Cybersecurity Of Autonomous Vehicle Platooning

Presenter: Soodeh Dadras
Advisor: Prof. Chris Winstead
Electrical and Computer Engineering Department
Utah State University

Agenda

- What is Autonomous Vehicle Platooning?
- Pros and Cons of Autonomous Vehicle Platooning
- Platooning Challenges
- Modeling and Results
- Conclusion

Autonomous Vehicle Platooning

- **Autonomous Vehicle:**
  - The car that drives itself.

- **Platooning:**
  - Group of Autonomous vehicles travelling together with relatively small spacing and small/zero relative velocity of the vehicles.

Leading Companies and Projects

Audi
Baidu 百度
BMW
BOSCH
DAF
DAIMLER
DELPHI

FCA
Ford
GM
Google
HONDA
HYUNDAI
intel
IVECO

JAGUAR
LAND-ROVER
lyft
MAN
Mercedes-Benz
Microsoft
MOBILEYE
NISSAN
RENAULT
NVIDIA

PSA GROUPE
SCANIA
TATA ELXSI engineering creativity
TESLA
TOYOTA
Volkswagen
VOLVO
YUTONG

VISLAB.IT Extend Your Vision

SARTRE
Safe Road Trains for the Environment

KONVOI

Università di Parma
Dip. di Ingegneria dell'Informazione
Consiglio Nazionale delle Ricerche
Progetto Finalizzato Trasporti II

CALIFORNIA PATH

Pros and Cons

- **Pros:**

1. Safety
2. Operational Efficiency (Increase highway capacity)
3. Driving Comfort
4. Transit time Efficiency

- **Cons:**

1. Computer failure
2. Degrading performance in case of interception
3. Increase in crashes involving pedestrians

Platooning Challenges

- Driver acceptance
- Reliability
- Legislation
- System Security

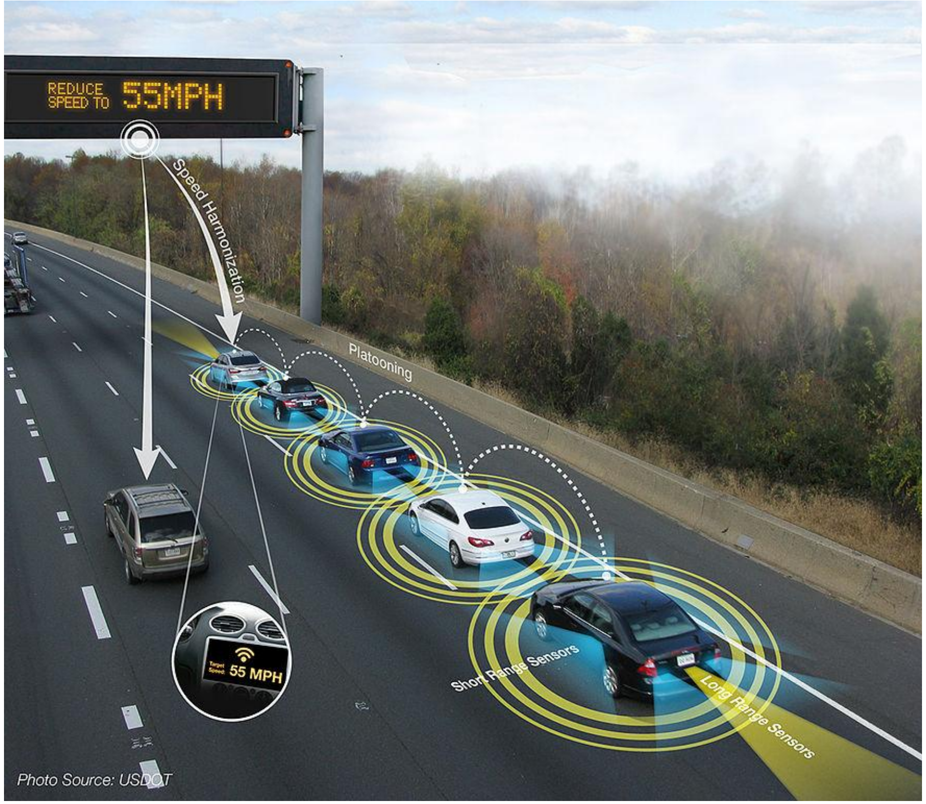
Cyber Security Of Autonomous Vehicle Platooning

