Announcements

Today: ***Last lecture*, special topic on smart transportation security**

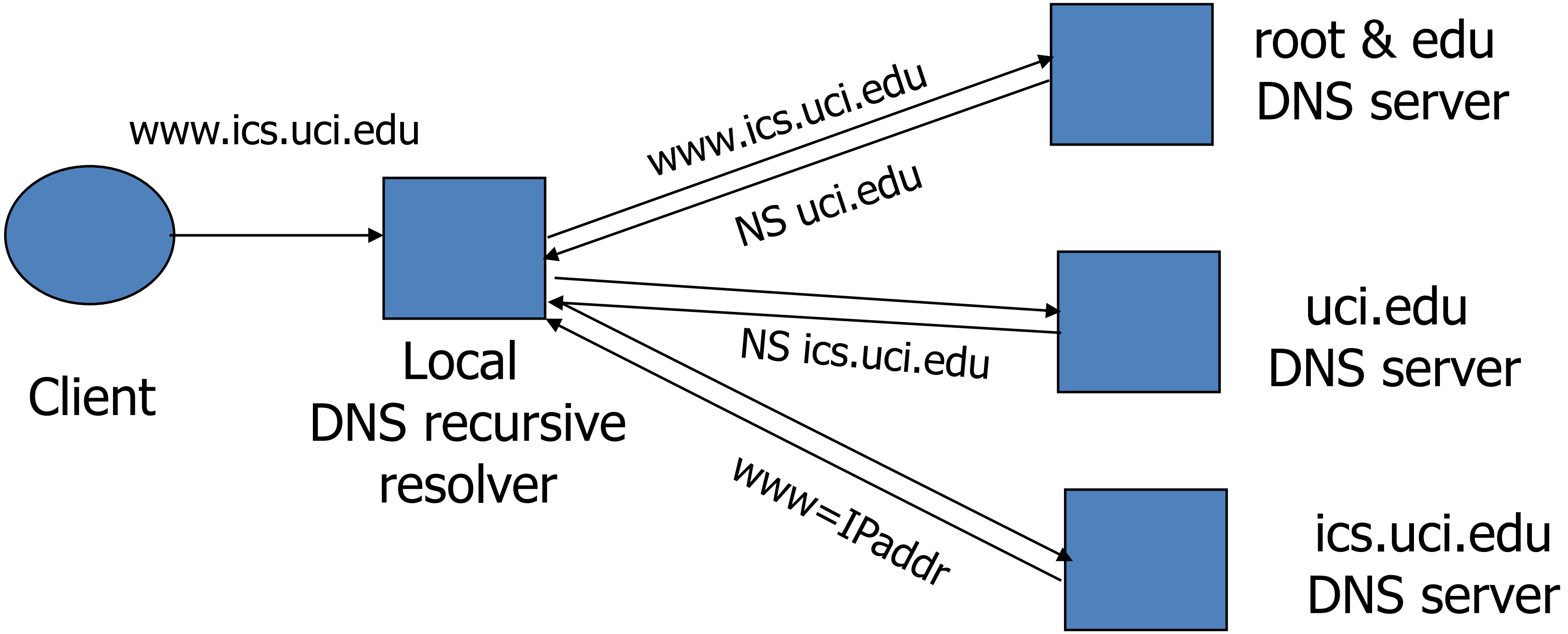
- Attention: **It's within the scope of final exam**

Final exam: *12/12, 1:30-3:30 PM*

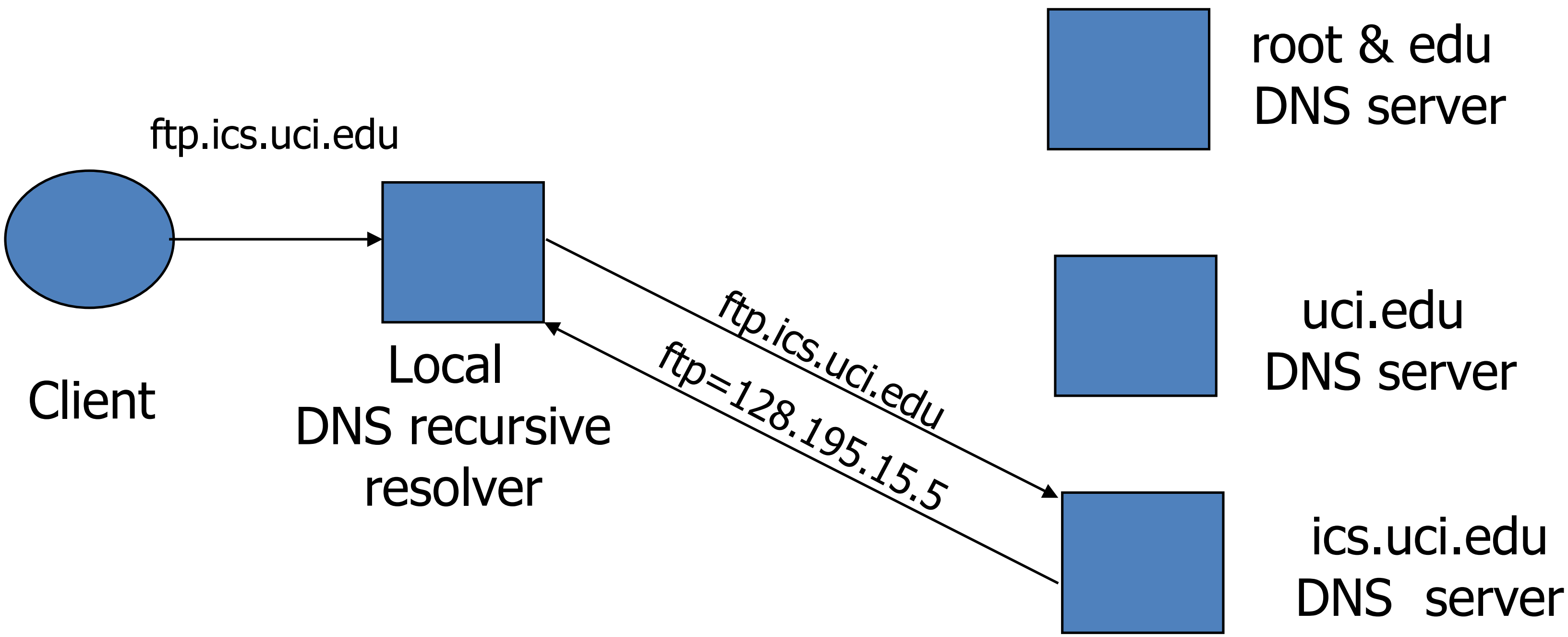
- Should be in this class room (HSLH 100A)
- Bring ***your photo ID*** with you

DNS: Domain Name Service

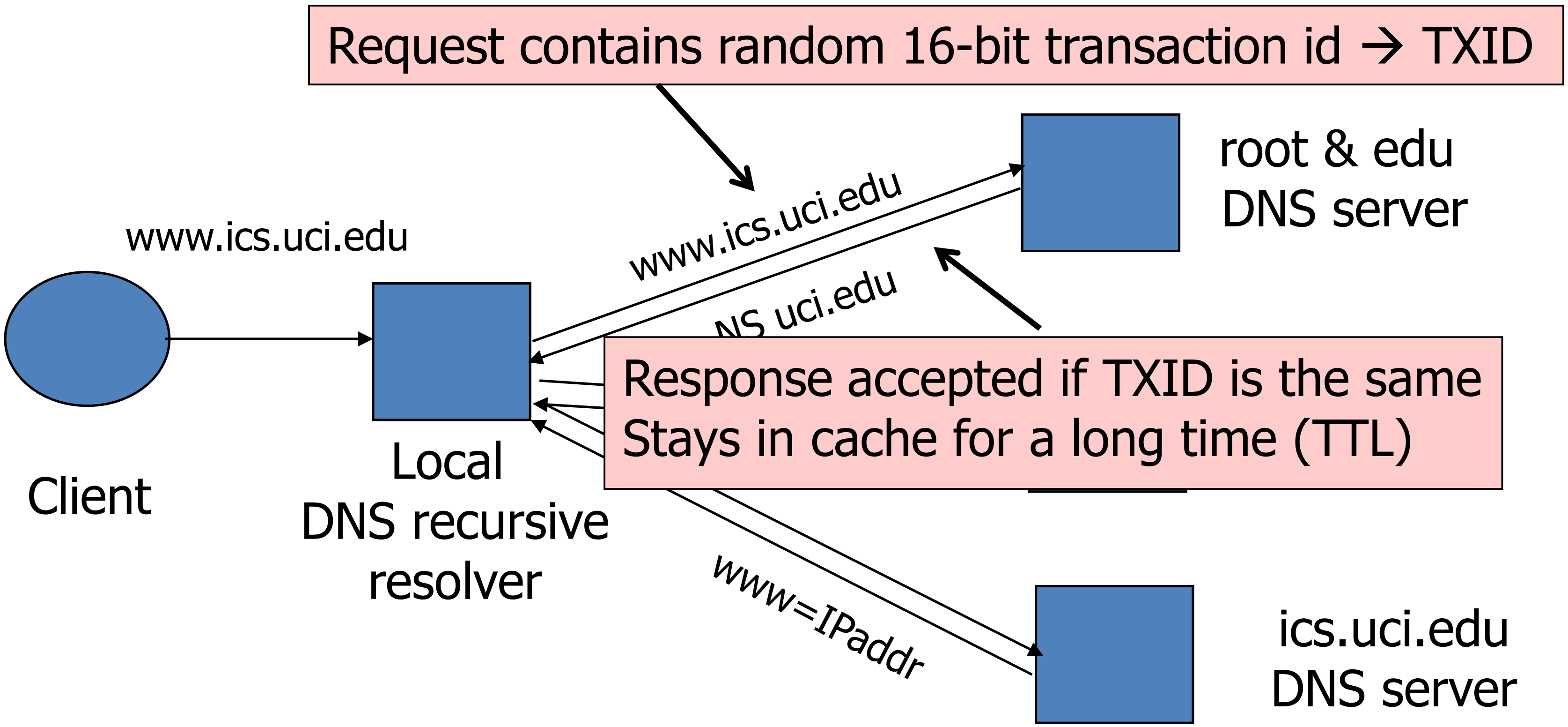
DNS maps symbolic names to numeric IP addresses
(for example, www.uci.edu ↔ 128.195.188.233)



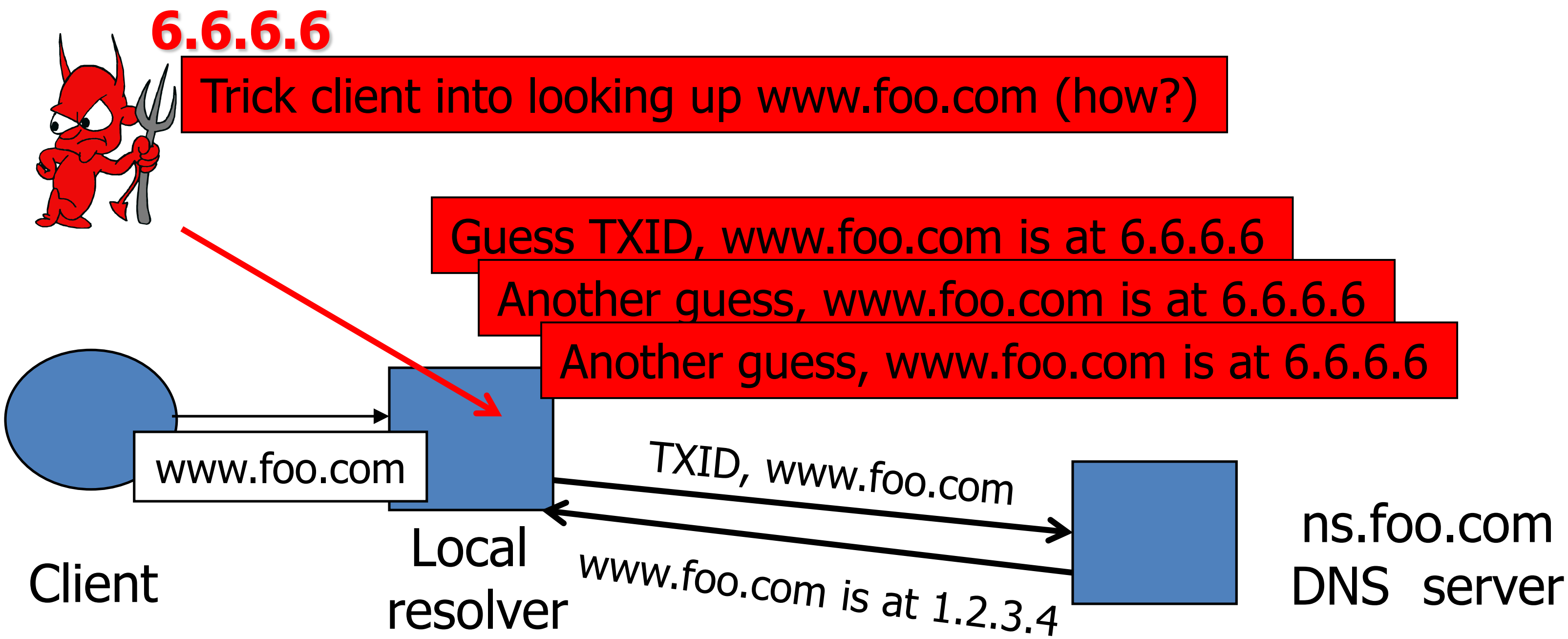
Cached Lookup Example



DNS “Authentication”



DNS Spoofing / DNS Cache Poisoning



Several opportunities to win the race

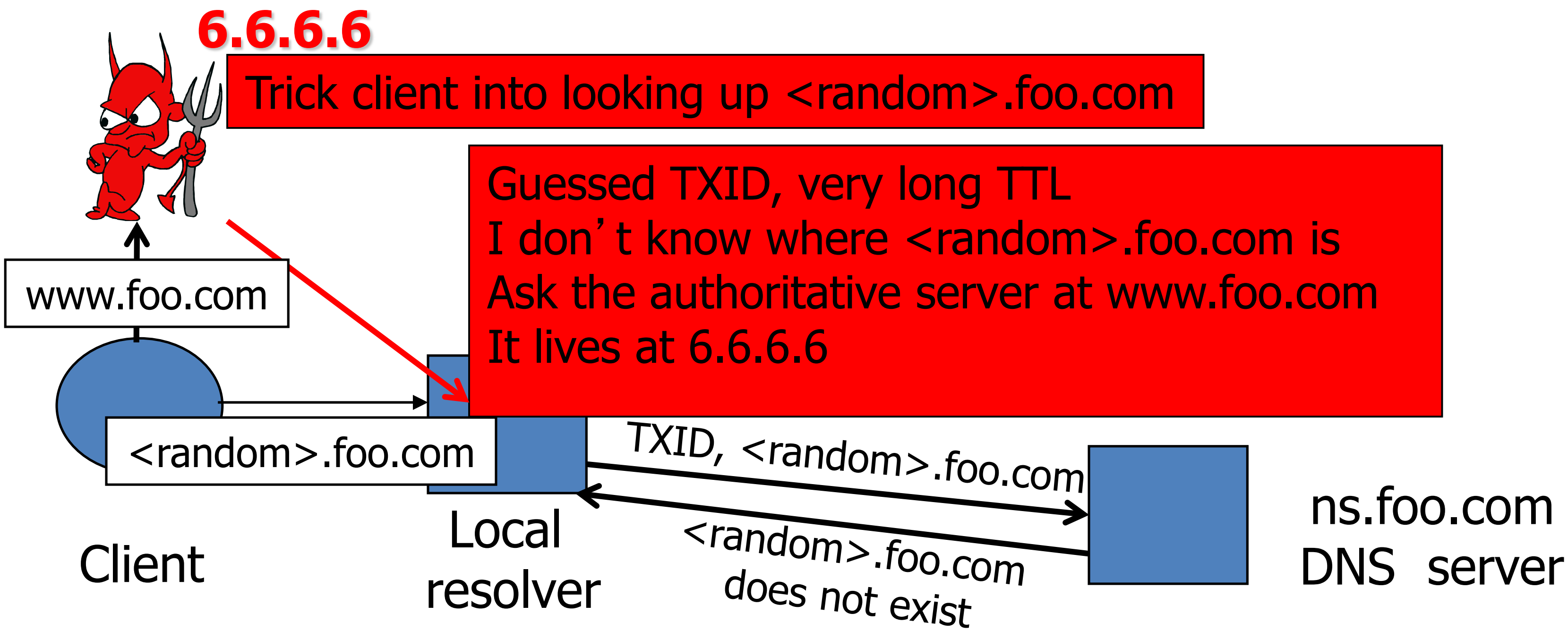
If attacker loses, has to wait until TTL expires

… but can try again with host1.foo.com, host2.foo.com, etc.

