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Greedy Data Dissemination Algorithm for Infrastructure-to-Vehicle Services

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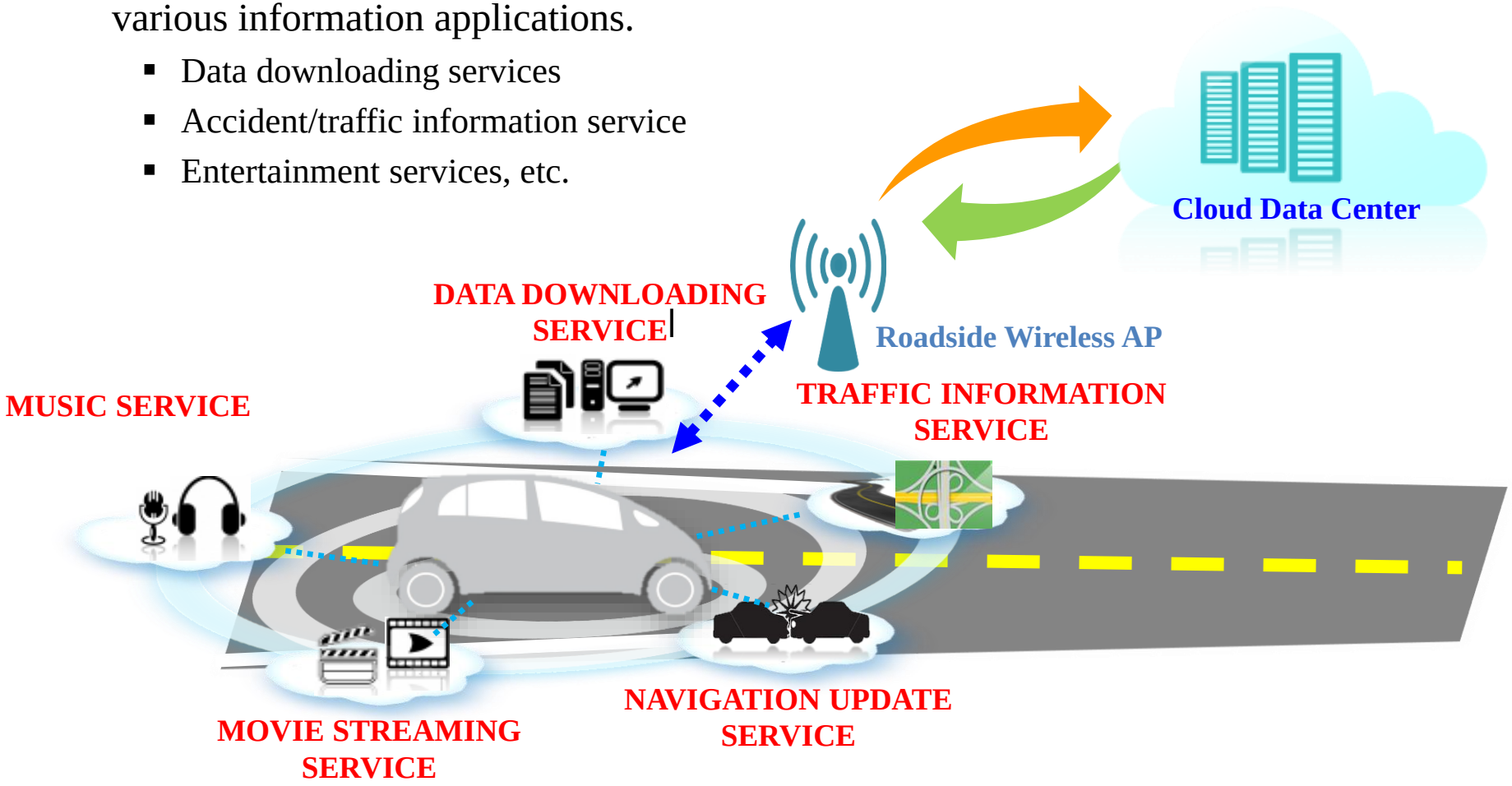
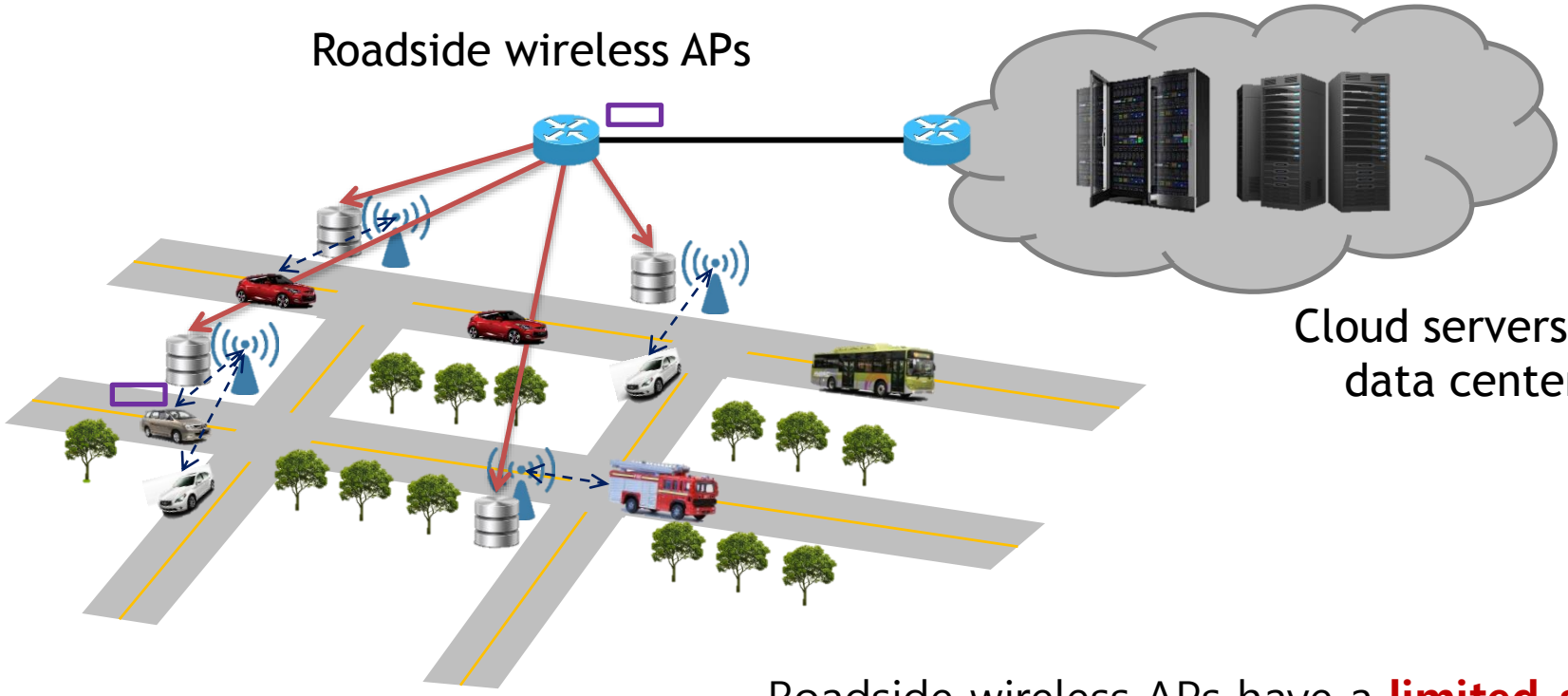
Vehicular Cloud System (VCS)

