Intelligent Energy Management System Simulator for PHEVs at a Municipal Parking Deck in a Smart Grid Environment

Preetika Kulshrestha, *Student Member, IEEE*, Lei Wang, *Student Member, IEEE*,
Mo-Yuen Chow, *Fellow, IEEE* and Srdjan Lukic, *Member, IEEE*
North Carolina State University
Raleigh, NC

Outline

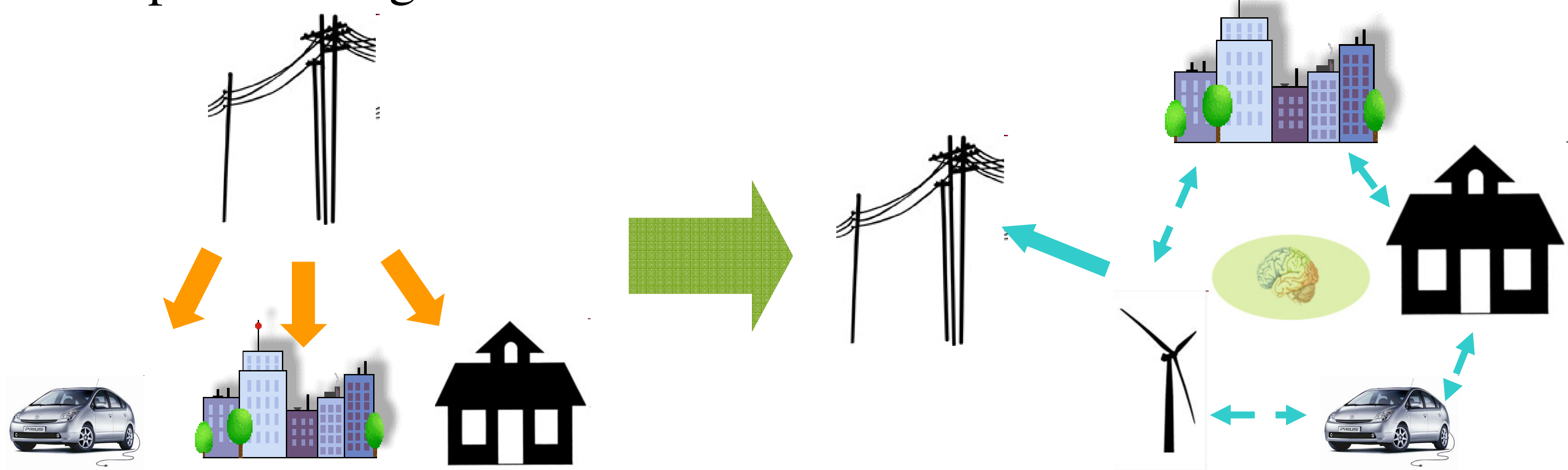
- Introduction
- System architecture
- Component description
- System simulator
- Sample system simulation
- Future work

Emergence of the “Smart Grid”

Optimization of power delivery - Capacity to deliver efficiently, reliably and intelligently

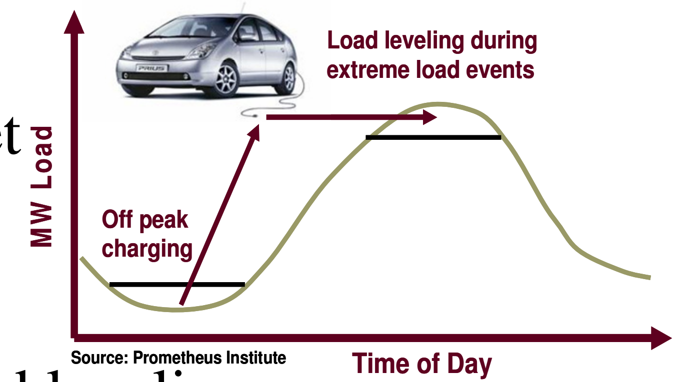
Features

- Decentralization of control
- Services customized to user’s needs
- Use of energy efficient systems
- Rapid reconfiguration



