Exposing New Vulnerabilities of Error Handling Mechanism in CAN

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Background and Motivation

- CAN: Communication protocol for automobiles and industrial automation
  - Wiring
  - Decentralization
  - Noise Resistance
  - Effective error handling and fault confinement mechanism
- We investigate CAN's error handling and fault confinement mechanism

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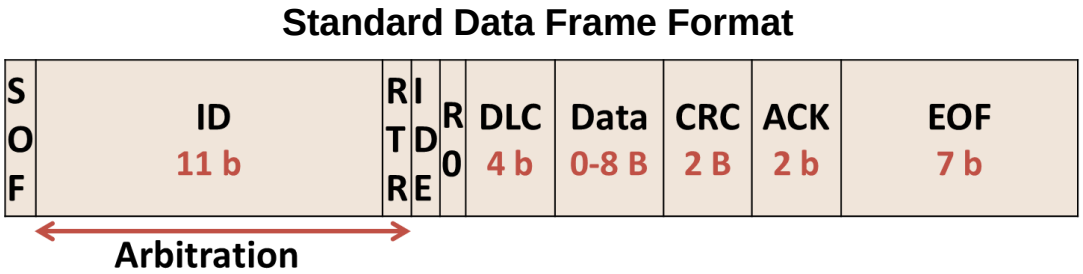
- CAN Operation
  - Format



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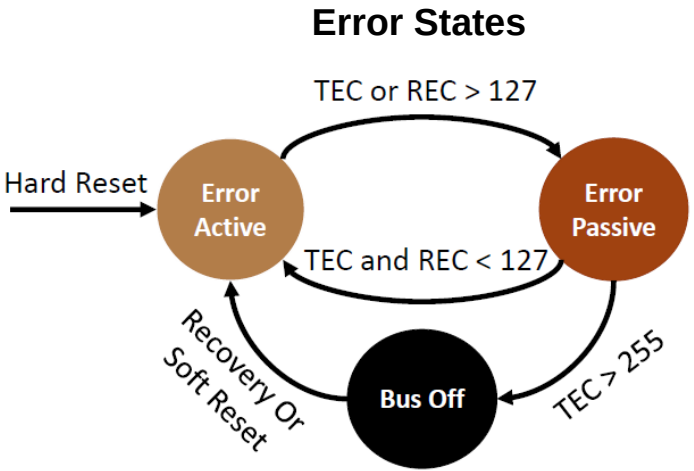
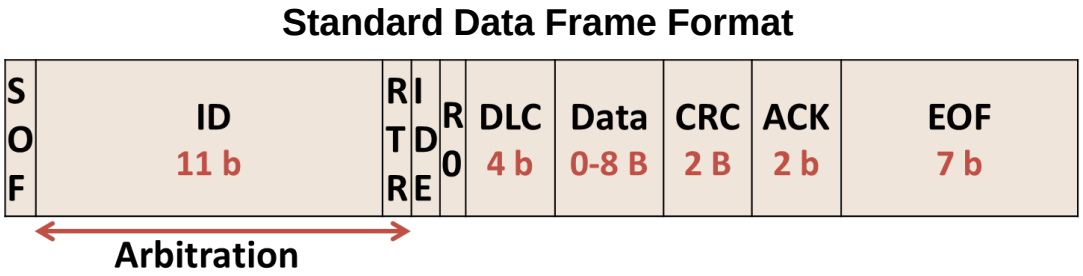
- CAN error handling and fault confinement mechanism
  - Error Counters: TEC, REC
  - Error States





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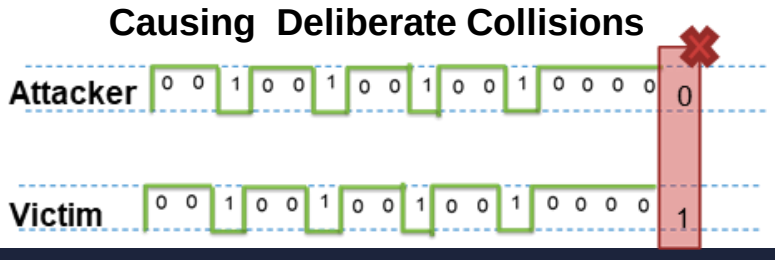

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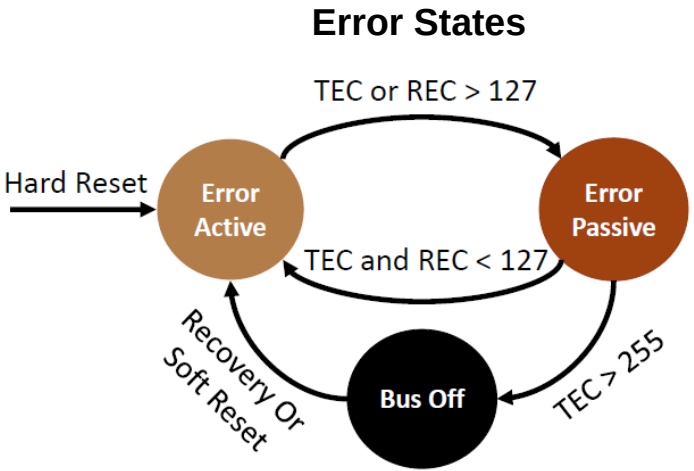

