

Research Article

Internet of Things-Based Intelligent Ontology Model for Safety Purpose Using Wireless Networks

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Intelligent transportation systems (ITS) are a newer trend in technology that improve the safety and performance in transportation systems. The exchange of information is considered as one of the key elements for ITS since it involves communication between vehicles and other components of ITS on road. On other hand, the data collections via Internet of Things (IoT) sensors play a major role for data collection and transmission between the vehicles and road segments in ITS. The data collection provides the current traffic and weather conditions that is considered necessary for driving in traffic. However, energy savings is one of the predominant objectives of electric vehicle (EV) while it is connected with ITS. In this research, we propose an ontology-based architecture for EVs using the data collected from IoT sensor network, which is intended to improve the overall driving experience. The system uses IoT sensor data to execute a range of activities in order to ensure the driver safety and comfort while on the road. The simulation is conducted on an Eclipse SUMO simulator, and the performance is reported. The results of simulation shows that the proposed intelligent model on making decisions along with weather and traffic conditions is reported efficient than existing ITS models.

1. Introduction

The technology referred to as intelligent transportation systems (ITS) is being developed to improve the safety of vehicles in road transportation. With the help of these technologies, it is possible to manage and monitor the numerous road components [1]. Through the implementation of ITS, it is possible to achieve a lower risk of accidents, lower carbon emissions, less traffic congestion, and air pollution through the ITS implementation [2]. At the same time, increasing the overall safety and reliability of transportation systems, traffic flow, travel speeds, and customer satisfaction across various transportation modes was as follows. The ITS provide various opportunities for collaboration as well as a dependable transportation platform [3].

As a result of the continued evolution of the ITS, the intelligent systems have arisen, which has resulted in a considerable boost in road transportation safety. By exchanging information across multiple applications and analyzing the findings, it is possible to increase the comfort and safety of drivers while on the road [4].

IoT sensors are essential in ITS since they serve as an information source. In addition to automobiles, IoT sensors can be deployed on a variety of infrastructure features such as bridges and roadways. IoT sensors offer data on traffic and weather conditions to drivers in order to make driving more enjoyable and safer. The term IoT sensor network refers to a collection of small computers that collaborate to achieve a shared purpose [5]. Using IoT sensor and wireless communication capabilities, ad hoc networking can be established without the requirement for an existing physical infrastructure or for central network administration to be established. It has been proven that IoT sensor networks may be utilized for data collection and processing in a range of industries, including industrial, medical research, home automation, military applications, and environmental detection [6].

By providing a common language and allowing for the definition of concepts and relationships at varying levels of formality, ontologies can be used to define the meaning of terms and the relationships between them in a specific domain. Due to their expressiveness, ontologies are required to enable increased interoperability between software agents involved in ITS [7]. In information and communication technology, an ontology is a conceptual framework that allows for the development of complete and rigorous conceptual frameworks that facilitate the flow of information and communication between diverse systems and organizations [8–10]. Internet of things (IoT) sensor data is infrequently used in research that employs ontologies [11–14] in conjunction with ITS, despite the fact that they are increasingly popular. The ontology can provide a semantic interpretation for IoT sensor data, which will improve driver safety and traffic flow overall.

In this research, we propose an ontology-based architecture for traffic electric vehicles (EVs) using the data collected from IoT sensor network, which is intended to improve the overall driving environment. The system uses IoT sensor data to execute a range of activities in order to ensure the driver safety and comfort while on the road.

2. Related Works

Recently, a number of research programs targeted at increasing road safety and traffic efficiency have been started. EV communications are the subject of one of the works mentioned above, which is [15]. If the user is looking for the most recent research on vehicular communication, look no further than T-VNets [16]. A number of active attacks can be detected by the system, which is capable of providing high levels of protection while keeping network resources available for other tasks. This work has a limitation in that it is only relevant to the ETSI ITS standard, which is a limitation in itself.

