ViewMap:
Sharing Private In-Vehicle Dashcam Videos

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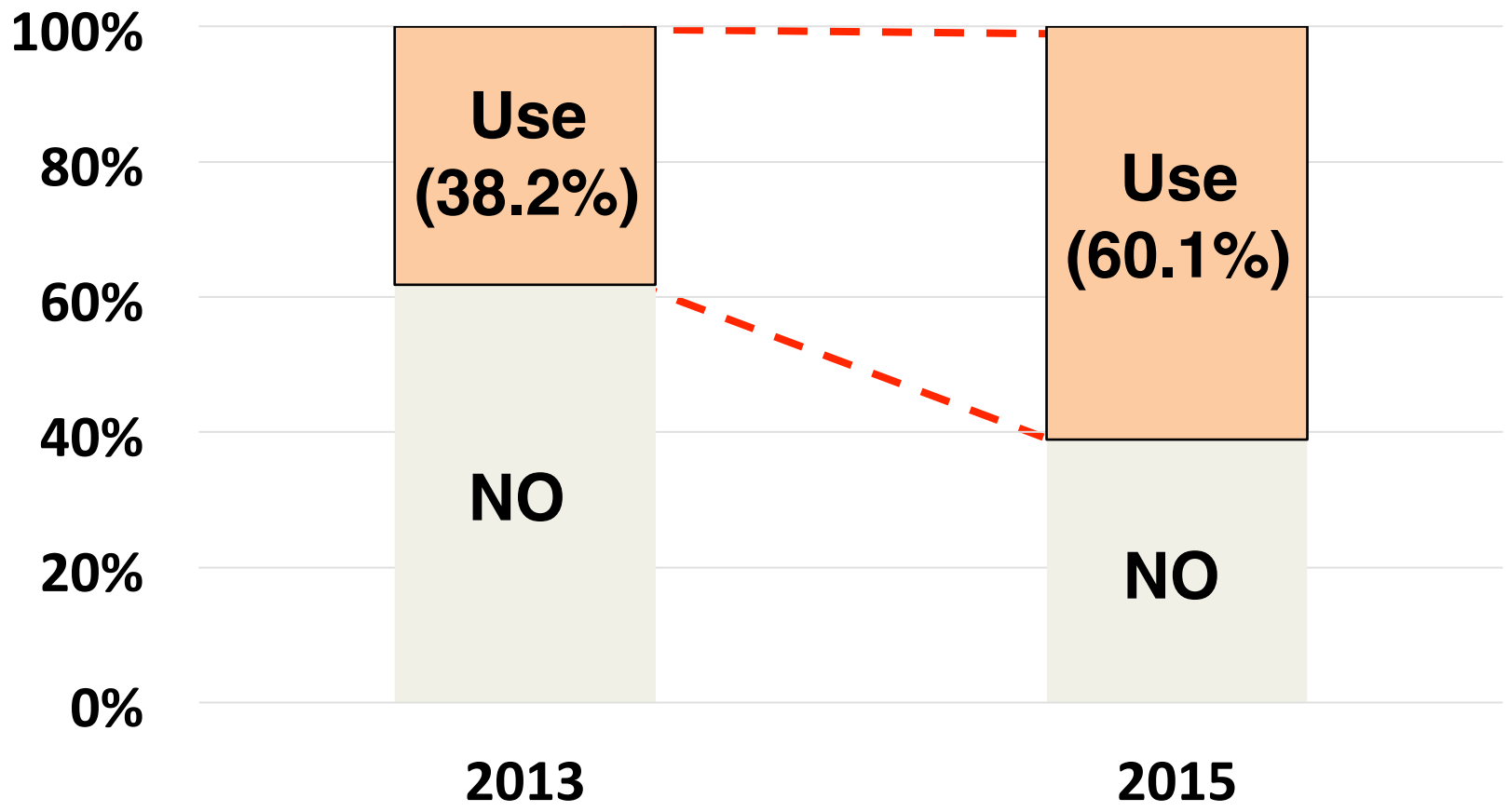
Dashcam (Dashboard Camera):

An onboard camera that continuously records the view (through a vehicle's windscreen), audio, and GPS.

Dashcam Popularity in Korea



[Top Rider. 2015. Research on Vehicle Blackbox]
https://www.top-rider.com:447/news/articleView.html?idxno=19493

Dashcams as “Silent Witnesses”

A Common Way to Find Witnesses

Looking for witnesses to a car accident!!

12 July, 2013. 21:10pm, Looking for someone who witnessed a car accident of a silver car and a black car at the crossroad in Pankyo-dong

