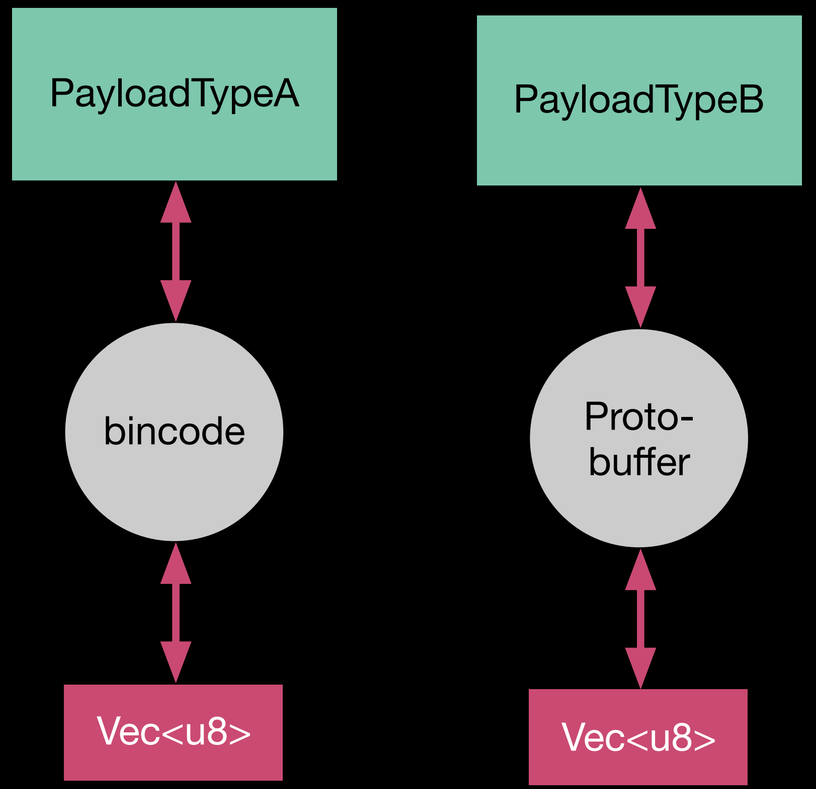
Need declarations of message types

```rust
#[macro_export]
macro_rules! handle_message {
    ($type: expr, $raw_msg: expr $(, $msg_type: ty)*) => {
        match &$raw_msg.type_uid {
            $(
                x if *x == <$msg_type>::type_uid() => {
                    let payload = $raw_msg.payload::<$msg_type>().unwrap();
                    if let Err(e) = Handler::<$msg_type>::handle($type, payload) {
                        log::error!("Failed to handle message: {}", e);
                    }
                }
            )*
            _ => {}
        }
    };
}
```

```rust
#[derive(Actor)]
#[Messages(PayloadA, PayloadB)]
struct SampleActor {
    id: RawId
}

impl Handler<PayloadA> for SampleActor {
    fn handle(&mut self, message: &PayloadA) {}
}

impl Handler<PayloadB> for SampleActor {
    fn handle(&mut self, message: &PayloadB) {}
}
```

Using proc macros we get:

- A super clean, self-explaining actor design
- Separating actor declaration / private logic with message handling logic
- Hiding dangerous type casting behind the curtain
- Minimal runtime cost (only an integer comparison)



The Codec Problem

The Codec Problem

- Messages could use different codecs
- We are adopting a fast se/de crate: *abomonation* by Frank McSherry
  - Super fast, but quite unsafe
  - Do not support HashMaps
- We could use different codecs for different messages
  - Important ones with hash maps: Bincode
  - Small, not-so-important messages: Abomonation

Specialization (RFC #1210)

- Allows trait impls to overlap with each other
- Allows a *default* impl of a trait

Specialization

Serde se/de traits

```rust
/// Data that could be serialized / deserialized to add/erase type information,
/// wrapped in a [Message] and send around the cluster.
pub trait Payload: Clone + Serialize + DeserializeOwned + UniqueTypeId + 'static {
    /// Serialize payload into a buffer vector
    fn serialize(&self) -> IoResult<Vec<u8>>;
    /// Deserialize from a buffer slice, get a [Cow](std::borrow::Cow) value
    /// back
    fn deserialize(data: &[u8]) -> Result<Cow<'_, Self>, Error>;
    /// Return the serialize buffer size of this payload, this method do NOT
    /// do any serialization
    fn size(&self) -> IoResult<u64>;
}
```

