Parked Vehicle Assisted VFC System with Smart Parking: An Auction Approach

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Outline

- Background & Motivation
- Problem Formulation
- Auction Design
- Simulation Results
- Conclusion

Background & Motivation

Mobile edge computing (MEC)

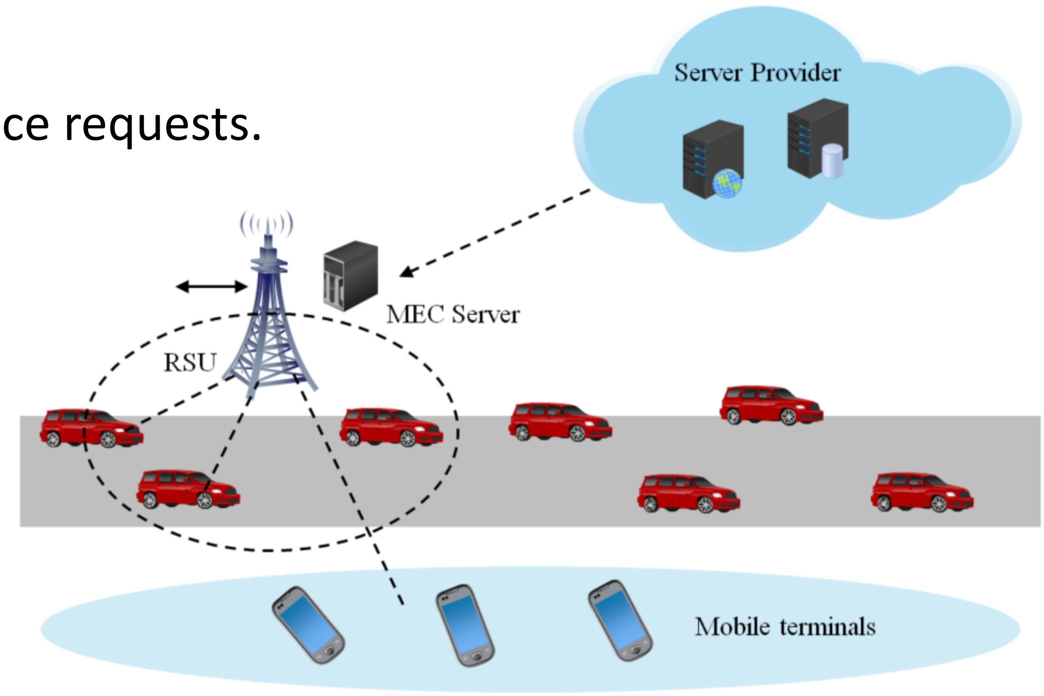
Offload the urgent computation workload from cloud to edge.

However, the fog computing service is limited:

- Density of RSUs.
- Heavy load of RSUs from service requests.
- Deployment cost of RSUs.