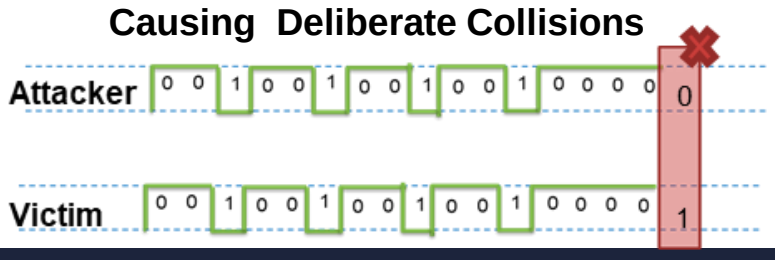

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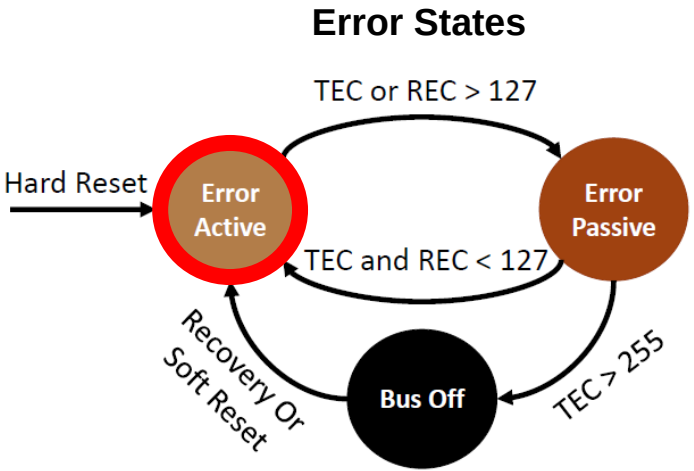
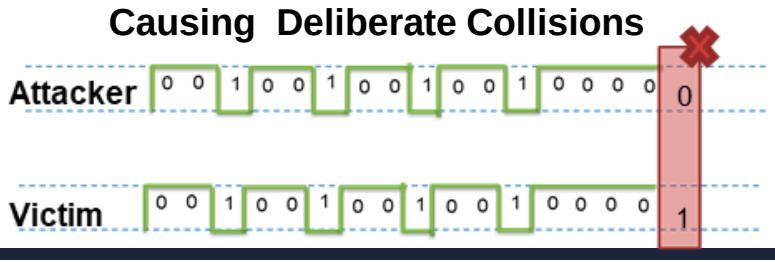
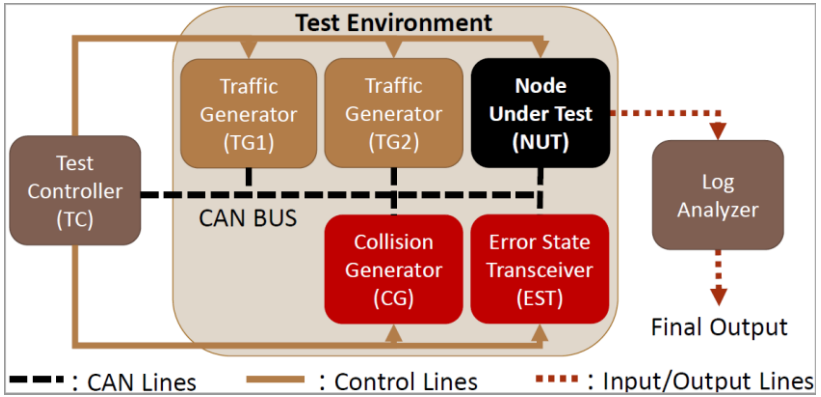




CANOX: A Protocol Testing Tool For CAN

- CAN Operation eXplorer (CANOX)
  - Explores the impact of operating outside of the error active state
  - Reveals possible vulnerabilities

CANOX Architecture



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- Node under Test (NUT)
  - logs its metrics throughout the experiment

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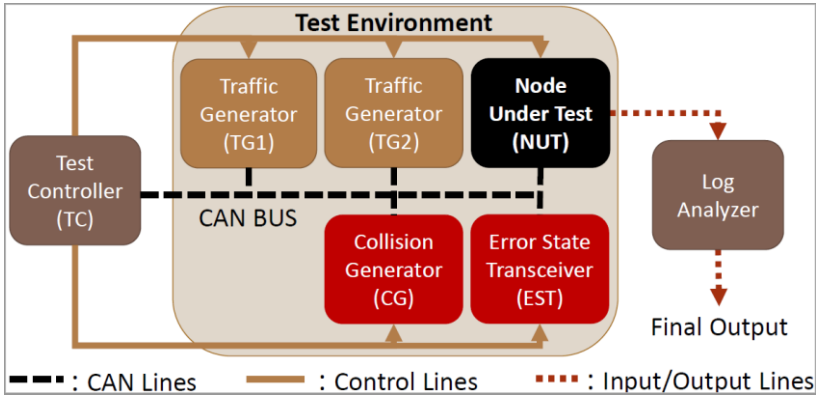

