Chapter 2

Integrating Cloud Computing with Next-Generation Telematics for Energy Sustainability in Vehicular Networks

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Additional information is available at the end of the chapter

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Abstract

This research focuses on new approaches to enhance the economic viability of newer hybrid/electric vehicle technology utilizing a telematic and cloud computing framework. First, an economic foundation is proposed that rewards drivers for energy efficient driver behavior in units of energy based on a predefined standard. Next, a service model is presented that allows drivers to transfer information regarding their energy efficiency through a telematic and cloud computing network. Based on existing cloud computing technology and telematic standards, a network architecture is proposed to transfer this information to service integrators and content providers that can use this information to create vehicle energy resource management capabilities for vehicle users and fleet owners. Such an architecture would enable drivers or fleet owners to redeem energy units for monetary or promotional incentives, thereby realizing more economic value for the vehicle investment.

Keywords: cloud computing, transportation telematics, pervasive computing, connected vehicle networks, mobile networks, vehicle ad-hoc networks, information and communications technology, sustainable mobility

1. Introduction

Recent decades have seen rapid growth in transportation to the point where its sustainability, both economically and environmentally, has been challenged. Vehicle ownership rates and miles driven have nearly tripled since 1950 [1], causing dramatic increases in congestion, pollution, and energy consumption. Furthermore, cars and light trucks alone now consume about 60% of

US transportation energy [2]. The federal government's growing concern over these issues has been realized through a pledge to reduce greenhouse gas emissions by 17% below 2005 levels by 2020 through more mandated stringent fuel economy standards for autos [3]. However, such standards are insufficient to make much of a difference to consumers in the near term since the expense of newer automotive technology can significantly offset fuel economy savings.

In fact, research suggests that the expense of newer hybrid/electric vehicle technology could actually reduce the benefit of a 50% fuel economy improvement by as much as 90% over the expected life of a vehicle [4]. As freeway traffic volume is relatively insensitive to fuel prices, the benefits of fuel economy are marginal at best even as fuel prices continue to climb in the short run. A 10% increase in fuel price would reduce fuel consumption by only less than 1% in the near term [5]. While the long-run benefits of both advanced technology and fuel price behavior may be more promising, such effects may not be realized until the year 2025 [6]. In order for fuel efficient technology to be successful in the near term, it is vital that additional value be created by augmenting it with capabilities such that drivers can realize full economic potential. Research suggests that additional fuel economy savings can be realized at little or no cost through alteration of driving behavior, such as adjusting speeds, aggressiveness, and distances, among others [7]. Further exacerbating this issue is the uncertainty surrounding the impacts on other modes of consumer transportation, namely mass transit. An increase in fuel price is said to have only a modest impact on transit ridership. It is estimated that even a 20% increase in fuel price results in only about a 2% increase in system ridership [8].

In energy, advances in automotive hybrid technology have made available near real-time vehicle fuel consumption information. This information can be leveraged to implement policies aimed at inducing energy-efficient driver behavior by monitoring fuel efficiency across a fleet or community of vehicles and dynamically providing incentives to drivers exhibiting more fuel-efficient behavior in order to preserve limited energy resources. New technology is being considered to help motivate improved driving behavior such as social networking and start-stop technology. Car-to-car communications through connected vehicle technology (CVT) has received widespread attention since it can provide a potential platform for realizing many advanced user services [9] to the extent that the US Department of Transportation has committed significant funding toward research in this area [6, 10]. While potential applications include using car-to-car negotiation to avert collisions [11], control pollution, and to share information about fuel consumption, fuel economy, routes, landmarks, etc., its potential as a platform for energy savings is yet to be fully explored. A CVT network [9] can serve as a possible platform for market-based transportation sustainability by serving as a connected dynamic decentralized system that monitors energy resource usage via the network and allowing drivers to manage their energy quotas with other vehicles in an energy information cloud managed through service providers. The added value of a platform with such capabilities is vital to energy transportation sustainability.

