An Efficient Wireless Power Transfer System To Balance the State of Charge of Electric Vehicles

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#IBM

Outline

- Introduction
- System Design
  - Overview of BSoC
  - Design of BSoC
- Performance Evaluation
- Conclusions

Introduction

Why electric vehicles?

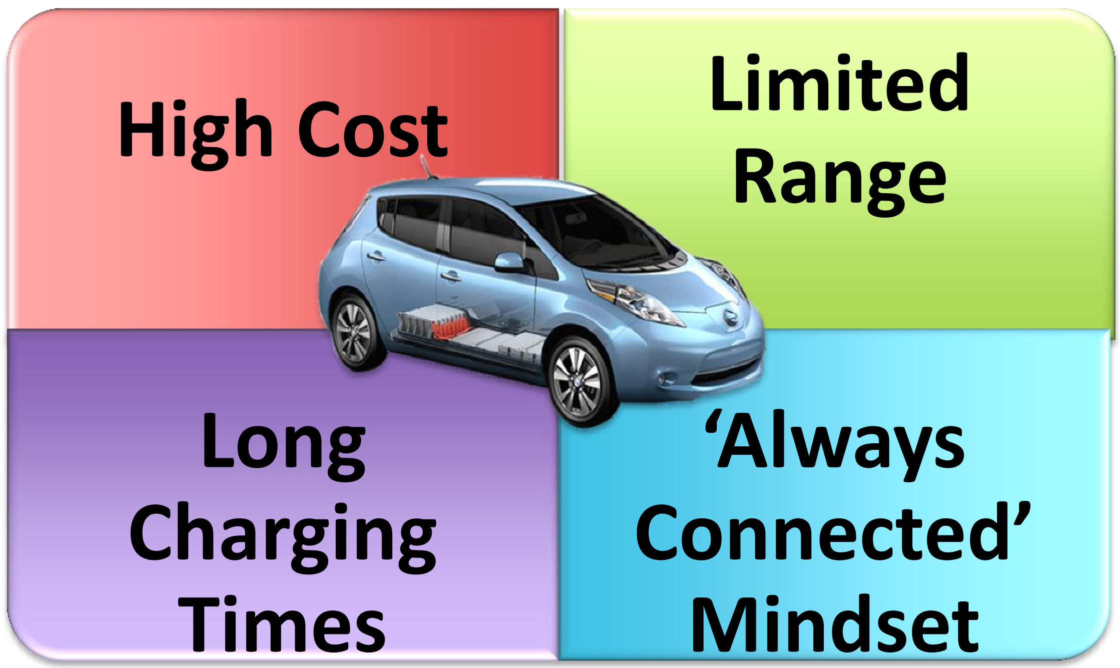
•Environment friendly

•Low cost

•Reduce dependency on fossil fuels

Introduction

Why electric vehicle charging?



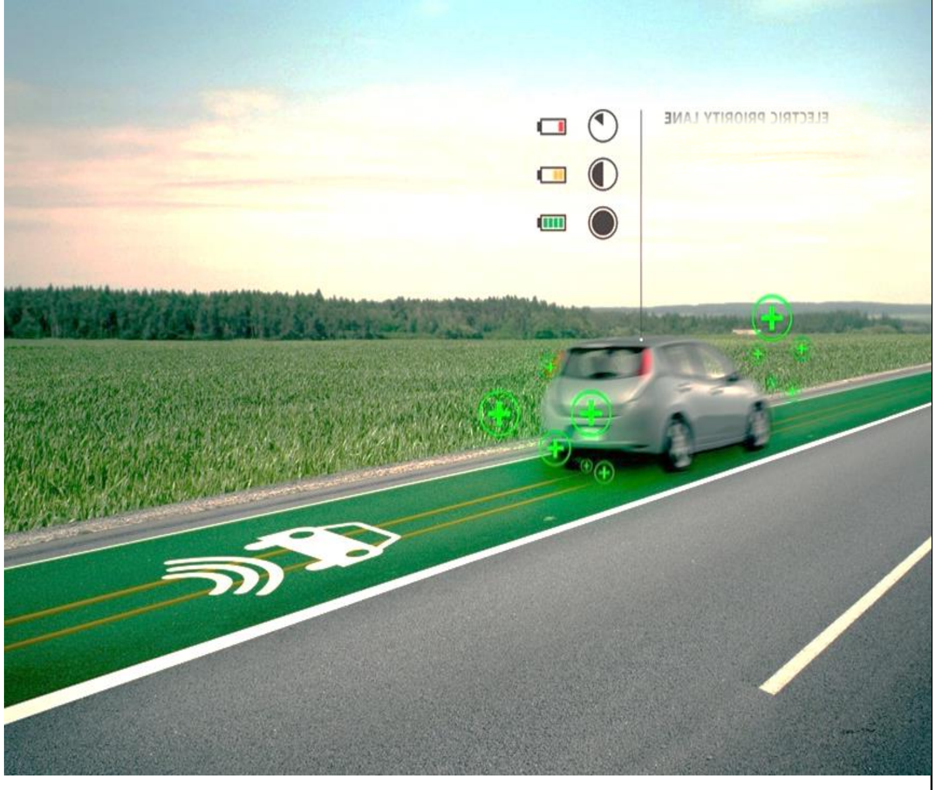
[1] Egbue, O, et al "Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions" *Energy Policy* vol 48.