… but what's the point of hijacking host2.foo.com?

DNS Spoofing / DNS Cache Poisoning

[Kaminsky]



If attacker wins, future DNS requests for www.foo.com will go to 6.6.6.6
The cache is now poisoned… for a very long time!
No need to win future races!

DNSSEC

- Goals: authentication and integrity of DNS requests and responses
- PK-DNSSEC (public key)
  - DNS server signs its data (can be done in advance)
  - How do other servers learn the public key?

MORE INFO: http://www.dnssec.net/presentations

Lecture 17
CS 134

Smart Transportation Security

Qi Alfred Chen

Department of Computer Science

Recent interest: Autonomy software security in smart transportation

Connected Vehicle (CV)

Autonomous Vehicle (AV)

U.S. Department of Transportation

TOYOTA

Ford

Qualcomm

lyft

Uber

TESLA

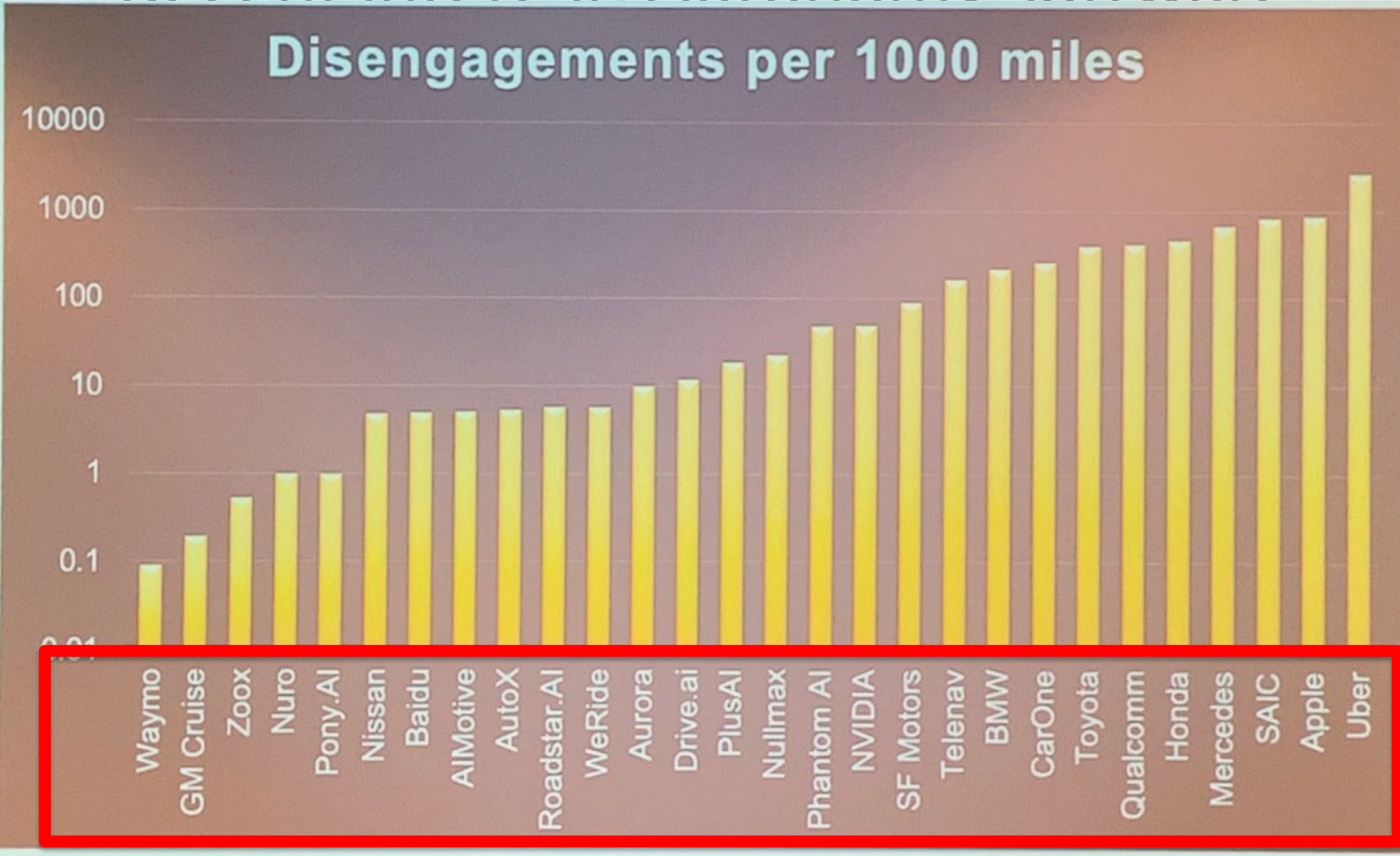
Aurora

GM

WAYMO

apollo

Recent interest: Autonomy software



of Transportation Aurora WAYMO apollo TESLA


BotRide Service Zone
We have 19 Pick up/Drop off points
BOTRIDE ZONE
John Wayne
Airport
ANTEATER

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Autonomy software

[ISOC NDSS'18]
First software security analysis of a CV-based transportation system

[ACM CCS'19]
First software security analysis of LiDAR-based AV perception

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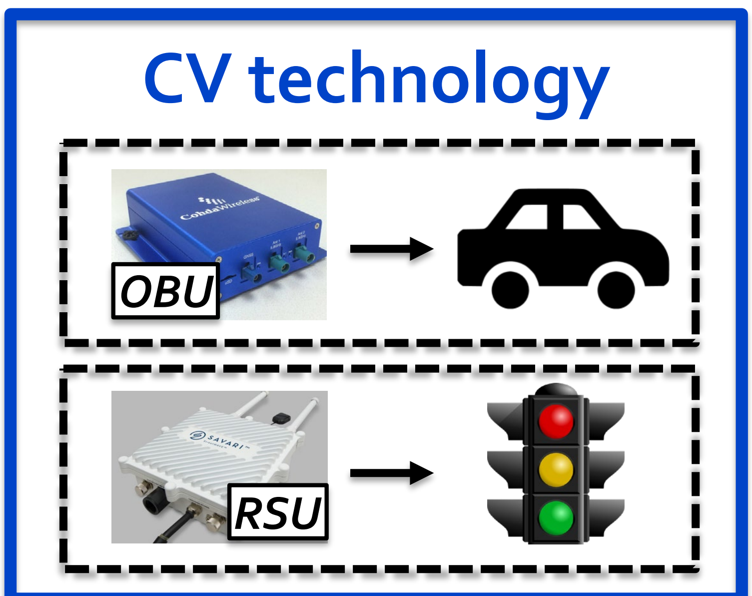
Background: Connected Vehicle technology

- Wirelessly connect vehicles & infrastructure to dramatically improve **mobility** & **safety**
- Will **soon** transform transportation systems today
  - 2016.9, USDOT launched ***CV Pilot Program***



Under deployment

NEW YORK CITY

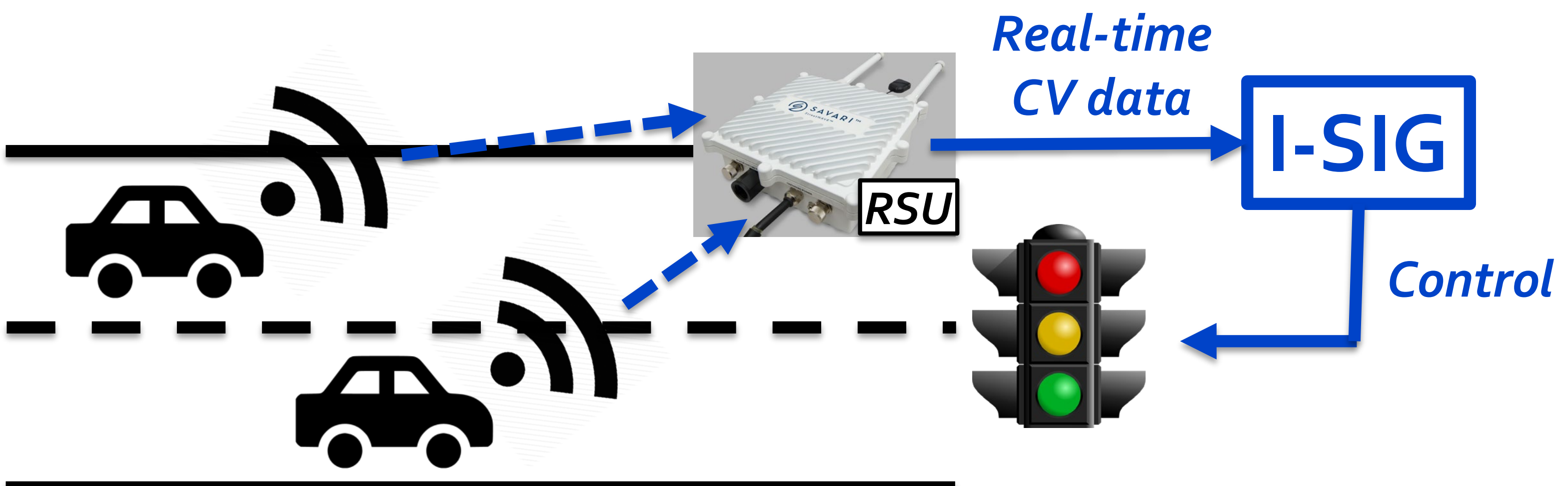
City of Tampa

WYOMING

CV = Connected Vehicle   OBU = On-Board Unit   RSU = Road-Side Unit

First security analysis of CV-based transp.

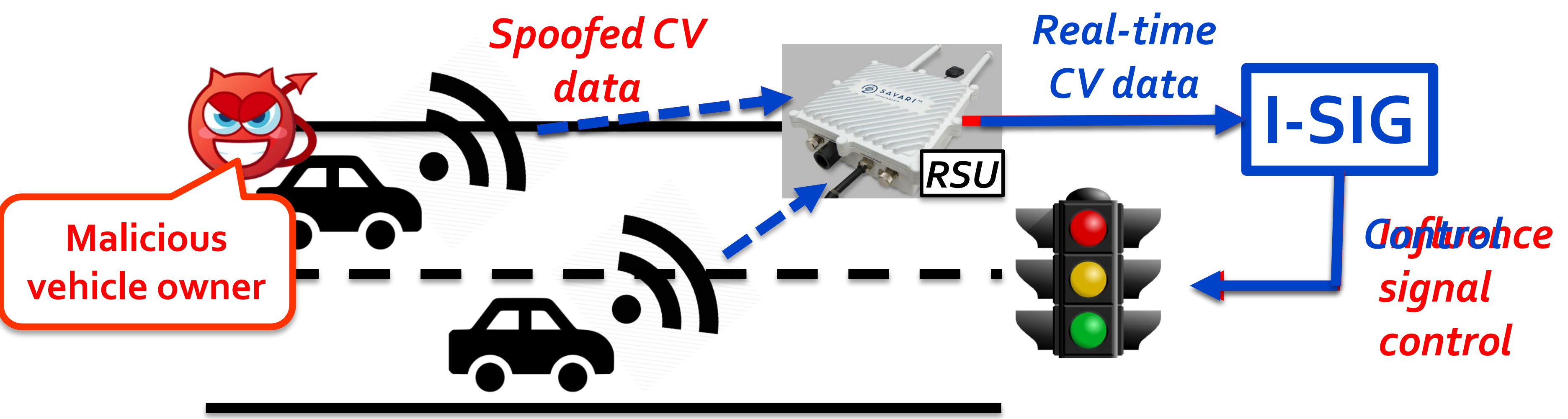
- **Target**: Intelligent Traffic Signal System (I-SIG)
  - Use real-time CV data for intelligent signal control
  - USDOT sponsored design & impl.
  - Fully implemented & tested in Anthem, AZ, & Palo Alto, CA
    - ~30% reduction in total vehicle delay
  - Under deployment in NYC and Tampa, FL



CV = Connected Vehicle OBU = On-Board Unit RSU = Road-Side Unit

Threat model

- Malicious vehicle owners deliberately control the OBU to send spoofed data
  - OBU is compromised physically[1], wirelessly[2], or by malware[3]
- Can only spoof data, e.g., location & speed
  - Can't spoof identity due to USDOT's vehicle certificate system



[1] Koscher et al.@IEEE S&P'10 [2] Checkoway et al.@Usenix Security'11 [3] Mazloom et al.@Usenix WOOT'16

Attack goals

Traffic congestion

Increase total delay of vehicles in the intersection

Personal gain

Minimize attacker's travel time (at the cost of others')