This chapter investigates the design of such a system by combining together economics, telematics, and cloud computing approaches for vehicle energy resource management. In particular, we leverage coordination mechanisms toward realizing an efficient energy resource allocation system incorporating parameters such as fuel efficiency and fuel price, among others. Each vehicle/user could receive energy resource quotas, receive credits for not exceeding them, and could trade any unused energy resources (potentially with businesses as well as other vehicles/users) using a cap and trade (CAT) mechanism [9]. The network would monitor real-time resource usage levels, manage resource accounts, and facilitate economic transactions between vehicles/users/business and service providers that serve as broker centers. In this chapter, we analyze whether such a system is viable from an architecture perspective. We first investigate the economic foundation of a system for on-the-fly vehicle energy management. We then overview the capabilities of telematics toward realizing an efficient energy allocation system incorporating parameters such as fuel efficiency and driving behavior. We then evaluate the implementation of such a system via a cloud-based connected vehicle network platform.

2. Economic foundation

The fuel utilization of a vehicle is defined as its fuel consumption per unit distance. It is determined by a vehicle's technical characteristics, such as weight, aerodynamic design, and type of fuel. A typical driving cycle is comprised of periods of vehicle acceleration and deceleration, braking, stopping, and cruising. Consequently, fuel efficiency is also affected by the consumption during these periods. Driver behavior during each of these periods can profoundly affect fuel efficiency. Overall, it has been shown that the vehicle cruise velocity and the average velocity are powerful predictors of fuel efficiency [12]. The foundation for establishing a usable energy resource framework is the notion of a monetary unit that can quantify the value of preferred driver behavior. While fuel-efficient driver behavior often results in monetary benefits, it is often difficult to value such benefits due to the market fluctuations in fuel prices. At the outset, we can value such benefits in units of fuel, assuming that the price of fuel remains constant. Fundamentally, fuel efficiency can be achieved when drivers drive in a fuel-efficient manner. The benefits to society for driving in a fuel-efficient manner are well known. To this end, drivers can be rewarded in units of fuel (or other incentives) for driving fuel efficiently, stimulating better behavior.

3. Telematics

Telematics is the combination of the transmission of information over a telecommunication network and processing of this information [13]. It is used in sensor applications to capture, store, and exchange data from sensor devices. In the area of automotive telematics, the vehicle in effect becomes a computing platform and exchanges information with other vehicles, drivers, or stationary systems using wireless communication. Such communication is achieved using various wireless communication technologies, such as cellular communication networks, satellite, and dedicated short-range communication, among others. Telematics is also often referred as Information and Communications Technology (ICT). Telematics has advanced to the point where focus is beyond just being able to connect vehicles to each other or to infrastructure [14]. Advanced transport telematics have developed to the point where efforts have focused on standardized platforms that support information services for demand management by providing information such as travel times, congestion levels, and accidents drawn from Internet websites and information services [15].

To communicate such information to entities external to the vehicle, in-vehicle devices need to use over-the-air services using multiple access methods in technologies such as Universal Mobile Telecommunications System (UMTS), wi-fi, third generation (3G) or fourth generation (4G) wireless. To address this issue, a next-generation telematics pattern (NGTP) is under development by a global consortium comprising major automobile industry players. Unlike its predecessor, the short-lived global system for telematics (GST) project which focused on a service-oriented architecture (SOA) approach to running multiple services on an in-vehicle or mobile computing system, NGTP offers a new telematics framework and a technology-neutral open telematics protocol to bring greater flexibility and scalability to delivering over-the-air services to in-vehicle devices and handsets [16]. NGTP 2.0 is being positioned as a pattern versus a protocol standard, where a pattern is a common paradigm used to address a common reoccurring problem [17], similar to the context used in software engineering. This approach can accelerate development and integration among various entities and enable an open, flexible, and technology-neutral approach using existing technologies to the extent possible. NGTP 2.0 promotes a standard message format used to unidirectionally transmit data from a telematic unit (TU) residing in a vehicle to a dispatch (DSPT) function that extracts the message from the bearer so that it can be handled transparently from backend systems.

