Revolutionizing Autonomous Vehicle Intelligence with Cutting-Edge Spatial Crowdsourcing Framework

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Abstract. Crowdsourcing is an approach for performing spatial tasks that depends upon the efforts of many people and has received increasing attention in the past couple of years. Because of their effectiveness and simplicity, crowdsourcing work is frequently conducted online so-called mobile crowdsourcing. Due to the special challenges of engaging in real physical locations, this conventional technique might sometimes fail. As a result, a completely novel model for data collecting known as advanced spatial crowdsourcing (ASC) has grown up in recent years. In this paper, review of the existing work has been done and suggested the methodology by constructing the architecture and features of crowdsourcing, including Mobile Crowdsourcing, Spatial Crowdsourcing, Autonomous Vehicle Crowdsensing, and much more. As crowdsourcing is very important for autonomous vehicle, our research suggested the integration of Advanced crowdsourcing with Autonomous vehicle & real-time intelligent system. The objective of this research is to identify and explore the ITS (Intelligent Transportation System) technology that is made possible by IoT devices, as well as vehicle safety, vehicle security, and intelligent vehicle systems implementing advanced crowdsourcing. Finally, research aims to offer a variety of crowdsourcing applications and services like healthcare, Smart city, autonomous vehicle, and advanced applications.

Keywords: Crowdsourcing · Mobile Crowdsourcing · Advanced Spatial Crowdsourcing (ASC) · Autonomous vehicle · real-time intelligent system · ITS Intelligent Transportation System · Internet of Things · Smart Cities

1 Introduction

1.1 Introduction to Crowdsourcing

Crowdsourcing is a type of human processing, where human processing is a way of getting people to carry out tasks that would often be given to a computer to perform autonomously, like language translation work. As the use of the Internet and personal

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mobile devices (PMDs) increases, crowdsourcing can assist in solving difficult problems that machines are unable to do on a large scale [1]. The development of the Internet of Things (IoT) and distributed data storage systems are prerequisites for scalability. Crowdsourcing technology makes it easier to use the crowd to fulfil a given job [2]. To complete a task, a crowdsourcing system recruits a "crowd" of human beings to assist in resolving a specific issue. The necessity to finish a lot of little, repetitive activities with high short-term peak loads is present in many occupations. The most important need is that the individual performing the duties be diligent and strive to complete them to the best of their abilities. In many circumstances, these jobs do not require specialized expertise. As the use of the Internet and personal mobile devices (PMDs) increases, crowdsourcing can assist in solving tough problems that machines are unable to do on a large scale [3]. The development of the Internet of Things (IoT) and distributed data storage systems are prerequisites for scalability. Powerful mobile crowdsourcing frameworks have greater potential to be developed thanks to the rise in mobile devices, better data capacity, and ultra-reliable and low-latency communications in current and next-generation cellular networks. The process of crowdsourcing starts from the design phase and terminates with the implementation phase. Three high-level kinds of crowdsourcing often exist [4] which are Open innovation, Data collection and Analysis.

1.2 Crowdsourcing: Architecture and Features

Crowdsourcing architecture and features are critical for autonomous vehicles. Crowdsourcing applications based on autonomous vehicle technologies include mobile, geographic, car infotainment, and passive sensing crowdsourcing. This task necessitates drivers or humans who are attempting to improve autonomous vehicle decisions based on crowdsourcing, such as current traffic information on the road, route optimization for emergency vehicles, finding empty parking slots, and so on [5].

The crowdsourcing architecture for autonomous cars and smart city infrastructure is shown in Fig. 1. The crowdsourcing platform's task requesters include OEM (original equipment manufacturer) of autonomous cars and smart city developers. Drivers and humans complete these activities using mobile devices and vehicle entertainment systems. Input from drivers and humans is kept locally before being sent to the data warehouse server for compilation and organization. The outcomes of completed tasks are communicated to the task requesters [6]. The activities completed by drivers and people help task requesters enhance the system. This is the process flow of an autonomous vehicle crowdsourcing platform.