"In fact, Munich Re, the world's second-largest reinsurer, found that **55 %** of corporate risk managers surveyed in a recent study named **cybersecurity** as their **top concern** for autonomous vehicles. Even more alarming, **64 %** of companies surveyed say they feel completely **unprepared** to address cyber security [1] "

Research Works Study the Security in Platooning

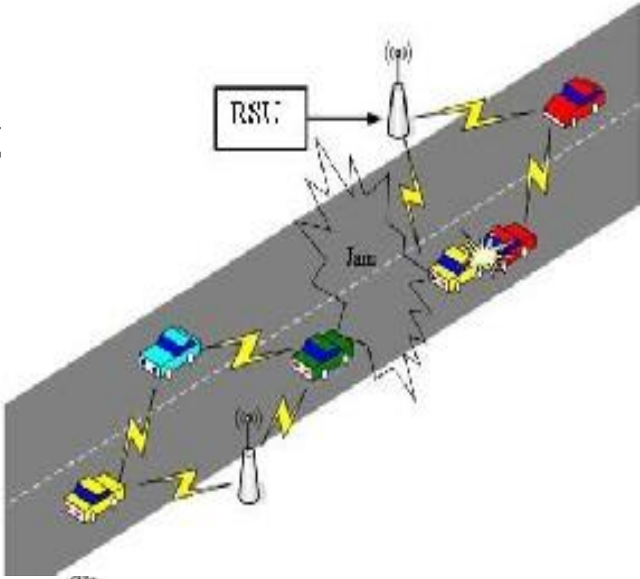
- **Communication security issues** [2,3]

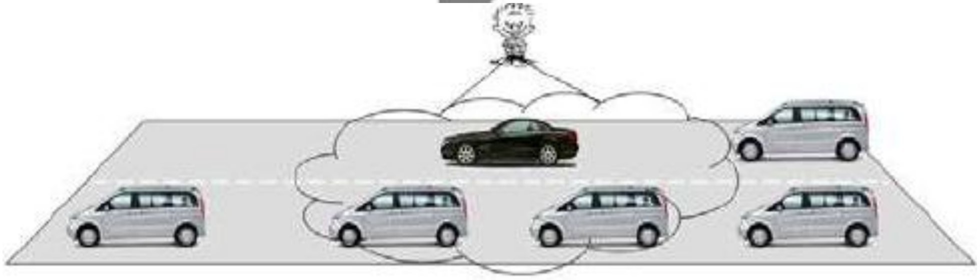
❖ Availability
❖ Confidentiality
❖ Data integrity
❖ Authentication



Security Attacks on Communication: Threats and Attacks on Availability

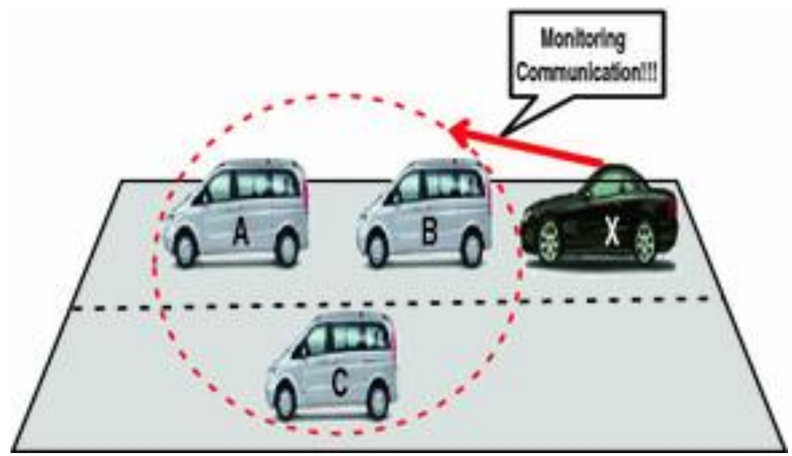
- Jamming attack
- DOS (Denial of service) or DDOS attack
- Malware attack
- Broadcast tampering attack
- Black hole attack
- Greedy behavior attack
- Spamming attack



