FRANKFURT UNIVERSITY OF APPLIED SCIENCES
FACULTY 2: COMPUTER SCIENCE AND ENGINEERING

HIGH INTEGRITY SYSTEMS

Master Thesis

AN EVALUATION OF DIFFERENT OPEN SOURCE ESP PLATFORMS TOWARDS CONSTRUCTING A FEATURE MATRIX

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November 15, 2020.

Official Declaration

I declare that this thesis has been written solely on my own. I herewith officially ensure that the work presented in the thesis is my own. I certify, to the best of my knowledge, my thesis does not violate anyone's copyright. Any external sources from the work of other people included in my thesis are fully acknowledged with citation and referencing.

Date	Signature

Acknowledgement

Abstract

Contents

1 Introduction

Nowadays, the explosion of the number of digital devices and online services comes along with an immense amount of data that is auto generated or collected from the interactions of users. For instance, from 2016, the Netflix company already gathered around 1.3 PB of log data on a daily basis [1]. With this unprecedented scale of input data, companies and organizations have tremendous opportunities to utilize them to create business values. Many trending technologies such as Big Data, Internet of Things, Machine Learning and Artificial Intelligent all involves handling data in great volume. However, this also brings about a challenge to collect these data fast and reliably.

Once the data is ingested into the organization, it needs to be transformed and processed to extract insights and generate values. In the context of enterprise applications, as the systems grows over time with more services, the need for an effective data backbone to serve these huge amount of data to these services and to integrate them together while maintaining a good level of decoupling becomes inevitable.

Moreover, all these steps of collecting, processing and transferring data must be done in real-time fashion. One of the prominent methods is event stream processing which treats data as a continuous flow of events and use this as the 'central nervous system' of the software systems with event-driven architecture.

1.1 Motivation

To develop a system evolving around streams of events, the primary basis is a central event store which can ingest data from multiple sources and serve this data to any interested consumer. Usually a Event Stream Processing platform will be used as it is designed orienting to the concept of streaming. However, in order to choose the suitable platform, user will usually be burdened by a plethora of questions which need to be answered. The concerns include how well is the performance and reliability of the platform, does the platform provide necessary functionalities, will it deliver messages with accuracy that meets the requirements, can the platform integrate with the existing stream processing framework in the infrastructure, to name but a few.

As there are many platforms now available on the market both open-source and commercial with each having different pros and cons, it could be challenging and time consuming to go through all of them to choose the most suitable option that matches the requirements. It would be greatly convenient to have a single standardized evaluation of these platforms which can be used as a guideline during the decision making process. Therefore, the goal of this thesis is to derive a feature matrix to help systematically determine the right open-source Event Stream Processing platform based on varying priority in different use cases.

1.2 Related Work

There are a number of articles and studies which compare and weigh different platforms and technologies. Many of them focus on evaluating the performance between platforms. There are comparisons of time and resource behavior of Apache Kafka and Apache Pulsar [2] [3], time efficiency between Apache Kafka and NATS Streaming [4].

Some other surveys cover more platforms and a wider range of evaluating aspects such as the comparisons of Apache Kafka, Apache Pulsar and RabbitMQ from Confluent [5] [6]. However, these assessments are conducted only briefly on the conceptual level. Apart from these studies, most of the scientific researches only concentrate on comparing different stream processing frameworks such as Apache Spark, Apache Flink and Apache Storm [7] [8] [9]. Therefore, in general, there is still lack of in-depth investigation into the differences of Event Stream Processing platforms and their conformability with event-driven use cases and this is where the thesis will fill in.

1.3 Contribution

In this thesis, three open source Event Stream Processing platforms, namely, Apache Kafka, Apache Pulsar and NATS Streaming are selected for evaluation based on preliminary measures and reasoning. Each platform is assessed against a set of criteria covering all important quality factors. The results are summarized in the form of a feature matrix with adjustable weighting factors of quality categories and features. Therefore, the matrix can be tailored to the need of user and adapted to individual use case to determine the most suitable platform for that case according to its priorities.

In the evaluation, sample implementations and code snippets are presented to illustrate the features of the platforms. Moreover, best practices for each platform in different use cases are also drawn out. These can be used as a reference for actual implementation of applications on top of these platforms.