Attack goals

This work

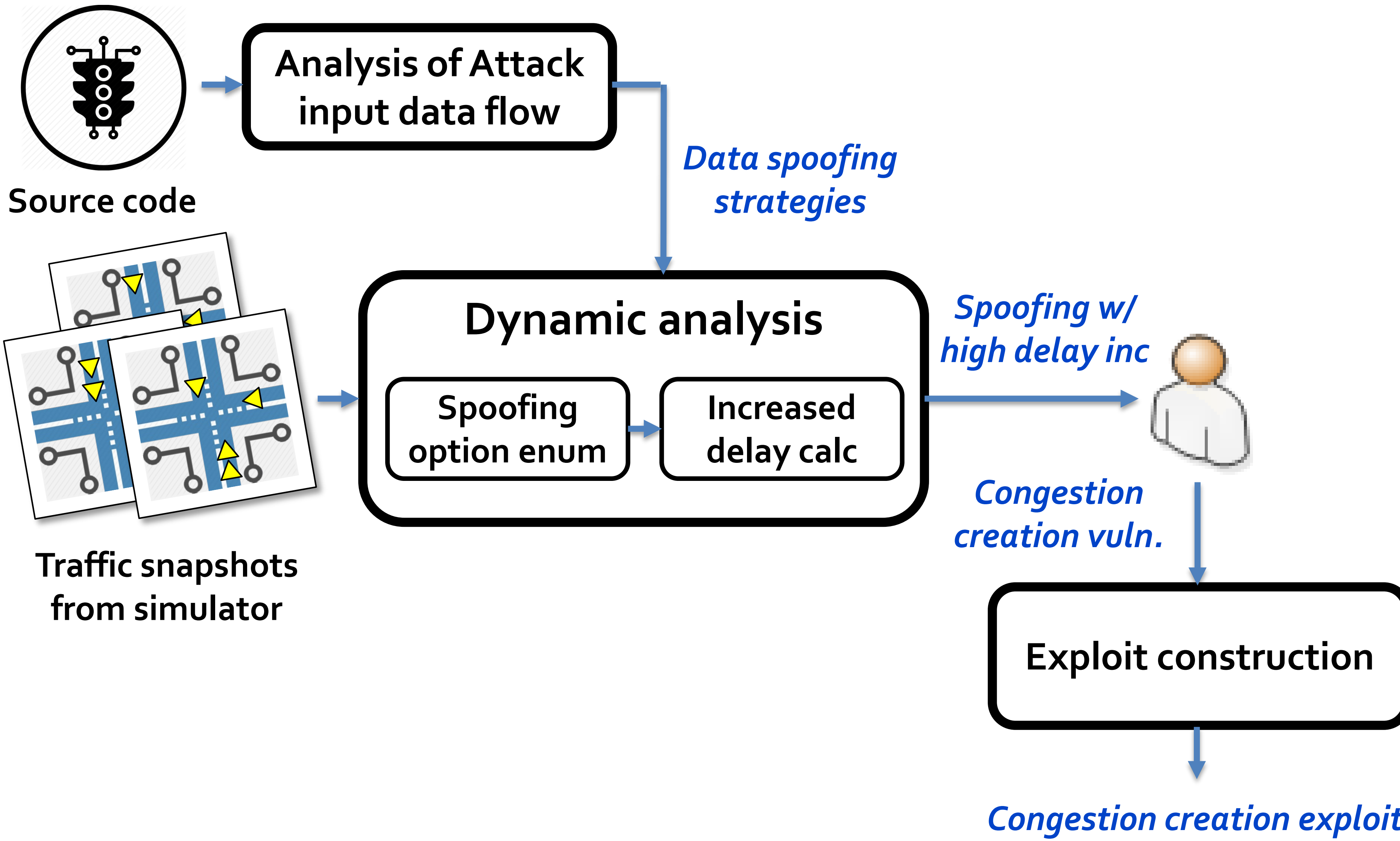
Traffic congestion

Increase total delay of vehicles in the intersection

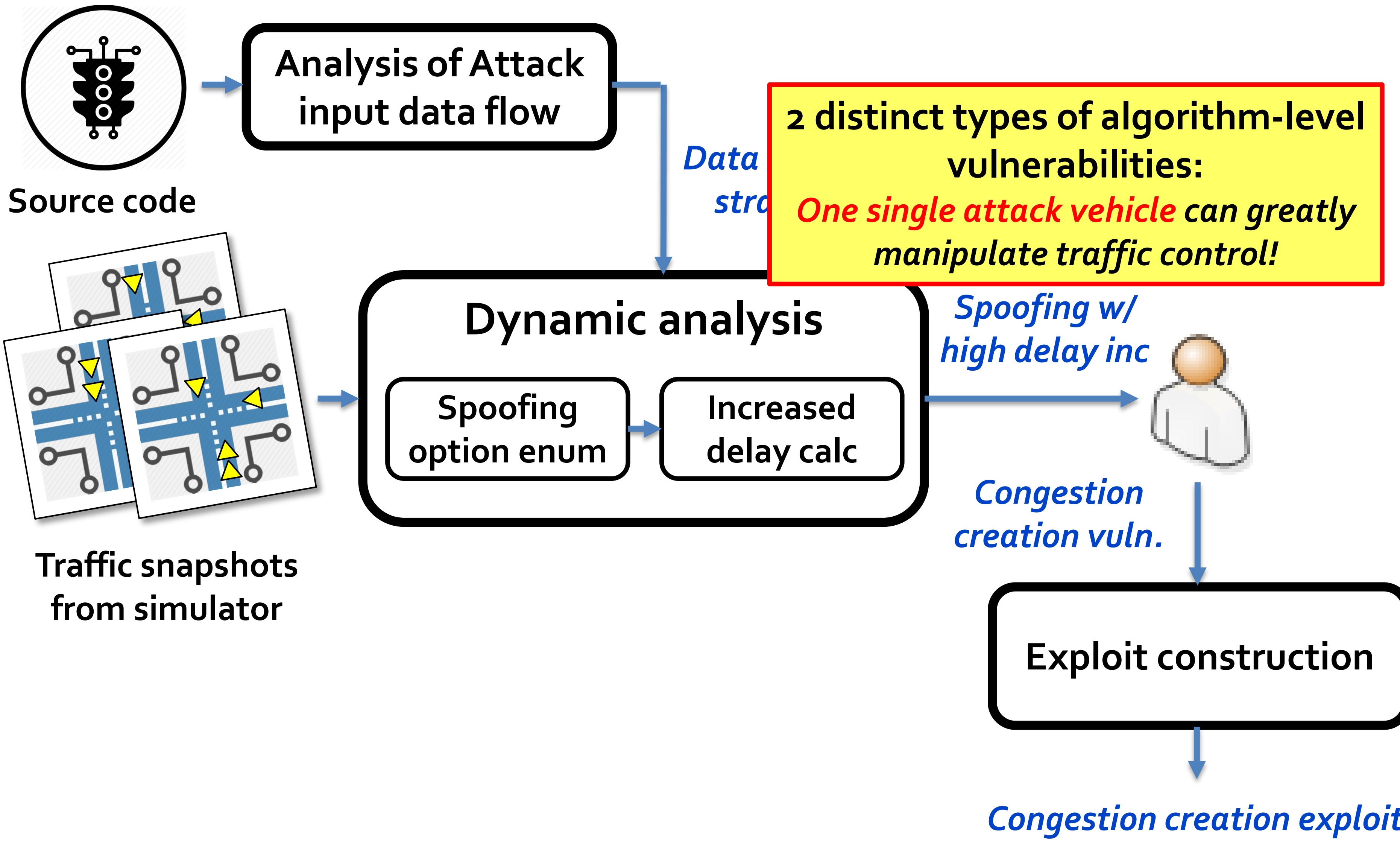
Personal gain

Minimize attacker's travel time (at the cost of others')

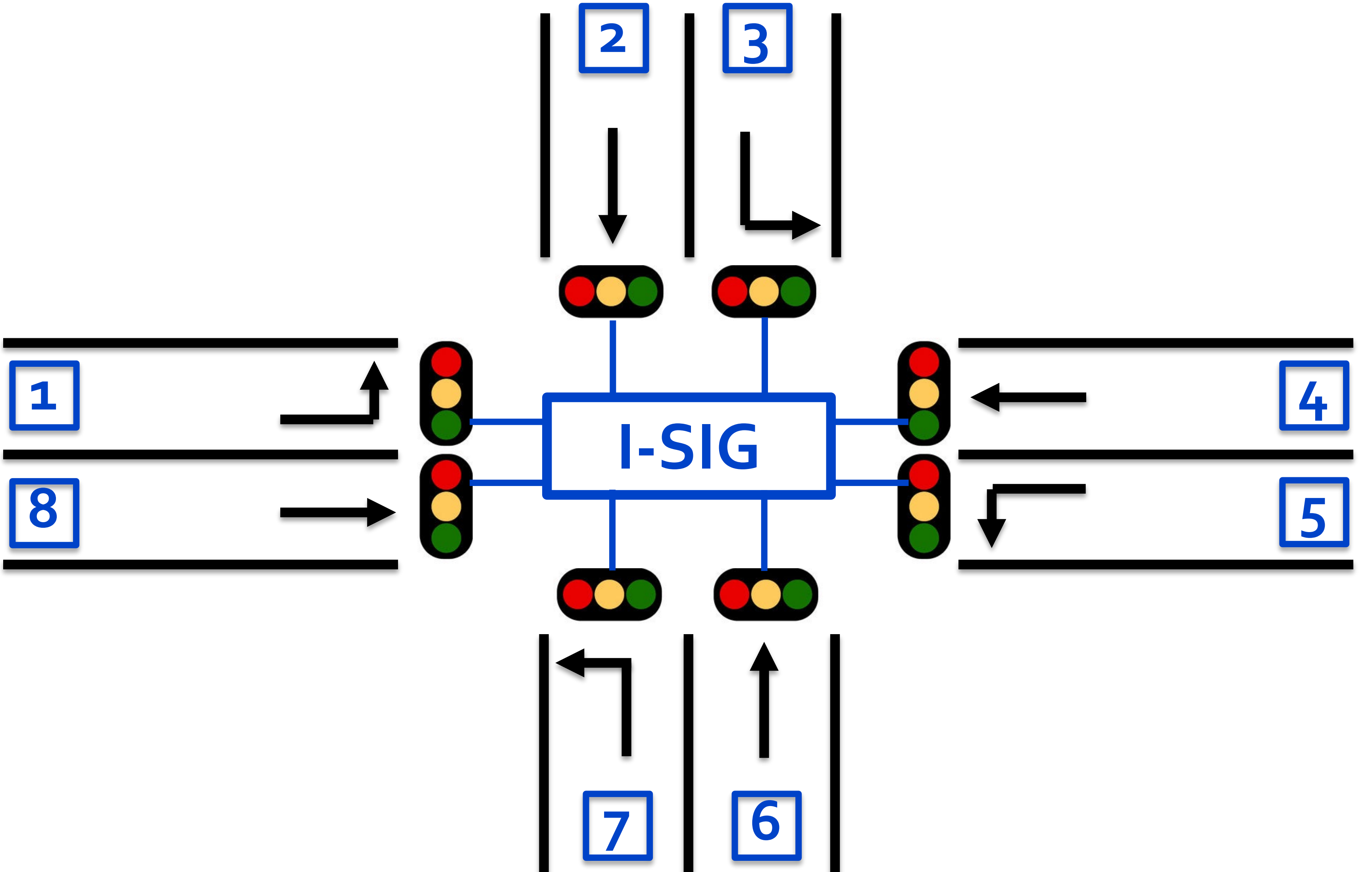
Analysis approach overview



Analysis result summary



I-SIG system



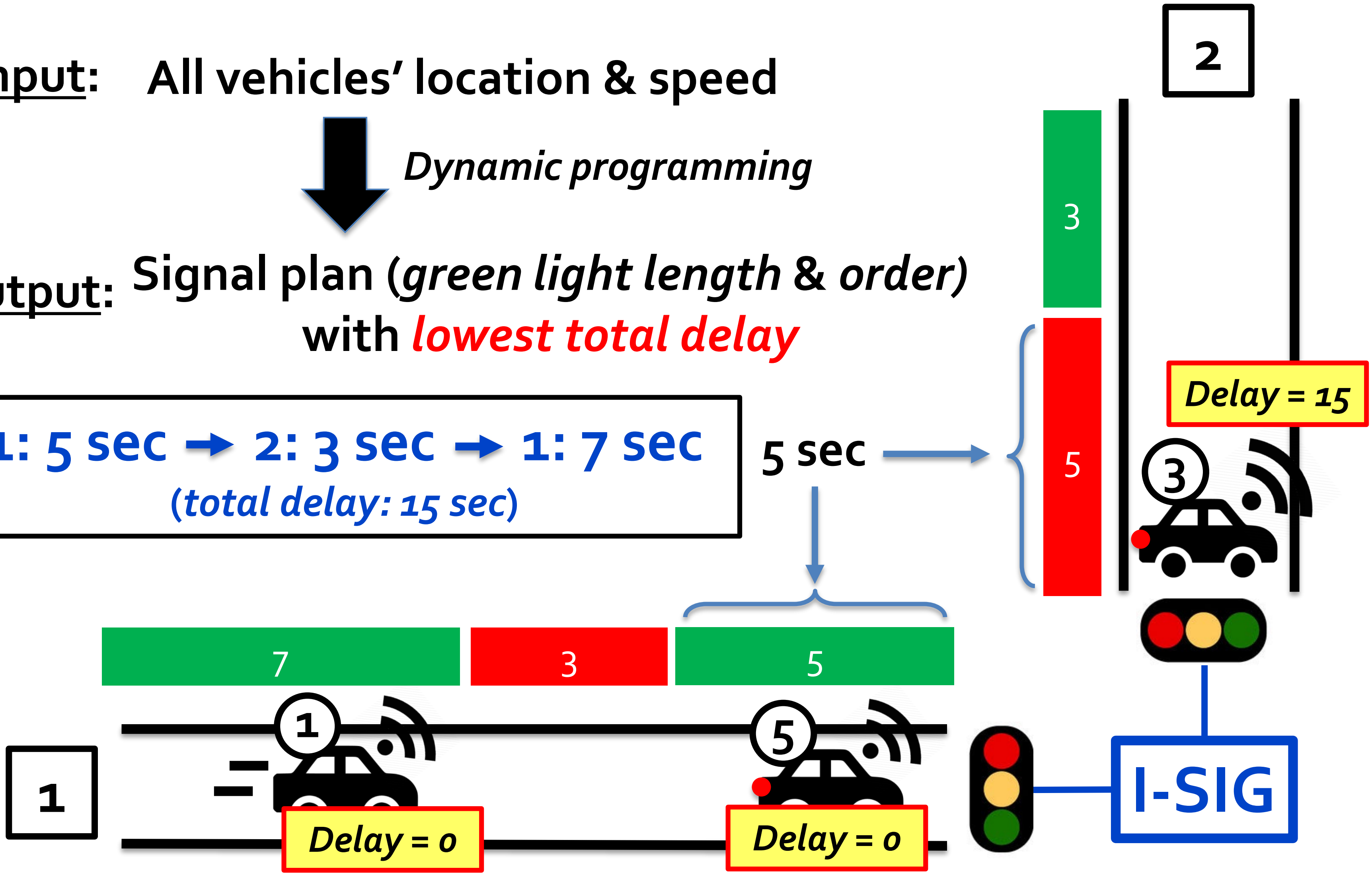
COP (Controlled Optimization of Phases)

Input: **All vehicles' location & speed**

Dynamic programming

Output: **Signal plan (*green light length* & *order*)**
with *lowest total delay*

