Universidade do Minho
Escola de Engenharia
Departamento de Informática

SPADE – Smart Python Agent Development Env.

Agentes e Sistemas Multiagente

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What is SPADE?

- A multi-agent systems platform written in Python (3.8 – 3.12) and based on instant messaging (XMPP).
- Complies with FIPA specifications for interoperable intelligent multi-agent systems
- Library that enables faster time-to-market for developing multi-agent distributed applications
    - Develop agents that can chat both with other agents and humans
- It is Open Source distributed under MIT license

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Summarized:

- Agent library with the purpose of simplifying the development of agents

SPADE provides:

- Agent Execution environment
- Provides a class library for multi-agent development
- Web-graphical administration and management tools for management and monitoring

SPADE Features:

- Provides agent life cycle management
- Message structure and transport management
- Support for agent code and execution state migration
- Agent presence notification (know the agent's state in real-time)
- Secure multi-agent distributed applications
- Further plugins being developed for SPADE

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SPADE Architecture:

- Agents:
  - Composed of a collection of active components called “Agents”
  - Each agent is a peer and has a unique name/ID
  - Each agent “lives” in a XMPP Server
- Multi-agent Server:
  - Server responsible to enable agents communicating & negotiating between each other
  - One XMPP server can contain several agents running simultaneously
  - The platform provides a homogeneous layer that hides to agents the complexity and the diversity of the unerdying tires (Hardware, Operational System, etc.)

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SPADE Agent Model - Connection mechanism to the platform

- In order for the SPADE agent to establish a connection with the XMPP server, it requires:
  - An identified designated Jabber ID (or JID) – composed by agent_name@server_domain
  - A valid password
- The JID will be the name that uniquely identifies an agent in the platform
  - e.g., myagent@myprovide.com
- Connection establishment are handled internally by means of the XMPP protocol
  - i.e., User Registration & Authentication

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SPADE Agent Model - Message dispatcher

- Each SPADE agent has an internal message dispatcher component (acts as a mailman), e.g.:
  - When a message for the agent arrives, it places it in the correct “mailbox”
  - When the agent needs to send a message, the message dispatcher does the job, putting it in the communication stream
- The message dispatching is done automatically by the SPADE agent library whenever a new message arrives or is to be sent

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SPADE Agent Model - Behaviors

- A behaviour is a task that an agent can execute using repeating patterns

- SPADE provides predefined several behaviour types, which support to implement the different tasks that an agent can perform. These are:
  - *OneShotBehaviour* & *TimeoutBehaviour* – applied to perform casual tasks
  - *PeriodicBehaviour* & *CyclicBehaviour* - applied for performing repetitive tasks
  - *Finite State Machine (FSMBehaviour)* – applied for more complex behaviours to be built

- Each SPADE agent can run several behaviors simultaneously

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Programmers Point of View

- SPADE provide a library of classes that programmers can use to develop their agents
  - *Agent* class (spade.agent.Agent): for creating a SPADE agent [e.g., *setup(), get()*]
  - *Behaviour* class (spade.behaviour.*): for carrying out the actual tasks [e.g., *run(), on_start(), on_end()*]
  - *Message* class (spade.message.Message): Agent Communication Language as defined by FIPA, following a syncronous message passing paradigm