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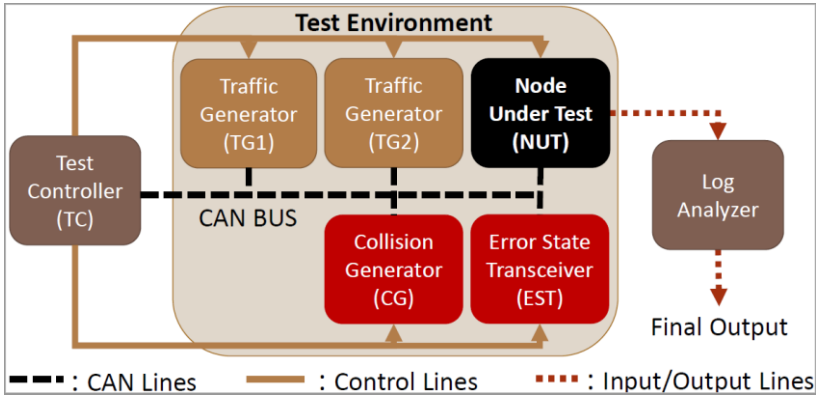

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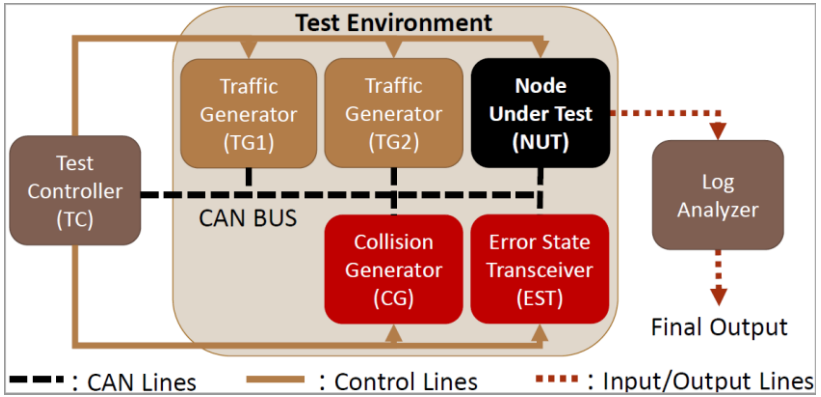

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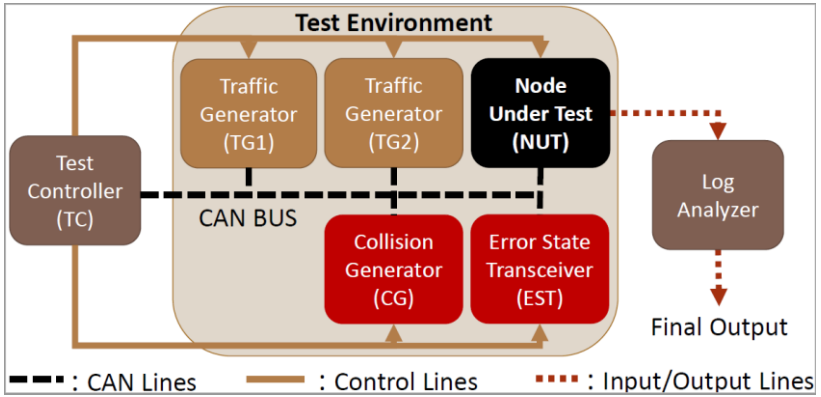

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- Log analyzer detects violations

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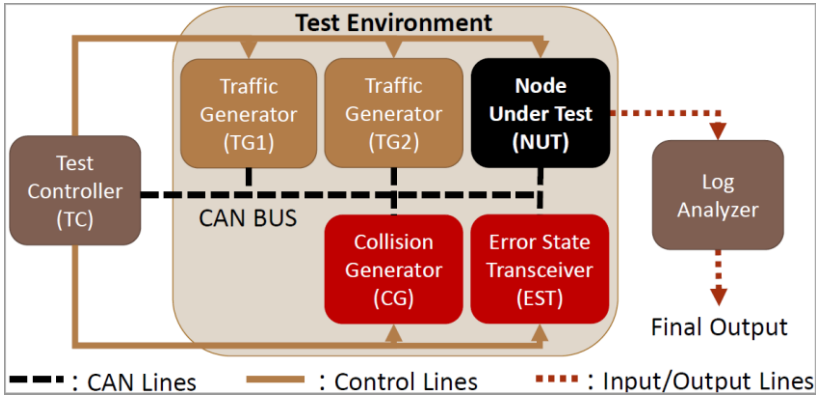

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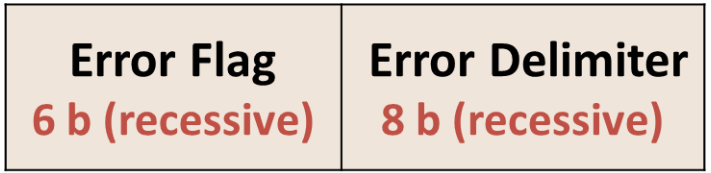
- Failure to send a passive error frame generates a new error