Please contact to Bundang Police center 031-786-XXXX

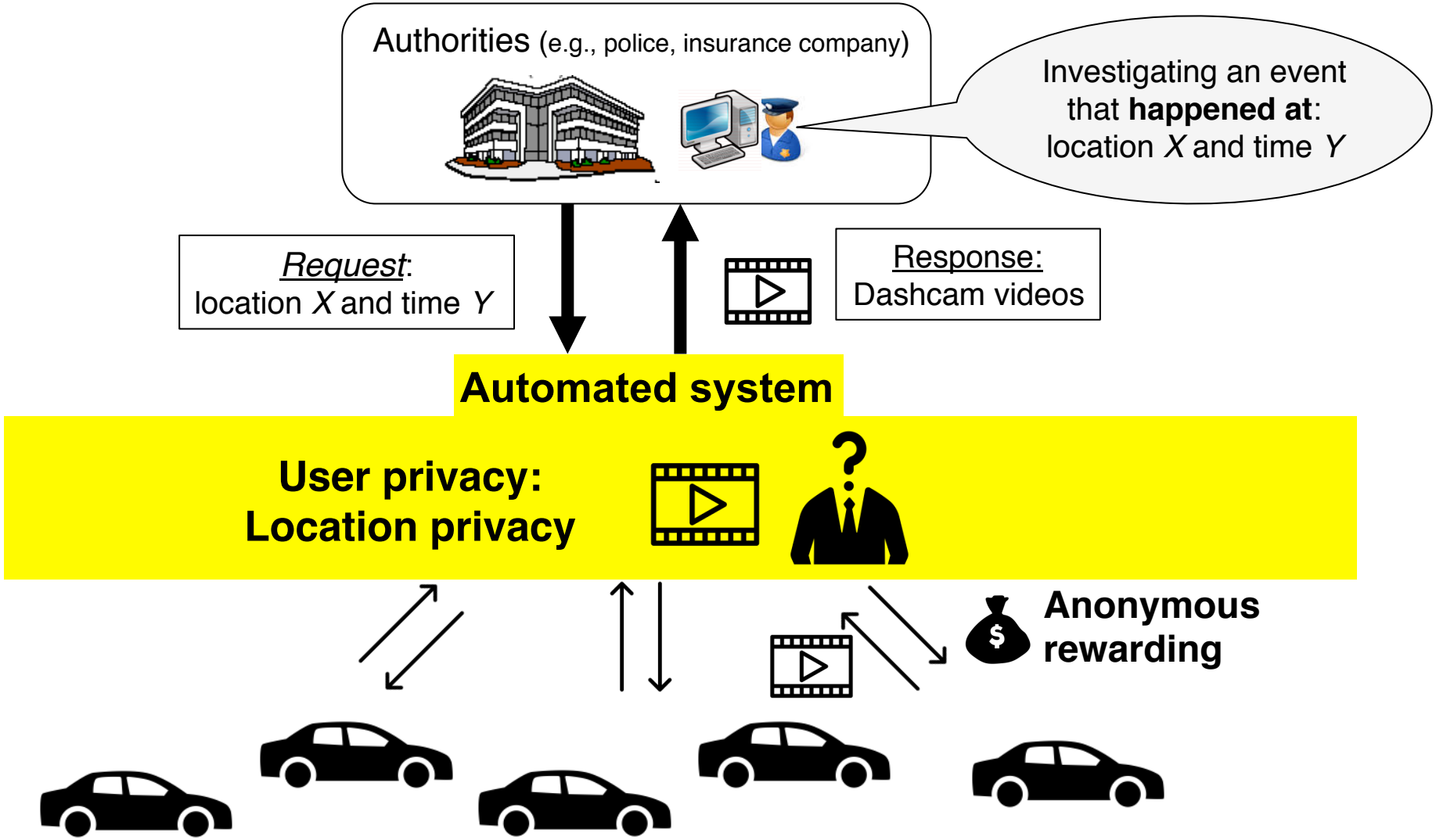
Limitations of Today's Practice

- Privacy
- Monetary reward
- Automation

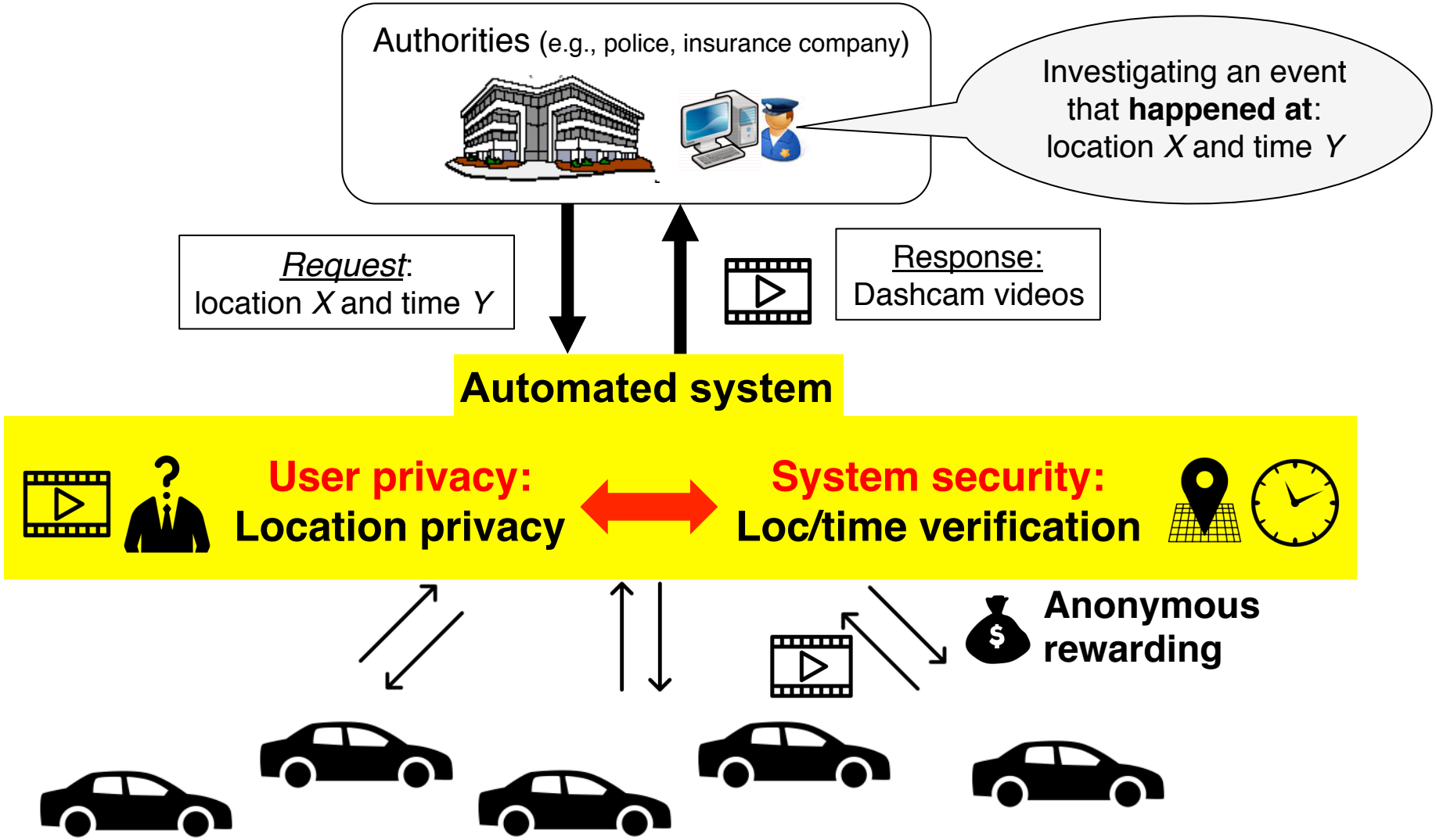
Privacy concerns and **monetary motives** are two major factors behind the sharing of dashcam videos.*

* S. Park, J. Kim, R. Mizouni, and U. Lee. Motives and concerns of dashcam video sharing. Proc. ACM CHI, 2016.