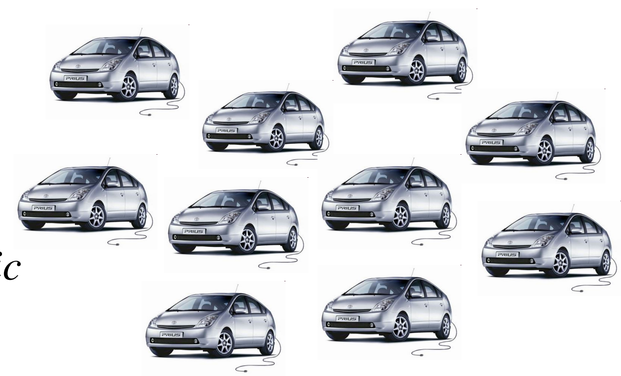
Introduction to PHEVs

- HEV with larger battery pack
- Can be charged from standard wall outlet
- 40 mile all-electric range (Chevy Volt)



Benefits

- Reduction in GHG emissions
- Reduction on oil dependence
- Load leveling
- Lower cost



Potential Synergistic Relation

A cluster of vehicles is a controllable load for the grid

Opportunities and Challenges

Opportunities

- US fleet's 176 million light vehicles = power capacity of 19.5TW= 24 x power capacity of the electric generation system.
- PHEV penetration by 2050 – 62% of the US fleet (EPRI prediction)

Challenges

- Potential load of 1000 cars => 4 MW load
- Potential dangers => Voltage instability and blackouts
- Infrastructure
- Need of an underlying framework to enable PHEV integration

