University of Pretoria
Software Engineering - COS 301

Defendr Specification

Dark nITes
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Contents

1 Introduction

1.1 Purpose

The intent of this software requirement specification document is to provide the requirements and implementation plan for the project named ***Defendr***. This document serves to clarify and communicate to all stakeholders' understanding and expectation of ***Defendr***.

This document is written for the perusal of the stakeholders: our client, Advance, and the COS 301 module and Computer Science department of the University or Pretoria. The final stakeholder is the development team itself, Dark nITes.

1.2 Scope

Defendr is to be a black box implementation of a DoS protection service, as well as a network load-balancer for various back-end applications (henceforth called service collectively). The service is to be situated between the client and server; requests from the client are passed through the service, dropping or blacklisting offending packets or IPs. The service should employ direct server return thus responses from the server are to be sent directly back to the client, and not routed back via the service.

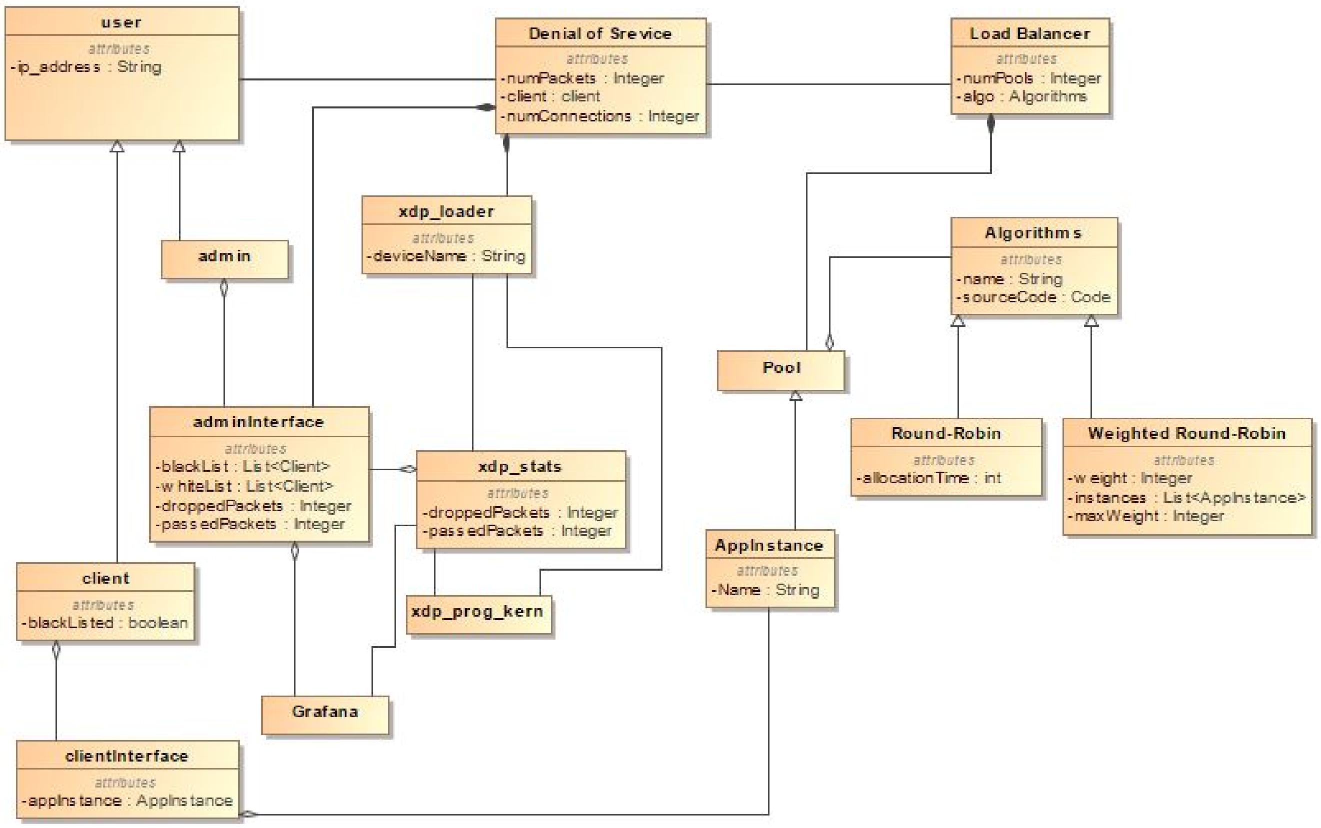
Packets that are permitted to pass through DoS protection will then be subject to the load-balancer which is various load-balancing pools with multiple instances of back-ends situated in them. The algorithm which is managing the particular pool's load-balancing, will decide which packets will be passed to the specific intended back-end instance.

