Report for the CPS Mid-Course Project

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1 Introduction and objectives

In this report we will describe the work done for the mid-course project of the course Cyber-Physical Systems and IoT security. The paper to which we refer is [1] **"Fingerprinting Electronic Control Units for Vehicle Intrusion Detection"** where is explained the design of an algorithm: the CIDS (Clock-based Intrusion Detection System), that is able to detect different kinds of attack. In this paper is shown the functioning of three kinds of attack: the "Fabbrication attack", the "Suspension attack" and the "Masquerade attack". What we tried to do was to implement the three attacks and the CIDS algorithm in a simulation environemnt using **ICSim**, instead of physically as shown in the paper.

2 System setup

We worked on a virtual machine with **LinuxMint22** as operating system. The simulator used is **ICSim**. All the code is written in **Python** and can be found at the following link: https://github.com/auli16/cpsProjectCANBus. We used the **can library** to create messages and to simulate the communication of the attackers with the ECUs. The procedure to run the code is the following:

1. In the directory where the simulator is located:

```
./setup_vcan.sh    //set up a virtual can interface
ifconfig vcan0     //verify vcan0 interface is up
./icsim vcan0      //run the simulator
./controls vcan0   //control panel
candump -l vcan0   //dump the messages in a file
```

2. Run *simulation.py* to create a dump of the CAN bus messages:
   (a) Select which attack to perform by changing the variable *scriptAttack*;
   (b) Initially the script will run the periodic ECU and also the candump command will start;
   (c) After 20 seconds will begin the attack;

(d) All the processes will be closed after 40 seconds after the beginning of the attack.

3 Experiments

For each attack we are assuming that the attacker is already in the system and is able to send messages to several ECUs. To emulate a periodic ECU so that you can at least see something in the simulator we created the script *periodicECU.py* where are sent messages every 2 seconds to open and close a certain number of doors of the car.

3.1 Fabbrication attack

In the Fabbrication attack we are trying to inject messages into the CAN bus to make the system behave in a different way. Essentially, we created a message with the ID of the doors in a way that in the middle of those two seconds gap between legitimate messages we sent other commands to open and close the doors and causing it to function differently from normal behavior.

3.2 Suspension attack

In the Suspension attack we are trying to stop the receiving of messages sent by a legitimate ECU. We made a DoS like attack: we sent a big quantity of messages with the same ID of the doors into the CAN bus in order to lose the messages sent by it. Here we put a very small time sleep, precisely because the aim is to clog the network and not receive packets from legitimate ECUs. The result was that the doors were stuck in the

3.3 Masquerade attack

In the Masquerade attack we are trying to send messages with the ID of the legitimate ECUs. The idea here is that we have to shield the fact that an ECU is compromised. After running the weak ecu script, the attacker will listen the CAN bus for 20 seconds, in this way it can calculate the period of the messages sent by the weak ECU and then it will send messages with the same ID and the same period. We decided to send a message to open different doors with respect to the ones opened by the weak ECU, and this can be seen at simulation time.

3.4 CIDS algorithm

CIDS is a new type of Intrusion Detection System (IDS) that is Clock-based. The algotithm measures and exploits the interval of periodic messages for fingerprinting ECUs. These fingerprints are then used for deriving a clock-behavioural scheme obtained by the Recursive Least Squares (RLS) algorithm. RLS is applied to timestamps and their offsets to derive covariance and skewness. Based on this scheme, CIDS uses the cumulative sum to detect shifts in the clock skew, in fact the intrusion is detected monitoring this parameter. We worked direcly on the dumps of the CAN bus messages obtained through the command *candump -l vcan0*. In each dump file we used *periodicECU.py* to send periodic messages from the ECU *0x19B* In the file *cids.py* we implemented the algorithm, this is composed by several parts:

1. Data preprocessing: we've taken the timestamps of the messages and we've inserted them in a vocabulary in which you can access with the ID of the ECU;
2. Offset calculation: the offset is given by the difference of the timestamps and the corresponding expected time (calculated with the period of the messages);
3. Recursive square least algorithm: we've implemented the RLS algorithm to calculate the covariance and the skew;
4. CUSUM algorithm: we've implemented the CUSUM algorithm to detect the intrusion.

Given the ID in which we are interested, as return we will get an indication of whether the ECU is compromised or not.