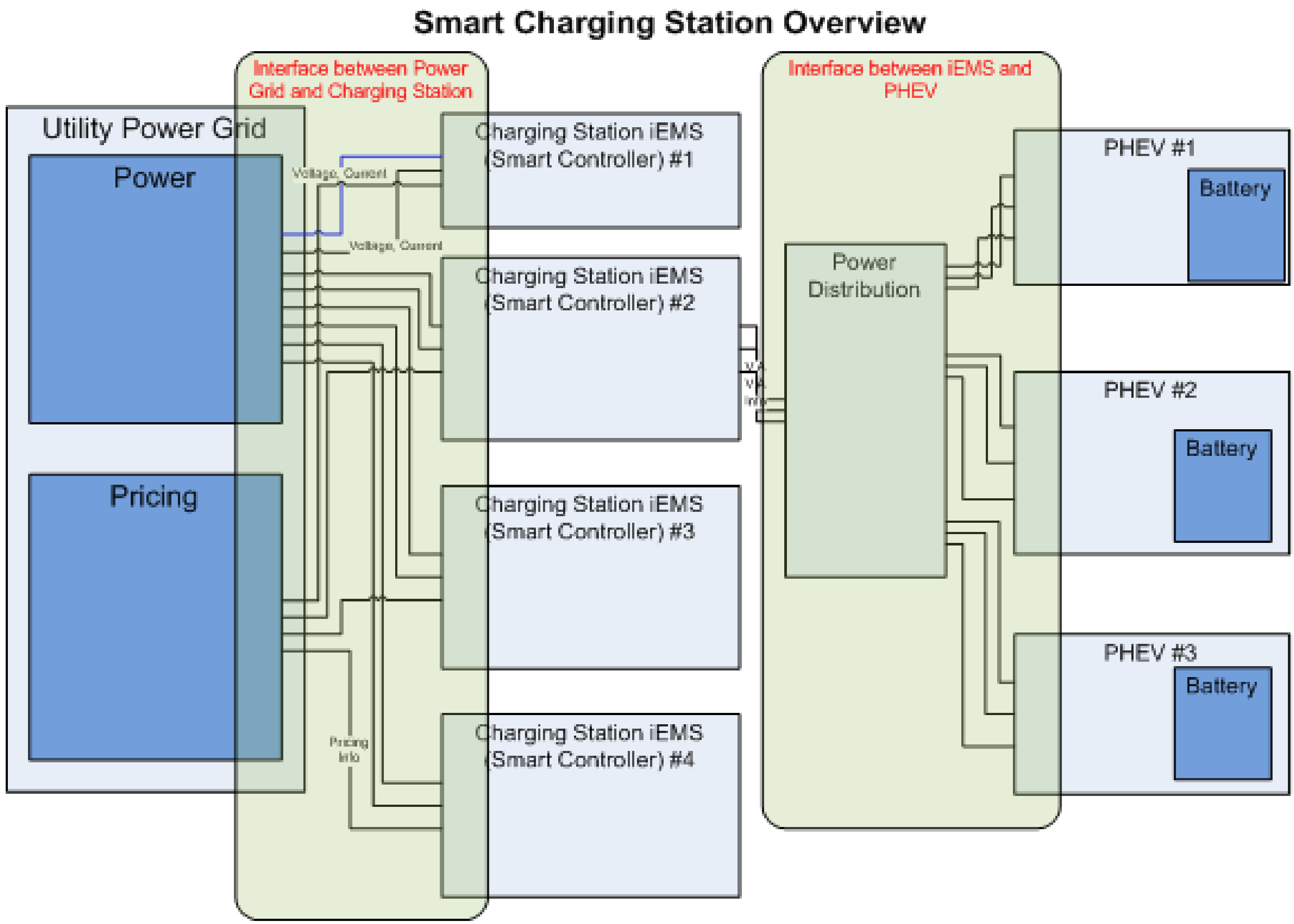
A Solution

Intelligent Energy Management at a Municipal Parking Deck

Related Work

- J. Tomic and W. Kempton, "Using fleets of electric-drive vehicles for grid support", *J. Power Sources*, vol. 168, issue 2, 2007
- M. Duvall and E. Knipping, "Environmental assessment of Plug-in Hybrid Electric vehicles", EPRI, July 2007
- Hutson, G. K. Venayagamoorthy, K. A. Corzine, "Intelligent Scheduling of Hybrid and Electric Vehicle Storage Capacity in a Parking Lot for Profit Maximization in Grid Power Transactions", *in proc. IEEE Energy2030,* Atlanta, GA, 2008
- S. B. Pollack et al, patent title "User interface and user control in a power aggregation system for distributed electric resources", IPC8 Class: AG01R2106FI, USPC Class: 702 62
- GridPoint: http://www.gridpoint.com/

System Architecture



Information Flow

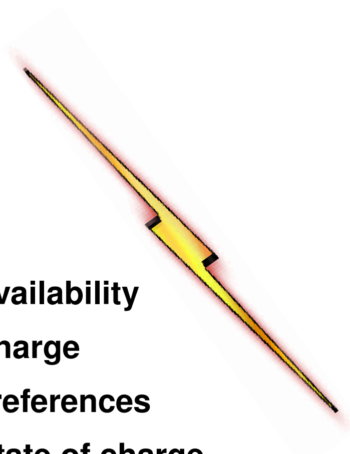
Utility

Pricing

Available power

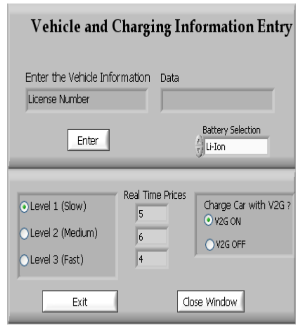
iEMS

Optimization



- Time of availability
- Type of charge
- Pricing preferences
- Current state of charge
- Power consumed
- .....

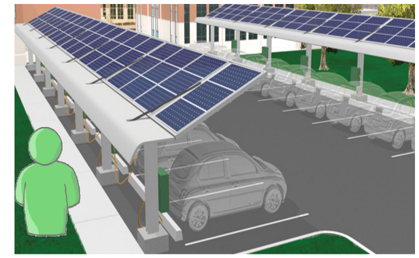
User Profile Entry



Data Acquisition

(DSP, FPGA etc.)