The NGTP 2.0 message contains fields that house header, DSPT, and service data. The service data field is essentially the data payload which could include road and vehicle information. Approaches have even been proposed to incorporate road information obtained from a telematic system to manage energy within hybrid-electric vehicles [18]. More recently, standards have been developed to transfer standardized information about vehicle fleets [19] over a telematics interface. The Association of Equipment Management Professionals (AEMP) Telematics Data Standard is an extensible markup language (XML) Web service that provides fleet information as a resource, typically on the Internet at a known uniform resource location (URL). Clients access the information sending requests to the server at the given Internet location. The server responds with an XML equipment information document whose vocabulary is defined by the standard. This architecture thus enables a path to transfer vehicle data from a telematic service provider to a vehicle owner. The data fields include header information detailing attributes about the vehicle (e.g., make, model, serial number), location (e.g., latitude and longitude), operating hours, fuel consumption, and distance traveled. Such data provide the foundation for utilizing the economic parameters described earlier. To leverage this information for Web services, XML has been reconciled with the predominant use of abstract syntax notation one (ASN.1) for efficient data transfer over cellular networks, which can integrate XML-encoding rules (XER) [20]. NGTP 2.0 can support both XML and ASN.1 encodings.

4. Cloud computing

A cloud computing platform could provide a feasible backend to the telematics frontend. Cloud computing is an Internet-based model which has been developed based on parallel, grid, and distributed computing concepts. Recently, cloud computing has become a commercialized service offering by many information technology (IT) companies so that client companies can

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offload the operation of their IT software, platforms, and infrastructure to reduce capital and operating costs. It enables organizations to access and configure these resources as a shared pool. Cloud computing infrastructure is based largely on a distributed paradigm, using distributed processing, memory, and data storage. It relies on advanced technology to data and resources. These cloud computing service providers can federate many network-based resources such as servers and storage systems into virtual resource pools on a large scale. In this environment, applications can run in remote distributed systems versus on a single computer or server. Cloud computing also supports the pervasive computing paradigm, in which a user can rely on many interoperating computers working behind the scenes. Using virtualization, hardware and software can be integrated in a unified context and dynamically configured as resources [21]. Examples of cloud computing service offerings include Amazon EC2, which provides a virtual environment for users to run applications [22]; Google app engine which, which allows users to run applications using the python language and provides Web-based interface to manage application execution [23]; Microsoft Azure, which provides a platform to deploy and manage Web-based applications and Microsoft-managed datacenters [24]; and Aneka which provides application programming interfaces (APIs) and tools for rapid development and management of cloud applications [25].

Cloud computer offerings have been classified into software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). SaaS consumers use the provider's applications running on a cloud infrastructure, accessing them using various client devices through a thin client interface such as a Web browser. The underlying cloud infrastructure includes network, servers, operating systems, and storage that are invisible to the consumer. SaaS providers are likely to be PaaS consumers, paying for memory, storage environments, and tools when they create SaaS applications. PaaS providers are consumers of IaaS providers, who offer cloud resources as virtualized resources pools, again masking the underlying computing and communications infrastructure that comprise the cloud. These roles have developed to the point where they have been standardized [26]. There have been numerous successful applications of cloud computing including college campus resource management [27], bioinformatics [28], medical information integration [29], land resource information management [30], and so on. The distributed nature of cloud computing offers the ubiquity required to support processing information obtained from large numbers of geographically dispersed vehicles.

