CEng 491 -- Project KickOff Document

Deep Learning based IOT Network Attack Detection System

Project acronym: DIONA

Description

Since the number of IoT devices have been increasing dramatically owing to improvements on Cloud and Fog computing, vulnerabilities to the cyber attacks and data breaches of enterprises, companies, etc. are also increased enormously. The connection between the IoT end-points and central control unit provides several functionalities. Having these functionalities and increasing use of Deep Learning in cyber security make the problem solvable by Deep Learning methods. Furthermore, there are no static IoT devices set-up for different scenarios. DIONA aims to solve this problem by closely observing the network traffic between the IoT devices and the central control unit with DL methods. These observation processes make DIONA a reliable solution to the cyber security problems mentioned above, since it provides a two-layered security pattern by its nature. The end-product will be able to work with different kinds of IoT end-points, since its training data is independent of the Network but dependent on the device itself. It will classify the traffic and label the corresponding device, and if it recognizes a threat, it will isolate the device from the Network. Since DIONA adaptable to all kinds of IoT devices, there is no limitation on the expected user group.

Master feature list

MF-1: The system will be designed in a distributed manner
MF-2: A Unified Command and Control System will be implemented for managing and monitoring of IOT instances and their network.(Optional)
MF-3: Master will run on an isolated network from the outside.
MF-4: Overall network traffic will be encrypted.
MF-5: System will utilize an indexed database system (search engine).
MF-6: Users will be able to observe the status via the front-end web server.
MF-7: System has the ability to manage the start/stop of IOT instances.
MF-8: System can manage the connection between IOT instances.
MF-9: System will be able to check the status of IOT instances.
MF-10: There will be an initialization script for IOT instances.(Optional)
MF-11: DL will detect behavioral anomalies of IOT instances by analyzing the normal behavior of IOT instances.
MF-12: DL will detect malicious behavior on the network side.
MF-13: System will have a managed firewall.
MF-14: Logs can be pushed and pulled between the IOT devices, and parsed for the overall system usage.
MF-15: Security alerts for different scenarios will be generated.

MF-16: The network traffic will be observed by network sniffing methods.

Work Packages

WP #	Term	WP title	Estimated number of person-months
1	491	Project planning and architecture design	3
2	491	Architecture implementation, control system preparation and database model decision	6
3	491	Implementation of IOT orchestration	6
4	491	Implementation of DL Engine for behavior analysis	8
5	492	Implementation of Security layer	6
6	492	Integration of DL Engine and Security appliance	7
7	492	Local testing of DL Engine Attack Detection system with IOT device actions	6
		Total:	**42**

Detailed Descriptions of High-Level Work Packages

WP1 - Project planning and architecture design

In this work package, the following functionalities / features / work items will be implemented

1. Develop the list of master features of the project. (All MFs)
2. Produce project development plan in accordance with the Master Feature List. (All MFs)
3. Design the overall architecture of the project. (All MFs)
4. Analyze risks and make a management plan. (All MFs)
5. Decide on a database model for behavioral classification and action logging. (MF-5)
6. Design and implement an architecture which will be the base for Deep Learning based analyzer, Network controller and Security implementation.

WP2 - Architecture implementation, control system preparation and database model

1. Setting up the fog layer infrastructure
2. Setting up the security layer infrastructure
3. Setting up the DL engine environment.

> Related MFs: MF-1, MF-2, MF-3, MF-5, MF-6 (extra MFs: MF-4)

WP3 - Implementation of IOT orchestration

1. Setting up an isolated IoT network.
2. Preparing control scripts for automatic initialization and management.
3. Preparing control scripts for directing logs and configs between the master and IOT instances.
4. Preparing some generic categorizations and preparing templates which are info and status models for IOTs.

> Related MFs: MF-7, MF-8, MF-9, MF-10

WP4 - Implementation of DL Engine for behavior analysis

1. Do research about the best DL model for anomaly detection.
2. Decide on DL framework (PyTorch, TensorFlow, Keras, etc.)
3. Search for suitable datasets for the DL model.
4. Data pre-processing
5. Feature engineering
6. Training the models with normal behaviors
7. Analyze and classify abnormal situations.
8. Try the suitable DL models and compare the success rates.
9. Choose the optimal model that performs the best

> Related MFs: MF-11, MF-12

WP5 - Implementation of Security layer

1. Setting up An isolated network for the security layer.
2. Installing log channels.
3. Installing packet sniffer.
4. Installing Parsing logs.
5. Installing monitoring systems.
6. Installing A network firewall.
7. Setting up rules for Security alerts.
8. Encrypting all traffic between the IoT fog and the security layer.
9. Encrypting all traffic between the security layer and the DL engine.

