

*Florida International University*

*Knight Foundation School of Computing and Information Sciences*

Software Engineering Focus

# Final Deliverable

AmLight - Learning OpenFlow/SDN Research and  
Experimentation

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**Abstract**

*Kytos is an ongoing, open-source, software-defined networking project aimed at delivering a modern, responsive, and easy-to-learn supporting platform to network developers. With mentoring from the AmLight team at Florida International University and current Kytos developers, the AmLight research project seeks to improve Kytos by enhancing graphical user interface features across several Networking Applications.*

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# Introduction

The Kytos project is an open-source Software-Defined Network (SDN) platform designed to be the fastest and easiest way to install, use, develop, and share Network Applications (NApps). Kytos is incredibly powerful and easy. Its modular design makes Kytos a lightweight SDN Platform and able to perform development and deployment with great speed.

## Current System

Kytos was started in 2014 and has been under active development since 2016. The project is composed of multiple subprojects with specific purposes and unique documentations. Developers can create and design their own NApps to be used with the Kytos SDN platform. Getting started with Kytos is easy and intuitive. The development team provides tutorials and documentation for new developers to get started with using Kytos and developing their own NApps. However, the current NApps lack many graphical user interface (GUI) features. This means that while it is easy for developers and programmers to use Kytos, it is not easy for regular users to do so. As of now, users need knowledge of Linux tools, JSON, and Application Programming Interfaces (APIs) to properly use Kytos.

## Purpose of New System

The purpose of the new system was to implement user friendly improvements. One such improvement was to change the dropdown in pathfinder containing metadata into a user input with autocompletion. Another improvement was to modify the panel showing the switches and interfaces for pathfinder. In the old implementation, the data would be shown without differentiating which was a switch and which was an interface. The new implementation now lets a user know the difference between each data. For `sdntrace_cp`, a new k-tool-bar with autocompletion, similar to the one in pathfinder, was to be implemented. This would also contain metadata that a user could input and search. Additionally, a panel also similar to the one found in pathfinder would be shown and implemented in the same way. Test cases for the NApps pathfinder and `sdntrace_cp` will be made to cover the desired endpoints. Handling of cookies will also help with displaying necessary data.

The new system features user-friendly names for switches and interfaces which were entirely numeric separated with colons previously. In the old implementation, the path from beginning to end would display a list of switches and interfaces that were long numbers only separated with colons. A better way to distinguish between a switch and interface would be to show the difference if an output was either one and simply tell the user, the show the user the unique ending numbers that distinguished each switch or interface



# User Stories

The following section provides an overview of the user stories that were implemented in this iteration of the project. These user stories served as the basis for implementing the project's features. This section also shows the user stories that are to be considered for future development.

## Implemented User Stories

- **User story # 1**
  - As a developer unfamiliar with Kytos, I want to familiarize myself with Kytos so that I understand the framework and what it can do.
- **User story # 2**
  - As a developer unfamiliar with the Kytos API, I want to familiarize myself with the API so that I can develop web user interfaces that use the API.
- **User story # 3**
  - As a developer unfamiliar with Vue.js, I want to familiarize myself with Vue.js so that I can build web user interfaces for Kytos.
- **User story # 4**
  - As a developer unfamiliar with Kytos development, I want to familiarize myself with the conventions and standards of code submissions so that I can contribute to the project.
- **User Story # 5**
  - As a developer working with others, I want to be familiar with using Github, so that I can work alongside other members of the team.
- **User Story # 6**
  - As a developer, I want to be comfortable working on a Linux system with a code base.
- **User Story # 7**
  - As a developer, I want to familiarize myself with Linux terminal commands through the installation of the Kytos virtual environment.
- **User Story # 8**
  - As a developer, I want to be comfortable navigating the Kytos UI to understand the different components.
- **User Story # 9**
  - As a developer, I want to understand the pathfinder component so I can better contribute to the UI .
- **User Story # 10**
  - As a developer, I want to have a better understanding of the Best Paths table to better contribute to the UI.
- **User Story # 11**

- As a developer, I want to change the dropbox input for Destination and make it a text input.
- **User Story # 12**
  - As a developer, I want to change the dropbox input for Source and make it a text input.
- **User Story # 13**
  - As a developer, I want to take the data on Best Paths and have the switches be displayed.
- **User Story # 14**
  - As a developer, I want to take the data on Best Paths and have the interfaces be displayed.
- **User Story # 15**
  - As a developer, I want to implement an autocomplete feature for the text input in Source.
- **User Story # 16**
  - As a developer, I want to implement an autocomplete feature for the text input in Destination.
- **User Story # 17**
  - As a developer, I want to make an API call so the metadata can be shown for the text input autocomplete feature for Source.
- **User Story # 18**
  - As a developer, I want to make an API call so the metadata can be shown for the text input autocomplete feature for Destination.
- **User Story # 19**
  - As a developer, I want to review the Kytos documentation so I can make a new k-tool-bar for sdntrace\_cp.
- **User Story # 20**
  - As a developer, I want to make the k-toolbar have a text input with autocomplete.
- **User Story # 21**
  - As a developer, I want to make an API call to obtain the metadata to be shown in the autocomplete feature.
- **User Story # 22**
  - As a developer, I want to review the Kytos documentation on how to make a panel for sdntrace\_cp.
- **User Story # 23**
  - As a developer, I want to differentiate the data in the panel for sdntrace\_cp.

## Pending User Stories

- **User Story # 24**
  - As a developer, I want to have a fully working implantation for test suites on the pathfinder NApp.

- **User Story # 25**
  - As a developer, I want to have a fully working implantation for test suites on the sdntrace\_cp NApp.
- **User Story # 26**
  - As a developer, I want cookie management to be fully implemented to show only required data .

# Project Plan

This section describes the planning that went into the realization of this project. This project incorporated agile development techniques that required the sprints to be planned incrementally. These sprint plans are detailed in this section. It also describes the components – both software and hardware – chosen for this project.

## Hardware and Software Resources

The following is a list of all hardware and software resources that were used in this project:

- Visual Studio IDE
- VirtualBox
- Ubuntu
- Kytos
- Python Virtual Environment
- GitHub
- Firefox
- Mininet
- MongoDB

## Sprints Plan

### Sprint 1

During Sprint 1, we:

- Familiarized ourselves with Kytos documentation.
- Familiarized ourselves with Vue.js documentation.
- Met with product owners to discuss goals for the project.

These following user stories were completed during this sprint:

- **User story # 1**
  - As a developer unfamiliar with Kytos, I want to familiarize myself with Kytos so that I understand the framework and what it can do.
- **User story # 2**
  - As a developer unfamiliar with the Kytos API, I want to familiarize myself with the API so that I can develop web user interfaces that use the API.
- **User story # 3**
  - As a developer unfamiliar with Vue.js, I want to familiarize myself with Vue.js so that I can build web user interfaces for Kytos.

