Data Offloading in Vehicular Networks

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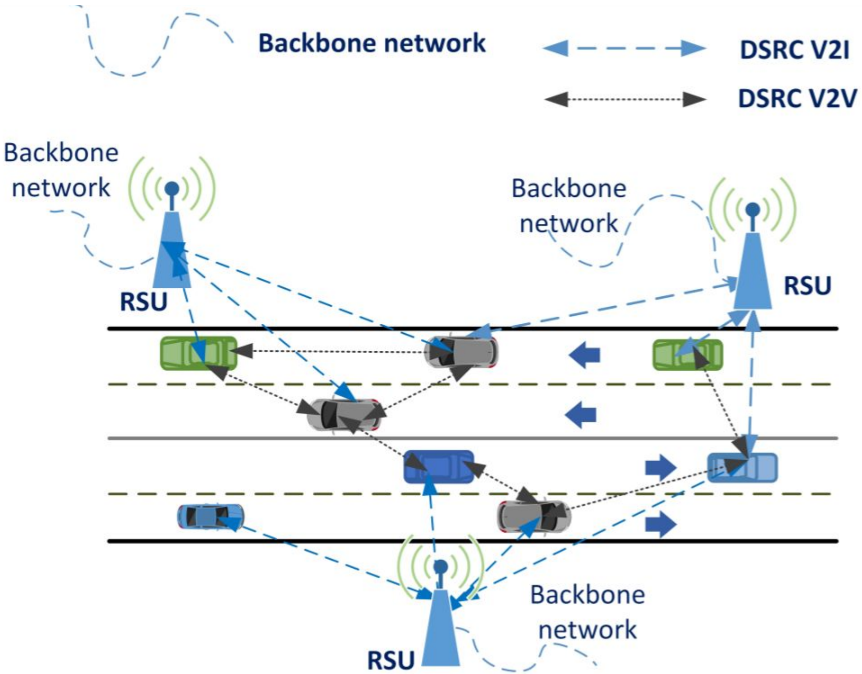
Data Offloading

- Connected vehicle safety systems + data-intensive infotainment ⇒ more demand on cellular infrastructure

- Vehicular Network components-
    - Vehicles with on-board units (OBUs)
    - Road-side units (RSUs)
    - Cell towers
- Data offloading: Utilizing V2V and V2I communication to decrease the data transfer demand on cellular networks



(a) DSRC Vehicular Network.

Problem Formulation

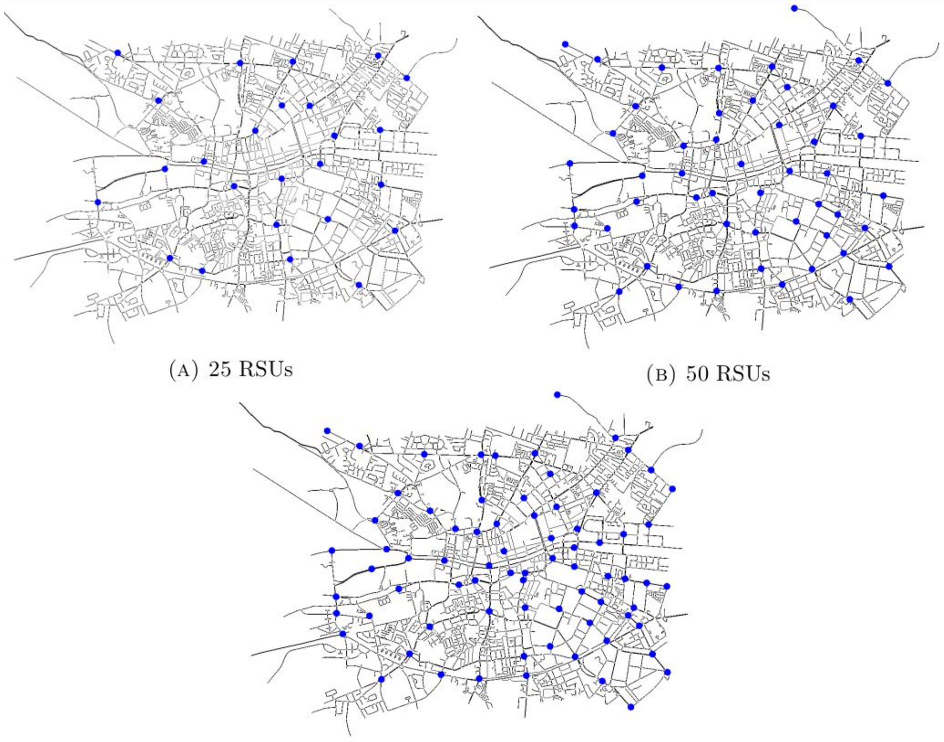
- Inputs: Vehicles, RSUs, Data items, Requests
  - For each time instant from 1…T
- Outputs: A schedule of V2V transfers, RSU transfers and cellular transfers
- Optimization problem: Maximize requests satisfied, minimize access to cellular
- Mixed integer linear programming problem - NP hard
- Heuristic algorithm for caching (considering V2V contact patterns, network quality)?