1.3 Autonomous Vehicle Crowdsourcing

Autonomous Vehicle Crowdsourcing is very important for developers to build a robust intelligent system. To progress smart systems, crowdsourcing is crucial in the context of autonomous vehicles since these vehicles require more input data to enhance the applications that are running for real-time control and decision-making. With the utilization of sensors included into autonomous vehicles, automatic sensing crowdsourcing uses passive data collection to send information to a centralized platform for processing and utilization. Scheduling the gathering based on its trajectories is one of the primary

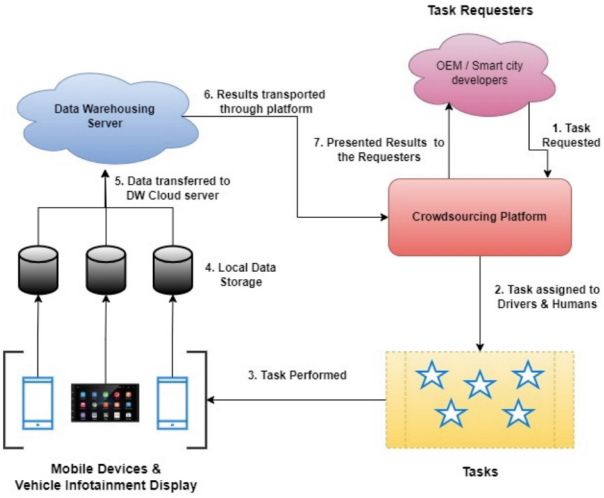

Fig. 1. High level Generalized architecture of ITS crowdsourcing.

goals of passive collection jobs. It is possible to follow autonomous vehicles in real-time using other passive collecting chores [7]. Making automated data collecting makes the system more dependable and safer since fewer discrepancies would be present in the data obtained and because humans are not occupied by gathering data operations while operating an automobile [8].

2 Literature Review

2.1 IoT Technologies Improving Mobile Crowdsourcing

Crowdsensing and crowdsourcing play a significant role in the development of new IoT applications and serve as the interface between human-based and object-based methodologies. With crowdsensing, the same notion is used, but instead of using human input, equipment or sensors collect the data. Crowdsourcing is a method of getting services, ideas, and useful data from a group of people [9]. User's contributions are crucial to the dependability and data quality of both crowd sourcing and sensing systems. Mobile crowdsensing, when the resource offered by the public is their sensing ability, can be compared to crowdsourcing. Crowdsourcing is a category of crowdsourcing strategies that makes use of independent, paid in full, and volunteer human resources to do a particular activity. The primary goal of the Inspection on MCS [10] and its Possible Applications in the IoT Era focuses on the use of crowdsourcing for data collection to address many significant issues in widely used computing systems, such as participatory urbanization, which promotes novel methods and strategies for citizens as individuals to actively participate in their city, neighborhood, and urban self-reflexivity. Another illustration is the use of mobile devices as channels for atmospheric sensing that encourage neighborhood action and promote good social change (Fig. 2).

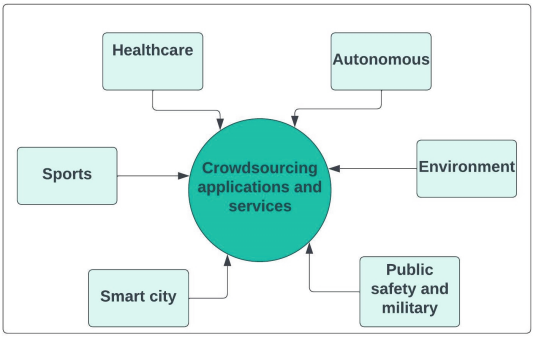

Fig. 2. Figure representing the different application of crowdsourcing with services.

As interconnectivity between all nodes of the layered communications network continues to increase exponentially, ITS technology enabled by IoT devices like embedded sensors in autonomous vehicles and new communications infrastructure might offer a hitherto unexplored foundation for mobile crowdsourcing applications. A variety of high-bandwidth network topologies, such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), and vehicle-to-drone (V2D), might be created because of the development of 5G networks [11].

Table 1. Research studies focuses for IoT crowdsourcing.

Year	Author	Focus
2017	He, S. et al. [9]	Establishes the IoT devices' locality with improvements
2018	Zhu et al. [13]	Using automotive fog computing for evaluating the crowdsourced dash camera footage in real time
2019	Wang, Y et al. [10]	Mobile crowdsourcing could be improved more honest and efficient with the use of incentive systems
2019	Park, J et al. [16]	To promote involvement in crowdsourcing, put attention on knowing how to ask: how to craft intriguing and relevant queries
2021	Tan, L et al. [15]	5G-enabled smart cities: a decentralized trustworthy service mechanism driven by blockchain for the crowdsourcing system

Research existing work has been demonstrated in the tabular form Table 1 which focuses on IoT crowdsourcing and improvements towards the same in some last years.