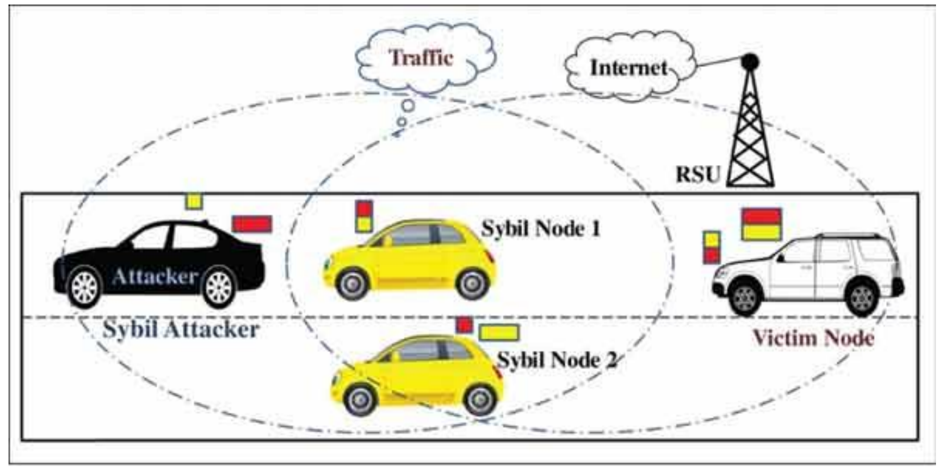


Security Attacks on Communication: Threats and Attacks on Confidentiality

- Eavesdropping attack
- Traffic analysis attack
- Man in the middle attack



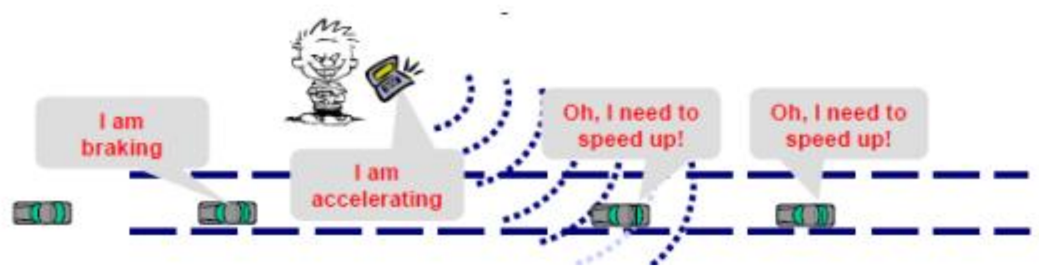
Security Attacks on Communication: Threats and Attacks on Authentication



- Sybil attack
- Tunneling attack
- GPS spoofing
- Impersonation attack
- Free-riding attack (or active free-riding attack)
- Masquerading attack
- Key and/or certificate replication
- Message tampering

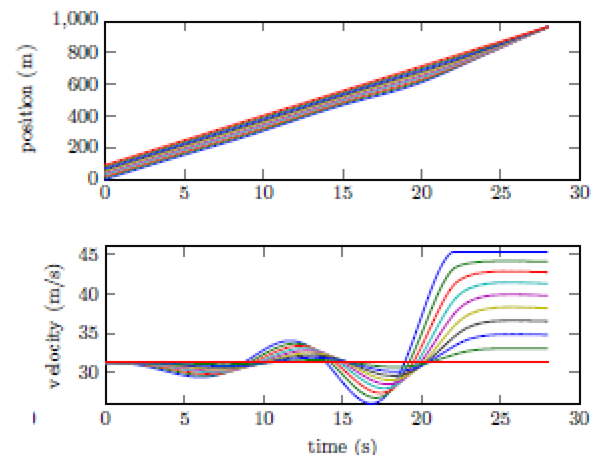
Security Attacks on Communication: Threats and Attacks on Data Integrity

- Replay attack
- Masquerading attack
- Message modification attack
- Illusion attack



