

# **Anomaly Detection in Industrial Networks**

PSE GRUPPE

KOMPETENZZENTRUM FÜR ANGEWANDTE SICHERHEITSTECHNOLOGIE

Advisor: M.Sc. Ankush Meshram

This Document outlines the requirements (both functional and non-functional), environment, target audience, and use cases of the software described below.

Version 0.5

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## 1 Purpose

The goal of this project is to create a software visualization tool for industrial network traffic to simplify the analysis of anomalous behaviour, both in realtime and from captured stored data.

This software is part of the ADIN framework and is referred to as the "ADIN Inspector".

One component to achieve this goal is a web interface built with modularity in mind so as to make it easily extendable.

The Web view is able to display a series of diagrams and charts to easily identify the behaviour of the network. Within the Web view the user has the ability to zoom, select, highlight, and filter out data to better understand the aforementioned behaviour in different OSI layers, as well as visualize the flow rate between network nodes.

To support this Web view a back-end messaging solution is needed. This allows the user to easily switch between multiple streams of captured data.

## 2 Overall Description

While computers can analyze raw data easily, for humans it's easier to recognize behavior using visual aids. Visual analytics is utilizing graphics to enhance human cognition to understand a problem better or find 'a needle in the haystack' within a huge amount of data. Making it an invaluable tool for security analysis.

Industrial network security aims to understand the communication network traffic generated in an industrial production system. Analyzing the traffic generated by underlying industrial protocols is the primary step.

Real-time visualization of analyzed network data will help the end-user to understand the system's communication behavior and changes within it more clearly. Deviations or incidents can be detected visually by operators as they are occurring or already persisting.

Supplemental to this, the ability of operators to run an analysis of past anomalous behavior can help strengthen infrastructure for future failure or attacks. As well as provide useful information for training of new security analysts.

### 3 Interfaces

The environment of the project is a modern browser with LAN access. The project is OS-agnostic. Therefore the underlying Operating system is irrelevant on the users end.

#### 3.1 Software

- Client
  - web-browser of the latest generation.
- Server:
  - Java
  - Kafka messaging framework
  - MongoDB database

#### 3.2 Hardware

- Client:
  - System capable of network connectivity
- Server:
  - Network capable system
  - System capable of running all backend-software components
  - System with adequate storage

## 4 Functional Requirements

### 4.1 Must Have

- When opening the Web view the user has to be greeted by a login screen.
- There need to be at least two levels of access for different account types (aka security roles). Level of access is defined as: the specific set of data streams the user is able to view and select to analyze.
- Once logged in an user has to be able to select a data stream to be visualized.
- The user has to have the ability to select multiple diagrams to visualize the selected data stream.
- The user can use at least these diagram types:
  - A timeline plot
  - A scatter plot

- A Network diagram
- The user is able to dynamically change which component of the data is used in both the X and Y axis of the diagram.
- The user should be able to add new diagrams to the GUI and configure them ( i.e. setting diagram type and axis) both at creation and at a later time.
- The GUI has to support a minimum of 4 different diagrams at once.
- Each diagram should be able to be maximised to take on the full size of the diagrams container.
- Each drawn diagram can be connected to a different data stream.
- The amount of data can be limited via a slider, effectively setting a limited time window, to which all diagram must update to.
- There needs to be an auto scroll function (play button) which automatically scrolls through the selected time window and whose speed is adjustable.
- The user has to be able to log out of the system.
- Within the slider the user is able to scroll through the timeline and the diagrams need to react in real-time.

## 4.2 Should Have

- The GUI should be able to support an undeterminate number of diagrams and scroll-bar.??

## 4.3 Nice To Have

- Interactive filter options (Sliders, drop down menus etc.)
- Extended selection of diagram types (To be announced).
- Save the session state and display it in the user profile.

# 5 Data Requirements

## 5.1 User Data

- User ID (Unique)
  - User Name (*Unique*)
  - User Password
  - User role

## 5.2 Event stream data for Web UI

- Timestamp
- 2 types of events: one is notification (warning etc.), one is actual data point
  - Notification
    - \* Severity level
    - \* Notification content
  - Data Point
    - \* Source
    - \* Destination
    - \* Packet type, eg. protocol or network layer
    - \* Packet summary

## 5.3 Raw packet metadata

Raw packet metadata include Time, Source, Destination, Protocol and Packet Length.

# 6 Non-Functional Requirements

**NF200** The rendering latency should be no longer than 2 seconds.

**NF300** The web UI should be viewable on modern web browsers.

**NF400** The framework should be able to handle data streams from at least 500 nodes.

**NF500** The web UI should be modular and easily extendable with:

NF510 New diagram types

NF520 New filters and aggregation methods

NF530 New data types for input data

**NF600** The system needs to provide access control that authenticates users.

## 6.1 Quality Requirements

| Product Quality       | really good | good | normal | not relevant |
|-----------------------|-------------|------|--------|--------------|
| <b>Functionality</b>  |             |      |        |              |
| Appropriateness x     |             |      |        |              |
| Accuracy              | x           |      |        |              |
| Interoperability      |             |      | x      |              |
| Security              | x           |      |        |              |
| <b>Reliability</b>    |             |      |        |              |
| Error tolerance       |             |      | x      |              |
| Recoverability        |             |      | x      |              |
| <b>Usability</b>      |             |      |        |              |
| Understandability x   |             |      |        |              |
| Learnability          |             |      |        | x            |
| Usability             | x           |      |        |              |
| <b>Efficiency</b>     |             |      |        |              |
| Time behaviour        |             | x    |        |              |
| Consumption behaviour |             | x    |        |              |