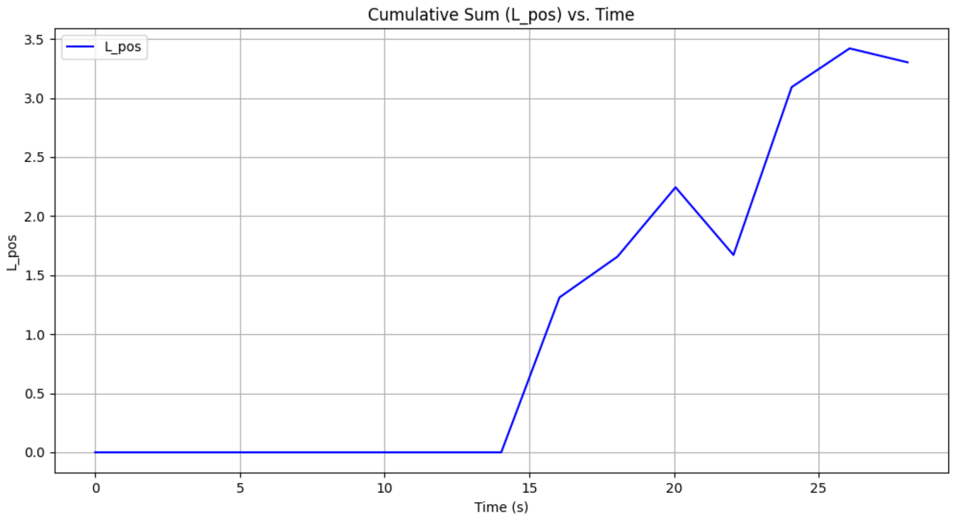
4 Results and Discussion

As said before we've implemented the three attacks and the CIDS algorithm in a simulation environment. We've taken different dumps of the CAN bus messages and we've analyzed them with the CIDS algorithm. The parameters which we've finetuned are the following:

- **threshold**: for the CUSUM algorithm is set to 5, it is used to understand if we can consider a certain value as an intrusion or not;
- **kappa**: is a value which also is used to make the system more or less sensitive to the offsets;
- **window_size**: Effectively we are trying to emulate a CIDS algorithm in real time, so we have to considere a window of messages to analyze up to a ceratin moment. We've set this value to 20 in a way to consider 20 * i offset at a time, where i is the number of the iteration of the CUSUM algorithm.

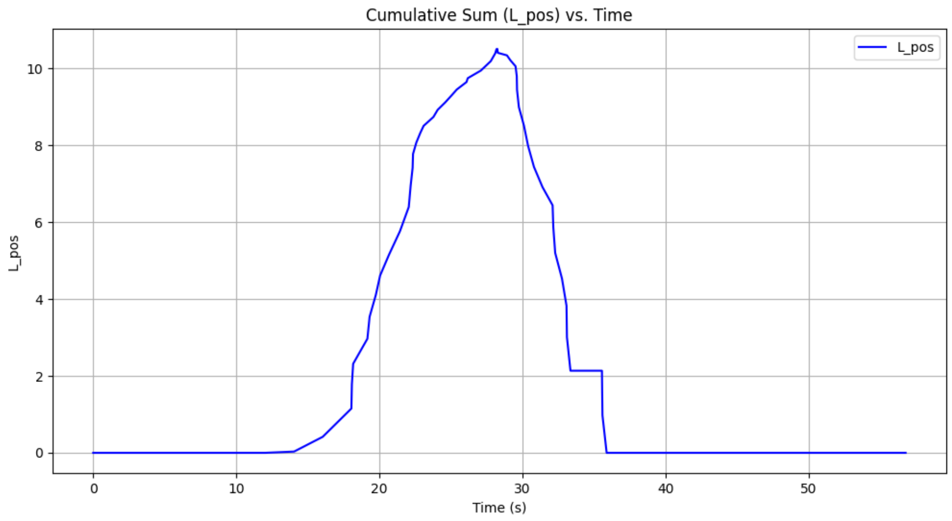
We've got 4 dump files of the CAN bus messages:

- *dump_noAttack.log*: this is the dump of the CAN bus messages without any attack. The algorithm didn't detect any intrusion for the ID of interest (419 = 0x19B).



