# Exposing Congestion Attack on Emerging Connected Vehicle based Traffic Signal Control

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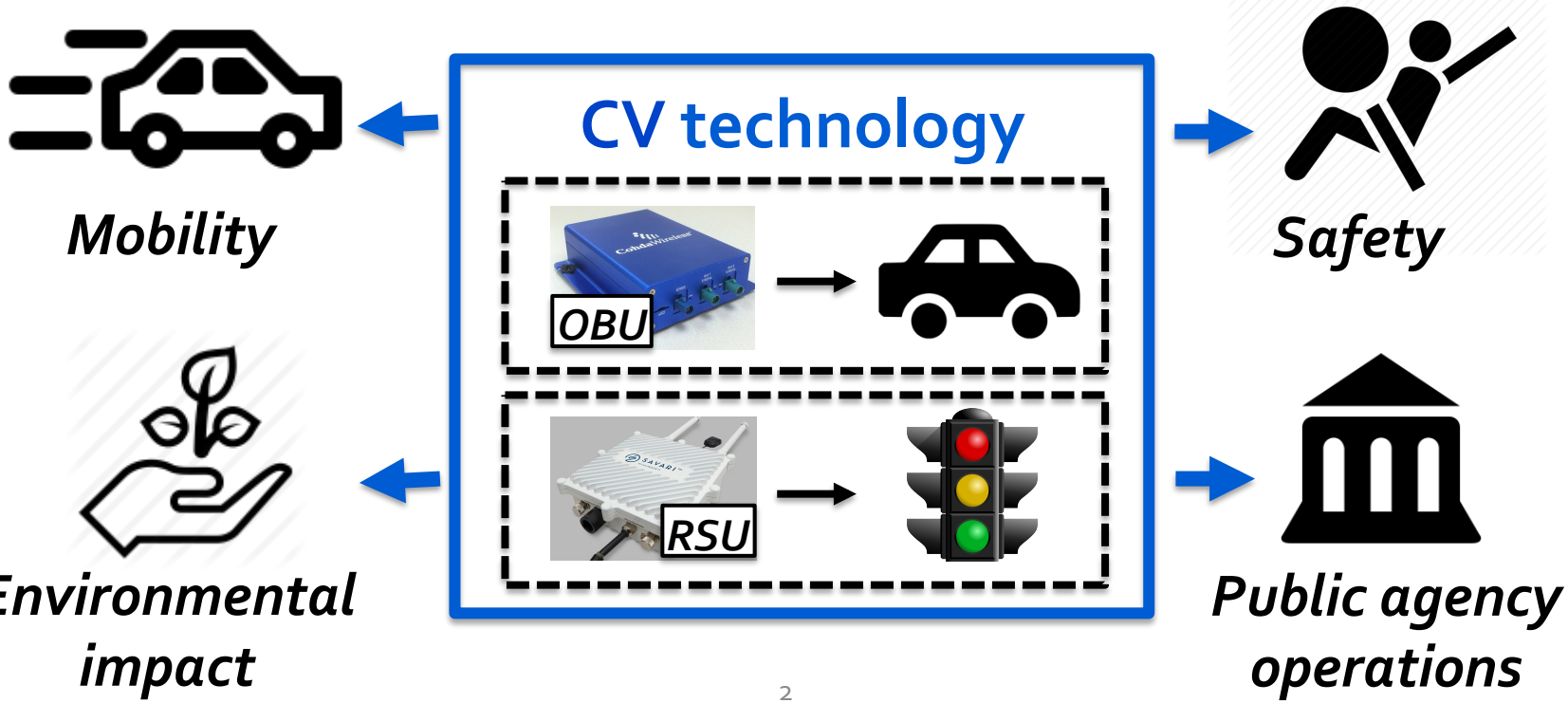
# Background: Connected Vehicle technology

- Wirelessly connect vehicles & infrastructure
- **Goal**: Dramatically improve mobility, safety, environmental impact, & public agency operations




CV = Connected Vehicle

OBU = On-Board Unit

RSU = Road-Side Unit

# Background: Recent advances

- Will ***soon*** transform transportation systems today
- 2016.9, USDOT launched **CV Pilot Program**
  - National effort to deploy, test, & operationalize CV-based transportation systems
  - Launched in **3 sites**