- Power Allocated
- Rate of charge
- Other control messages



Vehicle 1

Vehicle 2

Vehicle 3

.

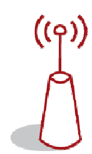
.

.

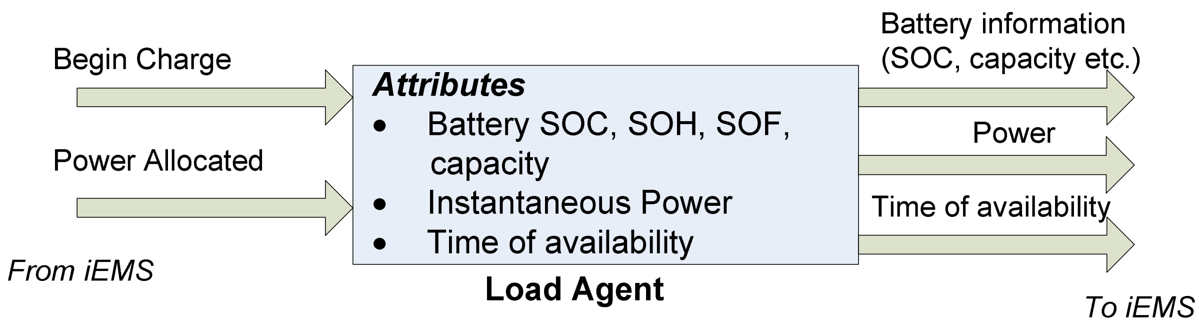
.

Vehicle n

Communication Medium: Wi-Fi, Bluetooth, Satellite ZigBee etc.

