Exploiting Transport Protocol Vulnerabilities in SAE J1939 Networks

Rik Chatterjee
Subhojeet Mukherjee
Jeremy Daily
Colorado State University

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Agenda

Electronic Control Unit (ECU)

Transport Layer Networking Specifications SAE J1939/21

Controller Area Network (CAN)

- Request Overload → Depletion of traffic from target ECU
- Connection Exhaustion → Denial of connections to target ECU
- BAM Block → Blocking Multi-packet Broadcast Messages
- Malicious CTS → Stopping all Multi-packet communication
- Memory Leak → Reading inaccessible memory on target ECU

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Transport Protocol

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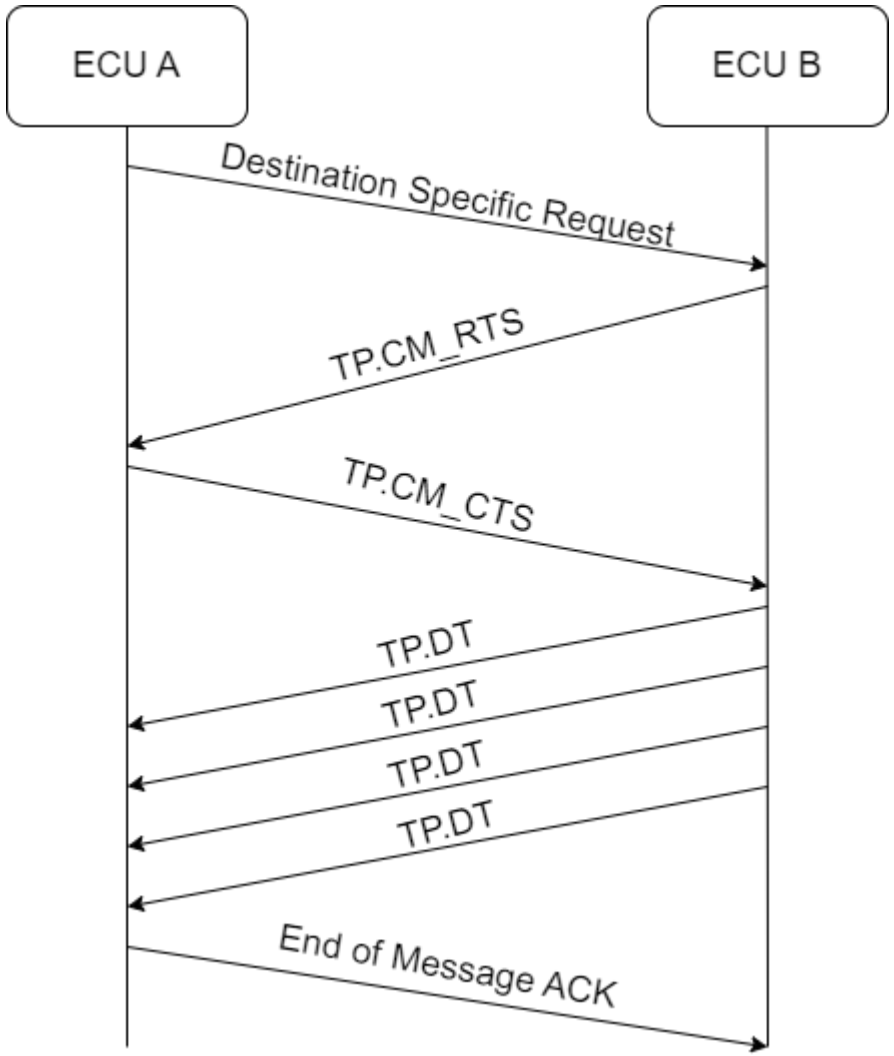
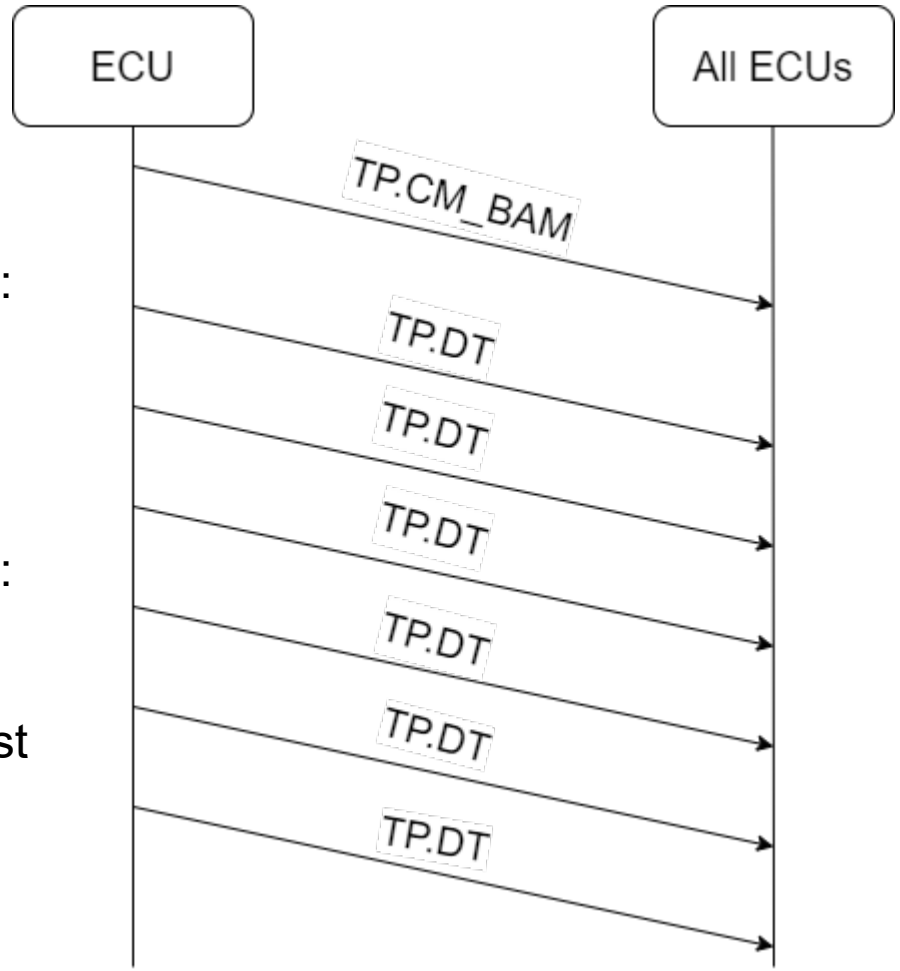
SAE J1939 Transport Protocol