CV = Connected Vehicle

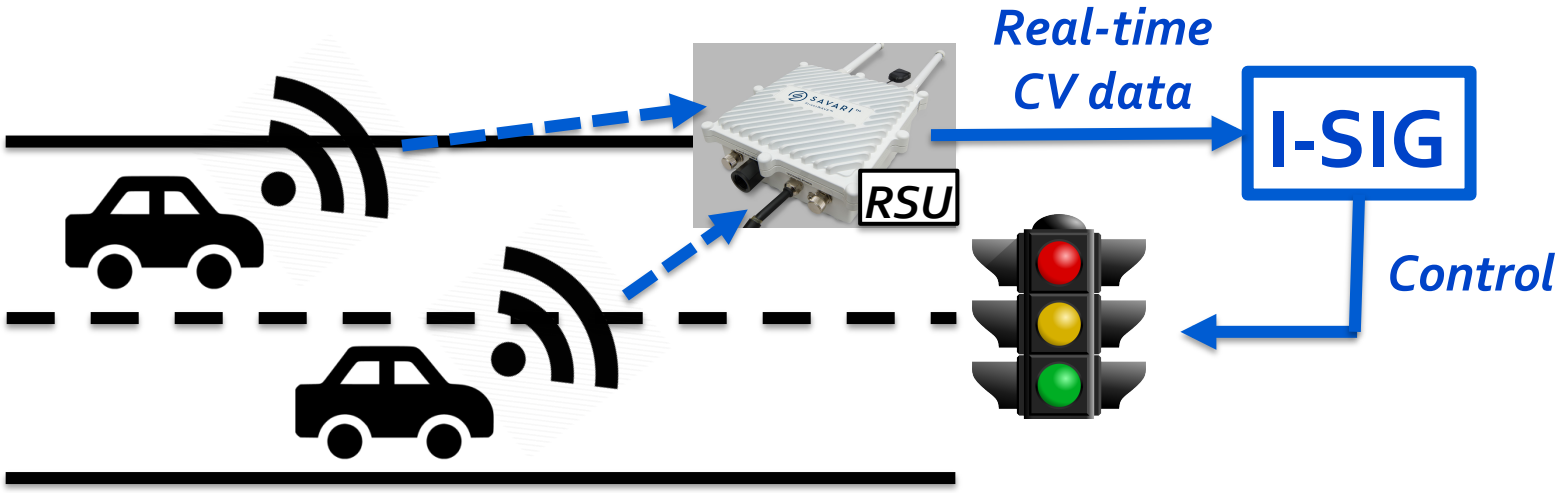
USDOT = United States Department of Transportation

# Cybersecurity of CV-based transportation

- However, such dramatically increased connectivity also opens a new door for **cyber attacks**
- **Highly important** to understand potential security vulnerabilities & new security challenges
  - Need to ensure ***security*** & ***safety*** for vehicles, transportation infrastructure, drivers & pedestrians
  - Need to perform study ***now*** so that they can be proactively addressed before nationwide deployment

# 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
    - 26.6% reduction in total vehicle delay
  - Under deployment in NYC and Tampa, FL



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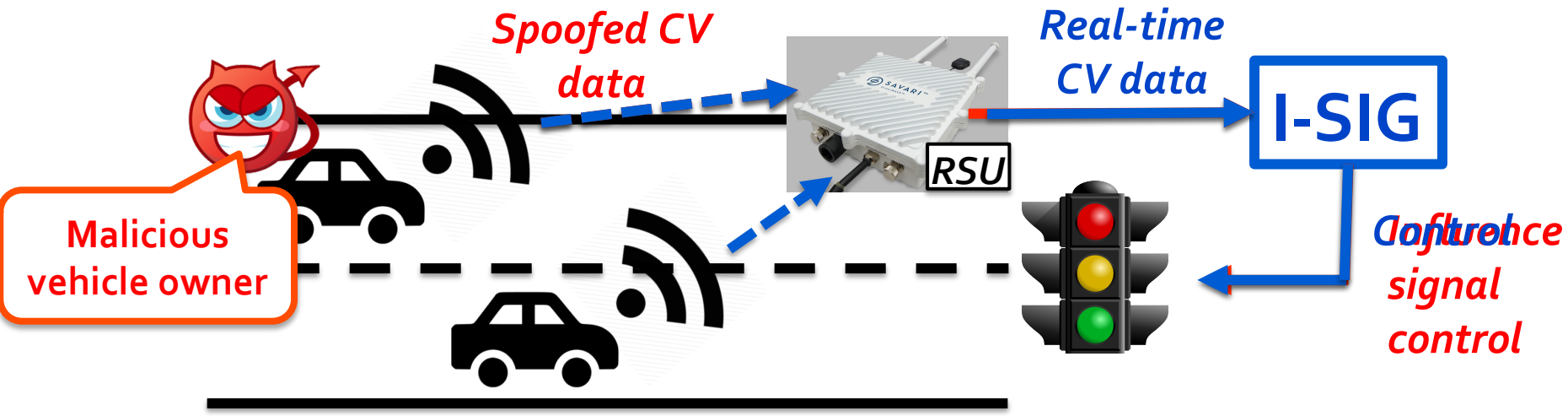
# Threat model