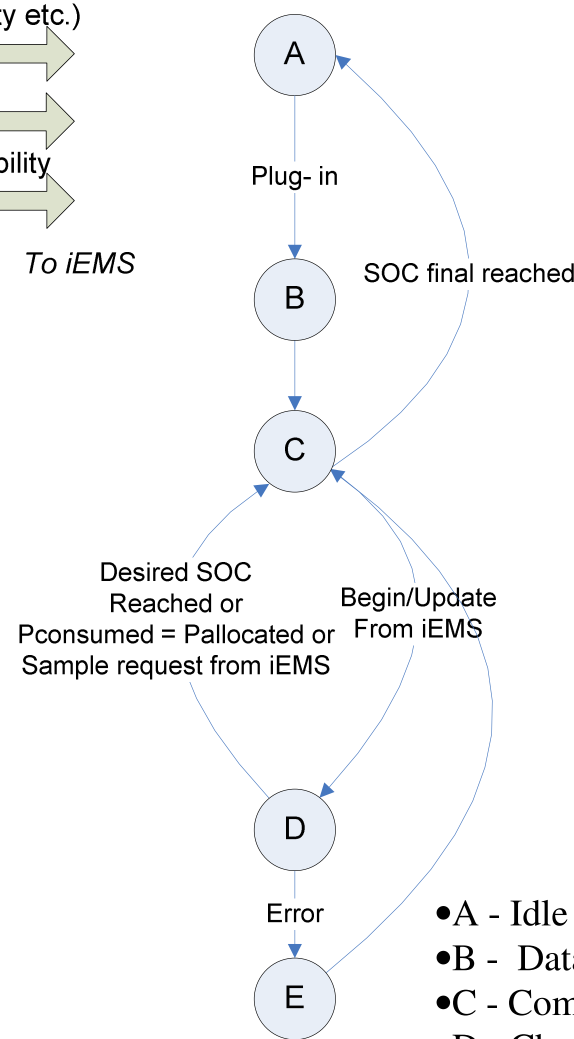


System - Component Description



States

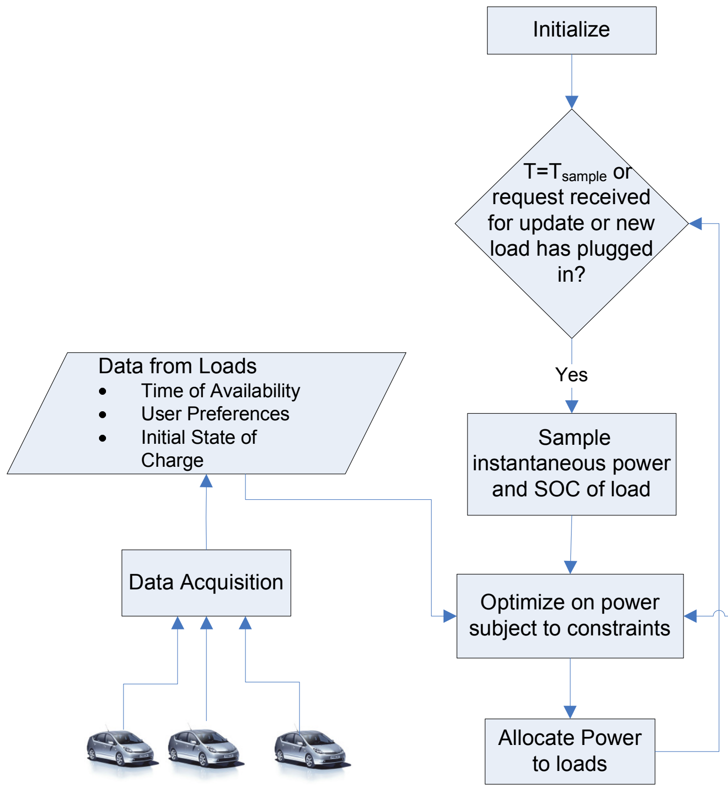
- Idle: There is no activity, the load may be waiting for a control action or it may have completed charging the battery.
- Data Acquisition: The data is acquired from the battery and the user.
- Communication: Data is communicated to controller.
- Charging: Battery charging is in progress.
- Error: There is an error in the system and system operation is halted until error is resolved.



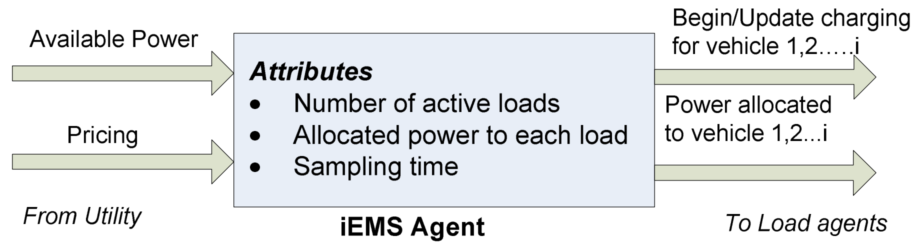
State transitions

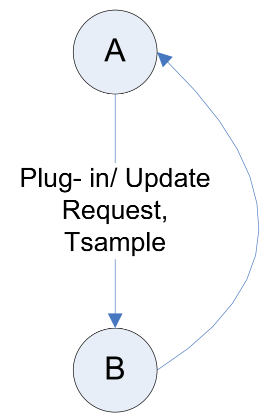
- A - Idle
- B - Data Acquisition
- C - Communication
- D - Charging
- E - Stop

System - Component Description



iEMS flow chart





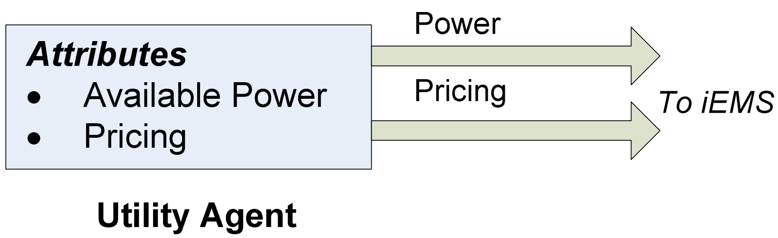
State transitions

- A - Communicate
- B- Optimize

States

- Communication: Inform the loads of power allocated/listen for signals
- Optimize: Calculation of power allocation when:
  - There is a change in utility power.
  - A load has plugged-in/out.
  - Periodically, after sampling the instantaneous power consumed by loads.