Specialization

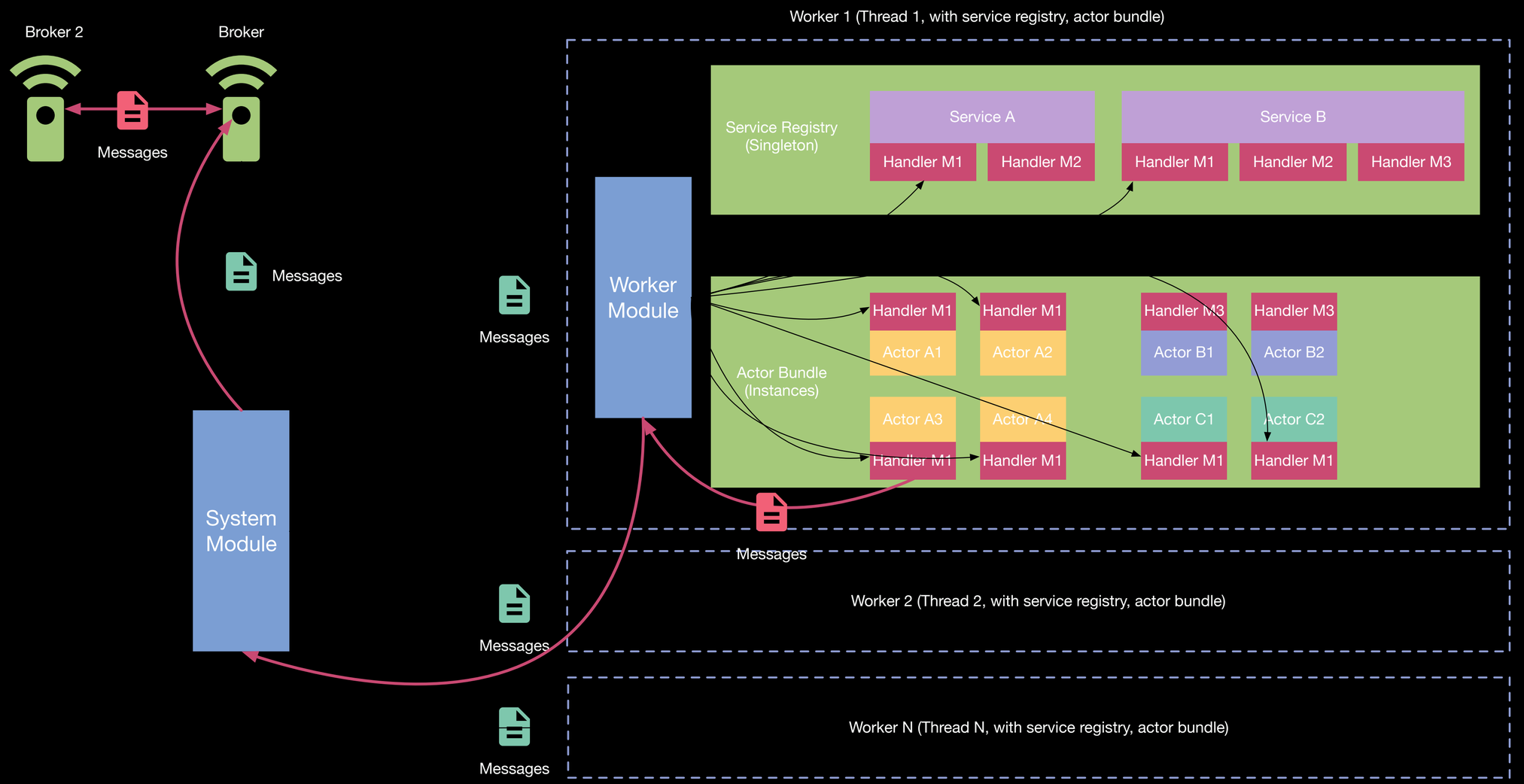
Default to serde/bincode

```
impl<T: Clone + Serialize + DeserializeOwned + UniqueTypeId + 'static> Payload for T {
    default fn serialize(&self) -> IoResult<Vec<u8>> {
        use std::error::Error;
        bincode::serialize(&self)
            .map_err(|err| std::io::Error::new(std::io::ErrorKind::InvalidInput, err.description()))
    }

    // Other impls
}
```

```
impl<T: 'static + Abomonation + DeserializeOwned + Serialize + UniqueTypeId + Clone> Payload for T {
    fn serialize(&self) -> IoResult<Vec<u8>> {
        let mut result = vec![];
        unsafe { abomonation::encode(self, &mut result)? };
        Ok(result)
    }

    // other impls
}
```

Specialization

- Available on nightly
- #![feature(specialization)]



Tick-based actor system

Tick - Why?

- Tick is useful for many use cases
  - Game design (logics are executed per frame)
  - Dataflow / Stream computation
  - Easier logic / waiting / event hook

Future with ticks

- Block tick for specific message

```
pub struct WaitForOnce {
    deadline: u64,
    message_signature: MessageSignature
}
```

- Create a *Stream*, with each output, step tick forward by 1
  - Maintain a map of each tick’s waits
  - If all waits are resolved, return Poll::Ready(messages)

Feature with ticks

- Wait for response
  - By setting deadline = 1
- User-defined pre-fetching
  - By setting dynamic deadline based on current traffic

Distributed Actor System

- Tick based message system
- Support multiple codecs with specialization
- Use compilation-stable type ids for arbitrary message type reflection
- We are working on open sourcing this actor framework in 2019

- Alibaba 🧡 Rust
- We are building quite some frameworks with Rust
- Looking forward to be a better participant of the community in 2019

Thanks for your time