Passive Error Frame



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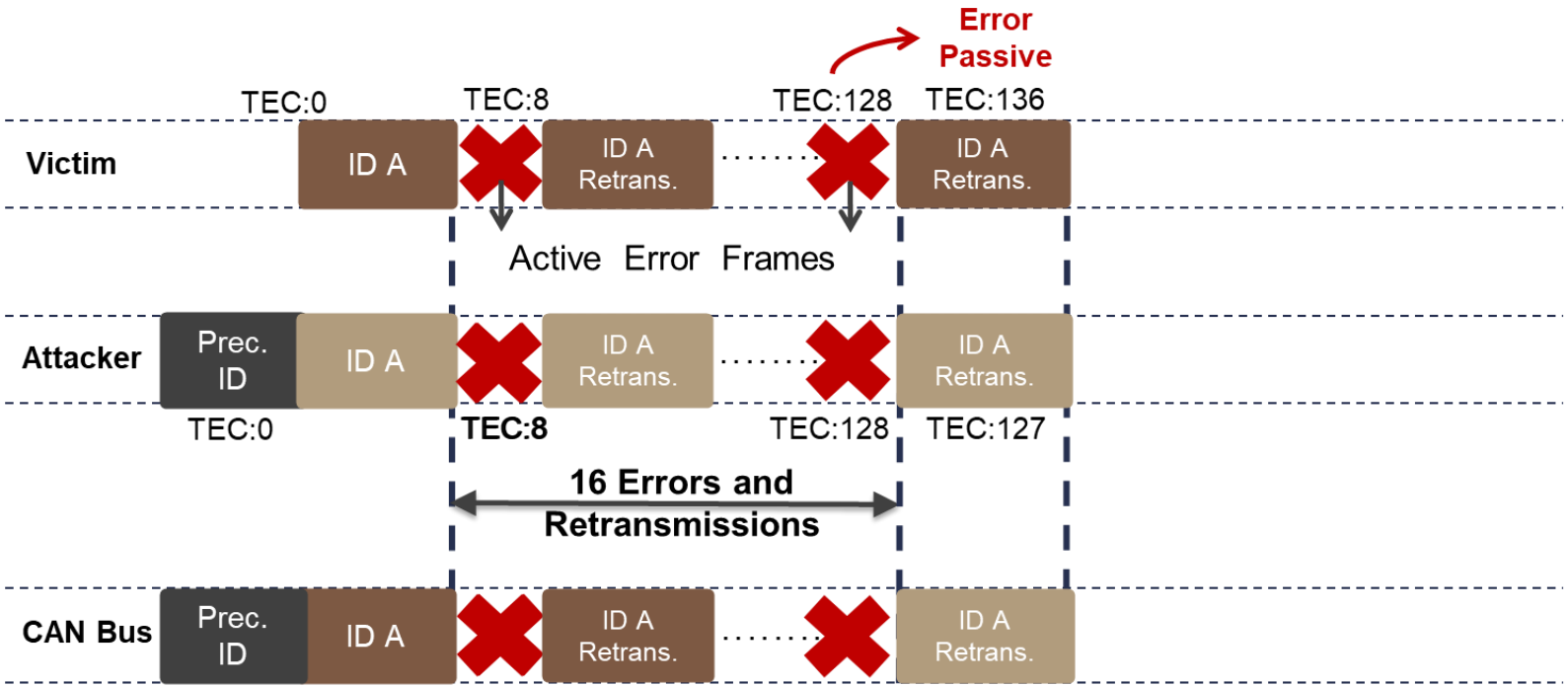

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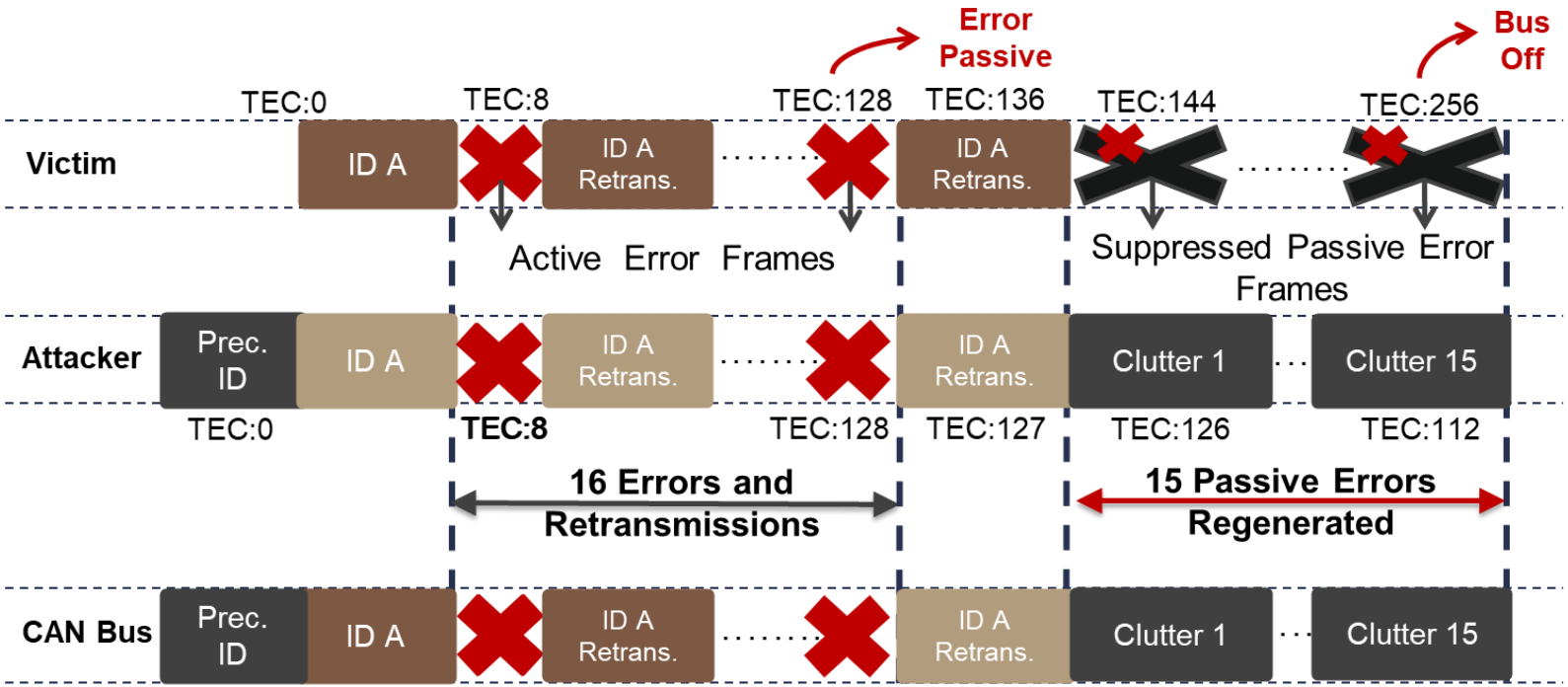