Goal: Automated Public Service System



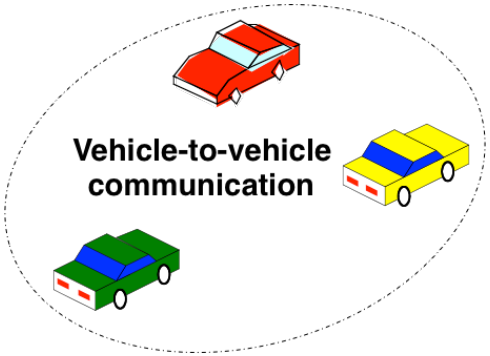
Goals and Challenges



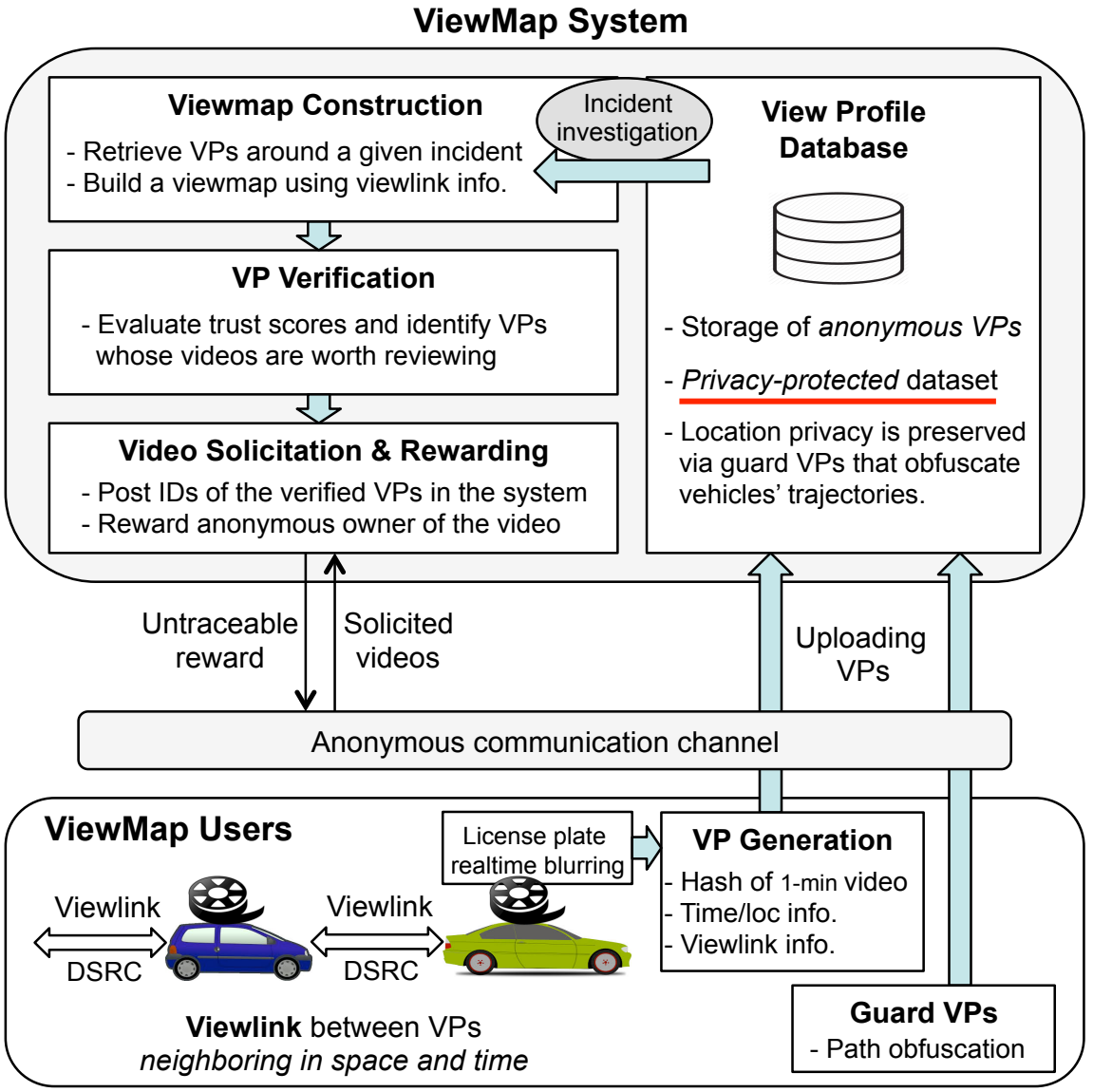
Our Approach

- View profile (VP): compact form of video
  - **Anonymized VPs** as entities for search/verification/reward
  - Minimal overhead: original videos are NOT transmitted

- DSRC-based inter-vehicle communication
  - Line-of-sight (LOS) of DSRC to link between VPs that share the same sight while driving
  - Such LOS-based VP links to build a map of visibility
  - Identification of VPs whose videos are worth reviewing

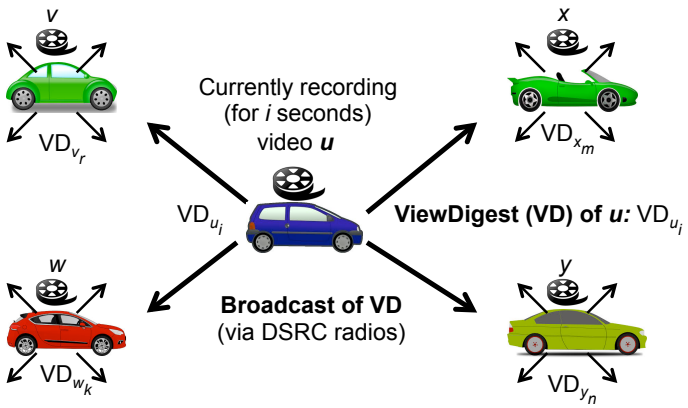


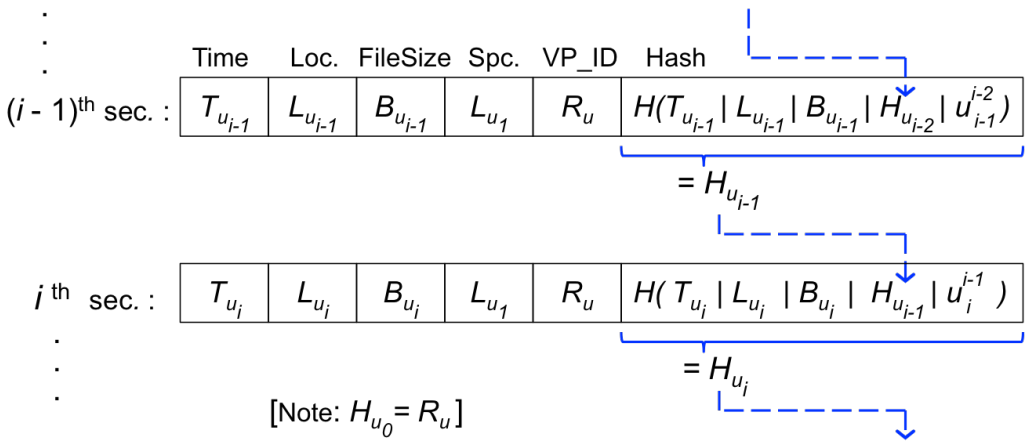
ViewMap Framework



View-Profile (VP)

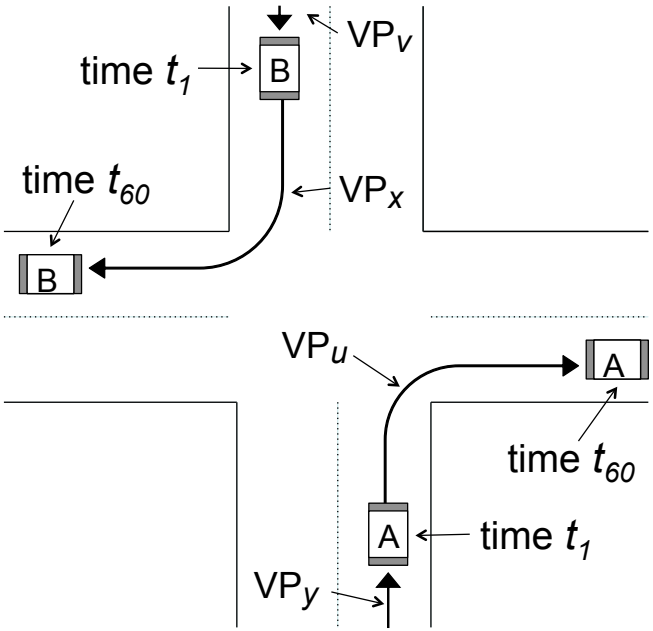
- Each 1-min video is represented by a view-profile (VP), which contains:
  1. Time/location trajectory
  2. Its own video fingerprint
  3. Video fingerprints of neighbor vehicles that **share the same sight via DSRC radios**





