Intrusion Detection Adapted for Automotive
– Challenges for Hardware
- An Implementation Example

2018 IEEE-SA Ethernet & IP @ Automotive Technology Day
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Statement given by “I Am The Cavalry”

Evidence Capture

Safety investigations drive substantial improvements, and records of electronic systems operations give visibility into root causes that may otherwise be opaque. These records can plainly show sources of error, be they malfunctions, design defects, human error or deliberate attack. Those waiting for proof of hacking or electronic sabotage will not find evidence without such logging and evidence collection in place. This capability will require more effort, over time, than others on this list, but it is foundational for improving safety in the long-term so starting now will help us achieve this goal.

Do your vehicle systems provide tamper evident, forensically-sound logging and evidence capture to facilitate safety investigations?

I read => Electronic systems shall record events like malfunctions, defects, errors, attacks etc.

Source: I Am The Cavalry / Five Star Automotive Cyber Safety Framework / February 2015 / Link: https://www.iamthecavalry.org/
Network Traffic Clustering

- Unexpected traffic example related to Microcontroller Units

- Connector defect
- Cable defect
- Unknown packet addresses
- Unknown multicasts
- Unexpected packets
- Unused VLAN priority levels
Network Traffic Clustering

- Unexpected traffic example related to OSI Layer 1 / 2 / 2.5

- Physical Layer
  - connector defect
  - cable defect

- MAC Address
  - unused priority levels
  - unexpected packets
  - unknown packet addresses
  - unknown multicasts

- Ethertype
  - VLAN Tag

- Software Stack
  - Microcontroller
  - Ethernet MAC

- Connector
Network Traffic Monitoring – Layer 1

Layer 1 Traffic Evaluation

- Front Processing
- Side Processing
- Rear Processing

Microcontroller
- Task 1
- Task 2
- Stack
- Stack
- Ethernet MAC

To / from Side Processing and Rear Processing
Network Traffic Monitoring – Layer 1

Layer 1 Traffic Evaluation Example – Based on Frame Length

<table>
<thead>
<tr>
<th>Frame Profile (length in bytes)</th>
<th>Task 1 reception</th>
<th>Task 2 reception</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short frame &lt; 128</td>
<td>50% of 1000Fps =&gt; <strong>500Fps</strong></td>
<td>30% of 500Fps =&gt; <strong>150Fps</strong></td>
<td>500Fps + 150Fps =&gt; <strong>650Fps</strong></td>
</tr>
<tr>
<td>Mid range frame 128 &lt; frame &lt; 1023</td>
<td>25% of 1000Fps =&gt; <strong>250Fps</strong></td>
<td>40% of 500Fps =&gt; <strong>200Fps</strong></td>
<td>250Fps + 200Fps =&gt; <strong>450Fps</strong></td>
</tr>
<tr>
<td>Long frame &gt; 1023</td>
<td>25% of 1000Fps =&gt; <strong>250Fps</strong></td>
<td>30% of 500Fps =&gt; <strong>150Fps</strong></td>
<td>250Fps + 150Fps =&gt; <strong>400Fps</strong></td>
</tr>
</tbody>
</table>
IEEE Standard Ethernet Frame

- Application Layer
  - Data

- Session Layer
  - Data
  - (D)TLS Record

- Transport Layer
  - TCP/UDP Data
  - IP Packet

- Network Layer
  - IP Header
  - TCP/UDP Data

- Link Layer
  - MAC Address
  - VLAN Tag
  - Ethertype
  - IP Header
  - TCP/UDP Data
  - CRC

- MAC Addresses
- VLAN Tags
- Protocol
- IP Addresses
- Port Addresses

Addressing Schemes
Network Traffic Monitoring – Layer 1

- Layer 1 Traffic Monitoring Example – Based on Frame Length

Microcontroller

Security Task
Security Stack

Task 1
Task 2
Task 3
Stack

Queues

Frames Filters

Ethernet MAC

- Short Frame Counter
- Mid Size Frame Counter
- Long Frame Counter

Frame Filters

Inbound Ethernet Frames

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Network Traffic Profiling – Layer 1

› Layer 1 Traffic Profiling Example – Based on Frame Length

Microcontroller

Security Task

Security Stack

Counter Value

Frame Length Profiles for Forensic Center

time

Ethernet MAC

<table>
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- Short Frame Counter
- Mid Size Frame Counter
- Long Frame Counter
Network Traffic Profiling – Layer 1

Layer 1 - Limitations

- VLAN Tag
- Priority (PCP)
- Packet Addresses
- Physical Layer
- Frame Layer
- MAC Address
- Broadcast
- Multicast
- Frame Length
- CRC Error
- Covered
- Not Covered

Ethernet MAC

Queues

Frame Filters

Counters
Layer 2 - Challenges

- $2^{48}$ counters ??

- Realistic solution:
  - Capture counters for passing frames -> 2 digit number range
  - Capture rejected frames in one special stack process
Network Traffic Profiling – Layer 2

Layer 2 Ethernet Frame Profiling

- Inbound Ethernet Frames
- Task 1: Stack
- Task 2: Stack
- Task 3: Stack
- Intrusion Detection: Stack
- Queues
- Address Filters
  - MAC Addr. Range 1
  - MAC Addr. Range 2
  - MAC Addr. Range 3
  - Residual Addr. Range
- Ethernet MAC
- Inbound Ethernet Frames

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Network Traffic Profiling – Layer 2

- Multi-Layer Profiling Example
  - Classify property ranges
  - Capture property rate
  - Count properties
Simplified Network Demo

- Switched networks – Expectations
  - Intelligent packet routing by switches
  - Switches provide as well features for traffic analyzes
Traffic profiling/monitoring

› Using Hardware support in form of IETF MIB counter inside the Ethernet MAC
  - Using register for number of good and bad packets with different length
  - We count frames with a length of 64 to 256 bytes, 256 – 512 bytes and 512 to 1023 bytes
› Device B and C will send there profile in a cyclic way to device A
Layer 2 implementation of residual Filter

- Packets which not pass the Uni/multicast addresses or VLAN filter will **not** be dropped.
- These packets are forwarded to a residual filter queue.
- Separating these traffic allows to route the traffic to an independent CPU inside the MCU to analyze.
Separating traffics inside the MCU

- Sorted packets inside the residual queue can be forwarded to an separate/isolated CPU to process the data independent
- CPU x counts periodical packets based on MAC addresses, Types etc...
At the End …

› What to do with all that data?
  
  – Device B and C will report their traffic behavior to Device A which manage the switch
  
  – Device A can analyze and may change the configuration of the switch ports for Device B and C
  
  – Device A sends the network healthiness state to a forensic center

› See the Demo at the Infineon booth!
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