Period-based Scheduling

- Assign ‘periods’ of time at each RSU to vehicles
- Calculate a score for each (in-range) *<vehicle,item>* pair
    - Estimate of potential transfer - higher weight if a request can be completed
- Select highest scoring vehicle and update transfers of contacted vehicles
    - Check for contacted vehicle acting as a cache itself (transfers may be affected)
- Prioritize vehicles that can
    - Help complete most requests in the future
    - Transfer the most data to other vehicles
- Process all other RSUs in increasing order of congestion
    - Estimated by number of requesting vehicles in range

Setup

- Tool used for simulation - SUMO
- Traffic map
  - Dublin city centre (3.5x5 km, 435 intersections)
- RSU positions
  - SCATS sensors grouped by k-means : 25, 50 and 75 RSUs
- Traffic loads
  - 150 second sample
  - Scaled using SUMO option --*scale* : ~ 250, 500 and 750 vehicles
- Request pattern
  - Two data items - random 50/50 split of requests
  - 20 percent of vehicles request both items



(A) 25 RSUs (B) 50 RSUs (C) 75 RSUs

FIGURE 1: RSU positions in the road network.

Source of SUMO configuration, network map and traffic flows: Maxime Gueriau and Ivana Dusparic. Quantifying the impact of connected and autonomous vehicles on traffic efficiency and safety in mixed traffic. In 23rd IEEE International Conference on Intelligent Transportation Systems, 2020.

Results

- Three values of $|\mathcal{V}|$ - 250, 500 and 750
- Two data items - 300Mb and 500Mb
- No seed vehicles ($\mathcal{V}_{seed} = \phi$)

TABLE 2: Values of constants used

Quantity	Value
RSU range	300m
β^r	10 Mbps
Vehicle-to-vehicle range	300m
w_{sat}	1.5
w_{nsat}	1
δ^r	0.4
l_1^d	300Mb
l_2^d	500Mb