## 7 Essential Test cases

### T100 Successful login

**Precondition** Open browser window.

**Action** The user enters the URL for the ADIN web server in the address bar and presses Enter.

**Reaction** The browser loads the ADIN website and shows the login screen.

**Precondition** ADIN website had been opened and show the login screen.

**Action** The user enters a valid username and the corresponding password.

**Reaction** Successfully logged in. The browser loads the ADIN main screen with one empty diagram.

### T101 Failed login (wrong username or wrong password)

**Precondition** Open browser window.

**Action** The user enters the URL for the ADIN web server in the address bar and presses Enter.

**Reaction** The browser loads the ADIN website and shows the login screen.

**Precondition** ADIN website has been opened and shows the login screen.

**Action** The user enters either a valid username and an incorrect password or a non existing username and an arbitrary password.

**Reaction** The login screen shows an error message that the username or password is incorrect and the entry field for the password is cleared.

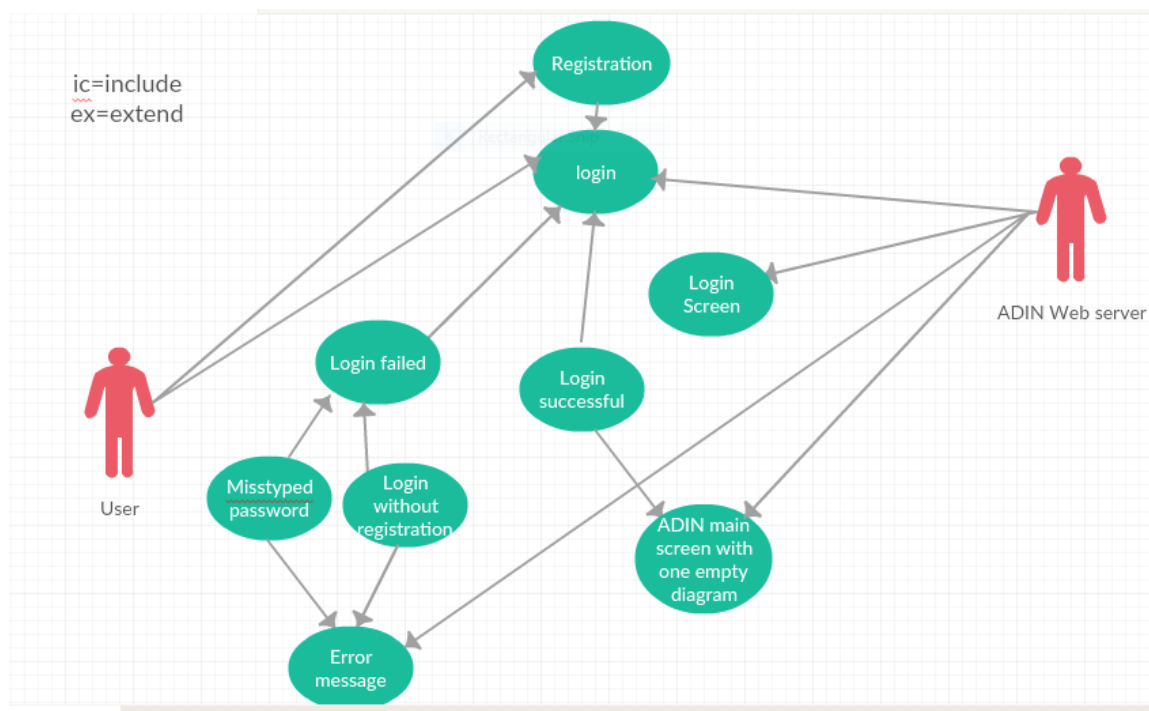


Figure 1: Log-in Cases

**T200** Open second diagram.

**Precondition** The browser has been logged in to ADIN and shows the main screen with one empty diagram.

**Action** The user presses the "New Diagram" button on the top right side of the screen three times.

**Reaction** The browser opens a modal with diagram settings

**Action** The user presses the create button at the bottom left

**Reaction** The browser opens a second diagram, splitting the diagram panel in to two.

**T210** Open multiple diagrams

**Precondition** The browser has been logged in to ADIN and [T200] has been passed.

**Action** The user repeats [T200] two more times.

**Reaction** The diagrams grid now displays four diagrams in a 2 x 2 formation.

**T300** Filtering

**Precondition** The browser has been logged in to ADIN and shows at least one diagram

**Action** The user enables a filter from the global filters section.

**Reaction** The diagram now only shows filtered data



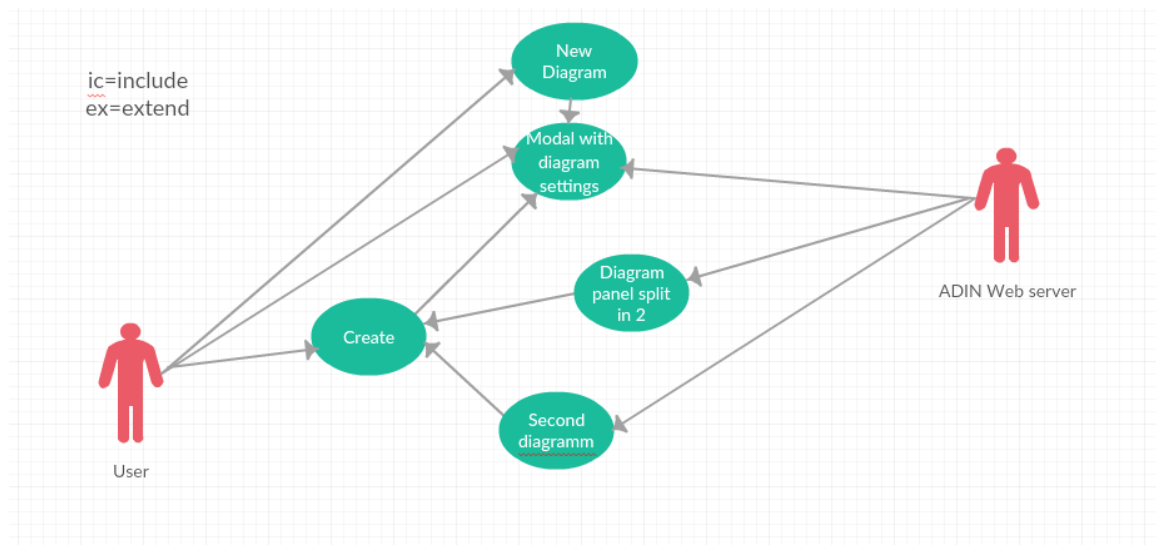