The service will measure the validity of request packets which have been sent to a protected service by two criteria: # of packets per second, and # of connections. The limitations will be specified by the owner of the back-end being protected.

The service will also comprise of two user interfaces, namely an administration interface and a client interface. The interface will provide access to the following metrics in raw and graphical data format:

- Current servers being protected,
- Current status of the server, i.e. total # of packets, # of packets being let through (success rate) or # of packets being dropped (failure rate),
- A heat-map that displays the geo-location of the origin of client request to protected back-ends,
- List of blacklisted IPs,
- Internal overhead.

1.3 Domain Model



1.4 Definitions, Acronyms, and Abbreviations

Term	**Definition**
Blackbox	A method of software testing that examines the functionality of an application without peering into its internal structures or workings.
DOS	Disk Operating System.
DoS	Denial of Service.
DDoS	Distributed denial of service.
Load balancer	A subset of the service that will distribute network traffic to various instance of an application, as determined by the current governing algorithm.
Client	The originating device from which a request is received.
IPs	Internet Protocol.
Packets	The units of data that are being transmitted from a client to a protected application.
XDP	eXpress Data Path.
eBPF	extended Berkley Packet Filter.
Prometheus	A monitoring system that has a time-series metric database and ways to query said metrics.
Grafana	A toolkit that presents data in a graphical form. Can be used in conjunction with Prometheus to graph the service's metrics.

2 User Characteristics

2.1 Client

The client is the primary user of the system. Their main focus is the protection of the integrity of their application. Their actions will only include the sending of packets and receiving of responses. By using this system, they will be able to protect the integrity of their application and experience an increase to throughput by virtue of DoS protection and network load-balancing. The client will use the front-facing segment of the system. These users cannot cause much detriment to the system as their interaction will strictly be limited to interacting with the front-end interface. As such, they are expected to have no more knowledge other than how to use the (protected and balanced) application. These users are required to have some form of computing device which will be able to use the front-end system as well as a connection to the internet.

2.2 Administrator

Administrators will have the duties of installing components of the system and maintaining its health and performance. As these decisions will determine the success of the service as well as the level of security, they will require a level of skill that ensures this .These users would be expected to have experience with networking and some degree of software development and maintenance. These users will be able to make changes to the system that are integral to its running, e.g. manually blacklisting IPs/IP ranges, adjusting packet filtering rules or removing services from protected pools.

3 Functional Requirements

3.1 DoS Protection

- R1.1. The subsystem must be able to detect and mitigate a DoS attack by dropping the offending packets from the source IP or IP ranges, and allow access after an exponential timeout.
- R1.2. The subsystem must provide functionality to gather metrics. These metrics packet success/failure rates, total # of packets per pool/back-end.
- R1.3. The subsystem rules that determine an incipient DoS should be able to be manually altered.

