Ontology based Service Discovery for Intelligent Transport Systems using Internet of Things

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***Abstract*—In this paper, we design and implement an ontological model, Service oriented Context Ontology for Intelligent Transportation System (ITS) application, that aids in service discovery for the commuters. We conceptualize and architecture the domain knowledge of the ITS system along with user requirements and preferences namely, the association of IoT devices, ITS components, services and user with each other so as to address the complex service request in a conflict free manner. We also present implementation details of a prototype system that demonstrates the capabilities of the proposed ontology.**

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

I. Introduction

Over recent decades, Information and Communication Technology (ICT) has significantly contributed not only to the advancements of society but also in the way of our living. Transportation being one such activity, has taken a giant leap where *User-Centric* services viz. door-to-door delivery, on-the-go needs, pay-by-utilization, etc. are being offered. The collaboration of ITC with application schemes aimed at ameliorating commuter's experience in all features of transportation has paved way for Intelligent Transport System (ITS). One of the appositeness of this system is associated with providing services offered by vendors (like fuel stations, retail, hotels etc.,) present alongside the road to commuters in need during transit [1]. Thus, there is a clear need for *service discovery techniques* that offer to locate a user preferred service based on his requirements from the vast pool of available ones.

The technological infrastructure for ITS's functioning and maintenance is provided by the Internet of Things (IoT) ecosystem where numerous types of sensors are deployed on the transportation infrastructure to gather data (about vehicle speed, traffic congestion, carbon emission etc.,) and process it so as to enable the intelligent applications to amplify and augment the user's experience while commuting. The data generated by these sensors are in large volumes and poses characters like rapid evolution, validity, and heterogeneity that are to be addressed for the effective and efficient functioning of the system. These challenges can be dealt with by designing a semantic knowledge-based ontological model to organize and annotate the data captured through the IoT devices by deducing the relationships among them. After the acquired data has been structured, semantic querying and reasoning techniques can be applied to provide the relevant services to the commuter on understanding their preferences. Here, the search technique is a predominant necessity in order to differentiate between the same type of services provided by different vendors [2].

A. Motivations and Use Case Scenario

It is anticipated that more than 20 billion devices will be connected to the Internet by the year 2025 and connected vehicle's share among it would be around 250 million. The explosive growth coupled with the assimilation of ITS with IoT is fraught with numerous challenges. The predominant being the heterogeneity issue where the IoT devices are of various types (with respect to the standards, manufacturer, and technologies embedded in them) that gather data in different types and at distinct rates. Consequently, interoperability between these devices has to be established for the functioning of any IoT application [3].

Fig. 1. ITS Usecase Scenario

We describe the following use case scenario, as depicted in Figure 1, to illustrate the challenges of service discovery technique in ITS. Taxis are a large fleet of vehicles touring for long distances on daily basis across the road networks. An ITS application designed for such a situation has to cater the requirements of both the taxi drivers and the passengers. For example, Ramu a taxi driver picks up his passengers at Majestic, Bengaluru having to drop them at T Nagar, Chennai. After he has driven for about 100 kilometers from Bengaluru he enters the Bengaluru-Chennai Highway and his vehicle runs low on fuel. Ramu can then query for the information on the nearest fuel stations in his close proximity through an ITS application that is installed on his mobile phone. Such a service discovery application should also consider the context information of the user, say Ramu prefers to use the services provided by a particular fuel vendor - Indian Oil and also rank the services based on users' satisfaction ratings. It can thus be noted that a service discovery technique has to take care of various

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search requirements and resolve the queries in a conflict-free manner.

To this end, an ontological model can be utilized to establish relationships among the IoT applications, IoT devices, and the data that they generate or consume so that hidden relationships can be inferred that aids in the effective utilization of the ITS and IoT resources. In an ITS-based user-centric application, the semantic knowledge embedded in the ontology helps to resolve the conflicts that arise when choosing the same type of services offered by multiple vendors as it captures the user's requirements and preferences. Using ontology-based search techniques the search space can be structured effectively based on the aforementioned parameters drastically reduces the size of the search space.