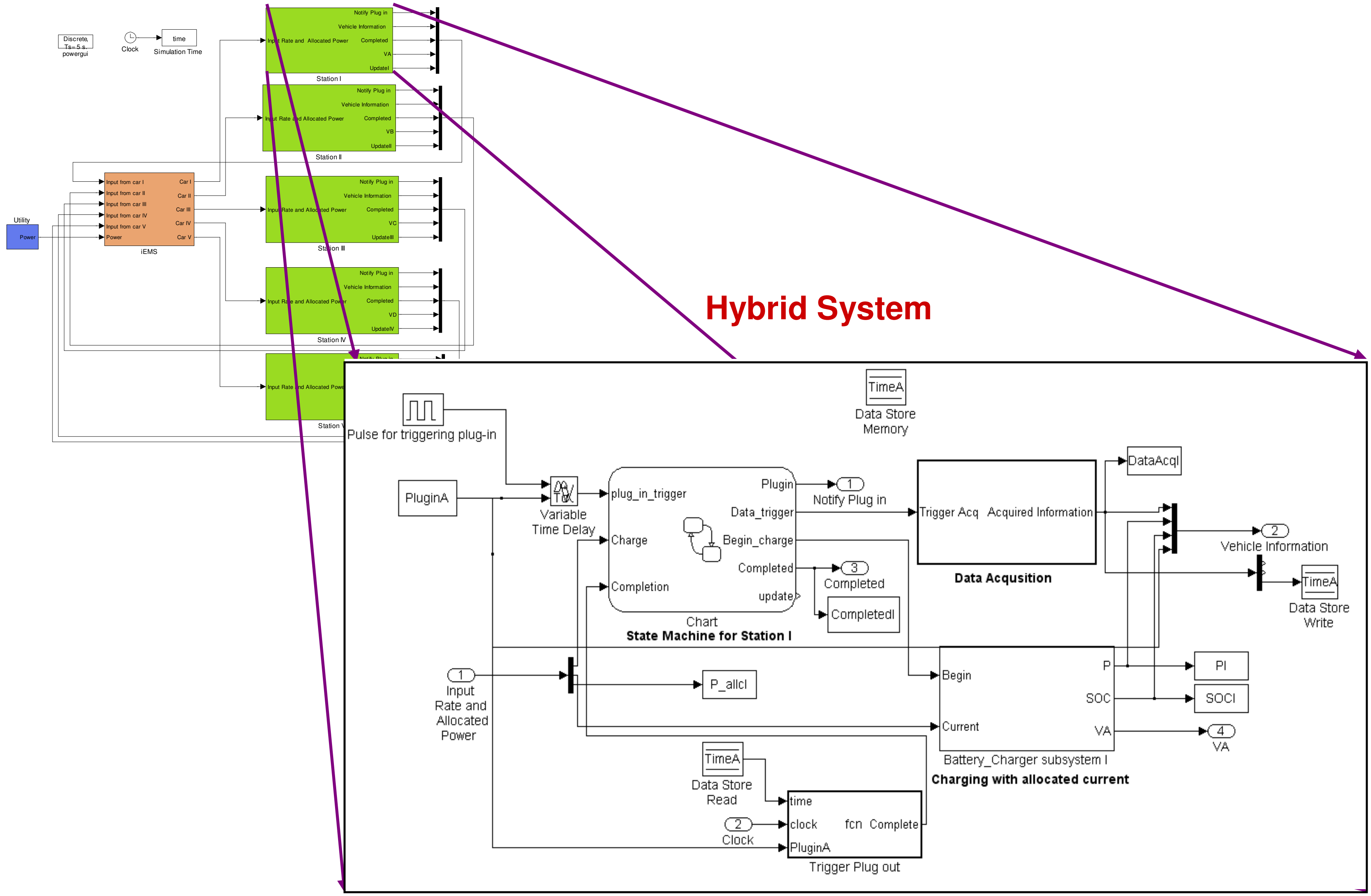
System - Component Description



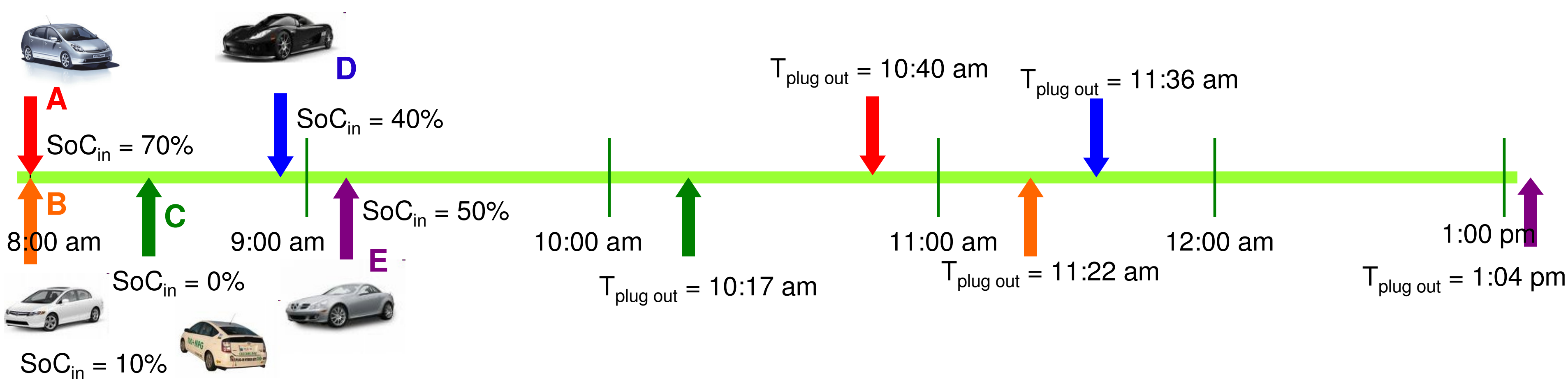
Functions

- Periodically inform the iEMS about the power available and pricing information

iEMS - System Simulator

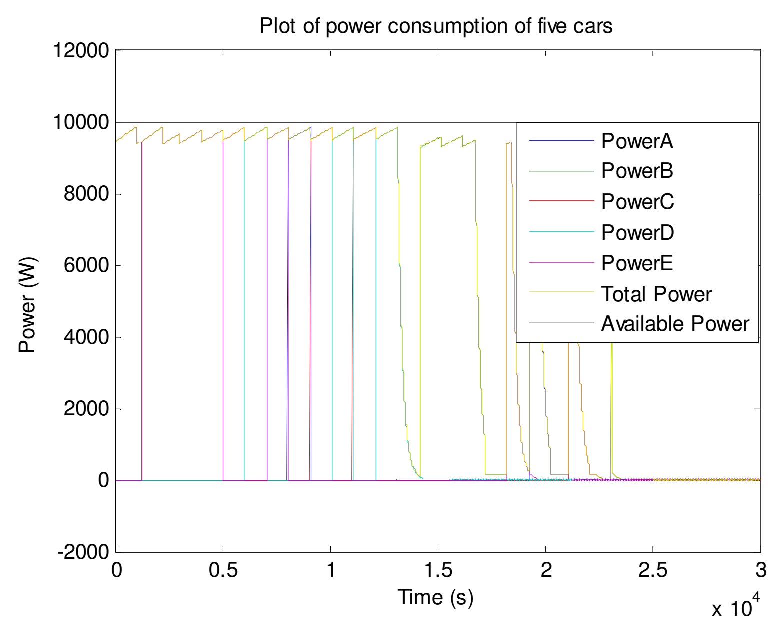


Sample System Simulation



Objective function: $$\max_{p} J(k) = \sum_{j}\sum_{i} w_i(k) SoC_i(k+j)$$

$w_i(k)$: the priority assigned for to vehicle i at time step k
Priorities are assigned based on capacity required and time remaining



