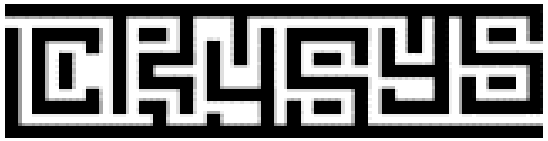

On the effectiveness of changing pseudonyms to provide location privacy in VANETS

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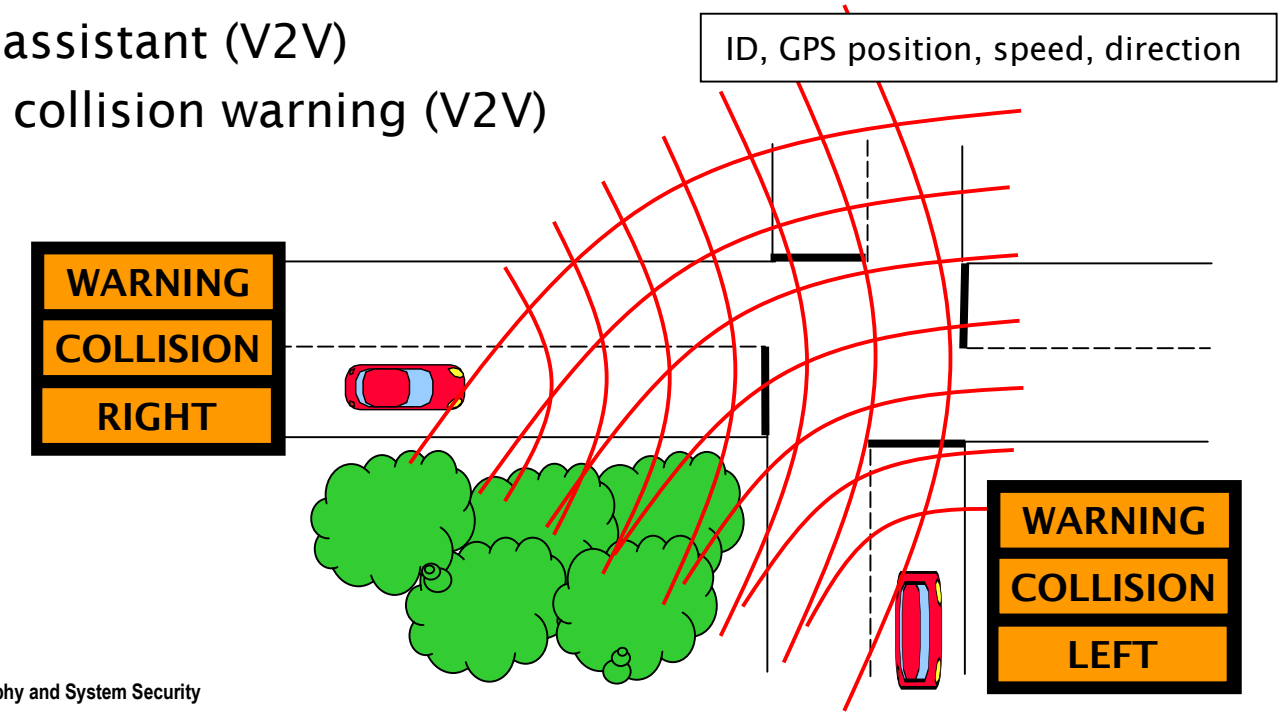
this is joint work with ***Tamas Holczer*** *and* ***Istvan Vajda***

Vehicular communications

- the promise of vehicular communications is to make road traffic safer and more efficient
- a number potentially useful vehicle safety applications has been proposed, such as
  - curve speed warning (I2V)
  - road condition warning (I2V)
  - lane merge assistant (V2V)
  - cooperative collision warning (V2V)
  - …



The location privacy problem and a solution

- vehicles continuously broadcast *heart beat* messages, containing their ID, position, speed, etc.
- tracking the physical location of vehicles is easy just by eavesdropping on the wireless channel
- one possible solution is to change the vehicle identifier, or in other words, to use *pseudonyms*