In this paper, we focus on architecting an ontological model based on semantic services in the ITS scenario wherein the IoT devices capture context-based data, deduce relationships between them in terms of domain and range and thus use semantic techniques to query the data in order to find the service required by the user.

B. Contributions

Our aim is to structure the search space of a service discovery technique based on various parameters so as to resolve the service inquisition requests in an efficient way. This paper presents a context-aware service-centric ontology named, Service oriented Context Ontology for ITS application (SoCo-ITS). Domain knowledge of the ITS system is incorporated along with user requirements and preferences that address the complex service request in a conflict-free manner.

II. Ontology Model for Service Discovery in ITS

In this section, we describe the ontological model for formalizing "service based contextual information" acquired by the IoT devices that are deployed in the ITS environment. SoCo-ITS is framed to define the morphological observations that in-turn describe the association of IoT devices, ITS components, services, and user with each other. These relationships facilitate service discovery based on certain situations and preferences of the traveler. Figure 2 depicts these relationships. We discuss our proposed ontology model in terms of domain concepts and relationships between them in the following subsections.

A. Entity

An entity (also known as a concept) is defined as a representation of an object or a thing related to the ITS domain, in accordance with the scenario. We have defined five entities in our ontology as Service, ServiceVendor, RoadNetwork, User, and Vehicle. Service and RoadNetwork entities are further composed to have subclasses as FuelStationServices, HotelServices, TollServices, RetailService, HospitalService and Expressways, NationalHighways, StateHighways, City-Roads respectively.

B. Properties

Properties in an ontological model are used to form binary relations and add certain restrictions on the participating entities. There are two such properties: Object Property and Data Property.

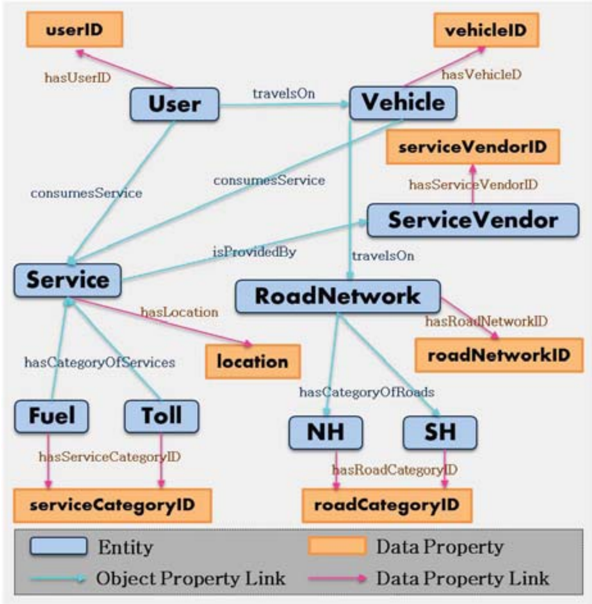

Fig. 2. The Proposed SoCo-ITS Ontology

1) Object Property: These kind of properties establish a relationship between the entities. Each object property contains a domain and range. In SoCo-ITS, the object properties are: consumeService, hasCategoryOfServices, hasListOfServices, travelsOn.

2) Data Properties: These properties are used to form relationships between the entities and their attributes. In SoCo-ITS we have formalized the following properties data properties to establish a relationship between the entity and its data type: serviceCategoryID, serviceID, serviceVendorID, userID, vehicleID, latitude, longitude, RoadNetworkID, and roadCategoryID.

Table I lists the above concepts along with their characters and description.

III. Implementation

We have designed and implemented our proposed ontology using Protégé 5.2.0 (https://protege.stanford.edu/). The designed ontology is extracted in RDF/XML format. To populate the individuals into SoCo-ITS, we have obtained the Bengaluru city's road network and service providers data from the Open Street Map (https://www.openstreetmap.org/). SPARQL query language (www.w3.org/TR/sparql11-query/) is used for resource inquisition from the populated ontology. We also developed a prototype application in Java through the Apache Jena framework (https://jena.apache.org/) to validate the effectiveness of SoCo-ITS in service discovery. To demonstrate the usability of the proposed ontology, Figure 3 lists a SPARQL query that retrieves all the services available in the Bengaluru city.