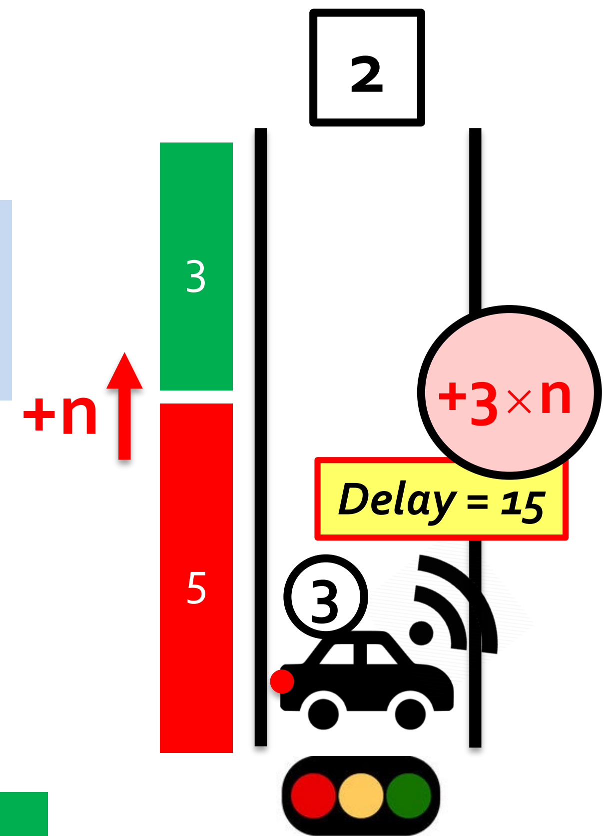
1: 5 sec → 2: 3 sec → 1: 7 sec
(total delay: 15 sec)

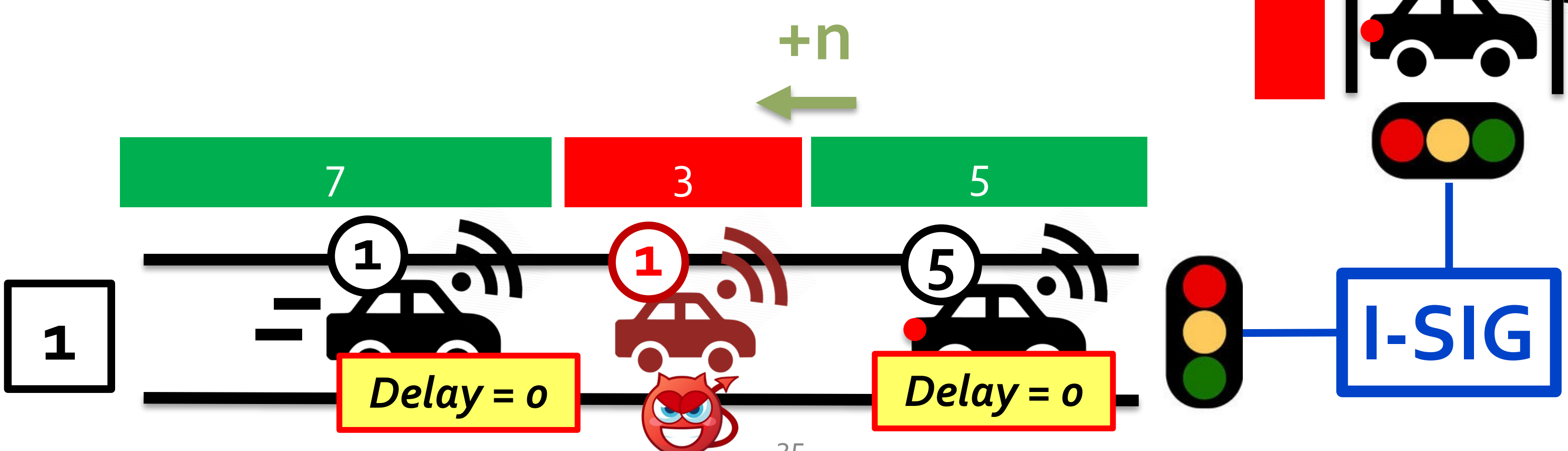


COP (Controlled Optimization of Phases)

Data from one single vehicle: *Very hard to affect signal plan*

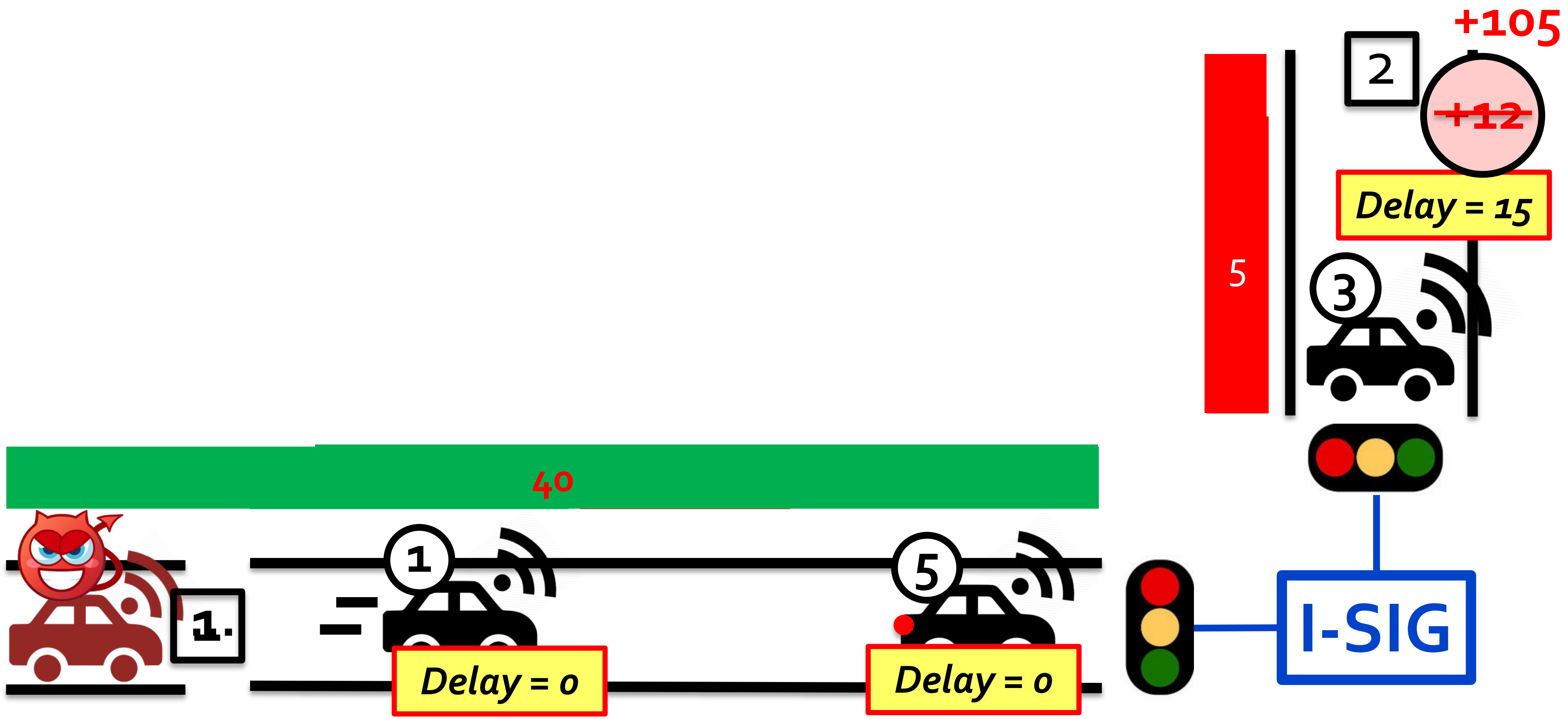
- Commonly, 1 vehicle vs **> 25 vehicles' delay** in **5 conflicting lanes**
  - ***Can't change even 1 sec***





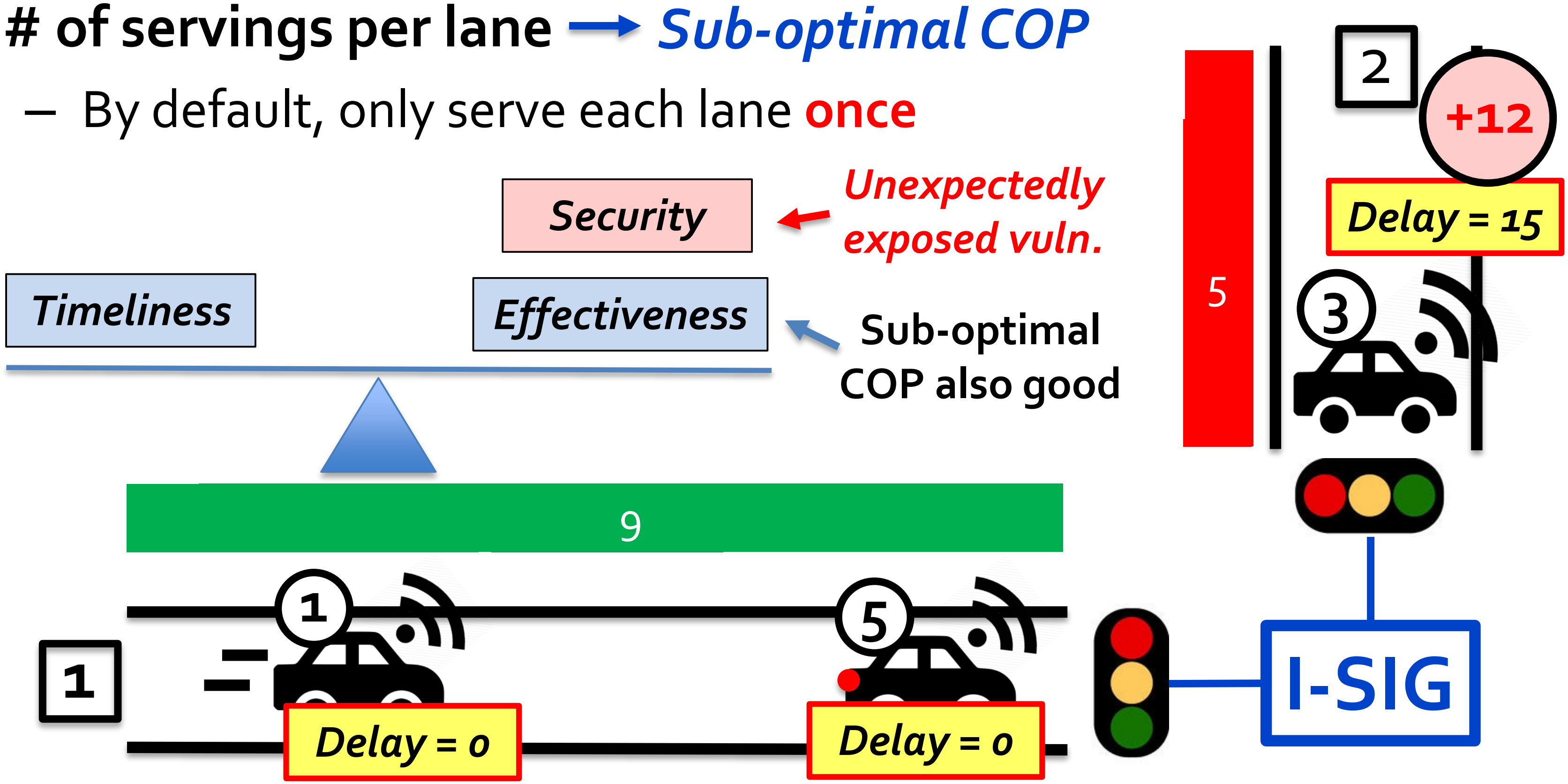
Vuln #1: Last vehicle advantage

- **Attack**: Spoof to arrive as late as possible to increase the delay of queuing vehicles in other lanes



Cause: Effectiveness & timeliness trade-off

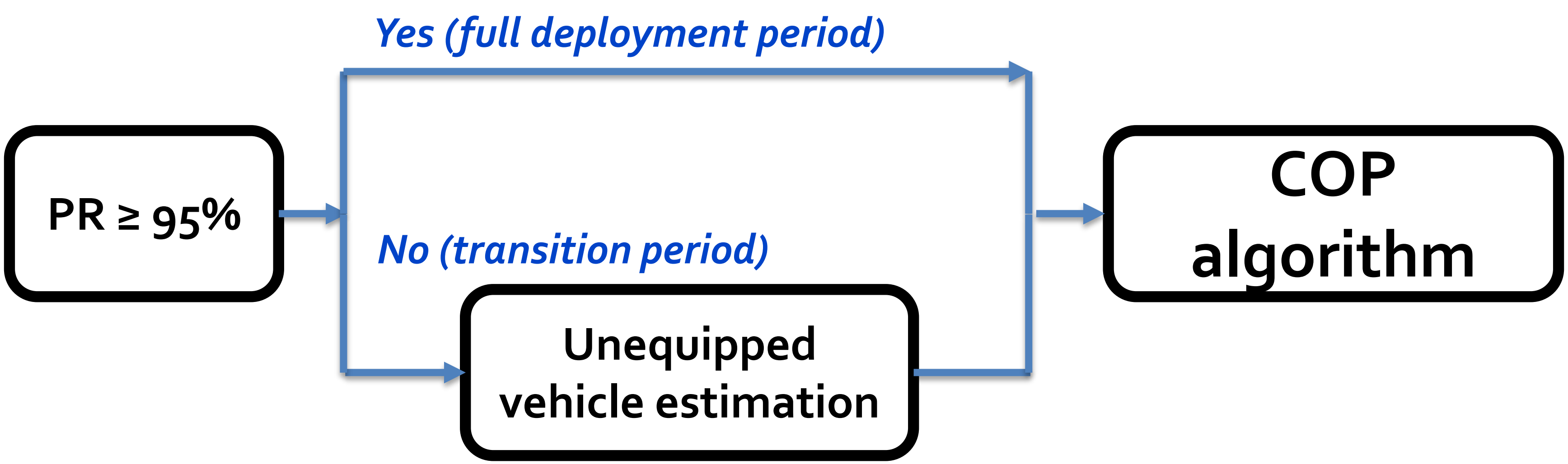
- COP on RSU = ***4-5 sec*** ⟷ decision time ***< 3 sec***
- To meet timeliness requirement, **customize COP to limit the # of servings per lane** → ***Sub-optimal COP***
  - By default, only serve each lane **once**