## Sprint 2

During Sprint 2, we:

- Met with product owners and were assigned tasks.
- Contacted with product owners about setting up the virtual environment.
- Learned to use GitHub to contribute.

The following user stories were completed:

- **User story # 4**
  - As a developer unfamiliar with Kytos development, I want to familiarize myself with the conventions and standards of code submissions so that I can contribute to the project.
- **User Story # 5**
  - As a developer working with others, I want to be familiar with using Github so that I can work alongside other members of the team.
- **User Story # 6**
  - As a developer, I want to be comfortable working on a Linux system with a code base.
- **User Story # 7**
  - As a developer, I want to familiarize myself with Linux terminal commands through the installation of the Kytos virtual environment.

## Sprint 3

During Sprint 3, we:

- Realized there were complications during setup of the virtual environment that prevented us from contributing code.
- Met with product owners to try and resolve the case.
- Implemented tests to try and solve these complications.

No user stories were completed during this Sprint.

## Sprint 4

During Sprint 4, we:

- Realized complications were due to a unique case of the hardware we were using to run Kytos.
- Resolved these complications.
- Began contributing towards the project.

The following user stories were completed:

- **User Story # 8**

- As a developer, I want to be comfortable navigating the Kytos UI to understand the different components.
- **User Story # 9**
  - As a developer, I want to understand the pathfinder component so I can better contribute to the UI.
- **User Story # 10**
  - As a developer, I want to have a better understanding of the Best Paths table to better contribute to the UI.
- **User Story # 13**
  - As a developer, I want to take the data on Best Paths and have the switches be displayed.
- **User Story # 14**
  - As a developer, I want to take the data on Best Paths and have the interfaces be displayed.

## Sprint 5

During this Sprint 5, we:

- Worked on UI components for pathfinder.
- Added text input and panel adjustments.

The following user stories were completed:

- **User Story # 11**
  - As a developer, I want to change the dropbox input for Destination and make it a text input.
- **User Story # 12**
  - As a developer, I want to change the dropbox input for Source and make it a text input.
- **User Story # 13**
  - As a developer, I want to take the data on Best Paths and have the switches be displayed.
- **User Story # 14**
  - As a developer, I want to take the data on Best Paths and have the interfaces be displayed.
- **User Story # 15**
  - As a developer, I want to implement an autocomplete feature for the text input in Source.
- **User Story # 16**
  - As a developer, I want to implement an autocomplete feature for the text input in Destination.
- **User Story # 17**

- As a developer, I want to make an API call so the metadata can be shown for the text input autocomplete feature for Source.
- **User Story # 18**
  - As a developer, I want to make an API call so the metadata can be shown for the text input autocomplete feature for Destination.

## Sprint 6

During Sprint 6, we:

- Completed pathfinder UI components.
- Started sdnttrace\_cp UI components.
- Started test cases for NApps.

The following user stories were completed:

- **User Story # 18**
  - As a developer, I want to make an API call so the metadata can be shown for the text input autocomplete feature for Destination.
- **User Story # 19**
  - As a developer, I want to review the Kytos documentation so I can make a new k-tool-bar for sdnttrace\_cp.
- **User Story # 20**
  - As a developer, I want to make the k-toolbar have a text input with autocomplete.
- **User Story # 21**
  - As a developer, I want to make an API call to obtain the metadata to be shown in the autocomplete feature.
- **User Story # 22**
  - As a developer, I want to review the Kytos documentation on how to make a panel for sdnttrace\_cp.
- **User Story # 23**
  - As a developer, I want to differentiate the data in the panel for sdnttrace\_cp.

## Sprint 7

During Sprint 7, we:

- Prepared for the upcoming showcase.
- Made posters and recorded videos.
- Prepared the final documentation.

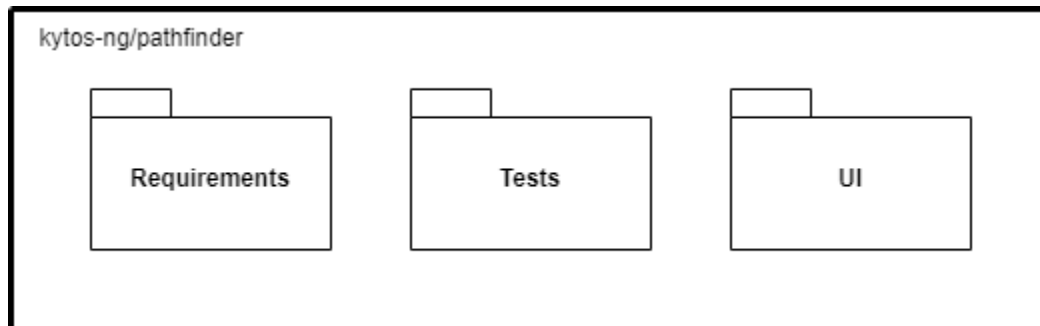
# System Design

This section contains information on the design decisions that went into this project. The architectural patterns are outlined and explained. The entire system is shown in a package diagram and the subsystems are defined. Finally, the design patterns used in the project are discussed.

