



SPADE – Smart Python Agent Development Env.

Agentes e Sistemas Multiagente

Pedro Oliveira, Paulo Novais



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

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

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 underlying tiers (Hardware, Operational System, etc.)

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



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

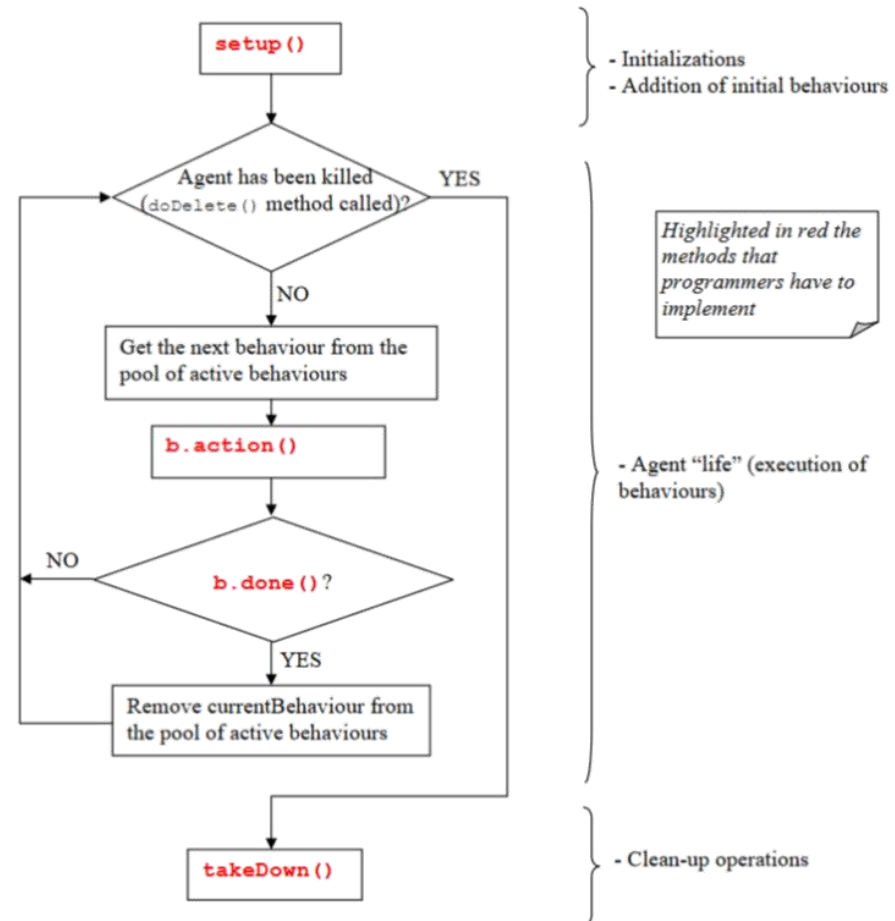
SPADE Agent Model - Behaviors

- 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

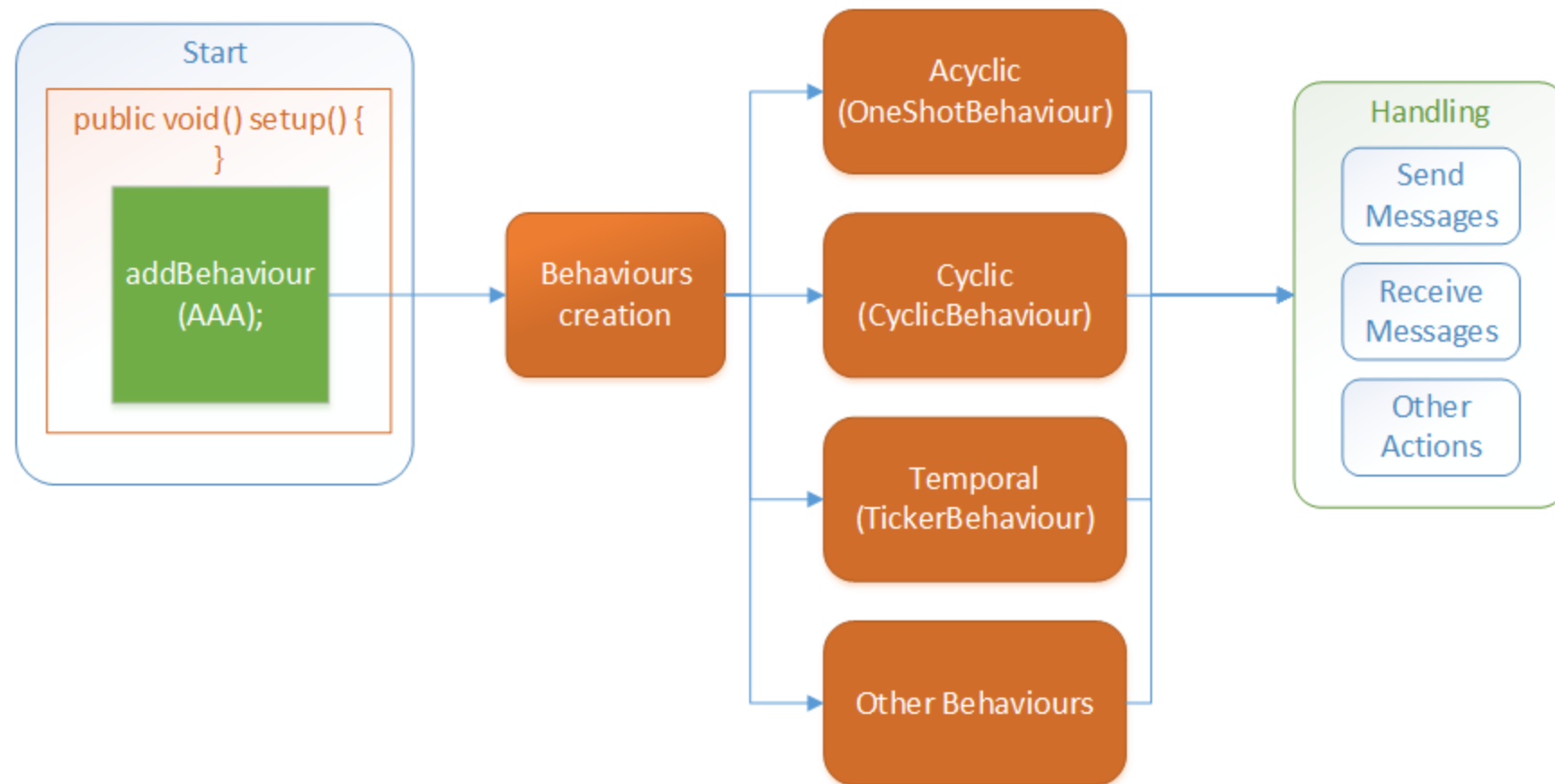
Programmers Point of View

- 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 synchronous message passing paradigm

Agent Life Cycle



Execution Pipeline



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.

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)
```

Simple Agent Code

```
import spade
```

SPADE Agent Code

```
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 asynchronous agent. That means that all the code to run an agent must be executed in an asynchronous 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.

Agent Code with Behaviours

```
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
adding +1 per cycle to
self.counter

CyclicBehaviour
called by Agent setup
funct.

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
```

```
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())
```


Create & Send Messages

```
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")
            # Create Message
            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
            # Send Message
            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)
```

Execute Python Code (Terminal)

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



Start Sender Agent

```
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())
```



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

- 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)