In addition, ITS are involved in projects that solve traffic congestion. The protocol is an ECODE protocol, which is detailed in detail in [17]. The key objectives of this technique are to determine the features of traffic in downtown districts as well as the locations of the most congested roads. A hybrid model balances the reactive and proactive modeling using traffic evaluation and communication overhead accuracy, resulting in a better balance between the two. Comparing the results of the hybrid method to the other options, it achieves the best results.

The authors in [18] discuss the quantity of cars on the road, the structure of the roadmap, and the complexity of the roadmap influence on vehicular communications, to name a few topics. According to the author recommendation, the new density meter should also be utilized to accurately depict the varied urban environments for cooperative IVS. There is a mechanism for detecting traffic congestion, detailed in [19]. With the technology, drivers can detect where traffic is backed up and then modify their routes to avoid it, lowering their overall CO₂ emissions and shortening their travel time. The system is now in beta testing. These works are limited in their ability to provide semantic information on traffic conditions beyond the data provided by IoT sensors due to a lack of a standardized knowledge management system. As a result of this characteristic, interoperability between these systems and other ITS programs is hindered.

In recent years, there has been an increase in the usage of ontologies for road transportation systems. [20] outlines the creation of an ontology to categorize and characterize interstate highway traffic. His mission was to develop a reliable system for gathering data on traffic patterns, road conditions, and situations involving EVs. Because of this, it assists the ITS in determining the severity of any particular situation. The level of congestion at a toll plaza, for example, can be critical information for an ambulance to have on its radar. These details are essential for emergency personnel who are on their way to the scene of an accident or medical emergency to know. When traveling at a leisurely pace down highway or road, this information may not be as important as it is in an emergency situation.

The authors of [21] proposed an automated EV and believe that it assists the drivers to make effective decisions while driving. Such representation combines inference rules and topological knowledge that can assist drivers in making better decisions and can be used to benefit automated EVs in the future. The fundamental issue with this method is that it does not take into consideration prior traffic laws. There was

nothing complicated about it; they just listed a collection of traffic code breaches that allow a certain move to be classed as either legal or illegal.

The authors of [22] propose the use of ontology-based spatial context models to represent spatial context. The Primary-Context Model and Primary-Context Ontology developed in this study make it possible for different ITS to communicate with one another more easily. The supporting ontology on a model of a car park system is constructed from a car park system model.

According to the research, [23] developed the generic assistance model for drivers using logic reasoning applied to a database of traffic conditions. Everything from automobiles to traffic signs to traffic lights, as well as the relationships between them, can be found in the same region. It is used to validate and build on the situation description, for example, by deducing traffic laws from the situation description. Logic inference is a type of inference. In this model, the ontological capabilities are presented using the example of a complicated intersection, and EVs, where many traffic lights and signs are demonstrated. One disadvantage of this approach is that each car must be aware of its destination route, making it impossible to simulate numerous scenarios based on the actual status of the intersection.

According to the authors of [24], the broad IoT sensor ontology A3ME and the idea of traffic management are merged into an ontology for traffic management that they have proposed. Additional concepts include IoT sensor class specializations in the areas of distance, position, and acceleration, as well as numerous operations when a car is moving [25, 26]. The ontology is created in OWL with the help of the JESS reasoner and the SWLR rules.

With the help of maps and traffic legislation, [27] built an ontology-based knowledge base. Even if it is capable of recognizing high-speed scenarios and making judgments at crossings in compliance with traffic regulations, it does not take into consideration key aspects.

Information about ITS is integrated into the ontological model defined in [28], which incorporates information from a variety of sources. According to the figure, ontologies are produced for each data source and then incorporated into single ontology via various similarity methods to form a single cohesive whole.

Because an EV is represented via symbolic terms, there is no way to explain something in between, such as the concept of uncertainty, when utilizing ontology-based methodologies. Consequently, Bayesian networks, in which state variables are determined by a set of probabilistic rules, can be used to explain uncertainty in a mathematical model. Rather than taking a broad approach, we limit the scope of the view to just describing the current context, providing the necessary ontology for that environment, and reaching conclusions about those conclusions in this work.