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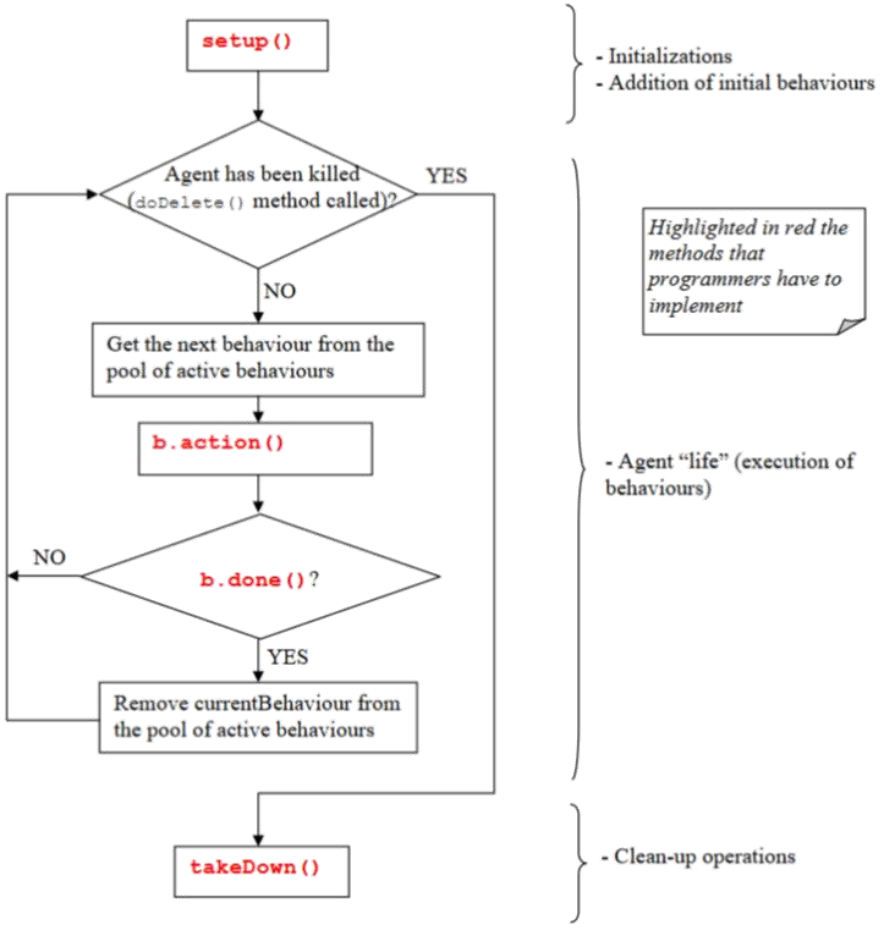
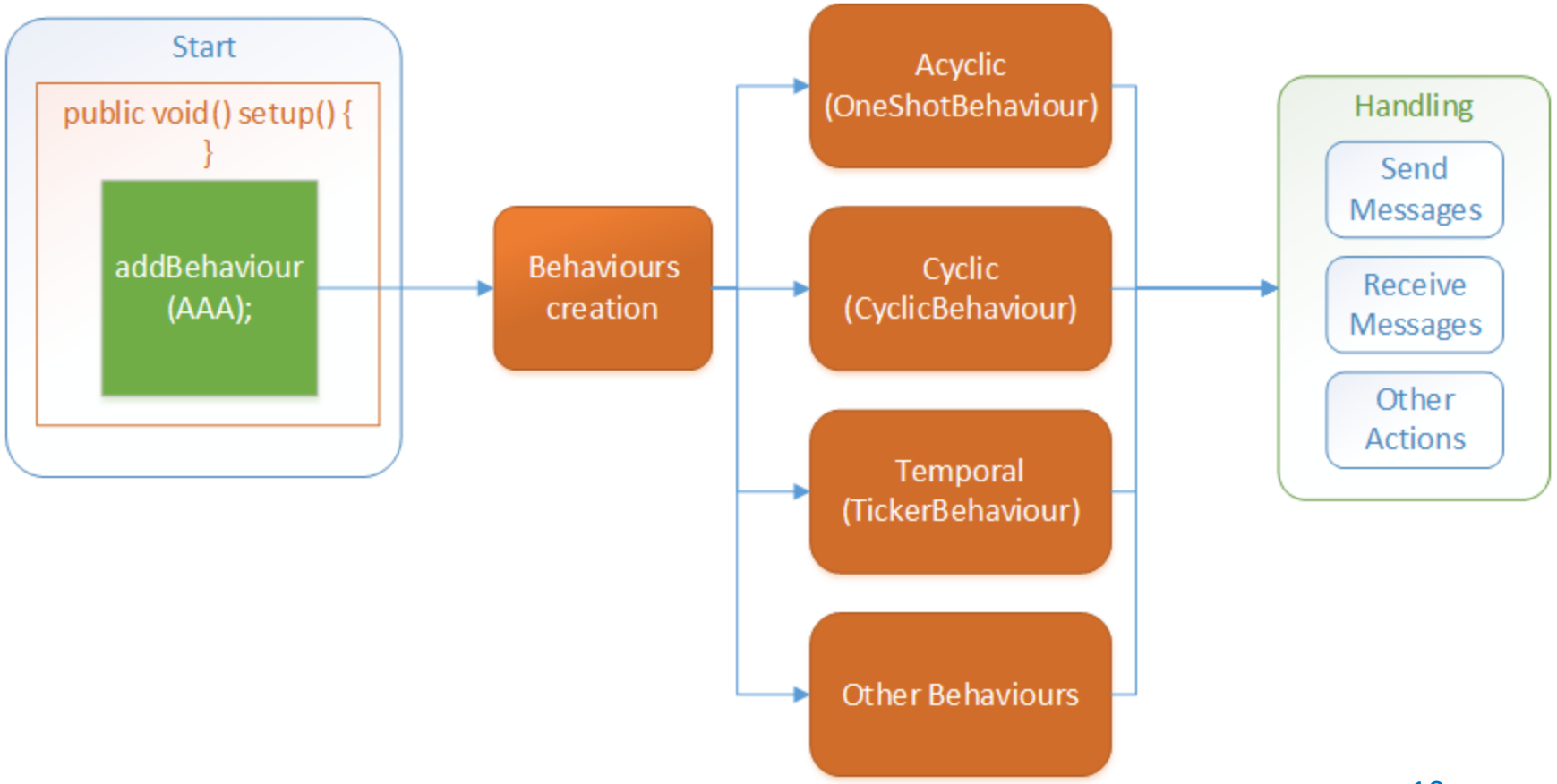
Agent Life Cycle



Execution Pipeline



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Performative - FIPA Compliant

- FIPA - Foundation for Intelligent Physical Agents.
- Promotes standards for agent development.
- Delivers Messages Representation, Agents Structure, Messages Structure, etc.
- FIPA Message Types: ask, inform, request, propose, refuse, etc.