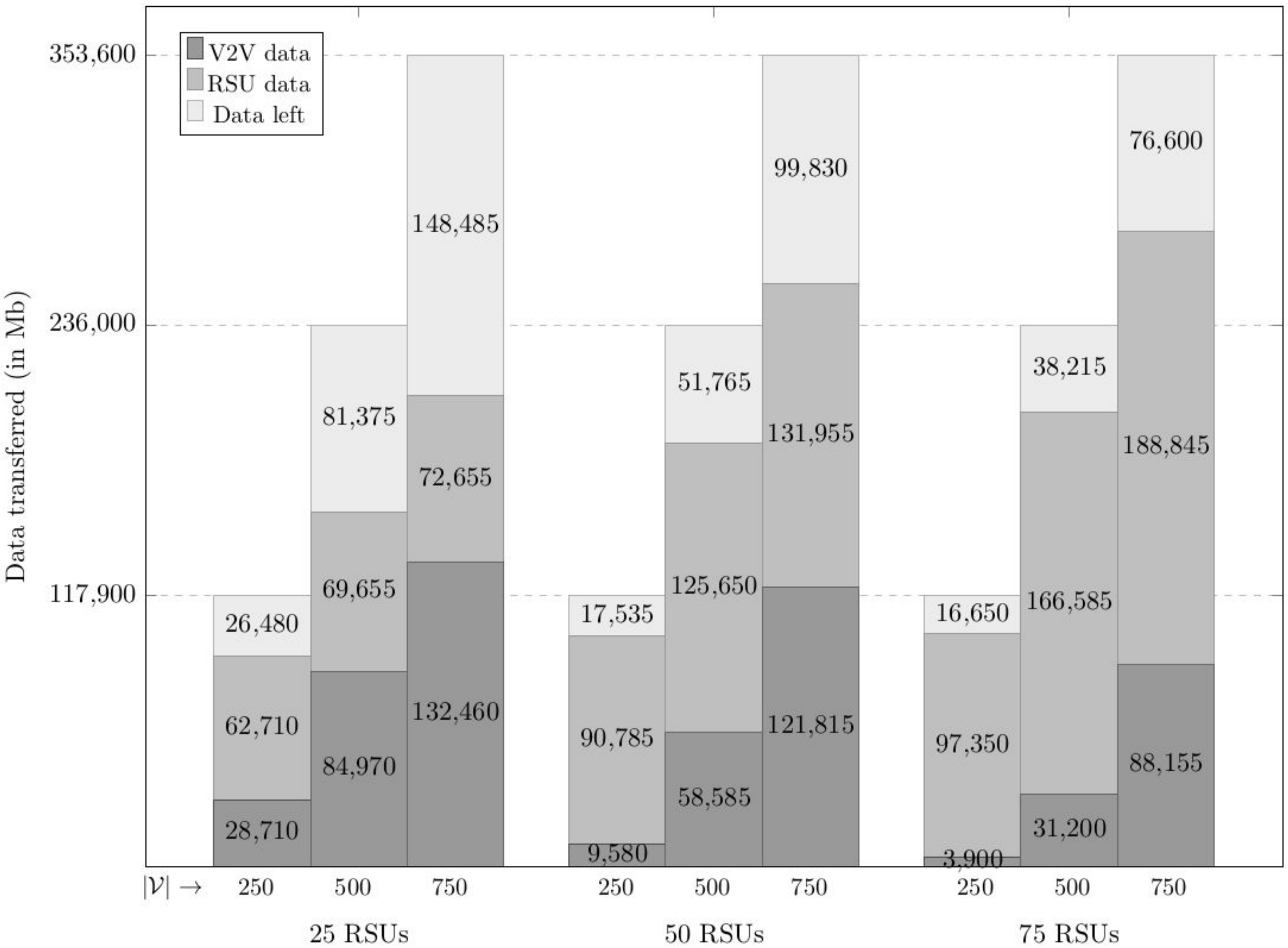
TABLE 3: Number of requests and total data demand

Number of vehicles	Number of requests			Data demand (Mb)		
	d_1	d_2	Total	d_1	d_2	Total
250	148	147	295	44,400	73,500	117,900
500	295	295	590	88,500	147,500	236,000
750	442	442	884	132,600	221,000	353,600

Number of RSUs

- Default values -
  - α^v = 5 Mbps
  - γ^r = 2
  - p = 10 seconds
- Increasing the number of RSUs leads to less remaining data
- Diminishing returns