Introduction

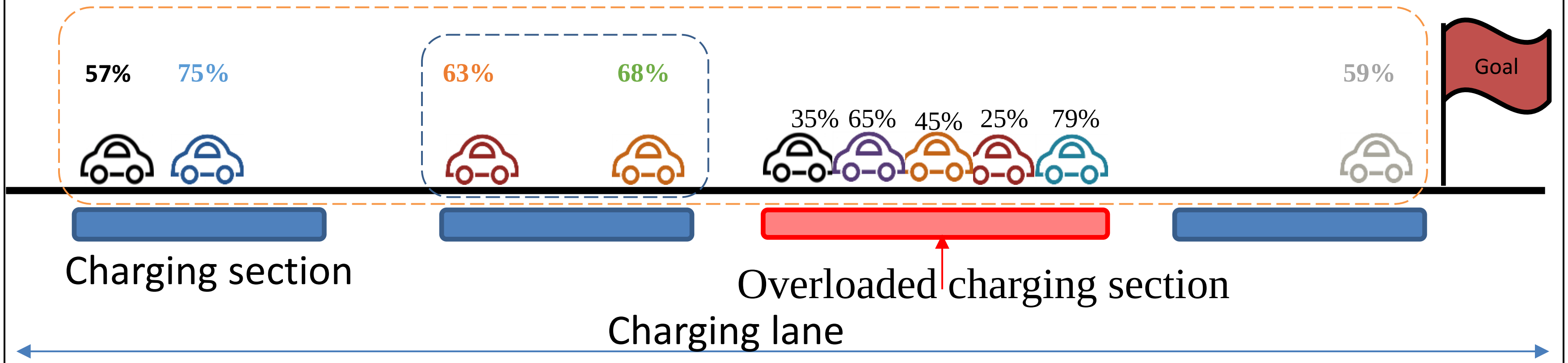
Dynamic WPT is a possible solution:

- Cost of infrastructure is high ($/kW)
- Power levels required are high (MW)

Compromising between number of vehicles served and minimize infrastructure cost.



Introduction



How to decide which vehicles are going to receive the service and what the power level is for each of them?

Some intelligence is needed in the infrastructure, we need a power scheduler

Introduction

Our proposed method: BSoC

- Try to balance State of Charge (SoC) of batteries.
- Use a (cloud/fog) hierarchical architecture to provide scalability and localization.
- Efficient vehicle-to-fog communication protocol

Advantages

- Distribute power evenly according to the scheduling policy
- Provide globalization and localization
- Reduce communication latency