Towards Privacy-Protected VP Database

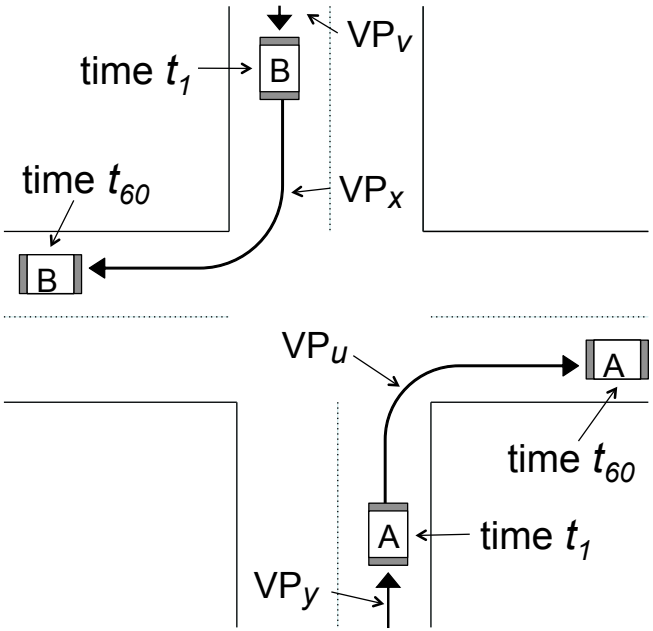
- Even anonymized VPs are subject to tracking.



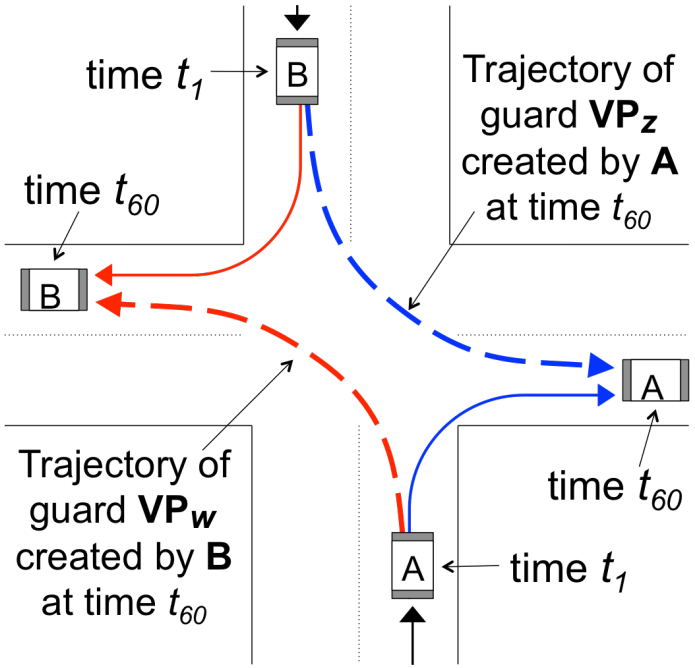
<Actual VPs' trajectories>

Towards Privacy-Protected VP Database

- Guard VPs: protection against location tracking
  - Path confusion any time, any place within DSRC range