FIGURE 2: Data transferred v/s number of RSUs

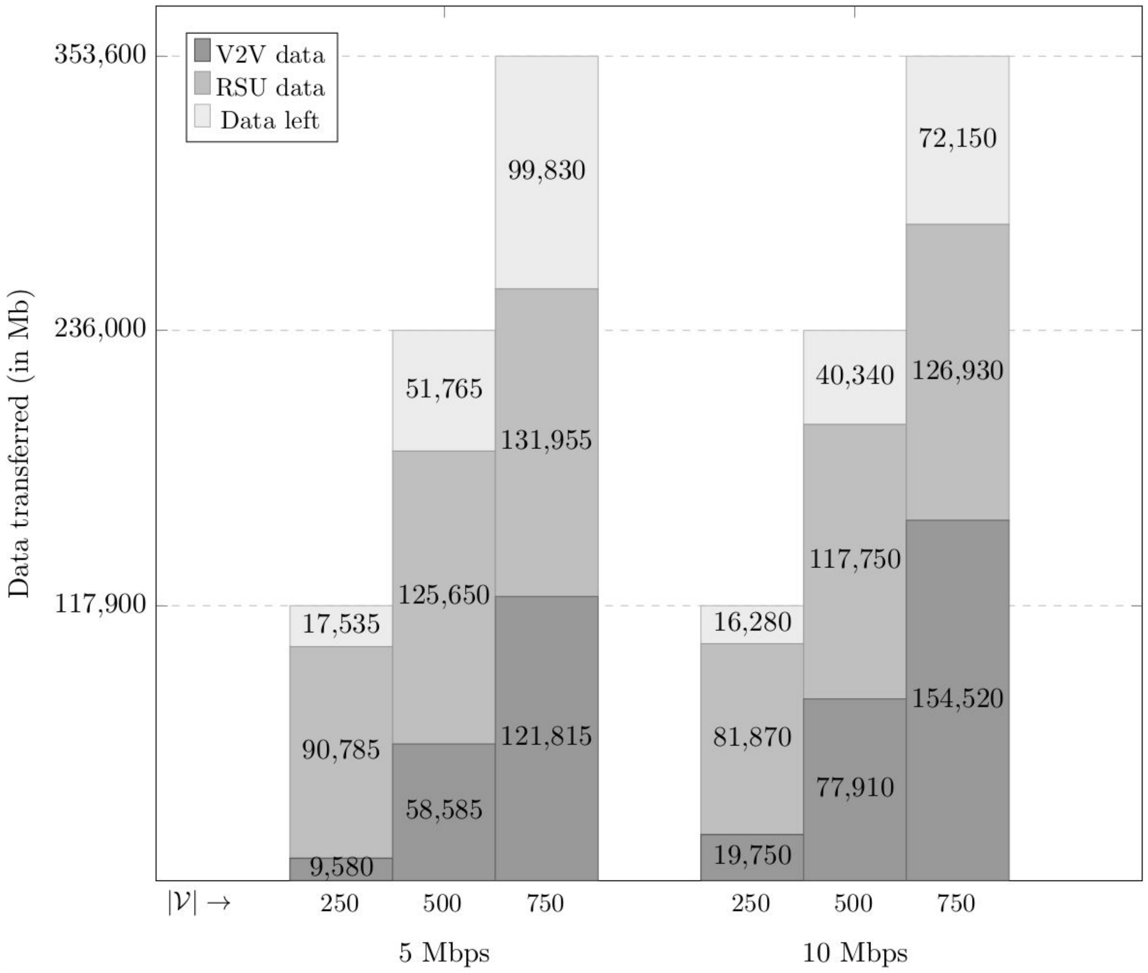


V2V transfer rate α^v

- 50 RSUs
- V2V rate increased to 10Mbps (equal to RSU rate)

- More V2V transfer, less data left
- % improvement higher with more vehicles -
    - 1.06% - 250 vehicles
    - 4.84% - 500 vehicles
    - 7.82% - 750 vehicles

FIGURE 3: Data transferred v/s vehicle rate α^v



- Number of satisfied requests dropped ⇒ Data distributed more uniformly
- Total requests satisfied within 10% increased or had a smaller drop

TABLE 5: Number of requests satisfied (varying V2V transfer rate α^v)

