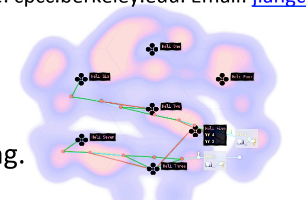
Scalability of Vehicle Networks through Vehicle Virtualization

Jiangchuan Huang*, Christoph Kirsch† and Raja Sengupta*
*Systems Engineering, Department of Civil and Environmental Engineering, University of California, Berkeley.
†Department of Computer Sciences, University of Salzburg.
Lab website: cpcc.berkeley.edu. Email: jiangchuan@berkeley.edu. Presented by Elói Pereira*

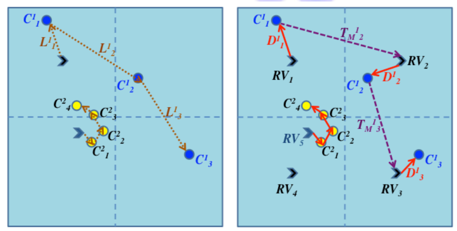
Cyber-Physical Applications:

- Google Street View.
- Real-time traffic reporting.
- Unmanned aerial vehicle (UAV)-based sensing.
- Mobile sensor networks.



Virtual Vehicle (VV):

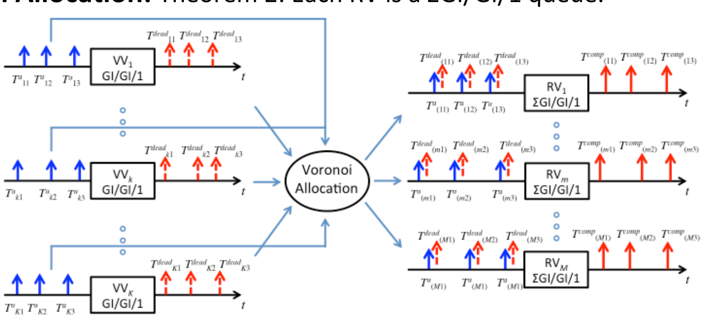
- A replica of a real vehicle (RV).
  1. Physical-mobility: travels (binding) with an RV.
  2. Cyber-mobility: migrates from one RV to another.



(a) Customer view (b) Provider view

- Theorem 1: Each VV is a GI/GI/1 queue.
- Provider aims to complete each task before virtual departure time.
- The virtual departure time is like a deadline for each task, thus called **virtual deadline**.
- Virtual vehicle and virtual deadline create a soft real-time system.
  - Tardiness = max{Actual completion time – Virtual deadline, 0}
  - Delivery prob = Pr (Actual completion time ≤ Virtual deadline)
- High performance isolation if a statistically dominant subset [1], e.g., Delivery prob = 98%, of the virtual vehicle's tasks are completed no later than their virtual deadline.

Voronoi Allocation: Theorem 2: Each RV is a ΣGI/GI/1 queue.



Gain: # VVs / # RVs.

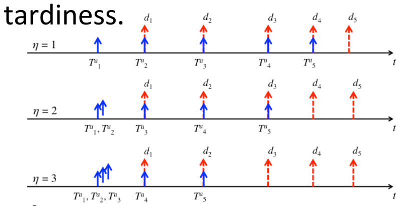
- *Multiplexing gain*: a customer may not fully utilize her VV.
- *Migration gain*: gain by migrating the VV to an RV closer to the task.

Scheduling: Earliest Virtual Deadline First (EVDF)

- Theorem 3: EVDF achieves minimum tardiness.

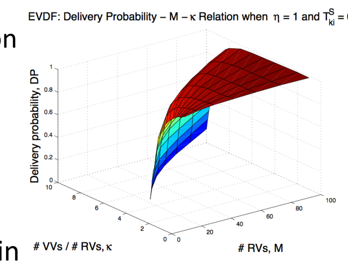
Worst-Case Arrival: "η = 1" process.

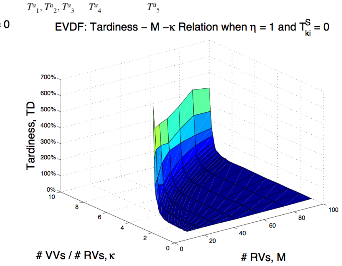
- Theorem 5: Assume EVDF, the "η = 1" process achieves maximum tardiness among all the renewal processes.

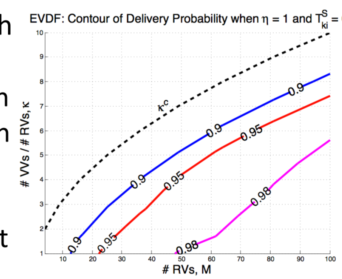


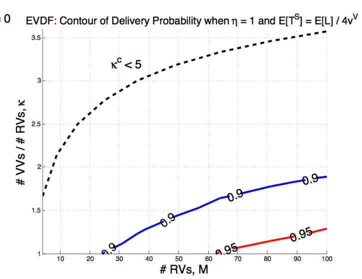
Conclusion:

- High migration gain and high performance isolation.
- Economy of scale: migration gain increases with # RVs.
- Migration gain happens when traveling, not standing still.
- Migration cost is bounded.



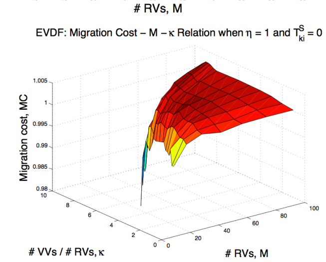






Migration Cost:

- MC = (size)*(inter distance)*(**1**{migration}) / (inter virtual departure time).
- MC has unit (bit-meters/second).



[1] Gerald J. Popek and Robert P. Goldberg. Formal requirements for virtualizable third generation architectures. *Commun. ACM*, 17(7): 412– 421, July 1974.