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SPADE Message & Template Structure:

- Message & Template structure share the same attributes:
  - Messages are applied to communicate between agents
  - Templates are applied to dispatch received messages to the behaviour that is waiting for that message

- Message & Template classes are composed by the attributes:
  - **to**: the JID string of the receiver of the message
  - **sender**: the JID string of the sender of the message
  - **body**: the body/content of the message, in string type
  - **thread**: the thread-id of the conversation
  - **metadata**: a (key, value) dictionary of strings to define metadata of the message.
    - Useful, e.g., to include FIPA attributes like ontology, performative, language, etc.

```
template = Template()
template.sender = "sender1@host"
template.to = "recv1@host"
template.body = "Hello World"
template.thread = "thread-id"
template.metadata = {"performative": "query"}

message = Message()
message.sender = "sender1@host"
message.to = "recv1@host"
message.body = "Hello World"
message.thread = "thread-id"
message.set_metadata("performative", "query")

assert template.match(message)
```

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Simple Agent Code

SPADE Agent Code

```
import spade

class DummyAgent(spade.agent.Agent):
    async def setup(self):
        print("Hello World! I'm agent {}".format(str(self.jid)))

async def main():
    dummy = DummyAgent("dummy@localhost", "your_password")
    await dummy.start()

if __name__ == "__main__":
    spade.run(main())
```

Execute Agent in XMPP Server

Execute Python Code (Terminal)

```
$ python dummyagent.py
Hello World! I'm agent your_jid@your_xmpp_server
$
```

Note

A SPADE agent is an asyncronous agent. That means that all the code to run an agent must be executed in an asyncronous loop. This is done by the `spade.run()` function. This function receives a coroutine as a parameter and runs it in an async loop. In our example, the `main()` coroutine is the one that is run in the loop.

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Agent Code with Behaviours

```python
import time
import asyncio
from spade.agent import Agent
from spade.behaviour import CyclicBehaviour

class DummyAgent(Agent):
    class MyBehav(CyclicBehaviour):
        async def on_start(self):
            print("Starting behaviour . . .")
            self.counter = 0

        async def run(self):
            print("Counter: {}".format(self.counter))
            self.counter += 1
            await asyncio.sleep(1)

    async def setup(self):
        print("Agent starting . . .")
        b = self.MyBehav()
        self.add_behaviour(b)
```

SPADE Agent Code

CyclicBehaviour called by Agent setup funct.

CyclicBehaviour adding +1 per cycle to self.counter

Execute Python Code (Terminal)

```
$ python dummyagent.py
Agent starting . . .
Starting behaviour . . .
Counter: 0
Counter: 1
Counter: 2
Counter: 3
Counter: 4
Counter: 5
Counter: 6
Counter: 7
```

```python
async def main():
    dummy = DummyAgent("dummy@localhost", "your_password")
    await dummy.start()
    print("DummyAgent started. Check its console to see the output.")

    print("Wait until user interrupts with ctrl+C")
    await wait_until_finished(dummy)

if __name__ == "__main__":
    spade.run(main())
```

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Create & Send Messages

```python
import time
from spade.agent import Agent
from spade.behaviour import OneShotBehaviour
from spade.message import Message


class SenderAgent(Agent):
    class InformBehav(OneShotBehaviour):
        async def run(self):
            print("InformBehav running")
            msg = Message(to="receiver@your_xmpp_server")     # Instantiate the message
            msg.set_metadata("performative", "inform")  # Set the "inform" FIPA performative
            msg.set_metadata("ontology", "myOntology")  # Set the ontology of the message content
            msg.set_metadata("language", "OWL-S")       # Set the language of the message content
            msg.body = "Hello World"                    # Set the message content

            await self.send(msg)
            print("Message sent!")

            # set exit_code for the behaviour
            self.exit_code = "Job Finished!"

            # stop agent from behaviour
            await self.agent.stop()

    async def setup(self):
        print("SenderAgent started")
        self.b = self.InformBehav()
        self.add_behaviour(self.b)
```

Create Message

Send Message

Execute Python Code (Terminal)

```
$ python sender.py
SenderAgent started
InformBehav running
Message sent!
Agent finished with exit code: Job Finished!
```

Start Sender Agent

```python
async def main():
    senderagent = SenderAgent("sender@your_xmpp_server", "sender_password")
    await senderagent.start(auto_register=True)
    print("Sender started")

    await spade.wait_until_finished(receiveragent)
    print("Agents finished")


if __name__ == "__main__":
    spade.run(main())
```

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Programming Requirements:

1. Download & Install Java Development Kit (JDK)

2. Download XMPP Server (Openfire)

3. Installation & Configuration Tutorial of XMPP Server (Openfire)

4. Install SPADE Python Package (inside conda env.)

5. Multiagent System Development in Python:
   - Create new Python Project
   - In the Python script, import SPADE module
   - Follow the Quick Start guide to build our first SPADE agent

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- Tutorial for Linux/Unix:
  - JDK & Openfire Guideline Tutorial

- Tutorial for Mac OS:
  - Homebrew Guideline Tutorial
  - JDK Guideline Tutorial
  - XMPP Guideline Tutorial
  - Openfire Guideline Tutorial
    - Install OpenFire
    - Terminal:

```
$ sudo chmod -R 777 /usr/local/openfire/bin
Password:
$ sudo su
sh-3.2# cd /usr/local/openfire/bin
sh-3.2# export JAVA_HOME=`/usr/libexec/java_home`
sh-3.2# echo $JAVA_HOME /Library/Java/JavaVirtualMachines/jdk1.8.0_101.jdk/Contents
/Library/Java/JavaVirtualMachines/jdk1.8.0_101.jdk/Contents/Home /Library/Java/Java
sh-3.2# cd /usr/local/openfire/bin
sh-3.2# ./openfire.sh
Openfire 4.0.2 [Aug 9, 2016 1:51:21 PM]
Admin console listening at http://myMac.local:9090
```

Running these commands above one by one(setup the java_home variable in openfire.xml)

[Note]:
Grant the write permission to openfire.xml before you launching Openfire.