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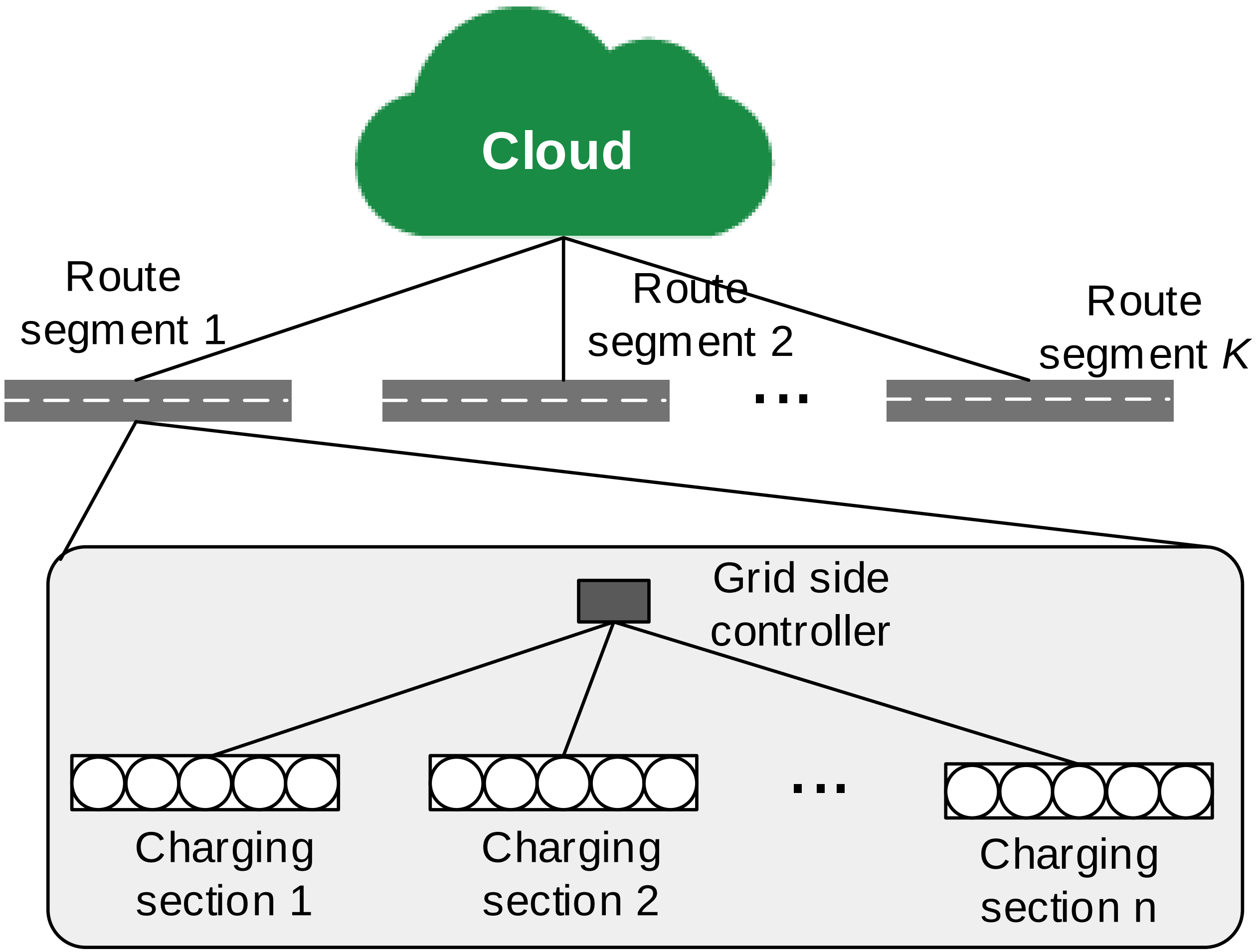
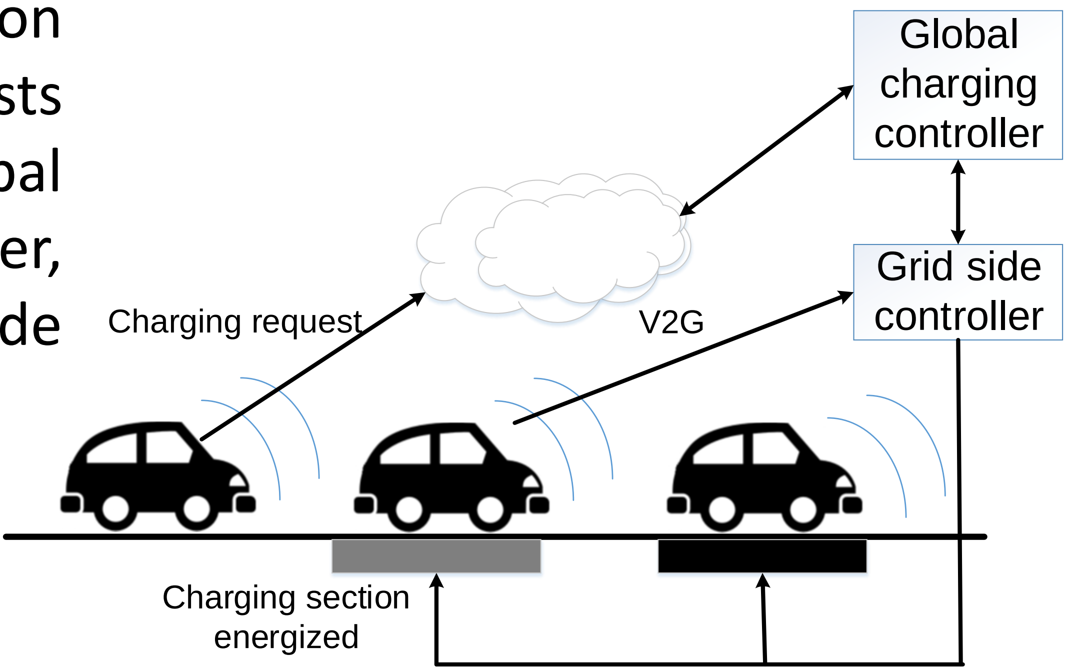
Overview of BSoC