Communication & Computation

Low latency service

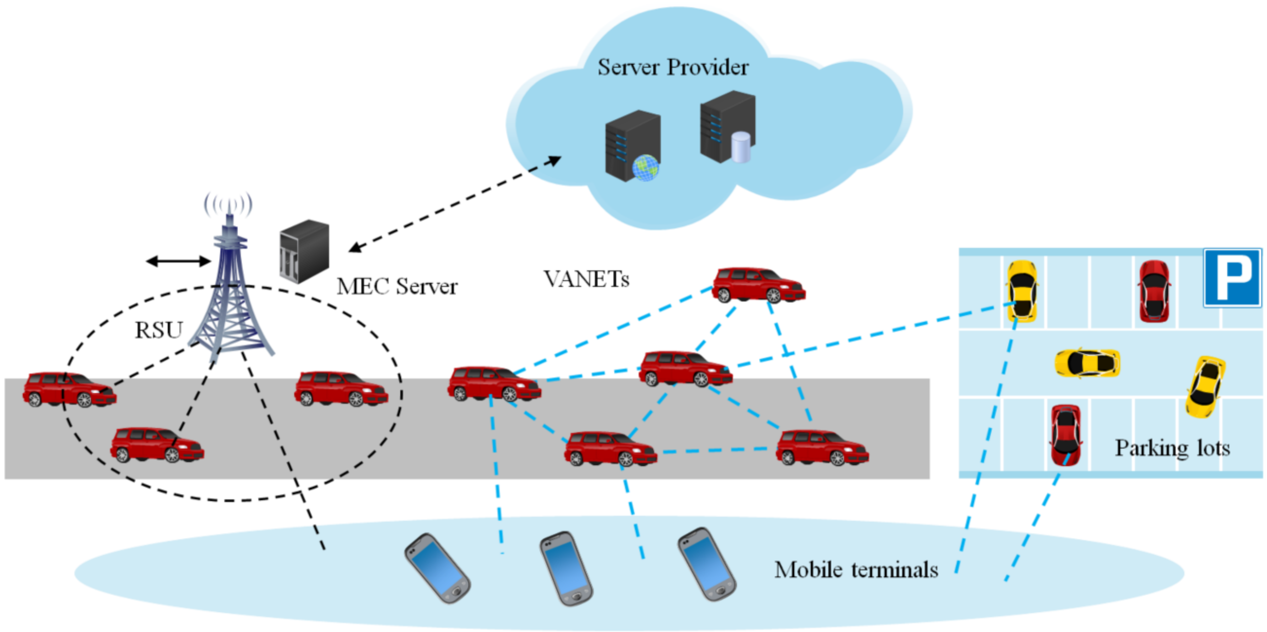


Background & Motivation

Vehicular fog computing (VFC)

Modern vehicles become more and more powerful.

- On-the-move vehicles ⇨ VANETs
- Parked vehicles ⇨ Parking vehicle assistance (PVA)



The parked vehicles act as static network infrastructures.

Background & Motivation

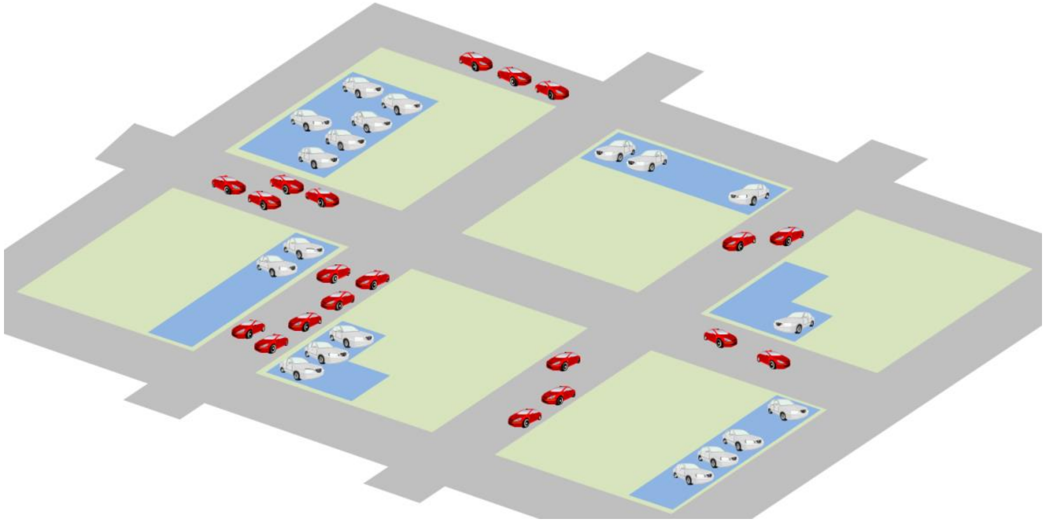
Smart parking system (SPS)

Increased population and limited parking places of a city

When on-the-move vehicles search for parking slots:

- Cause traffic congestion
- Waste unnecessary time and energy

SPS guides the vehicles to the available parking slots with less effort, time and fuel consumption.