Research Works Study Security In Platooning

- **Control security issues**

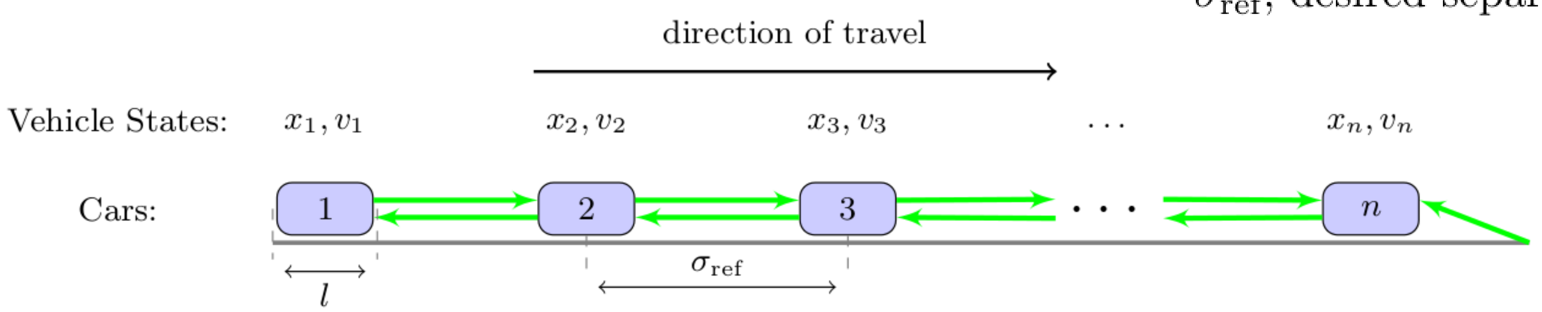


- Destabilizing attack [4]
- High-speed Collision induction attack [5]
- Energy efficiency attack [6]
- False data injection [7]
- Traffic flow instability attack [8]

Platoon Model

- Bidirectional structure [9]:

x_i, car i's position
v_i, car i's velocity
l, car length
σ_{ref}, desired separation

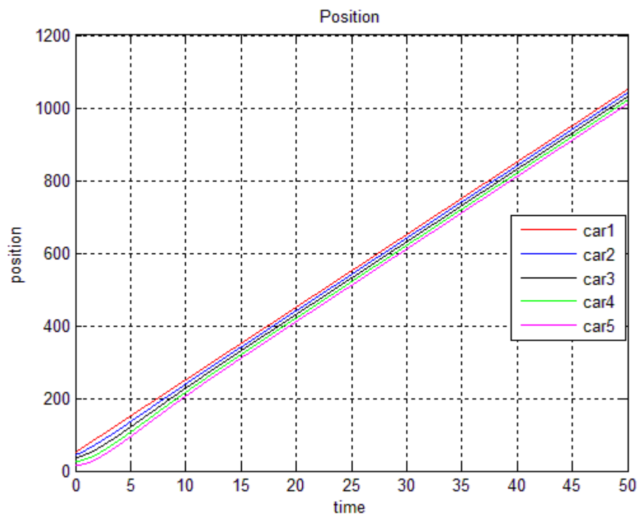


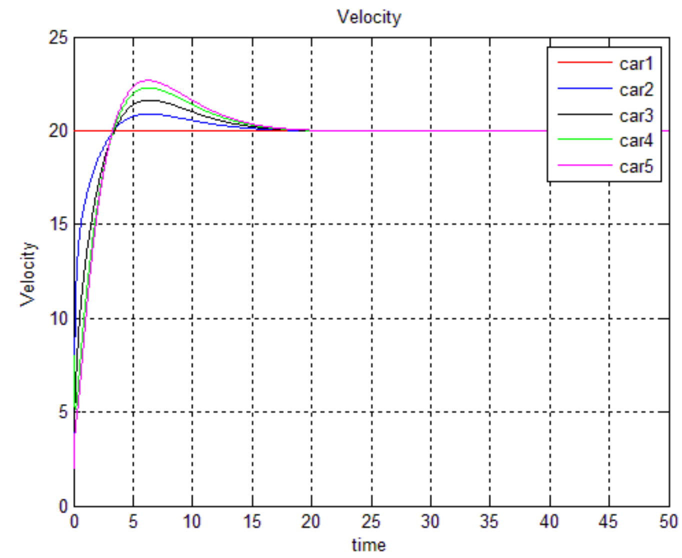
Each vehicle receives states of the vehicles in front and behind.