5. Service model

The service model for the above can be conceptualized from the user perspective in **Figure 1**. In this figure, agents residing in the vehicle will collect and transmit energy-related data, as well as other vehicle information, over a presiding wireless bearer air interface. Many different wireless approaches can be used to access the cloud platform from a TU residing in a vehicle. Currently, 3G wireless data services such as evolution data optimized (EVDO), wideband code division multiple access (W-CDMA), and high-speed packet access (HSPA) have typical upload data rates in the range of 50–400 Kbps, while fourth-generation (4G) data

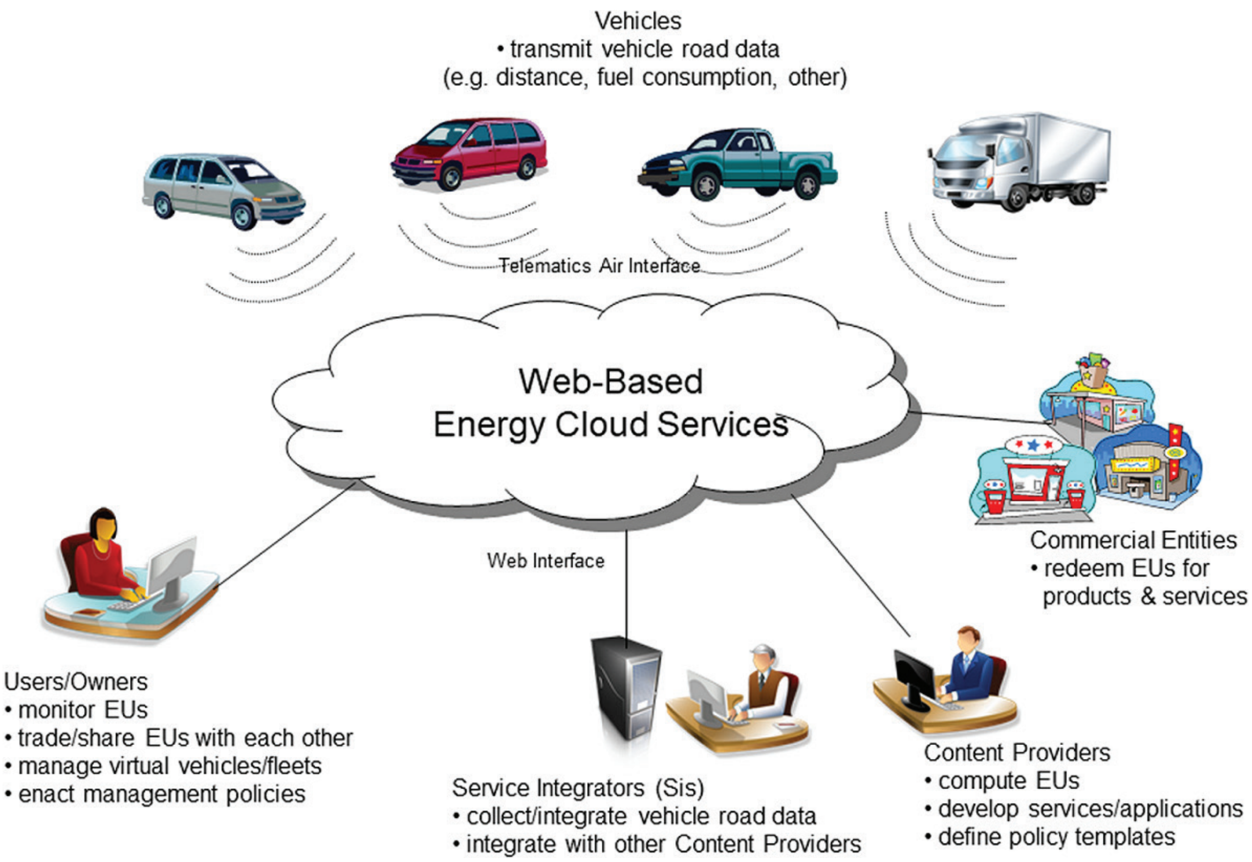

Figure 1. Service model.

services can achieve much higher data rates [31]. The least amount of data that is uploaded from a TU at a given time, the more expedient and economical the service will be. For energy consumption management, it is necessary to employ a data management cycle driven by the types of information that is being reported to the cloud [32]. For vehicles, a popular cycle is the driving cycle, usually associated with a single trip [12]. This cycle has also been adapted by AEMP. As discussed earlier in the UPS application, uploading such information at the conclusion of a drive cycle (or trip) may be more convenient.