- TP.CM_RTS: Connection Management Message: Request-to-Send
- TP.CM_CTS: Connection Management Message: Clear-to-send
- TP.CM_BAM: Broadcast Announcement Message
- TP.DT: Data Packets



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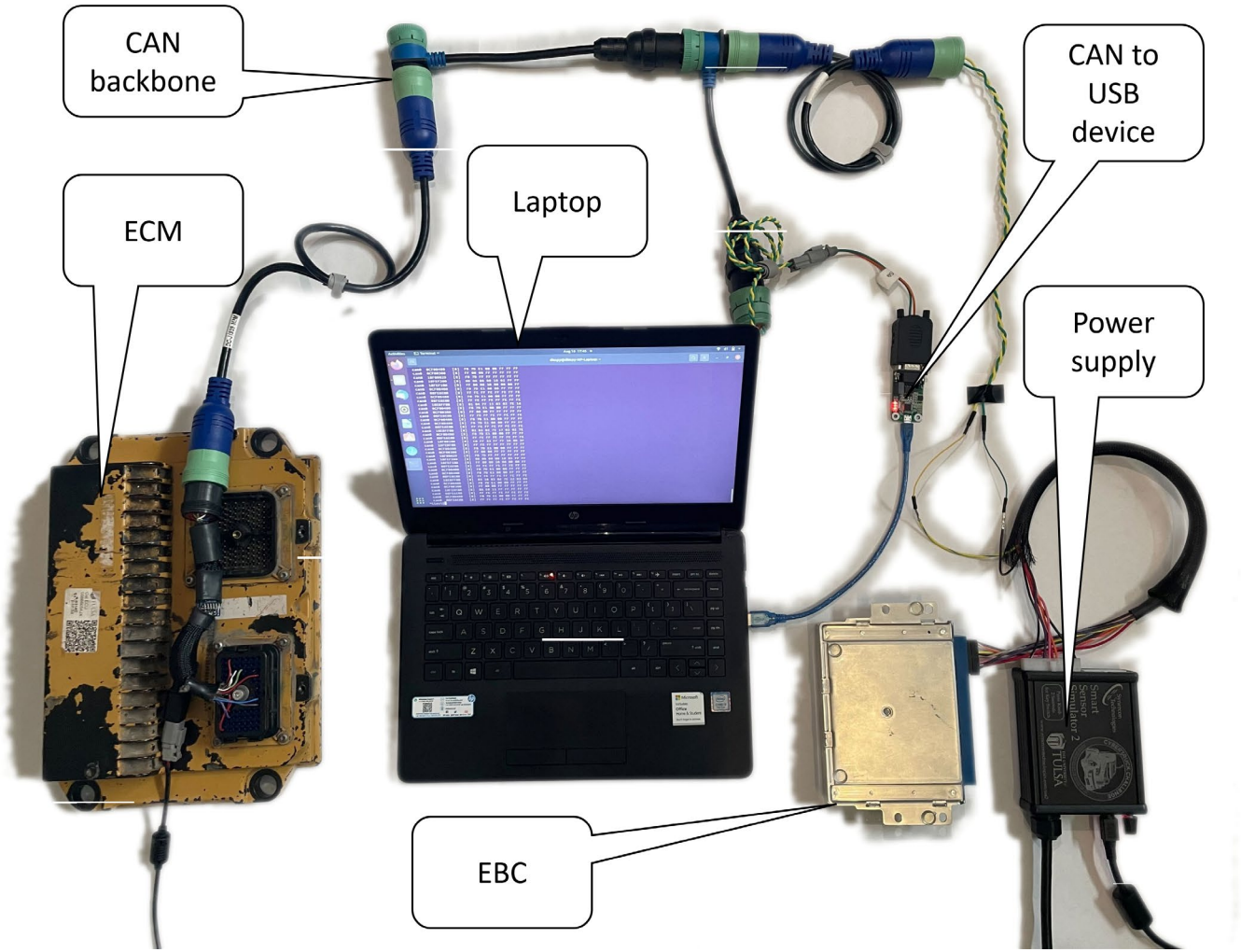
Testbed Setup