Design of BSoC

- Power Distribution Architecture: It consists of cloud-based Global Charging Controller, fog-based Grid Side Controller.



Design of BSoC

- Power Scheduling Model: Based on vehicle model and battery model, it tries to balance the SOC.

Vehicle dynamics

$$m\dot{v} = F_{trac} - \frac{1}{2}\rho_{air}C_d A_f v^2 - mgsin(\alpha) - mgC_r\cos(\alpha)$$

$$P_{batt} = P_{req} - P_{add}$$

Battery model

$$I = \frac{V_{oc} - \sqrt{{V_{oc}}^2 - 4R_{int}P_{batt}}}{2R_{int}}$$

$$y_{i+1} = y_i - \frac{\int Idt}{Q_{batt}}$$

Design of BSoC

- Power Scheduling Model: Based on vehicle model and battery model, it tries to balance the SOC.

$$min \sum_{i=1}^{m} \left(y_i(t_i^e) - \frac{\sum_{j=1}^{m} y_j\left(t_j^e\right)}{m} \right)^2 \text{ s.t.}$$

$$\sum_j x_j(t) \leq A, \forall j, t$$

$$x_j(t) \leq a_j, \forall j, t$$

$$y_i(t) \leq 1, \forall i, t$$

Power Scheduling model

Power Scheduling Model

Input: Parameters of all EVs

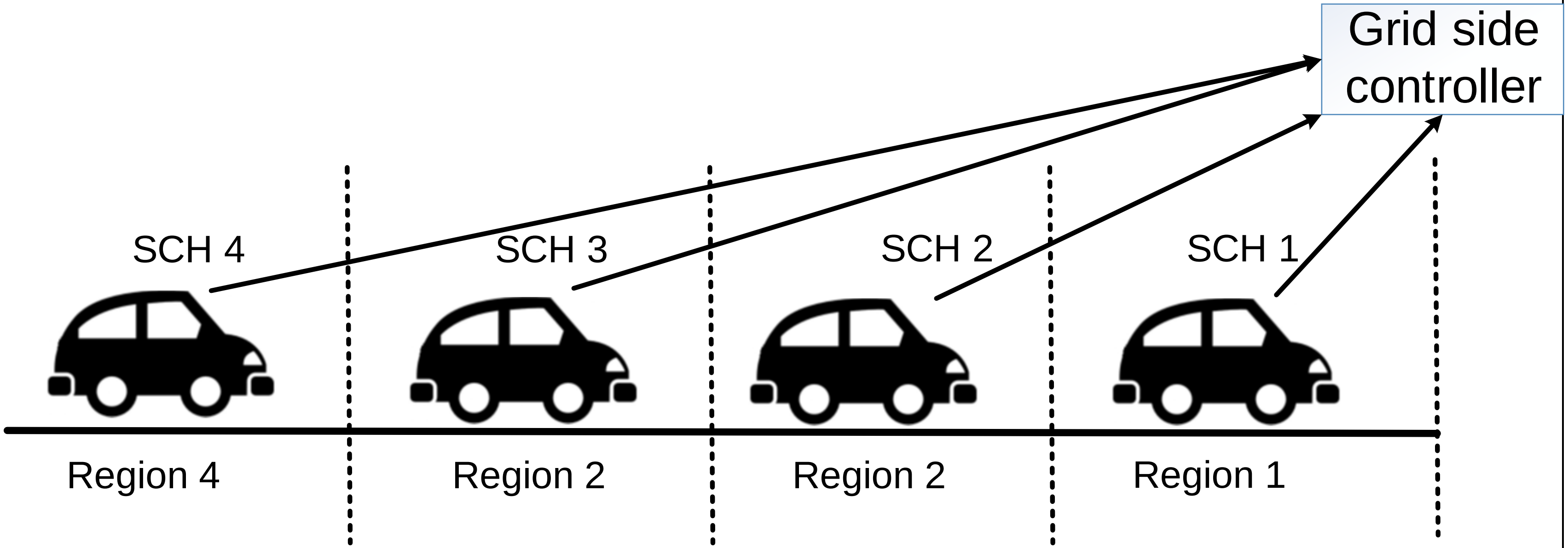
Output: Power allocation of all charging sections