3.2 Load-Balancer

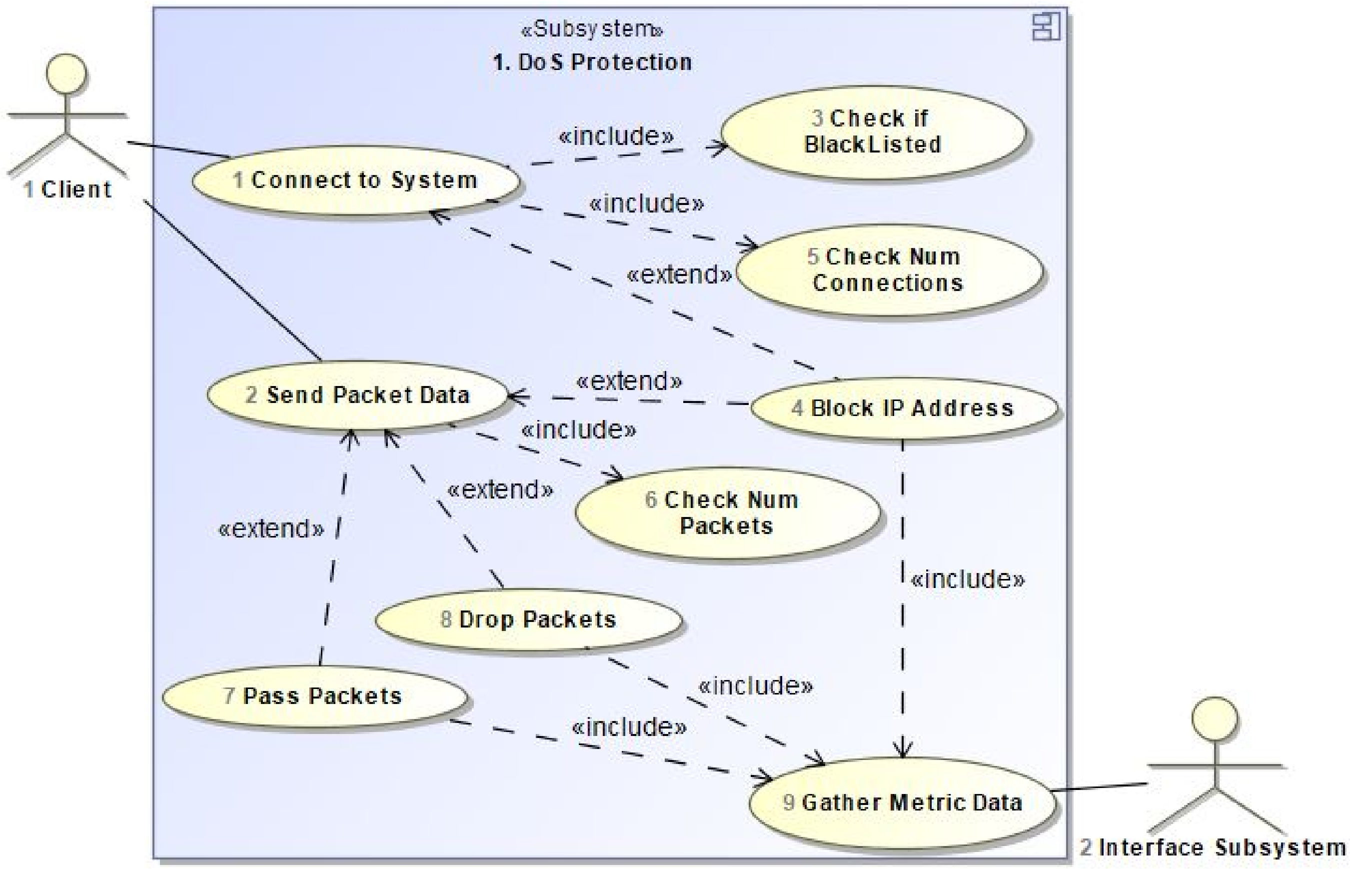
- R2.1. The subsystem needs to be configurable; applications/back-ends should be able to be dynamically added/removed
- R2.2. The subsystem must have multiple load-balancing pools, where pools are defined by the back-ends. Members of each pool are instances of the back-end that are to be load-balanced.
- R2.3. The subsystem must support multiple load-balancing algorithms, of which Round Robin and Weighted Round Robin must be included, different per pool. These algorithms should be changeable on-the-fly. Network load anomaly detection, with an option of prediction, should also be included.
- R2.4. The method of request response should be via a direct server response to the requesting client, that is responses should not return via the service.