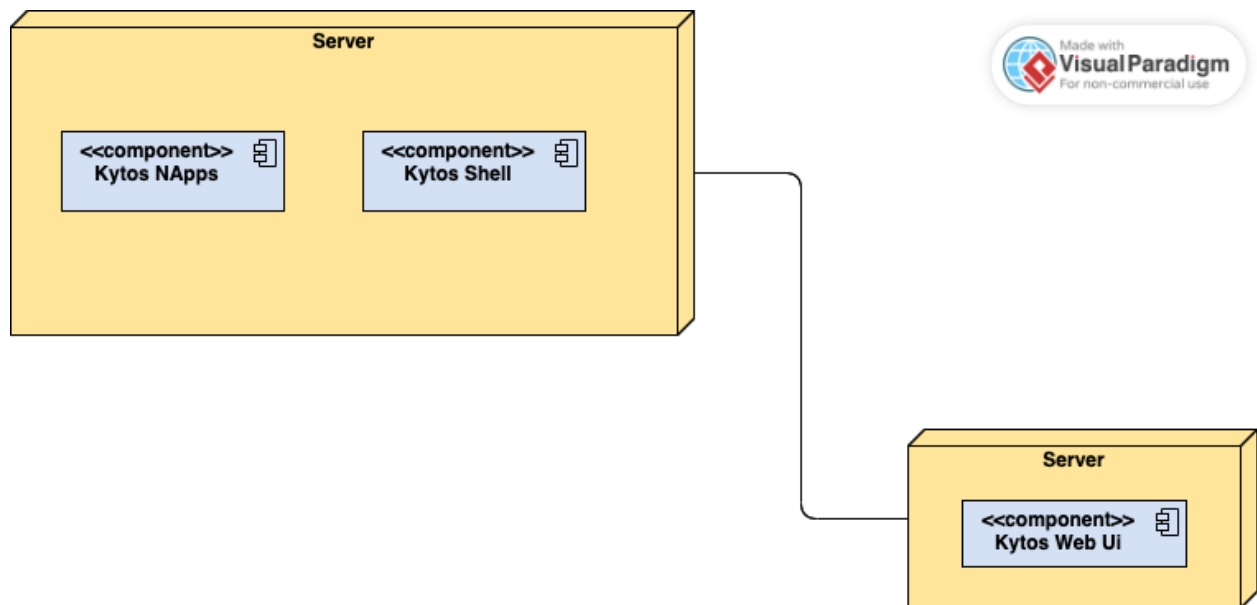
## Architectural Patterns

The Kytos project works as an umbrella for a multi-component architecture, in which any of the components are interchangeable. That means that other developers who would like to work on this project independently are free to replace any of its components with a modified version of their own. The Kytos of\_core uses a Client Server architecture: the client being the web UI, or anything else that may access the system using the REST API. The server is the of\_core module hosted by Kytos.

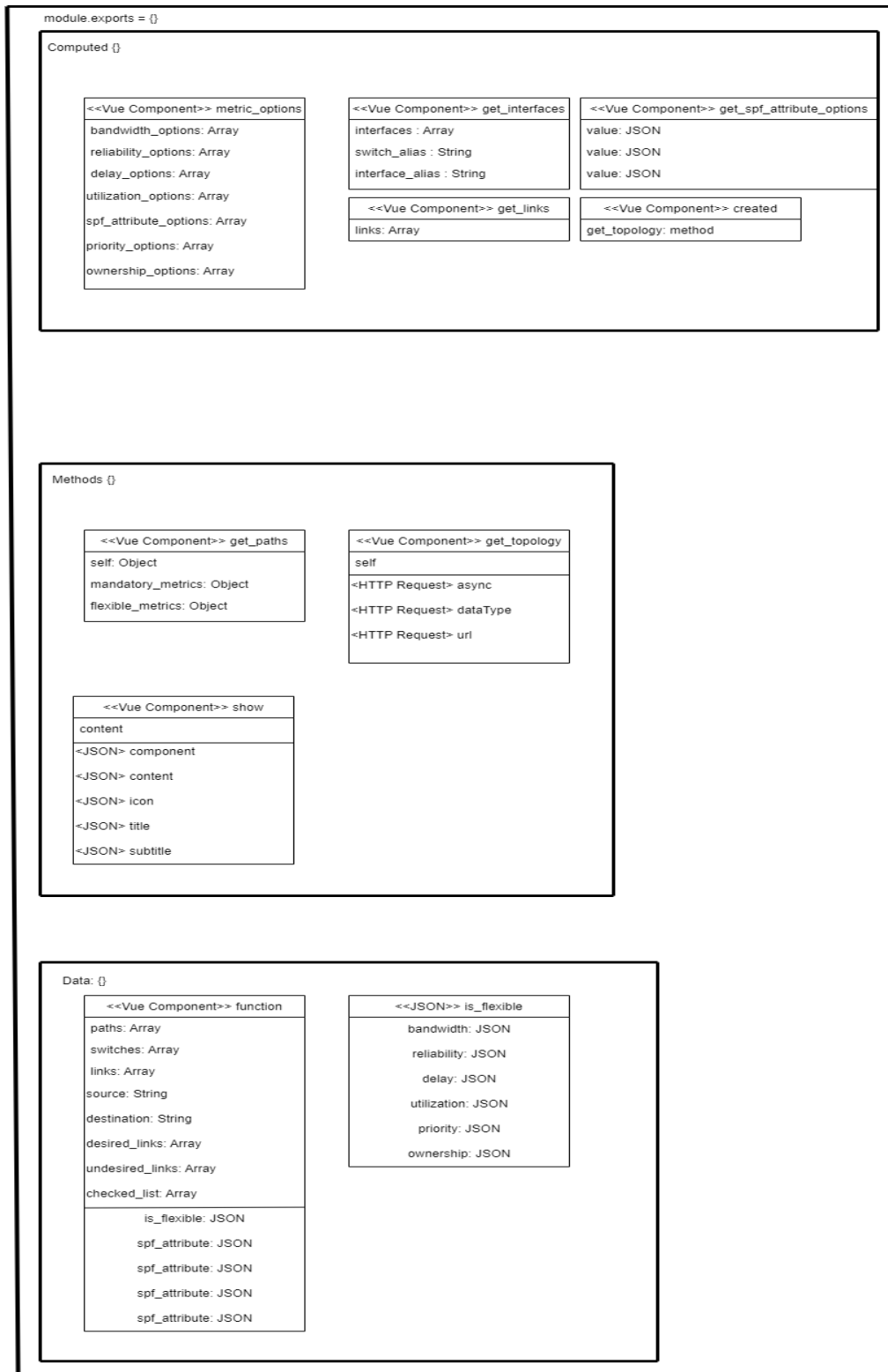
## System and Subsystem Decomposition (*Package Diagram*)

