Chapter 9: Green Vehicular Technology and Application

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Outline

1. Introduction
2. Electric vehicles (EVs)
3. Vehicle to cloud
4. Solar vehicle application
5. Conclusion

Technical roadmap for Green Vehicular Technology and Application

Green Vehicular Networks

Solar vehicle application

- Introduction
- Solar energy for vehicle propulsion
- Case study

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- Standards for conductive charging of EV

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- V2G concept
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- V2G cost-emission optimization

Vehicle to cloud

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- Data of the cloud
- Cloud Quest Technologies (CQT) project

Intelligent cloud processing platform for traffic flow

- Intelligent traffic guidance service system
- traffic flow data

Intelligent disaster management system

- Emergency response system architecture
- Compare with traditional method

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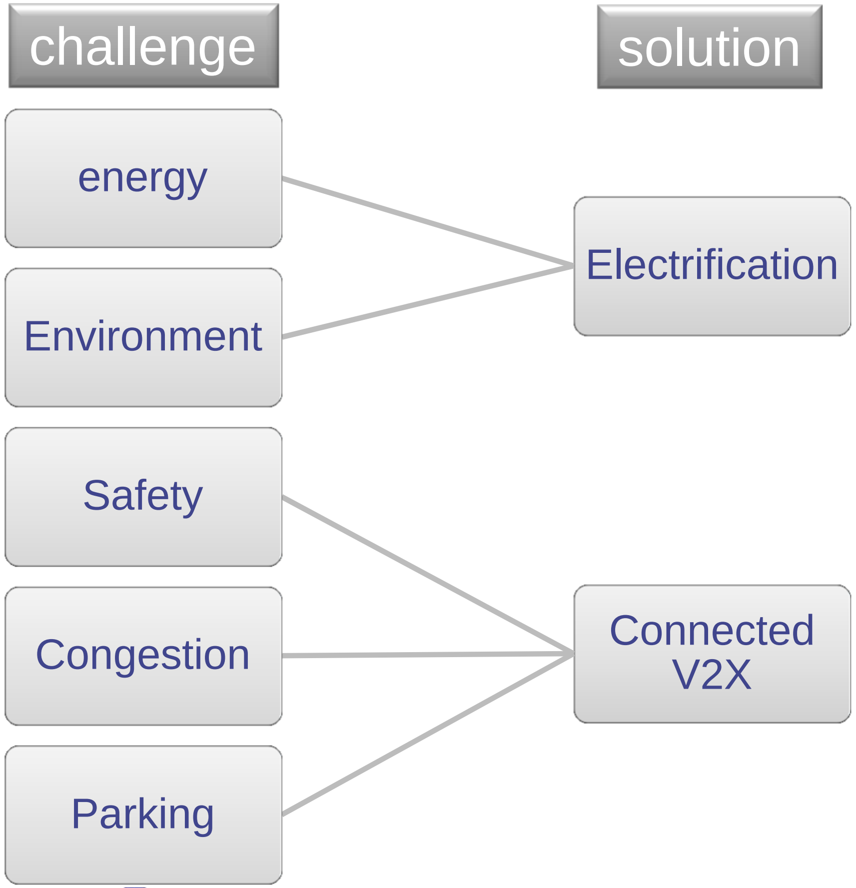
Challenge to sustainable auto industry



1. Introduction

- "Given the role that **transport** plays in causing greenhouse gas emissions, any serious action on climate change will zoom in on the **transport sector**.", Yvo de Boer, Executive Secretary of the United Nations Framework Convention on Climate Change (UNFCCC), Tokyo, January 2009
- The electric car finally seems to be on the verge of breaking through, offering significant environmental benefits, especially in urban areas.
  - **high battery costs**, **green electricity supply** and **charging infrastructure**.
- Plug-in hybrid electric vehicles (PHEVs) are hybrid electric vehicles that can draw and store energy from an **electric grid** to supply propulsive energy for the vehicle.

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2. Electric vehicles (EVs)

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2. Electric vehicles (EVs)

All electric	Any power train that relies solely on an electric motor for propulsion
Hybrid-electric powertrain	Integrates an electric motor with a combustion engine—also simply called a hybrid or a HEV
Plug-in hybrid	Any hybrid vehicle with an energy storage system rechargeable via a standard home 120- or 240-V outlet
Mild hybrid powertrain	When the brake is released, the starter motor restarts the engine. The starter motor does not provide power to the wheels. These hybrids are also called belt-alternator-starter or micro hybrids.
Full-hybrid powertrains	Full hybrids are composed of: (a) weak HEVs, with electrical systems capable of maintaining vehicle speed and (b) strong HEVs, able to assist directly in vehicle acceleration.

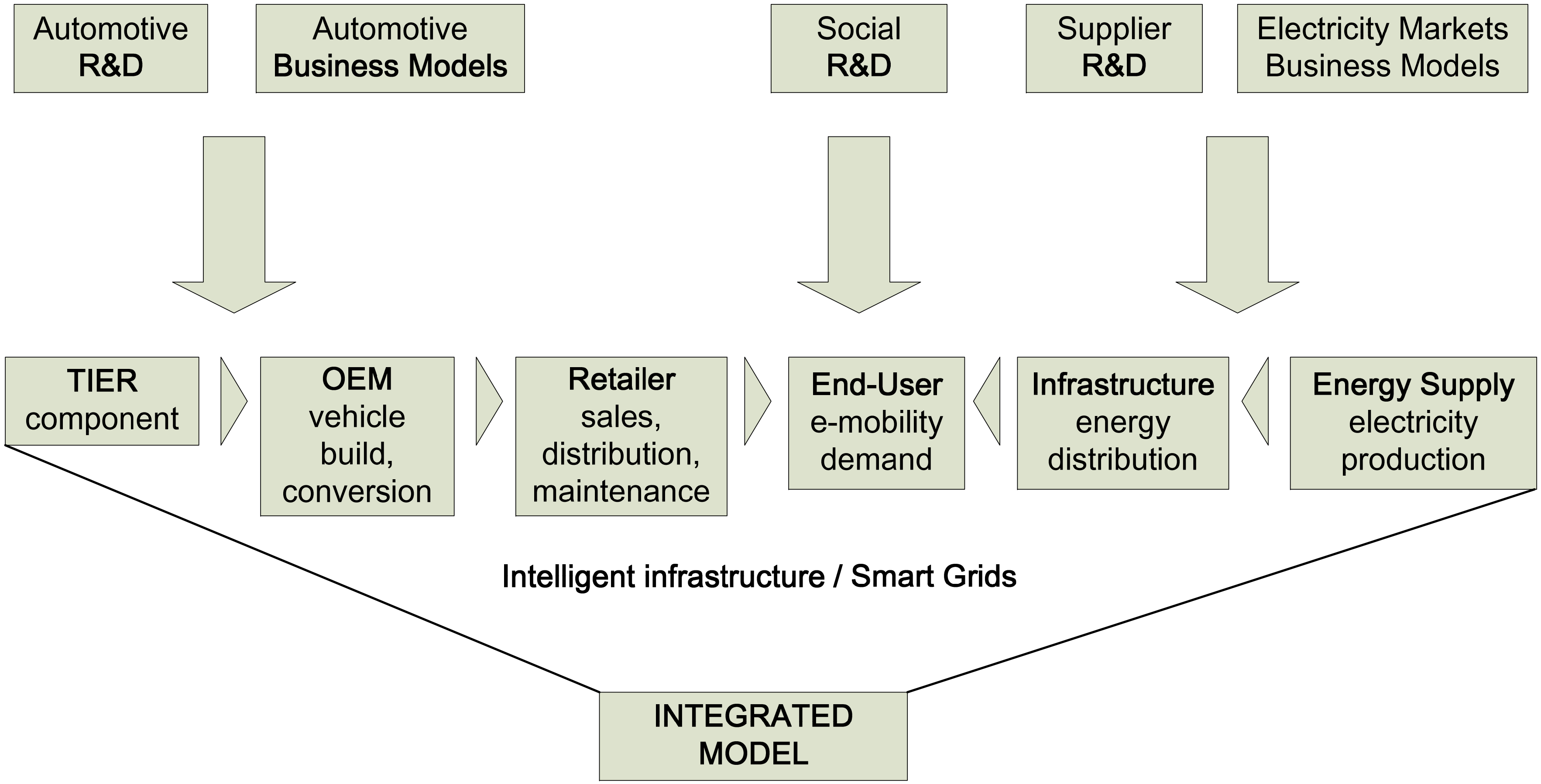
Electric-powered vehicles (cont.)

Parallel full hybrid	In parallel systems, an electric motor—powered by the battery—is connected to the engine flywheel, allowing a clutchless-power train to capture torque from the electric motor in parallel with the engine.
Series full hybrid	In a series hybrid, the engine is used—not to power the wheels—but solely to generate power for electric motor and battery.
Power-split/series full hybrid	This allows the engine power to be split or to behave like a series hybrid with power flowing from the engine to the generator to the electronics and directly to the electric motor and finally to the wheels.