> Related MFs: MF-13, MF-14, MF-15, MF-16

WP6 - Integration of DL Engine and Security layer

1. Setting up API between the security system and the DL engine (JSON)
2. Determining the statistical significance of the base lines and anomalies.
3. Feeding the engine with mock data.
4. Installing data streams monitoring system.
5. Creating a testing dataset for testing in the upcoming stage.
6. Creating a training dataset for training the DL engine.

> Related MFs: MF-11, MF-12, MF-14, MF-15, MF-16

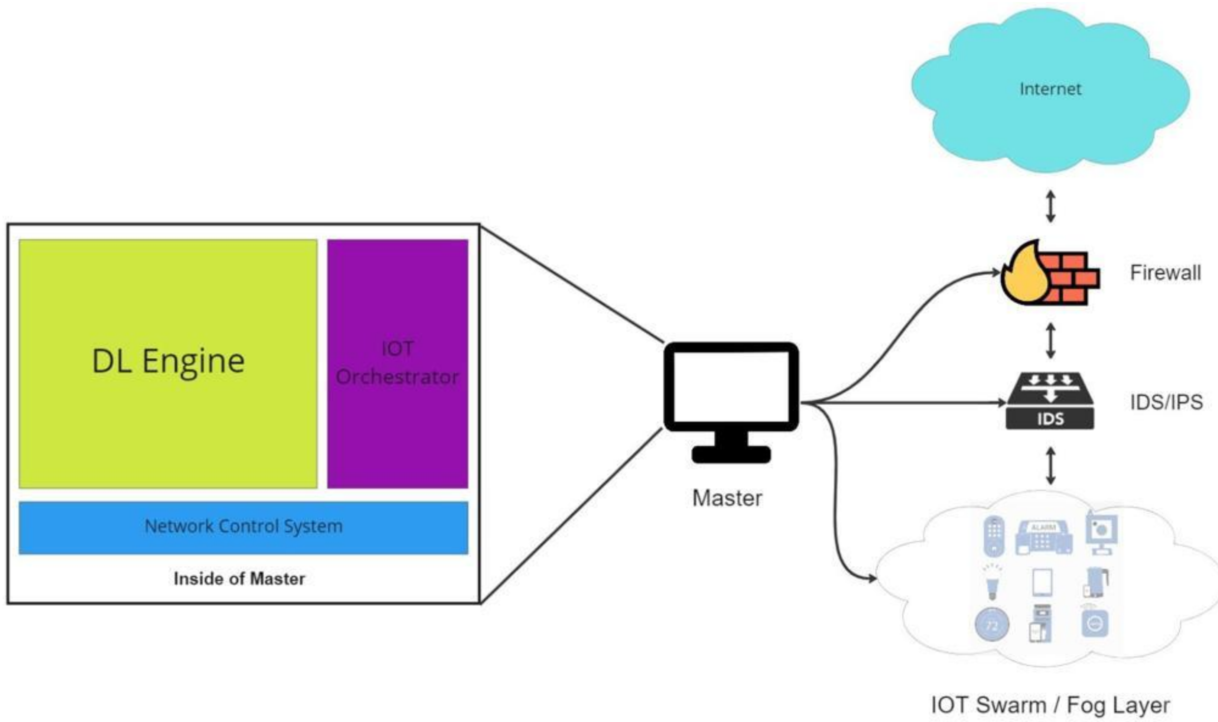
WP7 - Local testing of DL Engine Attack Detection system with IOT device actions

1. Setting up the testing environment.

2. Testing the overall system with the dataset which is obtained from previous WPs.
3. Check response of security appliances according to signals which are given by the DL system that analyzes behaviors of IOT devices.
4. Detects inaccurate or erroneous responses of security appliances.

> Related MFs: MF-11, MF-12, MF-13, MF-14, MF-16

Overall Systems Architecture



DIONA is a system that encloses three main components: master, IoT Swarm / Fog Layer and IDS/IPS. Master, on the other hand, is the main system that contains three subsystems: DL Engine, IoT Orchestrator, Network Control System.