Background & Motivation

We consider a robust VFC system:

PVA in VFC + Smart parking

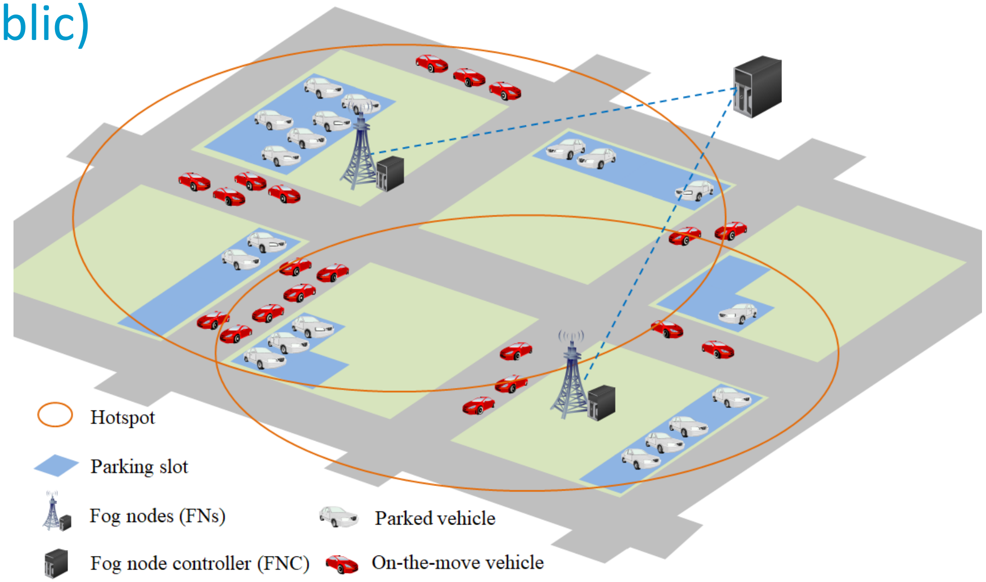
Benefits:

- Improves the traffic and parking efficiency.
- Attract the vehicles with fog capability to park at proper parking spaces to assist the delay-sensitive computing services.
- The fog service provider can achieve cost saving by turning off redundant fog computing servers.
- The parked vehicles receive monetary rewards to compensate their service cost.

Problem Formulation

We provide **a parked vehicle assisted VFC system**:

- Fog network controller (FNC) (maintain sufficient FNs)
- Hotspots (consist of delay-sensitive computation requests)
- Parking places (private or public)
- On-the-move vehicles (fog capability)