- Cloud services in vehicular networks
  - New emerging technology that can provide data dissemination service in advance for various information applications.
    - Data downloading services
    - Accident/traffic information service
    - Entertainment services, etc.



Prefetching for Data Dissemination

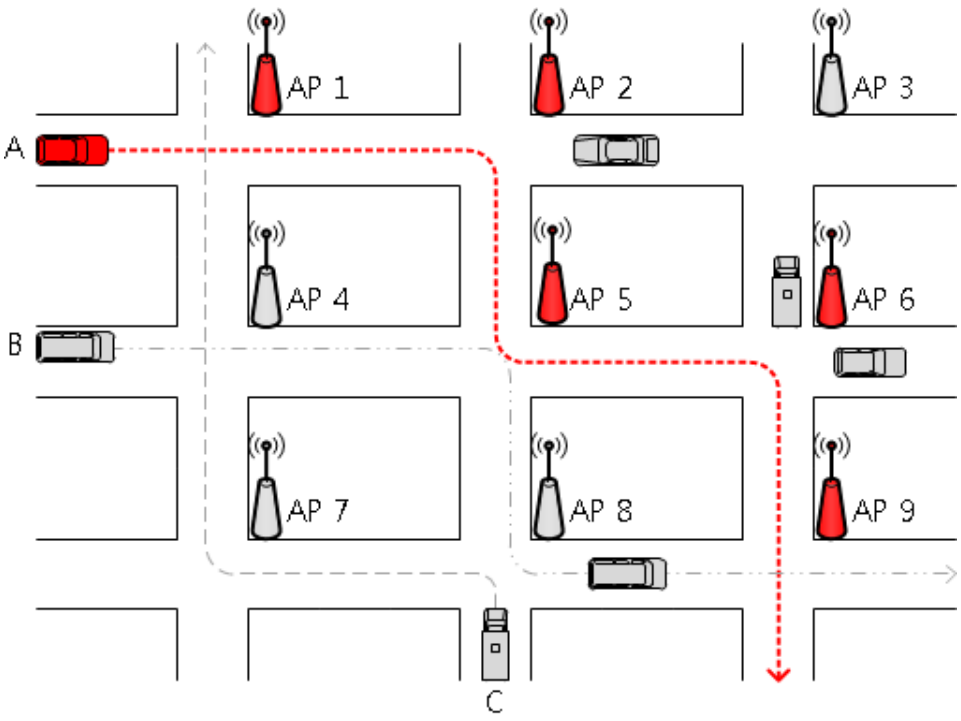
- To expedite the data dissemination to vehicles
  - Pre-fetch some data from the data center **in advance.**
    - Vehicle route is predictable from online navigation and local term achieved traces.



Roadside wireless APs have a **limited-sized local data storage**.

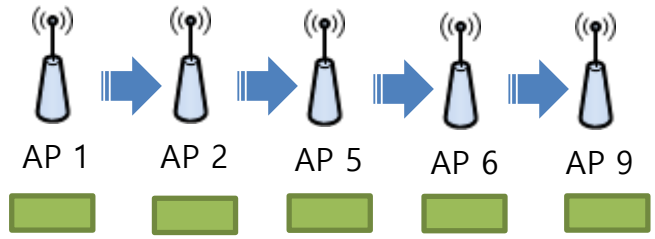
Example Scenario

◆ Vehicle A wants to download a data chunk during the journey.



Policy 1 - inefficient

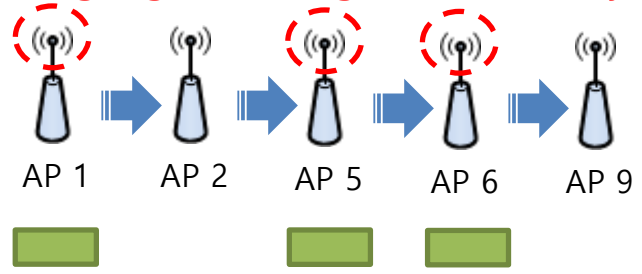
Every AP on the path has the data chunk



Policy 2:

A subset of APs have the data chunk

strong signal → high connectivity



Prefetching for Single Route

- How to select a subset of APs?
  - Choose **APs with high connectivity** with the vehicle in a greedy manner until the dissemination failure probability becomes lower than a threshold.

connectivity	θ_1	θ_2	θ_5	θ_6	θ_9
selection decision	x_1	x_2	x_5	x_6	x_9

Select AP in the descending order of θ_i until $p_A < \varepsilon$.