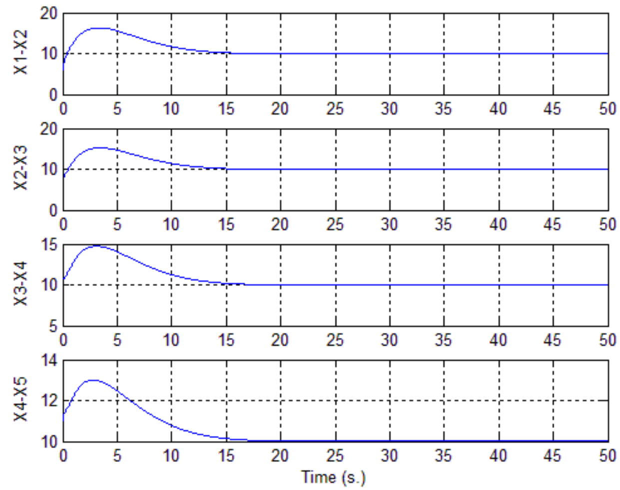
$$u_i = k_p(x_{i+1} - x_i - \sigma_{\text{ref}}) + k_p(x_{i-1} - x_i + \sigma_{\text{ref}}) + k_d(v_{i+1} - v_i) + k_d(v_{i-1} - v_i)$$

with k_p position gain and,
with k_d velocity gain

System Performance







Attack Model

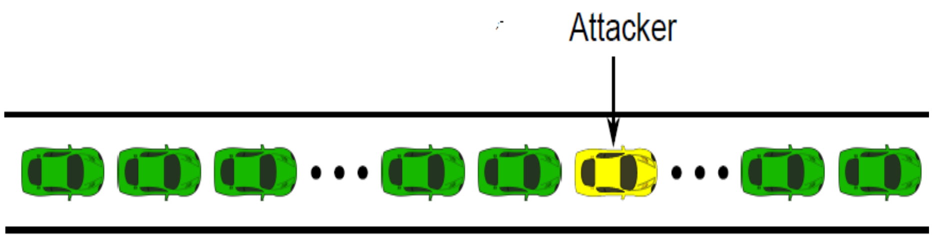
- Attack objective

  Causing **collision** by attackers' motion and gain modification

While:

Attacker is not affected

Attacker is not detectable



$$u_i = k_p(x_{i+1} - x_i - \sigma_{ref}) + k_p(x_{i-1} - x_i + \sigma_{ref}) + k_{d_a}(v_{i+1} - v_i) + k_{d_a}(v_{i-1} - v_i) + \mathrm{u}_a$$