Monte Carlo Simulation

Simulation Parameters

State of Charge at plug-in: Uniform random number between 10% and 75%

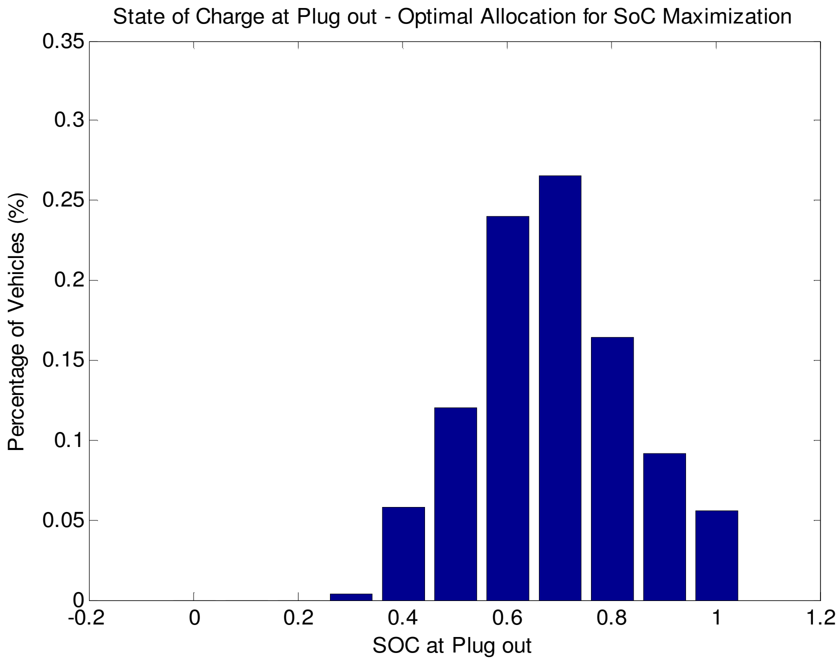
Time of Availability: Uniform random number between 0.5 and 2 hours

Time of Plug-in: Uniform random number between 0 and 2 hours

Simulation Run Time: 4 hours

Battery Capacity: Uniformly distributed between 6 Ah and 15 Ah

Number of times the simulation was run for each algorithm: 100



	Optimal Allocation for SoC Maximization	Dynamic Priority Allocation	Equal Priority Allocation
Percentage of vehicles leaving with SoC 55% or higher	81.8% (409)	69.6% (348)	67.6% (339)
Number of vehicles leaving with SoC 35% or lower	2 0.4%	32 6.4%	40 8.0%

Conclusions

- This paper proposes an iEMS for managing power at a parking deck
- System components, functions and behavior are outlined
- A simulator (test-bed) is developed to simulate the real world scenario
- The simulator will contribute towards evaluation of varied scenarios and iEMS algorithms
- Optimization on a chosen objective is formulated and simulation results presented

Future Work

- Exploration of different objectives for optimization
- Extension of the problem to multi-objective optimization and incorporation of additional constraints
- Network in the Loop iEMS – performance evaluation with communication delay, packet drop, and signal strength
- Decision on optimal sampling time
- Extension of the concept to distributed control
- Real world implementation and demonstration of the iEMS

Acknowledgement

This work was partially supported by the National Science Foundation (NSF) under Award Number EEC-08212121

THANK YOU!