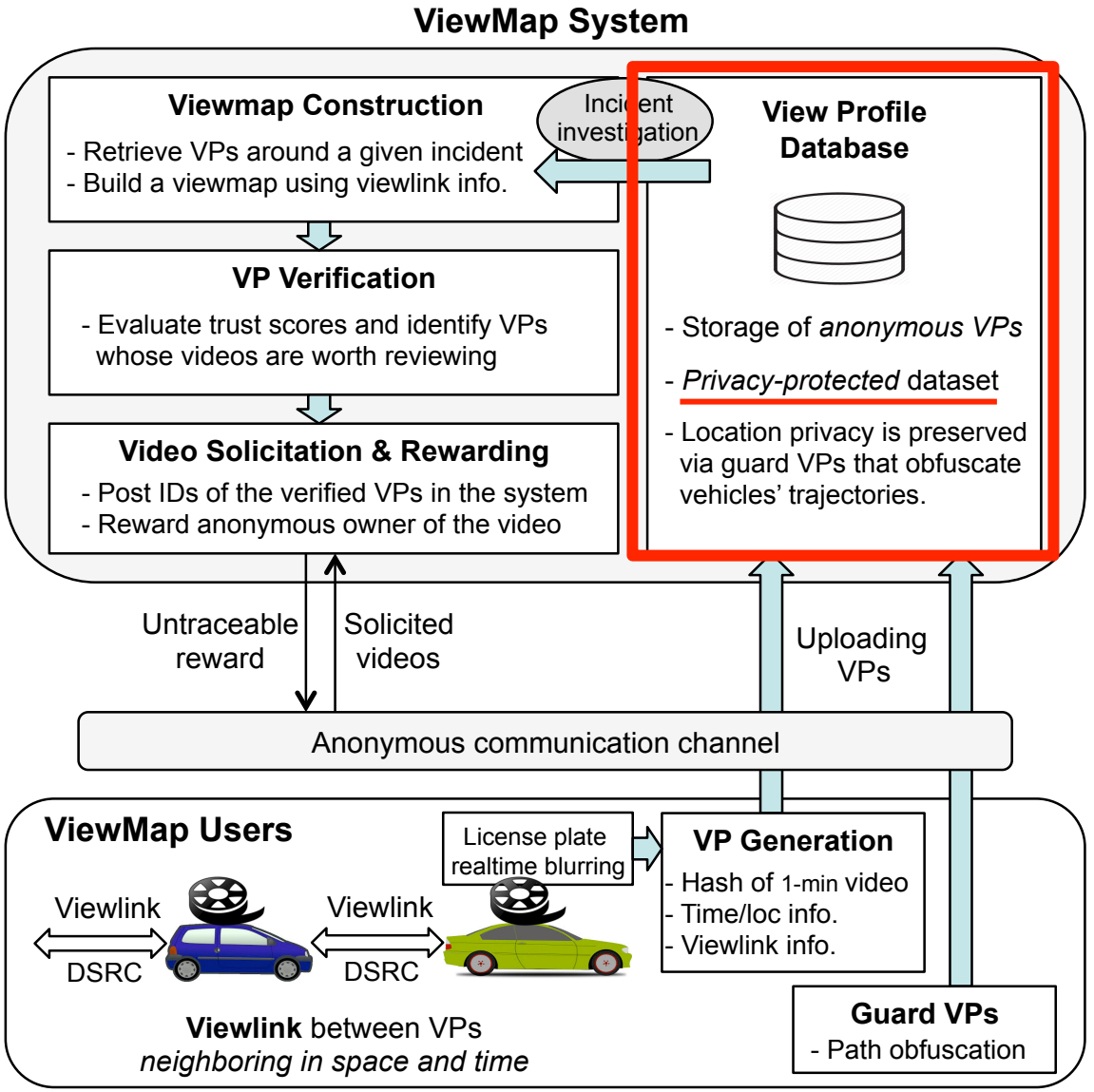


<Actual VPs' trajectories>



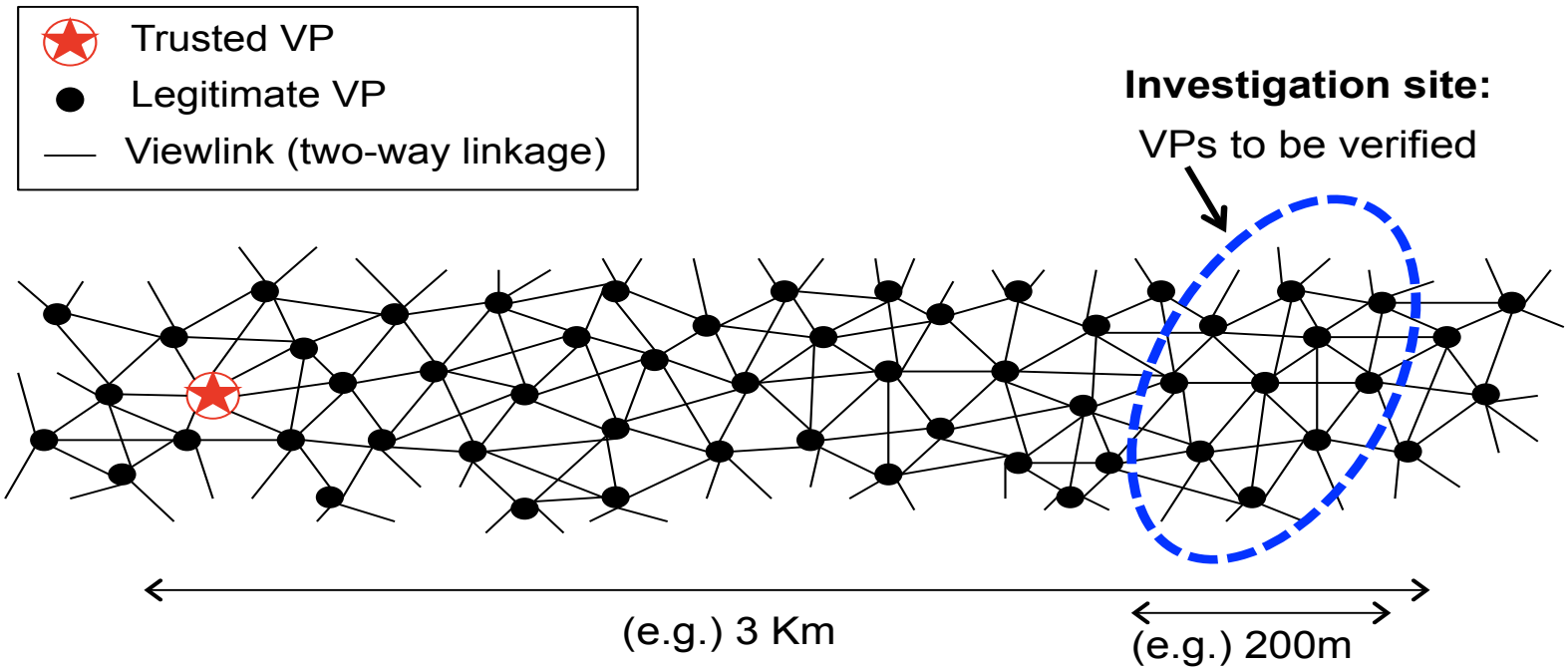
<Guard VPs' trajectories>

When Video Evidence is Required for a given incident



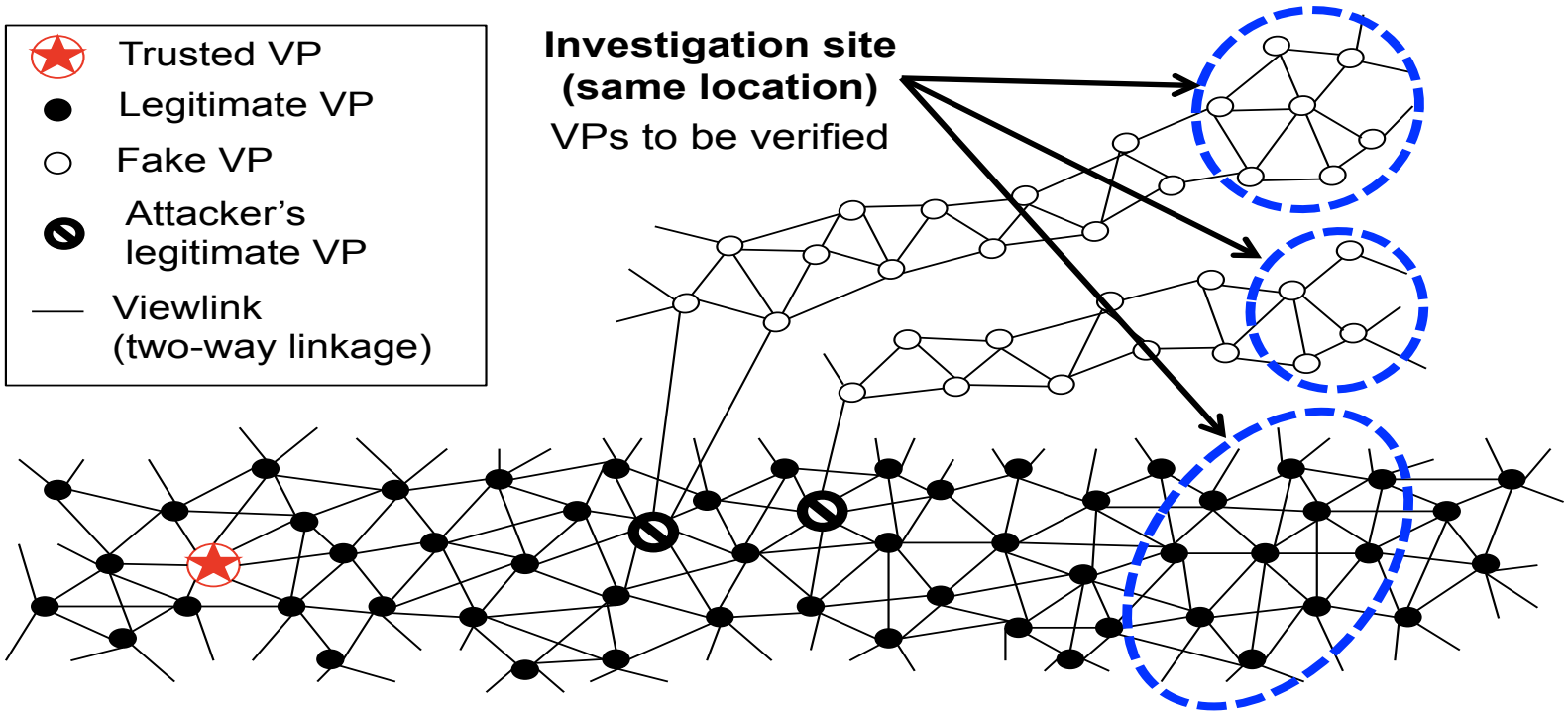
ViewProfile Verification

- Viewmap construction
  - Trusted VP (e.g., from police cars) and anonymous VPs (from normal users)
  - Creating edges between ‘two-way’ neighbor VPs
- Viewmap structure
  - **Single-layered when all members are legitimate VPs**