3. Proposed Method

The system is designed with a four-layer structure in mind. As shown in Figure 1, IoT sensor networks have been placed along the road infrastructure to monitor traffic flow. These

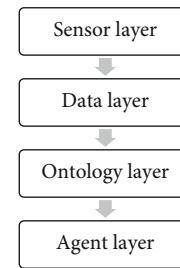


FIGURE 1: Layered architecture of the proposed model.

IoT sensors will be able to monitor a range of elements like weather conditions and traffic flow. The raw IoT sensor data is stored, i.e., database layer of system architecture. In the ontology layer, semantic processing is performed on the raw data that has been collected.

The ontology for road traffic scenarios has been built, which includes cars, infrastructure elements, IoT sensors, and driver behavior, amongst other things. A reasoning rule set is applied to directly onto ontology, since there exist relationships between them. The many agents of the last layer, which is referred to as the agent layer, are responsible for carrying out all of the tasks. To execute any task, the agents must communicate with one another as well as with the ontology.

IoT sensors, weather components, EVs, and agents, for example, are all organized hierarchically within a holonic traffic architecture and communicate with one another.

3.1. IoT Sensor Network Layer. IoT sensors, in particular, comprise a network of IoT sensor nodes that are dispersed throughout the EVs and along the routes and are grouped into a IoT sensor network to provide information. When several IoT sensors are incorporated into a single system, the likelihood of IoT sensor-to-IoT sensor interference is reduced.

IoT sensor networks such as this maintain track of a wide range of environmental variables, the most important of which are weather and traffic flow. IoT sensors are strategically positioned on the map at specified points for each lane. They make it possible to determine the location of an EV, its wheel-base, and the moment of discovery. The detection data can be generated while running simulations by capturing periodic samples from the simulated data at certain lane locations and combining them into a single data set.

In addition, IoT sensors that detect temperature and humidity within the EVs may be separated from those that measure temperature and humidity outside the EVs.

3.2. Data Layer. Data is collected, manipulated, and stored in this layer, which is a sublayer of the ontology or agent layer. It is reasonable to presume the dispersion of IoT sensors over a geographical area, and that they are collecting an array of data. The primary objectives of this project are the development of real-time dashboards combined with meteorological data. The data from IoT sensor conform to a certain format specification.

The key data sources are traffic flow and EV flow statistics. Every time an EV goes through the system, the system records the EV most critical attributes. A few instances of such characteristics include the time of detection, the coordinates (latitude and longitude), the EV speed and angle of velocity, its destination, and the length of the EV wheelbase. For the purpose of generating the flow, additional factors such as the length of the current lane and the normal EV flow are taken into consideration. As well as being assigned to lanes at random, flow detectors sample the present traffic by compiling a list of the cars that have been spotted as well as the relative time.

It will be necessary to collect IoT sensor data in an incredibly scalable manner in order to translate and analyze it on the cloud. Weather data must also be accessible via telephone calls is an additional need. Any proprietary service, such as Google Weather or OpenWeatherMap, can be used to generate the forecast. Customers are provided with APIs, which are subsequently implemented in EVs and used for navigation as well as the reporting of changes in the EV internal status. When it comes to big data processing, we rely on Google BigQuery to load IoT sensor data, transform it, and then combine it with weather information.

Besides flow statistics, we also gather information on the weather. The weather conditions addressed in this section are peculiar to the city in which the traffic is being carried out. It is possible to find the longitude and latitude of the city center by searching for a specific item in the meteorological database.

3.3. Ontology Layer. In ontology layer, entities associated with road traffic have been connected together. Japanese traffic regulations were utilized in the development of the ontology. In order to construct the ontology in the OWL-RDF language, the Protégé tool was utilized. The material in the traffic ontology has been organized into three groups of interconnected ideas to make it easier to comprehend. The first group includes items that are connected to automobiles, and the second includes elements that gets related closely with road infrastructure, and finally, the IoT sensors.