2.2 Advanced Cloud Technologies for Crowdsourcing

Crowdsourcing is the process of solving issues, obtaining new ideas, or creating content by enlisting the help of a large number of individuals, particularly those who are part of an online community such as social media users, mobile users, and so on. Advanced

cloud technology can help make crowdsourcing more successful and efficient. The use of cloud-based technology for crowdsourcing platforms has made it simpler to offer tasks to the crowd and collect data from humans in real-time from many sources with high accuracy. Users of the crowdsourcing platform may crowdsource without having to worry about the technical infrastructure of cloud computing [12]. Cloud computing enables data access as well as crowdsourcing services. Here are some advanced cloud technologies for crowdsourcing.

- **Internet of Things (IoT) Integration:** Cloud technologies can be combined with IoT devices equipped with various sensors to enable real-time data collection from a variety of sources such as autonomous vehicles and smart city crowds, enriching crowdsourced datasets with diverse data types, and improving crowdsourced information quality as well [13].
- **Container orchestration:** Container management tools are key crowdsourcing technology. Kubernetes is a container management system that makes it easier to build, grow, and operate distributed crowdsourcing applications.
- **Big Data Processing:** Cloud-based big data processing frameworks such as Apache Hadoop and Apache Spark allow for the efficient processing and analysis of massive crowdsourcing datasets. Machine learning techniques for real-time data processing are provided by big data processing [14]. It simplifies and adds value to cloud-based crowdsourcing procedures.
- **Blockchain for Crowdsourcing Verification:** Blockchain technology can increase the transparency, trust, and security of crowdsourcing platforms by providing an immutable record of contributions and outcomes. It may be used to validate contributions and ensure that incentives are delivered properly [15].
- **Crowdsourced AI Training:** Crowdsourced AI tools and AI models are taught to conduct cloud-based operations for crowdsourcing platforms. The cloud-based crowdsourcing platform becomes more robust and representative when AI is used [16].

2.3 Concepts and Logics for Crowdsourcing

Crowdsourcing is a large group of direct and indirect sources which collects data like smart sensors, smartphone data, and other sources in a closed environment that helps the autonomous vehicle to improve its internal system and makes it intelligent. There are some factors which are important like (a) To determine the type of data that needs to be collected (Images, videos, text, personal data, medical data, public data, etc.). (b) Determine the internal and external sensors involved. (c) Create (or outsource) a platform for registering the sensors, sharing the data, and managing the sources. (d) Gather the data through the cloud platform [17].

There are different benefits for collecting data through crowdsourcing:

- Deliver for high-quality and relevant data.
- Improvements in the system.
- Assists in reducing expenses.
- Increases data variety.
- Saves computational time.

Crowdsourcing data collecting drawbacks are as follows:

- Complex to handle and filter the useful data.
- Lack of anonymity for the collected data.
- Tracking and evaluating data collecting is challenging [18].
- It is challenging to assess competence.

In our research study, explanation of an elementary description of crowdsourcing with existing work has been showcased, explained why it is crucial for autonomous vehicles, described how crowdsourcing structure with features assists the system make more accurate decisions, and subsequently discuss them in more detail by emphasizing all the finer points. System Architecture has been constructed that incorporates the cloud to increase the system's intelligence regarding autonomous vehicles. At last, examined the rational future paths required for the advancement, creation, and use of automated real-time crowdsourcing platforms. These technologies will serve as the foundation for a wide range of use cases, including sophisticated surveillance of traffic, extremely detailed modelling of the road network, enhanced Kalman filter estimates, and other services that will support the introduction of driverless vehicle technology on public roads.

2.4 Increasing Crowdsourcing Technology

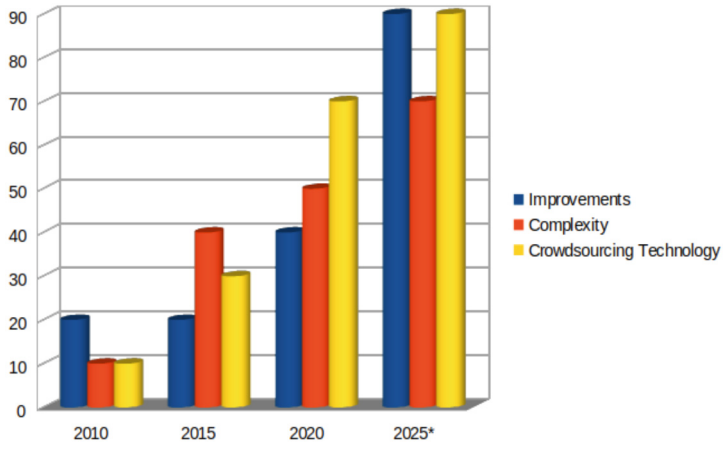

Fig. 3. Visualizing how mobile crowdsourcing can enhance the improvement in the system.