From the user perspective, vehicle information is managed by a service integrator (SI) function, as defined by NGTP 2.0. The SI will collect vehicle data and publish them to content providers (CPs) who will develop the services and applications that users or owners can access to manage vehicle or fleet energy consumption. These applications can be developed as per the user's needs. The SI function avoids having CPs to develop custom code to integrate the data with their internal applications. Under NGTP 2.0, SIs and CPs are defined as functions (or roles), so there is no reason why they could be provided by the same organizational entity. For example, today, there are telematic service providers which users can subscribe to in order to obtain services such as pay-for-use insurance, location-based information, and road-side assistance. In these instances, the telematics service provider acts as the SI and CP.

In our model, users can access their services either through a Web portal, desktop application, or mobile app. The user can be presented with a virtual vehicle (VV), which is an abstraction of their physical vehicle. Users can also group multiple virtual vehicles into a virtual fleet (VF). Users can define the access control and the frequency of data collection for each vehicle and/or vehicle fleet. The aforementioned vehicle energy parameters require only mild computational effort and can be associated with both user and vehicle profile management so that the user can manage driver behavior at the individual vehicle or fleet level. Much of this behavior will be driven by the accumulation of EUs and how well the user can capitalize on either trading them with other users or redeeming them for products and services. This creates the opportunity to integrate information delivery with e-mail, blogs, wikis, and social networking services. Trading can be done according to the aforementioned types of policies, whereby CPs can create the virtual policy templates within the applications to enact such policies.

6. System model

The service model would be supported by a system model that calls for coherent integration of a variety of technologies related to cloud computing and telematics. This integration is visualized in **Figure 2** by using a layered approach. The telematic layer embodies many of the capabilities discussed earlier. The TU would utilize a software agent in the form of a fixed or downloadable application atop an open/standard embedded vehicle platform such as open services gateway initiative vehicle expert group (OSGI/VEG), AutoStar, automotive multimedia interface collaboration (AMI-C), cooperative vehicle-infrastructure systems (CVIS), OSEK virtual document exchange (OSEK/VDX), or android. Such platforms offer a middleware layer that standardizes APIs such that service providers or vehicle manufacturers can deliver service solutions more easily [33]. Such systems will utilize real-time operating systems such as QNX or Linux. The vehicle data layer comprises two functions as defined in NGTP 2.0. The DSPT function communicates with the TU, encodes or decodes the dispatcher portions of the NGTP messages, selects wireless bearers depending on the situation at hand, and manages connectivity to the TU. The service handler (SH) function encodes or decodes the service data portions of the NGTP messages, applies additional user or vehicle information, and may conceal certain vehicle characteristics. The DSPT-SH interface focuses on the transportation of information versus analyzing message content. The vehicle virtualization layer acts as a manager and collector of vehicle information and virtualizes the physical vehicles, so that users need not worry about the physical vehicle locations. This layer becomes the enabler for vehicle information applications and management. This layer comprises the SI and CP functions, both defined earlier. Unlike the vehicle data layer, most of the functions of the vehicle virtualization layer are service oriented versus technology oriented. With such information, the physical vehicle can then be abstracted into the virtual vehicle whose characteristics can be offered for use by various applications. Each virtual vehicle will publish data and metadata that describe the technical characteristics of the vehicle (e.g., owner, vehicle identification number, rated fuel efficiency) as well as trip characteristics (e.g., fuel consumption, distance, and time). Information collected from vehicles can be published to different CPs, depending on the context of the application. Different Web services or applications can access the data. An application can subscribe to multiple vehicles or vehicle fleets.