1.4 Organization of this Thesis

The thesis is organized as follows. Chapter 2 gives theoretical background of the topics stream processing and Event Stream Processing (ESP) platforms. Chapter 3 enumerates prominent open-source ESP platforms currently available and furthermore derives criteria to choose the top three platforms which are considered in this thesis. Moreover, it also includes the elaboration of comparison metrics and the form of the feature matrix. After that, chapter 4 presents the evaluation of each platform against the comparison scheme and gives a discussion on the resulted feature matrix. Finally, the conclusion summarizes and proposes future improvement for the matrix.

2 Background

In order to conduct the comparison effectively, it is necessary to first lay a good theoretical basis of stream processing and the concrete roles of an Event Stream Processing platform. Based on that, a comprehensive set of evaluation metrics can be determined.

2.1 Stream Processing

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2.2 Event Stream Processing Platform

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3 Evaluation Scheme

3.1 Considered Platforms

To successfully write your thesis, you should definitely respect some rules. They are explained in the following sections.

3.2 Evaluation Metrics

3.3 Structure of Feature Matrix

3.3.1 Evaluation Metrics

At the beginning of your thesis, estimate the complexity of the work you are going to have. Take into account that you will have problems with certain aspects of your thesis that will consume a lot of time. Consider times for recreation and delays you can not influence, for instance, asking your supervisor, waiting for orders to be shipped, complex problems during the implementatuon phase, and so on …

For some students it is a good idea to agree upon a rough plan (with their supervisor) on how to make progress on their thesis and what goals to achieve. Milestones might help to control your progress. If you fail to meet a milestone in time, contact your supervisor on why this happened or when to expect it to be fulfilled.

If you have a problem, try to solve it on your own twice over. Some things just take time. In case you fail to solve it on your own, write an email to your supervisor and tell him about your problem and what you did to solve it. Make an appointment if necessary. Please do not jump right into his office, supervisors have other stuff to do, too.

For quotations, either use “quotation” or “quotation”. For some words, you should use a tilde to link them, for example, when referring to chapter 5 you should use it. Or use chapter 5. This prevents words from being separated by a line break or some other rare circumstances. Use BibTeX within your thesis and learn the different citation options [10, 11].

One last piece of advice. Do not try to attend courses in parallel to your thesis. You should take this seriously and not think that writing a thesis is done quickly.

3.3.2 Rules for Supervisors

“With great power comes great responsibility” `:-)`

- It is very important, that if you want specific things to be done that you send these important instructions by mail. Your student might be in a moment of confusion when telling him.
- Attend the “Diplomandenseminar” and give your student the feeling, that this is important to you, too.
- Offer your students the opportunity to talk to you right after the “Diplomandenseminar”. While discussing things, tell your student to write down the results of this discussion and tell him to send you this summary by mail to ensure (if necessary), you did not talk at cross purposes.
- Last but not least: Please be gentle to your students `:-)`

3.4 Hints on Typesetting

To get this template running, you need at least

- either TeXLive 2010 (use update utility and install the most recent packages!)
- or MikTeX (IMPORTANT: install the cm-super font package manually!)

This template is confirmed to work in both situations. In case it does not work for you, there is something wrong with your LaTeX environment `:-)`

You can use `pdflatex` or `latex` to typeset this template.

3.4.1 Structuring Text, English Hints

Another text about the following sections …

3.4.1.1 Text

Always try to structure your text in a manner that makes sense. Either use indentations, itemize or enumeration environments.

This sentence will have an indentation at the beginning. Now an enumeration starts:

1. One.
2. Two.
3. Three.

Sometimes you do not want an indentation. Use the `noindent` command in such a case.

One Is the first number.

Two Is the second number.

Glossary Use the glossary package for acronyms. In addition, the glossay package can help you to avoid typing the same word in different ways. For example students tend to mix-up the writing of the word *User-Agent* in different ways: user-agent, User-Agent, user agent, User agent. This inconsistency can be avoided by just using the glossary entry: User-Agent (UA).