- 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



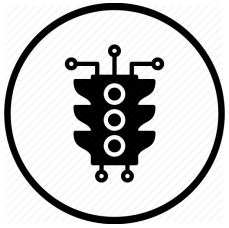



[1] Koscher et al. @IEEE S&P'10 [2] Checkoway et al. @Usenix Security'11 [3] Mazloom et al. @Usenix WOOT'16

# Attack goal

- Create **traffic congestion**
  - Increase total delay of vehicles in the intersection
    - *Directly subvert the design goal of I-SIG*
  - ***Damage***: City functions & individual (wasted fuel, time)
  - ***Incentive***: Politically or financially

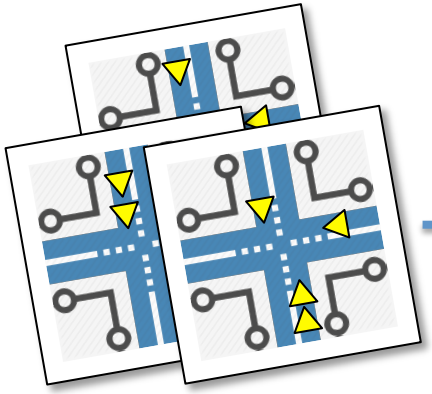
# Analysis approach overview



Source code

Analysis of Attack input data flow

*Data spoofing strategies*



Traffic snapshots from simulator

**Dynamic analysis**

Spoofing option enum → Increased delay calc

*Spoofing w/ top delay inc*

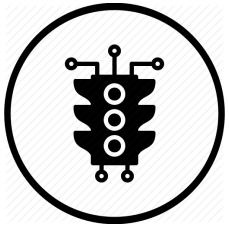
*Congestion creation vuln.*

Real-time attack requirement (e.g., decision time ≤ 4 sec)