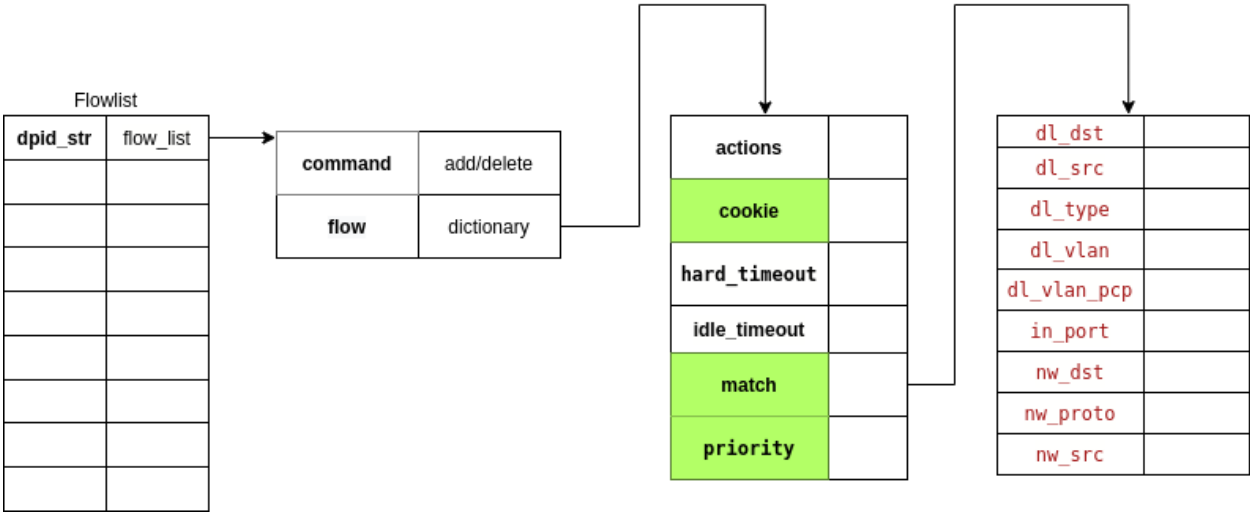


## Deployment Diagram



## Design Patterns *(Class Diagram)*





# System Validation

## Learning Kytos

### Test Case #: 1

**Test Data:** Object data. Containing interfaces.

**Expected Results:** Easier to read names for interfaces.

**Actual Results:** Interfaces output now string names with a numeric designation.

**Pass/Fail:** Pass

### Test Case #: 2

**Test Data:** Object data. Containing both interfaces and switches.

**Expected Results:** Easier to read names for switches and interfaces.

**Actual Results:** Interfaces and switches output now string names with a numeric designation.

**Pass/Fail:** Pass

## Running Kytos

### Starting Kytos

**Test Data:** Kytos shell. Run daemon to launch Kytos and Napps

**Expected Results:** Linux command prompt with Kytos logo. Check installation video

**Actual Results:** Kytos up and running with Napps

**Pass/Fail:** Pass

## Kytos API

### Making API call with Kytos

**Test Data:** Metadata components

**Expected Results:** Metadata displayed in terminal a dictionary format

**Actual Results:** Metadata displayed in terminal a dictionary format

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**Pass/Fail:** Pass

# Glossary

The following are terms used throughout the final project documentation.

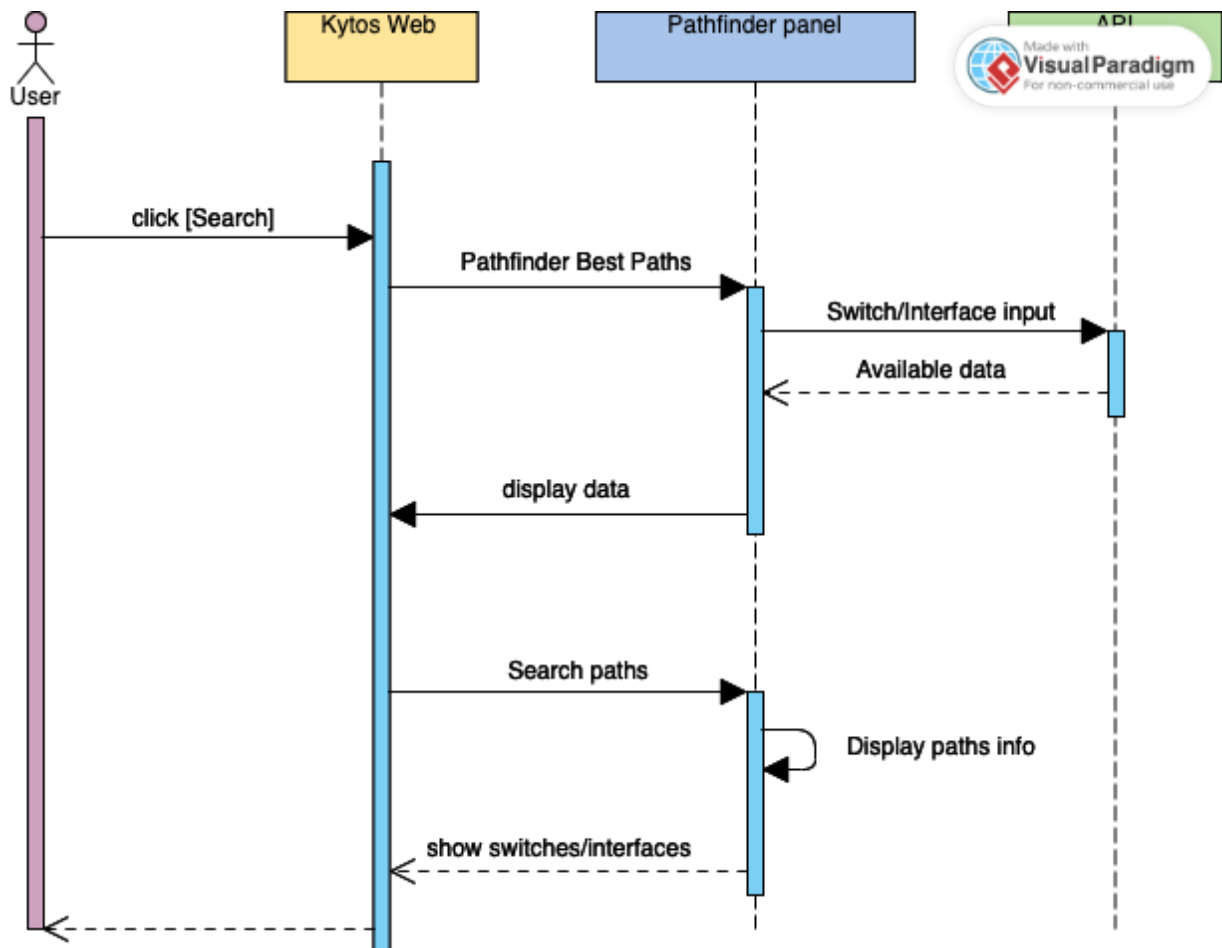
**Daemon** - a computer program that runs as a background process, rather than being under the direct control of an interactive user.

