SoCo-ITS: Service Oriented Context Ontology for Intelligent Transport System

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ABSTRACT

Intelligent Transport System (ITS) is a culmination of technological and application systems that are contrived to improve the performance of road transportation and upgrade the commuter's experience. The integration of Internet of Things (IoT) with the transport system has contributed to the development of ITS. In this paper, we concentrate on the commercial servitization standpoint of the application. We structure and formulate an ontology called Service-Oriented Context Ontology for Intelligent Transport System: SoCo-ITS. This ontological framework abets in identifying appropriate services required by the commuters in transit based on their situation, predilection and ITS environmental information. We discuss the detailed implementation description and also accentuate its role in ITS through a use case scenario and an exemplar application portraying the importance of the proposed ontological model.

CCS CONCEPTS

• **Information systems** → **Information systems applications**; *Retrieval models and ranking*; • **Theory of computation** → **Semantics and reasoning**; • **Computing methodologies** → **Ontology engineering**; • **Computer systems organization** → Sensor networks.

KEYWORDS

Internet of Things, Intelligent Transport Systems, Ontology, Service Discovery, User Centric Services

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1 INTRODUCTION

The unprecedented growth of Information and Communication Technology (ICT) has made a mark on all the aspects of human life. One such aspect in which the effect of ICT can be perceived is transportation. In the last few years, ITS has been augmented with the Internet of Things (IoT) to consort significant improvement in the efficiency of the transportation system [1]. Numerous sensors are deployed into the framework of ITS that capture and enunciate data (such as road cognition, speed of vehicles, congestion, *etc*). This data can be further processed to drive the intelligent application to perform better in context to the user's requirements. The forthcoming praxis of ITS applications concentrates on thrust areas like vendor servitization. This strand of ITS is kindred with providing commuter-centric services that are offered by the purveyors present alongside the road network, during any incommodious situation. In this context, there is a requirement for a *service discovery technique* that pinpoints utilities to the commuters by monitoring their preferences and taking their behavior into account under various ITS scenarios [2].

Although the use of IoT in ITS has dramatically improved the system performance, its integration with ITS imposes a great degree of challenges. Primarily, the heterogeneity *i.e.*, the IoT devices (like sensors, actuators *etc.*,) are classified by manufacturing standards and embedded technologies. Therefore interoperability between the devices becomes a concern, as it is very essential in the ITS application development. This issue can be addressed by establishing an ontology that defines concepts and relations for the domain structure. Another major challenge that arises is the extraction of required information by querying through the humongous data captured by the sensors. The data captured is structured using an ontological model so as to provide relevant information to the traveler during his need [3].

ITS assimilated with ambient intelligence intends to provide leading-edge facilities to the commuters in order to transform their travel experience by understanding their preferences and delivering a range of personalized services becomes a predominant necessity [4]. This paper apprises on defining an ontological architecture for context-oriented user-centric servitization in ITS scenario, that facilitates the travelers during their commute. The proposed ontological model aids in answering a wide range of queries in context to servitization from the user's perspective. Some of them are (i) *List all the services*: An information query by the users who intends to know the list of services available to them in the route they travel, (ii) *List all the service providers*: A metadata information query by the users who are interested in all services providers providing particular type of service, (iii) *Produce a list of users who have availed services offered by the particular service tradesmen*: An information query by the users, who intend to know how frequently a particular service is used along with ratings of the provider, and (iv) *Generate the frequency of service opted by an individual for a particular service*: An information level query requested by the salesmen and user. By the salesmen to improve the delivery of services through statistical information gained from the query results and by the traveler to decide on which service to choose. Our contributions in this regard are as follows:

- We propose *Service Oriented Context Ontology for Intelligent Transport System: SoCo-ITS* framework that can be inferred in a user-centric ITS implication for discovery of utilities. A search space for service sighting is effectively formulated using SoCo-ITS based search techniques. This takes into consideration various hidden parameters enabling efficient handling of service inquisitions by the commuters during their travel.
- We design and define the high-level conceptual overview of service extraction model *Context Oriented Service Extraction Model: COSEM* which incorporates the SoCo-ITS ontology in extracting service information, in accordance with the user's requirement.
- We also illustrate the role of SoCo-ITS ontological framework using an exemplary use case scenario of ITS.

The organization of the rest of the paper is as follows. A review of recent works is carried out in Section 2. In Section 3, an outline of the commercial services provided by the purveyor in the ITS environment and detailed design description of SoCo-ITS is given. An application uplifting the use of SoCo-ITS is demonstrated in Section 4. We finally conclude and put forth our future research perspectives in Section 5.