ViewProfile Verification

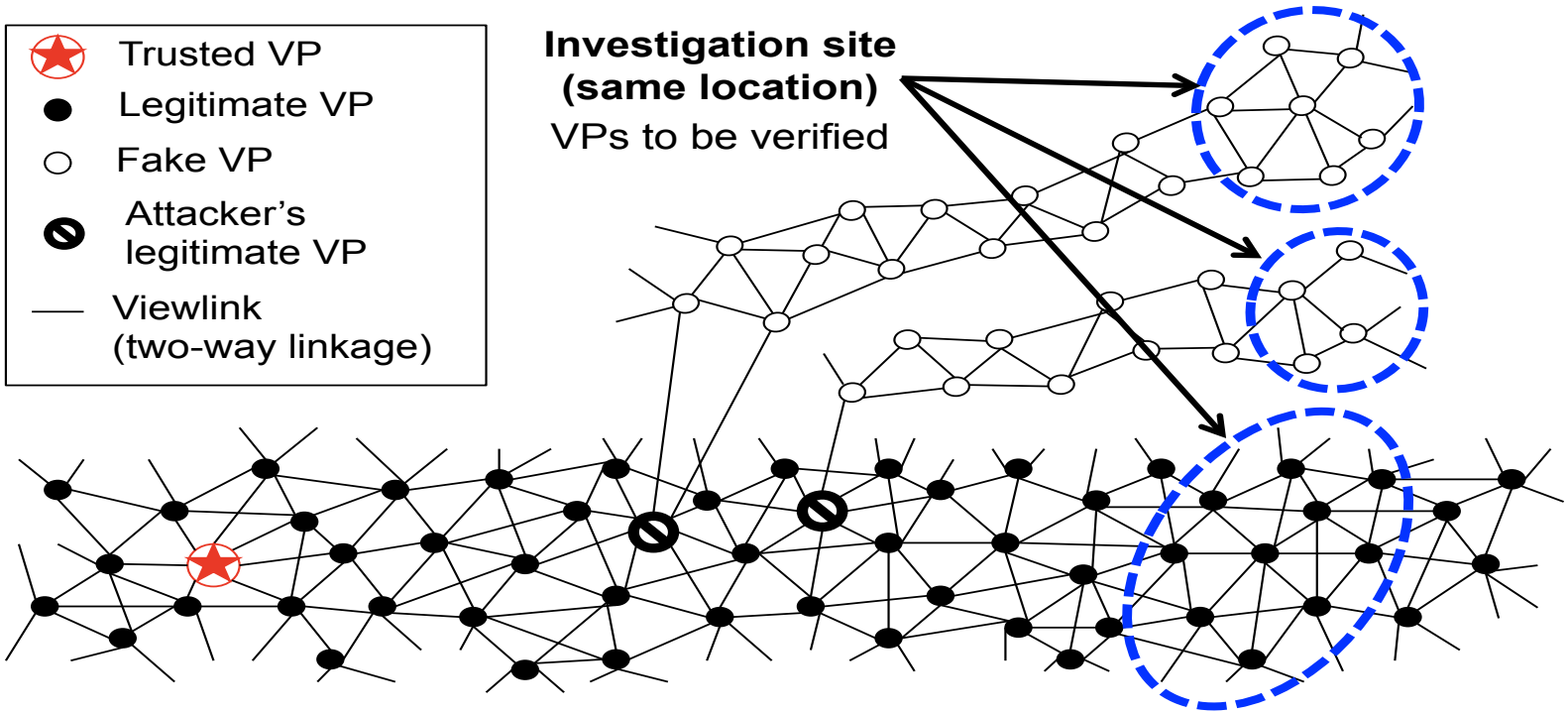
- **A viewmap with fake VPs results in multi-layered structure**
  - Validation of two-way linkage prevents attackers from creating arbitrary edges with other users' legitimate VPs
  - Location proximity checking between neighbor VPs precludes long-distance edges as well