Figure 2: Second Diagram

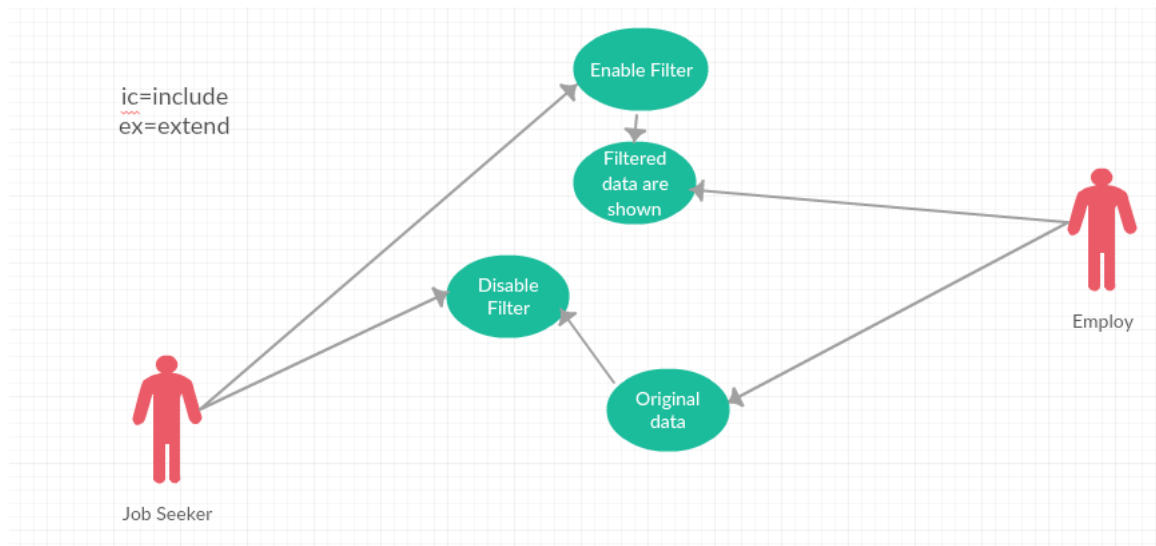


Figure 3: Enable/Disable Filter

**Action** The user disables the same filter.

**Reaction** The diagram shows original data again

**T301** Filter chaining

**Precondition** Logged in to ADIN and at least one diagram and one global filter is active

**Action** The user enables another filter from the global filters section.

**Reaction** The diagram now only shows relevant data

**T400** Full screen a diagram

**Precondition** Logged in to ADIN and shows at least two diagrams

**Action** The user presses the full screen button on the top right corner of the diagram

**Reaction** The diagrams window is maximized to the diagram's container of the web page.

**T450** Full screen and exit Full screen

**Precondition** Logged in to ADIN and shows at least two diagrams

**Action** The user presses the full screen button on the top right corner of the diagram

**Reaction** The diagrams window is maximized to the diagram grid of the web page.

**Action** The user presses the exit full screen button on the top right corner of the diagram

**Reaction** The diagram grid of the web page is restored.

**T500** Play button basic functionality

**Precondition** Logged in to ADIN and shows at exactly one diagram.

**Action** The user presses the play button at the bottom left of the web page.

**Reaction** The play button turns into a stop button.

**Reaction** The diagram updates according to the time shown at the play head.

**Action** The user presses the stop button.

**Reaction** The diagram remains static with the currently displayed data.

**T510** Time window(s)

**Precondition** Logged in to ADIN with one diagram. The play head is in its default position all the way to the left

**Action** User drags the left diagram time window key-frame to the right.

**Reaction** The timestamp above the keyframe updates according to its position

**Action** User drags the right diagram time window key-frame to the right.

**Reaction** The timestamp above the keyframe updates according to its position

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**T511** Multiple Time windows