- ➢ Testbed 1:
  - Cummins 870 ECM
  - Bendix EC-80 EBC
- ➢ Testbed 2:
  - Cummins 2350 ECM
  - Bendix EC-80 EBC
- ➢ Testbed 3:
  - Caterpillar ADEM 3 ECM
  - Bendix EC-80 EBC
- ➢ Testbed 4:
  - Caterpillar ADEM 4 ECM
  - Bendix EC-80 EBC

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Research Truck - PACCAR PX-7-Powered 2014 Kenworth T270

- Details:
  - Cummins 2350 ECM
  - Bendix EC-60 EBC
  - Allison RDS-200 Transmission Control Unit
  - Paccar CECU Body Controller Unit

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Request Overload

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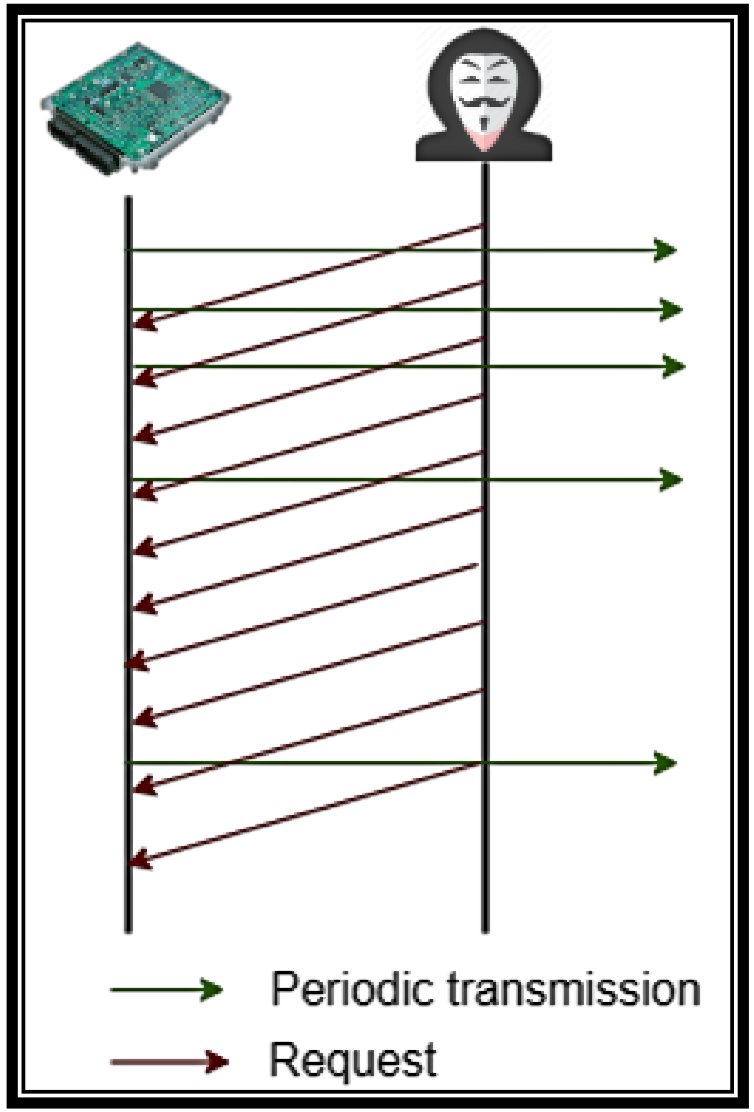
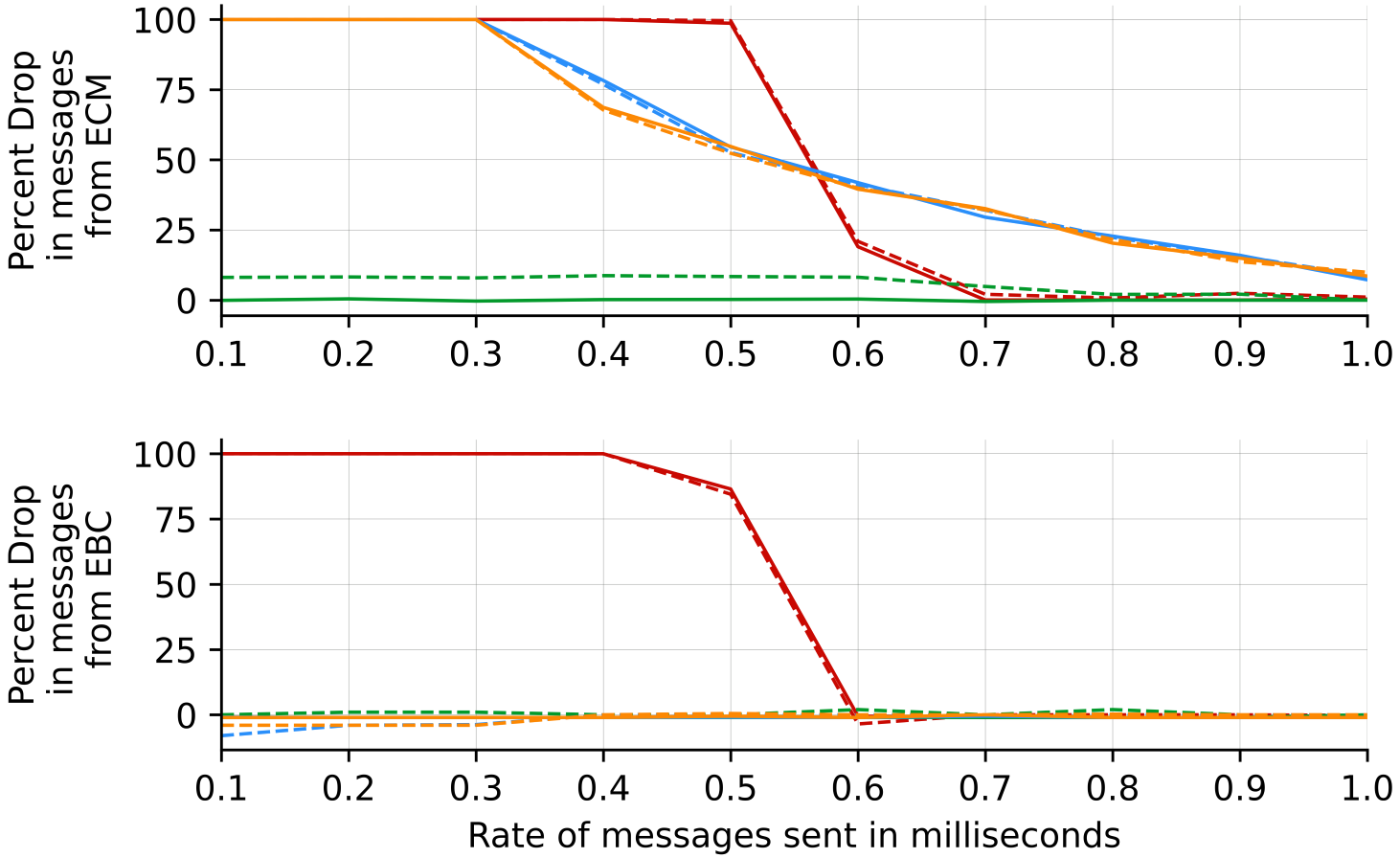
Hypothesis

