ROS-Defender: SDN-based Security Policy Enforcement for Robotic Applications

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**Introduction & Background**

**Problem**
- The Robotic Operating System (ROS) is a popular framework for robotic system development using a publish-subscribe system.
- Current solutions for security of ROS do not provide protection against compromised nodes or denial of service and do not support reactive low-level network policies that can be updated dynamically at runtime.

**Challenges**
- ROS is designed around the concept of topics, higher semantic than network packets; users would like to define policies per-topic.
- Most attacks happen and get detected on network level.
- Need fast detection and response.

**Opportunities**
- SDN offers an opportunity to define and control policies at the network level, thus allow to defend against intrusions.

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**Our Approach**

**Design**
- Create ROS-Defender that leverages SDN to control per-flow policies.
- Define a ROS-Policy-Language that allows a user to specify policies for ROS applications, enforced at network level.

We take an intrusion prevention approach where:
- A user-defined policy is enforced at network level with the help of ROSDN which replaces the normal ROS network communication with a SDN.
- Attacks are detected by ROSWatch, a log and network-based anomaly detection which not only detects attacks but also learns rules that can be used to automatically update the policy and prevent future attacks.
- A policy engine ensures that policies expressed in ROS-level abstractions by a user familiar with ROS, are translated into network-level policies.

**Advantages**
- The approach does not require any API changes or software alterations on the part of the developer and it provides security benefits to both ROS and SROS.

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**Experimental Results**

**Turtlebot3 robot**
- This system consists of a Turtlebot3 robot, a Northbound Zodiac Wx switch, and a laptop which is acting as both the SDN controller and ROS master/decision maker.

**Virtual robot**
- This system is a pure virtual version of our Turtlebot3 system. It leverages the Gazebo package (a well-known robotics simulator) to emulate the sensor input for a variety of different robotic systems, and uses Mininet for the networking component.
- **Turtlebot** - Standard simulated robot for ROS platform.
- **Husky** - An outdoor rugged ground vehicle.
- **AR Drone** - Simulated Autopilot for the AR Drone platform.
- **ABB industrial robot** - Simulated pick and place industrial robot with ROS and Robot Studio.
- **Udacity** - Simulator for a self driving car.

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**Conclusion**

In this paper we proposed ROS-Defender, a comprehensive security architecture for ROS based robotic systems. ROSDefender does not require changes to the existing ROS code since it’s using available ROS application programming interfaces and SDN level mechanisms to monitor and execute access control actions.