**Precondition** Logged in to ADIN At least 2 diagram windows open

**Action** User clicks on one of the diagrams

**Reaction** Corresponding keyframes highlight in the timeline and display their timestamp on top of themselves

**Reaction** All NOT corresponding keyframes gray out and hide their timestamps

**Action** User now clicks on a different diagram

**Reaction** Previously highlighted keyframes gray out and keyframes corresponding to selected diagram highlight and display their timestamp

**Reaction** All NOT corresponding keyframes gray out and hide their timestamps

**T512** Time Window dragging restriction

**Precondition** Logged in to ADIN At least 2 diagram windows open Test case [T711] passed One diagram has been selected

**Action** User tries to drag a not highlighted keyframe from the timeline

**Reaction** Unable to drag and drop not highlighted keyframes

## 8 Software Modeling

### 8.1 GUI

The basic data structure needed for graphs are a given set of nodes and a given set of edges, as they are often drawn as node-link diagrams. In the postal data set, nodes could represent the origins and destinations of postal flows. Edges represent the flows between the respective origins and destinations. In intelligence analysis, investigators use semantic graphs to organise concepts and relationships as graph nodes and links in hopes of discovering key trends, patterns, and insights.” A key issue in graph visualisation is the size of the graph, i.e. the size of the data to visualise. With a growing amount of data to display, graphs can become too complex and overburdening for the analyst’s cognitive capacity. It thus becomes difficult for the user to conduct significant analysis. Because of the issues described above, research often focuses on ways to solve the problems of visual clutter, e.g. by aggregation or clustering techniques, which is also one of the main topics of cartographic generalisation.

In this subsection we’ll discuss the GUI, its components and the workflow of a typical user.

As the program is opened the user is greeted with a login screen shown in Figure 4. After the user has entered its credentials and clicked on the login button he is shown Figure 5.