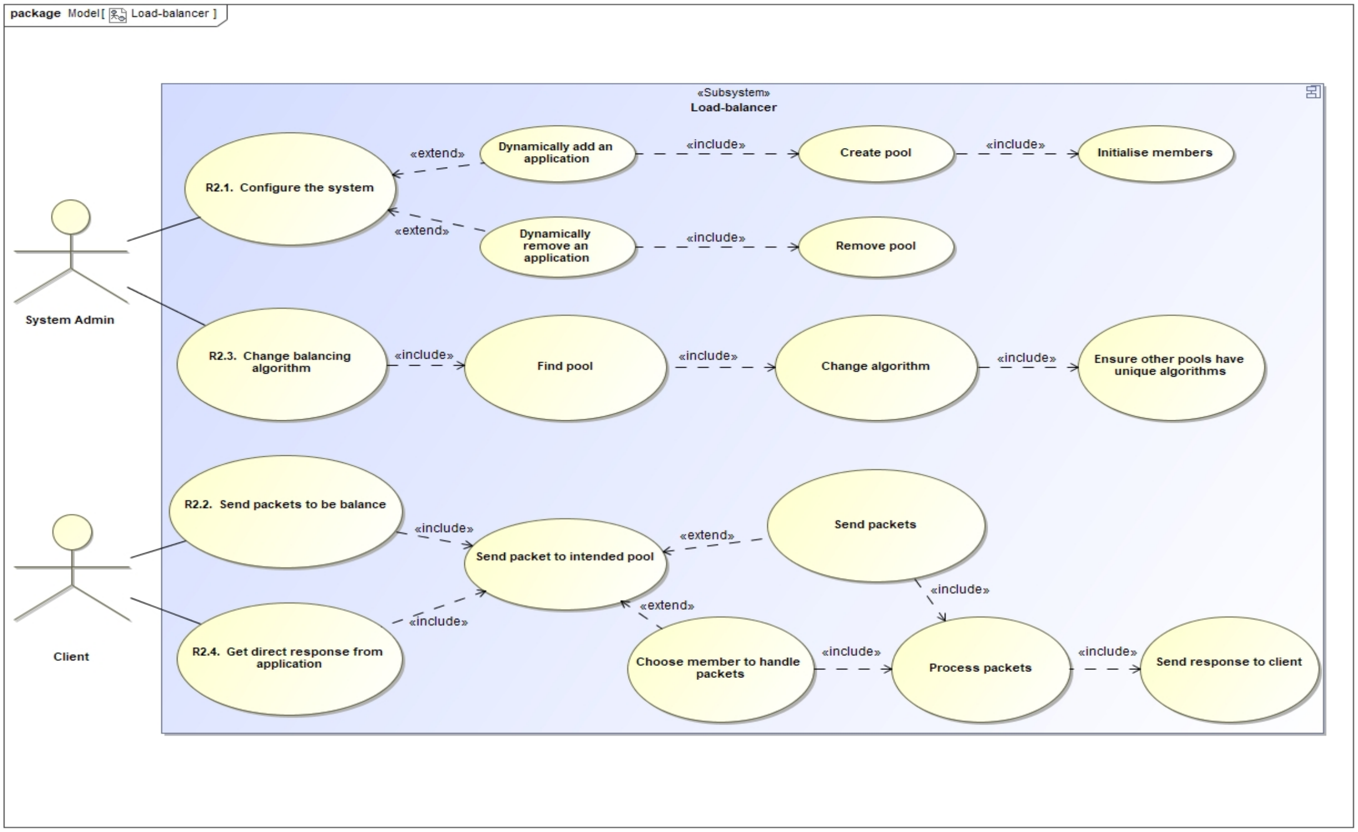
3.3 User Interface

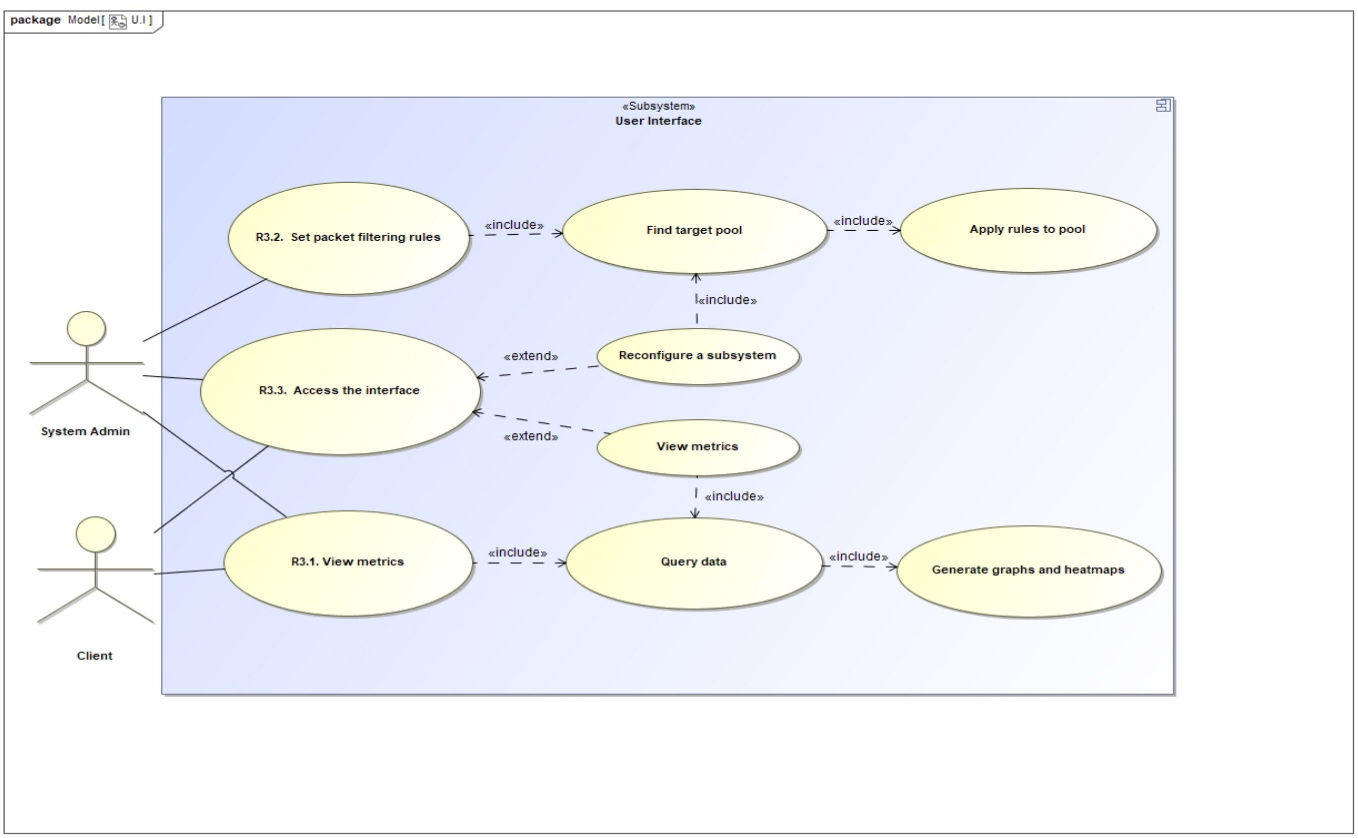
- R3.1. The interface should show the metrics in a graphical medium, i.e. graphs and heat-maps.
- R3.2. The interface should also provide a means of manually configuring the service, e.g. blacklisting/white-listing IPs/IP ranges, defining rules that govern network traffic