The integration of grid and EV

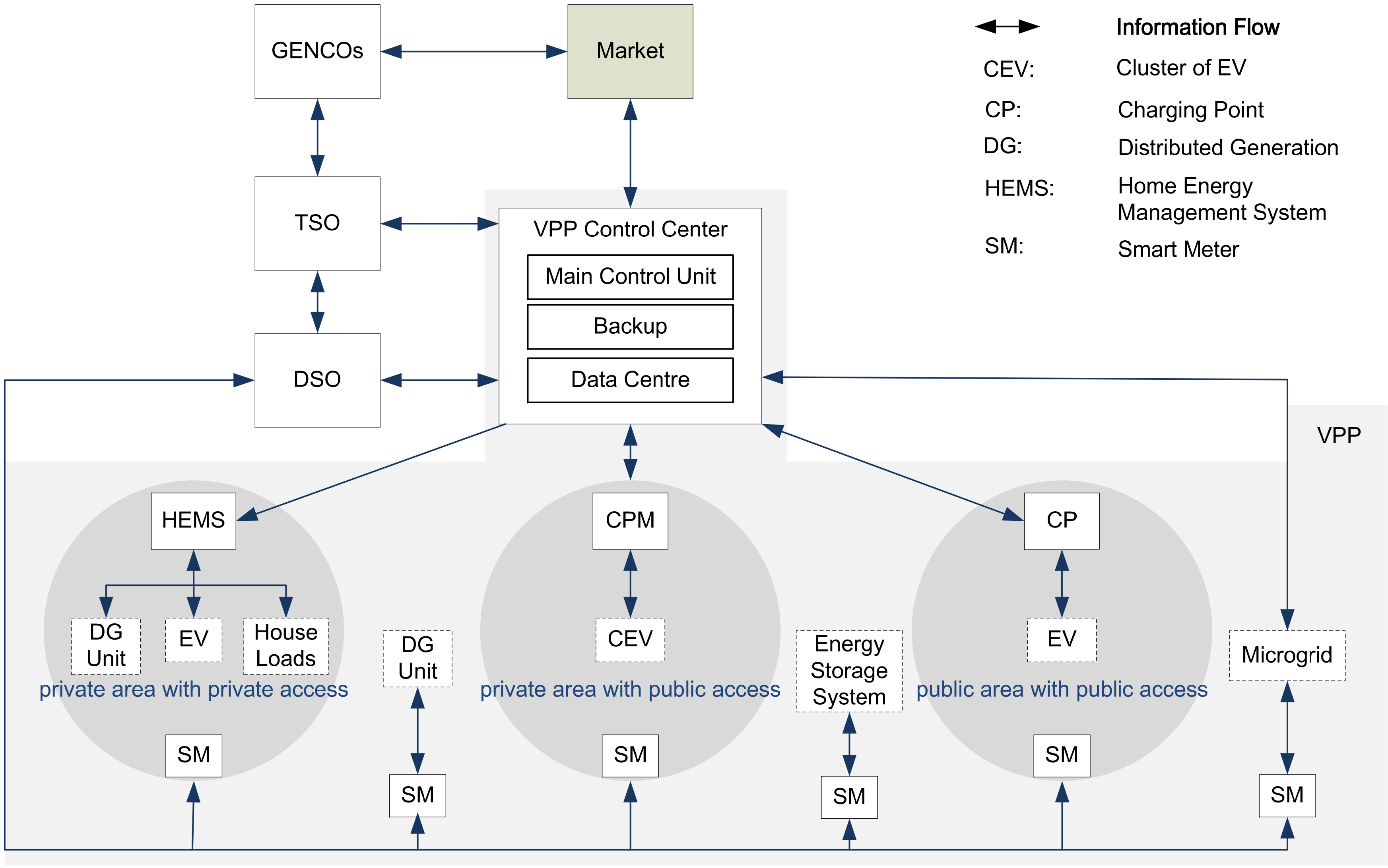
- Electric Vehicle (EV) Integration into **Smart Grid** is to reduce energy cost and usage and to increase the stability of local power system by managing the charging operations of the EVs.
- Two primary types of power interactions are possible between the vehicle and the electric grid.
  - **Grid-to-vehicle charging (G2V)** – consists of the electric grid providing energy to the plug-in vehicle through a charge port
  - **Vehicle-to-grid (V2G)** - capable vehicle has the ability to provide energy back to the electric grid.

Integrated model



Source: Cardiff University Integrated approach of EVs integration

Figure 1. Interaction between the VPP control center and the VPP resources, DSO, TSO and market in the direct control approach

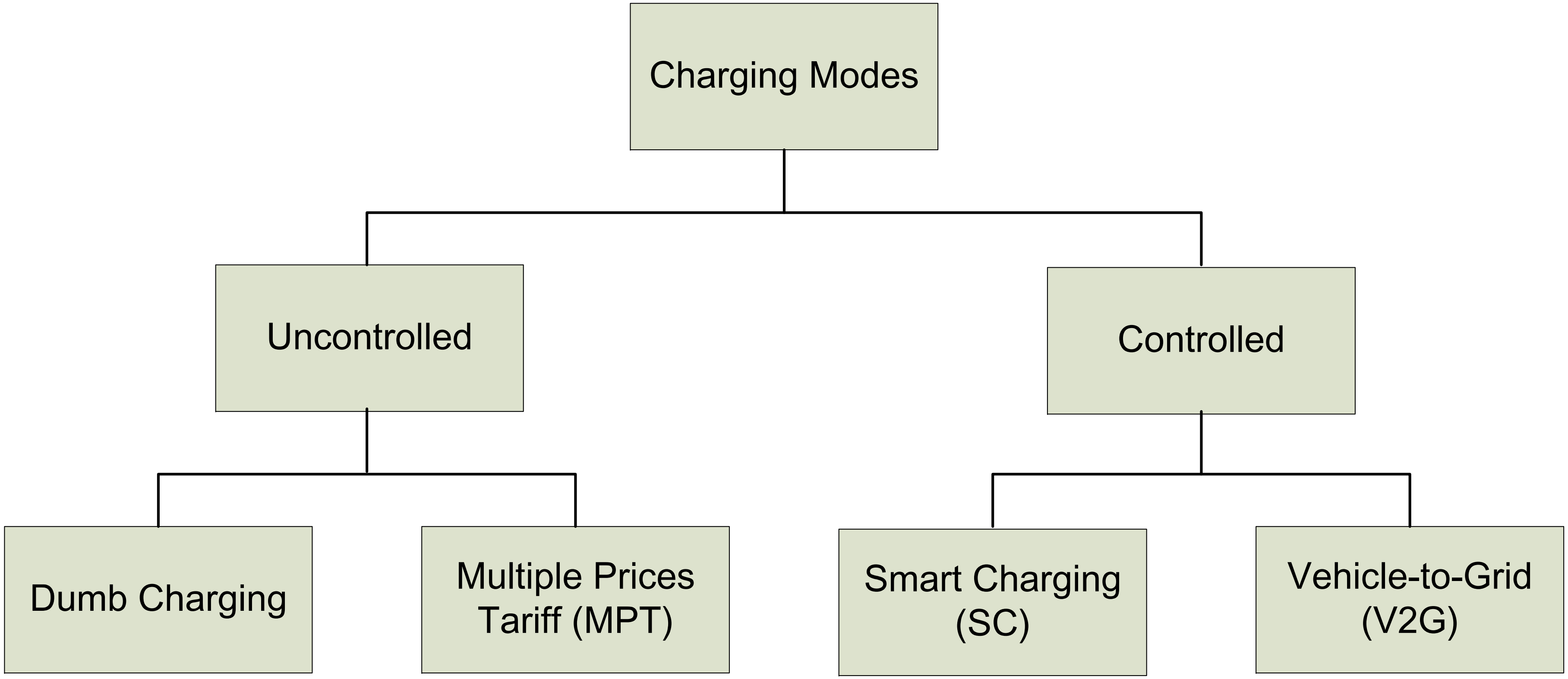


Source: "Virtual Power Plant Control Concepts with Electric Vehicles," ISAP 2011, Greece, 2011.

Possible EV charging approaches

- EV as **uncontrollable static loads**:
  - EV owners define when and where EV will charge how much power they will require from the **grid** and the period during which they will be connected to it
- EV as **controllable dynamic loads**:
  - EV owners give the **aggregator** the possibility to manage their charging during the period they are connected to the grid
  - They only inform the aggregator about the time during which their vehicles will be connected to the grid and the batteries' SOC they desire at the end of that same period
- EV as controllable dynamic loads and **storage devices**:
  - EV are not regarded just as dynamic loads but also as dispersed energy storage devices
  - They can be used either to absorb energy and store it or inject electricity to grid, acting in a V2G perspective

Charging approaches

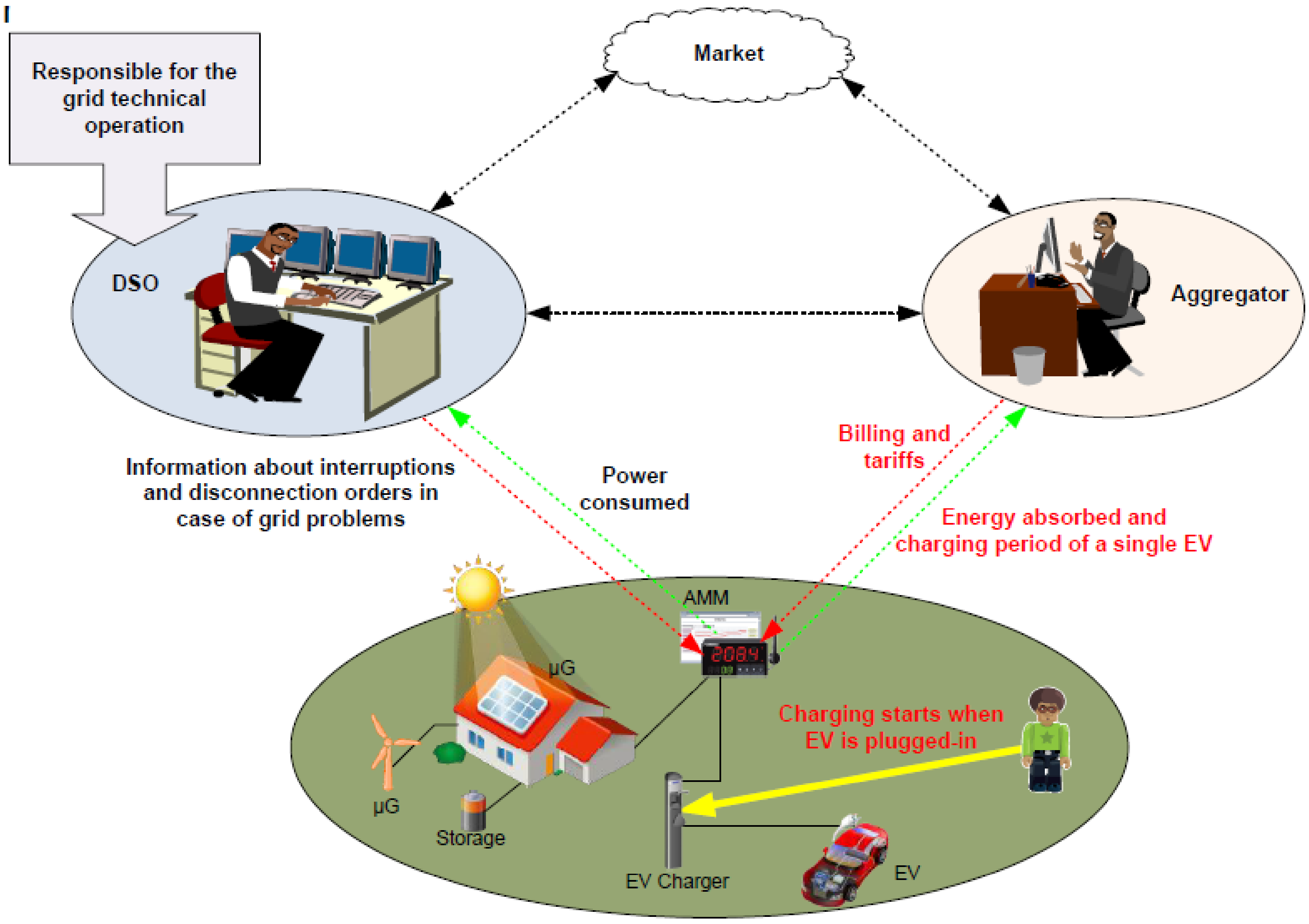


Source: "Advance Metering Infrastructure Functionalities for Electric Mobility," The Proceeding of IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe), Gothenburg, October 2010.