RSU = Road-Side Unit

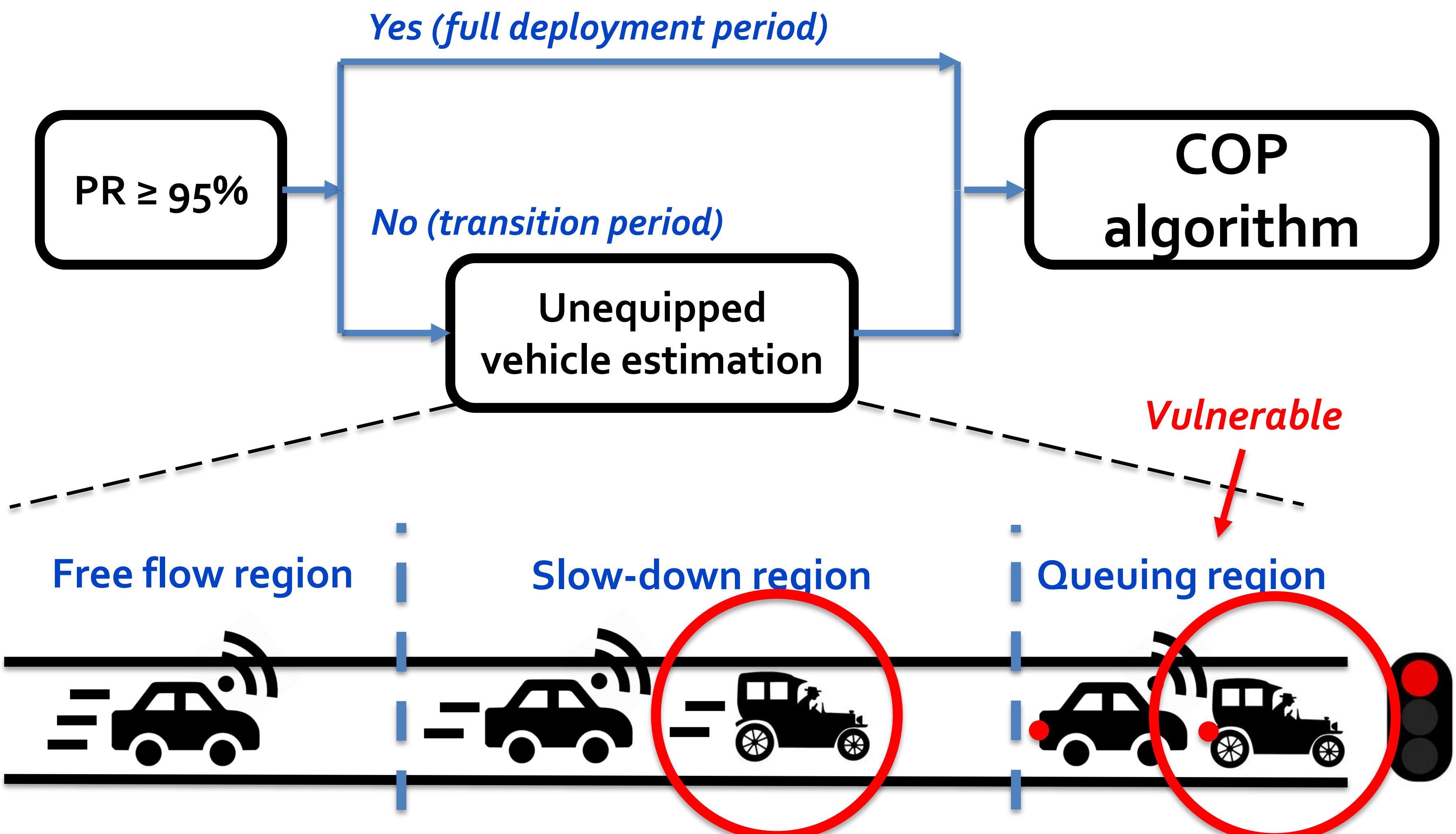
Vuln #2: Curse of transition period

- I-SIG has 2 operation modes based on PR:
  - PR ≥ 95%, full deployment: Directly run **COP**
  - PR < 95%, transition: COP becomes ineffective, use ***an unequipped vehicle estimation algorithm*** as pre-processing step



PR = Penetration Rate

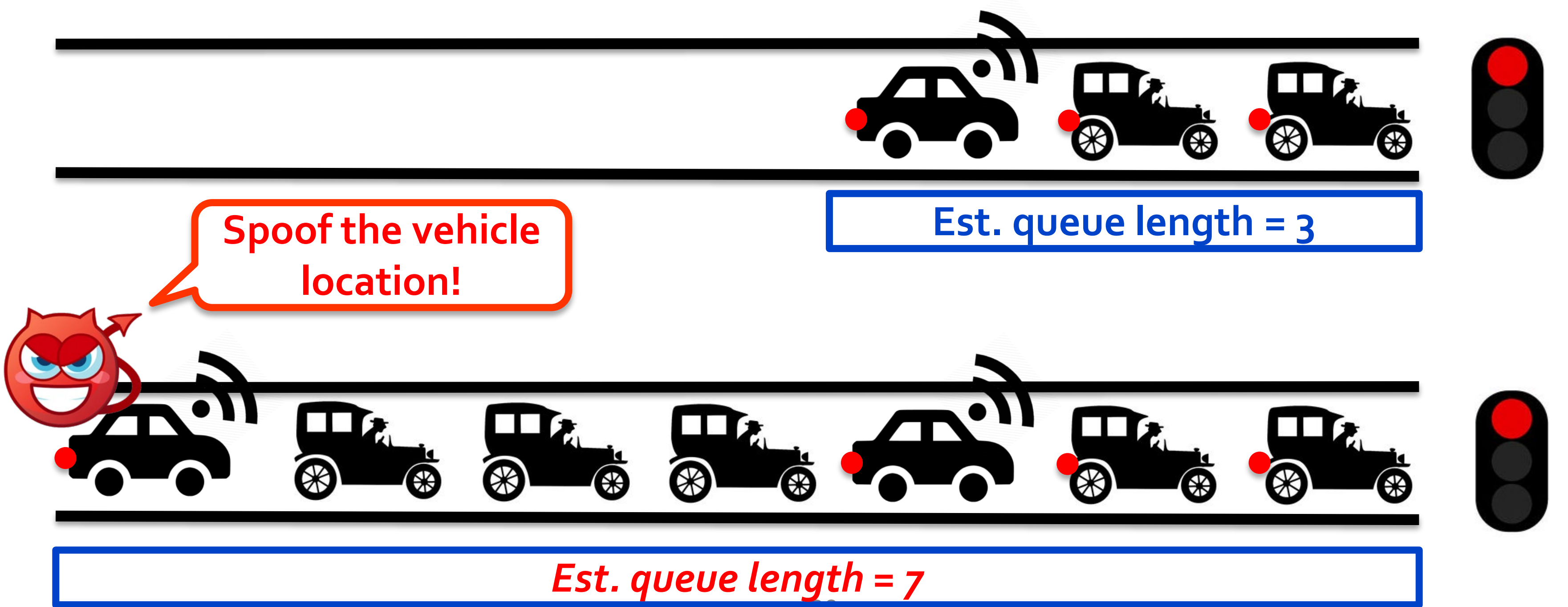
Unequipped vehicle estimation algorithm



PR = Penetration Rate

Vulnerable queue estimation

- Data from ***one single attack vehicle*** can add ***30-50*** "ghost" vehicles to COP input
- Dramatically increase length of (wasted) green light



Attack video demo

- Demo time!
  - https://www.youtube.com/watch?v=3iV1sAxPuLo

Recent interest: Autonomy software security in smart transportation

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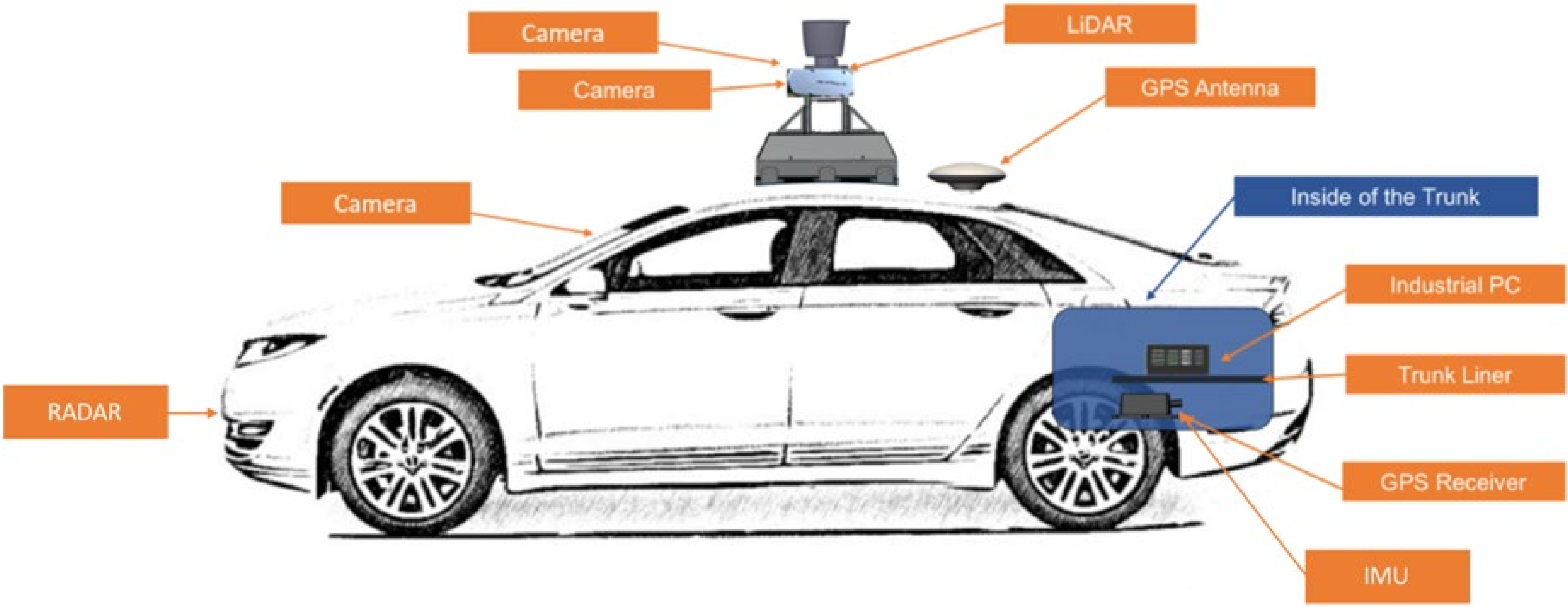
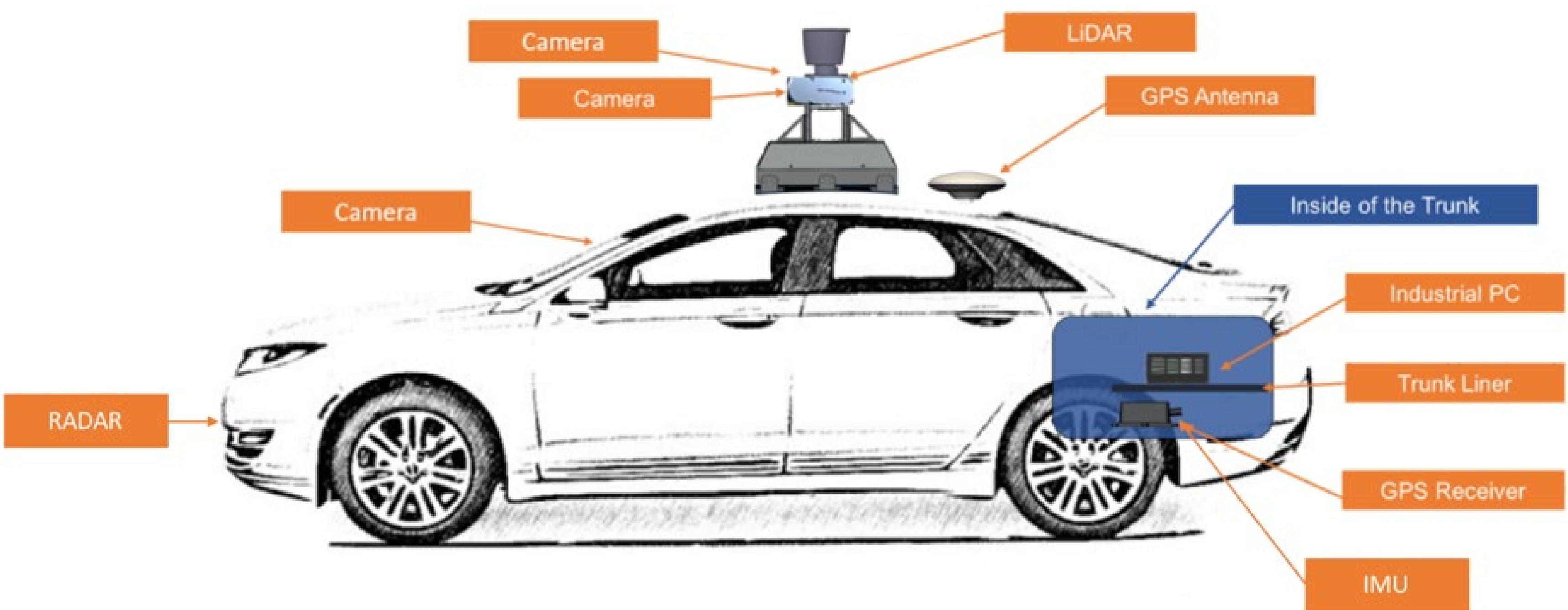
Background: Autonomous Vehicle technology

- Equip vehicles with various types of sensors to enable self driving



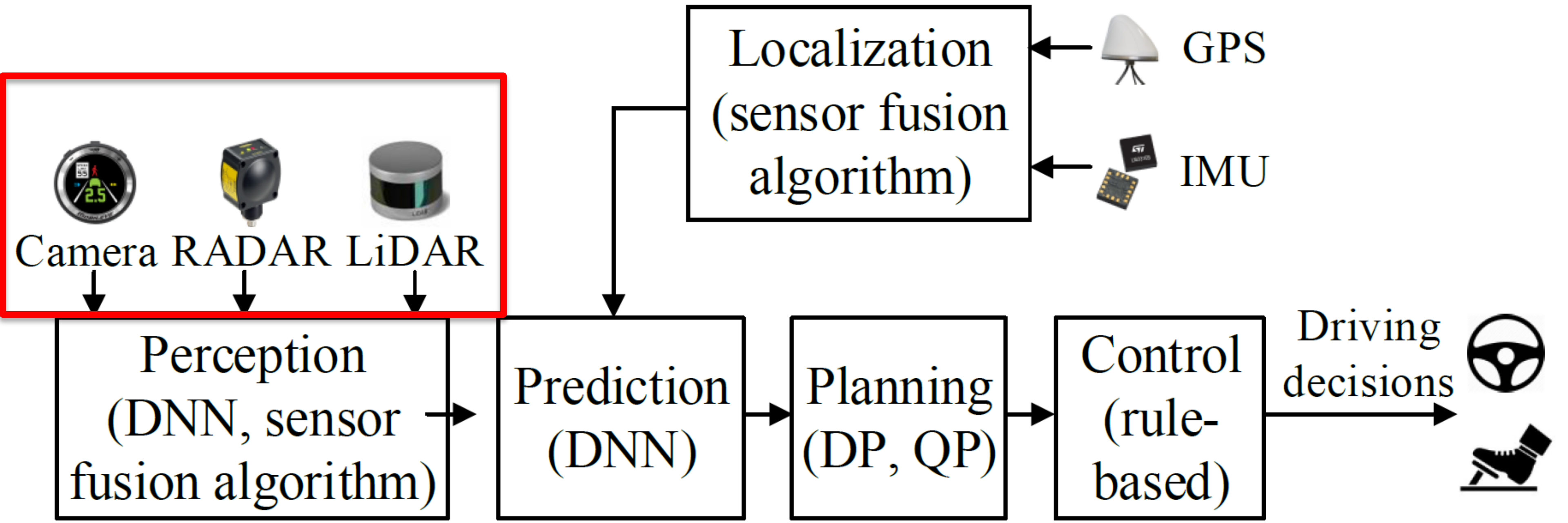
Goal: First security analysis of AV autonomy software