- **Specification**
  - All directed requests to an ECU must be processed.
- **Attack**
  - Send a high volume of SAE J1939 requests to the target ECU
- **Expected result**
  - In an attempt to serve the sent requests, the ECU fails to perform regular, more critical tasks like transmission of periodic messages



Observation on Testbed 2



Line color significance:

Red: On flooding with messages of ID 00000000_{16}

Blue: On overloading with valid request messages

Orange: On overload with invalid request messages

Green: On flooding with messages of ID $1C000000_{16}$

Line shape significance:

Solid: High priority ([0,3]) messages

Dashed: Low priority ([4,7]) messages

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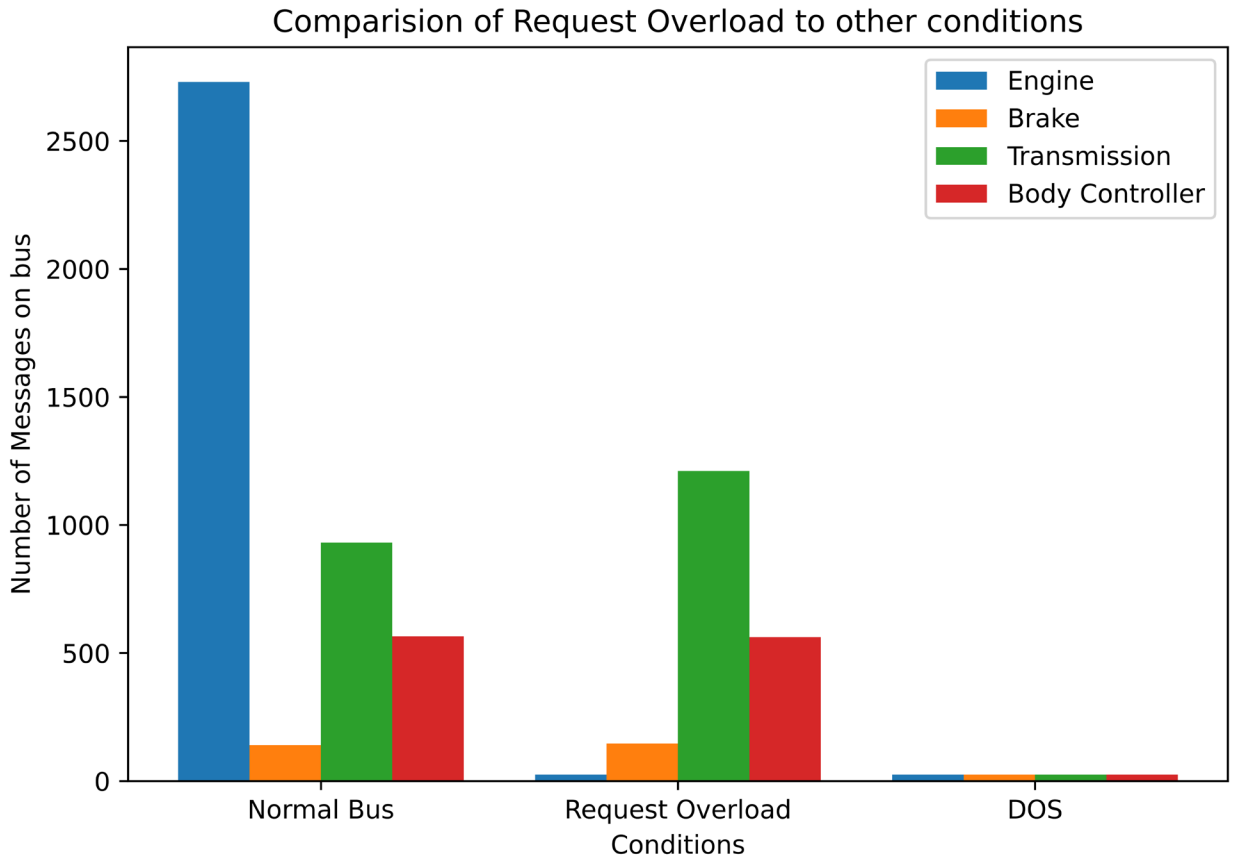
Observation on a Kenworth T270 Truck