Uncontrolled approaches

- **Dumb charging**
  - EV owners are completely free to charge their vehicles whenever they want; electricity price is assumed to be constant along the day
- **Multiple prices tariff**
  - EV owners are completely free to charge their vehicles whenever they want; electricity price is assumed not to be constant along the day, existing some periods where its cost is lower

Figure 2. Uncontrolled approaches

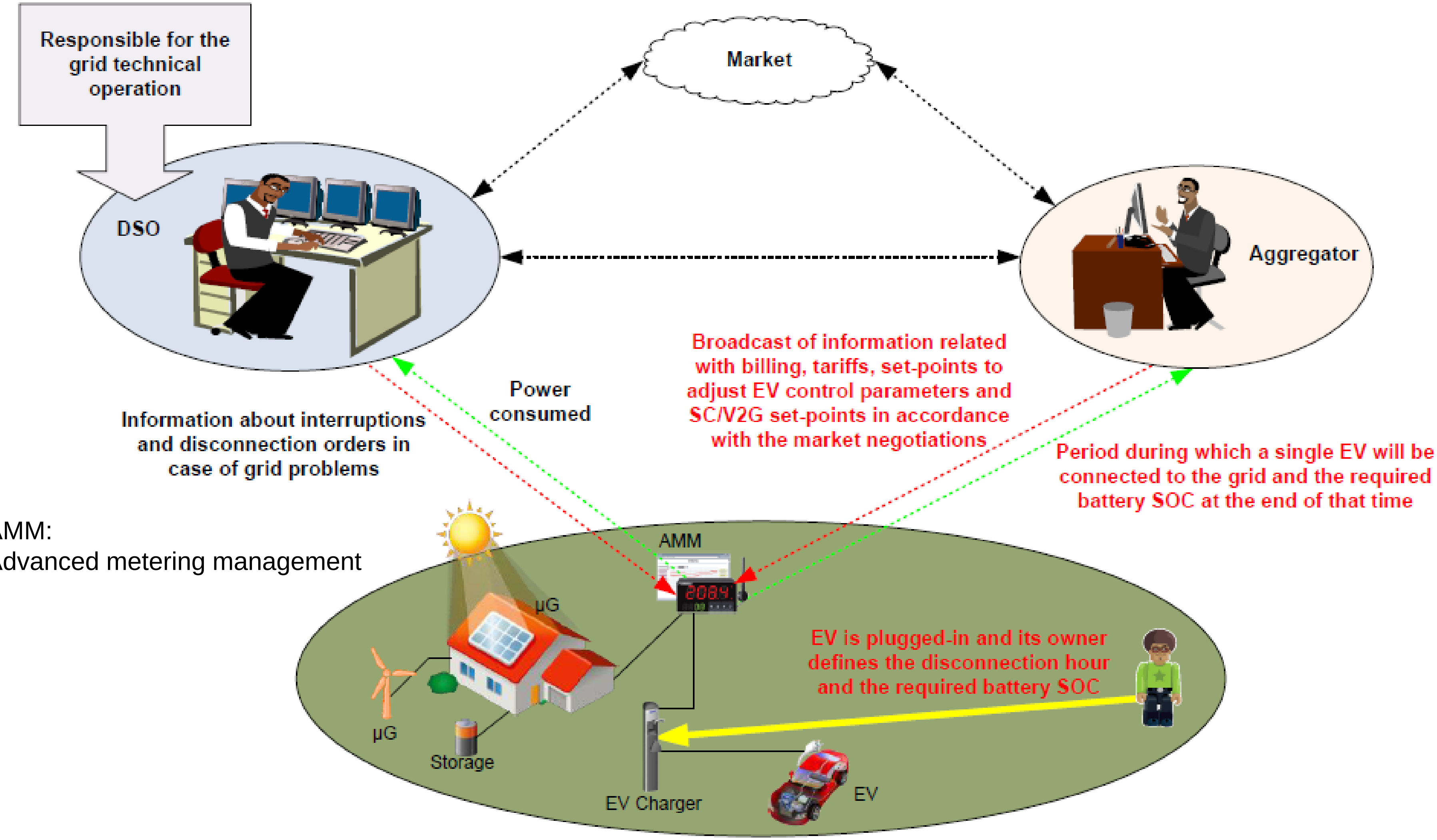


Source: "Advance Metering Infrastructure Functionalities for Electric Mobility," The Proceeding of 2010 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe), Gothenburg, 11-13 October 2010, pp. 1-7

Controllable approaches

- **Smart charging**
  - Active management system where there is an aggregator serving as link between the electricity market and EV owners; enables congestion prevention and voltage control
- **V2G** mode of operation
  - Besides the charging, the aggregator controls the power that EV might inject into the grid; EV have the capability to provide peak power and perform frequency control

Figure 3. Controllable approaches

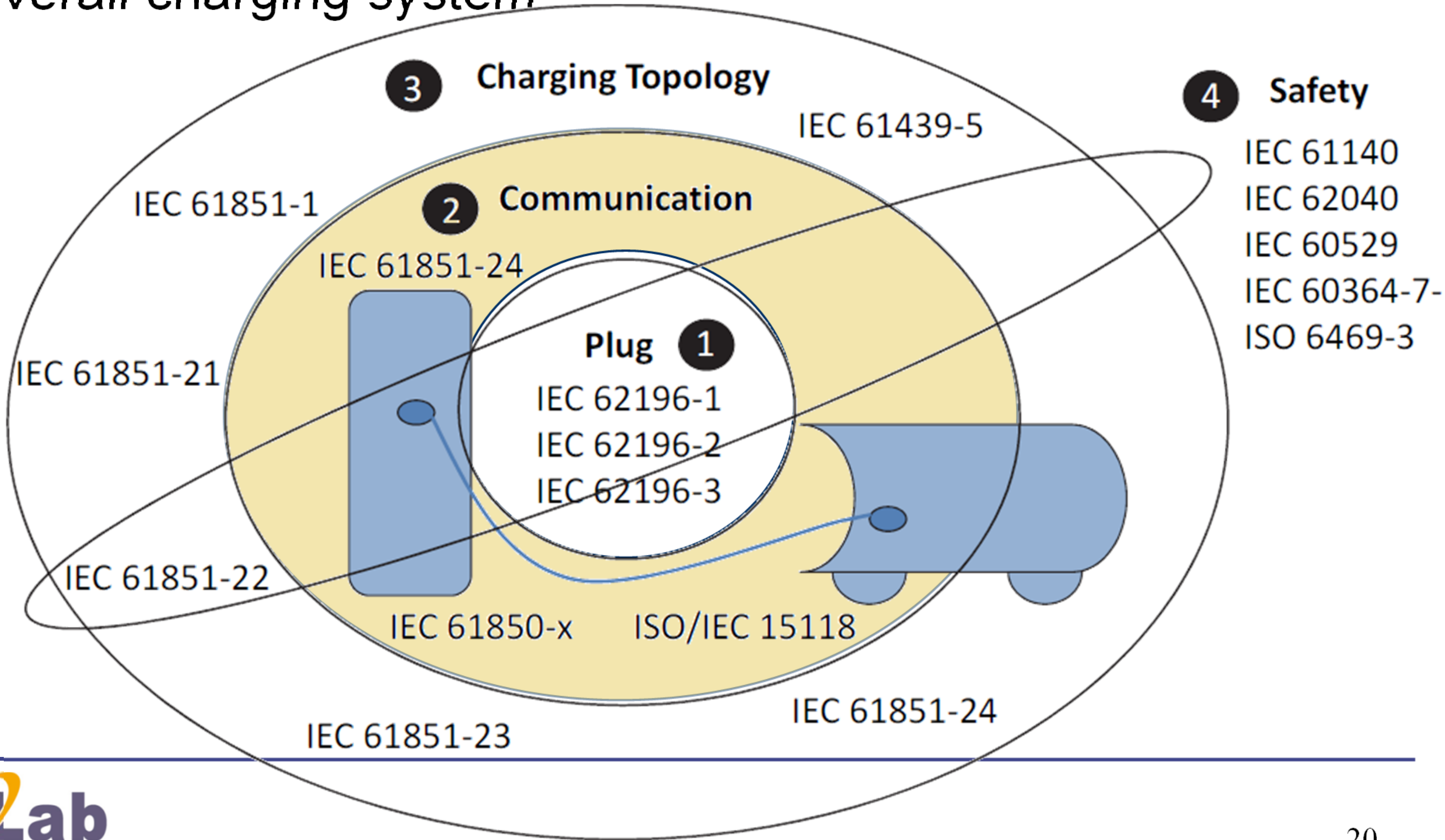


AMM:
Advanced metering management

Source: D. Rua, D. Issicaba, F. J Soares, P. M. R. Almeida, R. J. Rei and J. A. P. Lopes, "Advance Metering Infrastructure Functionalities for Electric Mobility," The Proceeding of 2010 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe), Gothenburg, 11-13 October 2010, pp. 1-7

Standards for conductive charging of EV

- The selection and definition of the connector system will have an effect on the fields of communications, safety and overall charging system