3.4. Mapping of Data from IoT Sensors to Semantic Data. When it comes to integrating and exchanging IoT sensor data, IoT sensor networks face a significant obstacle to overcome. In order to get the most out of IoT sensor data, we must convert it into semantic data that computers can comprehend and process.

A similar technique was utilized in this work, as previously reported in [47]. The labels of data sources, as well as IoT Sensor data, can be included in the mapping file schema specified by the researchers. Specifically, it is divided into two parts: SourceMapping that involves source information that maps the ontology of Semantic IoT Networks (SIN) and IoT sensor annotation that annotates each IoT data with an unit information and sensor type, as well as the location of the IoT sensor.

In order to begin the procedure, the study manually creates a file for mapping the file schema. Secondly, it was advised that IoT sensor data be converted to RDF using a mapping schema and SIN ontology correspondences that had been specified in the previous step. Table 1 contains

TABLE 1: Mapping schema classes and elements in SIN.

Mapping schema	Description	SIN class
Location name	IoT sensor location	Sin:D
Sensor id	Total IoT sensor	Sin: S
Type	IoT sensor type	Sin: P
Observation value	IoT sensor output	Sin: SO
Unit	Data unit	Sin: UOM
Text of observation value	Observation values	Sin: OV
Observation time	IoT data time	Sin: O

mapping schema classes and components onto SIN ontology.

As a final outcome, an RDF file containing the sensor data-driven SIN ontology item is created and saved. The ontology elements include concepts, individuals, and relations that were formed during the traffic light adjustment scenario.

3.5. Agent Layer. The multiagent system is located at the very top of the hierarchy of systems. The data contained in the ontology is queried by the various agents, who subsequently use the information to accomplish their tasks. When creating the multiagent platform, the study uses FIPA ACL protocol to facilitate agent interactions with one another.

The key objectives of this research were to control the temperature of the air conditioner and to change the duration and intensity of traffic signals based on the weather conditions. Detailed information on each of these two options is provided below. The following agents are in charge of dealing with these situations:

- (i) *Driver Personal Agent*: in the case of a driver, this agent is responsible for carrying out the obligations that are special to the driver while also taking into consideration habits and preferences
- (ii) *Environment Agent*: it is in charge of transmitting environmental data collected by the EV sensors, such as temperature and humidity, to the driver
- (iii) *Air Conditioner Agent*: the drivers are in charge of adjusting the settings of air conditioner while considering the humidity and temperature levels within and outside the EVs along with driver preferences
- (iv) *Car Agent*: IT is created to follow a specific route, as well as traffic signs and rules, in order to fulfil the numerous responsibilities associated with car movements
- (v) *Road Agent*: it carries out the tasks involved in road segments to find if the road is congested or not based on the data collected by sensors on traffic flow
- (vi) *Traffic Light Agent*: while changing the duration of traffic lights, this agent also takes into account the flow of traffic as well as the current weather

conditions when determining whether to update the timer

- (vii) *Weather Agent*: for example, the Weather Agent gives weather information to other agents and creates forecasts depending on the current weather conditions

3.6. Traffic Light Control. Traffic signal changes that consider weather condition and traffic flow are discussed. In order to detect traffic flow, the agent must first examine the traffic ontology, which provides specifics about where the traffic signal is currently located and where it should be placed in the future. Each segment and lane are documented in detail in the ontology, including their location and the maximum density that may be achieved. Using SWRL principles, the reasoner may calculate the length of a lane by comparing the beginning and ending coordinates of each segment.

In the preceding section, we explored how the raw sensor data is converted to semantic data, and then it is sorted using SIN ontology in order of utilizing it by the agents. According to this scenario, the SIN ontology is often queried by the road agent to retrieve the detected EVs by the IoT road sensor information from the SIN ontology.