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Connection Exhaustion

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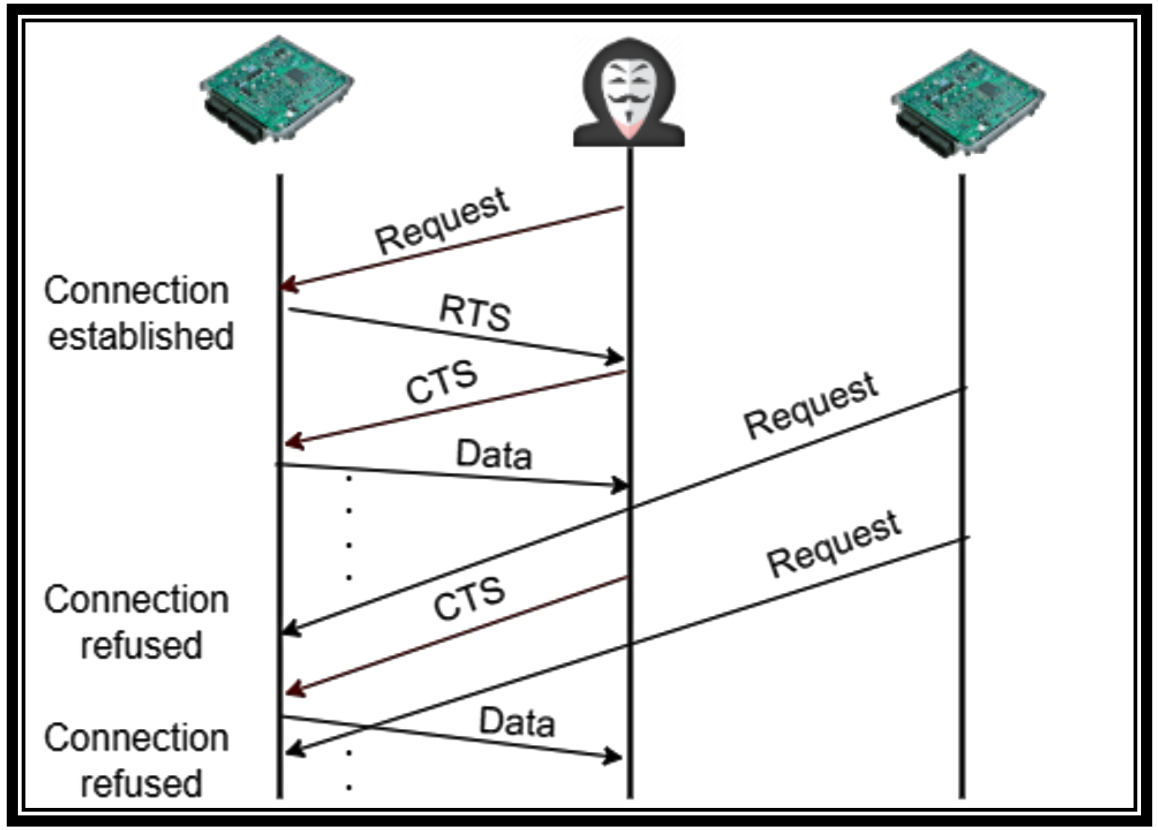
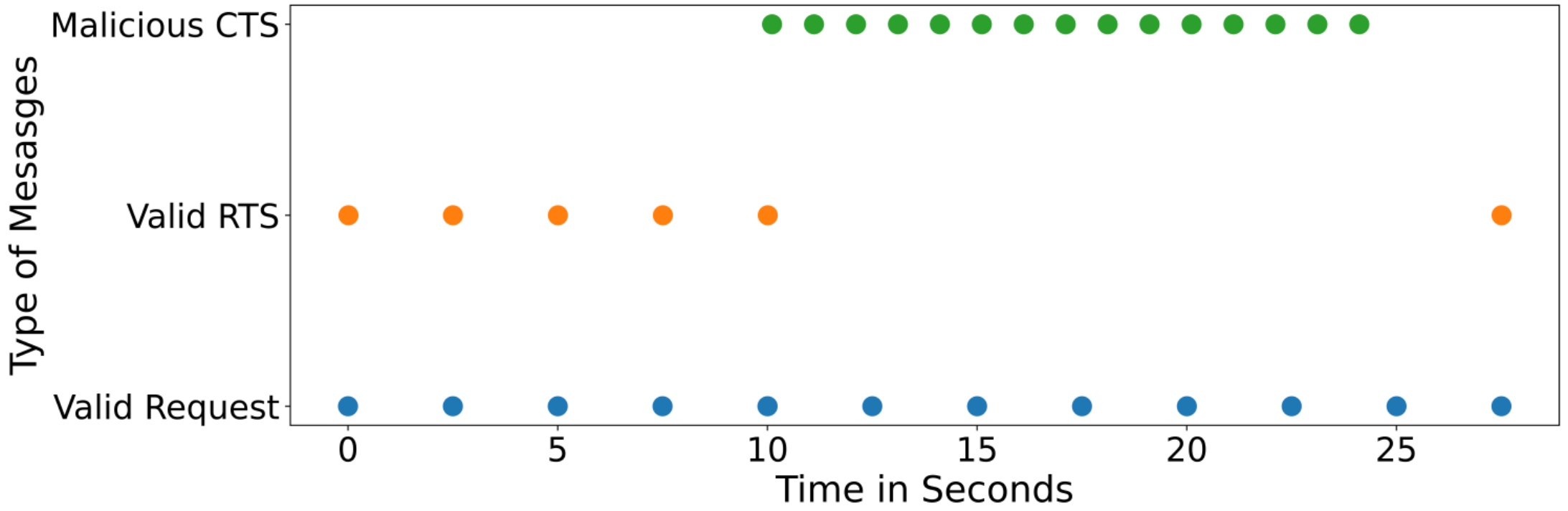
Hypothesis