**Exploit construction**

*Congestion creation exploit*

# Analysis result summary



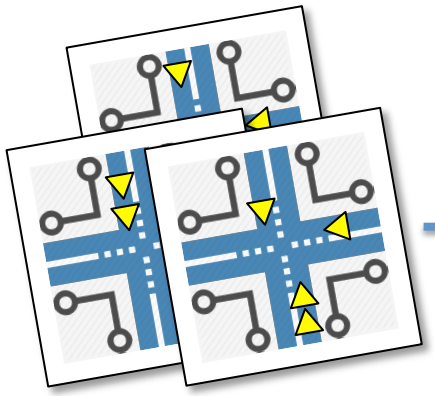
Source code

Analysis of Attack input data flow

*2 strategies*

*Data spoofing strategies*

**2 types of vuln.:**
***#1: Curse of transition period***
***#2: Last vehicle advantage***



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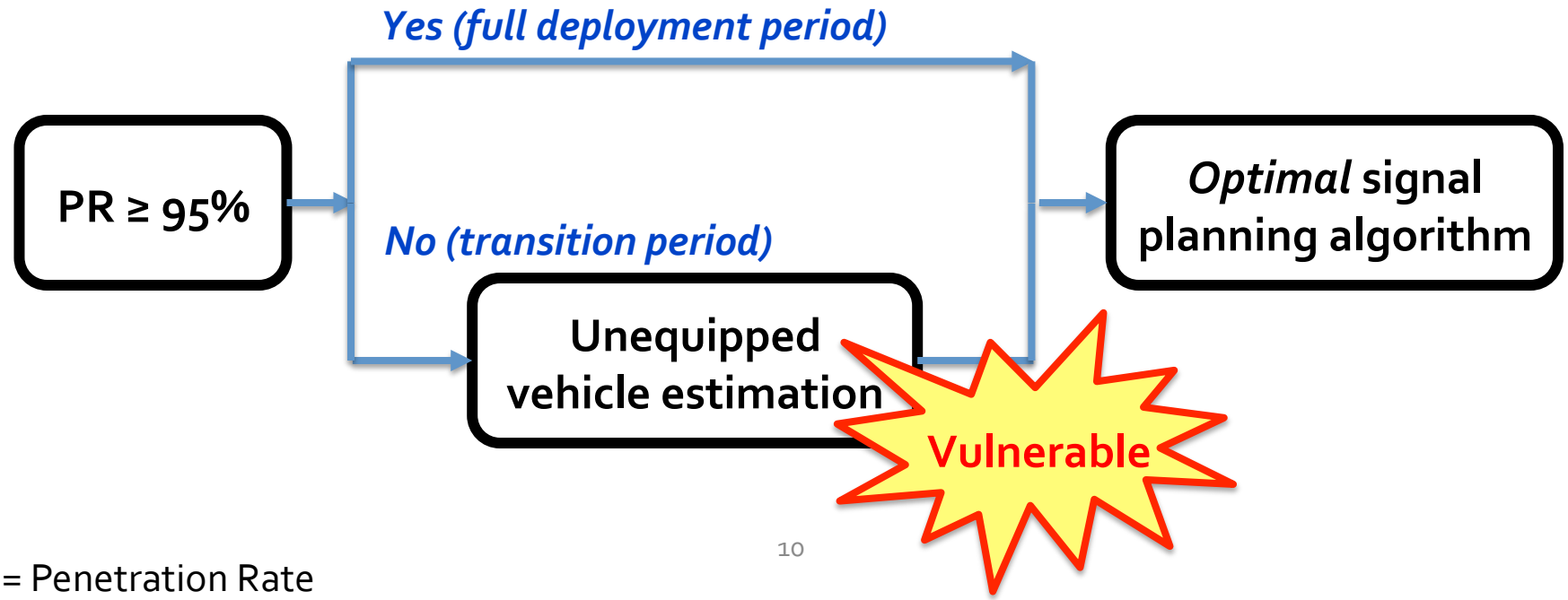
# Vuln #1: Curse of transition period