IV. Conclusions

With the ever growing technological advancements and penetration of the Internet into the physical objects around us there is a huge scope for development of a myriad range of potential applications that assist the user to perform his day-to-day activities efficiently. ITS being one such application has surfaced to offer user-centric services that serve the

TABLE I
SoCo-ITS Ontology Details

	Name	Sub-Classes	Description
Concepts	Service	Fuel Station Service	Offers refill of fuel and maintenance services to the vehicles.
		Hospital Service	Offers medical assistance to commuters.
		Hotel Service	Offers boarding, lodging, food, and parking facilities to travelers.
		Toll Service	Offers inquiry, help desk services to the vehicles.
		Retail Service	Offers parking and retail services to the travelers.
	Road Network	Expressway	Represents category of roads that have limited access points.
		National Highway	Represents the network of trunk roads for traveling long distance; numbered by the national authority.
		State Highway	Represents road network that links important cities or towns in the state; numbered by the state province.
		City Roads	Represents network of roads within a city.
	Service Vendor	-	Constitutes an individual or a firm that provides services to the traveler.
	User	-	Represents travelers who opts for a certain service according to their need and preferences.
	Vehicle	-	Represents an entity used by the commuter to travel.

	Name	Domain	Range	Description
Object Properties	consumeService	User/Vehicle	Service	Associates user with the service he uses.
	hasCategoryofServices	Service	Sub-Classes of Service	Identifies categories of services available to the traveler.
	hasListofServices	Service Vendor	Service	Provides list of services offered by a particular service vendor.
	travelsOn	User/Vehicle	Road Network	Identifies the road network on which the user/vehicle commutes.
	hasCategoryofRoads	Road Network	Sub-Classes of Road Network	Identifies the type of roads that constitutes the network.
Data Properties	serviceId	Service	xsd:string	Unique identity for a particular service.
	userId	User	xsd:string	Unique identity for a individual user.
	vehicleId	Vehicle	xsd:string	Registration number of the vehicle.
	serviceVendorId	Service Vendor/Service	xsd:string	Unique identity of a particular service vendor.
	serviceCategoryId	Service	xsd:string	Enables unique identification of a particular category of service.
	roadNetworkId	Road Network	xsd:string	Represents each road in the road network with an unique identity.
	roadCategoryId	Road Network	xsd:string	Unique identification for each category of road network.
	latitude	Service	xsd:string	Constitutes the latitude of a particular service.
	longitude	Service	xsd:string	Constitutes the longitude of a particular service.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX so: <http://www.uvce.com/cse/searchiot/ontologies/service-ontology#>

SELECT ?entity
WHERE {
        ?entity rdf:type ?type.
        ?type rdfs:subClassOf* so:Services.
}
```

Fig. 3. SPARQL Query to List all the Services

users on a commute. However, due to the vast number of related services and interoperability issues concerned with IoT devices service discovery becomes a significant challenge. We have efficiently handled these challenges by designing an ontological model that incorporates the domain knowledge of ITS, IoT along with user requirements and preferences in form of relationships. Our future work is to design a semantic matchmaking algorithm that effectively reduces the search space of the service discovery algorithm using the proposed ontology.

References

[1] Z. Ning, X. Hu, Z. Chen, M. Zhou, B. Hu, J. Cheng, and M. S. Obaidat, "A Cooperative Quality-Aware Service Access System for Social Internet of Vehicles," *IEEE Internet of Things Journal*, vol. 5, no. 4, pp. 2506–2517, 2018.

[2] S. Pattar, R. Buyya, K. R. Venugopal, S. S. Iyengar, and L. M. Patnaik, "Searching for the IoT Resources: Fundamentals, Requirements, Comprehensive Review and Future Directions," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3 third quater, pp. 2101–2132, 2018.

[3] S. Tarannum, S. Srividya, D. S. Asha, R. Padmini, L. Nalini, K. R. Venugopal, and L. M. Patnaik, "Dynamic Hierarchical Communication Paradigm for Wireless Sensor Networks: A Centralized, Energy Efficient Approach," *2008 11th IEEE Singapore International Conference on Communication Systems*, pp. 959–963, 2008.