**Kytos** - A software designed network controller that uses OpenFlow protocols

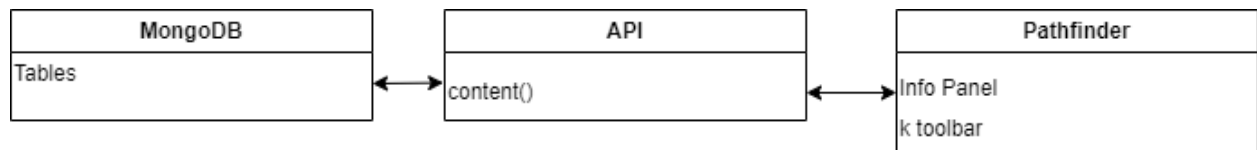
# Appendix

## Appendix A - UML Diagrams

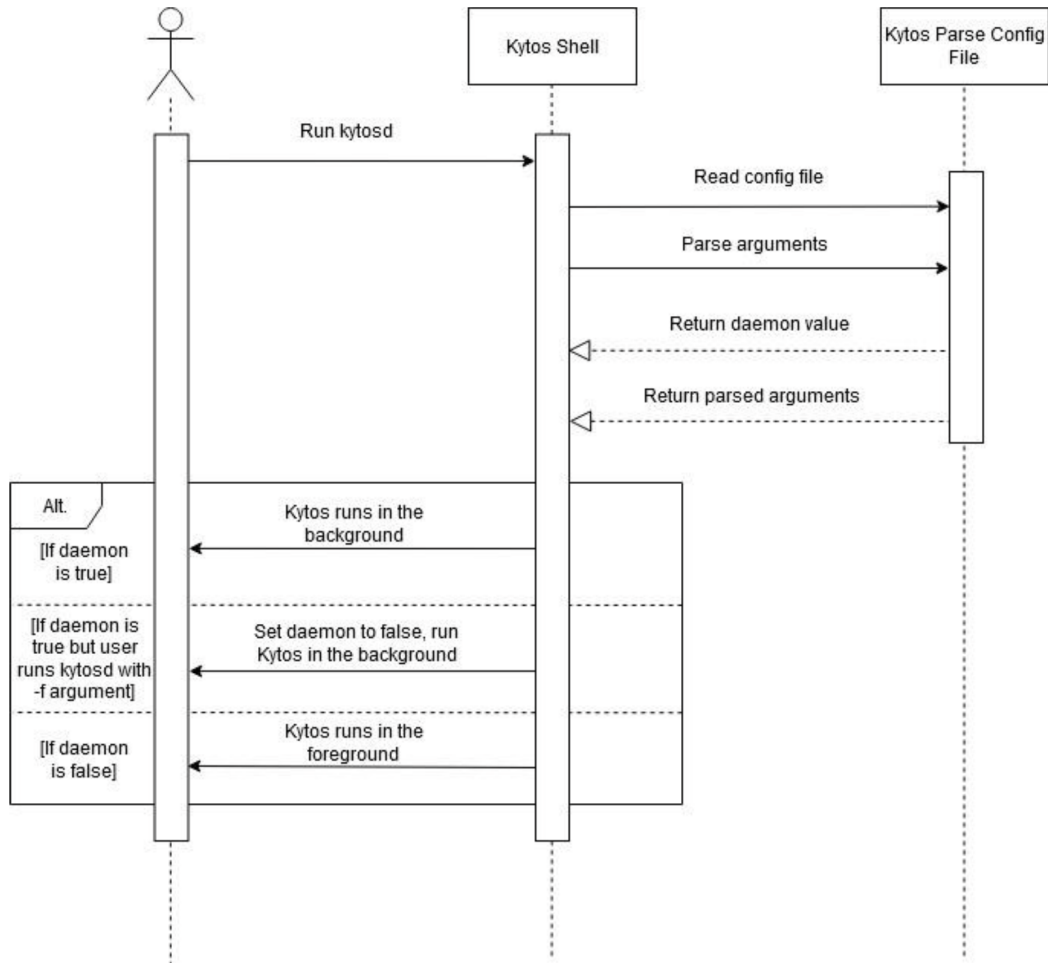
### Component Diagram



### Composite Diagram

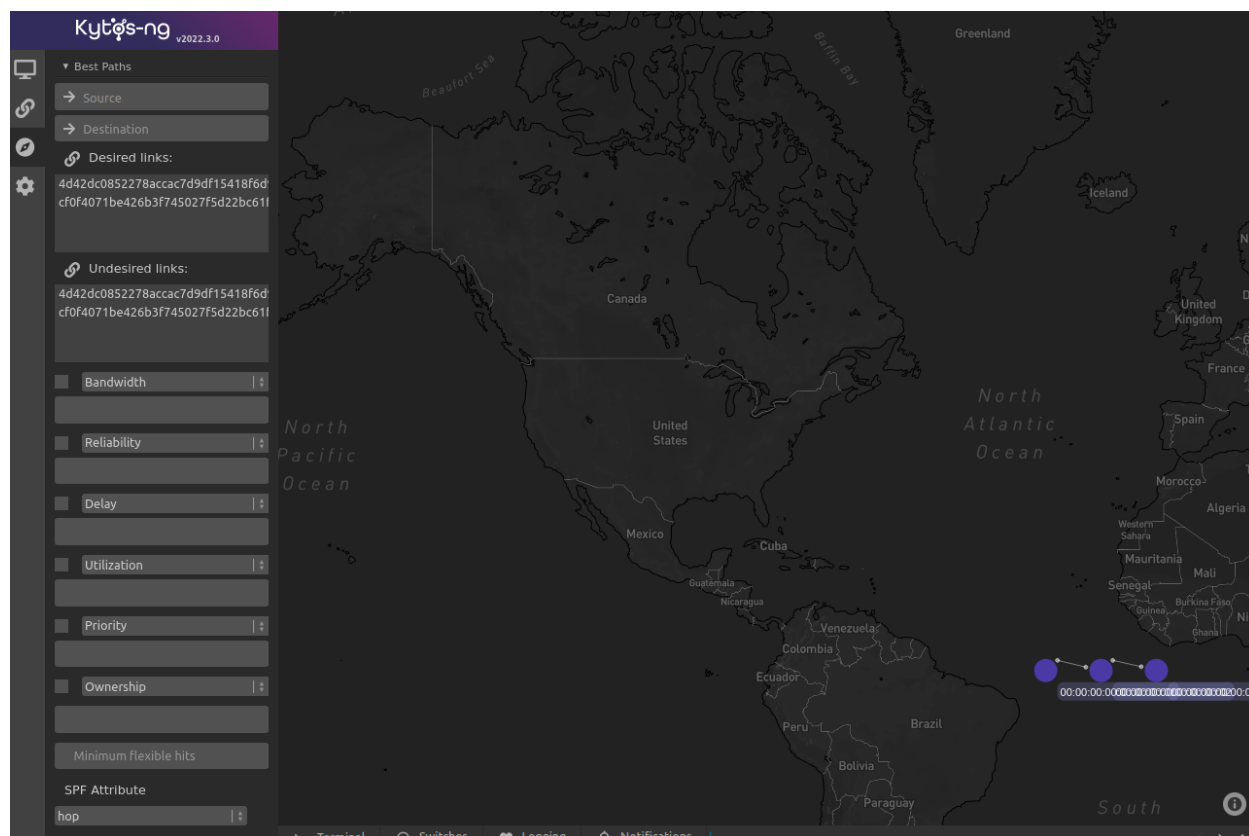


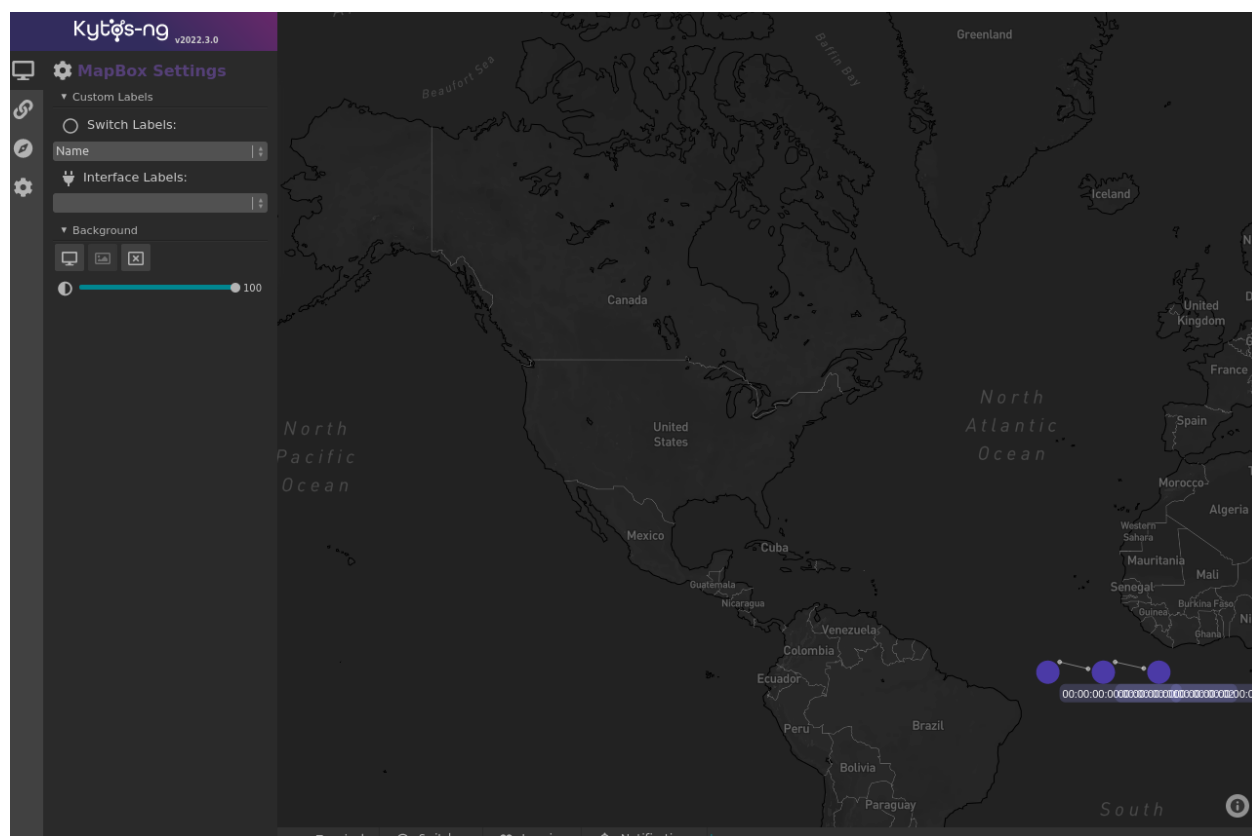
## Use Case Diagram

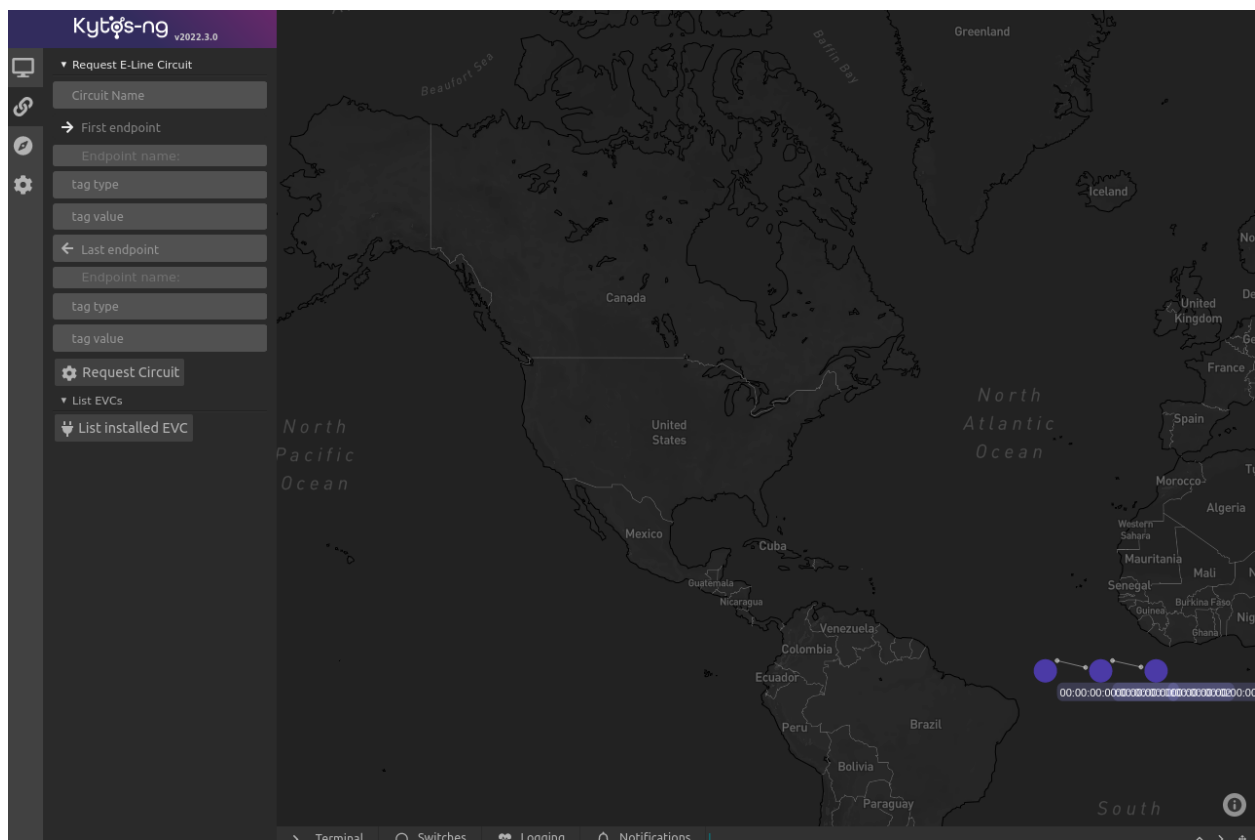


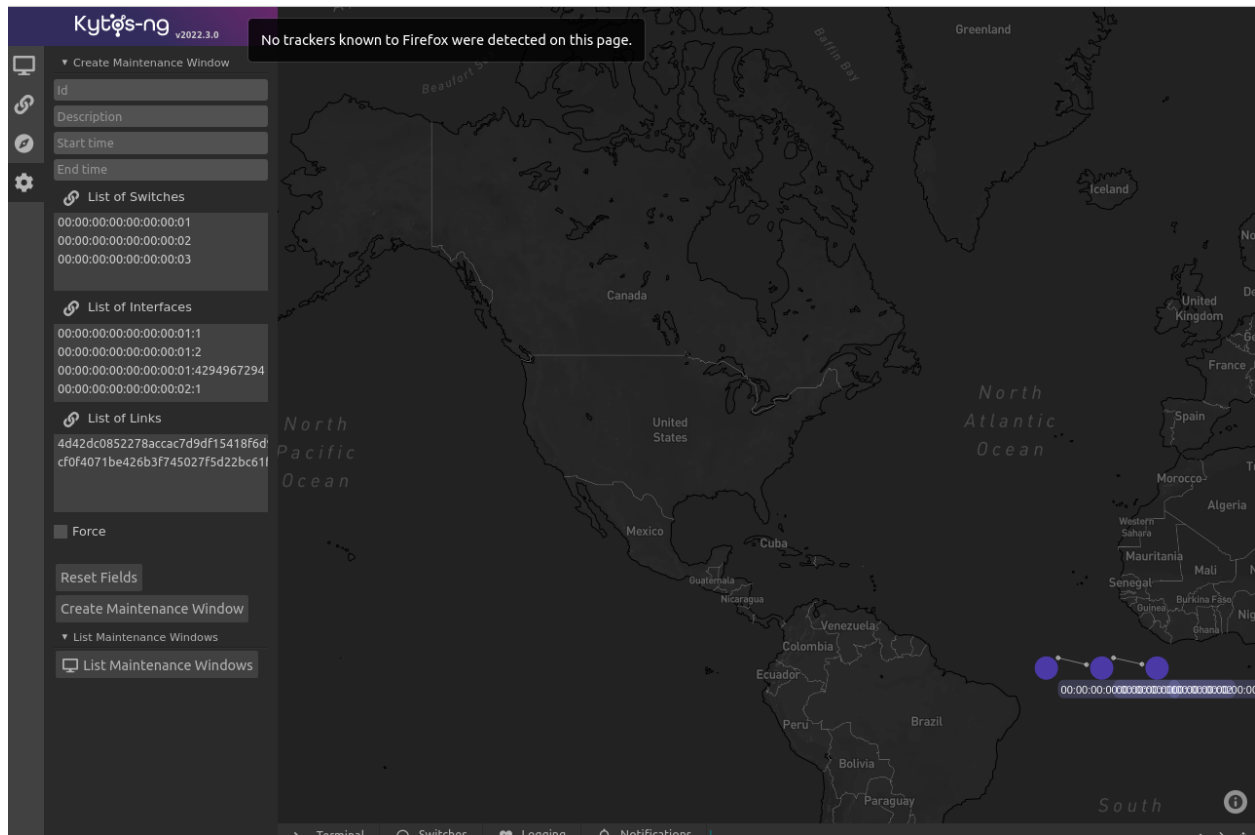
## Collaboration/Sequence/Timing Diagram

## Appendix B - User Interface Design









## Appendix C - Sprint Review Reports

### Sprint 1

#### Sprint Review Meeting Minutes: 1/29/2023

##### Attendees:

##### Capstone II:

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe

Start time: 8 pm

End time: 9 pm

We met up with the product owners, connected through slack, and discussed setting up the dev environment. We were also given access to the GitHub repository and tutorials for setting up for

the different networks we will be using. For now our individual user stories have not been made yet, but we are to:

- Review the documentation of Kystos-ng
- Make sure dev environment is running properly