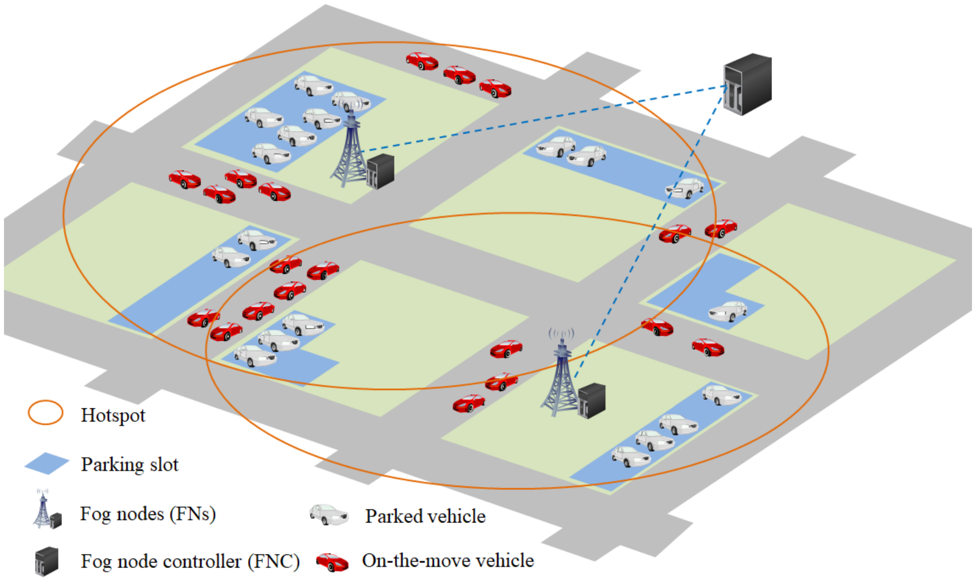


Fog-capable vehicles has potential to offload the computation workload from the FNs near the hotspots when they are also parked nearby.

Problem Formulation

Parking places:

- Parking slot inventory
- Reserve price



Hotspots:

- Workload arrival rate
- Delay toleration

Fog network controller (FNC):

- Operation energy cost
- Play monetary rewards for service offloading

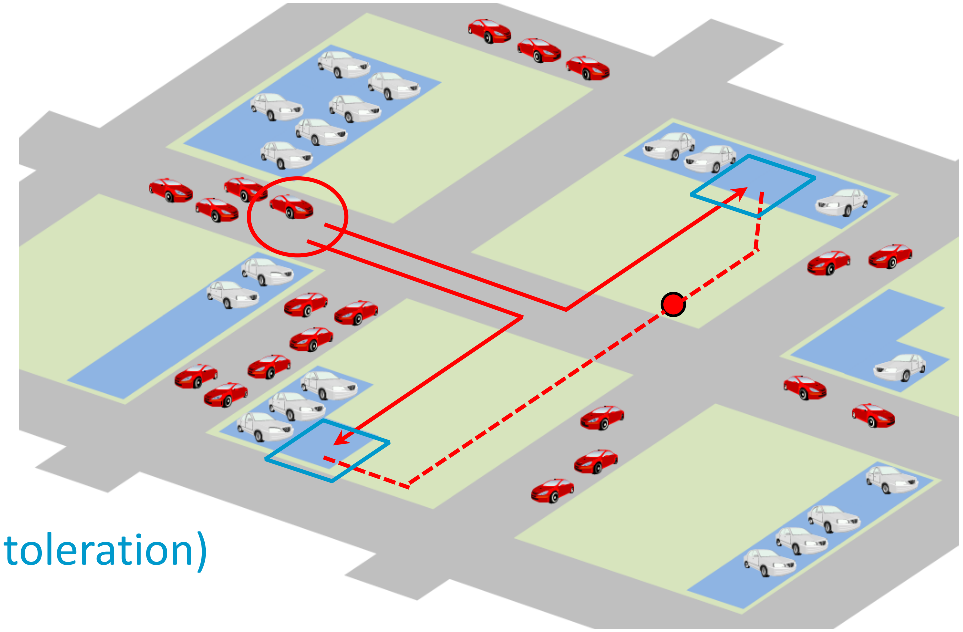
Problem Formulation

On-the-move vehicles:

- Current car position
- Traveling destination
- Average driving speed
- Walking speed

⇒

- Remaining driving time
- Walking time (traveling toleration)
- Driving energy cost