k_{d_a} : velocity gain for the attacker

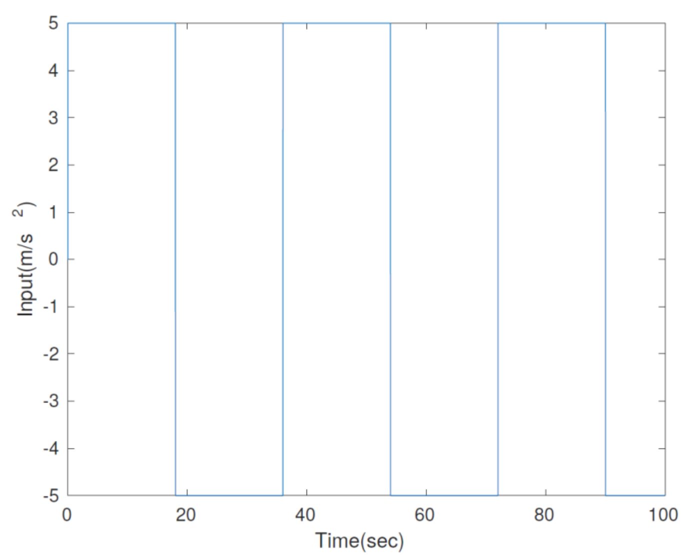
u_a : Attacker's input

Simulation Results

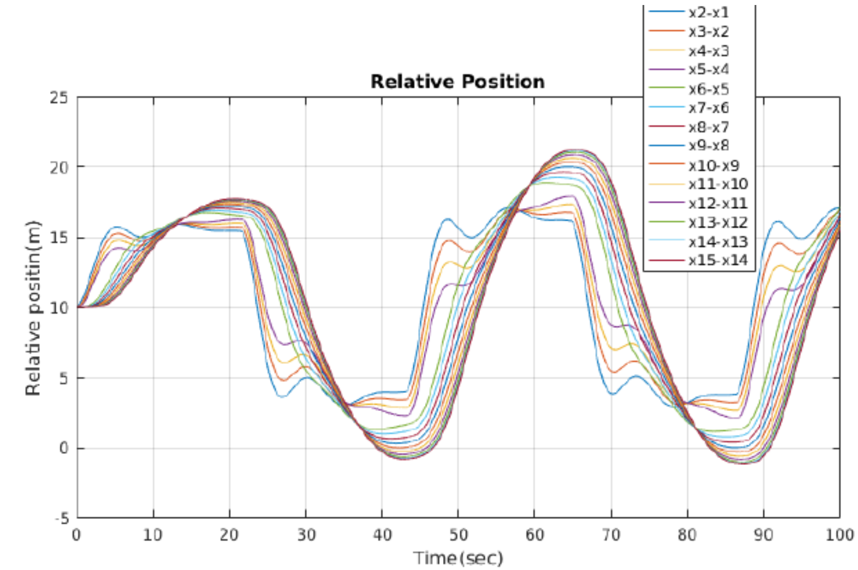
- 15-vehicle platoon
- Attackers # 1 and #5
- Gains for normal and attacker's vehicle
- Attacker’s Input