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

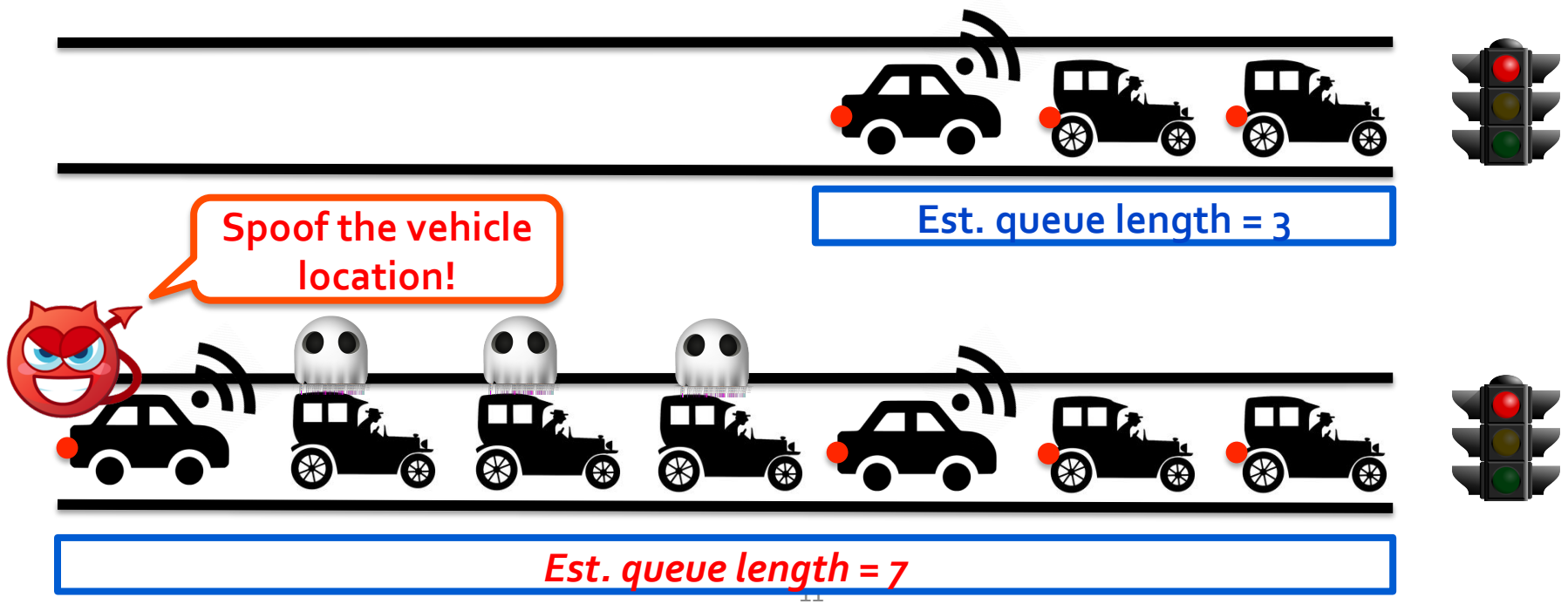





PR = Penetration Rate

# Vulnerable queue estimation

- Find the queue estimation part highly vulnerable
  - Data from ***one single attack vehicle*** can add a queue with tens of "ghost" vehicles
  - Cause delay increased by 20-50%, sometimes even **> 70%**



# An urgent & fundamental problem

- An **urgent** problem for the current design
  - Transition period is **unavoidable**, and **long** (***25-30 yrs*** *est. by USDOT*)
  - First thing needs to be resolved for its deployment in practice
- **Fundament cause:** Lack a sufficiently robust signal control algorithm for the transition period
  - Low PR is ***inherently more sensitive*** to data spoofing
    - *Fundamentally more challenging to ensure robustness*
  - Need joint research effort in both transportation & security communities



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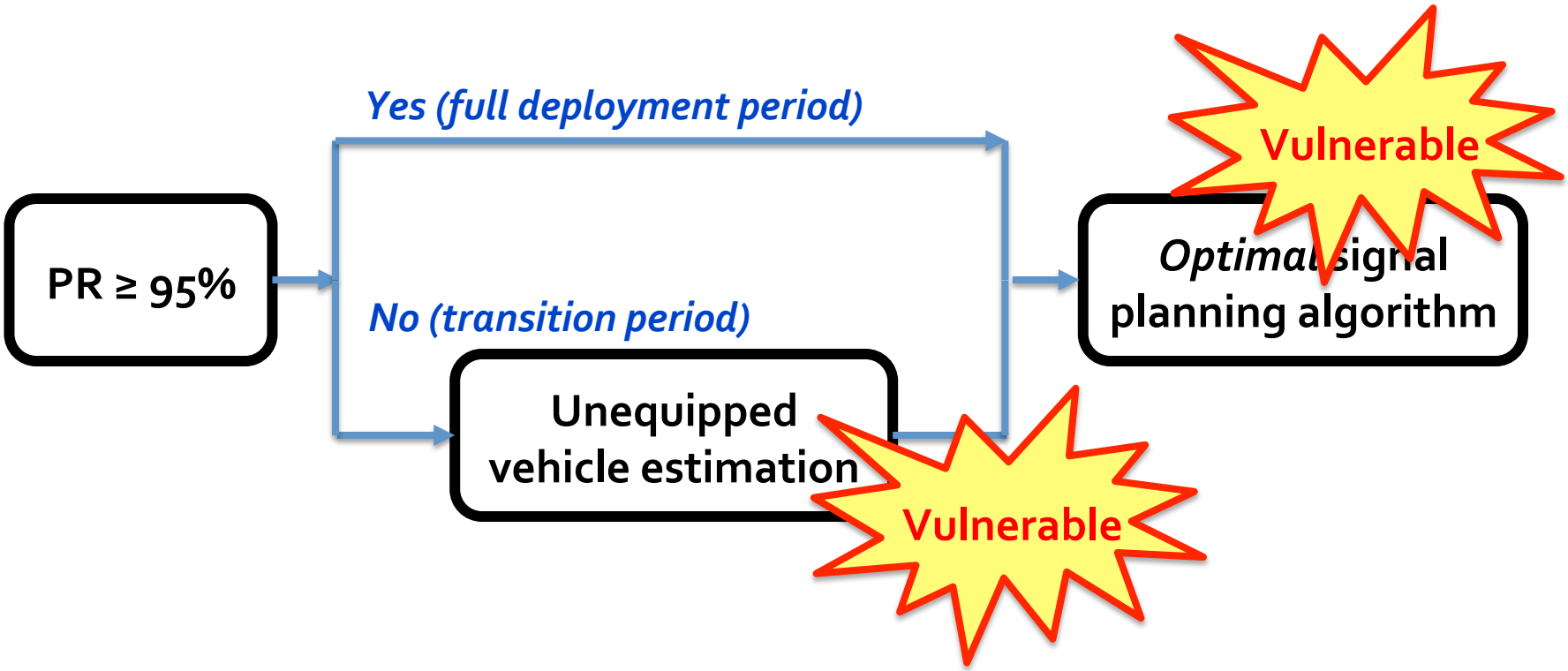
PR = Penetration Rate