- R3.3. The interface must be accessible from anywhere, and not from just a specific machine, i.e. the interface must be hosted somewhere accessible, but for demo purposes localhost will do

3.4 Use Case Diagrams




package Model[Load-balancer]
«Subsystem»
Load-balancer
R2.1. Configure the system
«extend»
Dynamically add an application
«include»
Create pool
«include»
Initialise members
«extend»
Dynamically remove an application
«include»
Remove pool
System Admin
R2.3. Change balancing algorithm
«include»
Find pool
«include»
Change algorithm
«include»
Ensure other pools have unique algorithms
R2.2. Send packets to be balance
«include»
Send packet to intended pool
«extend»
Send packets
«include»
Client
R2.4. Get direct response from application
«include»
«extend»
Choose member to handle packets
«include»
Process packets
«include»
Send response to client


package Model[U.I]
«Subsystem»
User Interface
R3.2. Set packet filtering rules
«include»
Find target pool
«include»
Apply rules to pool
«include»
Reconfigure a subsystem
«extend»
R3.3. Access the interface
«extend»
View metrics
System Admin
«include»
R3.1. View metrics
«include»
Query data
«include»
Generate graphs and heatmaps
Client

4 Quality Requirements

4.1 Performance

The system must be able to perform at a high speed and have the ability to handle great volumes of packets, i.e the same number of packages the application which it is protecting is using. In other words, the system should have the same performance capabilities as the services it is protecting so that a bottleneck will not occur. This can be measured by looking at the drop rate and number of packages.

The step by step actions taken by the system will be logged to ensure the performance of the system. This includes the time when a packet arrives, the IP address, the location where the IP address originates from as well as the category of threat placed on the IP address. Having this information logged will ensure that the system will still be able to perform if any tests needs to be done to ensure the validity of the system.

4.2 Security

The security of the system has to be excellent, since one of the main purposes of the software is to protect the services against DOS attacks and if it's not adequate it will make it easier for malicious users to carry out a DOS attack. The software runs on the kernel which exposes the client to other threats if security isn't good enough. Role based access control is used to access the interface which allows for modification of the system's control values. This ensures security for the system by not allowing incorrect IP addresses to be blacklisted, etc by any unauthorized entities.

4.3 Availability

The system should have the same availability as the services it wants to protect. Seeing as the system also has an interface in the form of a program, which allows for the modification of the system by allowing it to manually blacklist IPs/IP ranges, adjust packet filtering rules or remove services from protected pools, there will be a possibility that the program will encounter challenges seeing that it is fallible. Thus we have come to an agreement with the client, that the system can be expected to have a 99.5% up-time.

4.4 Maintainability

The software must be changeable so that the software as a whole can work on the latest version of Linux and can be adapted to protect against new threats. The code also needs to be written in such a manner to ensure that any developer can understand the code and that he/she will be able to continue coding or make changes to the system at any point. The developers of the Defendr system all follow the practices set out in their coding standard document. This document is based on the current and most used practices of coding in the world and will ensure consistency throughout all code for the system.

4.5 Scalability

The system should be able to scale to the size of the server which it is protecting, without requiring additional changes to the basic structure of the system. It should also be able to accommodate a different number of load balancing pools. This can be tested by flooding the system with numerous requests for the services which are being protected and ensuring that the system doesn't break.

4.6 Flexibility

The system must be highly flexible so that it can accommodate different services with different volumes. This will be ensured through the interface designed to allow users to allocate and remove services which have to be protected as well as the modification of the systems control values. The user should be able to add and remove services as they see fit through the use of a user interface. This can be clearly seen and tested in the interface as any changes made will be updated and shown to the user. This will allow for example an IP address which was previously blacklisted to be allowed again. The IP address will no longer show up in the blacklisted section and one can monitor the packets arriving from the address for testing purposes to ensure the IP address is no longer blacklisted.