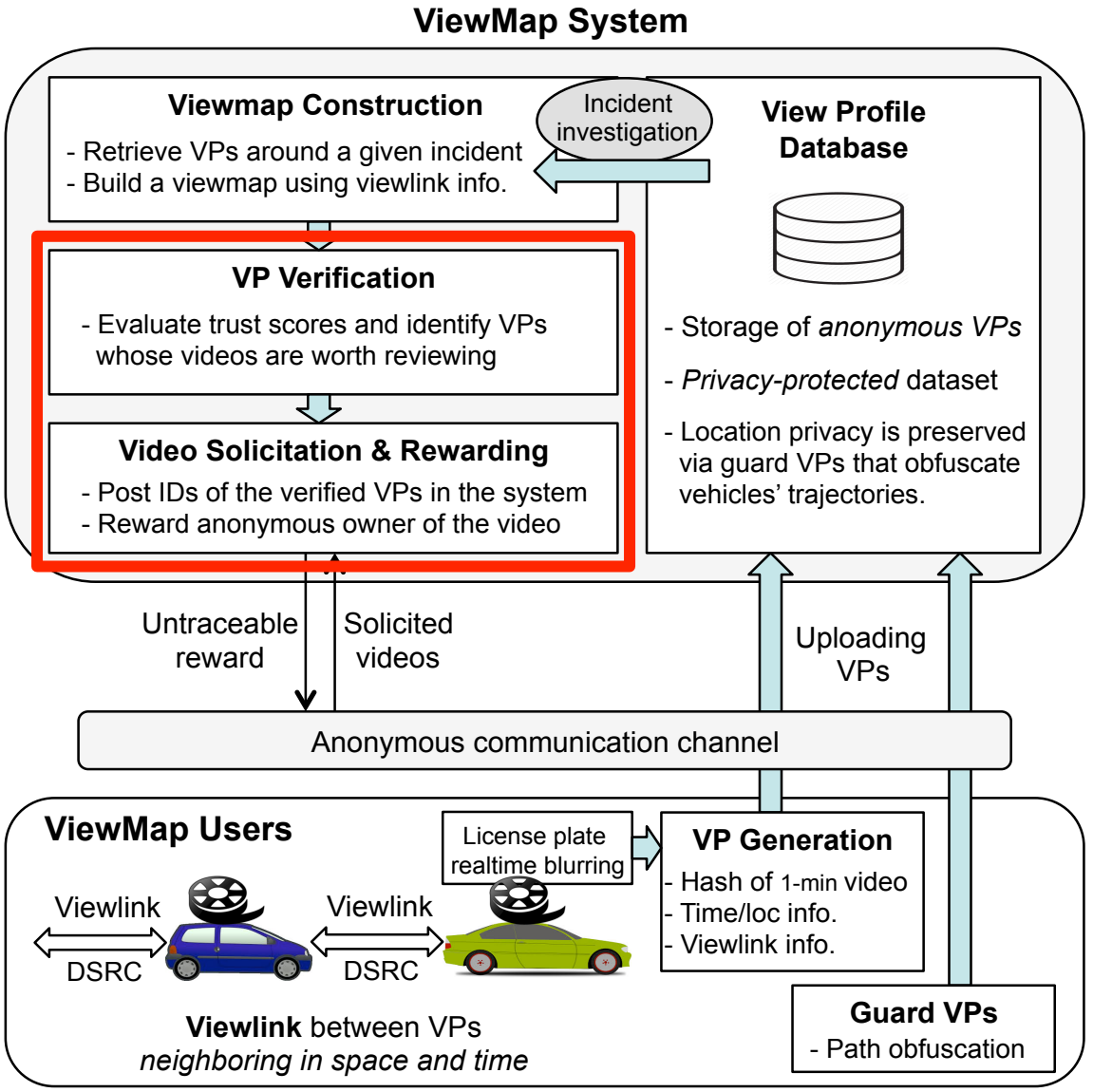
ViewProfile Verification

- Evaluating ‘trust scores’ of VPs via TrustRank on viewmap
  - Trusted VP (as a “trust seed”) has an initial probability (trust scores) of 1, and distributes its score to neighbor VPs
  - Iterations of this process propagate the trust scores over all the VPs in a viewmap

$$\mathbf{P} = \alpha \cdot \mathcal{M} \cdot \mathbf{P} + (1 - \alpha) \cdot \mathbf{d}$$



ViewMap Framework

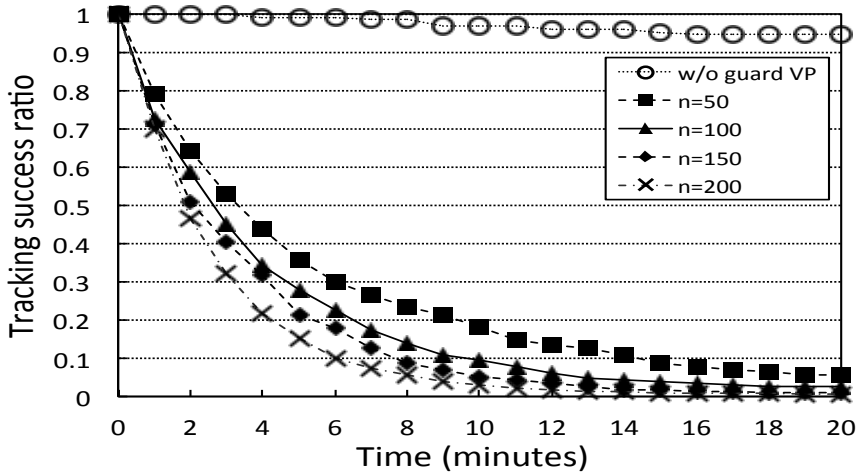


Evaluation of ViewMap

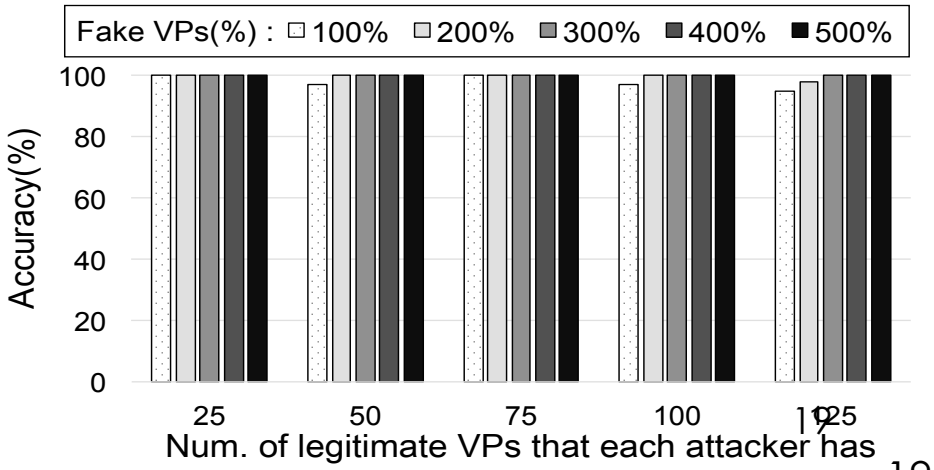
- Security analysis (see the paper)
  - The more fake VPs, the lower their trust scores
  - The worst case: attackers in vicinity of trusted VPs ← a highly restrictive condition for attackers as they cannot predict the future investigation

- Evaluations via large-scale vehicular simulations
  - High degree of location privacy (tracking success ratio < 0.1%)
  - High verification accuracy (> 95%)

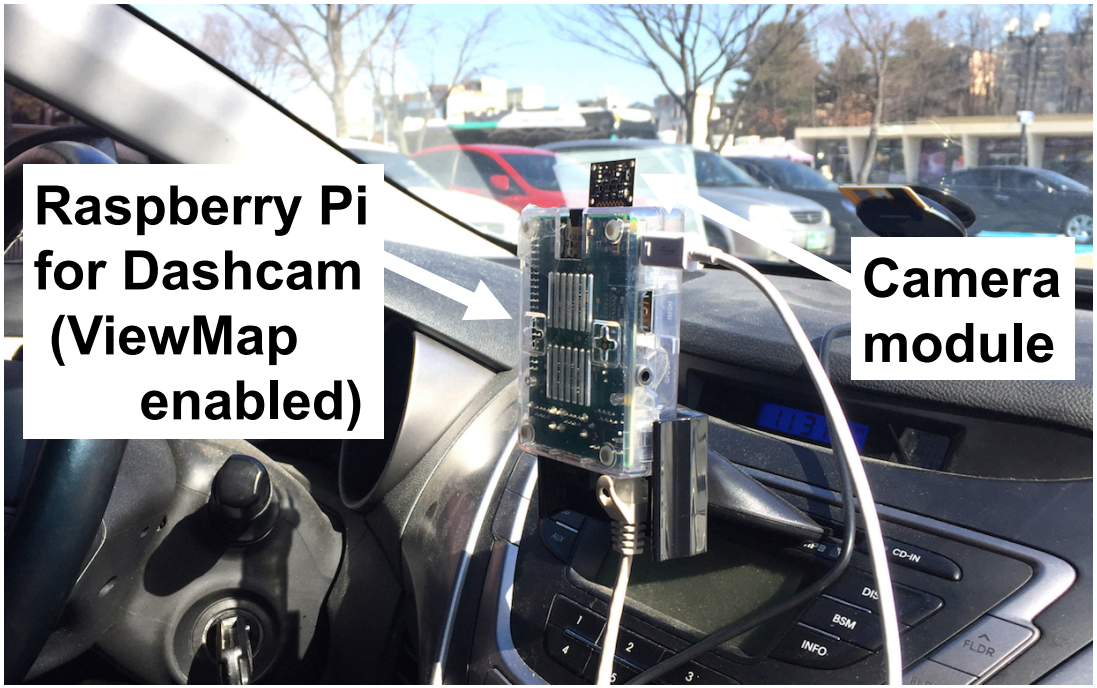
[User Privacy: location anonymity]