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Download & Install Java Development Kit (JDK)

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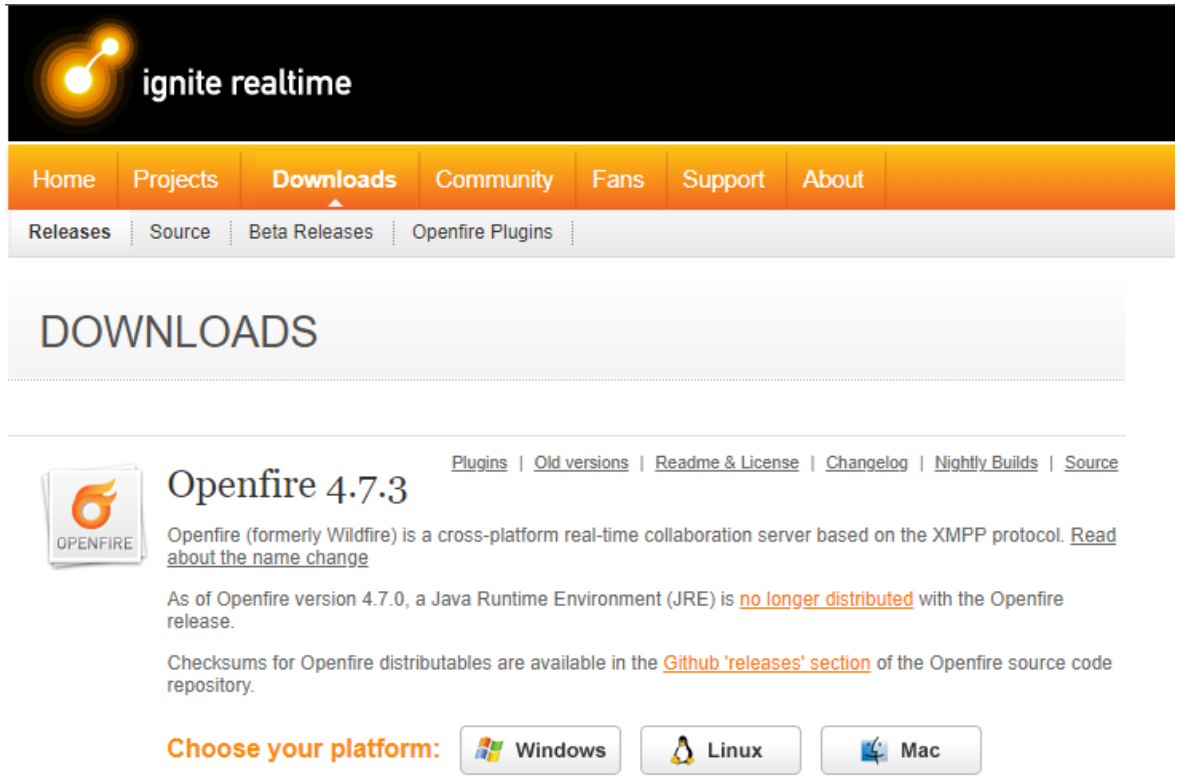
Product / File Description	File Size	Download
Linux ARM v6/v7 Soft Float ABI	72.86 MB	jdk-8u202-linux-arm32-vfp-hflt.tar.gz
Linux ARM v6/v7 Soft Float ABI	69.75 MB	jdk-8u202-linux-arm64-vfp-hflt.tar.gz
Linux x86	173.08 MB	jdk-8u202-linux-i586.rpm
Linux x86	187.9 MB	jdk-8u202-linux-i586.tar.gz
Linux x64	170.15 MB	jdk-8u202-linux-x64.rpm
Linux x64	185.05 MB	jdk-8u202-linux-x64.tar.gz
Mac OS X x64	249.15 MB	jdk-8u202-macosx-x64.dmg
Solaris SPARC 64-bit (SVR4 package)	125.09 MB	jdk-8u202-solaris-sparcv9.tar.Z
Solaris SPARC 64-bit	88.1 MB	jdk-8u202-solaris-sparcv9.tar.gz
Solaris x64 (SVR4 package)	124.37 MB	jdk-8u202-solaris-x64.tar.Z
Solaris x64	85.38 MB	jdk-8u202-solaris-x64.tar.gz
Windows x86	201.64 MB	jdk-8u202-windows-i586.exe
Windows x64	211.58 MB	jdk-8u202-windows-x64.exe

[Download XMPP Server (Openfire)]



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Installation & Configuration Tutorial of XMPP Server (Openfire)

Installation Guide

openfire

« Back to documentation index

Openfire is a powerful instant messaging (IM) and chat server that implements the XMPP protocol. This document will guide you through installing Openfire. For a full list of features and more information, please visit the Openfire website:
http://www.igniterealtime.org/projects/openfire/

Installation

Windows

Select Openfire installer that is better suiting you (with or without Java JRE, x86 or x64). Run the installer. The application will be installed to `C:\Program Files\Openfire` by default.