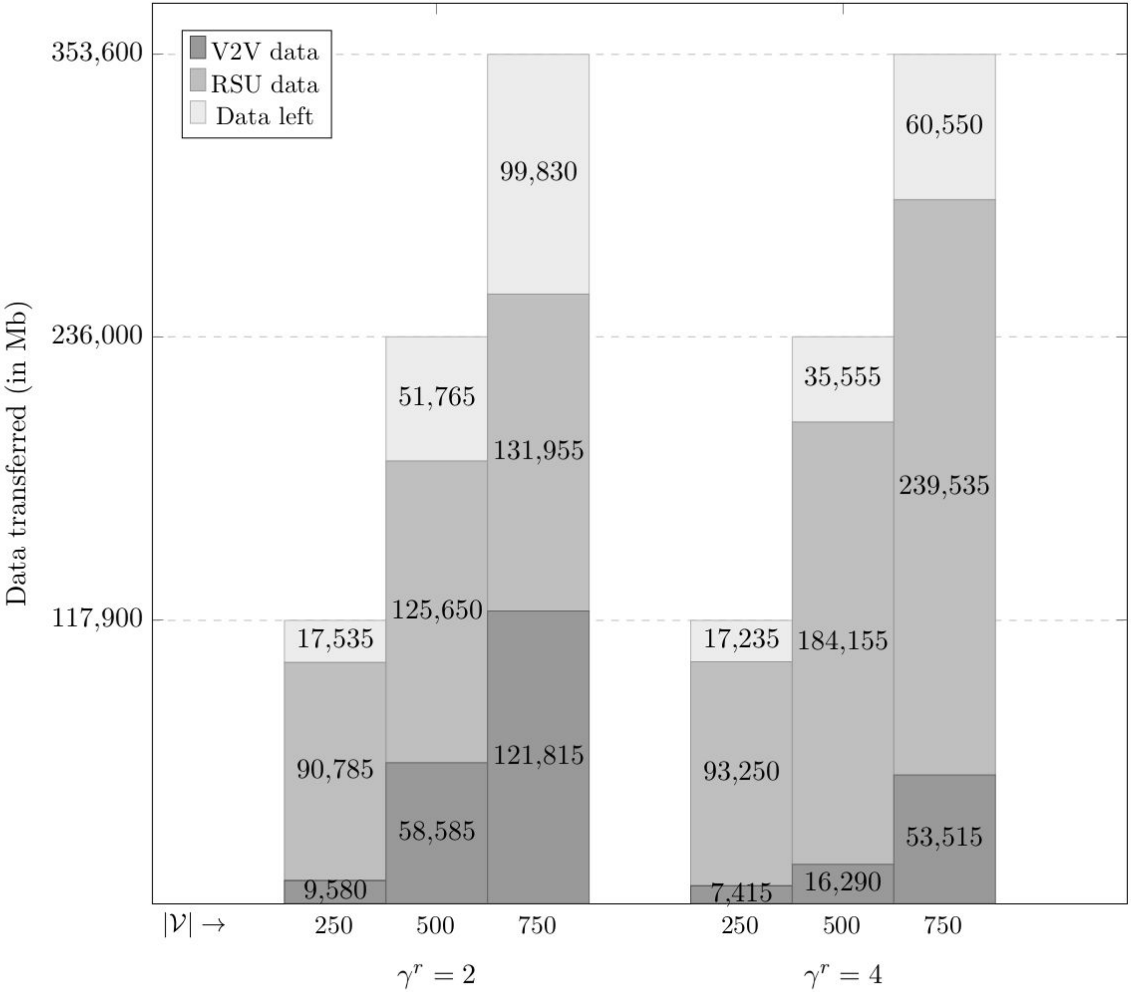
Test case	Requests satisfied			Total requests satisfied (within 10%)
	d_1	d_2	Total	
250 vehicles, 5 Mbps	109	109	218	229
250 vehicles, 10 Mbps	92	109	201	232
500 vehicles, 5 Mbps	182	175	357	383
500 vehicles, 10 Mbps	74	175	249	357
750 vehicles, 5 Mbps	221	147	368	432
750 vehicles, 10 Mbps	52	153	205	449

RSU capacity γ^r

- RSU capacity doubled

- More RSU transfers, less V2V transfers
- Less data left overall
- % improvement highest for more vehicles (more contention for RSUs)

FIGURE 4: Data transferred v/s RSU capacity γ^r



- Number of satisfied requests increased
- Supports result that RSU transfers more specific

TABLE 6: Number of requests satisfied (varying RSU capacity γ^r)

Test case	Requests satisfied			Total requests satisfied (within 10%)
	d_1	d_2	Total	
250 vehicles, $\gamma^r = 2$	109	109	218	229
250 vehicles, $\gamma^r = 4$	111	110	221	231
500 vehicles, $\gamma^r = 2$	182	175	357	383
500 vehicles, $\gamma^r = 4$	217	222	439	464
750 vehicles, $\gamma^r = 2$	221	147	368	432
750 vehicles, $\gamma^r = 4$	300	306	606	655

Future Scope of Work

- Incorporate cellular downloads during a vehicle’s journey+coverage quality
- Implement data fairness/priority
- Network level congestion for simultaneous transfers
- Testing more request patterns

Thank You

Special thanks to Prof. Arobinda Gupta for his mentorship and supervision