[System Security: verification accuracy]



Real Road Experiments

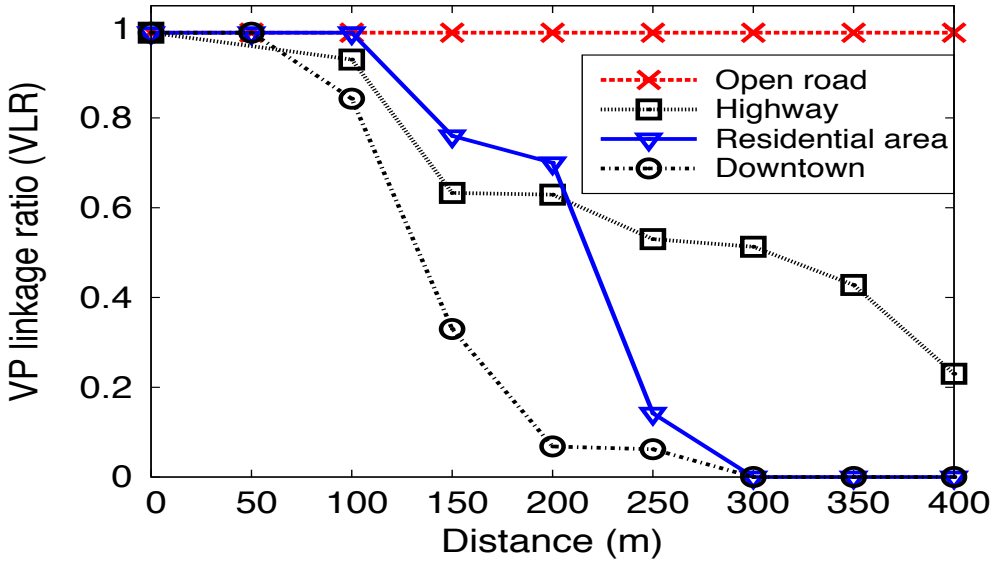


- Field measurement aims to answer:
  - Does our VP linkage reflect a line-of-sight (LOS) in reality?
  - What are the implication of such LOS properties on linked VPs and their videos?

Measurement Results

- VP linkage ratio (VLR) on various environments

Line-of-sight condition appears a dominating factor to VP linkage.

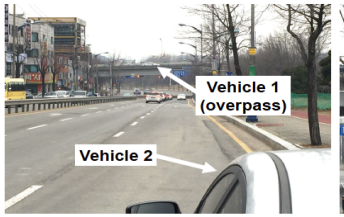


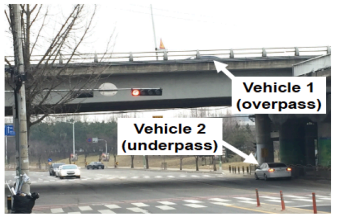
Measurement Results

- Two vehicles situated in LOS / NLOS conditions

Scenario	Condition	VP linkage	On Video
Open road	LOS	100%	100%
Building 1	NLOS	0%	0%
Intersection 1	LOS	100%	93%
Intersection 2	NLOS	9%	0%
Overpass 1	LOS	84%	77%
Overpass 2	NLOS	0%	0%
Traffic	LOS/NLOS	61%	52%
Vehicle array	NLOS	13%	0%
Pedestrians	LOS	100%	100%
Tunnels	NLOS	0%	0%
Building 2	LOS/NLOS	39%	18%
Double-deck bridge	NLOS	0%	0%
House	LOS/NLOS	56%	51%
Parking structure	NLOS	3%	0%

(a) Intersection 1 (LOS). (b) Intersection 2 (NLOS).





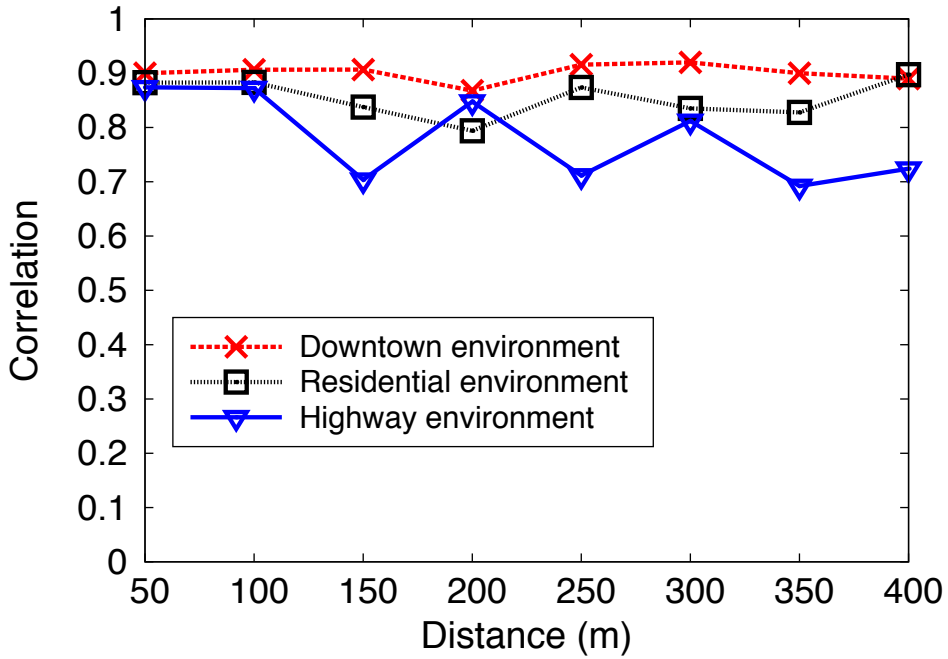
(c) Overpass 1 (LOS). (d) Overpass 2 (NLOS).

Clear dependency between VP linkage and video contents

Measurement Results

- Quantification of the degree of association between two events:
  - Linkage between two VPs and Visibility on their videos

Strong correlation indicates that
VP linkage is indeed associated with the shared "view".



More in the Paper…

- Anonymous rewarding
  - Untraceable via blind signatures
- Video privacy
  - Not fully addressed in this paper
  - Realtime license plate blurring implemented in ViewMap

- Analysis of ViewMap
  - Overhead, security, and privacy analysis
- Prototype implementation
  - Raspberry Pi as ViewMap-enabled dashcam

Closing Remarks

- A new application with unique challenges:
  - Combination of location privacy, location authentication, anonymous rewarding, and video privacy at the same time
- ViewMap: comprehensive solution package
  - finds, verifies, rewards private video evidences
- Key insights:
  - LOS of DSRC to link between videos, in their compact form, view-profiles (VPs) that share the same “view”
  - Inter-vehicle communications to create path-confusion for protection against location tracking
  - LOS-based VP links to build a viewmap to automatically identify videos that are worth reviewing