In order to calculate the true density of traffic flow, it is necessary to take into account both the EVs and lane length using an IoT road sensor. At any given time, the estimation is conducted in terms of total number of EV road segment on a certain route. Density can be calculated using the following formula:

$$\text{density} = N/L, \quad (1)$$

where N is the EVs detected, and L is the lane length.

The result is then compared to the maximum value in order to decide how dense a lane should be constructed. If the lane density \geq maximum density is as follows, the lane is deemed congested. If you look at the regulations provided in Table 2 for changing traffic signal length periods based on criteria such as light color and level of congestion, you will notice that they are put to use in that situation.

Upon red light on a congested segment, a shorter time is displayed for the duration of the signal, but a longer time is displayed for the duration of the signal when it is red but not on a congested road segment. Upon a green light on a congested segment, the signal duration is increased; otherwise, the signal duration period is maintained.

3.7. Route Management. A bioinspired modeling is used for reducing the traffic congestion control, where it focuses entirely on the traffic management via bat optimization algorithm. The solutions for congestion control rely on the information of traffic flow provided by IoT road sensors, which are used to compute the shortest and most cost-effective route. There are two sorts of interactions that are required by the various tactics.

- (i) *Request Road Segment Information*: in order to obtain information regarding a specific type of indirect coordination named stigmergy that enables interaction between the actions and agents, after

TABLE 2: Rules to adjust traffic light.

Traffic signal	Not congested	Congested
Red	No change	Decrease
Green	No change	Increase

that, the SIN ontology would look for information on both long and short-term STIs, because sensors in traffic lanes would provide this information. The GPS Navigator Agents will provide the necessary information for anticipatory STIMGREDIES as soon as possible through the interaction described above

- (ii) *Provide Estimated Position*: the Road Agent would get the anticipated location of the GPS Navigator Agent for the predetermined time interval from the Road Agent. If GPS navigator agents communicate with one another on a frequent basis, they may be able to use current traffic data as weights for route computation

3.8. Ontology-Based Framework for IDA. In the ITS IDA system, validation, representation, and interpretation are all linked challenges that must be addressed simultaneously. These concerns were resolved in this study by the development of a new IDA framework that makes use of the most up-to-date semantic technologies.

The workflow of the proposed framework is illustrated in Figure 2. If you are doing an IDA study, the first step is to collect information on the dynamic system that is being investigated. It is possible to complete the process manually, though automatic sensing devices are more commonly used these days. Each observation includes the measurement of system attributes and the provision of an estimated value, as well as the provision of a contextual information and time stamp, such as increasing the quality of data measurement. Validation and storage of these observation records are accomplished through the use of large archives of observation records.

The validation process includes data preprocessing methods such as outlier detection, noise reduction, and input error correction, among others. In order to properly assess the stored readings, the information from the sensors must be linked to the observation records. This data should be precise enough to determine the precision of the sensor, its working range, engineering units, and other relevant information. It is critical that the data collection and validation tasks be adapted to the specific requirements of each application under consideration.

As a result, there is no implementation guidance for these activities provided in this document. Instead of this, a reusable data representation model is proposed. The construction of a fundamental framework for a knowledge base (KB) is a critical component of the knowledge management process. The three main ontologies are as follows:

- (1) A measurement ontology is unified into observation records via semantic annotation