Private information

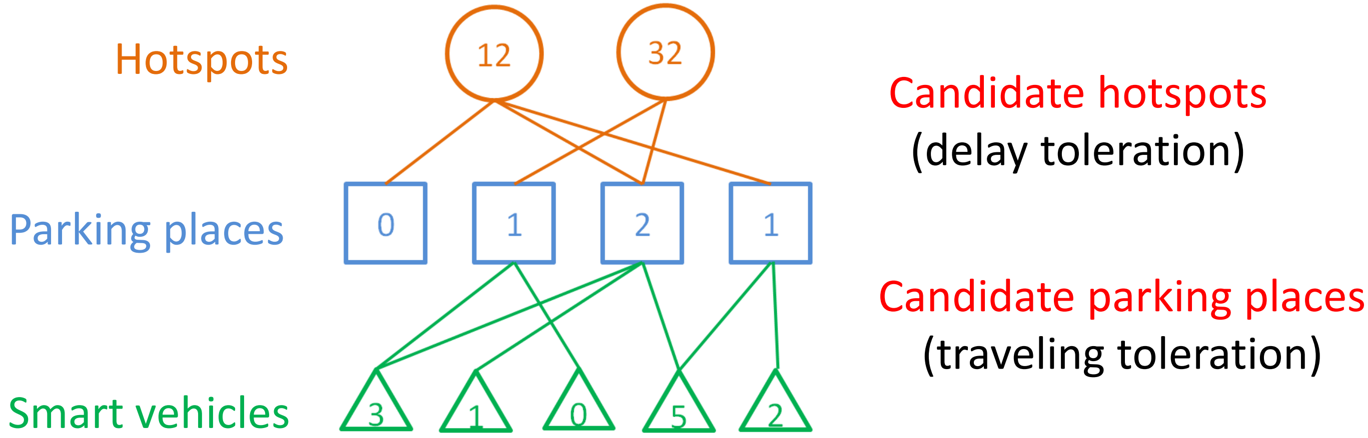
Parking duration

Fog capability: CPU as the unit of computing resource

Service delay = queuing delay + network delay (delay toleration)

Problem Formulation

Objective:



- **Parking places:** receive more parking income
- **FNC:** *max* (Energy cost saving – offload expense)
- **Smart vehicles:**

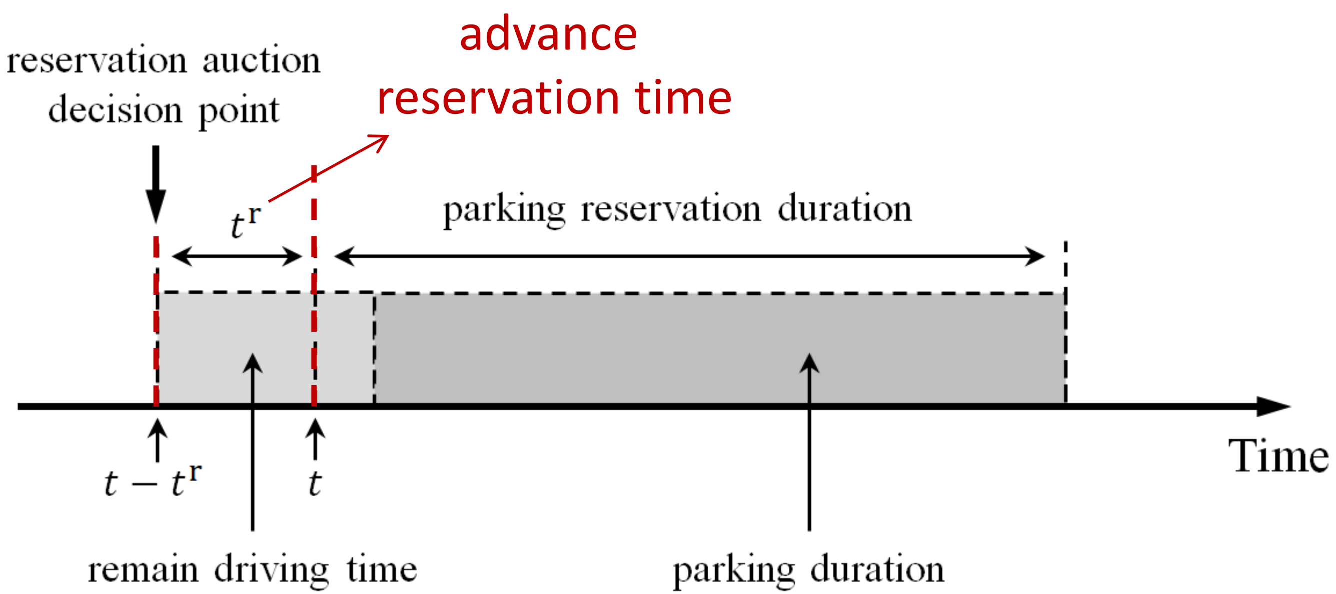
  Max (service reward – service cost - parking payment
  - traveling time - traveling cost)

It motivates us to employ a parking reservation auction to regulate the proposed VFC system.