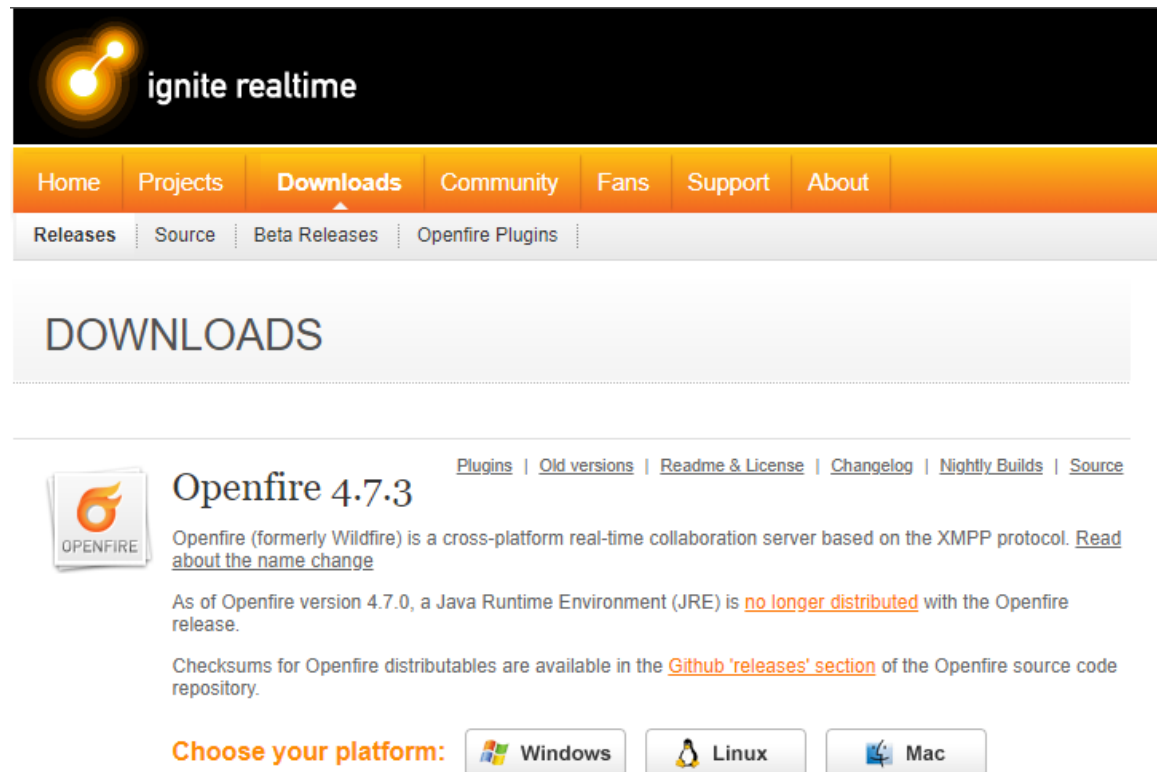
[Note]:

Grant the write permission to openfire.xml before you launching Openfire.

[Download & Install Java Development Kit \(JDK\)](#)

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Windows x64	211.58 MB	jdk-8u202-windows-x64.exe

[Download XMPP Server \(Openfire\)](#)




The screenshot shows the Openfire website. At the top is the 'ignite realtime' logo. Below it is a navigation bar with links: Home, Projects, Downloads (highlighted), Community, Fans, Support, and About. Under 'Downloads' are sub-links: Releases, Source, Beta Releases, and Openfire Plugins. The main heading is 'DOWNLOADS'. Below this, the 'Openfire 4.7.3' section is visible. It includes the Openfire logo, a description of the server, and links to various resources. At the bottom, there are buttons to 'Choose your platform' for Windows, Linux, and Mac.

ignite realtime

Home Projects **Downloads** Community Fans Support About

Releases Source Beta Releases Openfire Plugins

DOWNLOADS




 **Openfire 4.7.3** [Plugins](#) | [Old versions](#) | [Readme & License](#) | [Changelog](#) | [Nightly Builds](#) | [Source](#)

Openfire (formerly Wildfire) is a cross-platform real-time collaboration server based on the XMPP protocol. [Read about the name change](#)

As of Openfire version 4.7.0, a Java Runtime Environment (JRE) is [no longer distributed](#) with the Openfire release.

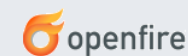
Checksums for Openfire distributables are available in the [Github 'releases' section](#) of the Openfire source code repository.

