Abstract

In the past few years, the integration of automation techniques with the traditional transportation system has minimized on-road hazards and traffic congestion. Further, this also assists in communication among the vehicles. The researchers have developed diverse techniques and methods such as Advanced Driving Assistance System (ADAS), Intelligent Transportation System (ITS). However, none of these techniques provide prior safety-related information to the users. Safety-as-a-Service (Safe-aaS) is one of the uniquely developed platforms that provide safety-related customized information to the users.

Typically, Safe-aaS comprises five layers- device layer, edge layer, decision layer, decision virtualization layer, and application layer. In the Safe-aaS environment, heterogeneous forms of stationary and mobile sensor nodes are present in the device layer. The stationary sensor nodes are deployed at a particular geographical location. On the other hand, sensor nodes are either inbuilt or externally placed into the vehicles. These sensor nodes sense and transmit data to the edge layer/cloud, depending upon the time-critical nature of data. Thereafter, the primarily processed sensed data is transmitted to the decision layer for further processing. The generated decisions are logically mapped with the user's selected decision parameters in the decision virtualization layer. Finally, the customized decisions are provided to the users. During registration, the users provide their credentials, select the decision parameters, and make payment through the web portal. In a road transportation environment, decision parameters may include a number of sharp turnings, number of potholes, speed limit, distance between neighboring vehicles, sudden weather conditions, and driver's behavior.

In a Safe-aaS implemented scenario, a huge volume of data is generated and transmitted to the cloud/edge. Therefore, the processing, analysis, and storage management of this colossal volume of data is a complex task. In case of any delay in delivery of their decision/delivery of incorrect decisions, may lead to a hazardous situation. On the other hand, the sensor nodes present in the device layer, are energy-constraint in nature. Sensing, processing, and computation of the same data may result in unnecessary energy consumption. Therefore, it is necessary to conserve this energy for future applications as well as timely delivery of accurate decisions.

To fulfill the above-mentioned criteria, we propose the adaptive decision-generation mechanism named as "Dec-Safe". In " Dec-Safe", we categorize decisions as static and dynamic. Static decisions are generated from the relationship mapping between static parameters such as a number of sharp turns on a road, the location of potholes, and the location of speed breakers, whose value does not vary frequently with time as static. Therefore, the utilization of storage units and the number of overall sensor nodes required are reduced. As a result, the overall energy utilized for decision generation is reduced. On the other hand, dynamic decisions are those whose value varies frequently such as weather, road conditions, and sudden hazardous situations. Dynamic decisions are generated when users select dynamic decision parameters. The decision parameters selected by the users may overlap with each other. We apply the clustering method to extract similar decision parameters. Therefore, the same dynamic decision is delivered to multiple users simultaneously with minimum delay and certain customization.

In Safe-aaS, the registered users access the safety services during their journey from the source to the destination. The users make payments for the services through the web portal.Safety Service Provider (SSP)s are the centralized entities, which manage the entire Safe-aaS platform. The sensors and vehicle owners rent their sensor nodes to the Safe-aaS platform and receive the amount. The profit of the SSP is the remaining amount after providing the rent to the sensor and vehicle owners, and maintenance charges. Therefore, complex transactions take place among these sensor and vehicle owners, SSPs, and users. As these decisions are time-critical, maintaining the Quality of Service (QoS) and providing optimal prices to the users for their requested decision parameters, are major concerns of the SSPs. Based on these above-mentioned reasons, the SSP suggests low and high-price parameters to the users periodically.

Typically, in Safe-aaS, customized time-critical decisions are generated and delivered to the users. The processing, analysis, and storage of this generated data is quite complicated. Moreover, another major challenge associated with the Safe-aaS platform is to provide accuracy in the generated decisions. To improve the accuracy and minimize the latency incurred in decision generation, we place the edge servers at the network edge. Therefore, unlike the traditional Safe-aaS platform, the analysis and storage of data are done at the user's location. The edge servers are deployed at certain geographical locations. As a result, the overall computational and processing costs are also minimized. Therefore, we introduce the edge intelligence layer in the Safe-aaS platform to provide accurate decisions with ultra-low latency. We apply one of the popular Artificial Intelligence (AI) models, Artificial Neural Network (ANN), at the edge nodes to classify and select edge servers. The fuzzified decisions are generated at the edge server, and further, these decisions are propagated to the decision layer. Therefore, latency in decision delivery is also minimized.

In the Safe-aaS environment, the users are likely to select decision parameters as per their requirements. However, we introduce that based on their geographical location, the decision

parameters are suggested by the SSP. In that scenario, the users are not charged for enjoying the safety services. Generally, the processing cost of the decision parameters is quite high. Therefore, the total price charged from the users is based on the selection or de-selection of parameters or number of times safety services are availed by them. In such cases, the decision is not generated by the ANN on the server side if there is no parameter selection. Hence, the profit of the SSP is determined by estimating the cash outflow and inflow of the number of users, sensor types, number of active sensors, and their geographical location.

Keywords— IoT, IIoT, IoV, ITS, ADAS, Autonomous Vehicles, Safe-aaS, Road-Safety, Safe-Driving, Service-Oriented Architecture, RSU, Sensors, AI, ANN, Machine Learning