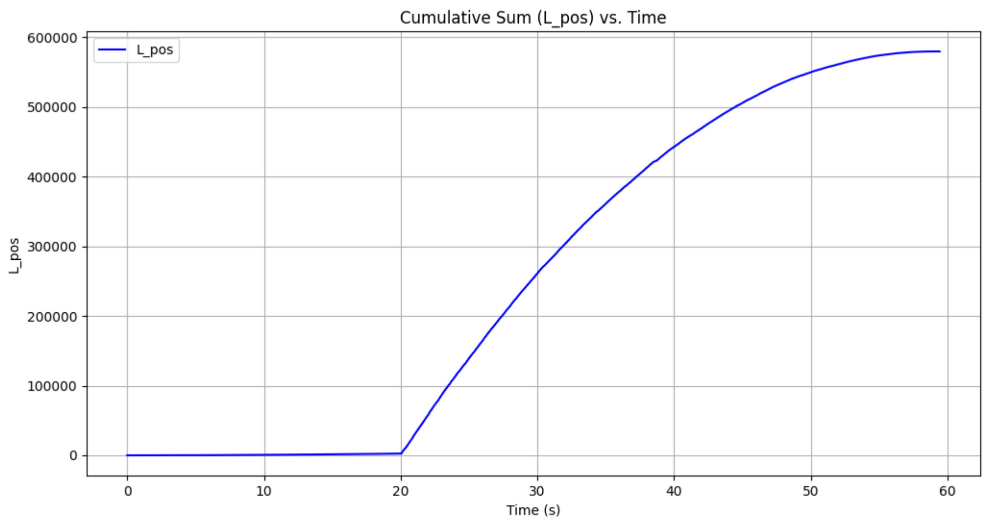
  Since L_{pos} does not exceeds the given threshold, we can conclude that in this dump we have no attacks for this ECU, confirming what we expected;

- *dump_fabr.log*: this is the dump of the CAN bus messages with the Fabbrication attack. The ID of interest is detected as compromised (419 = 0x19B);



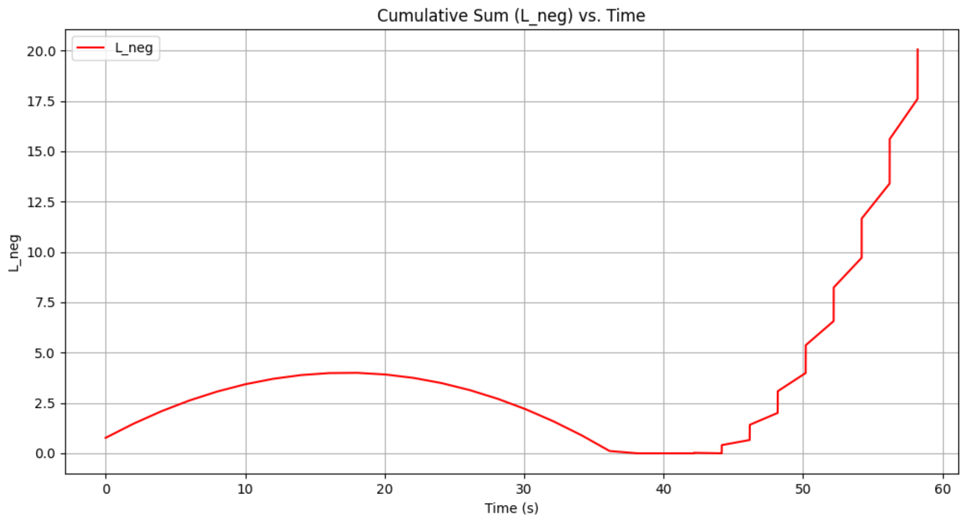
In the image above L_{pos} exceeds the threshold after 20 seconds, therefore we have a compromised ECU. The shape of the curve characterizes a Fabrication Attack;

- *dump_susp.log*: this is the dump of the CAN bus messages with the Suspension attack. The ID of interest is detected as compromised (411 = 0x19B);



The value of L_{pos} starts to increase after 20 seconds and it follows a logarithmic behavior. The values reached by L_{pos} are really high due to the fact we are sending a lot of messages with the same ID. CIDS is detecting an intrusion since the values are above the threshold;

- *dump_masq.log*: this is the dump of the CAN bus messages with the Masquerade attack. The ID of interest is detected as compromised (419 = 0x19B), in this case with a lower value of L with respect to the Fabbrication attack.



The initial curve is under the threshold, and the values start to grow after 40 seconds because of the implementation of the attack. After that time CIDS is able to detect the variations in L_{neg}.

References

[1] Kyong-Tak Cho and Kang G. Shin. "Fingerprinting Electronic Control Units for Vehicle Intrusion Detection". In: *Proceedings of the 25th USENIX Conference on Security Symposium* (2016), pp. 911–927.