

# Preserving Privacy in Road User Charge (RUC) Architectures

Alexandre Bayen, PhD, Teddy Forscher, and Susan Shaheen, PhD

tsrc.berkeley.edu - innovativemobility.org

## KEY TAKEAWAYS

Smartphones, connected devices, and connected vehicles enable privacy preserving collection of road user charges (RUC).

Privacy preserving architectures enable the precise accounting of a mileage fee (based on mileage, road used, and time the road was used, etc.), without recording or storing information.

Users of this type of architecture only disclose the same information as using a toll tag reader system (like FasTrak).

This architecture has already been implemented, tested, and deployed for other applications (traffic information apps in particular) in the past 10 years.

“With current penetration of smartphones and the existence of technology like FasTrak, it is possible to build privacy preserving road user charge architectures.”

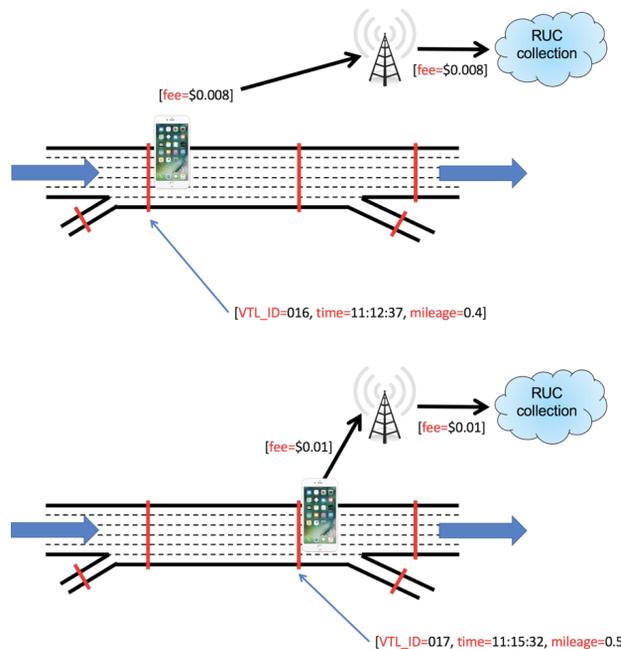
## TOPIC/ISSUE

One of the major concerns for the technical implementation of a RUC is the ability to collect the mileage of motorists in a way that preserves and protects individual privacy. With the widespread use of connected devices/smartphones and the growth of connected vehicles and the existence of toll tag readers, it is possible to build and deploy architectures capable of computing advanced fee structures (based upon on mileage, road type, time of day, and speed, among other features) that respect motorist privacy. A possible architecture can rely on the use of virtual trip lines (VTLs) – a technology that dates back to 2007, when the first privacy aware traffic collection apps for smartphones emerged [1]. VTLs are virtual landmarks deployed at specific locations of the transportation network at which charges need to be applied. They can be imagined as virtual screen lines capable of counting cars or motorists (via smartphones, connected devices, or connected vehicles) as they pass, using the underlying mapping system of the connected device. Based on this detection, the connected device can compute a fee onboard, based on the features of the VTLs. This technology has been demonstrated to be privacy preserving and does not require the system to keep track of vehicle location, only the fees incurred.

## RESEARCH FINDINGS

An architecture for privacy preserving RUC can be deployed near instantaneously for all vehicles registered in California.

- Among possible data collection paradigms, Virtual Trip Lines (VTLs) can collect geo-localized data for RUC in a privacy preserving environment.



**Illustration of fee collection for RUC without disclosure of sensitive information. At each VTL crossing, a fee is recorded (e.g., \$0.008 for VTL 16 [top], and \$0.01 for VTL 17 [bottom]).**

## RESEARCH FINDINGS (continued)

- While initially deployed for traffic monitoring systems [1], VTLs can very easily be adapted to road use charges.
- The VTL protocol works like tolls, FasTrak readers, or license plate readers. It “checks in” at specific pre-specified locations and performs the device fee computation.
- It can calculate a fee at each “virtual toll” location crossed, without disclosing any privacy invasive information about the user to the system (such as location and time where/when the fee is applied, vehicle type, occupancy, etc.).
- The architecture can be used to store the sum of the fees, leaving all computations on the device side, thus not transmitted.
- The VTL paradigm enables the network operators to selectively apply RUC based on the following parameters (which do not need to be stored on the system):
  - Mileage driven or “virtual” tolls crossed,
  - Time at which they are crossed (as the fee might depend on time and/or location),
  - Type of vehicle (if the fee depends on it), and
  - Vehicle occupancy (if the fee depends on it).
- VTLs can be deployed on an as needed basis and in a flexible manner (for example in response to specific operations, such as construction).
- Flexible pricing is possible as well.
- The accounting mechanism for VTL-enabled RUC is the same as for FasTrak readers, but it can be scaled instantaneously throughout the State.

## APPROACH

The approach for privacy preserving RUC can be deployed on various connected platforms (connected devices, smartphones, connected vehicles, FasTrak readers, etc.). In order to be scaled to all motorists with a California registered vehicle, any of these technologies can be used. For non-California vehicles, a variety of techniques can be used (for example using the average trip length as known in transportation planning, license plate readers at major entry points, downloadable apps, etc.). The collection system would be the same as for FasTrak, enabling direct collection. Fares can be published in advance and be adaptive (like for tolls on bridges, i.e., peak time, week day / weekend etc.). The nature of the information used to collect the fees does not need to be transmitted to the network (it can run locally); hence, no disclosure of any trip information needs to be collected by the system other than the fee incurred for every journey.

## CONCLUSION & RECOMMENDATION

An architecture for privacy preserving RUC can be deployed near instantaneously for all vehicles registered in California.

- It can run on smartphones, connected devices, connected vehicles, or by simply carrying a FasTrak-like device in each vehicle.
- For vehicles not registered in California, numerous alternatives are possible, including license plate readers at entry points, apps based on odometer use, etc.
- The collection of the fees is done exactly like the FasTrak system.
- Deployment of similar technologies already exist in the context of tolling (FasTrak, EZ pass, etc.) in the US and in the context of congestion pricing abroad (Electronic Road Pricing in Singapore).
- The corresponding architecture enables the system to operate with acceptable privacy-flexibility tradeoffs.

B.Hoh, M. Gruteser, R. Herring, J. Ban, D. Work, J.-C. Herrera, A. Bayen, M. Annavam, Q. Jacobson. 2008. “Virtual trip lines for distributed privacy preserving traffic monitoring,” Mobile Systems and Applications (MOBISYS), Breckenridge, CO.  
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