- **Specification**
  - Exactly one established connection for unidirectional transfer
  - Connection can be kept open for 1250 milliseconds by not sending the end of message acknowledgment
  - CTS message can be sent to request message retransmission
- **Attack**
  - Create multiple spoofed connections
  - Keep connections open by
    - Sending CTS at intervals less than 1250 ms
    - Not sending of end of message acknowledgement
- **Expected result**
  - Denial of legitimate connection attempts to the target

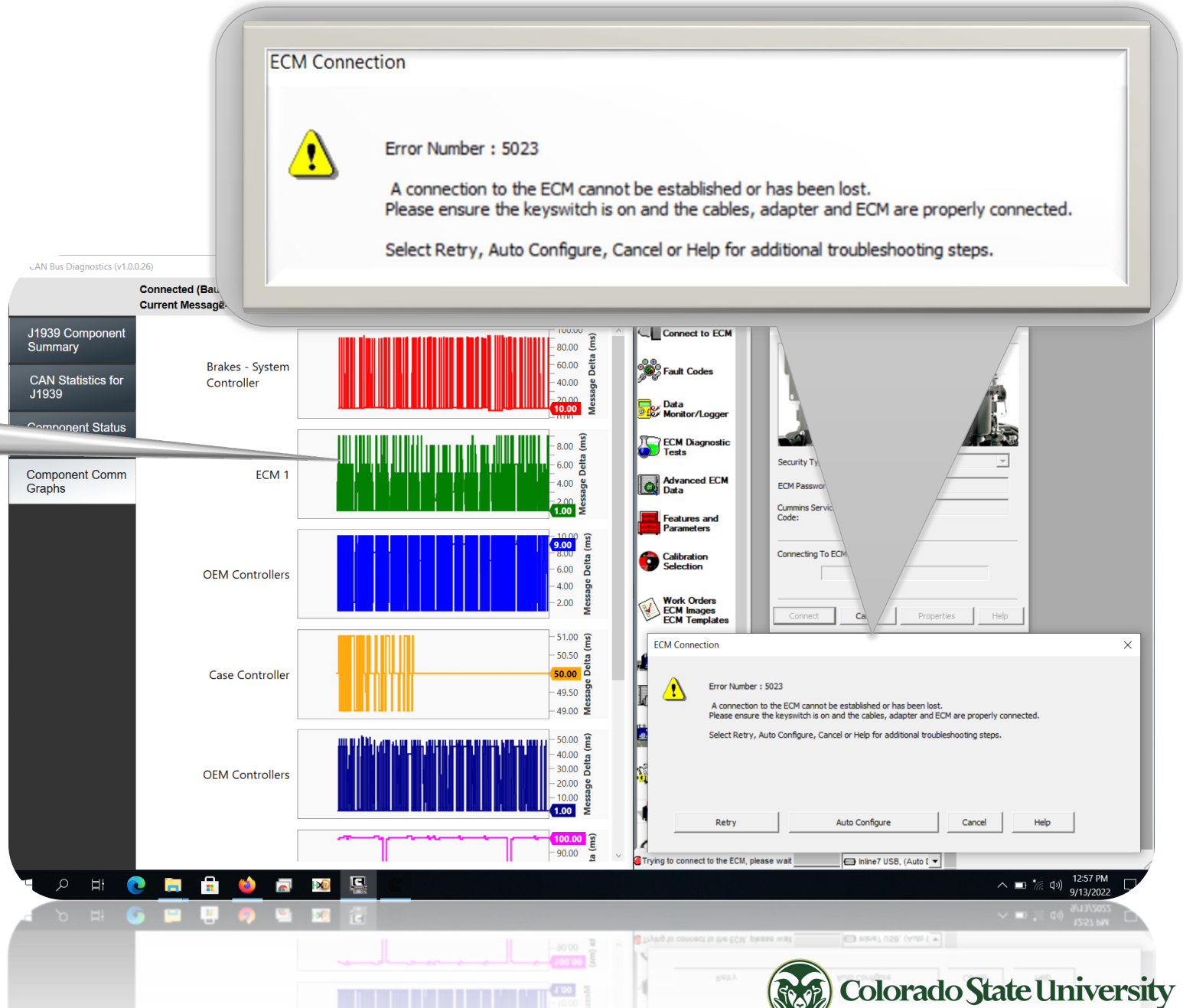


Observation on Testbed 1



Observation on Cummins Diagnostic Tool

ECM activity normal



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BAM Block