4.7 Monitorability

The system will be monitored through a GUI which displays packet rates (total and per pool), drop rates, heat-map, packet size, internal overhead and white and black listed IPs. The system as a whole will also log any action done. This includes the time when a packet arrives, the IP address, the location where the IP address originates from as well as the category of threat placed for the IP address. This ensures that any action taken by the system can be monitored.

5 Constraints

There are a couple of constraints imposed on the current system. The main component of the system which is in charge of the DOS protection and load balancing must be on a Linux machine and have access to any of the dependencies that the software requires. This component of the system must also be coded and developed in the language C to ensure that it will integrate and work with XDP and eBPF. This machine must be connected to the internet to ensure that all the logging that the system does is recorded to the systems database. The computers or devices running the program which is the interfaces for the users also must be connected to the internet to ensure the required information is sent to the database that holds all information for the system. The database service used for the logging from the system as well as any lists need to be done on a database that can handle a very large volume of data due to the nature of the system. This means that many free database services cannot be used due to their size limit.

6 Trace-ability Matrices

6.1 Requirements vs Use-cases

Requirement	**Priority**	**DoS**	**Load-balancer**	**U.I.**
R1.1	1	X		
R1.2	1	X		
R2.1	3		X	
R2.2	3		X	
R2.3	3		X	
R2.4	3		X	
R3.1	2			X
R3.2	2			X
R3.3	2			X

6.2 Requirements vs DoS subsystem

Requirement	**Check blacklist**	**Check #conn.s**	**Check #packets/s**	**Drop**	**Pass**	**Get Metrics**
R1.1	X	X	X	X		
R1.2					X	
R1.3						X

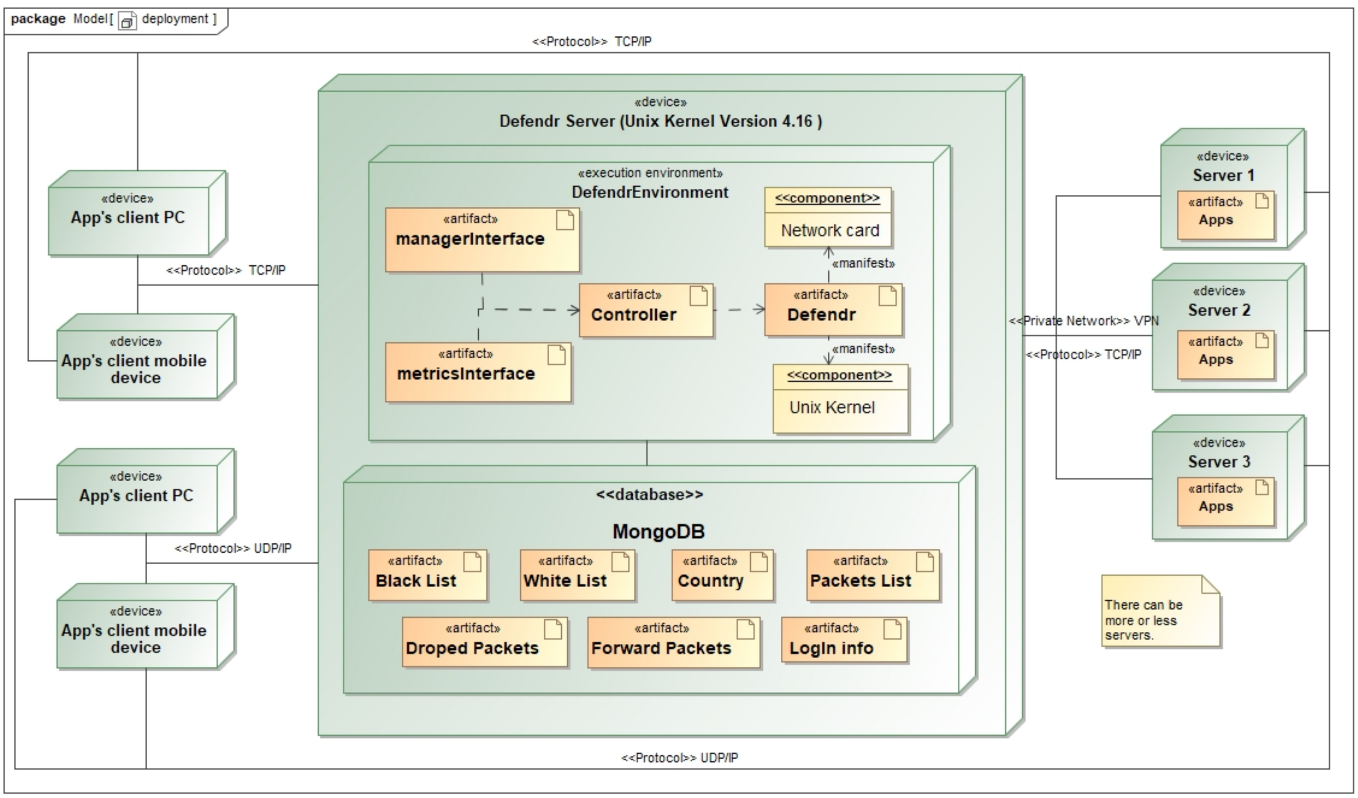
6.3 Requirements vs Load-balancer subsystem

