



RFP-159 Actor Runtime

Draft

12 Pages

Abstract

These are the requirements on how to add support for the Actor concurrency model to the OSGi environment. The general direction is to retain the composition of OSGi services as the basic model for creating applications, while at the same time allowing application developers to schedule concurrent execution with an actor runtime, rather than to use threads and locks. This requires that a balanced way is found to mix the blocking parts of the computation as expressed by calling services with the non-blocking parts of the computation as expressed by sending messages between actors. Each type of computation is structured around a modularity construct with different properties – bundles for the blocking and actors for the non-blocking. Perhaps the middle ground lies with a type of “actor service” which communicates through messages rather than method calls.

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0.3 Feedback

This document can be downloaded from the OSGi Alliance design repository at <https://github.com/osgi/design>
The public can provide feedback about this document by opening a bug at <https://www.osgi.org/bugzilla/>.

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0.5 Terminology and Document Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY" and "OPTIONAL" in this document are to be interpreted as described in 6.1.

Source code is shown in this typeface.

0.6 Revision History

The last named individual in this history is currently responsible for this document.

Revision	Date	Comments
Initial	Apr 16 2019	Todor Boev: Initial draft based largely on research in integrating Akka with OSGi services.
0.1	May 9 2019	Todor Boev: Numerous clarifications and updates. Added requirement numbers.

1 Introduction

Describe the state of the RFP and explain how the RFP came into existence. Discuss any other issues that are not addressed in the following chapters.

2 Application Domain

Today's software needs to be highly concurrent for several reasons. On one hand concurrent programs can make efficient use of all processor cores available to them. In this way concurrent programs can scale through parallelism. This is critical since for many years the only way to increase computational power is to add more cores or more machines rather than to make faster cores. On the other hand a lot of the software today needs to operate in real world conditions where it faces unpredictable concurrent events coming from the environment

much like humans do. These two forces combine to create the need for software that can use efficiently all computational resources available to execute as quickly as possible reactions to concurrently occurring events.

One proven way to build software that can handle such conditions is the Actor model of computation. On the JVM the most prominent implementation of this model is the Akka framework based on the Scala programming language. Outside the JVM the most prominent implementation of actors is the Erlang programming language and libraries and it's underlying runtime.

2.1 Terminology + Abbreviations

- **Message:** a data structure (DTO) which is considered immutable.
- **Behavior:** a functional object, which receives a message and returns a new behavior. Useful work is performed as side effects during the function call. State is passed from one behavior by enclosing it in the next behavior.
- **Actor:** an abstract container that manages the sequential atomic processing of messages by an unfolding chain of behaviors. The actor uses each behavior to processes one message and then replaces it with the next behavior.
- **Actor address:** an immutable identifier of an actor. Each actor has at least one address. The only way to send a message to an actor is to sent it to it's address. Actors can send messages to their own address.
- **Asynchronous message delivery:** sending a message does not return a value and does not block behavior execution (fire and forget).
- **At-most-once message delivery:** once sent a message can be delivered to the recipient zero or one time.
- **Supervisor:** an actor that decides how to handle failures in one or more other actors. Each actor has zero or one supervisor.
- **Supervisor hierarchy:** the tree formed by traversing the supervisor relationships between all actors.
- **Supervisor strategy:** a function specified by the supervisor that is called to make a decision on what to do with a failed child. E.g. the function can return a signal "restart" to cause the failed child to be reset to it's initial behavior and continue processing.
- **Actor runtime:** the engine which drives the concurrent execution of a large number of actors

3 Problem Description

As all other applications OSGi programs increasingly need to be deployed in real world conditions where the primary model of interaction is through large numbers of concurrent events coming over network interfaces or other asynchronous and unreliable channels.

Up until now we have addressed these conditions with concurrency primitives like Promises and PushStreams. These models however are functional in nature and do not model well concurrently changing state. At present we model dynamic state with services and service events. While this model has proven to be an effective way to structure an application the communication between the stateful services is still done through regular method calls done on multiple threads and protected by locks. These concurrency mechanisms have proven extremely hard to get right on one machine let alone in a distributed environment. There is a need for a more robust communication mechanism between services. One alternative to blocking method calls is asynchronous message passing. Introducing this communication mechanism should complement Promises and PushStreams to give OSGi an all-round ability to handle highly concurrent loads.

4 Use Cases

List one or more use case models that describe system functionality.

5 Requirements

The requirements describe the minimal viable actor system. Even though a lot of requirements go beyond the minimal actor execution model they are nevertheless needed to implement practical actor applications.

On the other it is highly preferable to use existing OSGi specifications to support as many of the requirements as possible. E.g. Promises are a great candidate to support any interactions of actors with non-actor services. The goal is to have an OSGi system extended with the actor programming model, rather than other way around.