Note: On Windows systems we suggest using a service to run Openfire (read the Windows Service section below). When using Openfire Launcher on Windows Vista or newer with UAC protection enabled, it has to be run with Run as administrator option, to be able to write changes to config and embedded database (if used) stored in `C:\Program files\Openfire\` folder. If Openfire is running via launcher without Run as administrator option from Program files, it can't get proper permissions to write changes. It shows errors (in red) when running the launcher and during the setup will require the current password for the administrator account (although this is a new installation and normally it doesn't ask for it). This is an effect of missing permissions and Openfire not being able to initialize the database and other resources.

Since 4.1.5 Openfire installs and runs the service automatically (also opens the browser and loads the web setup page). The launcher (if one wants to use it) is also made to run in elevated mode, so one don't need to run it as administrator manually. But you shouldn't use the launcher, if the service is running. Because this will create a conflict.

Linux

Choose one of the provided installers (x86 or x64, with or without Java JRE, rpm, deb or tar.gz).

If using rpm, run it using your package manager to install Openfire to `/opt/openfire`:

```
rpm -ivh openfire_X_Y_Z.rpm
```

If using deb, run it to install Openfire to `/usr/share/openfire`:

```
dpkg -i openfire_X_Y_Z.deb
```

If using the tar.gz, extract the archive to `/opt` or `/usr/bin`:

```
tar -xzvf openfire_X_Y_Z.tar.gz
mv openfire /opt
```

macOS

Install Openfire using dmg installer. This should install Openfire into `/usr/local/openfire`. Then you can run it via cmd or with the launcher.

Note: some Openfire installers do not contain a bundled Java runtime (JRE). Therefore, you must have JDK or JRE installed on your system. Openfire 4.3 (also 4.2 and older versions) requires Java 8. Starting with 4.4 version Openfire also supports Java 11. You can check your java version by typing "java -version" at the command line. We suggest using OpenJDK, which is usually provided as a package on Linux or you can download it for various platforms from AdoptOpenJDK.

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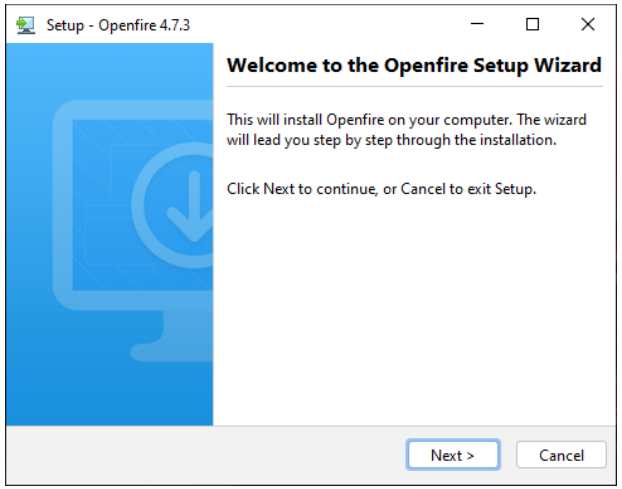
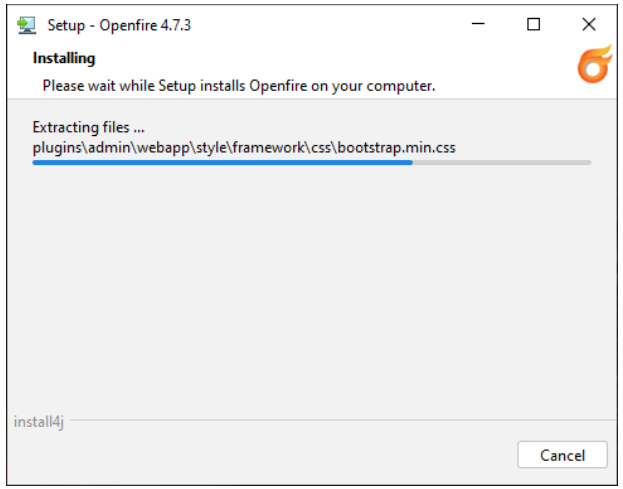
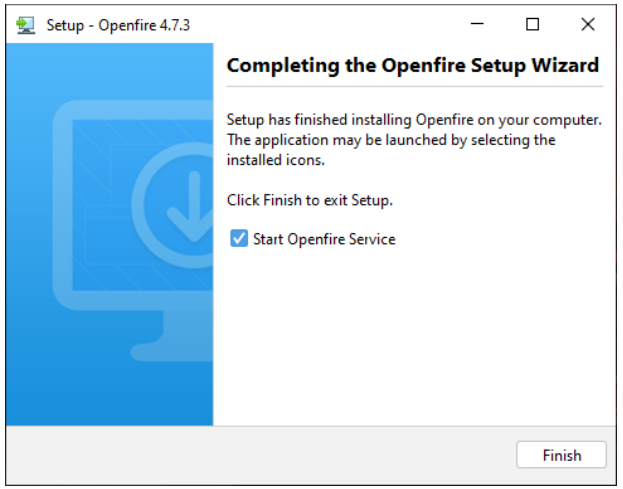
Installation & Configuration Tutorial of XMPP Server (Openfire)