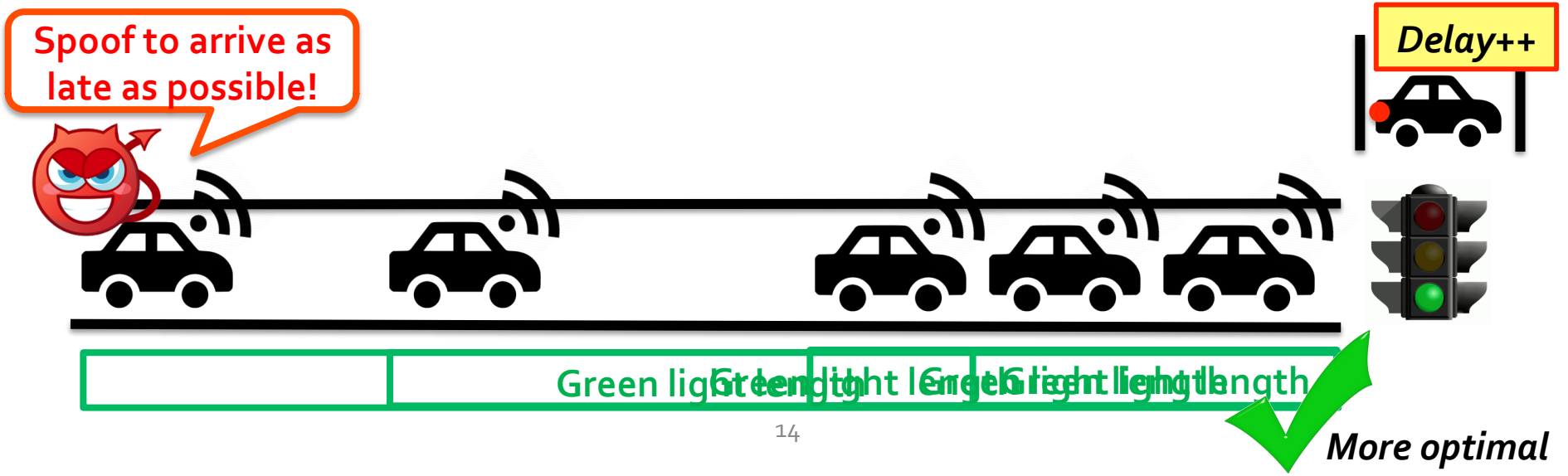
# Full deployment period is secure?




PR = Penetration Rate

# Vuln #2: Last vehicle advantage

- **Vulnerability**: Latest arriving vehicle determines signal plan
- **Attack**: Spoof to arrive as late as possible to increase the delay of queuing vehicles in other directions
- **Fundamental cause**: *Security vs deployability trade-off*
  - Limited decision time forces choice of ***a sub-optimal config.***
  - Such sub-optimal config unexpectedly exposes such vuln.



# Attack video demo

- Demo time!

# Defense discussion

- Robust algorithm design for the transition period
  - Inherently challenging, need joint research efforts in both transportation & security communities
- Speed-up control algorithm to avoid sub-optimal config.
  - E.g., offload computation to a nearby workstation or cloud
- Data spoofing detection using infrastructure-controlled sensors, e.g., camera
  - Cross check validity of driving data from OBUs



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# Conclusion

- The **first security analysis** of a CV based transportation system, I-SIG
  - Discover new vulnerability & analyze causes
    - *Current control algorithm design & config. are **highly vulnerable***
  - Construct & evaluate exploits to show the severity in practice
  - Propose defense directions based on the analysis insights
- Hope to inspire follow-up studies
  - E.g., other attack goals, other types of CV systems (***6o+ open sourced***), defense solutions
- Reported to USDOT CV Pilot Program office & sites (NYC and Tampa)

**https://tinyurl.com/congestion-attack**



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- Questions?