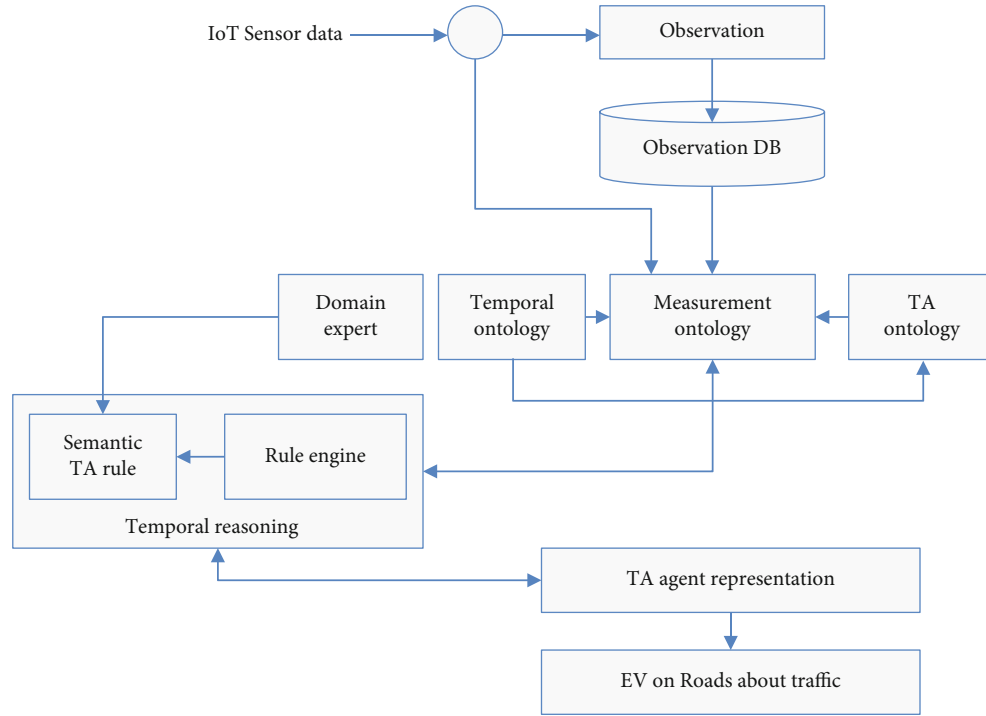


FIGURE 2: Workflow of ontology processing in ontology layer.

- (2) This section also includes an TA ontology for various depiction methods and levels of abstraction, which may be found here
- (3) A temporal ontology to assist in the reasoning process

It is necessary to develop consistency models in order to incorporate data from a variety of sources into the knowledge base, which must be written in a computer-readable language.

An expert agent is allowed to learn for recognizing and analyzing the trends via abstraction model in order to populate the knowledge base with qualitative episodes in this approach. Raw data is given as input to construct higher-level qualitative episodes, which are then used to construct higher-level qualitative episodes. However, machine learning may also provide this type of information, which was formerly provided by domain experts when constructing TA. Making the connection between operational data and abstract notions necessitates the participation of these people and their expertise. Expert knowledge, such as horn-like rules that aid in the depiction of TAs, can be included in the KB as expert knowledge.

A variety of inference engines are employed for a variety of functions. Reasoners that adhere to the consistency standards of the KB can produce classification schemes that are both sound and complete in their descriptions. It is still not possible to discern temporal dimensions of ideas or relationships using *D-L* inference processes, despite these efforts. As a result, there is a layer of temporal reasoning is applied.

Such type of temporal thinking is considered essential for ITS IDA interpretation since it allows for the identification of clear and consistent temporal pattern matching. It

is possible that further reasoning processes for TA representation agents will be necessary for representation techniques. The study also considers the importance of a query engine such that the clients can execute the queries on qualitative and measurements representations of states and process variables that they have access to, among other things.

4. Results and Discussions

The experiment listed below is a straightforward experiment for testing the automatic synchronization of traffic signal length time. As long as the qualitative segments are linked with the outputs of IoT sensor and temporal abstraction methods are used, all of the OCG Web Standards are fully compatible with SIN, enabling the tracking of abstraction tasks to be performed.

In this section, the experiments are conducted on Eclipse SUMO simulator, and performance is reported in terms of delay, energy spend per unit on number of EVs, and execution time of ontology-based estimation.

The results of simulation show that the proposed method achieves reduced delay (Figure 3), reduced energy consumption (Figure 4), and reduced time of execution (Figure 5). The use of this framework allows for the coexistence of knowledge-based and shaped temporal abstractions, which is unique for intelligent data analysis methodologies. The outcome is a more versatile data format, which opens up more analytical possibilities. A semantic sensor network initiative called the Semantic IoT Network is being used to combine ontology-based semantic IoT sensor data and observations of all kinds.