Auction Design

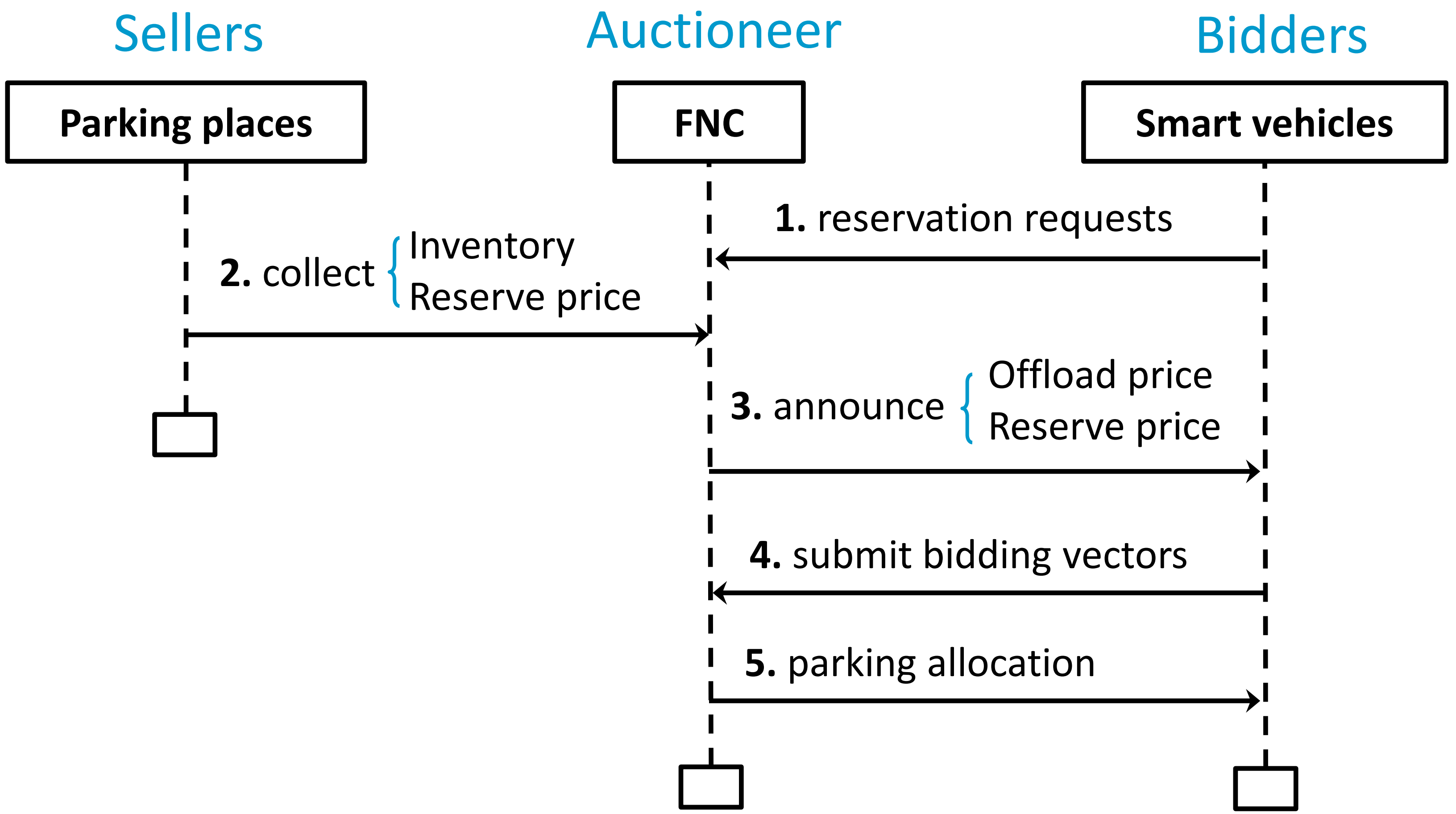
Reservation Auction Model

- Formulated on a rolling horizon of time slot intervals
- Starts at the decision point periodically.



Auction Design

Reservation Auction Model



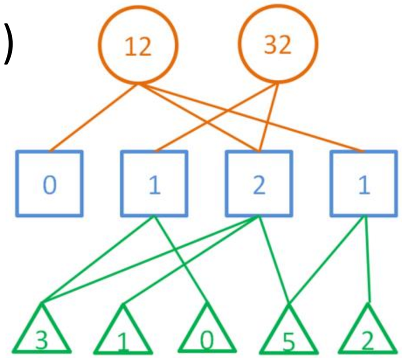
Auction Design

Strategy of smart vehicles:

Can cheat

For each candidate parking place,

Bidding vector = (Parking Value, Selected hotspot, # of CPU)



Strategy of FNC:

Allocation rule: to maximize the aggregate utility of vehicles

⇨ Maximum weight perfect bipartite matching (MWPBM) problem

Solved by Classic Kuhn-Munkres (KM) algorithm $O(N^3)$

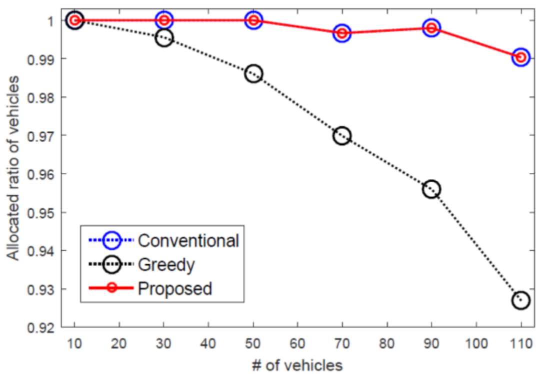
Payment rule: Vickrey Clarke Groves (VCG) mechanism with Clarke pivot payments

Economic properties:

1) Incentive compatible
2) Individually rational
3) Budget balance

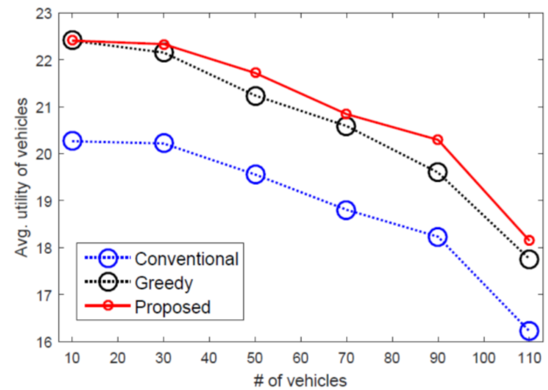
Simulation Results

Performance versus the number of vehicles:



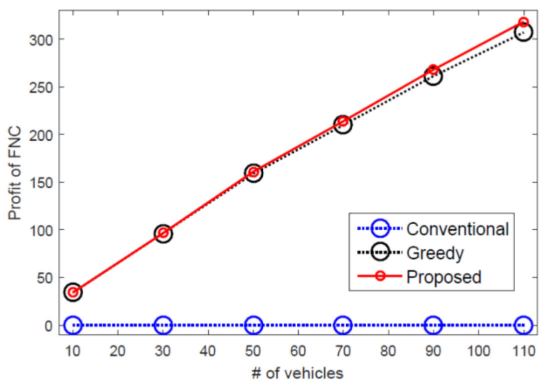
loss

Allocation ratio of vehicles

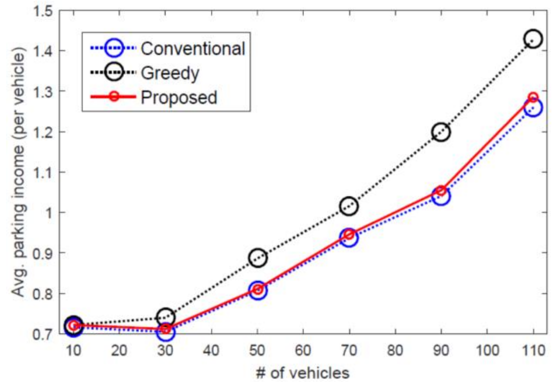


Avg. utility of vehicles

intensified competition



Profit of FNC



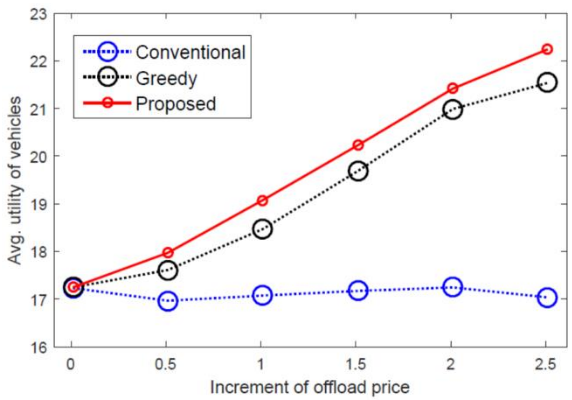
Avg. parking income (per vehicle)

additional income

The proposed auction provides win-win performance enhancement.

Simulation Results

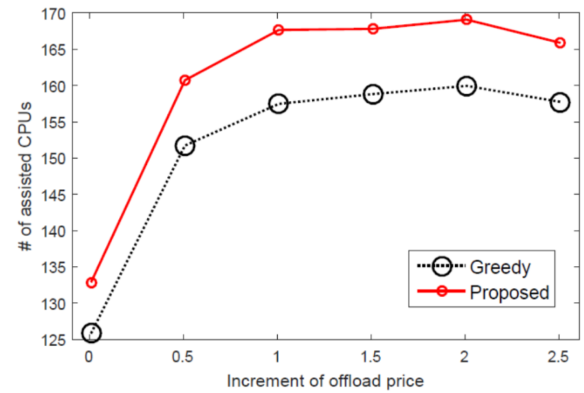
Performance versus the increment of offload price:



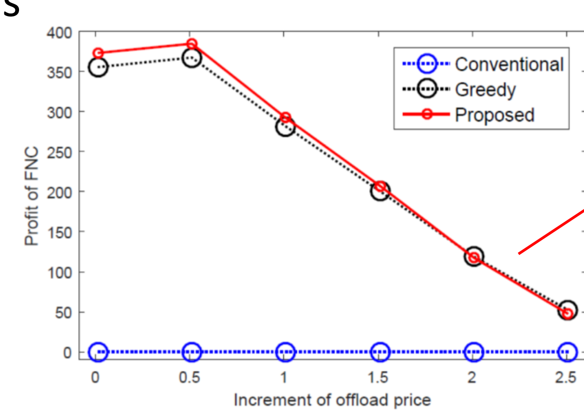
Avg. utility of vehicles

higher compensation

attracts more CPUs



# of assisted CPUs



Profit of FNC

unnecessary offload payments

An optimal choice of offload price exists and deserves further study in the future.

Conclusion

- We propose a VFC system by combining both PVA and smart parking.
- The proposed auction guarantee incentive compatible, individually rationality and budget balance.
- A win-win performance enhancement is achieved among FNC, smart vehicles and parking places.

The End

Thank You!