Requirement	Configure	Change alg.	Foward packets	Direct-server resp.
R2.1	X			
R2.2		X		
R2.3			X	
R2.4				X

6.4 Requirements vs U.I. subsystem

Requirement	Set rules	Access interface	View metrics
R3.1		X	
R3.2	X		
R3.3			X

7 Deployment model



8 Architectural Requirements

8.1 System Type

We have implemented a system that makes use of basically two system types. These include a Interactive Subsystem and an Event-Driven Subsystem. These two subsystem types are separated into front-end and back-end systems. The front-end is an instance of an Interactive Subsystem whilst the back-end is an instance of an Event-Driven subsystem.

8.1.1 Interactive Subsystem(Front-End)

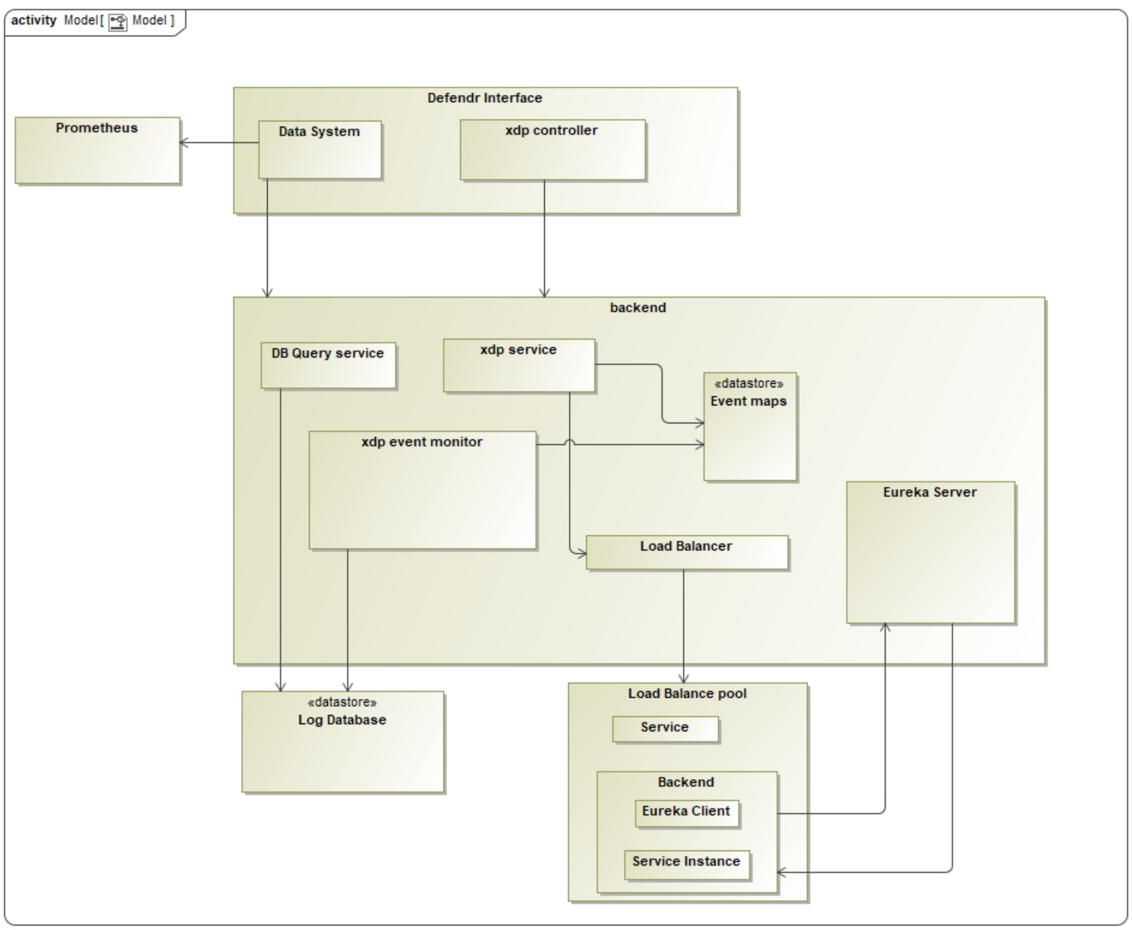
When the administrator logs in to the application, he interacting with the system. He inputs his user name and password and receives a clear feedback from the system. He either enters the rest of the application or an error message appears. Thereafter whatever buttons he clicks on, the application will give him a clear response based on what he pressed. Thus the front-end portion of the system is an Interactive Subsystem.