2 LITERATURE SURVEY

In this section, we present a review of recent works on this field dividing it into two subsections. In the first subsection, we present the previous work of ITS integrated with IoT and in the second subsection we summarize the works done on ontology facet of the ITS.

2.1 ITS and IoT

The meteoric rise in numerous intertwined smart devices with built-in sensors has facilitated the extraction of environmental data in the ITS scenario like traffic flow, data congestion *etc.* Chen *et al.*, [5] designed an emergency guidance tool that could assist the vehicles in choosing an alternative path for commuting during high traffic. Although the framework realizes less evacuation time than earlier methods, it could not handle load balancing in the presence of numerous hot spots. Wang *et al.*, [6] proposed an algorithm that collects the traffic information related to Internet of Vehicles and quantifies them. This method succeeded in collecting local traffic information, but the information flow is restricted to selected routes only. Zhou *et al.*, [7] worked on the content dissemination issue of the Device to Device Vehicle to Vehicle (D2D-V2V) based on IoV networks, but it was confined to single-hop D2D-V2V scenarios. Felipe *et al.*, [8] designed a smart sensor model for transportation planning, enabling the information to be used by the central traffic management for the betterment of the transport system. However, the implementation of this model is restricted to public bus transportation only.

2.2 ITS Ontology

In context to the ITS systems that are supported by ontologies, Lav *et al.*, [9] demonstrated the structure of a semantic web-based system to exchange information amongst the IoT devices, so that the data is accessed and processed by machines in the abstruse scenario. Goel *et al.*, [10] in their work have entrusted the context-aware smart traffic monitoring system that facilitates the premonition of the real-time traffic in a particular route and directs the commuters along a different route. However, this approach failed to detect the presence of abstruse vehicles in the road network. Fernandez *et al.*, [11] proposed a four-layered ontological architecture that structures the data regarding road infrastructure, traffic situation and weather conditions and makes it available to the commuters. But, this work does not consider factors regarding the congestion level of neighboring road segments. Cordoba *et al.*, [12] formulated an advanced driver assistance system called "SesToCross", based on the semantic knowledge to assist drivers in crossing the insertion of roads in the absence of signals. However, it can be used only by vehicles that is equipped with this application. Chen *et. al.*, [13] formulated a two-phase architecture named "TripImputor" to infer taxi trip travel time given present traffic conditions. But, this work could not yield accurate results and also lacks the consideration of users preferences. Akagi *et al.*, [14] in their work have defined a structured description for traffic management in ITS, the proposed structure is built by annotating the traffic events based on an ontological model. Abberley *et al.*, [15] developed an ontology model for traffic information that could assist the commuters in deciding their travel. Although it sufficed its purpose to a certain extent, it to predict certain situations such as an accident and thus gives an early warning. Fernandez *et al.*, [16] also proposed an

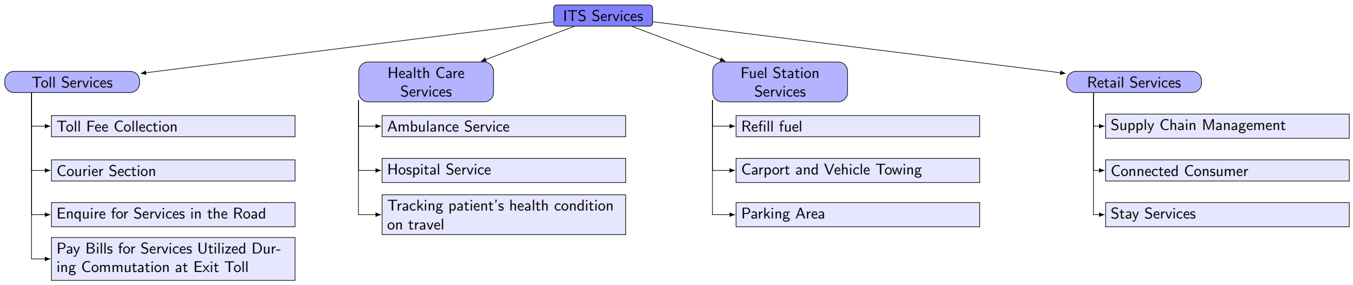

Figure 1: Different ITS Services.

ontology-based system providing assistance to the driver under various traffic conditions. Although the system provided useful information to the driver, also does not incorporate data concerning the traveler's behavior.

From the related works, we observe that a considerable amount of research has been carried out to uplift the characteristics of ITS integrated with IoT and ontological models designed for various ITS related circumstances. But, the servitization feature of the application is unexplored. This has inspired us to emphasize this strand aiding to the greater performance of the formal approach.