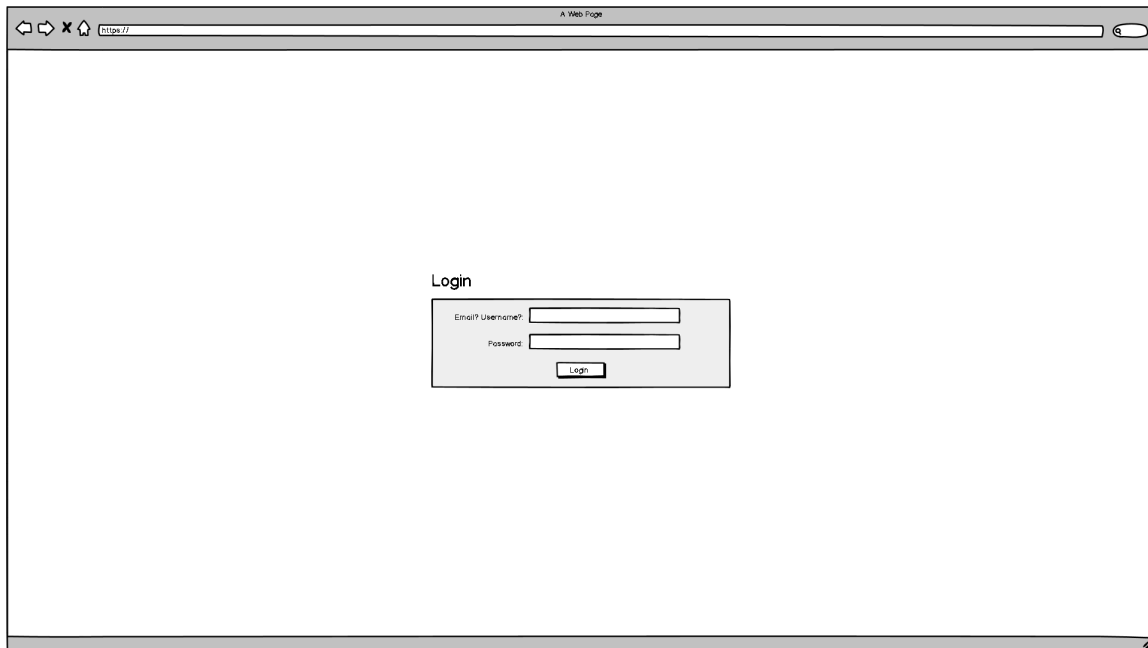


Figure 4: The Login Windows shown as the page is first loaded

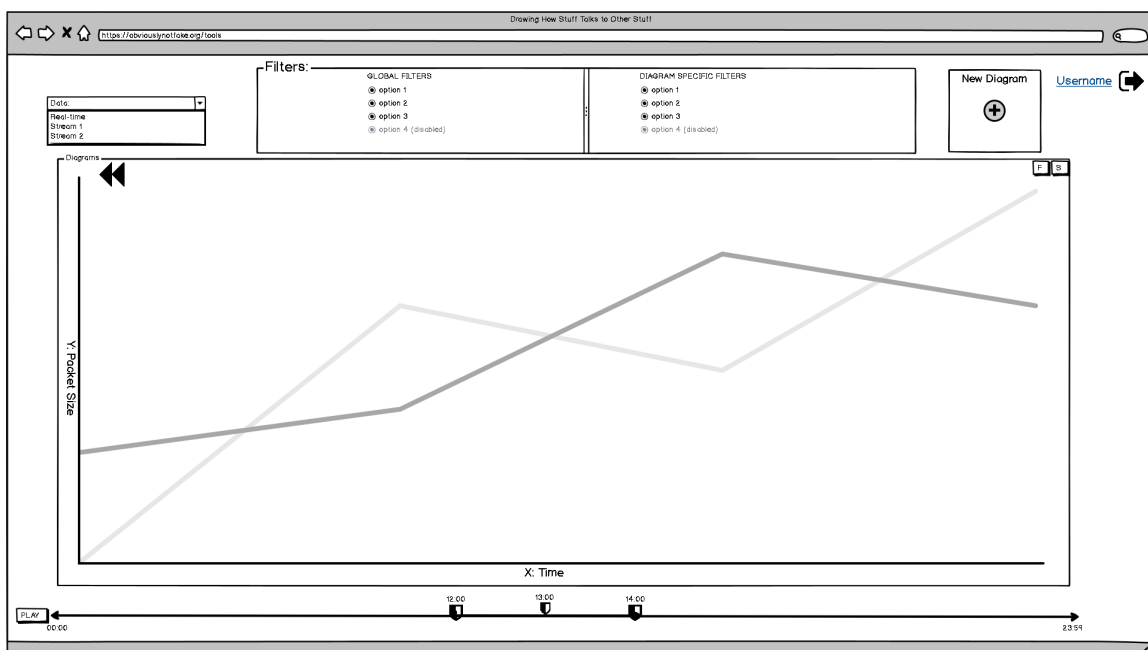


Figure 5: The Main window the user sees once he logs in

To discuss in depth this interface it has been divided into subsections labeled in Figure 6, these are:

1. The Data stream drop down menu allows the user to select which stream he is currently listening to. This dropdown menu shows the selected diagram's selected data stream and by default is set to real-time.
2. Here the user can set filters affecting all diagrams, namely limiting which layers and protocols are currently being shown.
3. Here are the filters that can further restrict the data being shown in the selected diagram.
4. By clicking this button the user can create a new diagram shown in number 5. The creation workflow is shown in Figure 7 to Figure 6.
5. Here is the currently logged in user, by clicking the button to the right of his name the user can log out.
6. This is the diagrams container, inside are all diagrams the user has created with all the set constraints. At most 4 diagrams are shown on the container, and more can be made visible via the slider on the right of the container.
7. This is a diagram.
8. By hovering with the mouse over a data point a tooltip is shown with all data associated with this data point.
9. These buttons control whether a diagram is fullscreen and the diagram settings. By clicking the button labeled F the diagram grows to take on all available space on the container, like shown in Figure 5.  
Clicking on the button labeled "S" replaces the diagram with the Settings for this diagram like shown in Figure 7
10. The play button auto scroll along the selected time frame
11. This timeline shows on the left and right bottom labels the beginning and end of all data streams, the labels on top show the currently selected time window and are movable to increase,decrease the time window, the middle shield icon shows the current time while being played, and is also movable to scroll by data manually.  
(TBD)