Algorithm 1

- Select one candidate power allocation W^k
- Find subgradient of W^k
- Take another negative subgradient of step W^k
- Continue these steps until global optimal solution is found

Design of BSoC

- Efficient vehicle-to-fog communication protocol: location based channel selection.



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Performance Evaluation: Settings

- Simulation in three aspects
  - 10-50 vehicles
  - 10 charging sections
  - 128 byte data packets
  - 500m communication range

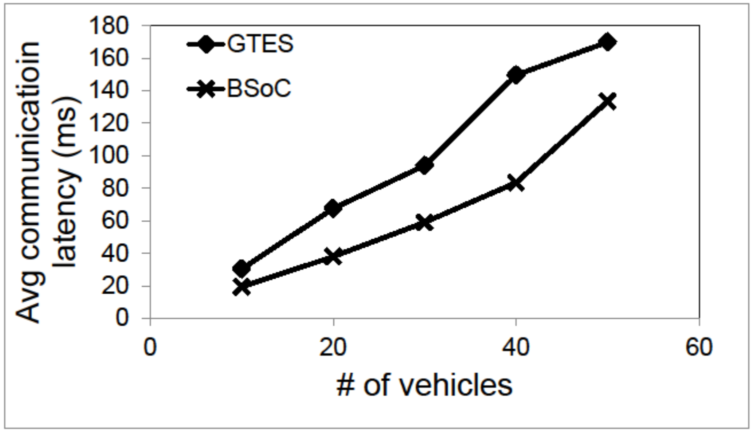
- Comparison methods
  - GTES[2]: Cloud-based power scheduling model
  - two power scheduling models (Equal Share, FCFS)
  - IEEE 802.11p communication protocol

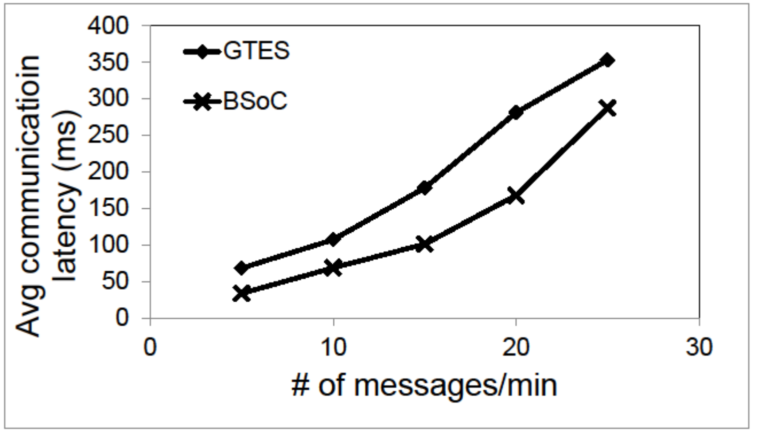
[2] Z. M. Fadlullah et al., “GTES: An optimized game-theoretic demandside management scheme for smart grid,” IEEE Systems Journal, 2014.