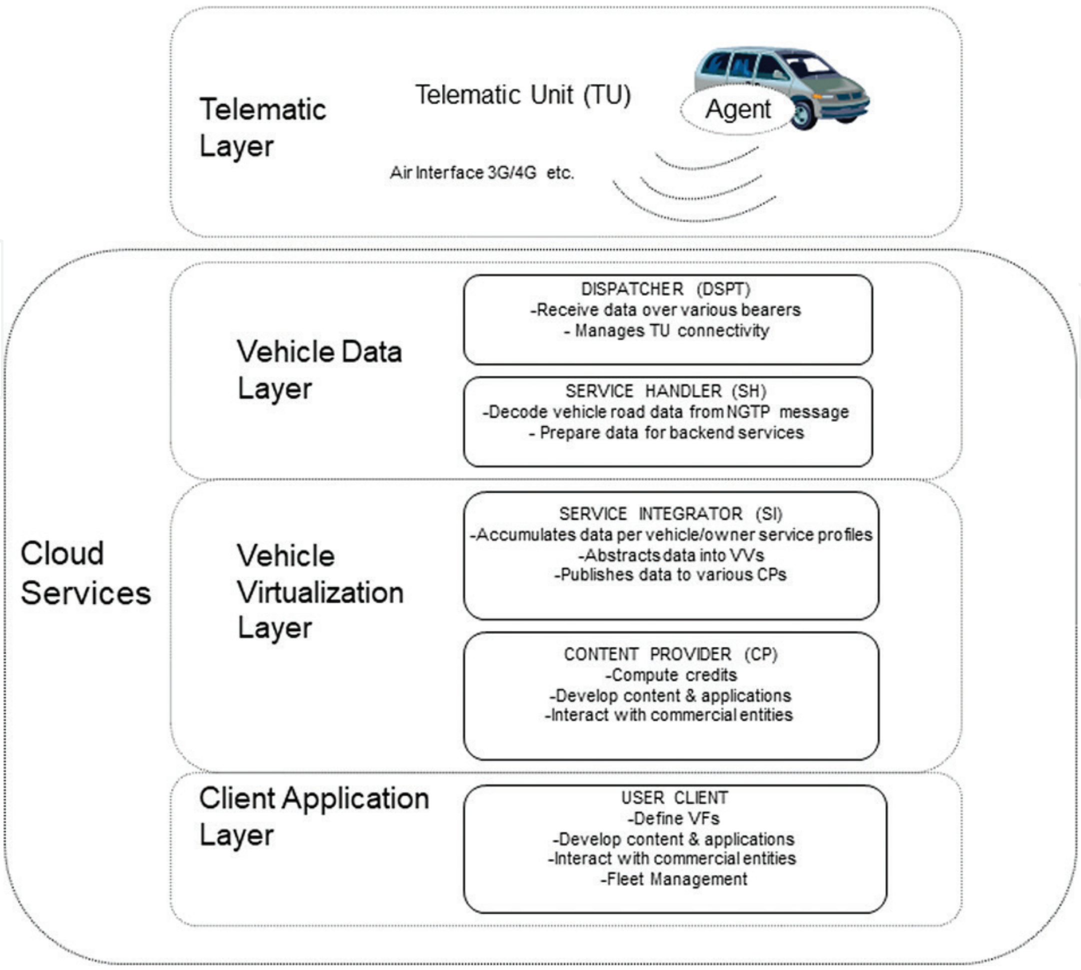

Figure 2. System model.

The essence of cloud computing is the ability to interact with many applications and services remotely from various locations over the Internet and other interfaces. A cloud model can provide a unified interface to access data from many vehicles, allowing it to be accessed and stored in a distributed manner, enabling service applications to be created around that data from multiple remote SIs and CPs. The PaaS layer allows users or companies to create and provide a rich set of applications based on need. For example, many applications can be developed for all of the vehicles owned by a particular user. Furthermore, the ability to integrate these applications with newer ones will likely be necessary. This avoids restricting one vehicle per user. This capability is similar to what has been done in cloud applications for sensor management [32].