3 ONTOLOGICAL MODEL

3.1 ITS Services

A wide range of services such as fuel services (refueling, vehicle repair, spa, parking space for vehicles, etc.,) stay services along the road (such as hotels, motels, resorts etc.,), health care services (like ambulance services, hospital services), smart retail store services and toll services are offered by the ITS environment. The classification of the services are illustrated in Figure 1.

3.2 SoCo-ITS: Service Oriented Context Ontology for ITS

This section capitulates the details of a domain-specific ontology designed for formalizing "Context Oriented Service Information" captured from the sensors deployed in the ITS environment. SoCo-ITS defines the semantic observations describing the discovery of a service, based on the commuter's preferences and a situation in the ITS scenario. In order to structure the resources, such as sensors and actuators along with the data captured by these devices in the ITS environment, we have leveraged the concepts of Semantic Sensor Network(SSN) ontology developed by the Semantic Sensor Network Incubator Group, a sector of World Wide Web Consortium(W3C). Along with modeling the IoT devices, SSN ontology helps to achieve the confederacy and interoperability between the components of IoT. Following this, we discuss the ontology modules and patterns of SoCo-ITS in terms of concepts and relationships among them. Figure 2 illustrates the components and relationships of SoCo-ITS.

3.2.1 Entity. An entity is "A physical object that is pertinent to the user, accordant to the scenario". It is also referred to as a class. Our proposed SoCo-ITS ontology has five entities.They are Service, ServiceVendor, RoadNetwork, User, and Vehicle. Some of the entities have sub-entities or subclasses. A detailed description of the entities are given in Table 1.

3.2.2 Properties. In an ontological model, properties are used to contend binary relationships on entities and to add some restrictions on them, there are two kinds of properties possessed by the entities. They are as follows:

a) *Object Properties*: Object properties are used to form a relationship between the entities. Each object property has a domain which is the source entity and the range which is the target entity. In SoCo-ITS, the object properties taht we have defined are: travelsOn, hasCategoryOfServices, consumeService, hasCategoryOfRoadNetworks, hasListOfServices. The Descriptive Logic(DL) language is used to describe the source and target entities of each object property along with the short description. The notation used is as follows

$$Domain \rightarrow Range$$

Table 2 describes the object properties framed in our ontology.

b) *Data Properties*: Data Properties are used to exert some kind of restrictions on the ontology class using the object property. The data properties that has been formalized in SoCo-ITS are: roadCategoryID, serviceID, userID, serviceVendorID, vehicleID, longitude, latitude, RoadNetworkID, and serviceCategoryID. DL language used to describe the domain and range of each data property and is depicted below.

$$Domain \rightarrow DataProperty$$

The data properties adhered to our ontology is explained in Table 3.

3.3 Context Oriented Service Extraction Model: COSEM

In this subsection, we present a high level overview of our contemplated model describing its comprehensive workflow.

Table 1: Entities defined in SoCo-ITS

Name	Sub-Classes	Description
Service	Fuel Station Service	Offers fuel refill and vehicle maintenance services.
	Hospital Service	Offers medical assistance to commuters.
	Hotel Service	Offers travelers boarding, accommodation, food and parking facilities.
	Toll Service	Offers vehicle assistance desk services.
	Retail Service	Offers travelers parking and retail services.
Road Network	Expressway	Represents the category of roads with limited points of access.
	National Highway	Represents the network of long-distance roads.
	State Highway	Represents the road network connecting major cities within the state.
	City Roads	Represents the road network in a city.
Service Vendor	-	Constitutes an individual or a company providing the traveler with services.
User	-	Representstravelerswho,accordingtotheirneedsandpreferences,chooseacertainservice.
Vehicle	-	Representsanobjectthatisused for commutation.

Table 2: List of Object Properties

Object-Property	Domain	Range	DL illustration with example
consumeService	User/Vehicle	Services	{Tanu} consumeService {FuelStationService}
hasCategoryOfServices	Service	Sub Class of Services	{Service} hasCategoryOfServices {FuelStationServices}
hasListOfServices	ServiceVendor	Service	{Sameera} hasListOfServices {HotelServices,FuelStationServices}
travelsOn	User/Vehicle	RoadNetwork	{Preetham} travelsOn {NH-4}
hasCategoryOfRoads	Road Network	Sub Class of Road Network	{RoadNetwork} hasCategoryOfRoads {NH,SH}

As we have stated earlier, our aim is to render service information to commuters that best suits their preferences. COSEM takes user's requirement as the input through an ITS interface in the form of SPARQL query (say a user enquires for fuel stations in his close proximity). This query is then applied onto the resource data (list of services near to the commuter's location) collected from the sensors that