3.4.1.2 English Hints

- Use an active voice and avoid using passive wherever possible.
- *Always* use the present tense (especially when you refer to content that occurs later in your text). For example:
  - *wrong*: The next chapter *will* explain ...
  - *correct*: The next chapter explains ...
- Either use American English or British English, but do not mix (e. g. summarize vs. summarise, analyze vs. analyse, ...). American English is preferred.
- Do not use filler words.
  - omit: “some kind of” and others ...
- Never use a comma before “that”.

- For enumerations, always use a comma before "and": "…module 1, module 2, and module 3.".
- The title of your thesis is capitalized except for words like and, or, with, the, a …
- *Always* address the reader using the third person: "As one can see from … " and not "As you can see … ".
- All tables, figures have to be explained very briefly in the text itself.
- Always use correct quantifications:
  - *wrong*: …a small amount of runs …
  - *correct*: …at most three runs …
- Never use "I". Depersonalize your sentences or use "we" if necessary.
- Read *The Elements of Style* by William Strunk, Jr., which is for example available at `http://www.crockford.com/wrrrld/style.html`. The (short) book provides an overview of typical errors and helps you to significantly improve your English.

3.4.1.3 General Hints

- Use non-breaking small space for some abbreviation
  - z. B.
  - u. a.
  - e. g.
- Use a non-breaking space just before references, parentheses and so which shall not begin at the beginning of a new line. This sentence will not break here (and here).
- Did you notice the overfull horizontal box (hbox)? You should avoid these! Underfull boxes are not that bad. But only fix them when most of the section, paragraph etc is ready. Otherwise you have to fix them more than once. You can tell LaTeX when to break a word if it does not do it correctly. Just put a \- at the corresponding position in the world. Vertical overfull boxes (vbox) occur if the document uses `\flushbottom` instead of `\raggedbottom`. That way, LaTeX ensures that each page ends with the last sentence in the last line (except for the final line in a section). To enforce this, LaTeX sometimes has to add extra vertical space between, e. g., paragraphs. Overfull vertical boxes are hard to fix, as additional content needs to be added or even has to be removed sometimes. Keep in mind that any changes to the type area (Satzspiegel)

might produce many additional over- or underfull boxes (and of course it will fix other boxes).

- Read `ftp://ftp.dante.de/tex-archive/info/german/l2tabu/l2tabu.pdf`. Really, read it.
- You can find many more good information at `http://www.dante.de/CTAN/info/lshort/german/l2kurz.pdf`
- The KomaScript guide is very useful: `ftp://ftp.dante.de/pub/tex/macros/latex/contrib/koma-script/scrguide.pdf`

3.4.2 Formulas, Figures, Tables, Definitions

3.4.2.1 Formulas

Define abbrevations with the `\acro{...}` command, use them in the text mostly with `\ac{...}`. (Yes, in this example there are still a lot of wrong abbrevations. Make it better :)

So, testing abbrevations the Advanced Encryption Standard (AES) is written in different form. Lets see, when using the AES again, what will happen :D .

Using the method shown in Table XX for all three functions yields.

$$f_a^4 = \texttt{0x2C79} = \mathrm{abc} + \mathrm{ac} + \mathrm{ad} + \mathrm{bc} + \mathrm{a} + \mathrm{b} + \mathrm{d} + 1 \tag{3.1}$$

$$f_b^4 = \texttt{0x6671} = \mathrm{abd} + \mathrm{acd} + \mathrm{bcd} + \mathrm{ab} + \mathrm{ac} + \mathrm{bc} + \mathrm{a} + \mathrm{b} + \mathrm{d} + 1 \tag{3.2}$$

$$\begin{split} f_c^5 = \texttt{0x7907287B} = {} & \mathrm{cde} + \mathrm{abde} + \mathrm{ade} + \mathrm{de} + \mathrm{abce} + \mathrm{bce} + \mathrm{ce} + \mathrm{be} + \mathrm{bcd} \\ & + \mathrm{acd} + \mathrm{bd} + \mathrm{d} + \mathrm{bc} + \mathrm{ab} + \mathrm{b} + 1 \end{split} \tag{3.3}$$

When typesetting formulas, pay special notice on constants, variables, and units:

$$\mathcal{F}_\omega\{x(t)\} = \int_{-\infty}^{\infty} x(t)\,\mathrm{e}^{-\mathrm{j}\omega t}\,\mathrm{d}t \tag{Fourier-Transformation}$$

The use of constants, variables and units is explained by “Rohde & Schwarz” in their famous document “Der korrekte Umgang mit Größen, Einheiten und Gleichungen” [12]. These rules are in compliance with ISO-31. Consequently, always typeset the following in italics:

- Variables like k, x, …
- Functions like $f(x)$,…
- Physical constants like c_0, …

- Indices that are variables or physical units, like $a_{i,j}$ or c_V.