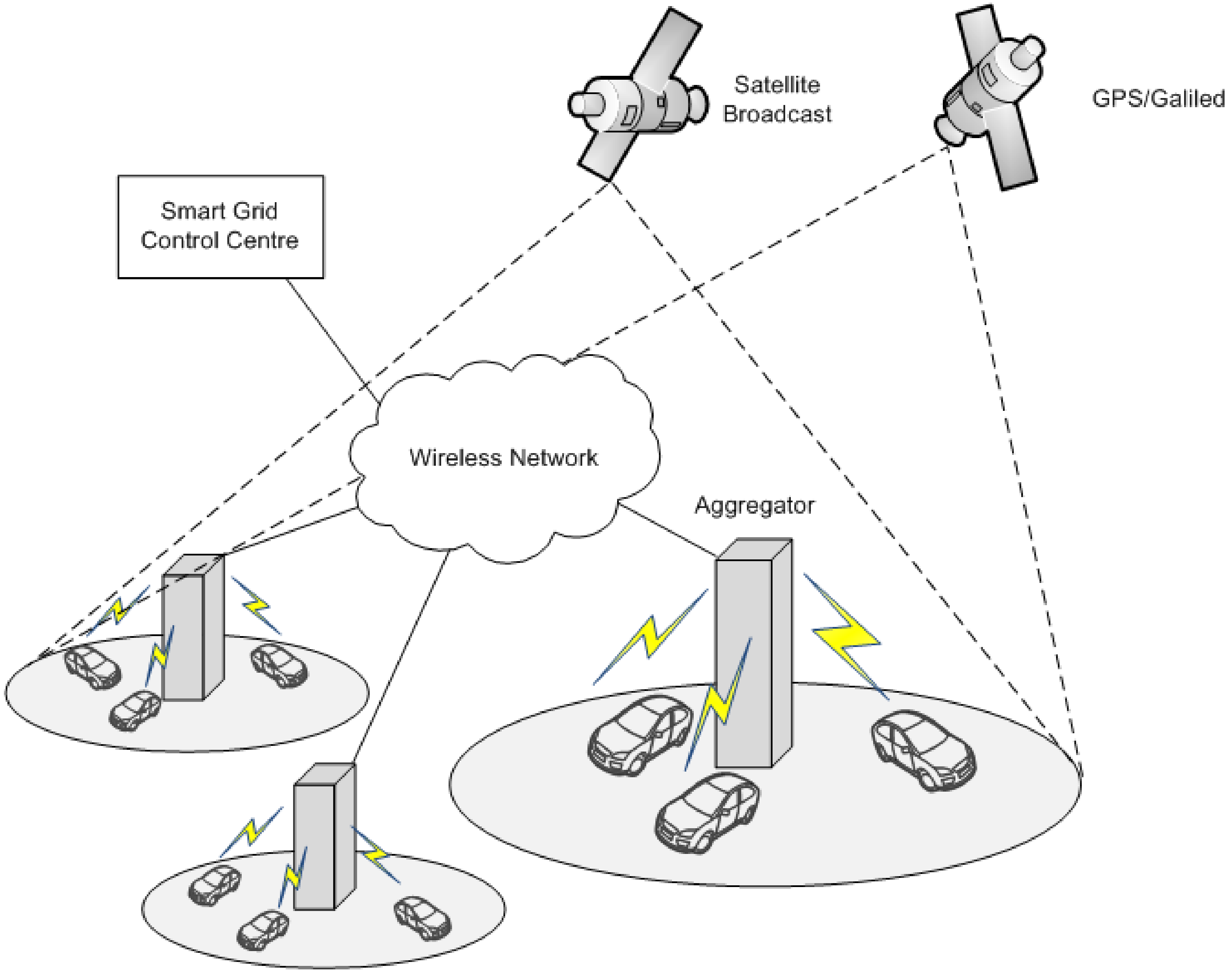
Vehicle to grid

- **Vehicle-to-grid** (**V2G**) describes a system in which plug-in electric vehicles, such as electric cars (BEVs) and plug-in hybrids (PHEVs), communicate with the **power grid** to sell **demand response** services by either delivering electricity into the grid or by throttling their charging rate.
- Vehicle-to-grid can be used with such ***gridable*** vehicles, that is, plug-in electric vehicles (BEVs and PHEVs), with grid capacity.

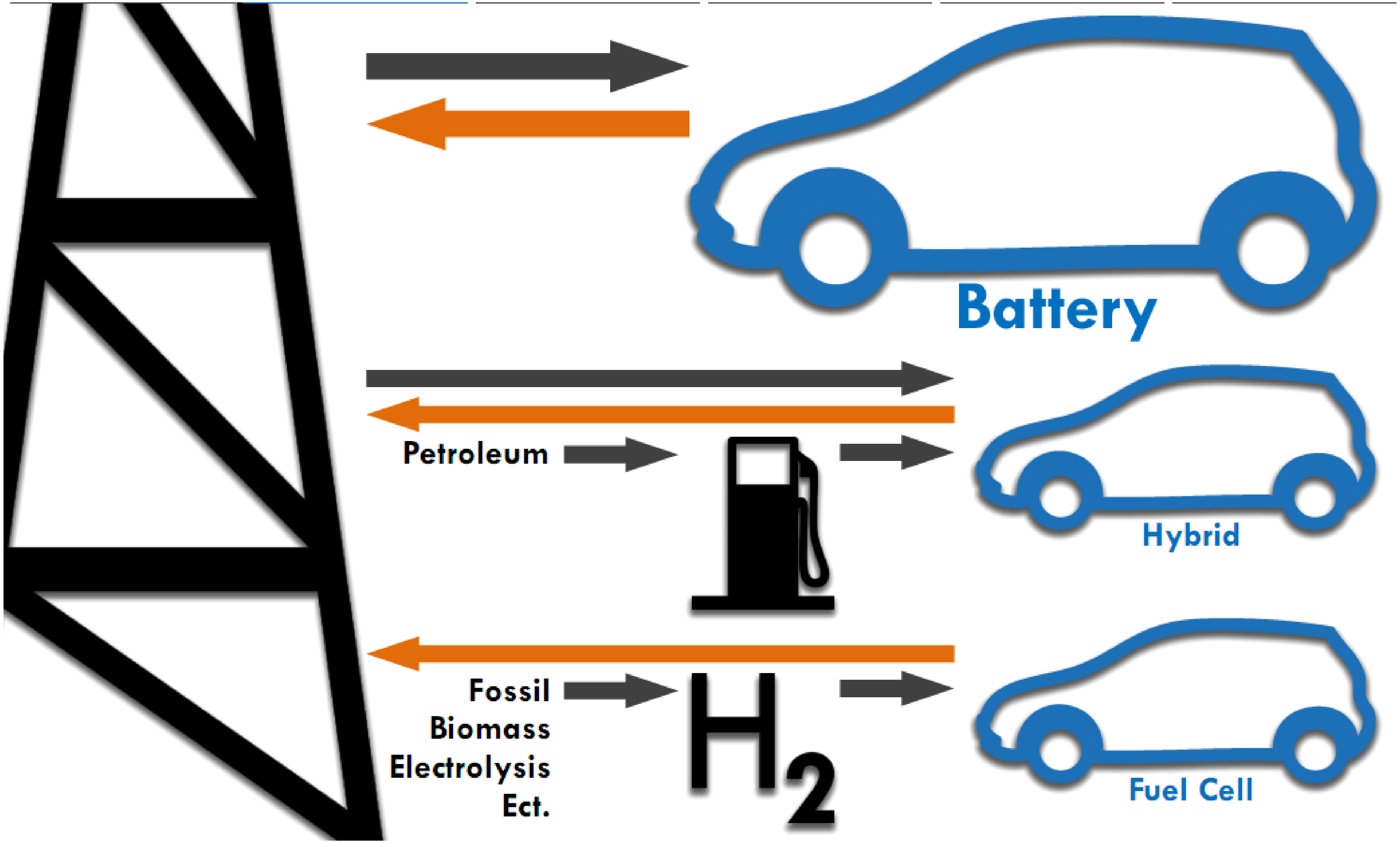
Vehicle to grid (cont.)

- V2G technology utilizes the stored energy in electric vehicle batteries to **contribute electricity back** to the grid when the grid operators request it.
- The V2G concept is that battery, hybrid, and fuel cell vehicles all can send power to the electric grid, power that all three already generate internally.
  - For battery and plug-in hybrid vehicles, the power connection is already there.
  - For fuel cell and fuel-only hybrids, an electrical connection must be added.

System model of V2G



V2G concept



Source: Zpryme Filled under: Electric Vehicles

V2G concept (cont.)

- A battery-powered or plug-in hybrid vehicle which uses its **excess rechargeable battery capacity** to **provide power to the electric grid** in response to peak load demands. These vehicles can then be recharged during off-peak hours at cheaper rates while helping to absorb excess night time generation. Here the vehicles serve as a distributed battery storage system to buffer power.
- A hybrid or Fuel cell vehicle, which generates power from storable fuel, uses its generator to produce power for a utility at peak electricity usage times. Here the vehicles serve as a distributed generation system, producing power from conventional fossil fuels or hydrogen.

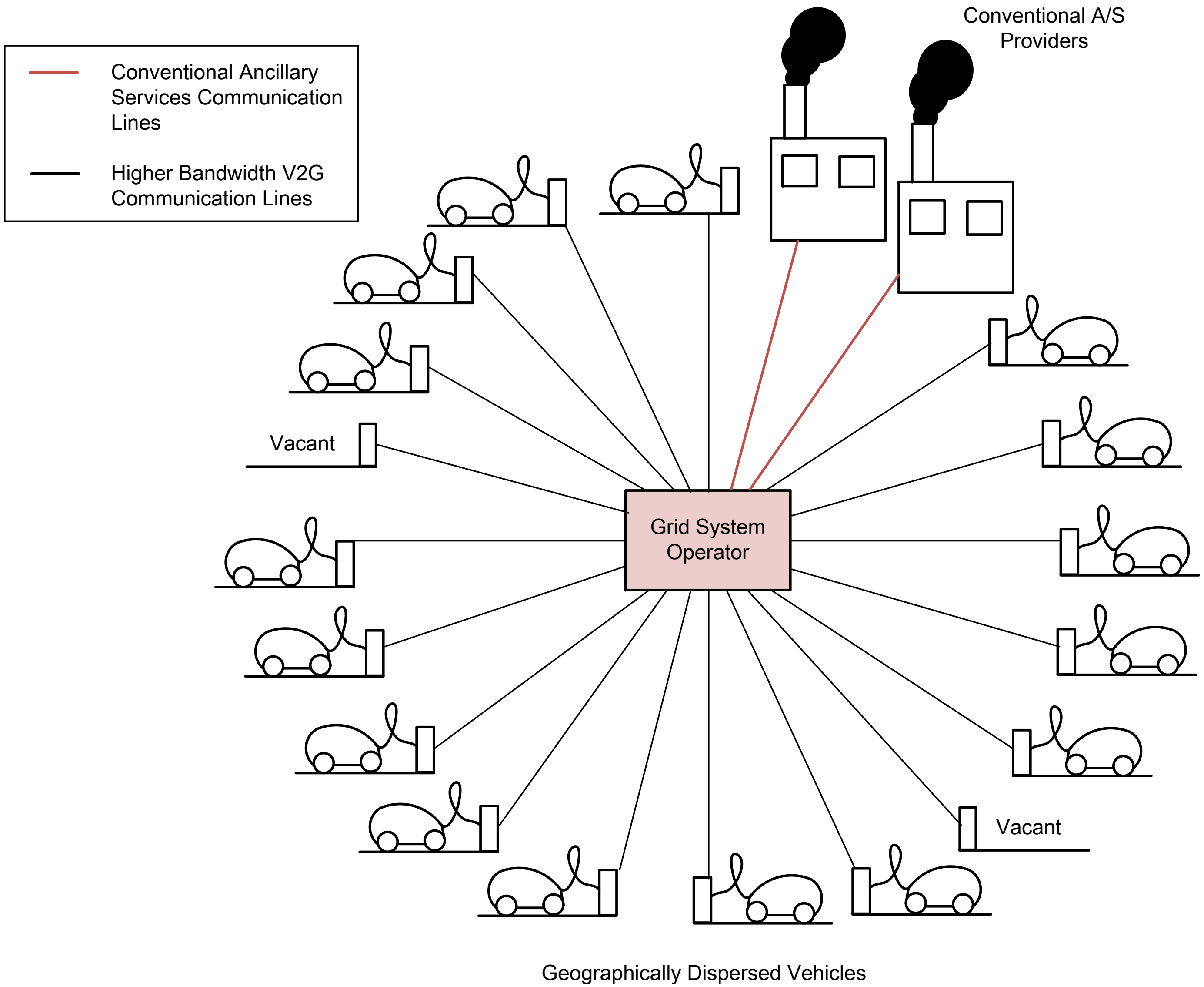
Architecture

- There are two architectures of V2G ancillary services with the goal of directing the development of a near-term feasible and economically viable V2G infrastructure.
  - The direct, deterministic architecture
  - The aggregative architecture

The direct, deterministic architecture

- The **direct, deterministic** architecture assumes that there exists a direct line of communication between the grid system operator and the vehicle so that each vehicle can be treated as a deterministic resource to be commanded by the grid system operator.
- Under **the direct, deterministic** architecture, the vehicle is allowed to bid and perform services while it is at the charging station. When the vehicle leaves the charging station, the contracted payment for the previous full hours is made and the contract is ended.
- The **direct, deterministic** architecture is conceptually simple but it has recognized problems in terms of near-term feasibility and long-term scalability.