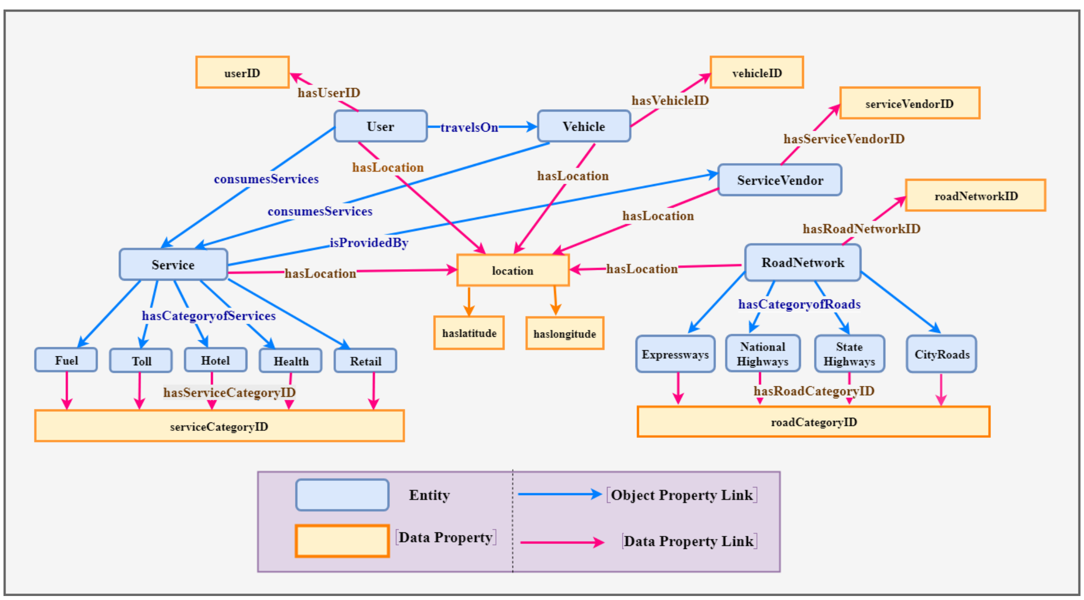

Figure 2: Proposed SoCo-ITS Ontology

Table 3: Data Properties defined in SoCo-ITS

Data-Property	Entity	Object-Property	Example with DL notation
serviceCategoryID	Service	hasServiceCategoryID	{FuelStationService} hasServiceCategoryID {FUEL001}
serviceID	Service	hasServiceID	{Shell} hasServiceID {FUEL}
serviceVendorID	ServiceVendor/ Service	hasServiceVendorID	{Taj Vivantha} hasServiceVendorID {TJ001}
userID	User/Vehicle	hasUserID	{Harry} hasUserID {ITS004}
vehicleID	User/Vehicle	hasVehicleID	{Hyundai i10} hasVehicleID {KA04-MH-6155}
latitude	Service	hasLatitude	{Mc Donalds} hasLatitude {87.9889}
longitude	Service	hasLongitude	{Mc Donalds} hasLongitude {23.5467}
roadNetworkID	RoadNetwork	hasRoadNetworkID	{Pune-Bangalore National Highway} hasRoadNetworkID {NH-04}
roadCategoryID	RoadNetwork	hasRoadCategoryID	{National Highway} hasRoadCategoryID {NH}.

is apprehended in the cloud, through SoCo-ITS ontological framework. This semantic ontology assists in filtering the commuter-centric utilities (filter only list fuel stations from the pool of services available) using service discovery technique that takes the commuter's context into consideration (particular brand of fuel station eg:shell). The resultant set of services is then indexed based on the ranking algorithm that is deduced depending on the attributes (such as: reviews,shortest distance,operating hours) and rendered to the user through the interface (list of shell petrol stations based on ranked using the algorithm is displayed to the commuter).

COSEM identifies the exact type of service that user is in need of thereby resolving the conflicts that occur while choosing similar type of services offered by several vendors. Figure 3 presents the steps involved in COSEM.