Always typeset the following upright:

- Functions with fixed name like $\sin(x)$ or $\Gamma(x)$.
- Mathematical constants like $\mathrm{\pi}$, i or e.
- Units and their prefixes, like $\lambda = 0.56\,\mathrm{\mu m}$, alternatively $\lambda = 0.56\,\mathrm{\mu m}$.
- Indices that represent names or identifiers, like x_{max} or μ_{B}.

In case it is necessary to make heavy use of user defined functions, one should use `\DeclareMathOperator` to define the corresponding function. Finally, a good example how it should *not* look like.

$$Throughput = 30mbit/s$$

In case you need some extra symbols: `http://mirror.ctan.org/info/symbols/comprehensive/symbols-a4.pdf`

3.4.2.2 Figures

Figures and tables are important to explain things. Here are some rules that apply, when using figures:

- Whenever possible use vector graphics (eps, pdf, svg, ...) instead of bitmap graphics (jpg, gif, ...).
- All figures should have the same font and size (do not scale them or the size will change) and "style" (line strength, arrow heads, ...).
- Some employees of the chair need all figures in `.eps`. However, do *not* convert your `.jpg` and `.png` to `.eps`, instead use a *wrapper* program to wrap these file types into the `.eps` format. As a consequence, you are forced to use `latex` to typeset your document instead of `pdflatex`. Appropriate wrapper programs can be found here:
  - Windows: click
  - Linux/Mac: click
- **Always** try to use your own figures, so you do not run into copyright problems and it is easier for us, to reuse these figures for papers. You might want to have a look at these tools to create your own figures:
  - Windows: MS Visio (available via MSDNAA), Graphviz, Gnuplot ...
  - Linux: xfig/jfig, IPE, Graphviz, Gnuplot ...

  – Mac: IPE, Graphviz, Gnuplot, OmniGraffle (commercial, academic licensing available) ...

There are many possibilities on how to include figures, here is just one example on how to do it. In case you need further assistance, please google for `l2picfaq`.

3.4.2.3 Tables

There are many possibilities on how to create and include tables. From a typographic point of view, *one should avoid any vertical lines*, cf. Table 3.1.

Table 3.1: Captions for tables are *always above* the table and give a short but informative description of the table. Always use full sentences here and end them with a full stop.

		Component	
Amount[a]	Price	Description	Role
23	1.234 $	good stuff	important
multirow example the other row	x	y	XXX
42	43.123,13[b]	good stuff	important

[a]This is a footnote inside a table, you need a minipage for this to work.
[b]This is another footnote inside a table.

3.4.2.4 Definitions

This is a definition. You can of course make a reference to it 3.2.

Definition 3.2 (A name) *A really good definition. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.*

3.4.3 Listings, Algorithms

3.4.3.1 Listings

For source code listings, three options are available:

- the `verbatim` environment,
- the `listings` package,
- and the `lgrind` package.

The verbatim environment is the most simple environment and not suited for large code listings (due to different limitations). Only use it for single

```
$ important shell commands
```

Otherwise, either use the `listings` or `lgrind` packages. The listings package is easier to use, therefore we present it here. *Important* advice: Only explain important functions and/or structures of your program in your thesis..Especially point out the big picture of your program, for instance, how different modules interact and which important input limitations to respect. Please note: Using special language characters (ê, ü, ä, ...) in your source code is strongly discouraged, as they may cause problems using the `listings` package.

```c
/*!
 * This is a Doxygen comment for a function.
 * \param first operand
 * \param second operand
 * \returns a+b
 */
int sum(int a, int b)
{
  return (a + b);
}
```

Listing 3.3: A sample listing of a C function. Description of the function is here. Please note that different languages are available.

```vhdl
entity InterLeavedMul is
  generic(wide : natural :=8); -- highest bit
  port(clk : in std_logic;
       rst  : in std_logic;
       x    : in std_logic_vector(wide-1 downto 0);
       y    : in std_logic_vector(wide-1 downto 0);
       N    : in std_logic_vector(wide-1 downto 0);
       start: in std_logic;
       done : out std_logic;
       xyN  : out std_logic_vector(wide-1 downto 0));
end InterLeavedMul;
```

Listing 3.4: A sample listing of a VHDL entity. Description of the entity is here. Please note that different languages are available.