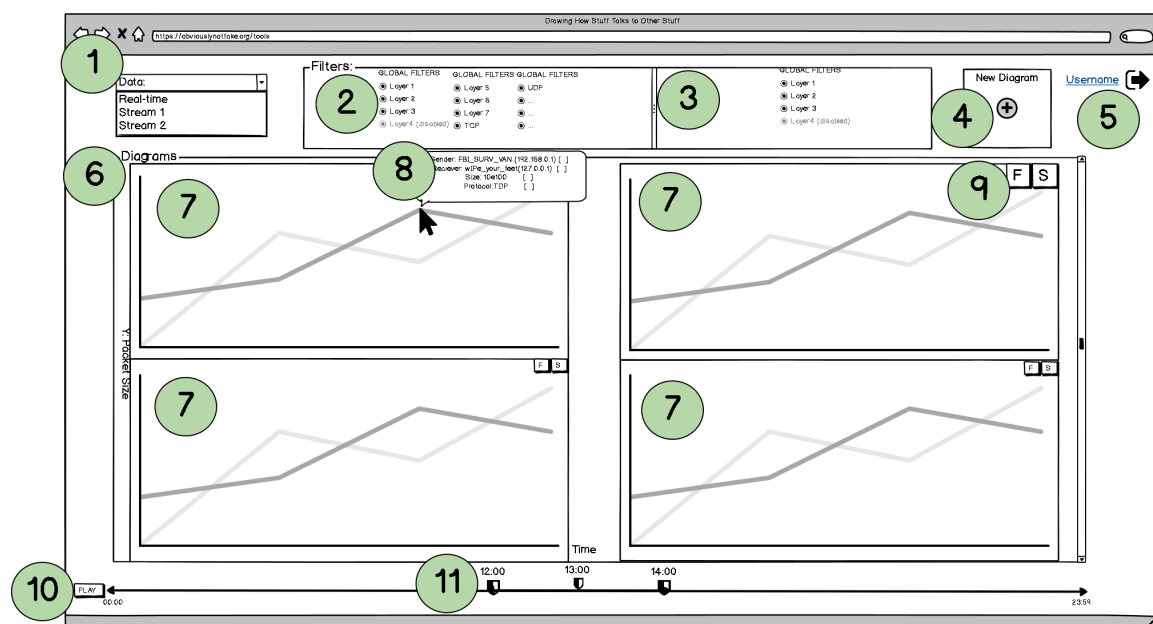


Figure 6: The GUI divided into relevant sections

Next we'll take a look at the workflow a user will go through when opening a new diagram.

As referenced above Figure 5 is what the user first sees. When he wants to create a new diagram, by clicking the button labeled new diagram, the Main window is split (shown in Figure 7) and the new diagram settings are shown where the new diagram will be.

The user sets here the settings for the new diagram, these are:

- Which data stream it draws its data from
- Which data is pulled to be represented as the x and y axis
- Any filters the user wants to apply at the start

Afterwards, the screen looks like Figure 8, the diagram container split, by going through this process two more times the diagram container fills up, containing four diagrams total (shown in Figure 9), at this point the diagrams have their minimum size.

Any diagrams created afterwards are spawned underneath the existing ones and the user can scroll up and down to view all of them (shown in Figure 10) (TBD)

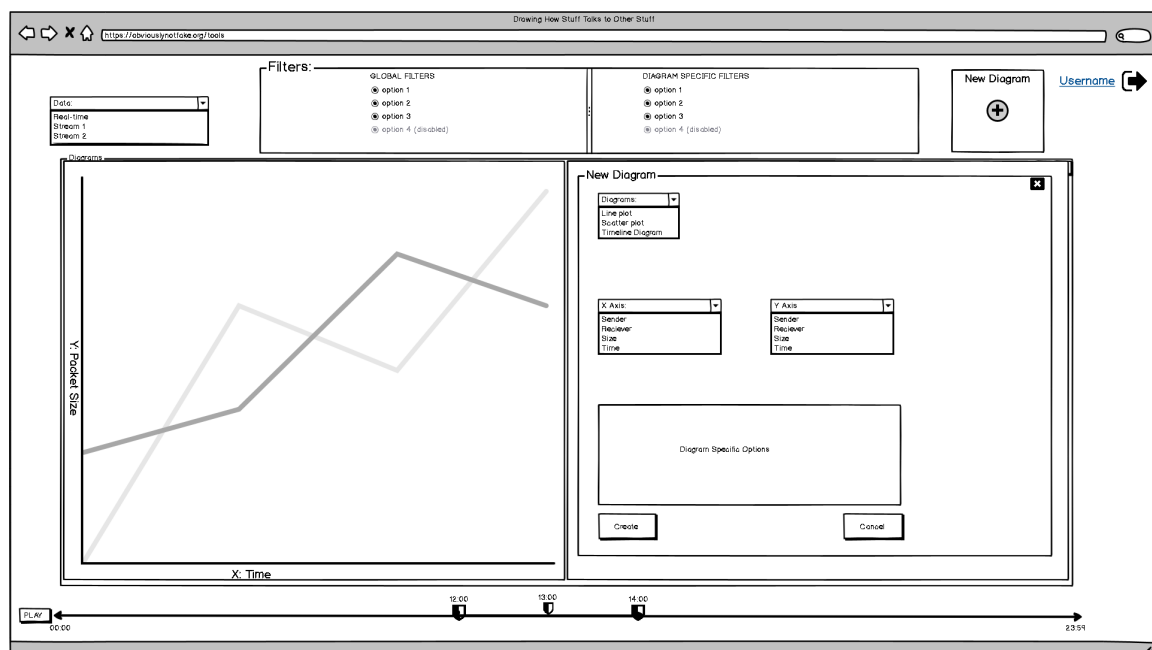


Figure 7: Main window split in two after user has clicked on the "New diagram" button. New diagram options are set up on the right.

TODO:MISSING SECTION ABOUT TOOLTIP FILTERING, NEED TO TALK ABOUT FINAL CHANGES TO THIS! IMAGES ARE NOT FINAL , STILL UP FOR DEBATE