For energy management, different applications can be developed and provisioned for different needs to respond to multiple audiences, especially those willing to promote sustainable mobility. Such applications fit well under the SaaS model, using the cloud as the application hosting platform. The end user can have one or more applications that use the vehicle data. These applications can be developed using a rich set of APIs provided by the SH. The end user requests the use of virtual vehicles or vehicle fleets and decides how to use that information either by developing their own applications or by utilizing predefined applications offered by a commercial entity, such as the vehicle manufacturer, fuel provider, car group, or similar.

Users can utilize policy templates to evaluate strategies to optimize fuel efficiency. These templates can be based on the economic parameters cited earlier to formulate decision strategies. In addition, geospatial information delivery methods based on geographic information system (GIS) technology can be leveraged to geographically view regions of fuel efficiency [34].

7. Network model

The service model that has been presented characterizes the end user's view of the energy services. Hidden from the user is the underlying network infrastructure that would be required to enable delivery of these services. **Figure 3** envisions a model architecture that could support delivery of these services. TUs will transmit the vehicle data at the conclusion of a driving cycle over the prevailing air interface of the cellular service provider's bearer network hosted by a base station (BS) unit. (While in this example we use cellular as a bearer network, other wireless access methods such as satellite could also be explored.) The BS is supported by the service provider's access service node (ASN), which serves as a gateway to their backend network. Vehicle data are carried as internet protocol (IP) payload in NGTP 2.0 ASN.1/XML format. The cellular provider's IP media subsystem (IMS) interconnects the backend