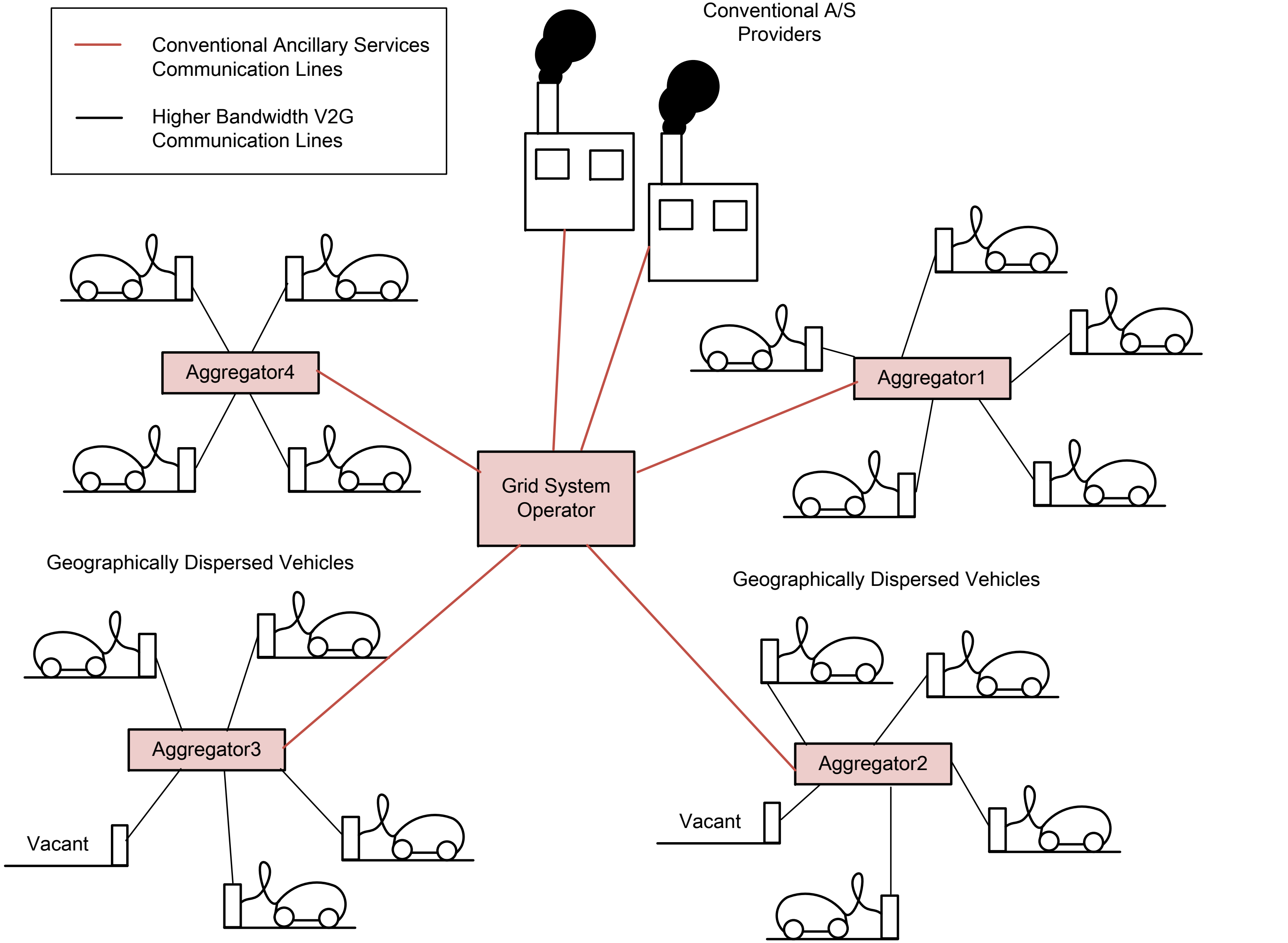
Figure 4. The direct, deterministic architecture



The aggregative architecture

- In **the aggregative** architecture, an intermediary is inserted between the vehicles performing ancillary services and the grid system operator.
- This **aggregator** receives ancillary service requests from the grid system operator and issues power commands to contracted vehicles that are both available and willing to perform the required services.
- Under **the aggregative** architecture, the aggregator can bid to perform ancillary services at any time, while the individual vehicles can engage and disengage from the aggregator as they arrive at and leave from charging stations.

Figure 5. The aggregative architecture



Cost-emission optimization

- Journal of Power Sources, Vol. 195, Issue 3, pp.898-911, Feb 2010. (Ahmed Yousuf Saber *et al.*)
- Objective function
  - **Fuel cost**
  - **Emission**
  - **Start-up cost**
  - Shut-down cost
    - Shut-down cost is constant and the typical value is zero in standard systems.

Fuel cost

- Fuel cost of a thermal unit is expressed as a second order function of generated power of the unit.

$$\mathcal{FC}_i(P_i(t)) = a_i + b_i P_i(t) + c_i P_i^2(t)$$

where a_i, b_i and c_i are positive fuel cost coefficients of unit i.

$\mathcal{FC}_i()$	fuel cost function of unit i
$P_i(t)$	output power of ith unit at time t

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Emission

- For environment friendly power production, emission effects should be considered. Like the fuel cost curve, the emission curve can also be expressed as polynomial function and order depends on desired accuracy. Here, quadratic function is considered for the emission curve as below

$$\mathcal{EC}_i(P_i(t)) = \alpha_i + \beta_i P_i(t) + \gamma_i P_i^2(t)$$

- where α_i, β_i and γ_i are emission coefficients of unit *i*.

$\mathcal{EC}_i()$	emission cost function of unit i
$P_i(t)$	output power of ith unit at time t

Start-up cost

- The start-up cost for restarting a decommitted thermal unit, which is related to the temperature of the boiler, is included in the model. Here, simplified start up cost is applied as follows:

$$\mathcal{SC}_i(t) = \begin{cases} h-cost_i & MD_i \le X_i^{off}(t) \le H_i^{off} \\ c-cost_i & X_i^{off}(t) > H_i^{off} \end{cases}$$

$$H_i^{off} = MD_i + c-s-hour_i.$$

$\mathcal{SC}_i()$	start-up cost function of unit i
$h\text{-}cost_i$	hot start-up cost of ith unit
$c\text{-}cost_i$	cold start-up cost of ith unit
MU_i / MD_i	minimum up/down time of unit i
$X_i^{on}(t)$	duration of continuously on of unit i at time t
$X_i^{off}(t)$	duration of continuously off of unit i at time t
$c\text{-}s\text{-}hour_i$	cold start hour of ith unit

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3. Vehicle to cloud

- Looking to the ultimate goal of the “connected car”, the automotive world is increasingly opening up to the “outside” world, to the Internet and to the “consumer electronics” devices.
- In this view, the connected car can receive on board rich information (i.e. traffic, advanced navigation, car parks, etc.) and high-quality multimedia entertainment; allow the car to communicate with the passenger’s consumer devices (mobiles, smart phones, tablets, etc.); enable interaction with central infrastructures for data collection and exchange.
- The objective is to connect cars to the “**Cloud**”.
  - **Vehicle to Cloud (V2C) Connectivity**

Ford CTO Paul Mascarenas says

- A car with a global positioning system connected to the cloud "**always knows where it is, and always knows what's ahead**," Ford CTO Paul Mascarenas said in a presentation.

- Over the long term, vehicles will serve as **wireless gateways** that manage and collect data a number of devices or sensors deployed in vehicles and highway infrastructure, utilizing **4G cellular** as the **last-mile wide-area connection** to the **cloud**.

Vehicle to cloud

- It introduces vehicle-to-cloud services and content, transforming the car into the ultimate connected mobile device.
- **Vehicle-to-cloud** now takes its place alongside vehicle-to-vehicle and vehicle-to-infrastructure technologies.
- Through **broadband wireless access**, users will be able to share content across devices, platforms and environments, such as streaming and synchronizing media content between the home and the vehicle.

Data of the cloud

- Data from a number of **heterogeneous sensors** such as GPS, odometer, **inertial measurement unit** (IMU**), laser scanners**, cameras and RGB-D cameras used by connected vehicles and moving entities have to be fused properly and efficiently for accomplishing the ITS tasks.

Cloud Quest Technologies (CQT) project

- "Vehicle to Cloud" (V2C) is innovative **Software as a Service** (**SaaS**) solution and technology platform to perform automotive related solutions.
- In the cloud, the data reports information such as mileage, driving behavior, fuel efficiency and it allows for potential failures to be diagnosed before they happen, reducing in-field breakdowns (and associated costs can be significantly reduced).

Source: http://cloudquestec.com/

Cont.

- CQT's vehicle management product is based on delivering the following framework:
  - **Smart Vehicle Modules (SVM)**" are hybrid hardware devices for the car which extract vehicle data by understanding the car lingo (engine conditions, sensors, cameras, …) while sending that information to the cloud via a data connection.
  - The hardware modules can be installed as a first fit and/ or aftermarket application which real time reports data to the driver via a **mobile application**, Personal Navigation Device (PND), embedded application or via the WEB.
- In the vehicle, it is CQT's mission to provide drivers with the best multi-modal human machine interface powered by the **Smart Vehicle Module** (SVM) and its connectivity to other auto electronic devices.