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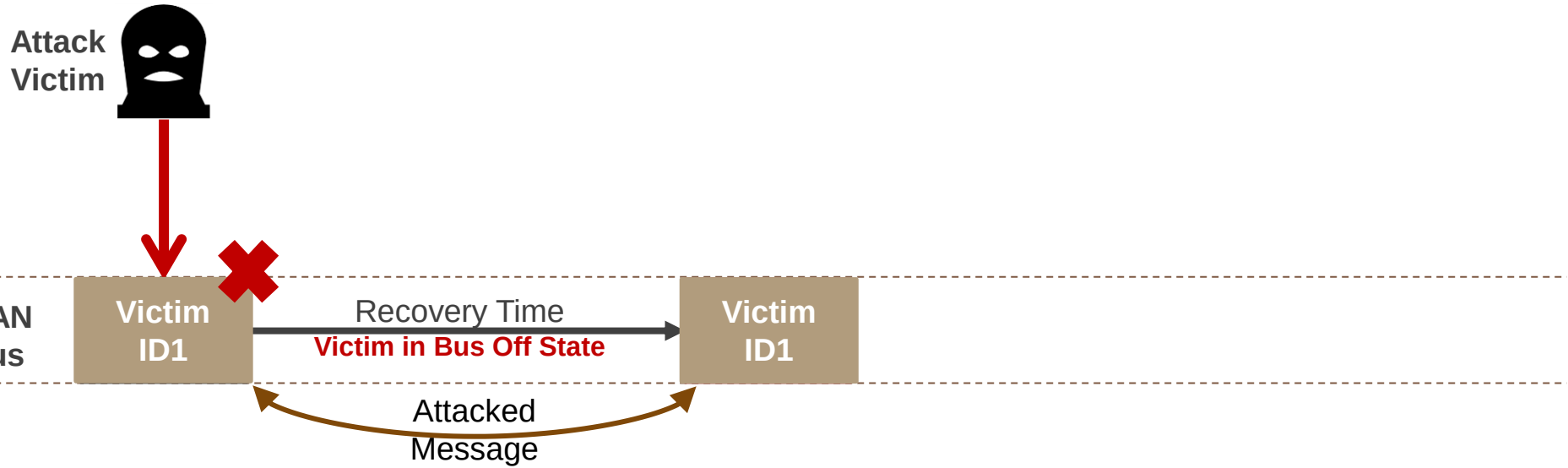