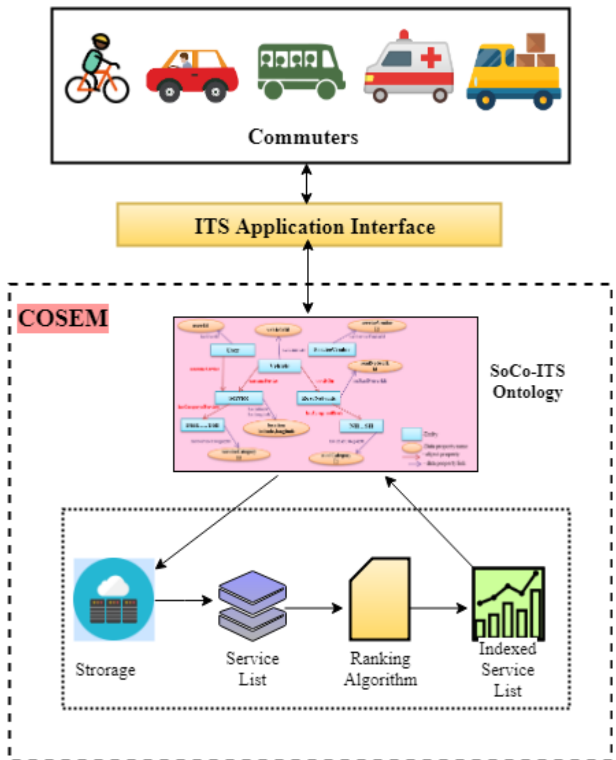

Figure 3: Workflow of COSEM

4 AN EXEMPLAR APPLICATION

In this section, we illustrate the use of SoCo-ITS ontology in ITS using an application "Pay-as-you-travel (PAYT)". We present the high level overall workflow of application, an use case scenario depicting the use of PAYT and how SoCo-ITS aids in upgrading its performance.

4.1 Pay as you travel

This application focuses on automated payment system in ITS. The functional modules of this system is mentioned below.

- Query Engine(QE)- This module accepts queries from the user and returns information based on their situation.
- User Profile Management(UPM)- This module stores the user data such as vehicle details, preferences, services utilized ,payment records, movement patterns, travel history.
- Service Manager(SM)- This contains the list of services provided by the commercial vendor to the user.
- Pricing Manager(PM)- It monitors the services utilized by the commuter and produces a final invoice based on dynamic pricing model.

The commuter requests for the required service through an user interface. This inquisition which is in the form of a SPARQL query is rendered by SoCo-ITS ontology. SoCo-ITS along with SSN and other ITS related ontology frameworks acts upon UPM and SM to produce a list of services as preferred by the traveler.On receiving the list, user avails the services and proceeds further. As he leaves the area of service, the PM is activated, which calculates the total bill amount considering all the utilities consumed by the traveler and based on dynamic pricing module. The bill thus generated is given to the user for further transactions. The complete process data is recorded in the UPM for future activities

4.2 Use Case Scenario

Suresh, a sporadic traveler, starts his journey from Bangalore to Mumbai in his privately owned smart automobile. The toll gate at the exit of Bangalore city scans RFID tag of the vehicle as he elapses through it. The information concerning Suresh and his automobile gets registered on the UPM of the ITS infrastructure. The UPM helps to keep track of the services consumed and the associated bills of Suresh. On the other hand, the SM contains list of services available on Bangalore-Mumbai Highway.Covering a distance of 500 kilometers on the highway, he stops to have food. He queries through the ITS application to find pure veg restaurants near to his location and that has rating above 4 only.On receiving the list of restaurants. He chooses to eat at Anand Bhavan and drives to that hotel. After having his meals there, Suresh decides to refill his vehicle with fuel. He puts this query request also on the ITS application, extracted list of fuel stations in his proximity are rendered to him. He selects the n Shell petrol station that is 600 meters away and travels there to refuel his automobile. After he avails the services and proceeds further, the pricing manager gets activated, calculating the bill amount for the food consumed at the restaurant and refueling his automobile thereby notifying to him about the cost that is deducted through the payment gateway.

5 CONCLUSIONS

With the infiltration of the IoT in transportation domain, ITS is able to re-architecture the traveler's experience and batten the new economy for impertinent use of transportation system. A noticeable impact of the ITS has been witnessed in applications such as traffic and transit management, vehicle control system and public vehicle transport management. Along with this accurate service provisioning and utilization in ITS play a vital role in upgrading the traveler's experience during conveyance. Due to increase in the number of data getting generated, searching and exploring the relevant services required by the user becomes a tedious task. To tackle this problem, various strategies have been suggested in the past. However, the user experience and personalized search results are not considered. In this regards, we have defined an ontological model called the SoCo-ITS in this paper for context oriented user-centric servitization in ITS scenario. The model captures contextual data from the deployed IoT devices, deduces relationship among them and forms a structure for the acquired data. This facilitates the travelers during their commute by providing them the required services during their need. We built a working prototype called COSEM as a proof of concept to demonstrate the functionality of our proposed ontology and also described a realistic application to highlight its importance.

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