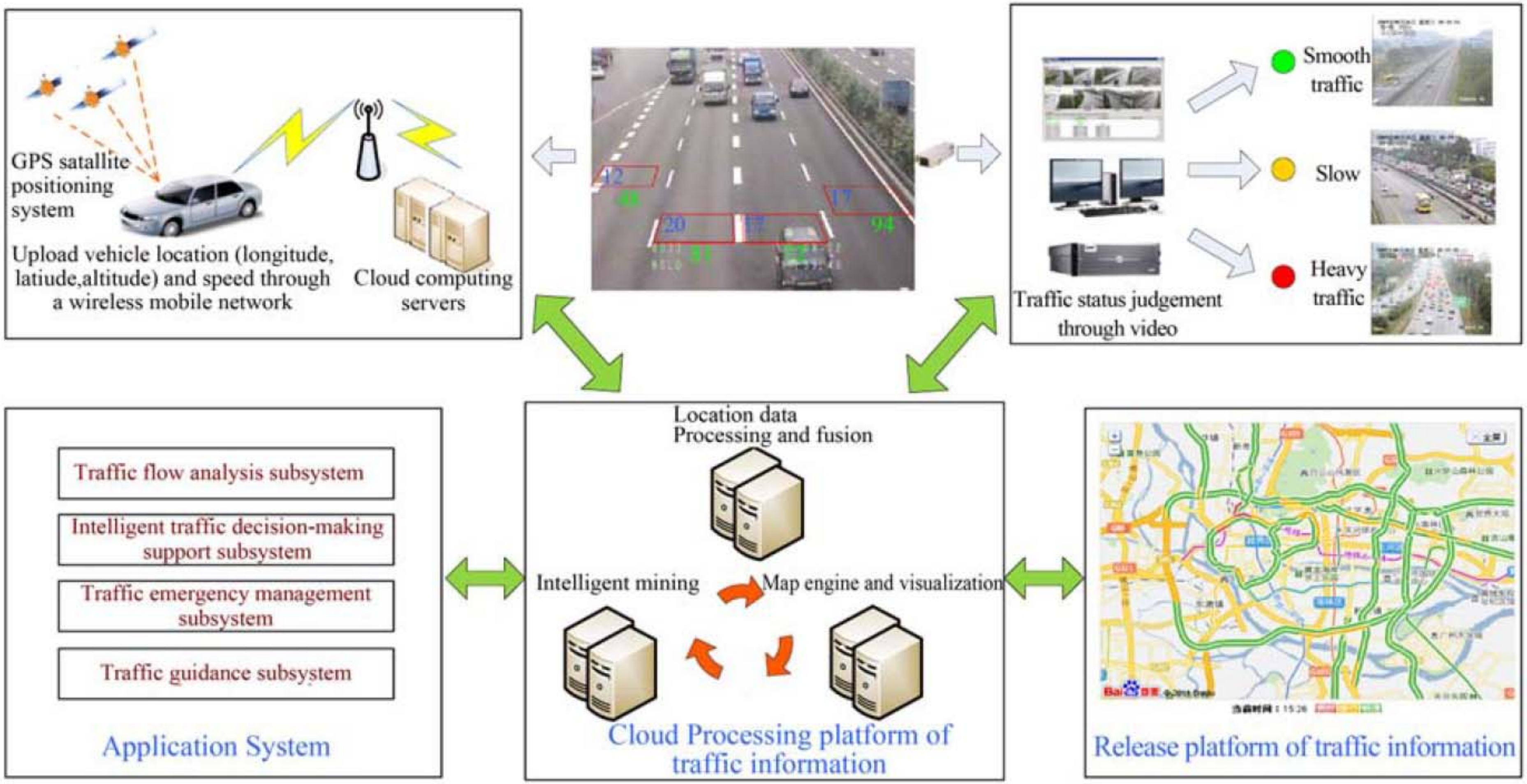
Case study

- **Intelligent cloud processing platform for traffic flow**
- Intelligent disaster management system

Case study: **intelligent cloud processing platform for traffic flow**

- **Traffic flow analyzing subsystem**
  - Combine Cloud Computing with data mining algorithms do some intelligent analysis on data, ex tract and dig out the deep level forecast information hidden in the data, and get the model and rules used by decision making systems.
- **Intelligent traffic decision making**
  - This subsystem provides data collection, query, statistics and other management functions , and can assist different roads management departments to do decision making analysis.

Figure 6. Architecture of intelligent cloud processing platform based on Internet of Car



Source: Z. Min, and D. Junping, "Cloud-Processing platform for Traffic Flow Based on Internet of Car," China Communications, 2011, 8(6): 86-92

Three modules

- The platform includes three modules:
  - **Traffic information collection** module is used to implement real time collection of traffic information based on Cloud Computing technology;
  - **Traffic information processing** module is used to verify, process and display the data collected;
  - **Basic data of traffic information management** module is used to manage historical database, real time database, fusion information database, release database that store traffic information, including organization, storage, retrieval, updating, maintenance and statistics of data, providing data services for other applications.

Data of the cloud processing

- Data of the cloud processing network platform will be obtained through the following ways :
  - **GPS** gives out the running cars positions and velocity, and 3G wireless network sends the information to cloud processing network platform;
  - **Microwave speed** device will be installed on some of the roads , the detection results will be sent to cloud processing network platform;
  - **Video monitoring** system will be installed on some of the roads , traffic flow can be analyzed from the traffic video, and then 3G wireless network sends the information to cloud processing network platform.

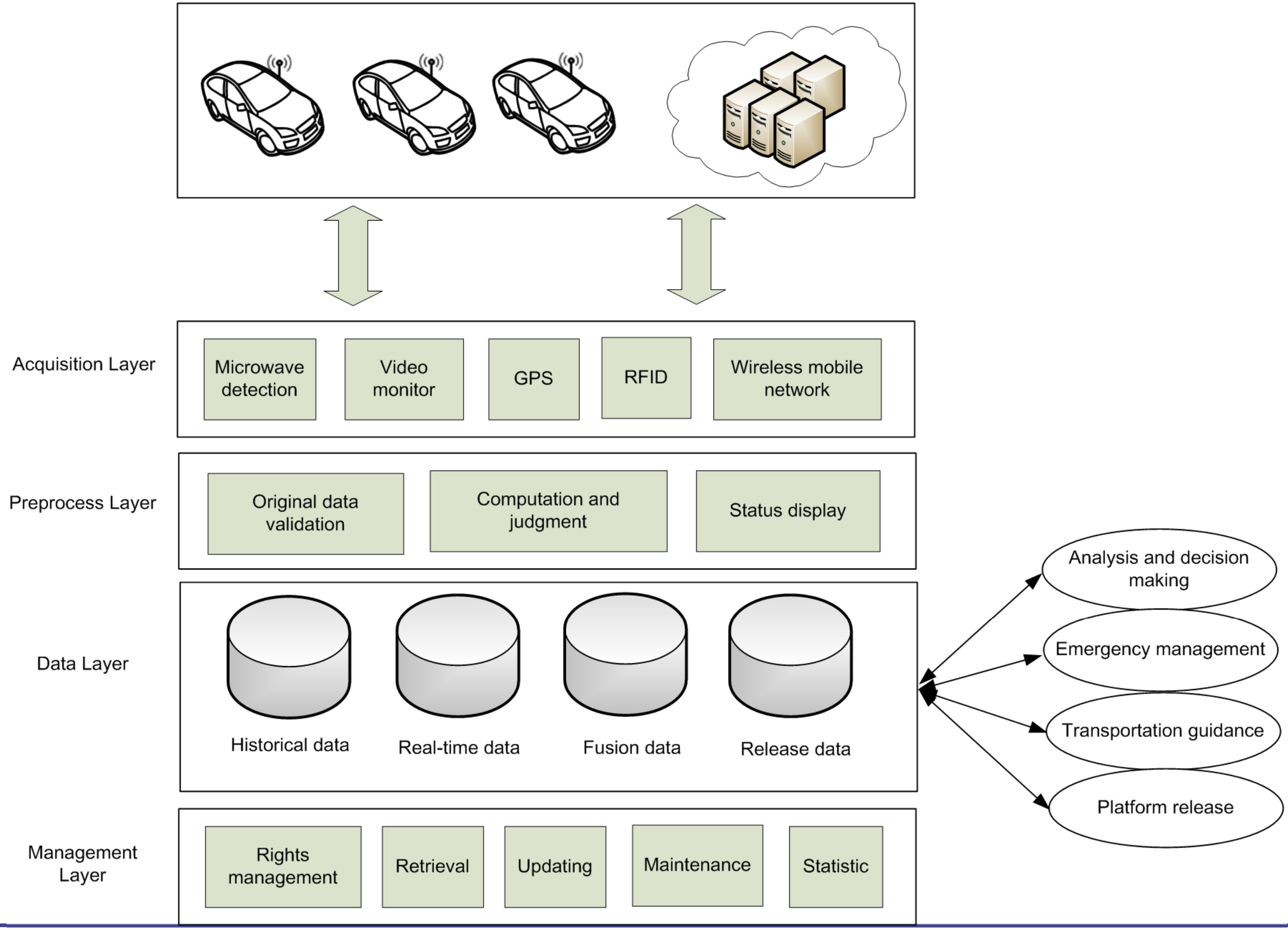
Intelligent traffic guidance service system

- **Parking guidance system**
  - According to real time and dynamic traffic information guide vehicles parking, find the **nearest** parking location and the **shortest** parking route to reduce the waiting time caused by parking, and increase the use efficiency of the whole roads transport network.
- **Intelligent traffic control and guidance integrated** system based on parallel system method
  - ITS adopts thought of artificial transportation systems and parallel systems to solve the integration implementation problems of traffic control and traffic guidance, and provides new ideas and methods for the integration of traffic control and traffic guidance.

Traffic data flow

- Acquisition and processing of traffic flow data
  - Cloud acquisition technology is adopted in acquiring traffic flow data, which are uploaded to the server in the way of wireless communication, as well as preprocessed and stored.
  - The platform consists of Acquisition Layer, Preprocess Layer, Data Layer and Management Layer

Figure 7. Internet of cars based basic data platform of traffic flow information



Cont.

- **Acquisition** Layer:
  - acquisition and generation of all the raw data. In this layer, the car equipped with GPS, intelligent terminals of 3G wireless communication is taken as a traffic flow information detection unit, and network of car information is estimated by the velocity of the car in different roads
- **Preprocess** Layer:
  - raw data validation, calculation, judgment, and the status display.
  - The acquired data should first go through the data validation process to determine whether they meet the predetermined conditions (such as scope, type, or any abnormal situation, etc.);

Cont.

- **Data** Layer:
  - Storage of acquired data and data after a variety of analysis and processing, including historical database, real time database, integrated information database and publication database, as well as providing an integrated generic database interface.
- **Management** Layer:
  - data organization, storage, rights management, retrieval, updating, maintenance and statistics for all kinds of databases storing traffic information, as well as providing data support for other applications .

Realization of cloud computing

- The primary goal of cloud computing is to provide **scalable access to computing resources** and **IT services**.
- In this platform, car not only provides traffic flow data, but also uses traffic flow data, which forms a complete information feedback system and makes it possible to control and optimize traffic flow.
- This new information collecting method has many advantages, such as low cost, good real time, high controllability, etc.