5.1 Execution model

This is simply a generic actor execution model not related to OSGi

- **Exec 1:** The actor runtime **must** provide at least one address for each actor
- **Exec 2:** The actor runtime **must** store behaviors as (functional) objects in order to allow them to enclose state.
- **Exec 3:** The actor runtime **must** guarantee that at all times an actor is associated with exactly one behavior
 - This also implies an actor is atomically initialized with a behavior upon creation

- **Exec 4:** An actor **must** have a way to access it's own address (self) from it's behavior
- **Exec 5:** An actor behavior **must** have a way to send one or more messages to an actor address (including "self").
- **Exec 6:** The actor runtime **must** guarantee asynchronous message delivery.
 - I.e. the behavior code **must** not block waiting for the message to be processed by the recipient.
- **Exec 7:** The actor runtime **must** guarantee "at-most-once" message delivery.
 - I.e. while it is allowed for messages to not be delivered it is not allowed for the same message to be delivered twice.
- **Exec 8:** It **must** be possible for messages to contain addresses of actors.
- **Exec 9:** An actor **must** process messages only in sequential atomic steps. At each step the actor first calls it's current behavior with the current message and gets back a new behavior. Then the actor replaces it's current behavior with that new behavior.
 - I.e. an actor maintains a continuation passing style of execution driven by messages.
 - It is permissible to execute each step on a different thread (e.g. from a pool), but it is not under any conditions permissible for two or more threads to execute steps concurrently. *Violating this principle renders the actor system unusable.*
 - This still allows users to have a mutable behavior object, which always returns itself, thus enabling an "object oriented" style of actor.
- **Exec 10:** The actor runtime **must** not deliver messages to a behavior which is no longer current for an actor
- **Exec 11:** It **must** be possible for a behavior to return a value which signals no more messages should be processed. After this happens the actor runtime must stop delivering messages to the actor and perform any post-death actions (see supervision and "death watch") below.
- **Exec 12:** An actor behavior **must** have a way to create a new actor by specifying an initial behavior for that actor. The creation call must **synchronously** return the address of the new actor.

5.2 Error handling

- **Err 1:** Each actor must have exactly one supervisor. The supervisor is always the actor who created a given actor.
- **Err 2:** The supervisor is established once during actor creation and can not be changed subsequently.
- **Err 3:** There must be exactly one root actor which has no supervisor.
- **Err 4:** There must be a way for a behavior to specify a supervisor strategy function when it creates a child actor.

- **Err 5:** An actor must process the errors of it's children sequentially as special messages within the regular message stream. The difference is that the error message is delivered to the parent's supervisor strategy function rather than to the parent's behavior.
 - The definition of an actor is thus expanded to include not just the current behavior function, but also the set of supervisor strategy functions it has attached to it's children. Each member function of the actor processes the next message as appropriate. No message is processed by more than one member function.
- **Err 6:** The following return values from the supervisor strategy function must be supported:
 - **resume:** the failed actor retains it's behavior. It then proceeds to process the next message.
 - **reset:** the failed actor is reset to the behavior with which it was created. It will then proceed to process the next message.
 - **stop:** the failed actor is stopped. It can no longer process messages and is garbage collected.
 - **escalate:** the supervising actor is stopped. The error is propagated up the hierarchy to it's supervisor.
- **Err 7:** When a supervisor is stopped all of it's children are stopped first.

5.3 Core capabilities

Not part of the core execution model, hard or impossible to implemented on top of the core execution model, so must be supported by the system instead.

- **Core 1:** Message ordering. Sender and receiver observe the same message order
- **Core 2:** Death watch: an actor can register an address in order to receive a message signifying that the actor referenced by this address has died.
 - This allows actors to clean invalid addresses they have
 - This allows actors to stop when the other actor was critical to their function, even though they are not it's supervisor
- **Core 3:** Message buffering. The actor runtime must be able to buffer (rather than drop) messages sent to an address while the actor executes it's current behavior.
- **Core 4:** Scheduled message delivery. It must be possible for an actor to schedule one-shot or periodic delivery of a message to an arbitrary address (including "self") after a given time interval.
- **Core 5:** Pub/Sub message delivery. The actor runtime should provide a global pub/sub subsystem where actors can subscribe for messages of a given type and respectively post messages.
- **Core 6 (?)**: Dead letters: subscribe to messages sent to addresses of dead actors

5.4 Core patterns

Can be implemented on top of the core execution model or the core capabilities.