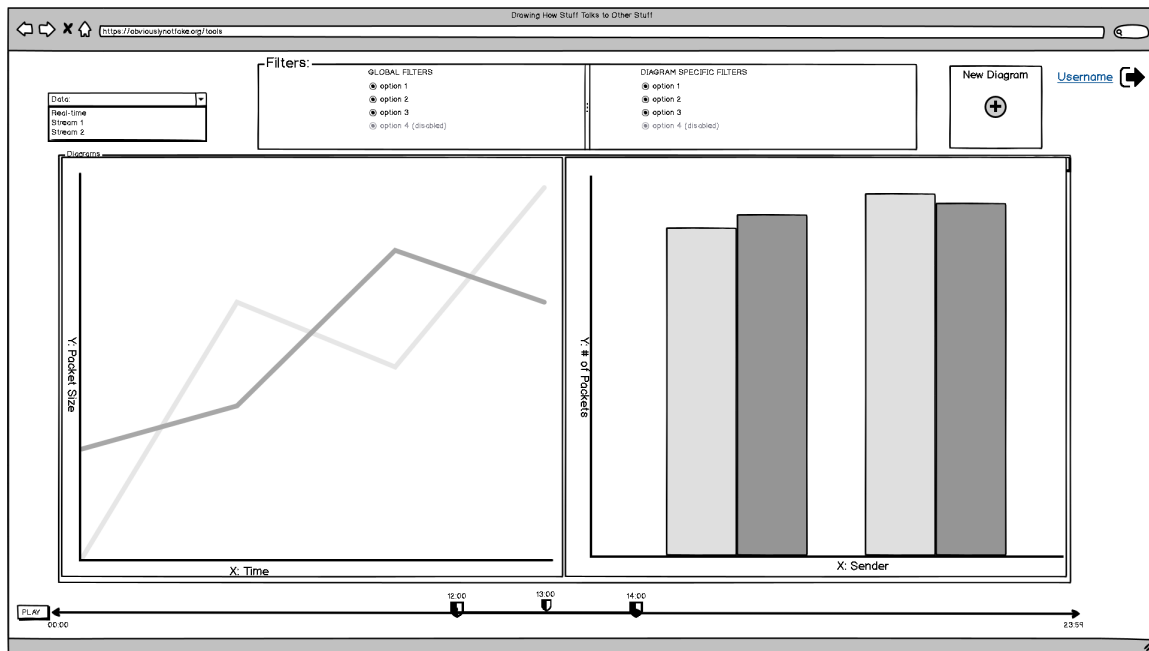


Figure 8: Main Window with two diagrams side by side.