Case study

- Intelligent cloud processing platform for traffic flow
- **Intelligent disaster management system**

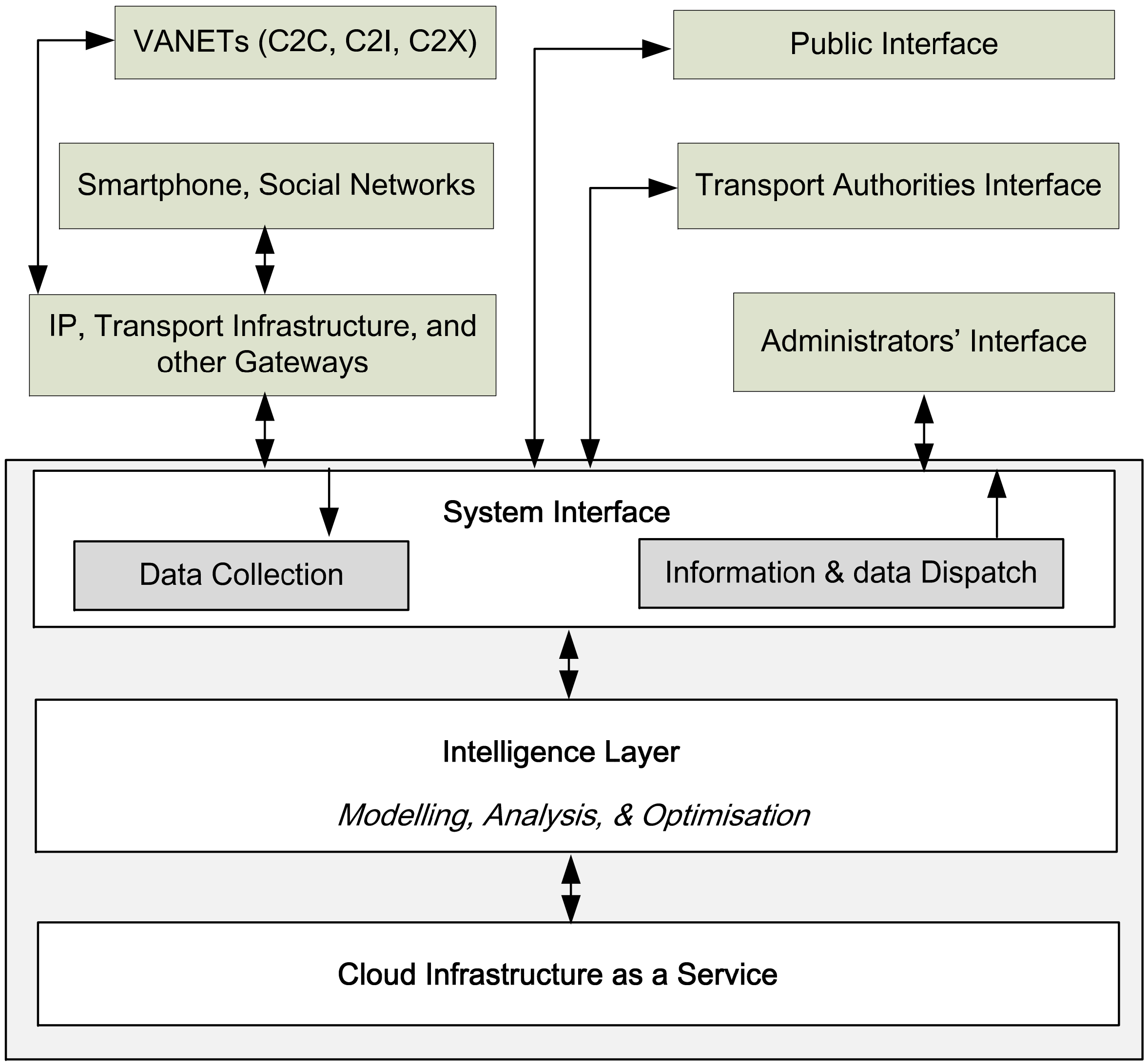
Case study: Intelligent disaster management system

- By exploiting ITS, VANETs, social networks, mobile and Cloud computing technologies, the system is able to gather information from multiple sources and locations, including from the point of incident, and is able to make effective strategies and decisions, and propagate the information to vehicles and other nodes in real-time.

Intelligent disaster management system

- **Intelligent Transportation Systems** (ITS) including VANETs (Vehicular Ad hoc Networks), mobile and Cloud computing technologies to propose an intelligent disaster management system.
- The system is intelligent because it is able to gather information from multiple sources and locations, including from the point of incident, and is able to make effective strategies and decisions, and propagate the information to vehicles and other nodes in real-time.
- The ability to monitor and manage transportation system in real-time and at high granularity has grown tremendously due to sensor and vehicular network that generate huge amount of extremely useful data.

Figure 8. Emergency response system architecture



Source: Z. Alazawi, S. Altowaijri, R. Mehood, M. B. Abdljabar, "Intelligent Disaster Management System based on Cloud-enabled Vehicular Networks," ITS Telecommunications (ITST), pp. 361-368, Aug. 2011.

Cont.

- **The Cloud infrastructure layer** provides the base platform and environment for the intelligent emergency response system.
- **The Intelligence Layer** provides the necessary computational models and algorithm in order to devise optimum emergency response strategies by processing of the data available through various sources.
- **The System Interface** acquires data from various gateways including the Internet, transport infrastructure such as roadside masts, mobile smart phones, social networks etc.

Details of the intelligence layer

- The Intelligence layer consists of various mathematical models, algorithms and simulations, both stochastic and deterministic.
- These models accept transport related data received from various sensors such as inductive loops, intra-vehicular sensor networks, VANETs and C2I communications, and user interfaces.
- The data received from various sources goes through an internal validation layer before it is accepted by the modeling and analysis layer.

Compare with traditional method

- **VANET** and **Cloud-based intelligent emergency response system**, which automatically collects data; intelligently processes the data; and, devises and propagates effective strategies and decisions based on the real-time situation, in line with appropriate policies and procedures already in place in the system.
- The difference with traditional method lies in the ability of the system to
  - **Acquire real-time data, and establish communication through VANETs**, **smart phones,** and **social networks**,
  - **Process** the data and devise an optimum strategy by data analysis,
  - **Coordinate** and **control** road traffic and other efforts through dissemination of information and management of the available transport infrastructure.

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4. Solar vehicle application

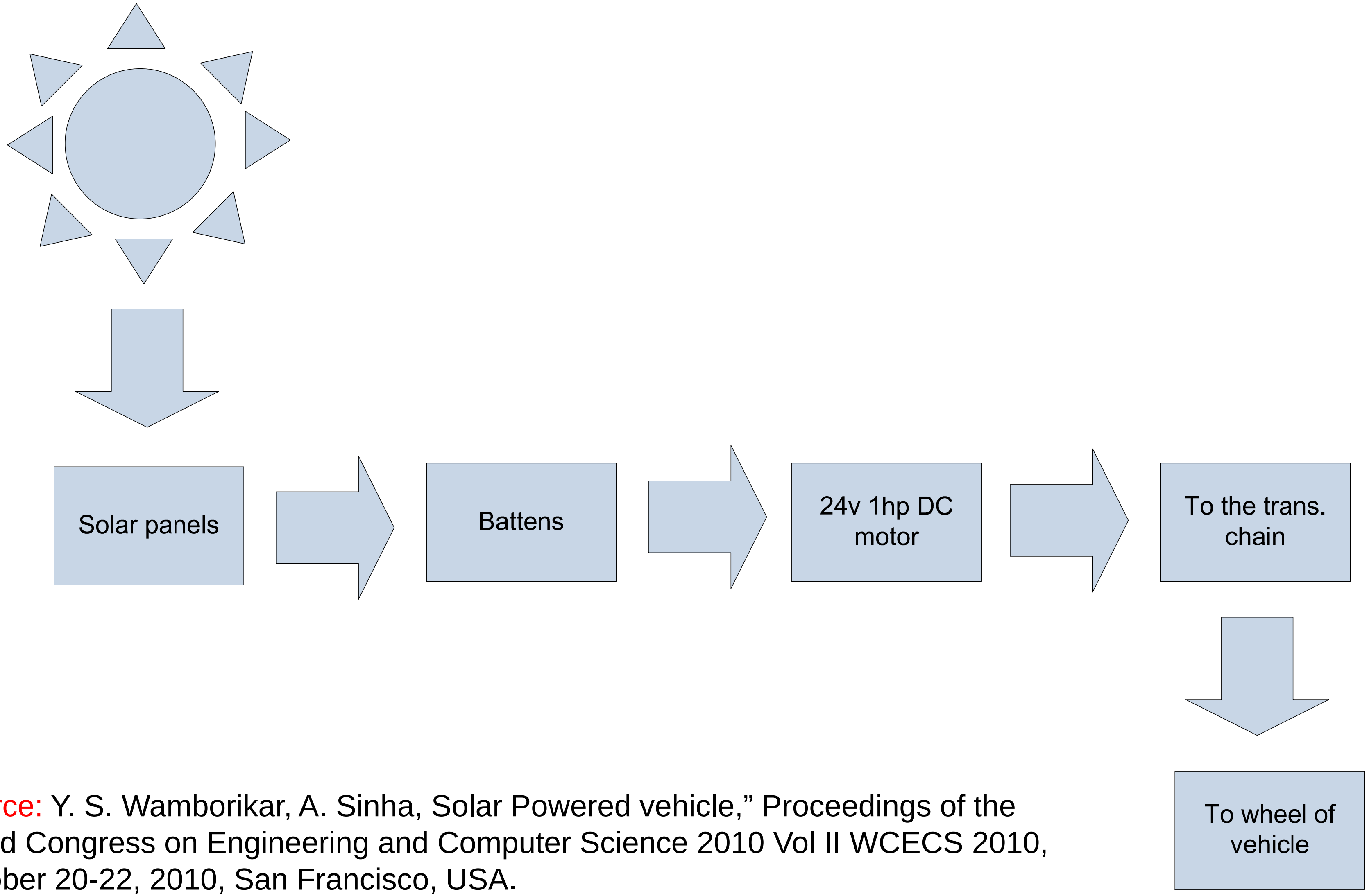
- As fuel costs continue to increase and questions arise regarding the future of our combustible resources, there has been renewed interest in electric and alternative fuel vehicles.
  - A **solar vehicle** is an electric vehicle powered completely or significantly by direct solar energy.
- Usually, photovoltaic (PV) cells contained in solar panels convert the sun's energy directly into electric energy. The term "solar vehicle" usually implies that solar energy is used to power all or part of a vehicle's propulsion.
- Solar power may be also used to provide power for communications or controls or other auxiliary functions.