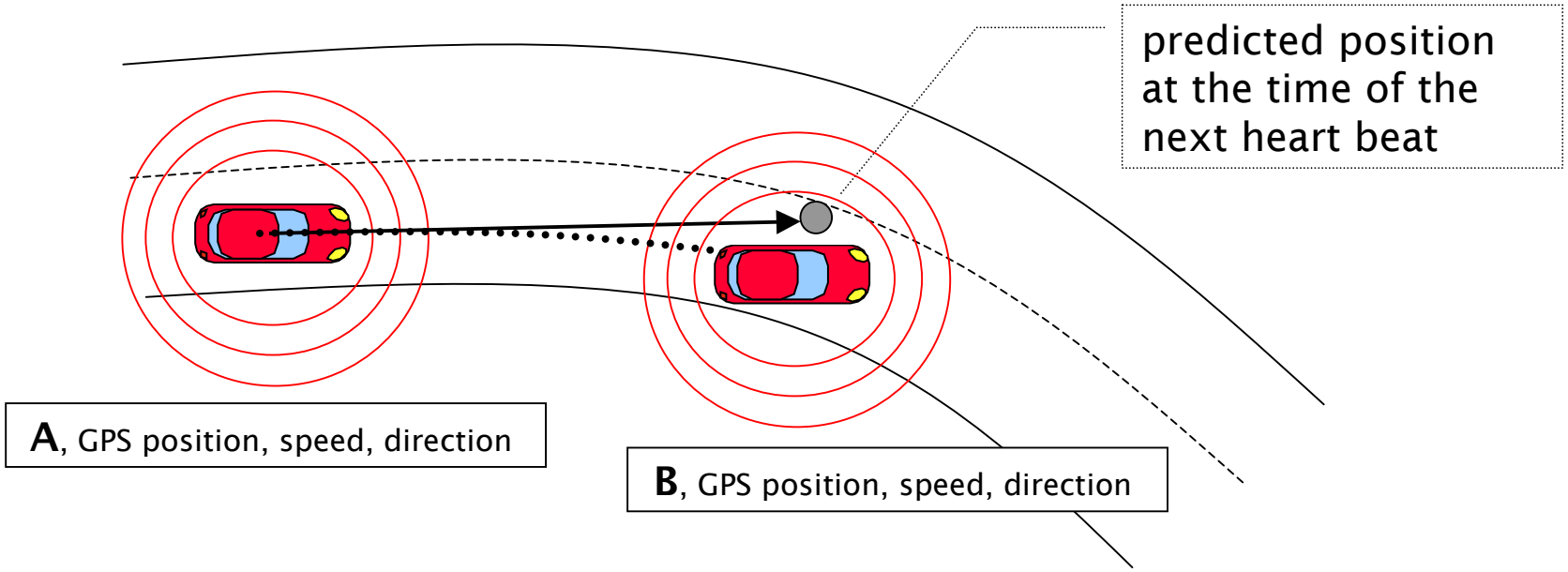
Our contributions

- we propose a framework to study the effectiveness of the pseudonym changing mechanism
  - we define a model based on the concept of the *mix zone*
  - we determine the best tracking strategy of adversary
  - we introduce a metric to quantify the level of privacy achieved

- we perform extensive simulations
  - we use a complex road map
  - traffic is generated with realistic parameters
  - we vary the strength of the adversary (number of monitoring spots)