You should thoroughly document your code using comments and (best case) by using a documentation system like Doxygen. Please ask your supervisor for additional rules (e. g. which repository system to use, etc.). Regularly commit your changes and backup your data!

3.4.3.2 Algorithms

For many theses, typesetting algorithms is necessary. There are at least four packages available that allow easy typesetting of algorithms.

- `program` offering the environment `program`.
- `algorithm` offering the environment `algorithm`.
- `algorithmic` offering the environment `algorithmic`.
  - This package sometimes has compatibility problems with `hyperref`.
- `algorithm2e` either offering the environment `algorithm` or `algorithm2e`.

Students are advised to use only *one* of these packages and not mix them. The author of this template suggests to use the package `algorithm2e` with the option `algo2e`. This prevents conflicts with other packages, just in case it is ever required to mix `algorithm` or `algorithmic` with `algorithm2e`.

Algorithm 3.5: INSERTION-SORT

Data: unsorted array $A[1 \ldots n]$
Result: array $A[1 \ldots n]$ with $A[1] \leq A[2] \leq \ldots \leq A[n]$

begin
    for $j \leftarrow 2$ **to** length$[A]$ **do**
        $key \leftarrow A[j]$;
        `/* Insert` $A[j]$ `into the sorted sequence` $A[1 \ldots j-1]$ `*/`
        $i \leftarrow j - 1$;
        while $i > 0$ **and** $A[i] > key$ **do**
            ;
            $A[i+1] \leftarrow A[i]$;
            $i \leftarrow i - 1$
        $A[i+1] \leftarrow key$

3.4.4 Protocols

3.4.4.1 2-Party Protocol Sessions

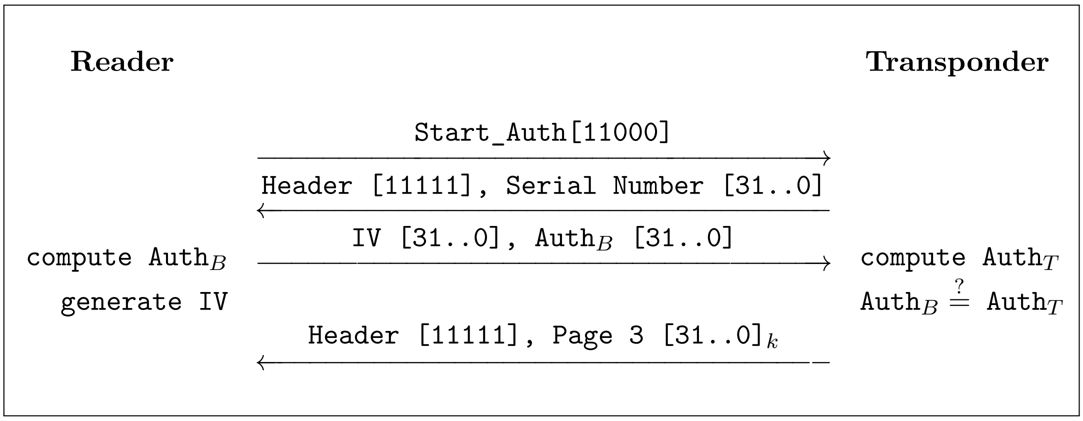

Figure 3.6: Mutual authentication of the HITAG 2 protocol in crypto mode.

3.4.4.2 Protocol Headers

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ID															
QR	Opcode				AA	TC	RD	RA	Z			RCODE			
QDCOUNT															
ANCOUNT															
NSCOUNT															
ARCOUNT															

Figure 3.7: DNS Request

4 Evaluation of Platforms

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5 Conclusion

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