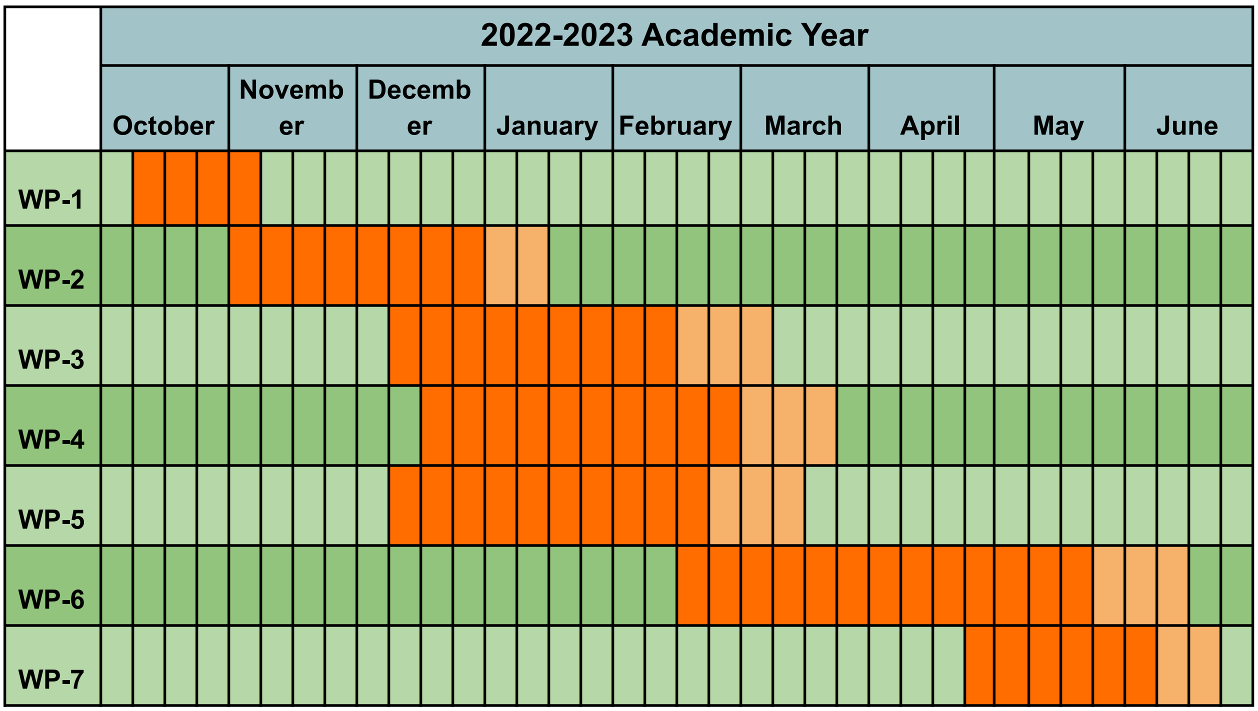
Master is the main computing unit of the DIONA, making the component the most crucial part of the overall system.

- It will collect behavioral data from the IoT Swarm and create a normal using this information with Deep Learning Engine. Thus, making behavioral analysis possible and, in the end, detects anomalies in the swarm.
- It will control IoT logging and configuration settings via IoT Orchestrator by creating control scripts that will be used in initialization, logging and categorization.
- It will detect network intrusions via Network Control System. If there are anomalies detected in the DL Engine, then NCS will look into the logs provided and network traffic to see if there is a network intrusion.

IoT Swarm/Fog Layer is the external component of the DIONA. Basically, it is representing the IoT Swarm that will be monitored within DIONA. IOT Orchestrator will work as a bridge between the IoT Swarm and DL Engine.

IDS/IPS is the network security measure that will be taken as a precaution. It will provide network traffic security, and work in between the firewall, IoT Swarm and master.

Timeline



Risk Assessment

Risk #	Description	Possible Solution(s)
1	Poorly pre-processed and obtained data may ruin the performance of the overall system, since DIONA depends on the DL Engine as it is the main computing unit.	Researching better feature engineering methods and gathering accurate usage history data.
2	Network traffic may be misleading to detect if there is an intrusion.	Using the anomaly detection service, DL Engine, with the Network Control System will decrease the errors in the intrusion detection process.
3	Lack of configuration and usage information about the IoT devices may result in a longer training period.	Carefully prepared configuration for the specific IoT devices, researching and utilizing the general usage history of such devices.
4	Network intrusion testing may be misleading since sniffing network traffic requires a time interval making the system time dependent. So, it cannot be decided at a real time that there is an intrusion.	The testing environment can be based on a simulation in which a user will be attacking and disturbing the functionality of the system in a pre-calculated time period. After that, seeing if DIONA succeeds in detecting the attack.