Choose your platform:

 Windows  Linux  Mac

Installation & Configuration Tutorial of XMPP Server (Openfire)

Installation Guide



[← 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**:

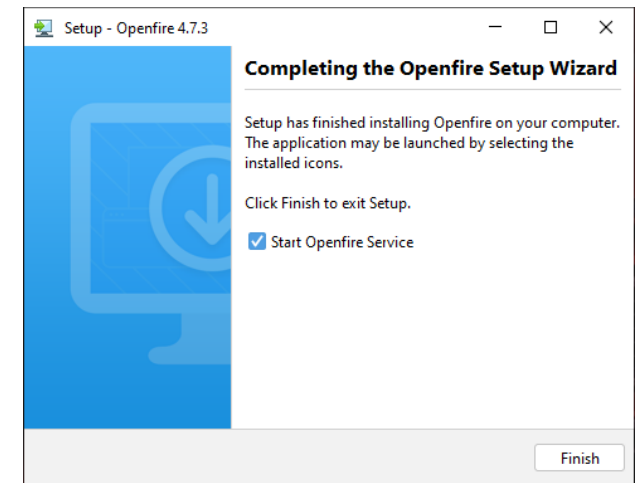
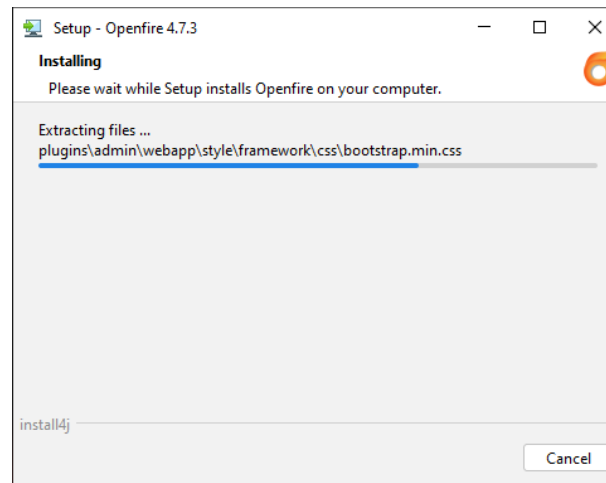
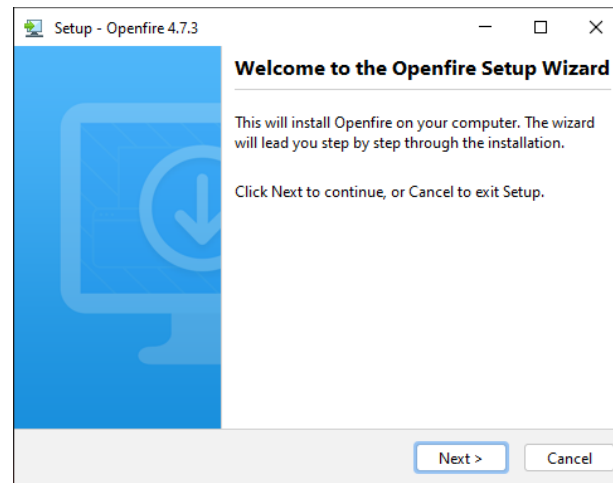
```
tar -xvzf openfire_X_Y_Z.tar.gz  
mv openfire /opt
```

macOS

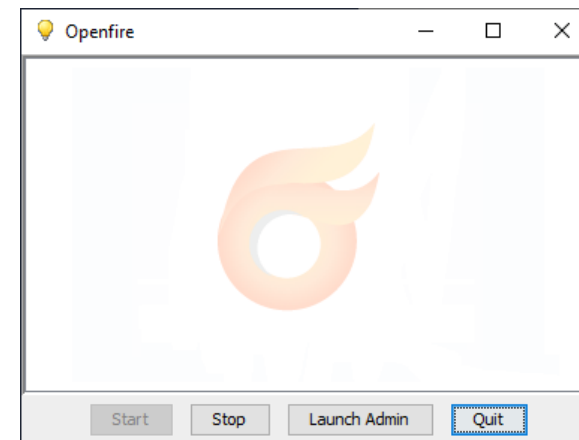
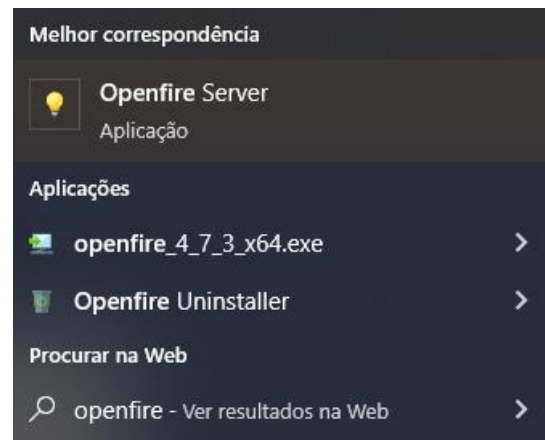
Install Openfire using dmg installer. This should install Openfire into **/usr/local/openfire**. Then you can run it via cmd or with the launcher.