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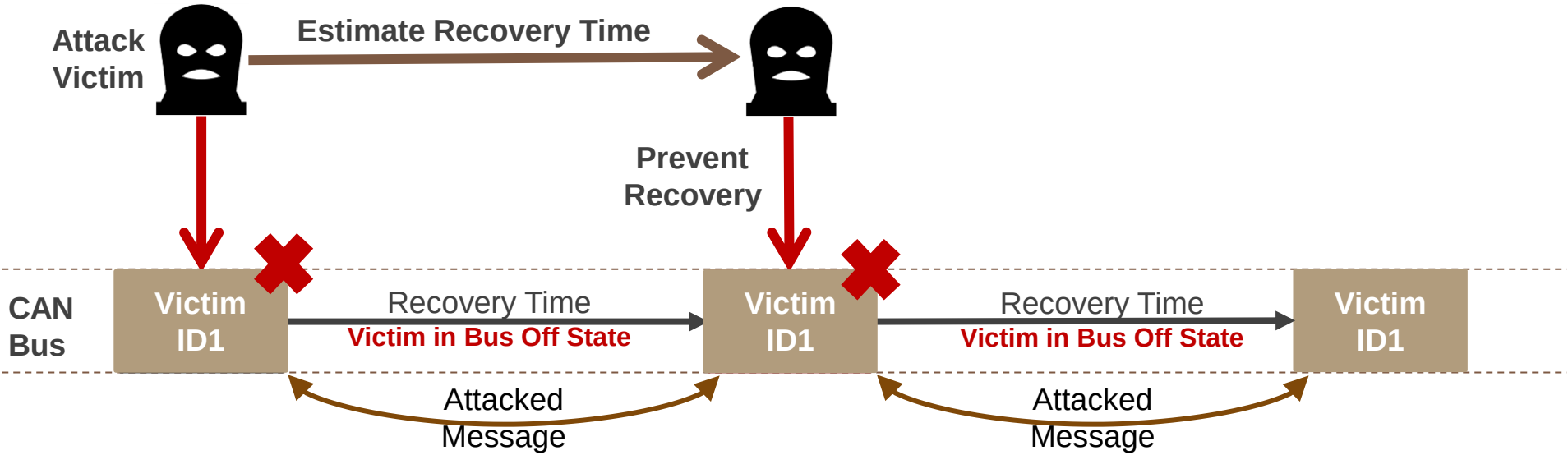

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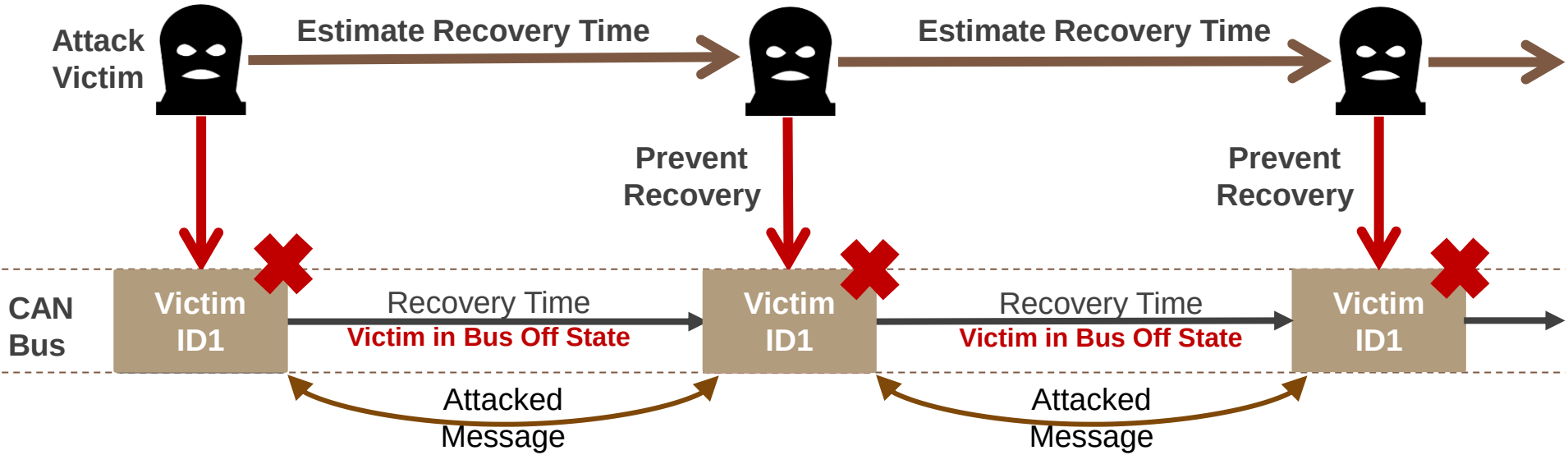

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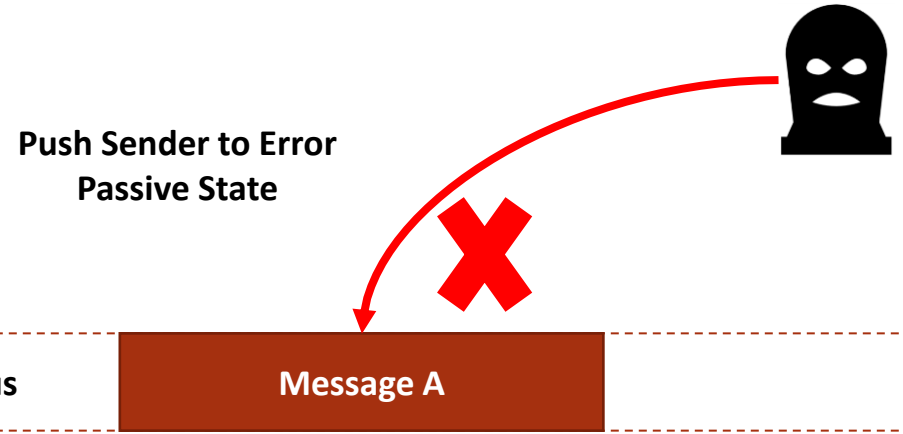