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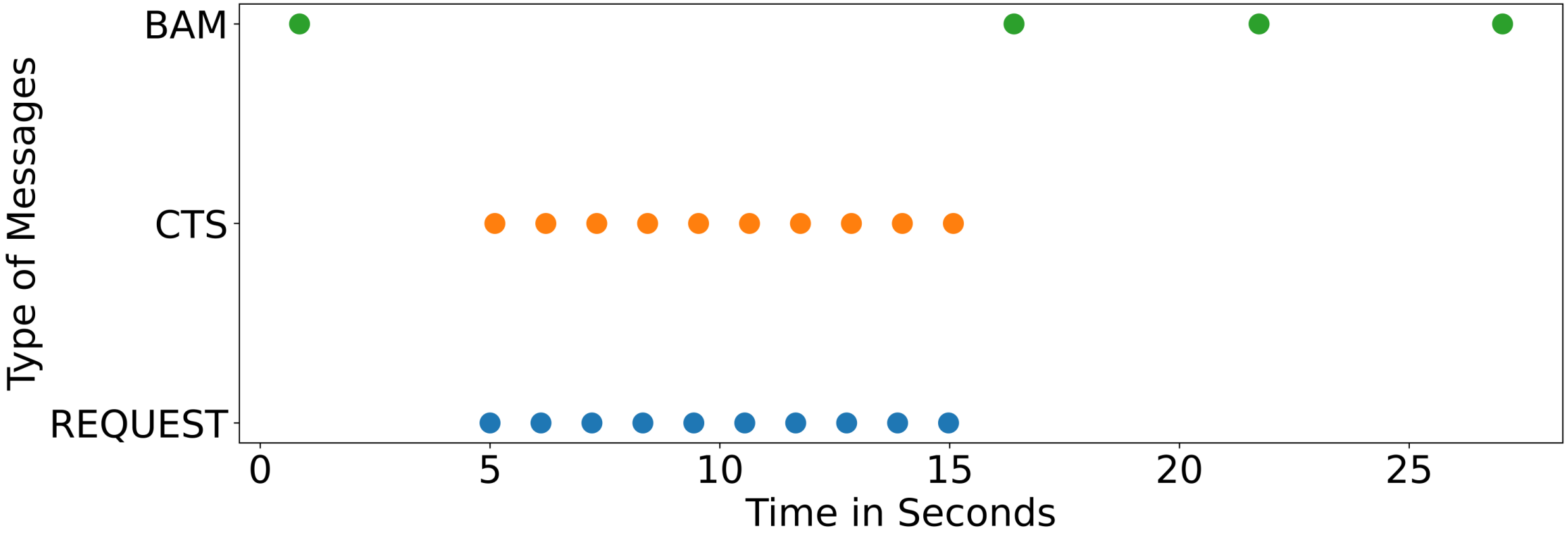
Hypothesis

- **Specification**
  - The SAE J1939-21 standard suggests that an ECU must respond to destination-specific requests.
- **Attack**
  - An attack can be constructed whereby an attacker sends destination-specific requests for messages that an ECU broadcasts globally as BAMs with the expectation that this might force the ECU to respond to such a request
- **Expected Result**
  - The global broadcast communication halts denying information to all ECUs on the network

Observation on Testbed 3



Malicious CTS

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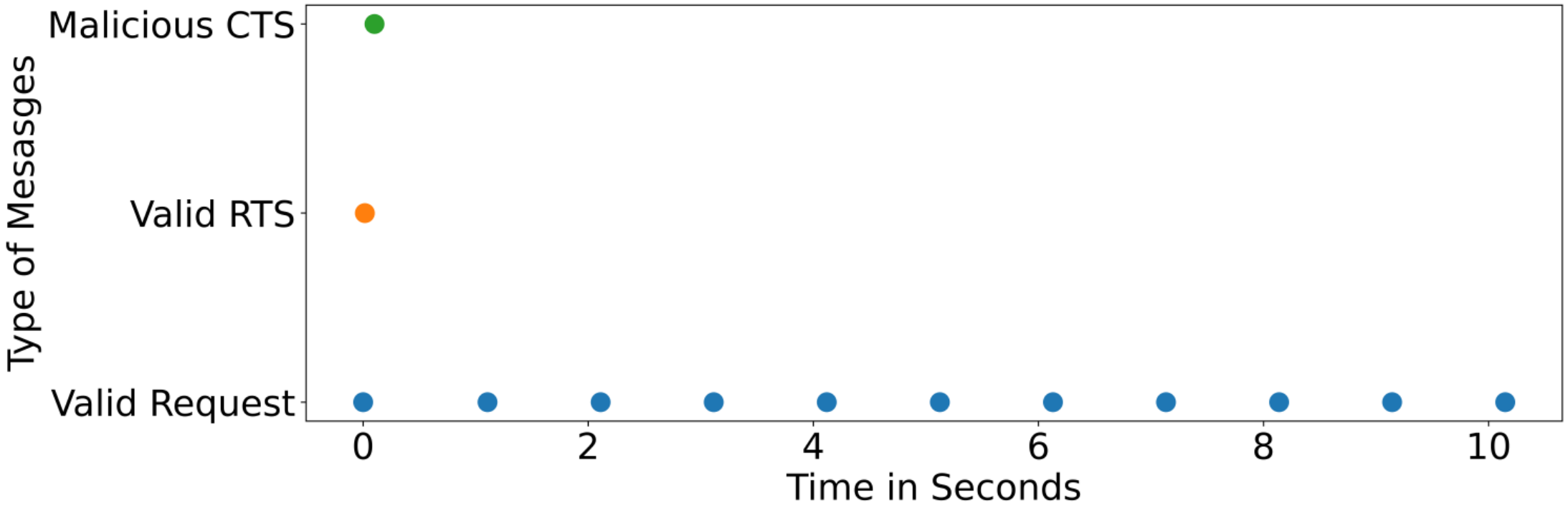
Hypothesis