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](#).

Installation & Configuration Tutorial of XMPP Server (Openfire)



Installation & Configuration Tutorial of XMPP Server (Openfire)



Installation & Configuration Tutorial of XMPP Server (Openfire)



Setup

Setup Progress

✓ Seleção de Idioma

Configurações do Servidor

Configurações da Base de Dados

Configurações de Perfil

Conta do Administrador

Server Settings

SPADE Agent MUST connect to this XMPP Domain

Below are network settings for this server.

XMPP Domain Name:

Server Host Name (FQDN):

Admin Console Port:

Secure Admin Console Port:

Property Encryption via:

☒ Blowfish

☐ AES

Property Encryption Key:

Configure Password for Server Connection

Installation & Configuration Tutorial of XMPP Server (Openfire)



Setup

Setup Progress

✓ Seleção de Idioma

✓ Configurações do Servidor

▶ Configurações da Base de Dados

Configurações de Perfil

Conta do Administrador

Database Settings

Choose how you would like to connect to the Openfire database.

☐ Standard Database Connection

Use an external database with the built-in connection pool.

☒ Embedded Database

Use an embedded database, powered by HSQLDB. This option requires no external database configuration and is an easy way to get up and running quickly. However, it does not offer the same level of performance as an external database.

Continue

Installation & Configuration Tutorial of XMPP Server (Openfire)



Setup

Setup Progress

- ✓ Seleção de Idioma
- ✓ Configurações do Servidor
- ✓ Configurações da Base de Dados
- Configurações de Perfil
- Conta do Administrador

Profile Settings

Choose the user and group system to use with the server.

- ☒ **Default**
Store users and groups in the server database. This is the best option for simple deployments.
- ☐ **Only Hashed Passwords**
Store only non-reversible hashes of passwords in the database. This only supports PLAIN and SCRAM-SHA-1 capable clients.
- ☐ **Directory Server (LDAP)**
Integrate with a directory server such as Active Directory or OpenLDAP using the LDAP protocol. Users and groups are stored in the directory and treated as read-only.

Continue

[Installation & Configuration Tutorial of XMPP Server \(Openfire\)](#)



Setup

Setup Progress

✓ Seleção de Idioma

✓ Configurações do Servidor

✓ Configurações da Base de Dados

✓ Configurações de Perfil

▶ Conta do Administrador

Administrator Account

Enter settings for the system administrator account (username of "admin") below. It is important to choose a password for the account that cannot be easily guessed -- for example, at least eight characters long and containing a mix of letters and numbers. You can skip this step if you have already setup your admin account. If you skip this step during the new installation, the default password would be "admin".

Admin Email Address:

admin@example.com

A valid email address for the admin account.

New Password:

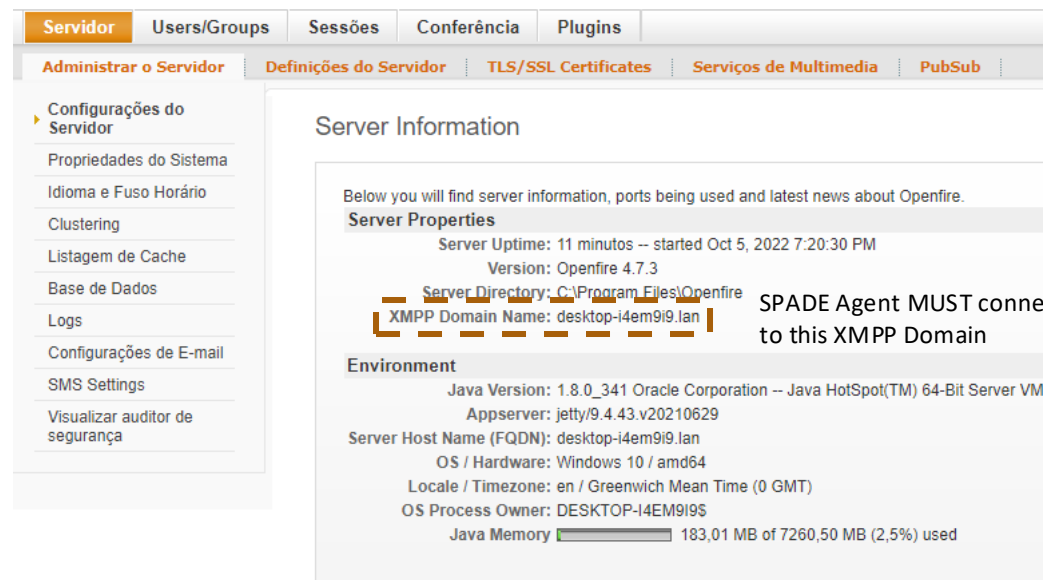
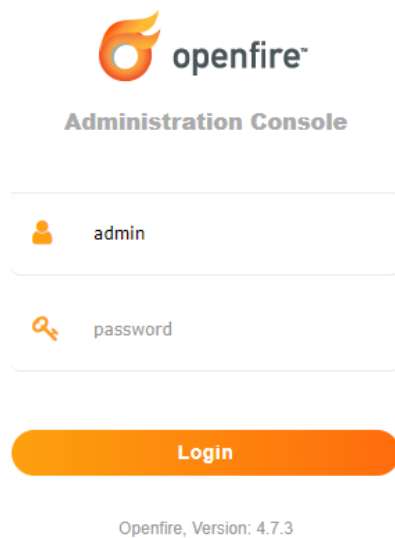
Confirm Password:

Continue

Skip This Step

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



The image shows the "Server Information" page in the Openfire Administration Console. The page has a sidebar with a menu of options: "Configurações do Servidor", "Propriedades do Sistema", "Idioma e Fuso Horário", "Clustering", "Listagem de Cache", "Base de Dados", "Logs", "Configurações de E-mail", "SMS Settings", and "Visualizar auditor de segurança". The main content area displays the following information:

- Server Properties**
 - Server Uptime: 11 minutos -- started Oct 5, 2022 7:20:30 PM
 - Version: Openfire 4.7.3
 - Server Directory: C:\Program Files\Openfire
 - XMPP Domain Name: desktop-i4em9i9.ian
- Environment**
 - Java Version: 1.8.0_341 Oracle Corporation -- Java HotSpot(TM) 64-Bit Server VM
 - Appserver: jetty/9.4.43.v20210629
 - Server Host Name (FQDN): desktop-i4em9i9.ian
 - OS / Hardware: Windows 10 / amd64
 - Locale / Timezone: en / Greenwich Mean Time (0 GMT)
 - OS Process Owner: DESKTOP-I4EM9I9S
 - Java Memory: 183,01 MB of 7260,50 MB (2,5%) used

Below the "Server Properties" section, there is a note: "Below you will find server information, ports being used and latest news about Openfire."

SPADE Agent MUST connect
to this XMPP Domain

[Install SPADE Python Package \(inside conda env.\)](#)

```
Anaconda Prompt (anaconda3)

(base) C:\Users\Utilizador>conda env list
# conda environments:
#
base                * C:\Users\Utilizador\anaconda3
SMA                  C:\Users\Utilizador\anaconda3\envs\SMA
helloworld           C:\Users\Utilizador\anaconda3\envs\helloworld

(base) C:\Users\Utilizador>conda activate SMA

(SMA) C:\Users\Utilizador>pip install spade_
```

A close-up, high-resolution image of a robot's head and upper torso is positioned on the left side of the slide. The robot has a white, smooth, human-like face with green eyes. Its neck and shoulder area are visible, showing a teal-colored collar and a circular metallic component with a dark center. The robot's head is turned slightly towards the right.

SPADE – Smart Python Agent Development Env.

Agentes e Sistemas Multiagente

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