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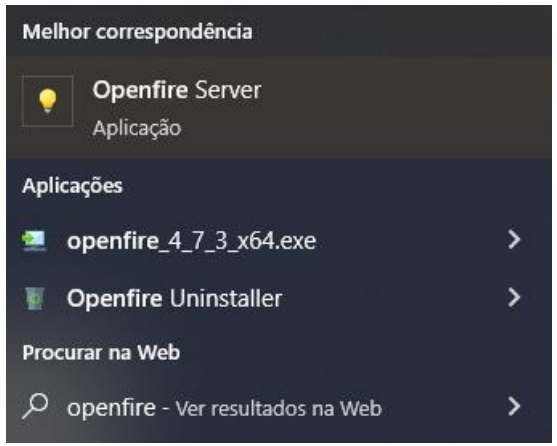

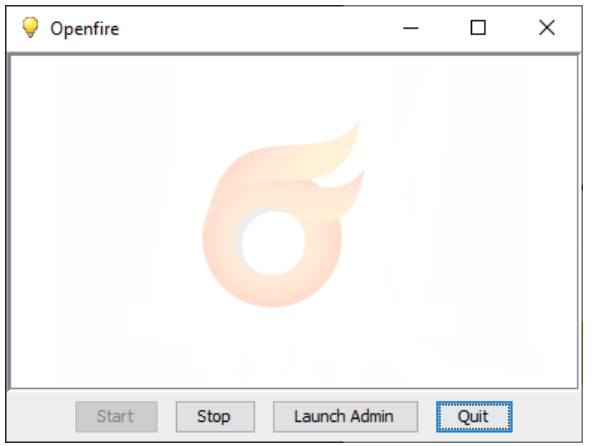

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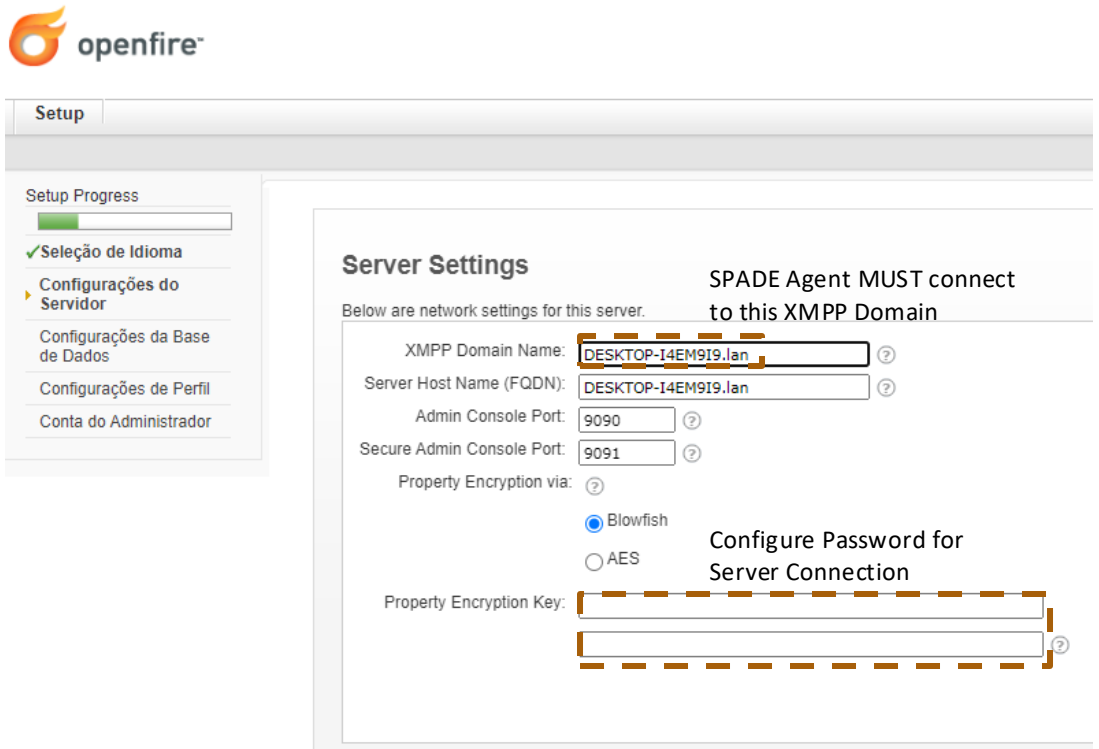