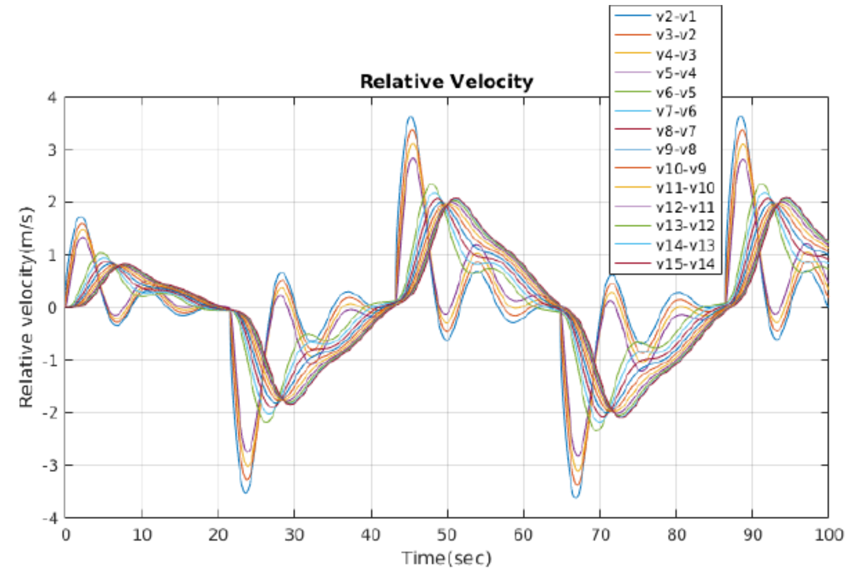
$$k_p = 1, k_d = 11$$

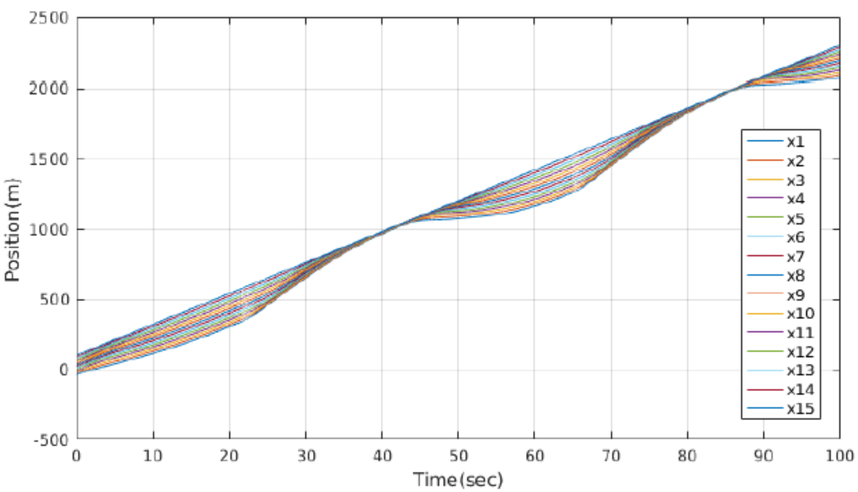
$$k_{d_a} = 0.3$$

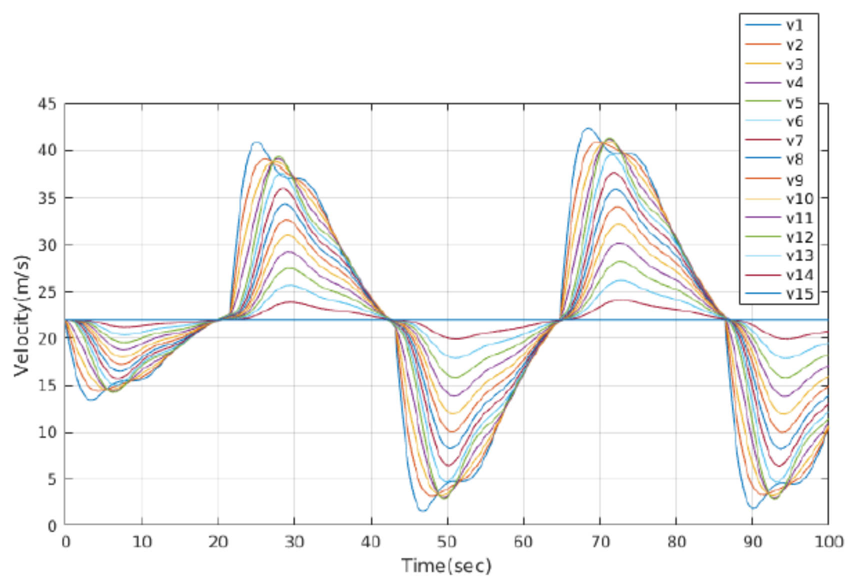


Simulation Results

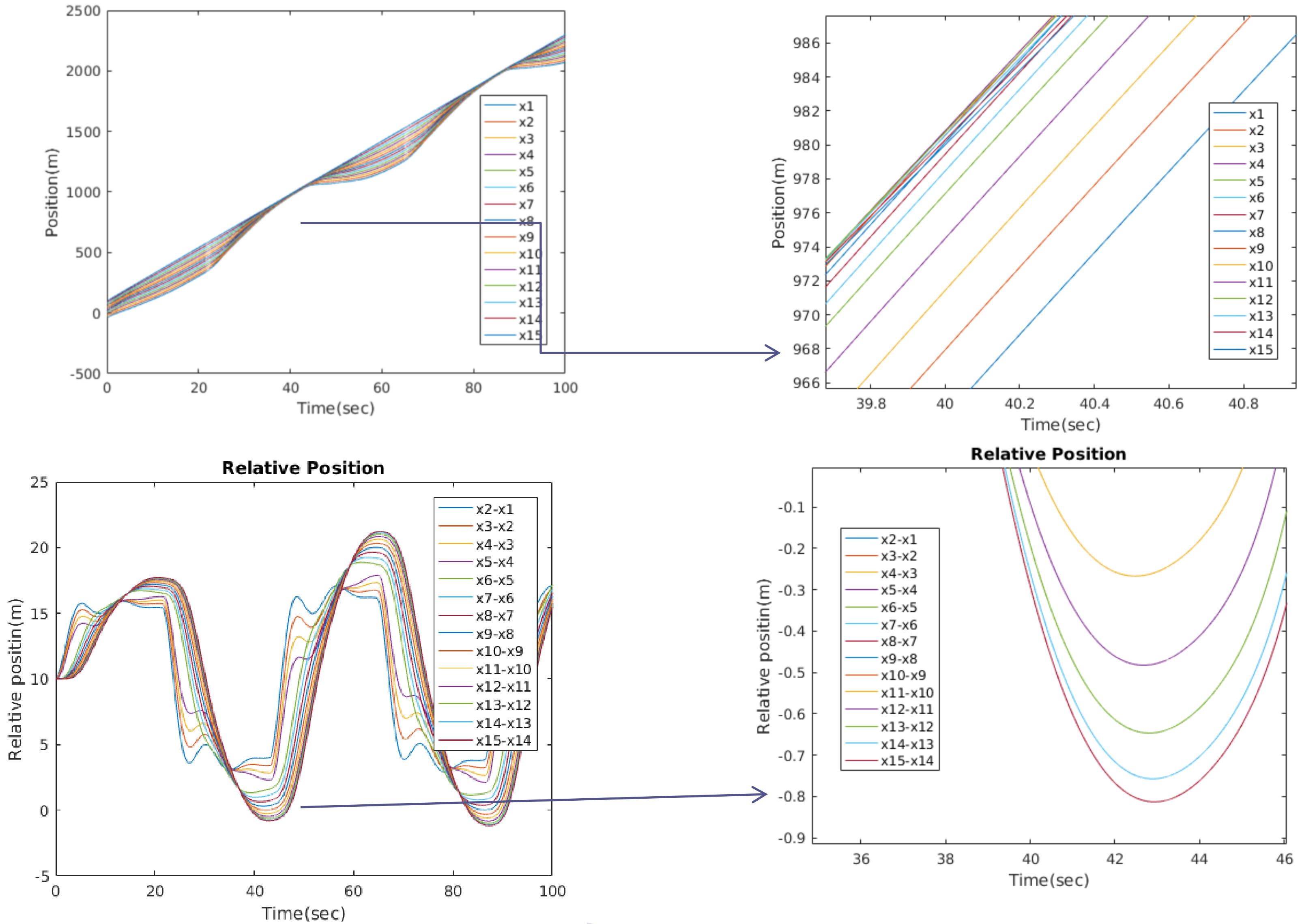








Simulation Results



Conclusion

- Simulation results show:

  - Attacker can easily disrupt platoon performance and stay **intact** and Attacker is **not detectable**.

  - Cyber security of autonomous vehicle platooning is an important issue and it needs immediate attention.

Bibliography

[1] https://techcrunch.com/2017/02/18/why-a-cybersecurity-solution-for-driverless-cars-may-be-found-under-the-hood

[2] Amoozadeh, M., Raghuramu, A., Chuah, C. N., Ghosal, D., Zhang, H. M., Rowe, J., & Levitt, K. (2015). Security vulnerabilities of connected vehicle streams and their impact on cooperative driving. *IEEE Communications Magazine*, *53*(6), 126-132.

[3] Azees, M., Vijayakumar, P., & Deborah, L. J. (2016). Comprehensive survey on security services in vehicular ad-hoc networks. *IET Intelligent Transport Systems*, *10*(6), 379-388.

[4] Dadras, S., Gerdes, R. M., & Sharma, R. (2015, April). Vehicular platooning in an adversarial environment. In *Proceedings of the 10th ACM Symposium on Information, Computer and Communications Security* (pp. 167-178). ACM.

[5] DeBruhl, B., Weerakkody, S., Sinopoli, B., & Tague, P. (2015, June). Is your commute driving you crazy?: a study of misbehavior in vehicular platoons. In *Proceedings of the 8th ACM Conference on Security & Privacy in Wireless and Mobile Networks* (p. 22). ACM.

[6] Gerdes, R. M., Winstead, C., & Heaslip, K. (2013, December). CPS: an efficiency-motivated attack against autonomous vehicular transportation. In *Proceedings of the 29th Annual Computer Security Applications Conference* (pp. 99-108). ACM.

[7] Biswas, B. (2015). *Analysis of false data injection in vehicle platooning*. Utah State University.

[8] Dunn, D. D. (2015). *Attacker-induced traffic flow instability in a stream of automated vehicles*. Utah State University.

[9] Yanakiev, D., & Kanellakopoulos, I. (1996, July). A simplified framework for string stability analysis in AHS. In *Proceedings of the 13th IFAC World Congress* (Vol. 182, pp. 177-182).