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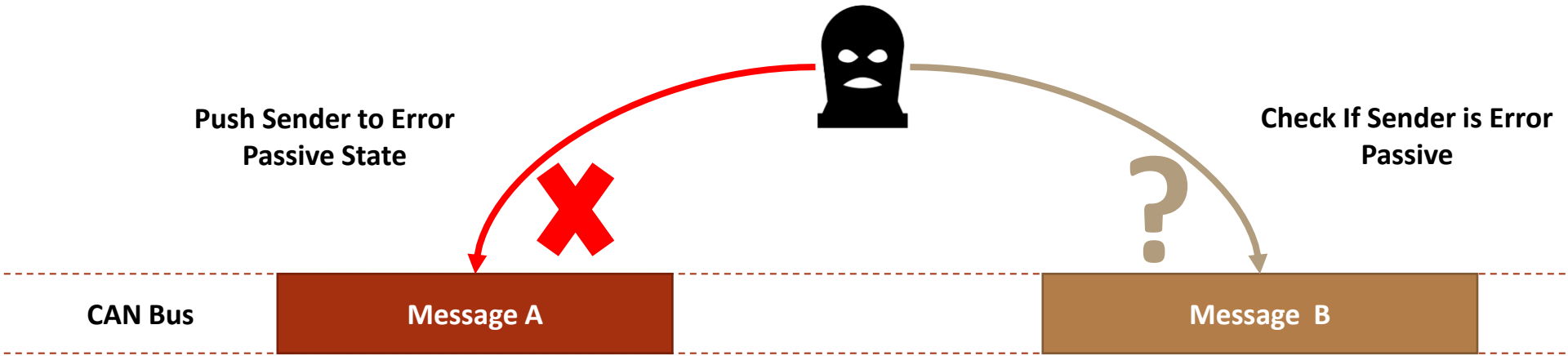

“Scan-Then-Strike” (STS) Attack

- **Threat Model:**
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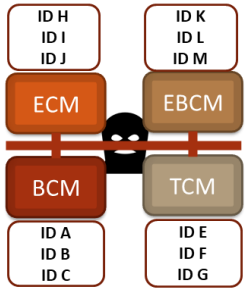
Attacker observing a vehicular CAN bus



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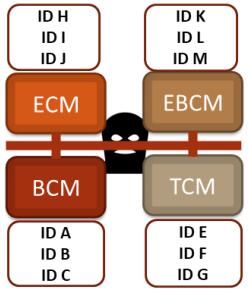

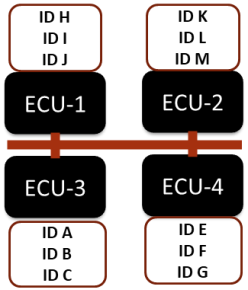

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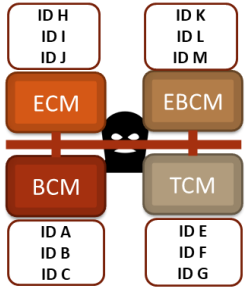

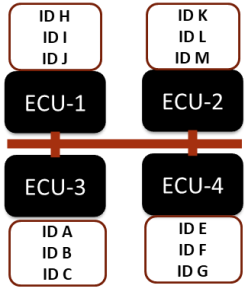

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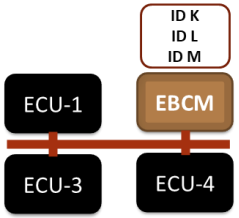

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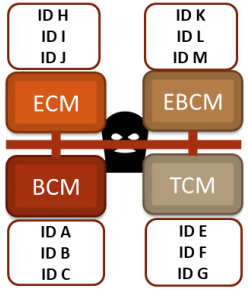

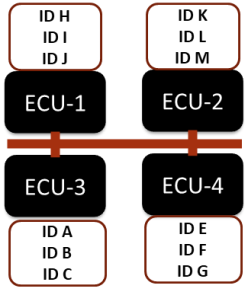

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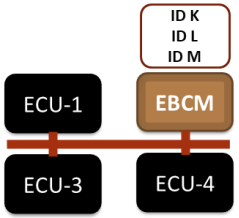

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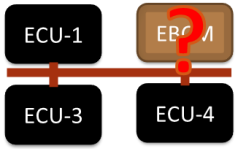

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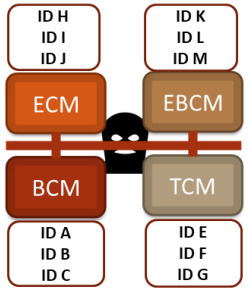

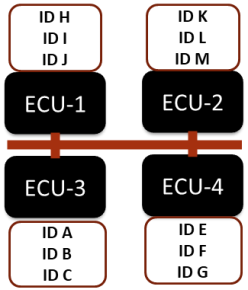

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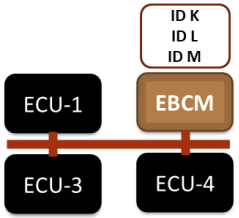

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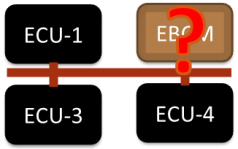

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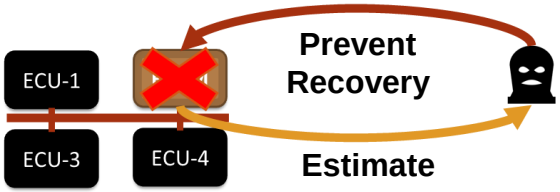