- **Pat 1:** Message deconstruction: something to help with pattern matching

- **Pat 2 (?)**: “Ask” (Req/Resp) message exchange: Actors sends a request, starts a timer to send a failure message to “self”. If response arrives before timeout expires, the failure message is ignored.
 - Something like a Promise: the failure and the response race to resolve the promise. Once resolved no further updates can take effect. Can be implemented with a helper actor to track the exchange.
- **Pat 3**: “At-least-once” message delivery: requires message equality, receiver acknowledges messages, sender tracks outgoing messages (to resend unacknowledged)
 - The tracking of acknowledgments may be supported by persistence (see the Persistence section)
- **Pat 4**: “Exactly-once” message delivery: requires message equality, receiver acknowledges messages, sender tracks outgoing messages (to resend unacknowledged), receiver tracks incoming messages (to ignore repeats)
 - The tracking of acknowledgments and duplicates may be supported by persistence (see the Persistence section)

5.5 OSGi integration

- **Int 1**: As a general rule actors should be treated more as a concurrency model, rather than as a universal computation model. The structure of the program should be expressed as standard OSGi service composition as much as possible (e.g. DS components). It's just that some services communicate through an async message passing medium (the actor system) and run actors as their internal implementation.
- **Int 2**: As a general rule all communication from the external world to the actor system **must** be asynchronous.
 - In practice this means external parties should be able to send messages to an address provided by the actor system, just like regular actors do.
- **Int 3**: As a general rule all communication from the actor system to the external world **should** be asynchronous.
 - In practice this means actors should wrap calls to the outside world in Promises, which once resolved send messages back to “self” as a regular external party (**Int 2**). The Promises should be scheduled on threads that do not drive the actor message delivery (bulk-heading).
- **Int 4**: It **must** be possible to initialize behaviors with arbitrary OSGi services prior to the first message being processed.
- **Int 5**: It **must** be possible to initialize behaviors with configuration provided by the Configuration Admin prior to the first message being processed
- **Int 6**: It **must** be possible to stop any actor when it's configuration or a service dependency goes away
 - This **must** happen asynchronously via messages or other native actor mechanisms (death watch).
 - Still the actor **must** be prevented from calling stale services. Since the actor should call the service through Promises as per **Int 2** those Promises be failed immediately and let the actor stumble upon the failure later within it's regular message flow.

- **Int 7:** It **should** be possible for supervisors to specify an “escalate” strategy when a child starts to fail because of an unbound service / configuration.
 - In practice this means there must be a dedicated exception or error message to which the supervisor strategy function can react.
- **Int 8:** It **must** be possible for any bundle to call the actor system to discover actor addresses
- **Int 9:** It **must** be possible for any bundle to send a message to an actor address asynchronously
- **Int 10:** It **must** be possible for any bundle to do an asynchronous request/response exchange with an actor
 - In practice this means the external party uses the “ask” pattern (**Pat 2**).
- **Int 11:** It **must** be possible for any bundle to subscribe to messages or to publish messages
- **Int 12:** It **must** be possible for a bundle to create an actor and receive back it’s address

5.6 Persistence

- **Pers 1:** An actor **must** be able to receive, examine and optimally update a persistent state object during message processing. I.e. part or all of the state that used to be encapsulated in the behavior is now made explicit to the system.
- **Pers 2:** It must be possible to identify an actor’s persistent state across system reboots
- **Pers 3:** It must be possible to initialize an actor not only with a behavior, but with initial state.
- **Pers 4:** It must be possible for a behavior to request commit to storage within the message processing step.
 - One would expect to have:
(behavior) examine message → (behavior) execute side effects → (behavior) build new state → (system) commit new state.
Instead there should be:
(behavior) examine message → (behavior) build new state → (system) commit new state → (behavior) execute side effects
 - Placing the side effects (making new actors, sending messages), after the commit to storage allows the actor to be recovered in correct state after a crash. In the first case it is possible for the actor to first affect the runtime state of the system, then for the system to crash before the state is committed. Then the actor can’t be recovered to a state that reflects what it has done. In the second case if the system crashes during commit one message will be lost, but the last committed state will remain valid since nothing was done. On the other hand if the system crashes right after commit once recovered the actor can re-run the side effects based on the state.
- **Pers 5:** It must be possible to re-run the behavior side effects when an actor is recovered from storage
 - This implies the behavior function should be split into two: *(message, state) → next-state* and *(next-state → next-behavior)*. Every message pass calls the first function, stores the result then calls the second function. When an actor is loaded from storage as an initial step only the second function is called.

5.7 Clustering

This is needed to implement classic actor “distributed applications”, where the same tightly coupled code base is split across many VMs and specialized, protocols to move messages between VMs are used.

This is not needed to implement “distributed systems”, consisting of multiple (not one) loosely coupled applications talking through generic protocols (e.g. REST, gRPC, MQTT).

- **Clust 1:** Provide a way to send messages to a remote actor address
- **Clust 2:** Provide a way to discover a remote or local actor address
 - I.e. call the system with some search query and get back an actor address.
- **Clust 3(?):** Use the RSA to distribute actor services

6 Document Support

6.1 References

- [1]. Bradner, S., Key words for use in RFCs to Indicate Requirement Levels, RFC2119, March 1997.
- [2]. Software Requirements & Specifications. Michael Jackson. ISBN 0-201-87712-0

*Add references simply by adding new items. You can then cross-refer to them by chosing <Insert><Cross Reference><Numbered Item> and then selecting the paragraph. **STATIC REFERENCES (I.E. BODGED) ARE NOT ACCEPTABLE, SOMEONE WILL HAVE TO UPDATE THEM LATER, SO DO IT PROPERLY NOW.***

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