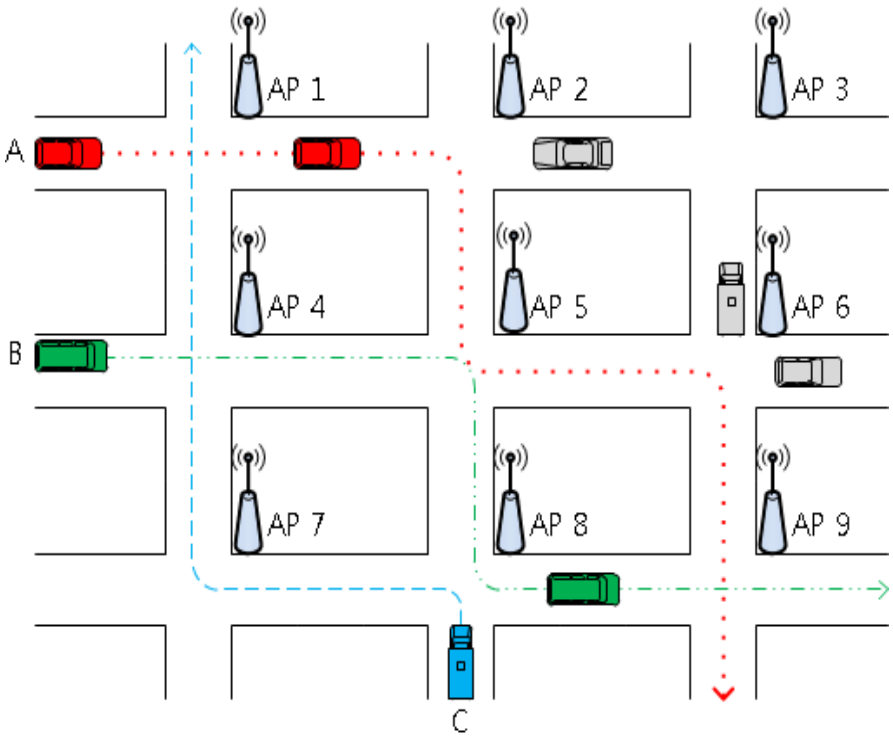
dissemination failure probability

$$p_A = (1 - \theta_1 x_1) (1 - \theta_2 x_2) (1 - \theta_5 x_5) (1 - \theta_6 x_6) (1 - \theta_9 x_9)$$

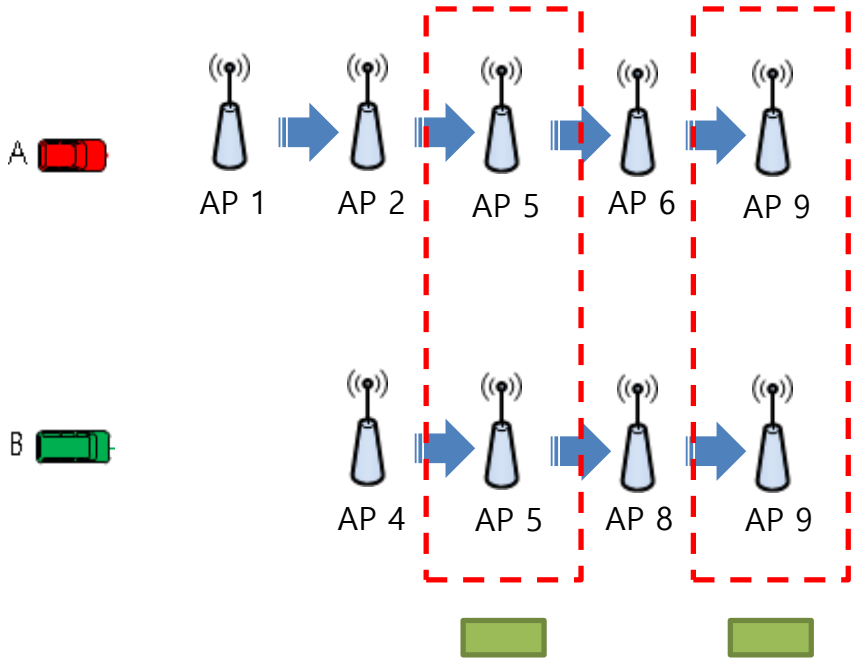
Prefetching for Multiple Routes

◆ How to select a subset of APs?