- New attack surface: Sensors
  - Key input channel for critical control decisions
  - Public channel shared with potential adversaries
    - *Fundamentally unavoidable attack surface*



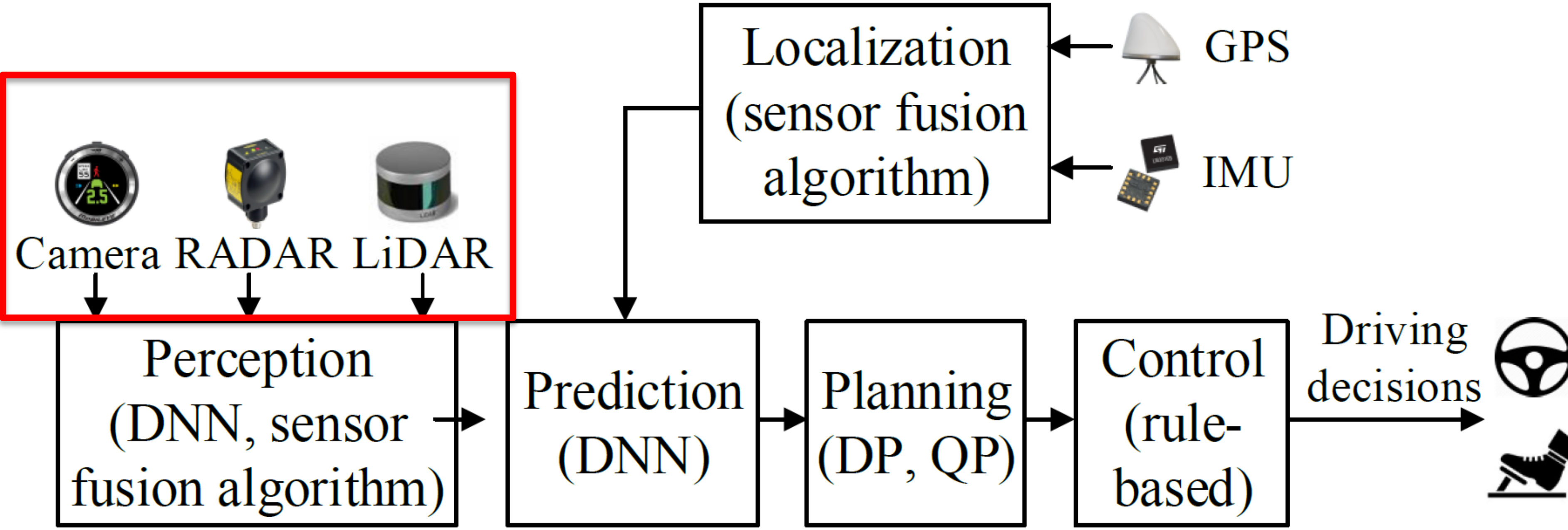
Background: AV autonomy software & possible sensor attacks

- Camera/LiDAR/RADAR:
  - **Spoofing attack**: inject spoofed obstacles -> emergency brake, rear-end collision etc.



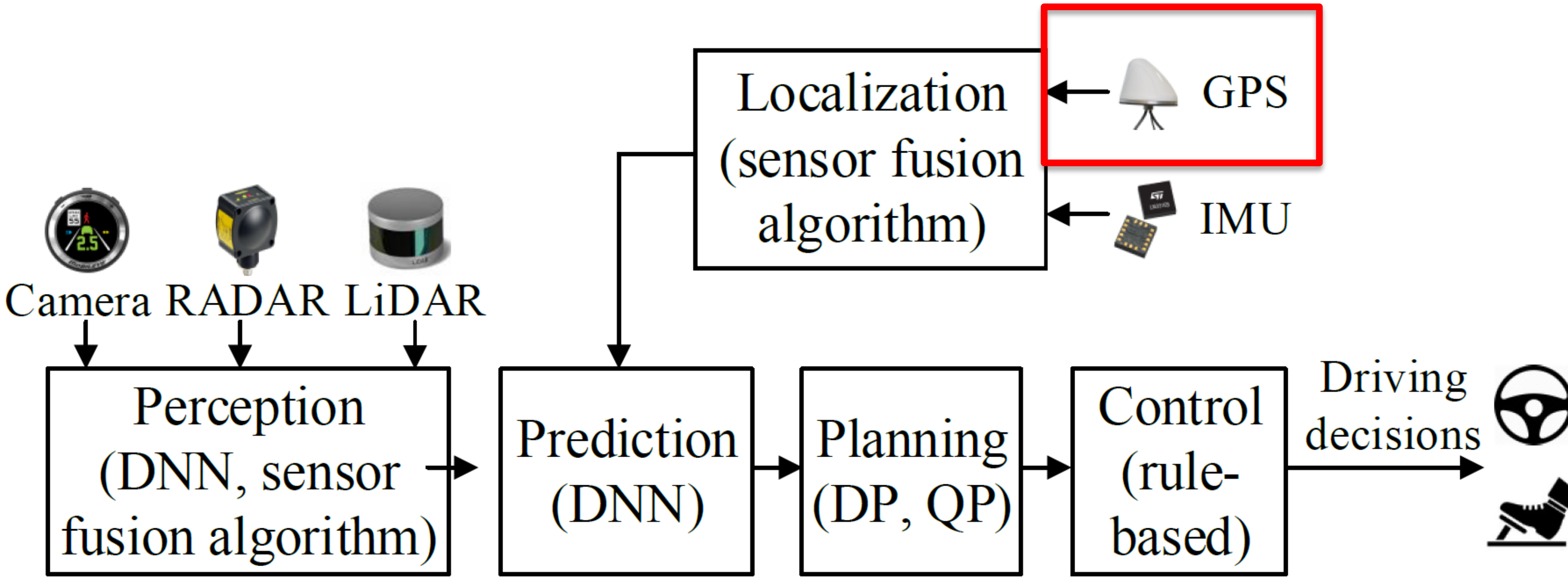
Background: AV autonomy software & possible sensor attacks

- Camera/LiDAR/RADAR:
  - **DoS attack**: prevent victim from performing object detection -> collide into a front vehicle



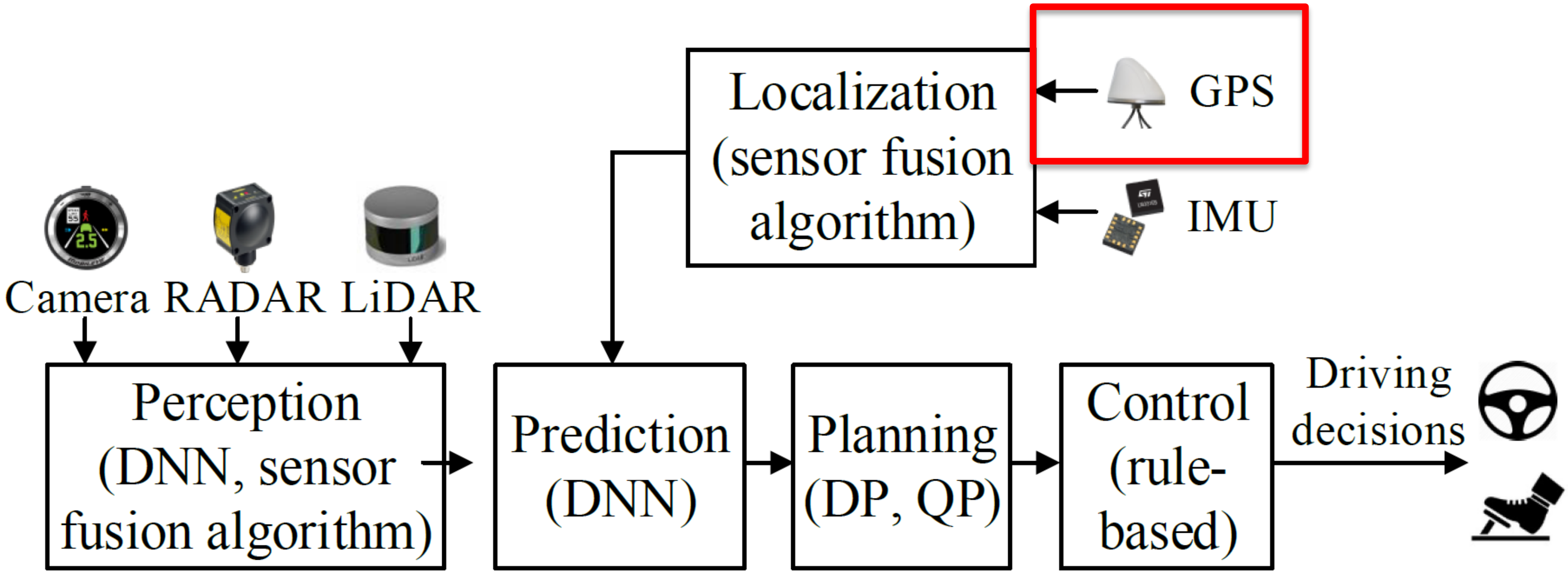
Background: AV autonomy software & possible sensor attacks

- GPS:
  - **Spoofing attack**: Make victim deviate from the lane -> crash into cars in the wrong way or adjacent lanes



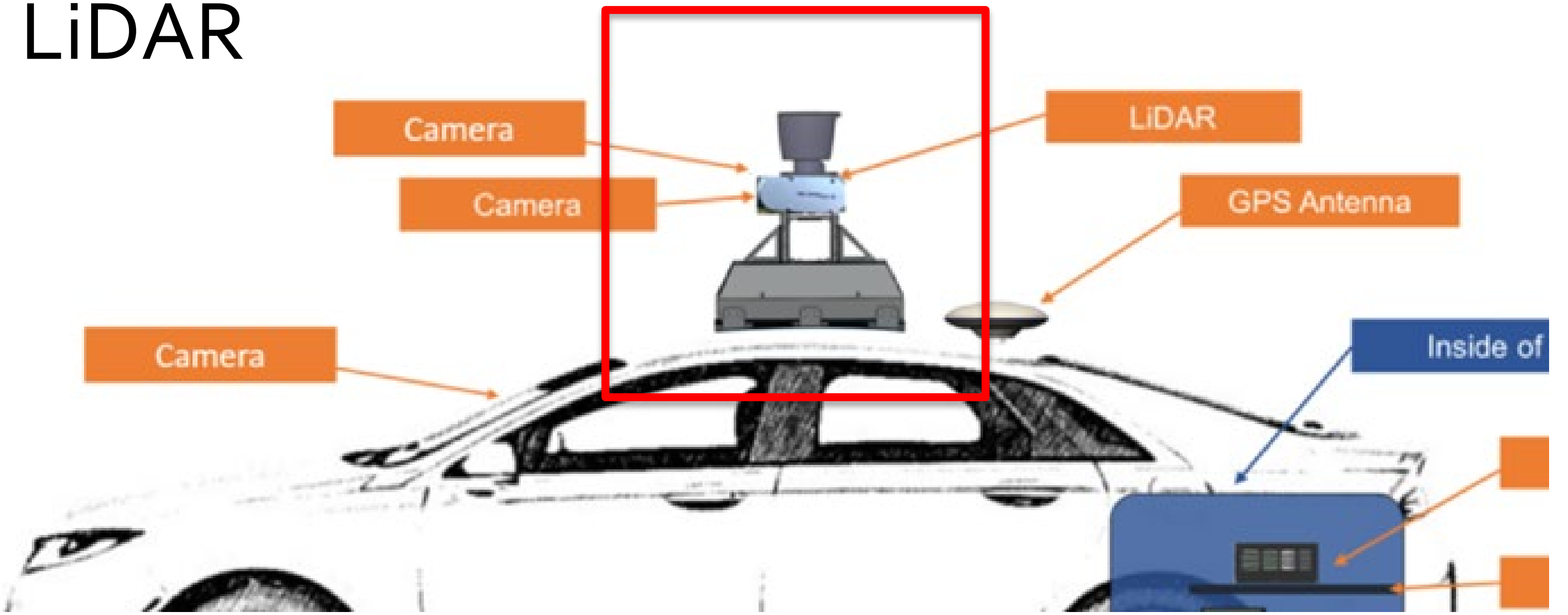
Background: AV autonomy software & possible sensor attacks

- GPS:
  - **DoS attack**: Victim unable to localize itself -> deviate from lane -> crash to cars in wrong way or adj. lanes

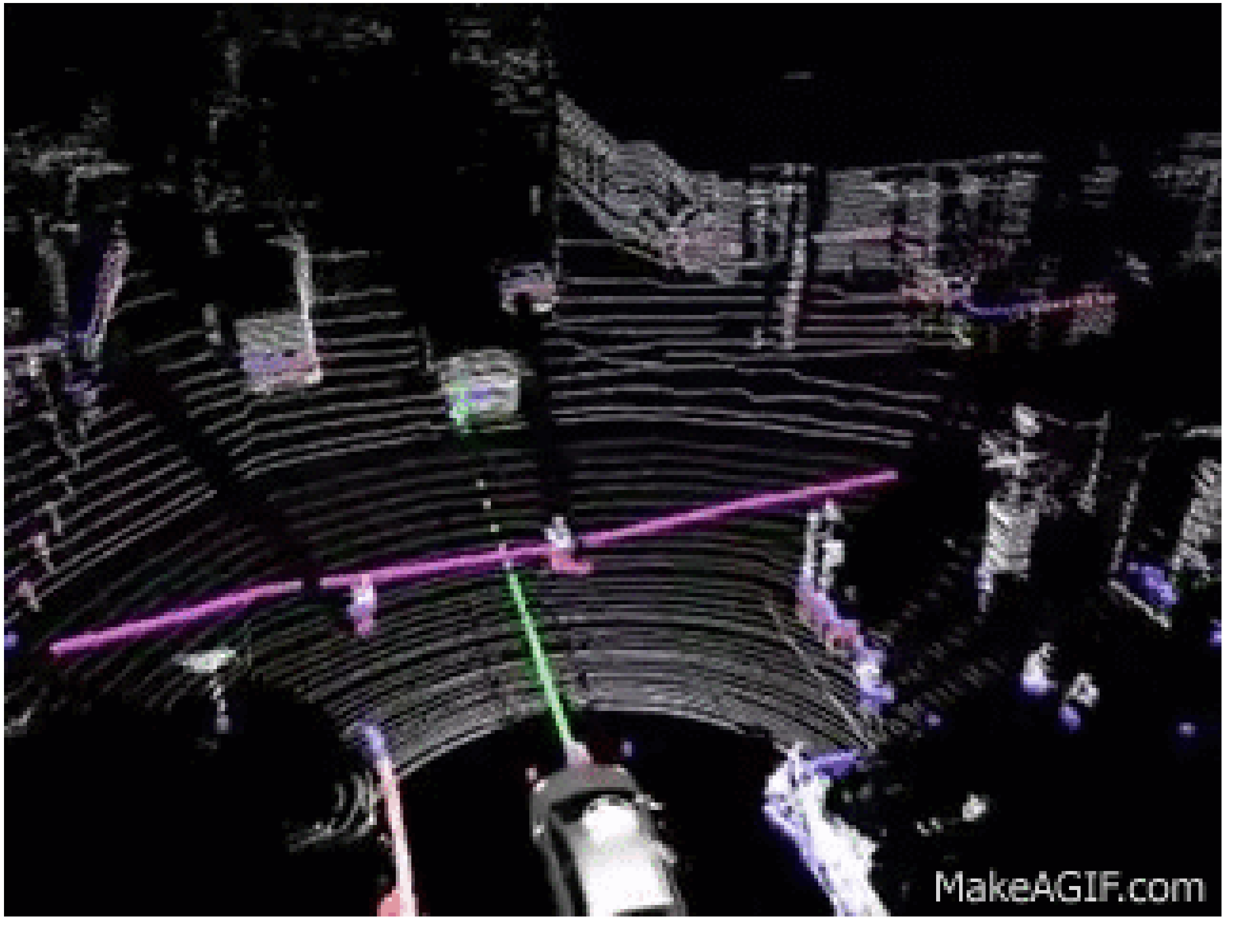


Goal: First security analysis of AV autonomy software

- New attack surface: Sensors
  - Key input channel for critical control decisions
  - Public channel shared with potential adversaries
    - *Fundamentally unavoidable attack surface!*
- LiDAR