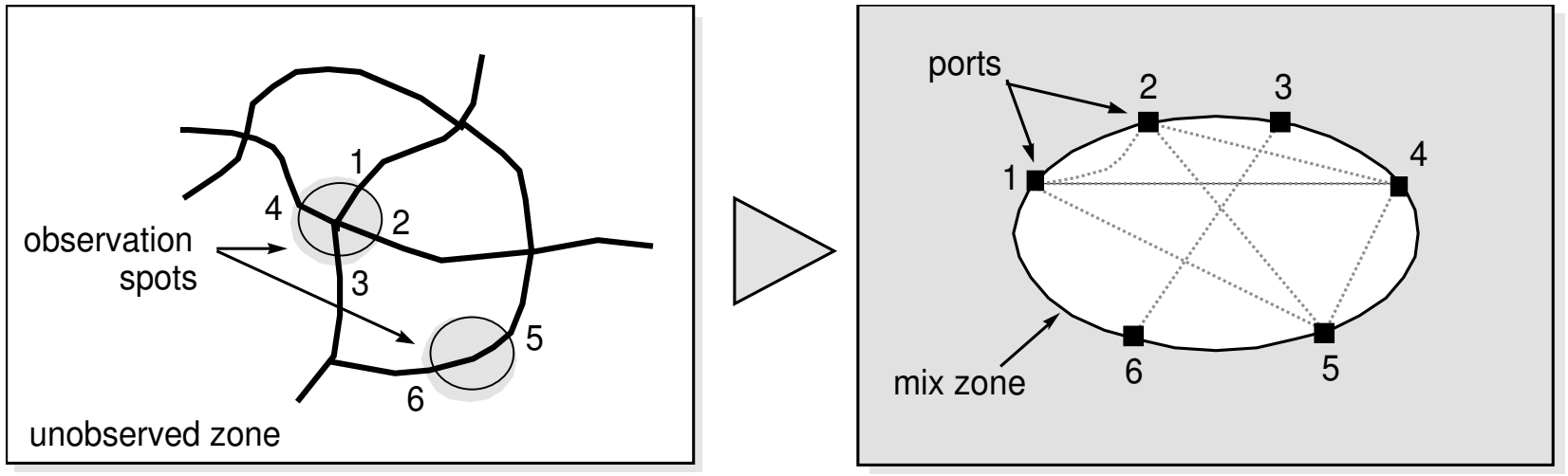
Adversary model

- changing pseudonyms is ineffective against a global eavesdropper



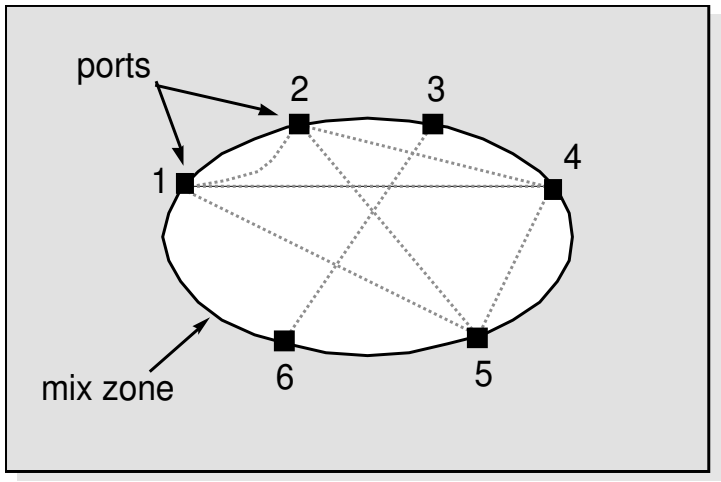
- hence, the adversary is assumed to be able to monitor the communications only at a limited number of places and in a limited range

The mix zone concept



- the unobserved zone functions as a *mix zone* where the vehicles change pseudonym and mix with each other
- note that the vehicles do not know where the mix zone is (this depends on where the adversary installs observation spots)
- we assume that the vehicles change pseudonyms frequently so that each vehicle changes pseudonym while in the mix zone

Model of the mix zone



- we assume that the adversary knows
  - q_{ij} - the conditional probability of exiting the mix zone at port j given that the entry port was port i (for all i, j)
  - $f_{ij}(t)$ – the (discrete) probability distribution of the delay when traversing the mix zone between ports i and j

Tracking strategy of the adversary

- the adversary observes entering and exiting events, and wants to relate them to each other

- more specifically, the adversary
  - picks a vehicle v in the observed zone
  - tracks v until it enters the mix zone at port s
  - then, observes the exiting events until time T (where the probability that v leaves the mix zone until T is close to one)
  - for each exiting vehicle at port j and time t, computes $p_{jt} = q_{sj} f_{sj}(t)$
  - the adversary decides to the exiting vehicle v' for which p_{jt} is maximal
  - the adversary is successful if v' = v

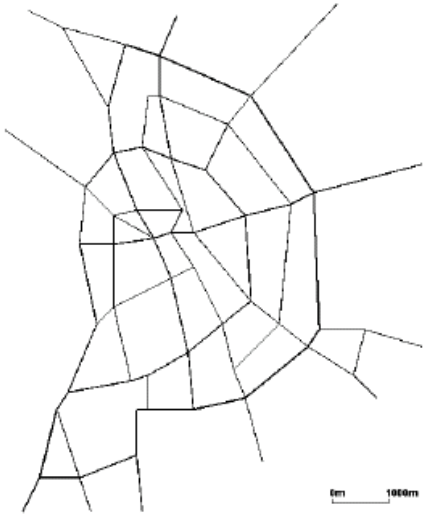
- this algorithm realizes a Bayesian decision
  - it minimizes the error probability of the decision
  - in this sense, it is optimal

Privacy metric

- the level of privacy achieved is characterized by the success probability of the adversary
  - if success probability is high, then level of privacy is low
- how to determine it?
- we used simulations to determine its empirical value in realistic scenarios