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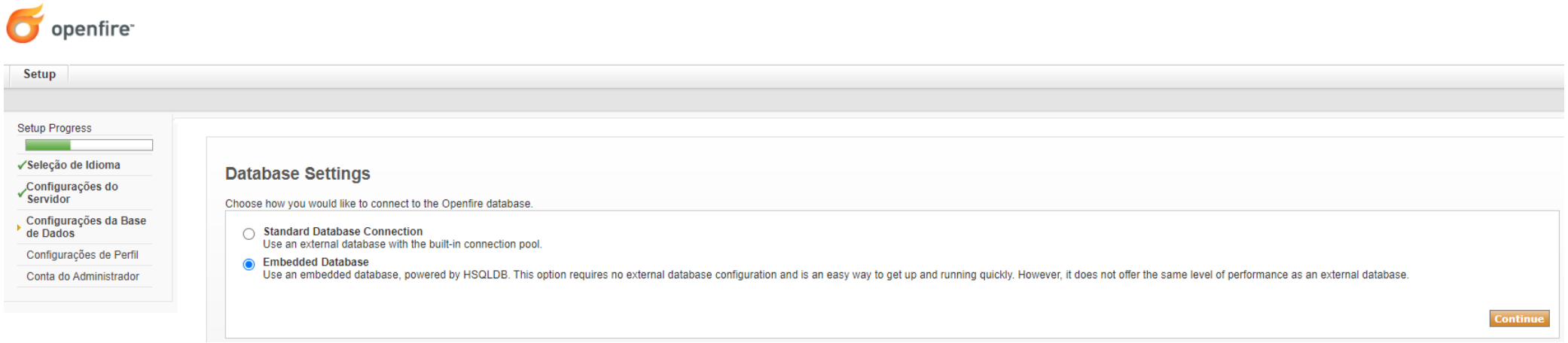

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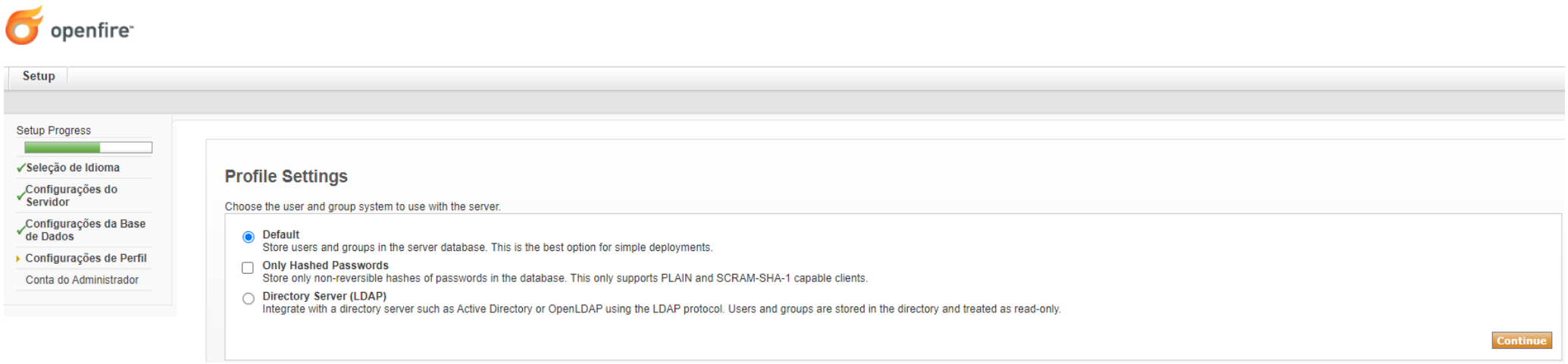

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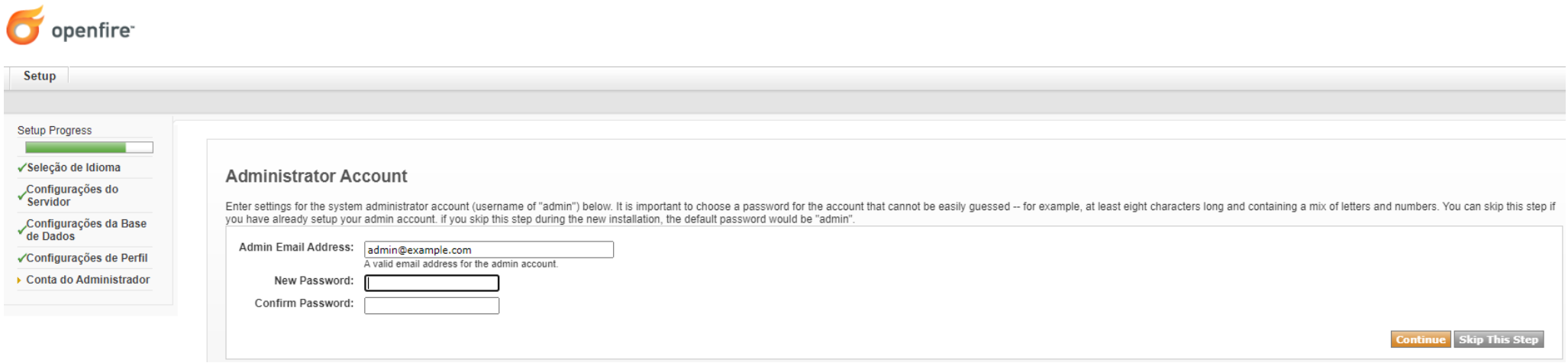