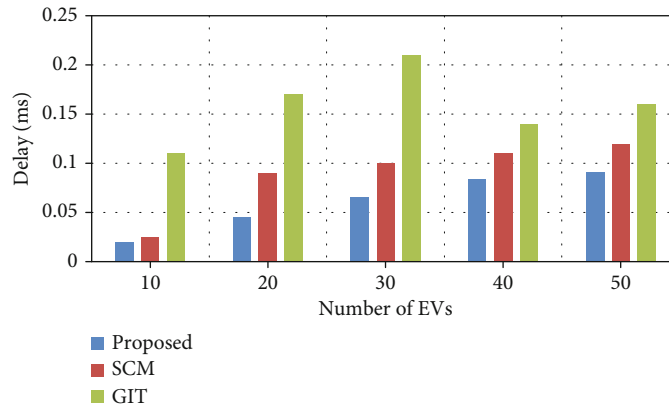


FIGURE 3: Delay.

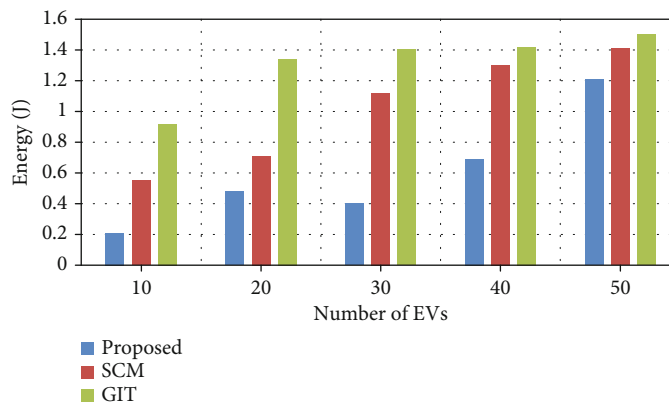


FIGURE 4: Energy consumption.

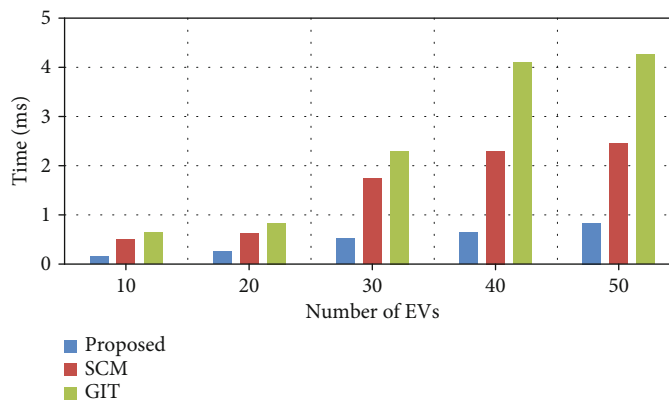


FIGURE 5: Execution time of ontological decision.

The data is semantically connected in the ontology layer, which is the final layer. Here, the study created an ontology to define the many ideas and relationships involved in road traffic. The agent layer, which is located at the very top of the stack, is responsible for all of the work that is done to improve the driving experience. It is possible to prioritize congested stretches of roadway over less congested sections of roadway using this technique.

5. Conclusions

In this paper, we develop an ontology architecture for a traffic sensor network, which can be used to improve the driving environment in urban areas. The system uses sensor data to execute a number of functions that are designed to improve the driver comfort. Raw sensor data will be stored in a database in the second layer of the system. The study uses

ontologies to define the traffic conditions in order to gain a better understanding of the data acquired by sensors. This comprises the location of EVs, infrastructure, and sensors, as well as the placement of sensors. However, despite the favorable results of the experiments, there is still much work to be done in this field.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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