Simulation settings

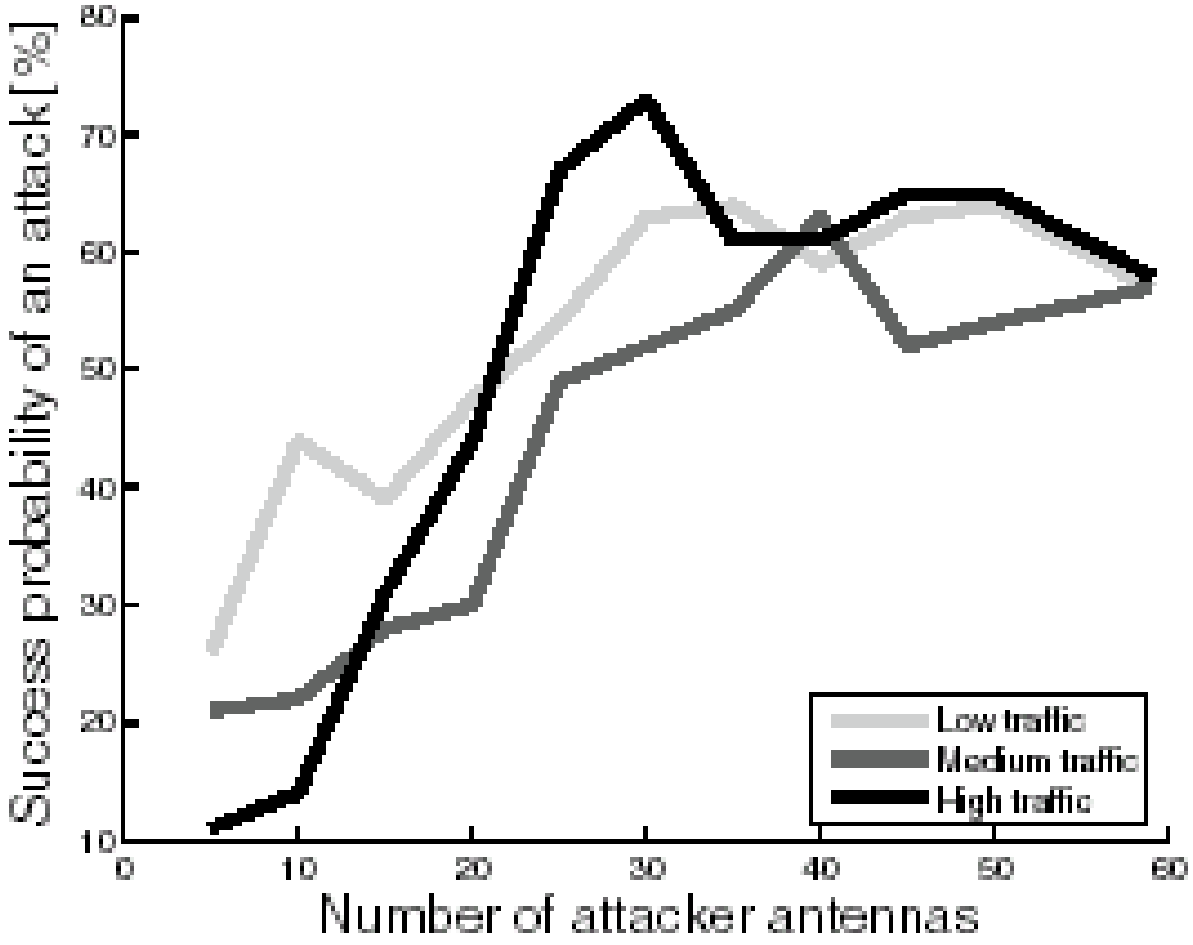
- we generated a simplified map of Budapest with MOVE
- we generated movement of the vehicles on the map with SUMO
  - low traffic: 250 new vehicles / time step
  - medium traffic: 500 new vehicles / time step
  - high traffic: 750 new vehicles / time step
- we selected the adversary's observation spots in intersections of roads
  - number of observation spots were varied from 5 to 59 with a step size of 5



Simulation settings

- we let the adversary build her model of the mix zone by letting her fully tracking vehicles for some time
- after that, we let the adversary pick a vehicle, track it until it enters the mix zone, observe exiting vehicles, and make a decision
- we run 100 simulations for each simulation setting
- we look at the percentage of the simulation runs where the adversary is successful

Simulation results



Conclusion and future work

- changing pseudonyms has been proposed as a mechanism to provide location privacy in vehicular networks
- we studied the effectiveness of this approach
- main contributions
  - a model based on the concept of the mix zone
  - characterization of the adversary's tracking strategy
  - privacy metric
  - simulation results using realistic settings
- in our future work, we intend to study how the frequency of the pseudonym change influences the level of privacy achieved

- this work has been carried out in the context of the SeVeCom Project (www.sevecom.org)