Solar vehicle

- A **solar powered vehicle** is built by Center for Product Design and Manufacturing (CPDM). It is expected to have sensors that measures temperature, speed, current and batteries' voltage. There is a strong need of monitoring system to allow the research team observes the condition of the solar vehicle.

Source: Z. Taha, R. Passarella, H.X. How, J.M. Sah, N. Ahmad, R.A.R. Ghazilla, and J.H. Yap, "Application of Data Acquisition and Telemetry System into a Solar Vehicle," in Proc. Computer Engineering and Applications, Second International Conference on, March 2010, vol.1, pp.96-100.

Figure 9. Basic block diagram representation of solar vehicle



Source: Y. S. Wamborikar, A. Sinha, Solar Powered vehicle," Proceedings of the World Congress on Engineering and Computer Science 2010 Vol II WCECS 2010, October 20-22, 2010, San Francisco, USA.

Solar energy for vehicle propulsion

- The estimation of net solar energy captured by PV panels in real conditions (i.e. considering clouds, rain etc.) and available for propulsion is accomplished by a solar calculator developed at the US National Renewable Energy Lab.
- The instantaneous power(P(t)) is estimated for assigned vehicle data and driving cycle by integrating a longitudinal vehicle model, expressed by the following Newton law reduced to vehicle wheels:

$$I\frac{d\varpi}{dt} = T_{EM} - T_R$$

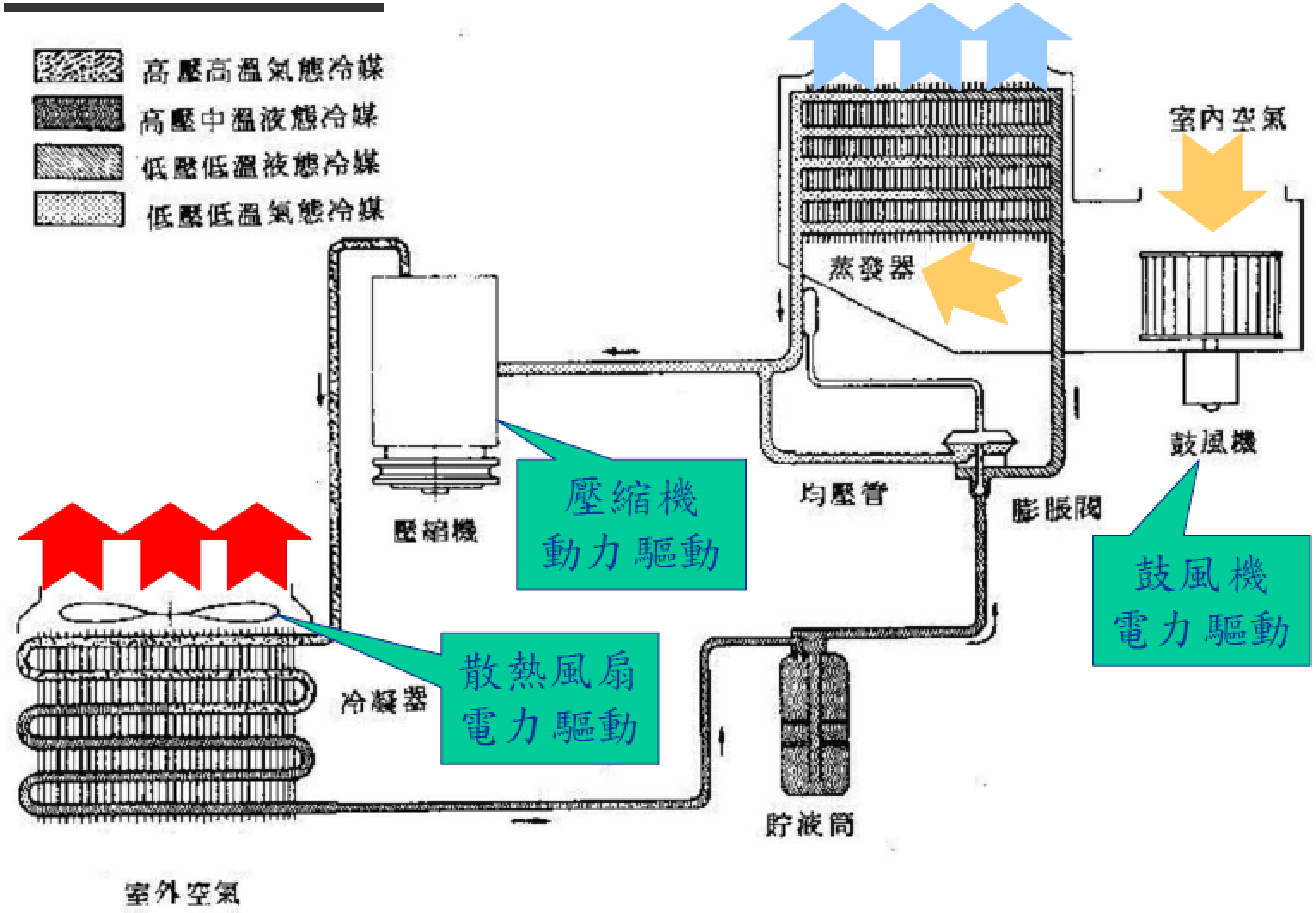
where I is the vehicle inertia, T_{EM} is the *EM* output torque and T_R is the resistant torque due to aero dynamic and rolling resistance.

Case study: 太陽能車用空調系統

- 能通光電研發太陽能車用空調控制系統，包括：太陽能供電裝置、控制裝置、以及動力裝置。
- 由於目前停車廠居多以露天為主，車輛停在露天停車場經過陽光曝曬一段時間之後，易造成車內溫度升高，車內高溫通常介於50~80℃之間，主要的原因是車內空氣不流通導致。
- 在車輛引擎停止運轉時，駕駛者按下控制裝置按鍵後，以啟動控制裝置所輸出的訊號及太陽能供電裝置所輸出的電源來驅動動力裝置，使動力裝置驅動車用空調系統之機械式壓縮機，讓車用空調系統所產生冷氣輸入至車內，使車內室溫保持在人可適應的溫度範圍

Source: 能通光電股份有限公司 http://www.solareasy.com.tw/

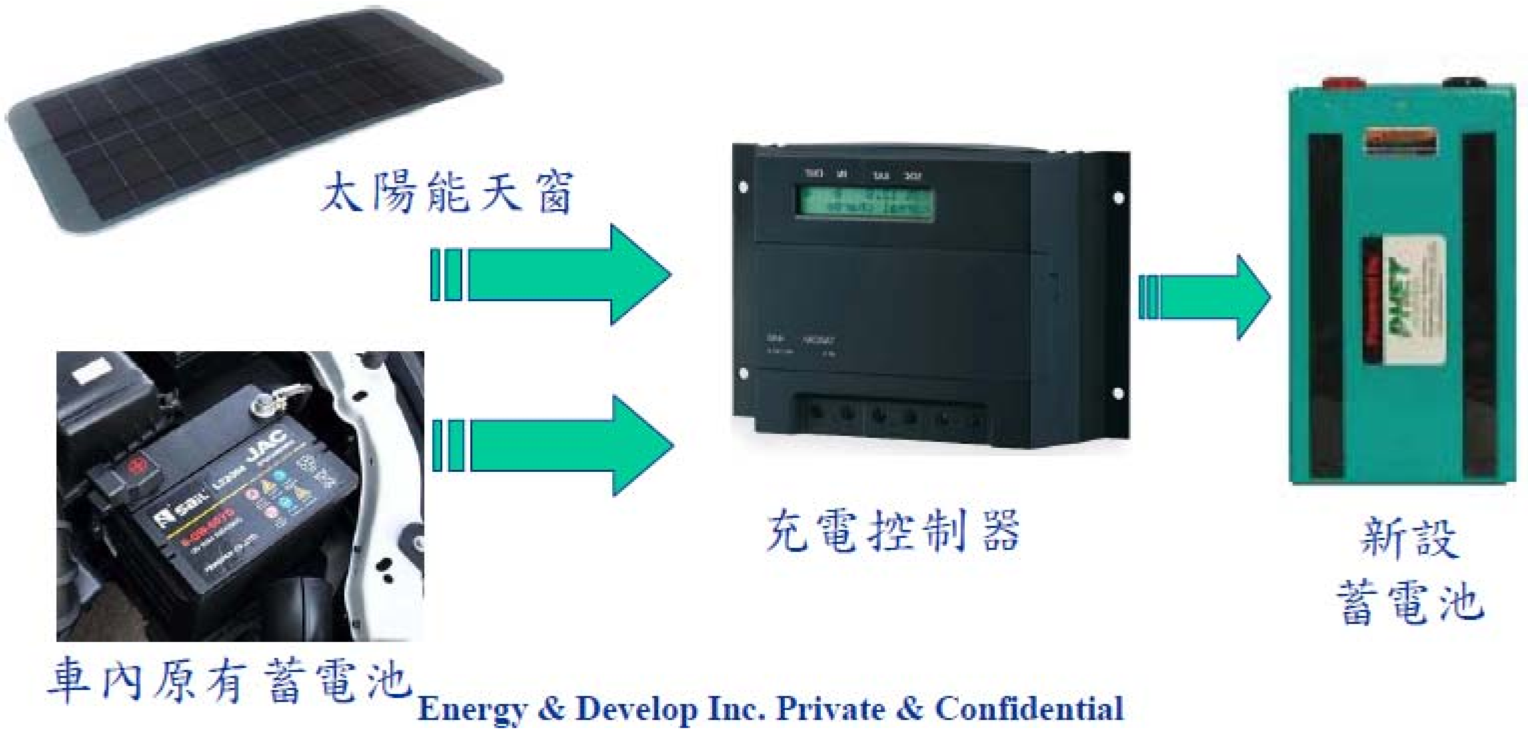
空調系統架構



Source: 能通光電股份有限公司 http://www.solareasy.com.tw/

充電系統架構

- 利用太陽能天窗對蓄電池進行充電，充電控制器必須有最大功率追蹤(MPPT)功能，以達到最有效的充電效率，當太陽能天窗發電效率較低時，啟動車內原有的蓄電池進行充電，讓電力有效持續超過三小時。



Outline

1. Introduction
2. Electric vehicles (EVs)
3. Vehicle to Cloud
4. Solar vehicle application
5. Conclusion

wMNLab NTPU CSIE

5. Conclusion

- This talk addresses the **energy efficiency** of Vehicular technology and application, which is integrating into Smart Grid to reduce **energy cost** and **usage** and to increase the stability of local power system by managing the charging operations of the EVs, introducing vehicle-to-cloud technology and solar vehicle application.

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Homework #9:

1. Try to state the architecture of V2G (**Vehicle-to-Grid**) services?
2. Try to describe the Internet of cars based the basic data platform of traffic flow information architecture of **vehicle-to-cloud**.
3. Try to explain the basic block diagram of **the solar vehicle**.