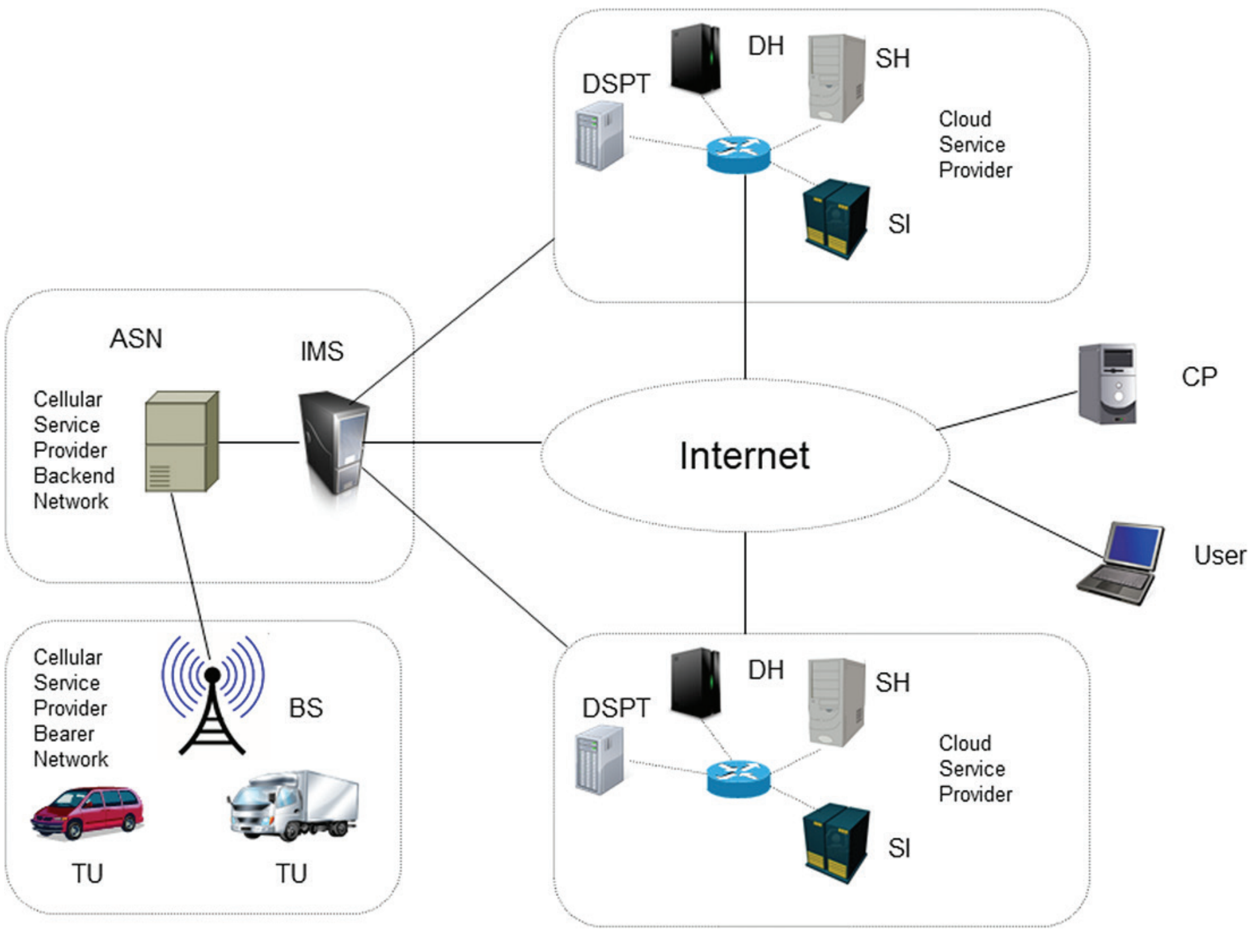

Figure 3. Network model.

network to external networks via IP. All data would be transferred in IP packet form. Several connectivity arrangements can be envisioned between the cellular service provider's backend network and the DSPT: direct connectivity to a DSPT node; connectivity to a cloud service provider's routing gateway; or connectivity to the cloud service provider's network via the Internet. The second option might be more desirable since there could be many distributed DSPT nodes on the cloud. As in the system model, DH, SH, and SI functions can be provided over a cloud service, thereby enabling a broader distribution of these functions. It should be noted that these functions need not reside on the same cloud nor be performed by the same service provider. Similarly, CPs and users are not confined to using the same cloud as well. As mentioned earlier, multiple federated clouds may have to be resorted to in situations where processing resources on a single cloud is insufficient.

Messages between the functions are unidirectional and technology independent. In a typical transaction, a TU will issue an NGTP 2.0 message to a DSPT in the conclusion of a driving cycle. The DSPT assigns a unique identifier (EventID) to identify and track the event. The DSPT will only process the NGTP message header and DSPT data fields. These fields include the nature of the service and network supporting the service. The message is then issued to the appropriate SH via hypertext transfer protocol secure (HTTPS). As stated earlier, message transmission in the IP datagram format enables layer 3 transport over a variety of layer 2 network options. The SH parses the service data payload field of the message. This data is essentially an AEMP equipment information (EI) document whose vocabulary is defined in [19]. Conceptually, the information about a vehicle is provided as a resource on the Internet, at a known uniform resource location (URL) of the DSPT. Furthermore, the SH can assign a URL to an individual vehicle. The SH processes the service data payload and enriches it for the SI. The SH provides this information in a common format by developing an API that enables SIs to parse the data and imports it into their databases for use by a CP that will develop and operate owner/end user applications.

8. Conclusions

As the next generation of more energy-efficient vehicles infiltrates the market, it is clear that their higher costs could offset energy savings over the long run. In order for fuel-efficient technology to be successful in the near term, it is vital that additional value be created by augmenting it with capabilities such that drivers can realize full economic potential. Such values can be enhanced through capabilities that motivate drivers to behave more fuel efficiently. To this end, we have proposed an architectural framework for real-time energy management use by vehicles. The framework is underpinned by a simple economic model which rewards drivers in units of energy when they drive more fuel efficiently than a given standard. By logging their activities using a combined telematic and cloud computing network, energy usage information could be transferred to service integrators and content providers that can use this information to build vehicle energy resource management capabilities. Such an infrastructure is quite feasible since many of the underlying capabilities needed for such a service are already available and have been standardized to many extents.

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