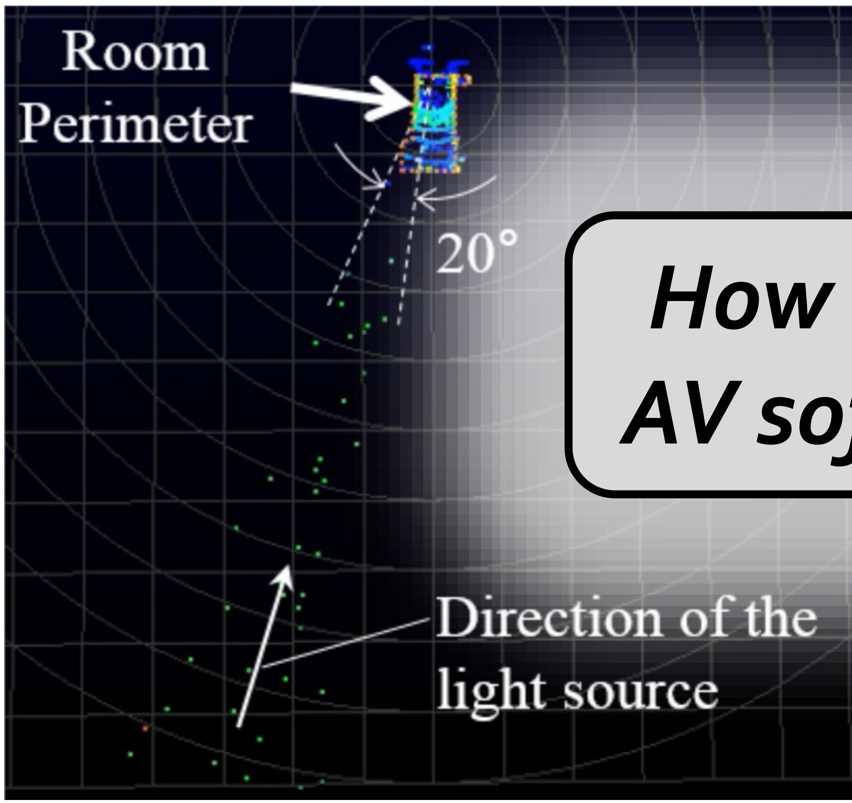


Background: LiDAR basics



Background: LiDAR attacks

- Known attack: LiDAR spoofing[1]
  - Shoot laser to LiDAR to inject points

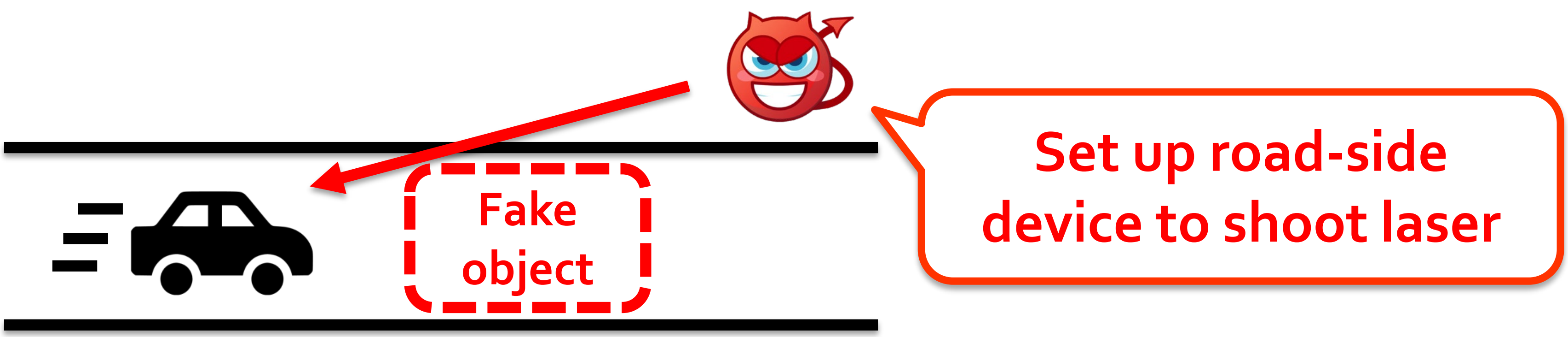


How to use this to attack AV software control logic?

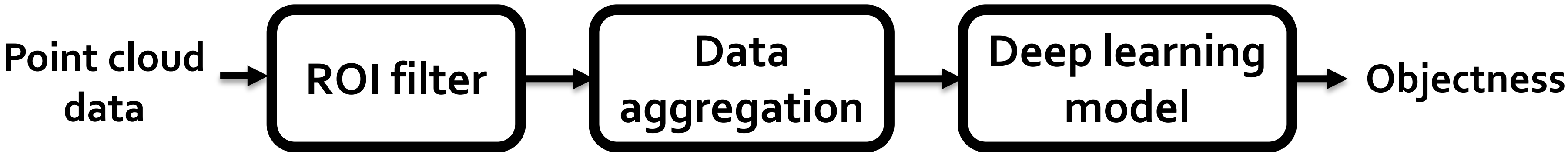
[1] Shin et al.@CHES'17

First security analysis of LiDAR-based perception in AV

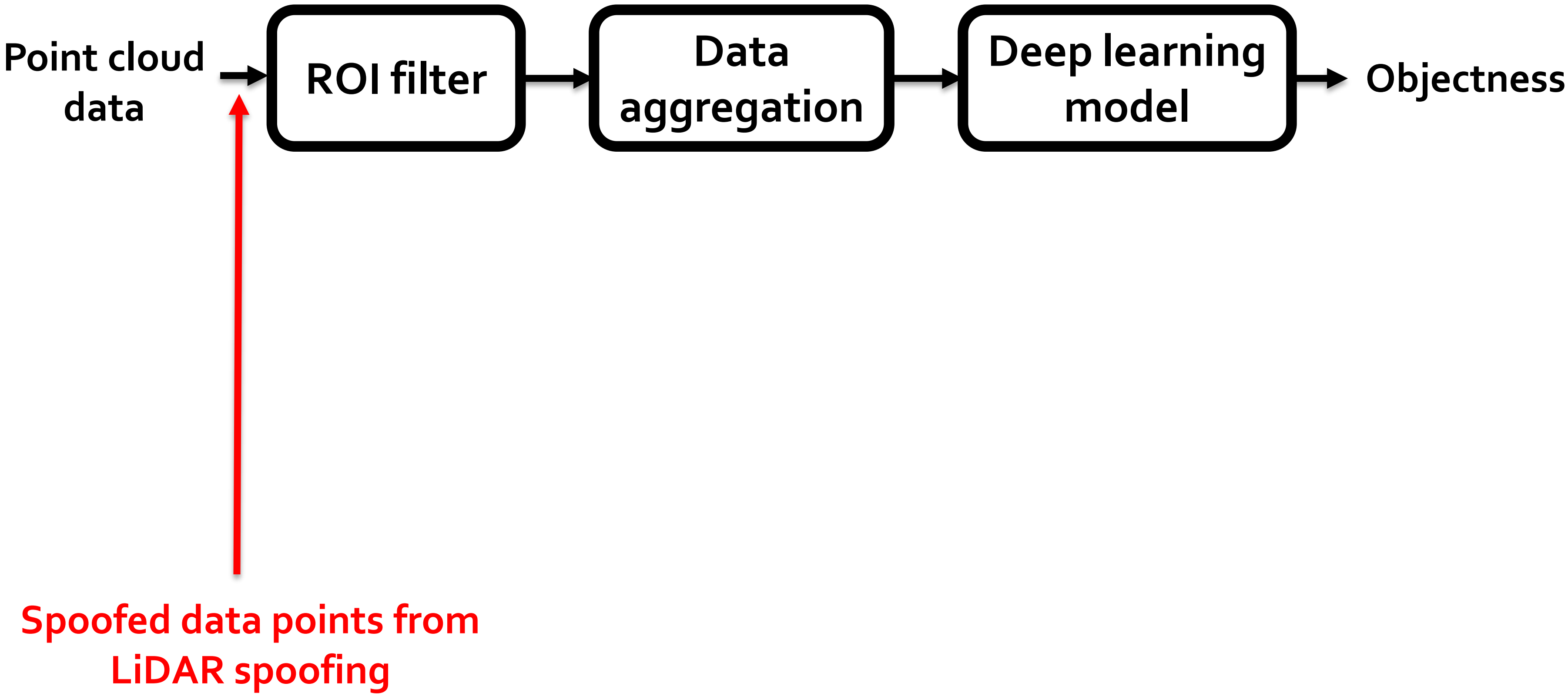
- **Target**: Baidu Apollo AV software system
  - Production-grade system, drive some buses in China already
  - Open sourced ("Android in AV ecosystem")
  - Partner with 100+ car companies, including BMW, Ford, etc.
- **Attack**: LiDAR spoofing attack from road-side laser shooting devices to create fake objects
  - Trigger undesired control operations, e.g., emergency brake



LiDAR input workflow in Apollo



LiDAR input workflow with attack

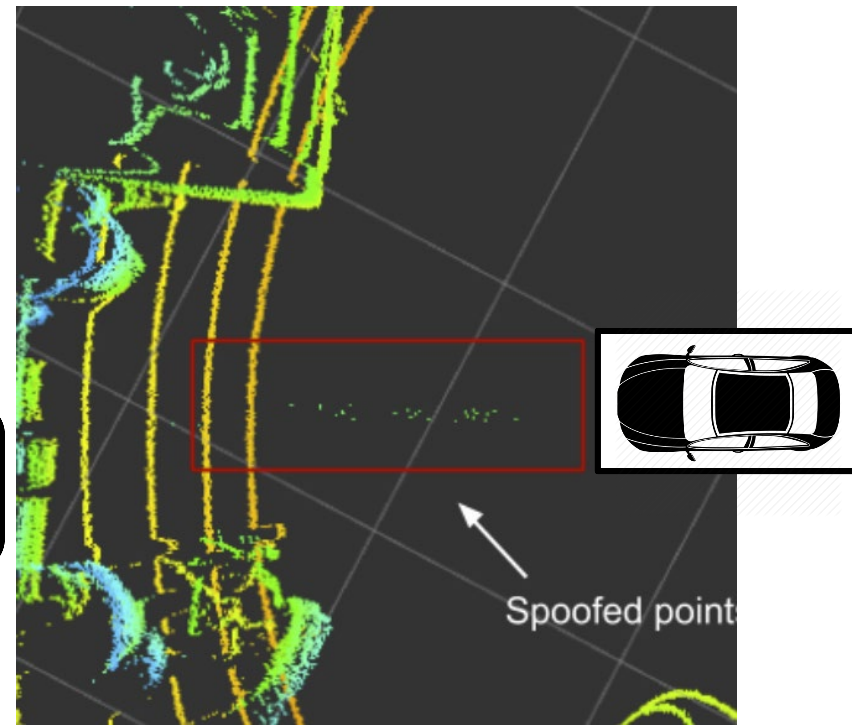


LiDAR input workflow with attack

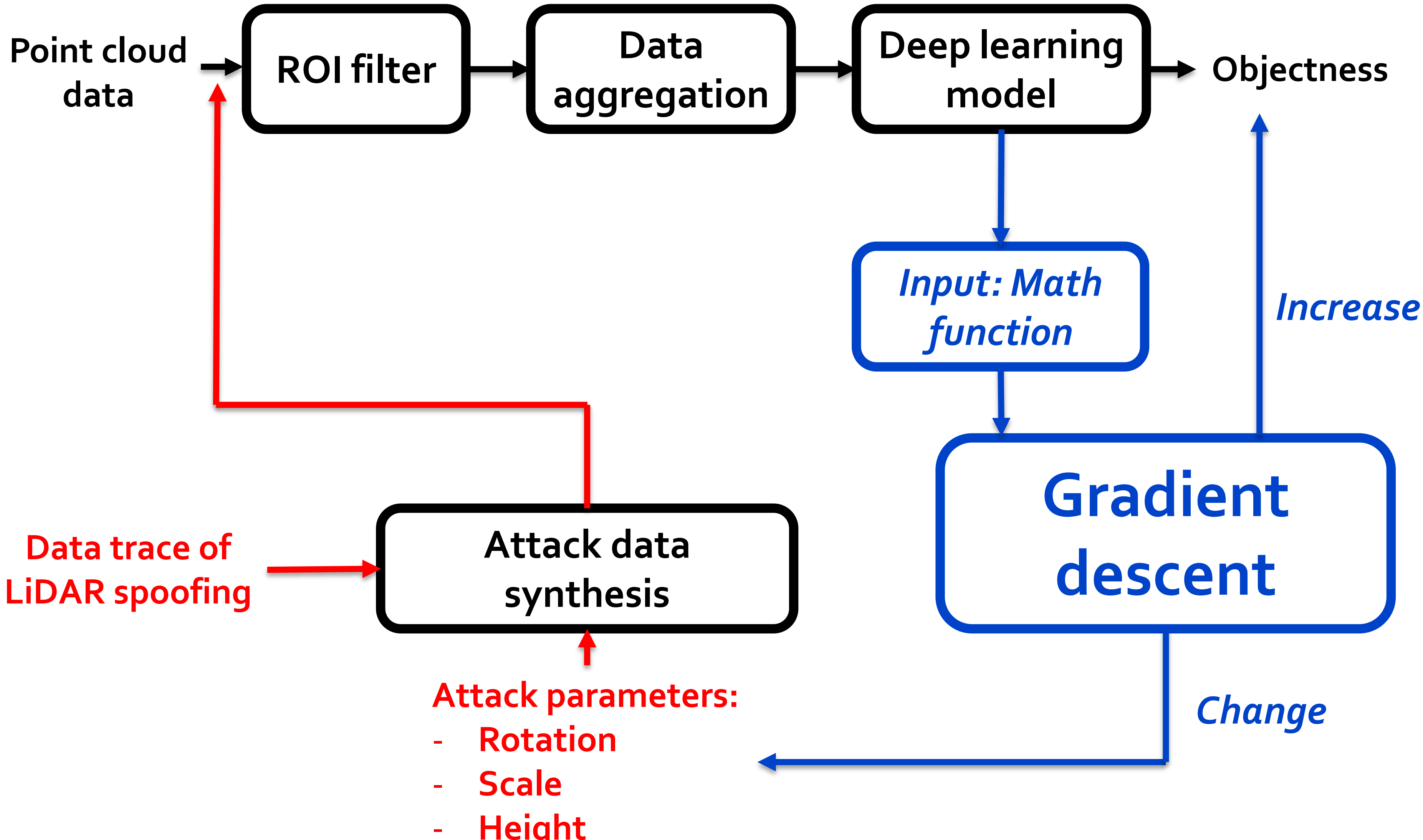
Point cloud data → ROI filter → Data aggregation → Deep learning model → Objectness