Performance Evaluation: Results

- Average communication latency

Setting: Number of vehicles (10-50)



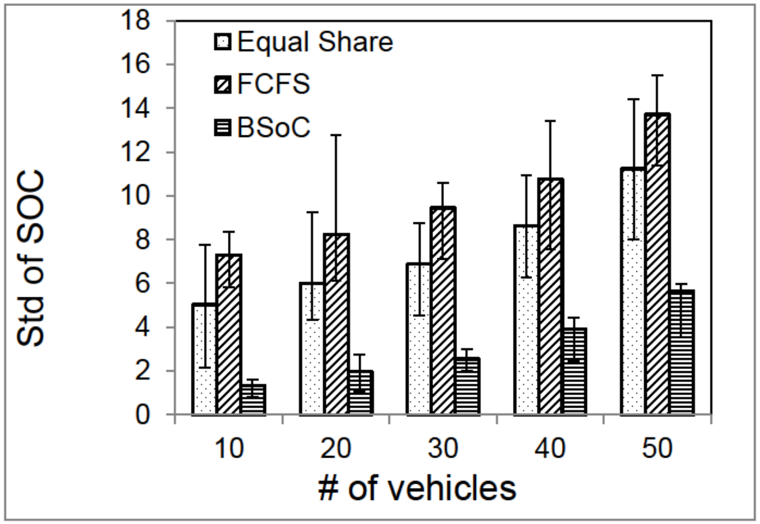


- Observation: BSoC < GTES, average communication latency as the numbers of vehicles increase
- Reason: The DSRC data transmission rate is faster and it is less affected by the channel congestion than LTE data transmission rate.

Performance Evaluation: Results

- Average State of charges

Setting: Number of vehicles (10-50)

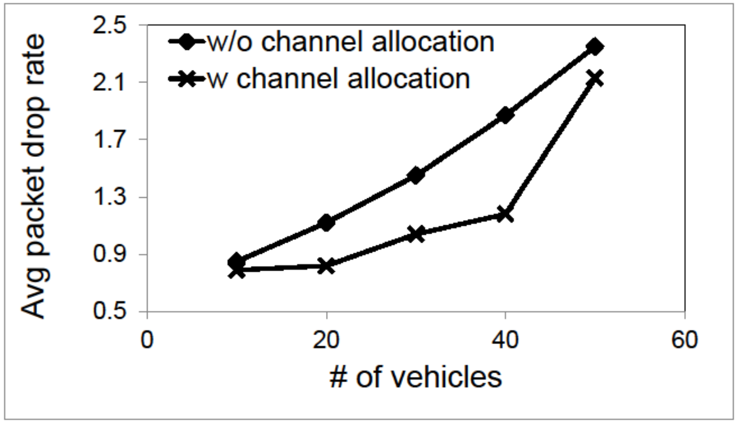


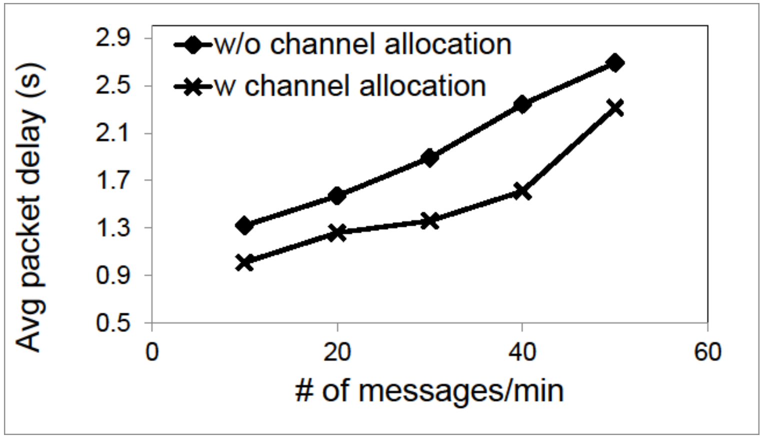
- Observation: FCFS > Equal Share > BSoC
- Reason: BSoC considers balancing the SOC levels of EVs. Equal Share considers the equal distribution of energy. FCFS distributes power based on EV’s arrival time.

Performance Evaluation: Results

- Average packet drop rate

Setting: Number of vehicles (10-50)





- Observation: w channel allocation < w/o channel allocation
- Reason: Since vehicles use their own channel for data transmission, it causes less packet drop rate

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Conclusion

- BSoC: dynamic WPT system, leverages power scheduling model and hierarchical cloud/fog architecture
- Extensive simulations show effectiveness:
  - Balance SOC efficiently
  - increase communication efficiency
  - minimize packet drop rate and packet delay
- Future work: consider different priority of vehicles and detect position of vehicles accurately

Thank you!
Questions & Comments?

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