– Minimize the amount of data transferred from a data center to roadside APs



Exploit route information of vehicles



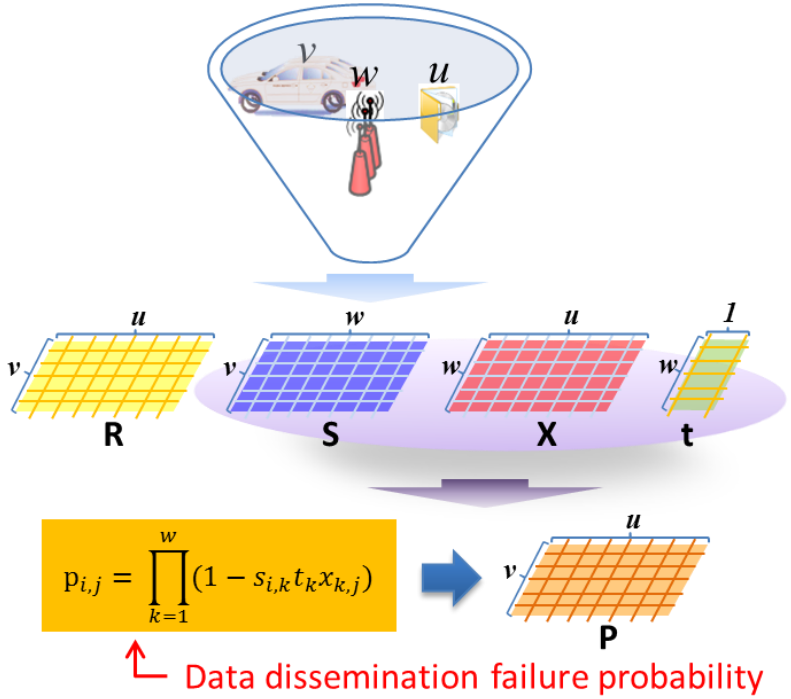
System Model

◆ Assumptions for the vehicular cloud system

- A data is divided into a number of small chucks.
- The vehicle route can be predicted from on-line navigation.
- Each AP is placed at an intersection and has a limited transmission coverage.
- Each AP has a stochastic characteristic for communication.

◆ Parameters used for system modeling

Parameter	Description
w	Number of wireless APs
v	Number of vehicles
u	Number of data chunks
R	Chunk request binary matrix
S	Vehicle route matrix
t	Communication probability vector
X	Binary decision matrix
P	Dissemination failure probability matrix



Proposed Dissemination Algorithm

◆ Optimization formulation

– Minimize the total amount of data transfer while keeping the dissemination failure probability lower than a threshold.

$$\text{minimize} \quad \mathbb{1}_w^T \cdot \mathbf{X} \cdot \mathbb{1}_u$$

$$\text{subject to} \quad \|\mathbf{R} \odot \mathbf{P}\|_{max} \leq \epsilon$$

$$\mathbf{X} \in \{0,1\}^{w \times u},$$

- $\mathbb{1}_l \in \mathbb{R}^l$: All-ones vector
- ϵ : Tolerable dissemination failure probability
- $\odot$: Hadamard product operation (i.e., $(A \odot B)_{i,j} = (A)_{i,j} \times (B)_{i,j}$)