- **Specification**
  - A CTS message should contain information indicating the packet number of the next data packet to be sent
- **Attack**
  - An attack can be constructed to send a malicious CTS message with value of the next packet to be sent that exceeds the total number of packets that can be sent indicated by the RTS message
- **Expected Result**
  - This may cause the targeted ECU to enter an unknown state and thus hinder normal operations

Observation on Testbed 3



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Memory Leak

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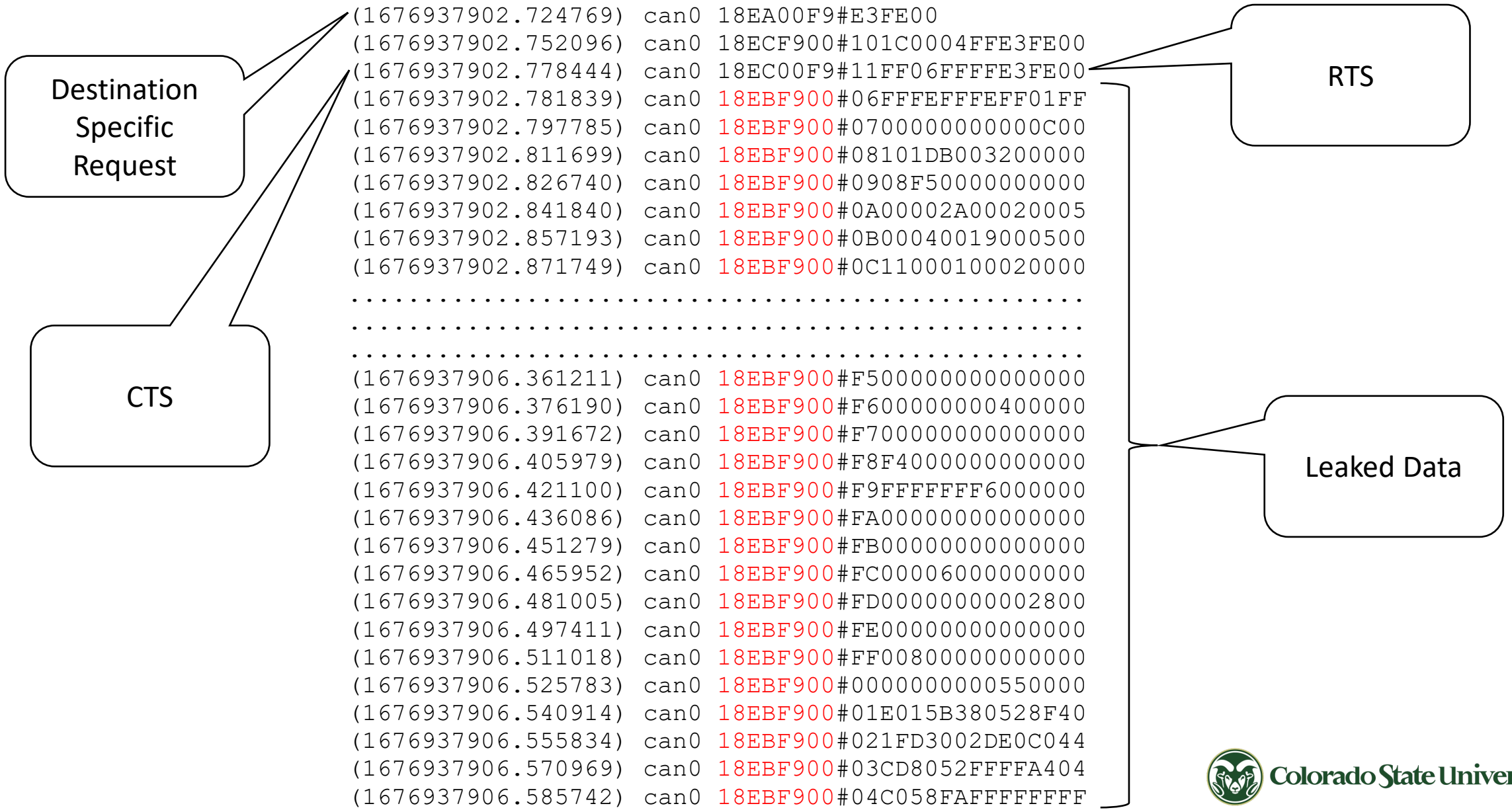
Hypothesis

- **Specification**
  - A CTS message should contain information indicating the number of data packets that can be sent over the transport protocol
- **Attack**
  - An attack can be constructed by sending a crafted CTS message with the value of the number of packets that can be sent larger value indicated by the RTS
- **Expected Result**
  - Get back data that is not supposed to be returned in multipacket transfer

Observation on Testbed 3



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Thank you

Questions ?