8.1.2 Event-Driven Subsystem(Back-End)

The back-end portion works as an Event-Driven subsystem because it depends on the incoming packet transmissions from various source IP Addresses before an action is taken. When an IP sends a packet to the system, the system immediately logs that packet into a database. Thereafter, it checks that said IP does not exceed the packet per second limit specified by the system. If it does, the IP is dynamically blacklisted and all corresponding packets are dropped.These are examples of events that take place before the system generates a response for aid events. This in indicative that the back-end is an Event-Driven subsystem.

8.2 Architectural Style

The architectural style used by our system is an event sourcing style coupled with CQRS (command query responsibility segregation). This style makes use of an event store where events of interest are saved in sequence. An event tracker then tracks these events as they appear within the store and then calls the appropriate event handlers. This allows for the system to access those events and reference them at any point in time. For our system, an event corresponds to a packet as well as the subsequent dropping or passing of said packet up the network stack. The XDP program would then save these events in the corresponding bpf map which serves as the event store. Finally a tracking program (Called the event monitor) would process these events and envoke the correct event handlers.



9 Technology Decisions

9.1 Interfaces

The interfaces were all coded in Python whilst making use of it's GUI library tkinter. All the GUI's were created using the add-on tool page which can be found on sourceforge.net. This tool allows for the user to drag and drop tkinter widgets onto the window and thereafter generate Python code that corresponds to what was created with Page. Many python libraries had to be installed some of which are pip, dnspython, pymongo, python-tk, urllib3, setuptools and many other packages.

9.2 Packet Dropper

The packet dropper program kernel files where coded in restricted c and ebpf which where compiled into object and llvm files using the llvm framework and clang compiler. To this end the llvm and clang libraries had to be installed as well as the bcc and kernel-headers packages in order to use bpf maps for key value stores within the kernel. The packett dropper files that are executed in the user space were however coded using standard c and compiled with the gcc compiler which was installed along side the standard linux build-essentials package.

9.3 Logging System

The logging system consists of two components: a MongoDB C driver and a Python driver. The proposal was to connect the interface whith the Defendr system so that information can be shared. As such the C driver exists to write data to the database, where Python interfaces can then read and modify the data. The database solution is a hosted MongoDB server, with 2 redundancy back-ups. It was decided to use MongoDB since it is not bound by the constraints of traditional normalisation rules. The database is also built for distributed services, allowing for a higher numbers of cheaper servers to be used instead of a monolithic approach. These components will allow Defendr to grow and adapt as time goes on, providing a more future-proofed approach as the clients needs and requirements change.

9.4 Metrics and Monitoring

The metrics system will be powered by Prometheus and Grafana. Prometheus is a monitoring tool that pulls internal statistics from (specified) hardware and software, and stores it in a time-series database. The internal data of software and statistics from hardware are provided by add-on libraries; exporters.
Grafana is the second component of the metrics system. Alongside Prometheus, Grafana is able to provide system statistics using data provided by Prometheus. Grafana performs queries using PromQL, a Prometheus specific database query language.

10 The software requirements/dependencies:

C

1. MongoDB (mongodb-org)
2. MongoC driver
   (a) Mongo client library (libmongoc-1.0)
   (b) BSON library (libbson-1.14)
   (c) SSL security library (libssl-dev)
   (d) SASL security library (libsasl2-dev)
3. Software builder (CMake)

4. Library querying (pkg-config)

Python

1. Hashing library (hashlib)
2. JSon library (json)
3. MongoDB client library (pymongo)
4. Directory management (os)
5. Regular expression library (re)
6. Python interpreter library (sys)
7. TK GUI Toolkin (TKinter)
8. URL manipulation library (urllib.parse)
9. Universal Unique ID library (uuid)
10. Web-base documents library (Webbrowser)

10.1 Unit Testing

Unit testing was done using the unit test framework. It supports test automation, sharing of setup and shutdown code for tests, aggregation of tests into collections and independence of the tests from the reporting framework