- Review tutorials provided my Product Owners
- Connect to GitHub

### **Sprint Retrospective Meeting Minutes: 1/29/2023**

#### **Attendees:**

#### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe

Start time: 8:15 am

End time: 9:15 am

What went wrong?

- Late start to project

What went right?

- Met with Product Owners
- Given access to resources needed work on project
- Joined a slack group chat with Product Owners
- We made our own WhatsApp group chat and are keeping in contact with each other

How to address the issues in the next sprint?

- Finish with setup of dev environment
- Work on user stories provided by the Product Owners

## **Sprint 2**

### **Sprint Review Meeting Minutes: 2/12/2023**

#### **Attendees:**

#### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 8 am

End time: 8:15 am

Everyone on the team is coordinated and connected with the Product Owners. The task given to us to complete are two different UI tasks and one backend task:

- Pathfinder UI
  - User interface work to make it more user friendly and display names instead of codes/metadata
  - Work on destinations if available to display names of places instead of coordinates
- Sdntrace UI
  - User interface improvements to add a new drop down tool bar menu
  - Menu should have inputs to receive requests
  - A new panel should be made to show a table with all trace results from requests
- Kytos end-to-end tests
  - Decouple dump-flows to filter only what is needed based on NApps cookie prefix
  - Test for pathfinder endpoints
  - Test for flow\_stats endpoints

### **Sprint Retrospective Meeting Minutes: 2/12/2023**

#### **Attendees:**

#### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 8:15 am

End time: 8:30 am

What went wrong?

- Late start to project
- Trouble setting up the dev environment

What went right?

- During meeting with Product Owners, we received an explanation of the issues to be work on

- We can start working on User Stories to show the Product Owners
- Easier access to contact and set up meetings were made
- GitHub resources are fully documented with clear instructions on what the issues are
- New addition of a team member to help contribute to the project

How to address the issues in the next sprint?