4-Suppression and Recovery Prevention

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Testbed Results

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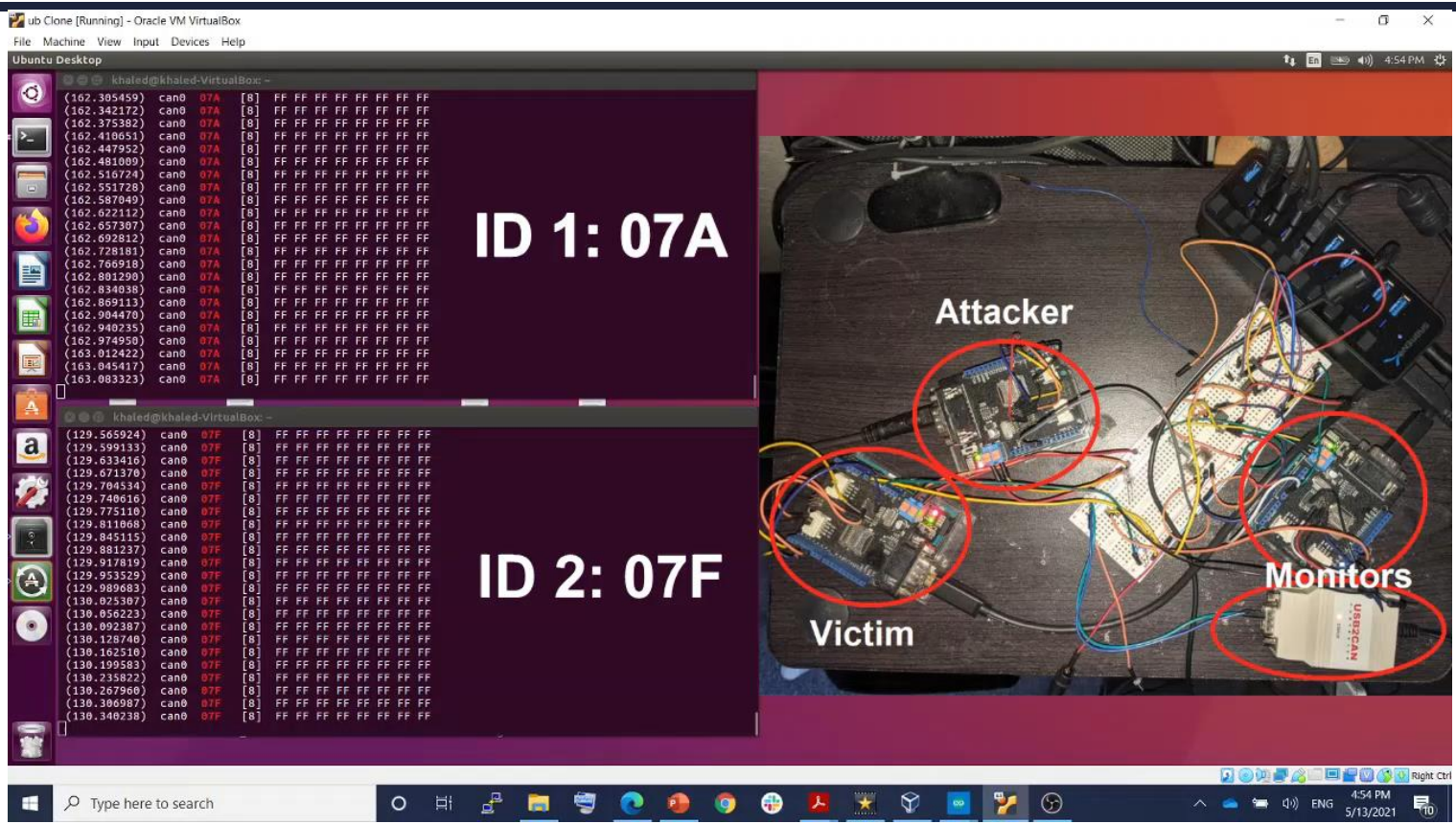
Vehicle Results

ECU #	Function	Suppression Rate
ECU-1	EBCM (Brake)	97.5%
ECU-2	BCM (Body)	91.4%
ECU-3	TCM (Transmission)	85%
ECU-4	ECM (Engine)	83%

Demo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Attacker
Monitors
Victim
USB2CAN
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Responsible Disclosure

- Reported vulnerabilities to:
  - Bosch Product Security Incident Response Team (PSIRT).
  - Cybersecurity and Infrastructure Security Agency (CISA)
    - Case opened
  - Society of Automotive Engineers (SAE)
    - Committee review for next standard revision
- Proposed mitigations to each of the discovered vulnerabilities

Conclusion

- CAN's error handling mechanism – a security weakness
- We introduced CANOX
  - A protocol testing tool to identify possible vulnerabilities
- Three new error-handling vulnerabilities revealed by CANOX
  - Each could be exploited separately
  - STS: an end-to-end attack via exploiting all three vulnerabilities
- Attack Implementation on a testbed and a real vehicle
  - Mapping Accuracy: 100%
  - Single Frame Bus Off Effectiveness: 100%
  - Persistent Bus Off Suppression Rate: 83-100%

Thank You!
Questions?

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