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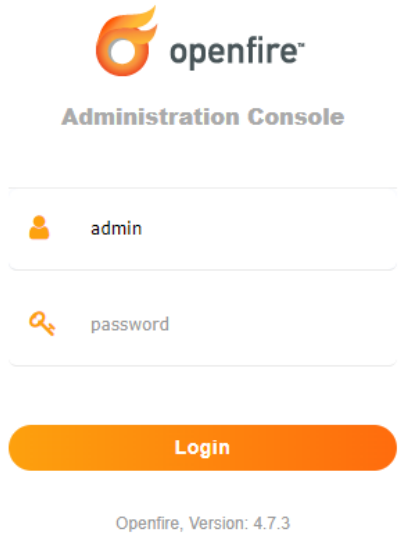
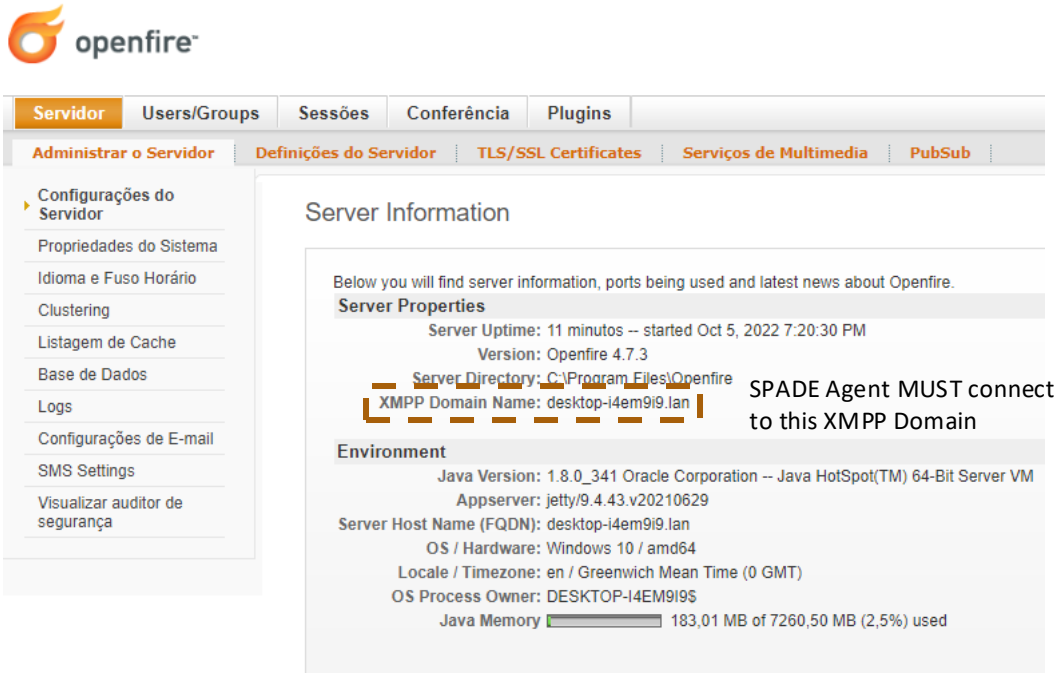
Installation & Configuration Tutorial of XMPP Server (Openfire)

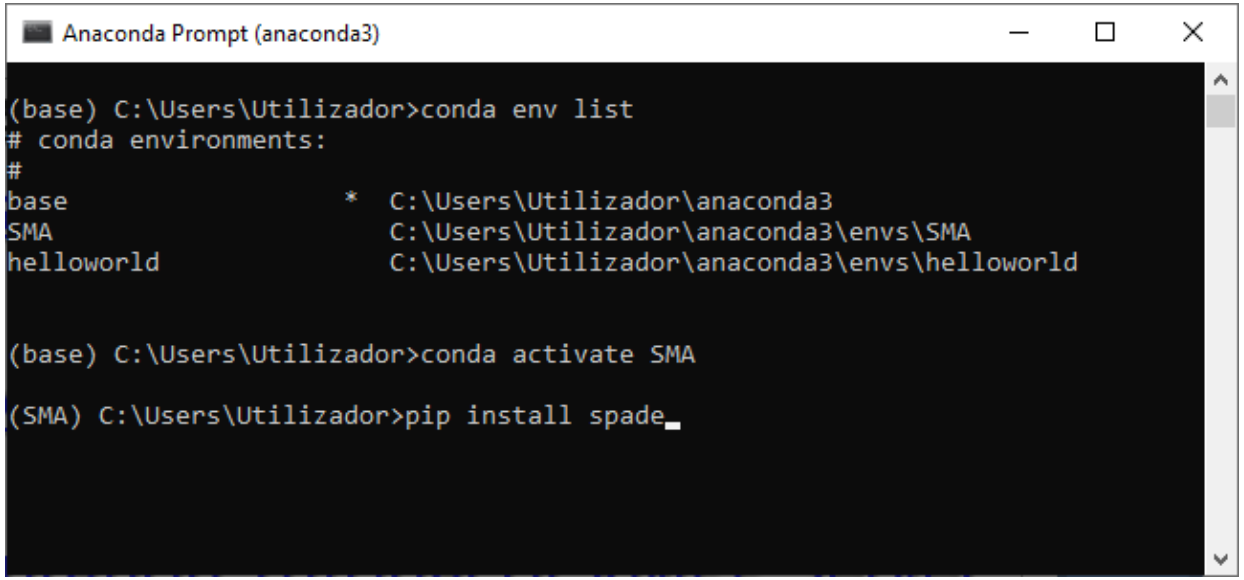
- Validate if XMPP Server is Configured and Online
- Open Browser: http://127.0.0.1:9090/
  - Username: admin
  - Password: admin





SPADE Agent MUST connect to this XMPP Domain

Install SPADE Python Package (inside conda env.)



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