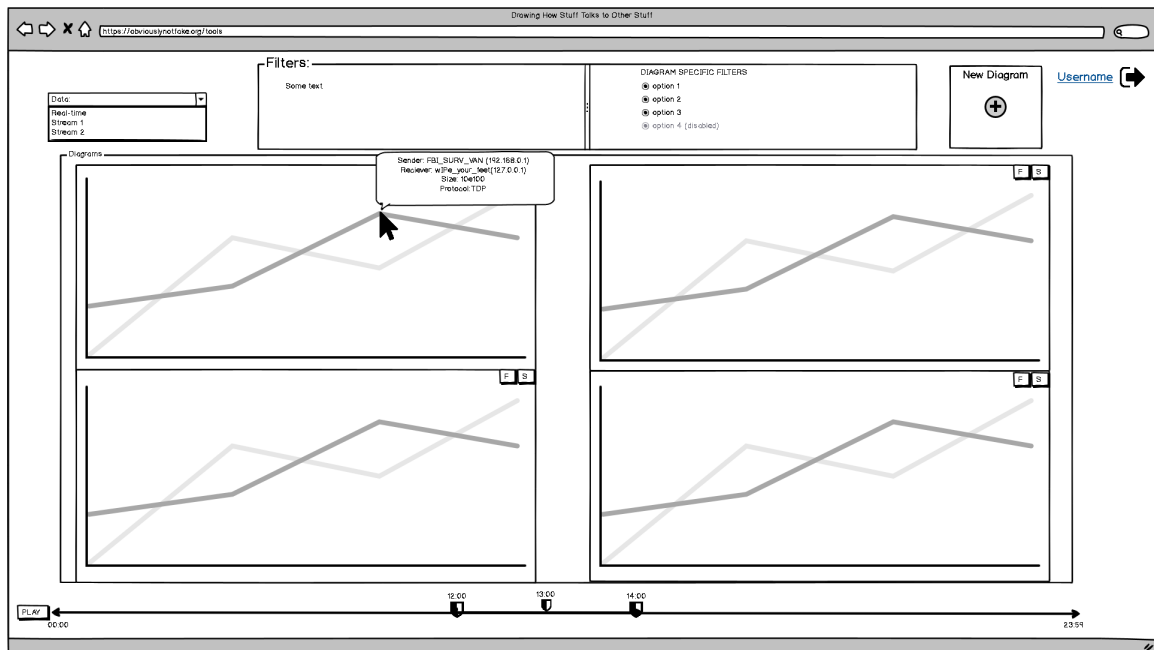


Figure 9: Main window with four diagrams open

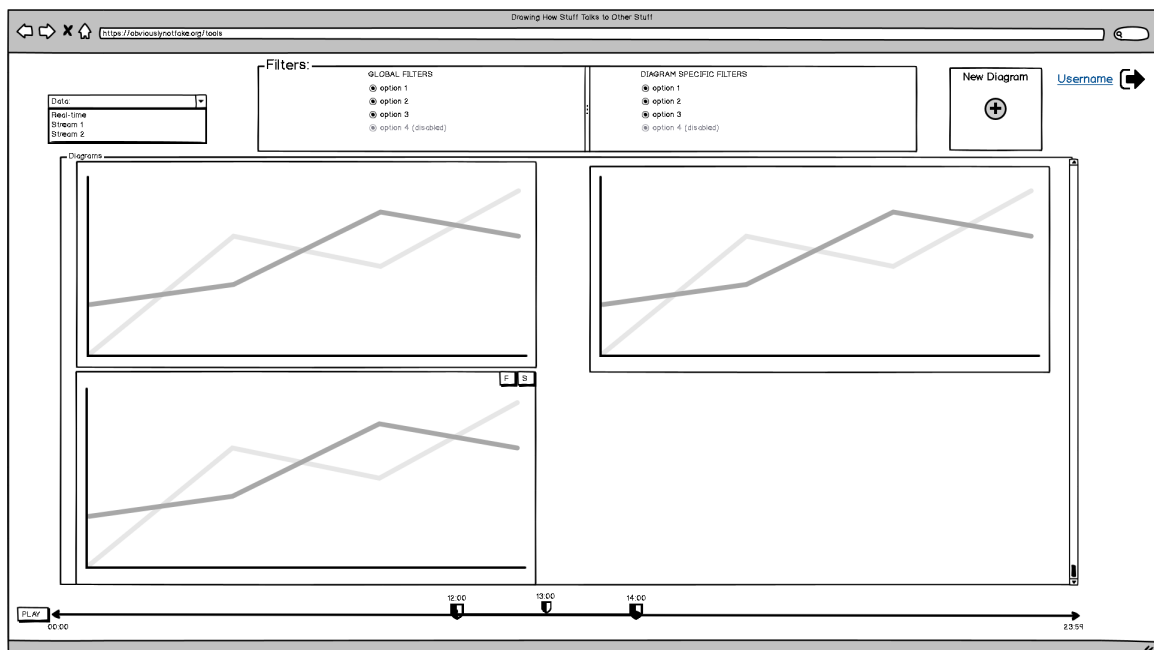


Figure 10: Main window with more than four diagrams open, more diagrams can be shown using the scroll bar

## 8.2 Scenario

**S100:** An operator wants to check manually/visually whether network nodes appeared or disappeared over the last day

- the operator opens the web page
- the operator selects the database as data source
- the operator selects a time-line-based diagram type
- the operator selects node addresses as the data to be displayed
- the operator moves to or selects the last 24 hours as the range of data to display
- the operator closes the web page

**S200:** A security analyst wants to look at the current flow rates between network nodes to see whether they change / there are trends

- the analyst opens the web page
- the analyst selects a source of live data
- the analyst selects an appropriate visualization type
- the analyst selects node addresses as the independent variable
- the analyst selects flow rates as the data to be displayed

**S300:** A security analyst wants to examine a specific point of data

Precondition: the analyst has already selected the relevant dataset and visualization type

- the analyst selects a data point
- the GUI displays a small pop-up window with all the data of this data point
- the analyst right-clicks one of the attributes in the pop-up window and selects "Display all matching types"
- the GUI marks all data points that have the same value in this attribute

**S400:** The user wants to look at alarms/notifications (TBD)

- the user opens the web page
- the user selects the database as data source
- the user selects the data stream from the relevant dissector
- the GUI displays the notifications along a timeline, according order of occurrence
- the user right-clicks on the x-axis and selects "use record number"
- the GUI displays the notifications along a timeline adjacently

**S500:** The user wants to look at normal data together with alarms/notifications

Precondition: Scenario /S100/ apart from closing the web page

- the user selects menu "data", entry "sources"

- the GUI displays a list of all known data sources with a checkbox in front of each
- the user selects the checkboxes for the data sources they want to examine
- the GUI displays data from all these data sources within the currently active visualization

## 8.3 Use cases

TBD

### 8.3.1 Interactivity

Visual analytics methods combine interactive visualisations with automated analysis techniques. This allows the user to decide e.g. which part of the data he or she wants to explore in more detail.

A basic principle for visual data exploration was introduced by Shneiderman (1997) by what he called the “The Visual Information Seeking Mantra:

Overview first, zoom and filter, then details-on-demand”. This lets the data analyst define to a certain level what he or she wants to see and visualise.

Similar to this, Bertin (1983) specified three “levels of reading”: The elementary level (allowing the analyst to look at the information about a single data record), the intermediate level (showing summarised information about a group of data records), and the global level (providing an overview of all data elements).

## 8.4 Object Modelling

## 8.5 Dynamic Modelling

# 9 Glossary

**data point** A tuple of values or key-value pairs.

**data source** A data source is a service that provides a network interface that can be accessed by the GUI and provides one or more data streams.

**data stream** A sequence of data points. A data stream may grow dynamically, in which case it will provide a kind of “read next” method.

**diagram** A graphical representation of data points as per a certain diagram type. Each data point is represented by a symbol whose position, size, color, shape etc. represent values of the data point. The diagram has labeled axes and, for other properties of the symbol, a legend that allow the user to determine the values represented by each symbol.

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**diagram container** The area of the GUI within which the diagram(s) are displayed.

**diagram type** A diagram type is a specific style or method of drawing a diagram and visualizing its data points.

**role** A security role is a list of access permissions. It determines which data streams (and, potentially, which diagram types and which data operations) are accessible to a user with a given role.