◆ Deterministic greedy data dissemination algorithm

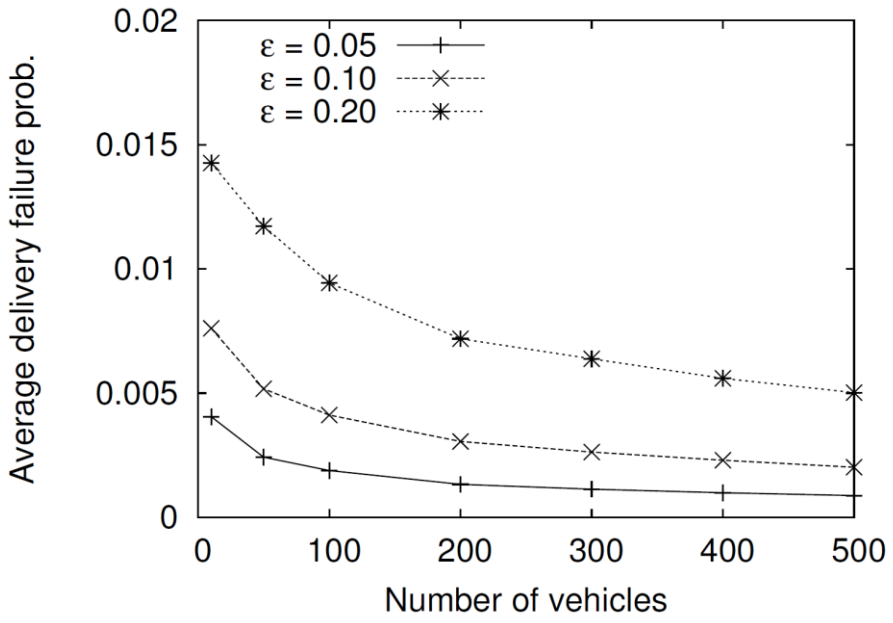
Algorithm 1 Proposed greedy algorithm

1: // Index set $\mathcal{A}_{\mathbf{x}_j}$: $\mathcal{A}_{\mathbf{x}_j} = \{i : x_{i,j} = 0, x_{i,j} \in \mathbf{x}_j, \forall i\}$
2: // Objective function $f\left(\mathcal{A}_{\mathbf{x}_j}\right) = f\left(\mathcal{A}_{\mathbf{x}_j}\right) = w - \mathbf{1}_w^T \cdot \mathbf{x}_j$
3: for $j = 1$ to u **do**
4: // Initialization
5: $\mathbf{x}_j = \text{argmin}_{\mathbf{x}_j \in \{0,1\}^{w \times 1}, |\mathcal{A}_{\mathbf{x}_j}| = 3} \left\| \mathbf{r}_j \odot \mathbf{p}_j \left(\mathcal{A}_{\mathbf{x}_j}\right) \right\|_{max}$
6: // Main loop
7: **while** $\mathcal{A}_{\mathbf{x}_j} \neq \mathcal{A}_{0_{w \times 1}}$ **do**
8: Find the index $i^* = \text{argmin\_}(i^* \in \mathcal{A}_{w \times 1} \setminus \mathcal{A}_{\mathbf{x}_j}) \left\| \mathbf{r}_j \odot \right.$
9: **if** $\left\| \mathbf{r}_j \odot \mathbf{p}_j \left(\mathcal{A}_{\mathbf{x}_j} \cup \{i^*\}\right) \right\|_{max} \leq \epsilon$ **then**
10: Stop the while loop
11: **end if**
12: $\mathcal{A}_{\mathbf{x}_j} \leftarrow \mathcal{A}_{\mathbf{x}_j} \cup \{i^*\}$
13: $\mathbf{x}_j[i^*] \leftarrow 1$
14: **end while**
15: **end for**

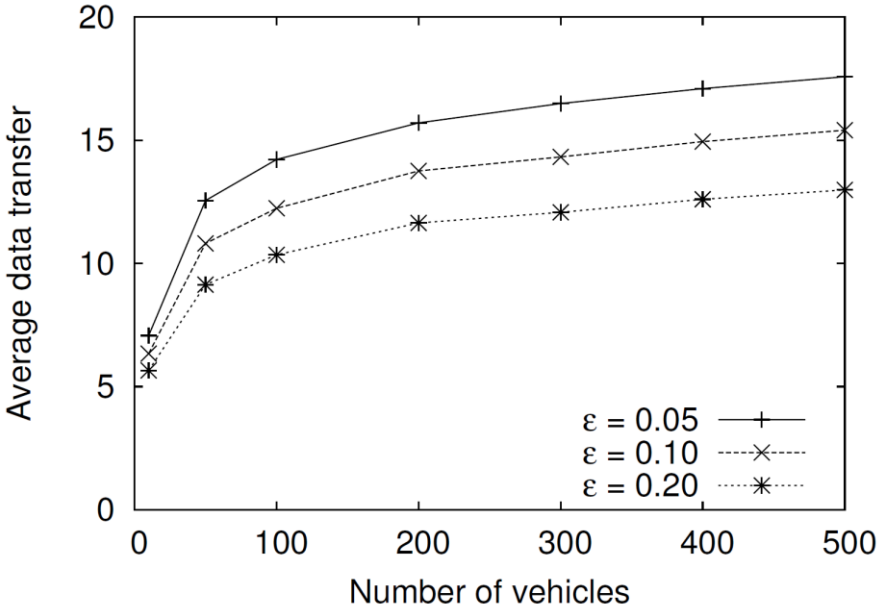
Simulation Results

- Performance of the proposed greedy algorithm
  - # of wireless APs = 50, # of data chunks = 100.

Average dissemination failure probability



Average amount of data transfer from server



Conclusion

◆Conclusion

- We proposed a greedy algorithm to minimize the amount of data transferred from a data center to the wireless APs.
- We verified that the proposed scheme could achieve efficient data dissemination in a variety of vehicular scenarios.