Data trace of LiDAR spoofing → Attack data synthesis → Point cloud data

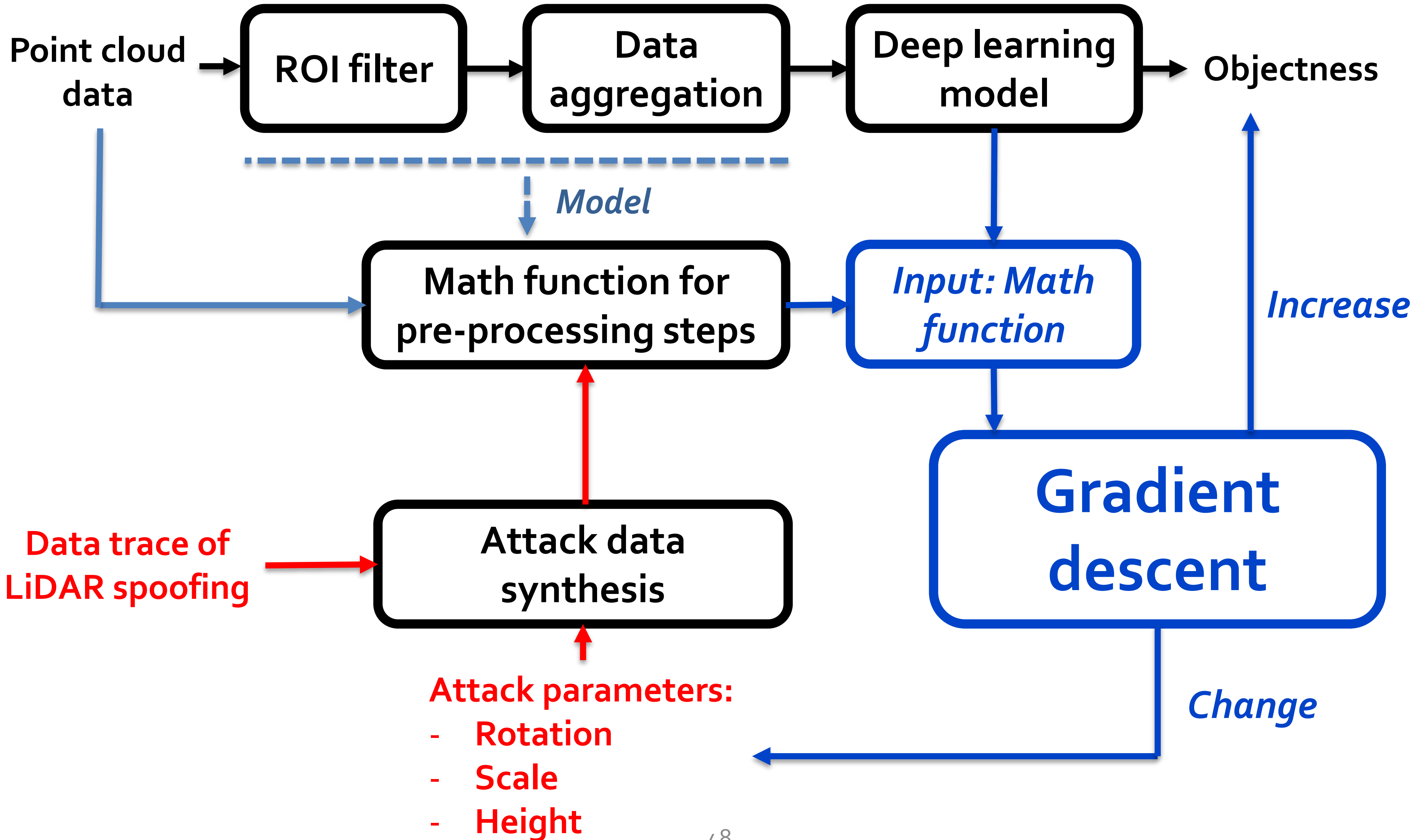
Attack parameters:
- Rotation
- Scale
- Height



Analysis approach

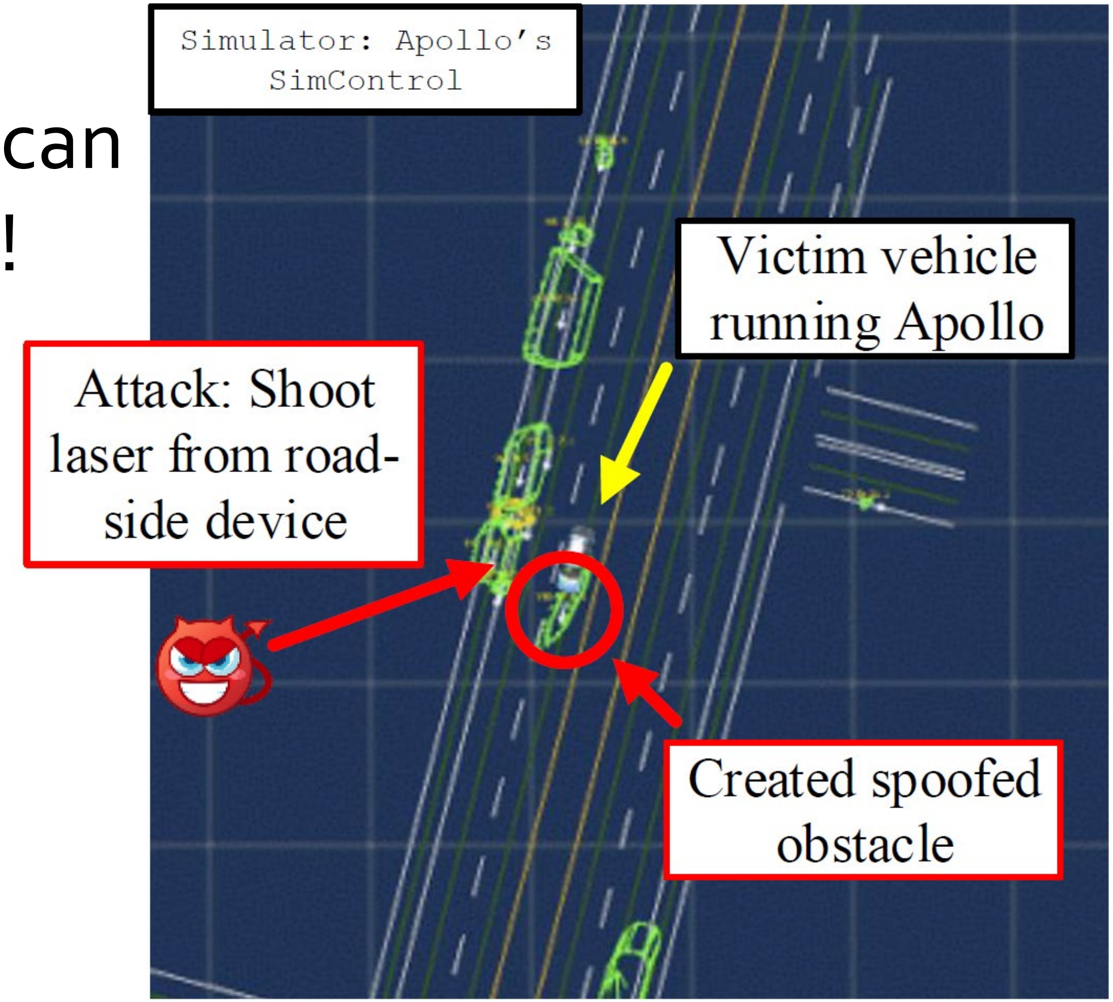


Analysis approach



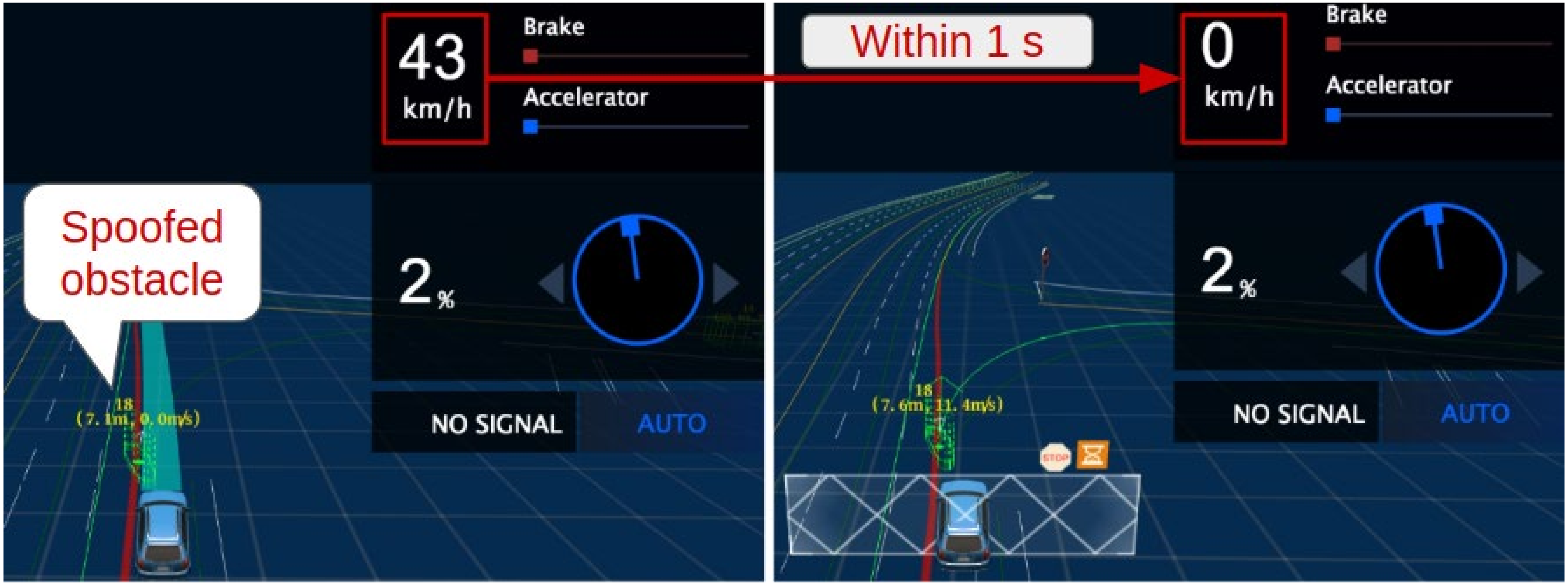
Analysis results

- Successfully find attack input that can inject fake object!



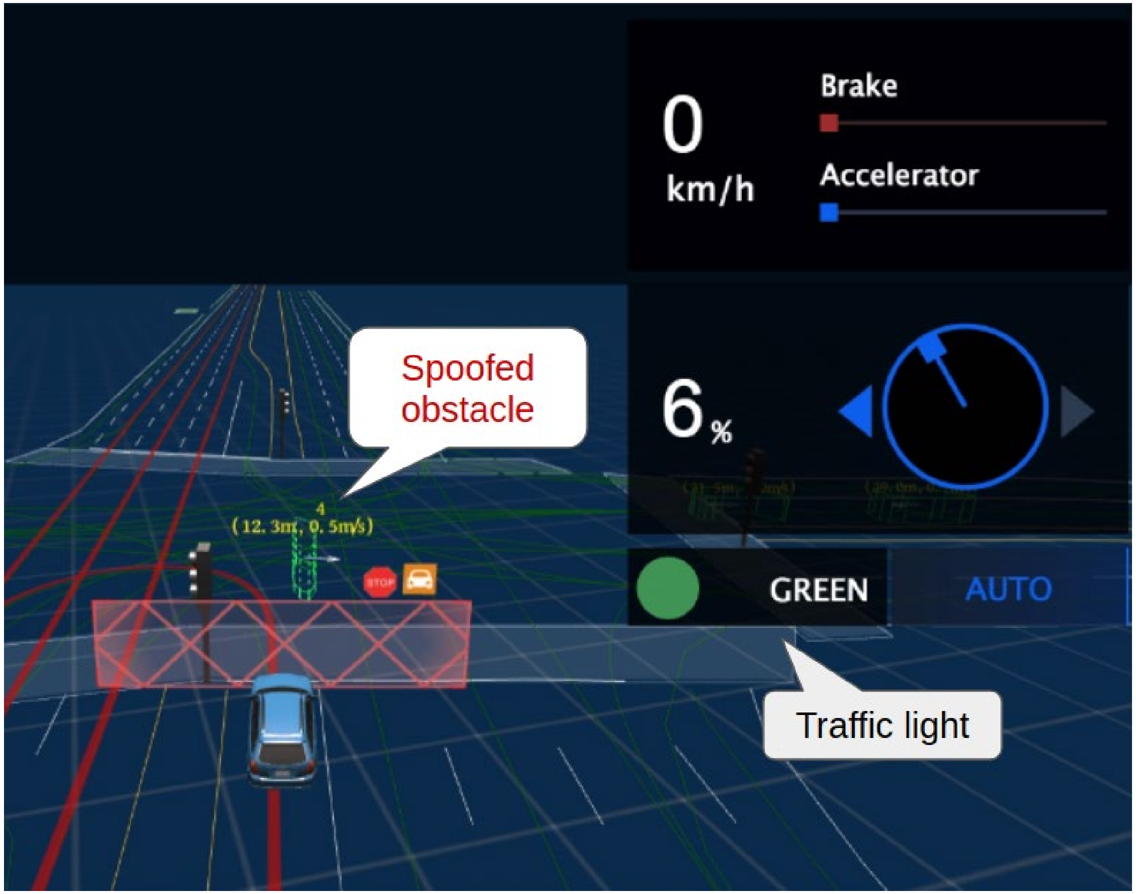
Security implication: Emergency brake attack

- Cause AV to decrease speed from ***43km/h*** **to** ***0 km/h*** within ***1 sec!***



Security implication: Car "freezing" attack

- **"Freeze" an AV** at an intersection ***forever***!



Conclusion

- Initiated ***the first research efforts*** to perform security analysis of autonomy software in CV/AV systems
- Discovered ***new attacks***, analyzed ***root causes***, and demonstrated ***security & safety implications***
- ***Only the beginning*** of CV/AV software security research
  - Initiated the ***ACM AutoSec workshop*** to build community
  - Interested in joining? ***Fill this form***: https://forms.gle/S7QzGkVMTcLzFvcT8

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