- If trouble with dev environment continues, contact Product Owners
- Start splitting up the workload to tackle each issue in an efficient way

## Sprint 3

### Sprint Review Meeting Minutes: 2/26/2023

#### Attendees:

#### Capstone II:

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 8 am

End time: 8:15 am

After meeting with Product Owners and giving an update, the following user stories were accepted:

- User Story 1: UI - Display human friendly ids in the constraint path list
  - Render names to appear more user friendly
- User Story 2: Replace source and destination k-dropdown with k-input-auto
  - Drop down should show metadata locations when implemented
- User Story 3: Create a new k-tool-bar with inputs to request a sdntace
  - Design of new k tool bar to send inputs
- User Story 4: Create a new k-info-panel with a table to show all trace results
  - Create a new k-info-panel with a table to show all trace results
- User Story 5: Decouple dump-flows only filtering for what you need based on NApps cookie prefix
  - Cookie filtering with dump flows
- User Story 6: Pathfinder endpoints test
  - Add a test suite for pathfinder endpoints
- User Story 7: Flow stats endpoints test
  - Add test suite for flowstats endpoints

## **Sprint Retrospective Meeting Minutes: 2/26/2023**

### **Attendees:**

#### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 8:15 am

End time: 8:30 am

What went wrong?

- Virtual environment for project on ide had to be modified

What went right?

- During meeting with Product Owners, we received an explanation of the issues to be work on
- Some members were able to get the Kytos project running locally

How to address the issues in the next sprint?

- Help those that need to run Kytos locally
- Start splitting up the workload to tackle each issue in an efficient way

## **Sprint 4**

### **Sprint Review Meeting Minutes: 3/19/2023**

### **Attendees:**

#### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 12 pm

End time: 12:15 pm

After meeting with Product Owners and giving an update, the following user stories were accepted:

- User Story 1: UI - Display human friendly ids in the constraint path list
  - Render names to appear more user friendly
- User Story 2: Replace source and destination k-dropdown with k-input-auto
  - Drop down should show metadata locations when implemented
- User Story 3: Create a new k-tool-bar with inputs to request a sdnttrace
  - Design of new k tool bar to send inputs
- User Story 4: Create a new k-info-panel with a table to show all trace results
  - Create a new k-info-panel with a table to show all trace results
- User Story 5: Decouple dump-flows only filtering for what you need based on NApps cookie prefix
  - Cookie filtering with dump flows
- User Story 6: Pathfinder endpoints test
  - Add a test suite for pathfinder endpoints
- User Story 7: Flow stats endpoints test
  - Add test suite for flowstats endpoints

### **Sprint Retrospective Meeting Minutes: 3/19/2023**

#### **Attendees:**

#### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 12:15 pm

End time: 12:30 pm

#### **What went wrong?**

- A team member had an issue reconnecting to Kytos
- Web component for autocompletion still not finished

#### **What went right?**

- Progress for work seems to be going smoothly so far
- Spilt work between team members allows for work to be done mor efficiently

#### **How to address the issues in the next sprint?**

- Continue testing with web component. Function works but not as intended

## **Sprint 5**

**Sprint Review Meeting Minutes: 4/2/2023****Attendees:****Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 12 pm

End time: 12:15 pm

After meeting with Product Owners and giving an update, the following user stories were accepted:

- User Story 1: UI - Display human friendly ids in the constraint path list
  - Render names to appear more user friendly
- User Story 2: Replace source and destination k-dropdown with k-input-auto
  - Drop down should show metadata locations when implemented
- User Story 3: Create a new k-tool-bar with inputs to request a sdnttrace
  - Design of new k tool bar to send inputs
- User Story 4: Create a new k-info-panel with a table to show all trace results
  - Create a new k-info-panel with a table to show all trace results
- User Story 5: Decouple dump-flows only filtering for what you need based on NApps cookie prefix
  - Cookie filtering with dump flows
- User Story 6: Pathfinder endpoints test
  - Add a test suite for pathfinder endpoints
- User Story 7: Flow stats endpoints test
  - Add test suite for flowstats endpoints

**Sprint Retrospective Meeting Minutes: 4/2/2023****Attendees:****Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 12:15 pm

End time: 12:30 pm

What went wrong?

- Progress on end point tests is a little slow
- Not that much of an update for other user stories

What went right?

- Progress for work on other stories is assumed to be going smoothly so far
- Spilt work between team members allows for work to be done more efficiently

How to address the issues in the next sprint?

- Get an update on progress from everyone

## Sprint 6

### Sprint Review Meeting Minutes: 4/16/2023

**Attendees:**

#### Capstone II:

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 12 pm

End time: 12:15 pm

After meeting with Product Owners and giving an update, the following user stories were accepted:

- User Story 1: UI - Display human friendly ids in the constraint path list
  - Render names to appear more user friendly
- User Story 2: Replace source and destination k-dropdown with k-input-auto
  - Drop down should show metadata locations when implemented
- User Story 3: Create a new k-tool-bar with inputs to request a sdnttrace
  - Design of new k tool bar to send inputs
- User Story 4: Create a new k-info-panel with a table to show all trace results
  - Create a new k-info-panel with a table to show all trace results
- User Story 5: Decouple dump-flows only filtering for what you need based on NApps cookie prefix
  - Cookie filtering with dump flows
- User Story 6: Pathfinder endpoints test
  - Add a test suite for pathfinder endpoints

- User Story 7: Flow stats endpoints test
  - Add test suite for flowstats endpoints

## **Sprint Retrospective Meeting Minutes: 4/16/2023**

### **Attendees:**

### **Capstone II:**

- Jamal Bradshaw
- Gabriela Ramirez
- Juan Camilo Torrente Uribe
- Kenny Afonin

Start time: 12:15 pm

End time: 12:30 pm

### **What went wrong?**

- Progress on end point tests is still a little slow
- Not that much of an update from other user stories

### **What went right?**

- Progress for work on other stories is assumed to be going smoothly so far
- Spilt work between team members allows for work to be done mor efficiently
- UI components are working as expected

### **How to address the issues in the next sprint?**

- Get in touch with product owners to discuss shortcomings

## **Appendix D - Other Documents**

### **User Manuals**

### **Installation/Maintenance**

[https://docs.kytos.io/developer/setup\\_develop\\_environment/](https://docs.kytos.io/developer/setup_develop_environment/)

- \$ apt install git python3 python3-venv libpython3-dev

- `$ python3 -m venv kytos-environment`
- `$ source kytos-environment/bin/activate`
- `$ pip install --upgrade pip setuptools wheel`
- for repo in python-openflow kytos-utils kytos; do  
    (kytos-environment) `$ git clone https://github.com/kytos/${repo}`  
done
- for repo in python-openflow kytos-utils kytos; do  
    (kytos-environment) `$ cd ${repo}`  
    (kytos-environment) `$ python3 setup.py develop`  
    (kytos-environment) `$ cd ..`  
done

### Shortcomings/Wishlist

- GitHub issue #17: Having the metadata or port name displayed would be useful.
- GitHub issue #152: Fully implemented cookie test case were not able to be finished.
- GitHub issue #202: Test cases were not able to be fully implemented and tested.
- GitHub issue #203: Test cases were not able to be fully implemented and tested

# References

AmLight Kytos team for guidance.