As shown in the Fig. 3, how the mobile crowdsourcing can enhance the overall improvement in the system. From 2010 onwards crowdsourcing technology was adapting for improving the system and these types of technology are playing a vital role for now and future aspects. But the challenge was the increasing of the complexity that will be minimized in the future by using different suggested approaches like data optimization. Also, there are many advanced tools for developers like MATLAB and Simulink that can

automate the process and solves the complexity to make the system efficient [19]. There are small scale development projects like smart irrigation system using IoT, these types of system can be improved by adding our approach i.e., Advanced Spatial Crowdsourcing [20].

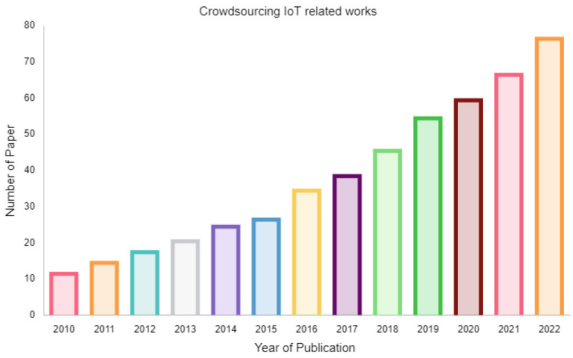

Fig. 4. Statistics of increase in crowdsourcing IoT research works.

For the research comparison study, existing works from reliable and pertinent databases, including Google Scholar, IEEE Explore, and Scopus, are considered. A high rise in crowd-IoT applications has been observed recently, according to research projects spanning the years 2010 to 2022. The numbers pertaining to the rise in crowd-IoT application efforts are displayed in Fig. 4.

3 Methodologies

3.1 Computing Crowdsourcing

To process data or store it concurrently, a network of computers known as the cloud coordinates their efforts. Many ITS crowdsourcing platforms will be built on top of cloud computing infrastructure; the scalability provided by developments in cloud computing technology and approaches works hand in hand with the IoT and communications technologies outlined in the preceding section. The system may be made more efficient by using cloud computing methods and technologies such as edge computing, distributed file processing, storage, job management, worker dependability measures, and trust mechanisms. In this part, high level of several essential cloud attributes that support ITS [21] crowdsourcing has been discussed. A simplified representation of how these cloud-based structures operate is shown in Fig. 5.

In Table 2, All the possible types of crowdsourcing have been suggested with implementation platform and its accuracy with included all the environmental factors.

3.2 Advanced Automated Crowdsourcing Management

For managing crowdsourcing platform is very complex as there is a lot of data is collected and stored for real-time decisions and analysis. Procedures must be in place to distribute

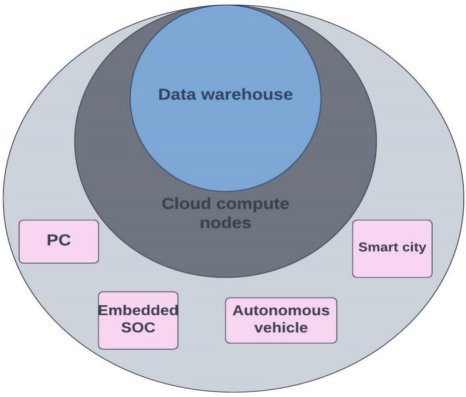

Fig. 5. A diagram representing the relationships between devices in computing crowdsourcing.

Table 2. Possible types of Advanced Spatial Crowdsourcing.

S. No	Crowdsourcing Type	Implementation	Precision
1	In-Vehicle Sensors	Local Platform	High Accurate
2	V2X (Vehicle-to-Everything)	Cloud Platform	Less Accurate
3	External users' data	Cloud Platform	Less Accurate*
4	External sensors	Cloud Platform	High Accurate
5	Third Party Applications	Local / Cloud Platform	Less Accurate

positions across the platform due to the complexities of ITS crowdsourced applications, the enormous number of activities, and the numerous prospective employees. Allocation of duties presents a special set of difficulties for spatial tasks. It can also be made advanced using cloud IoT architectures. The previously described cloud-based platforms would work in cooperation with automated management systems. The responsibilities can be allocated spatially, outcomes may circulate through the network at optimized points of access, and information can be pipelined, gathered, and preserved in locations that are geographically optimized to be best for use according to the areas it has been gathered at. This is achieved by consequently optimizing the task distribution by the cloud engineers. The latest developments in cloud computing technology are setting the stage for Intelligent autonomous vehicle system to continue functioning as a significant crowdsourced platform. By integrating traditional autonomous vehicle networks into the IoT, updated networks will become advanced cloud computers, giving system engineer employees much more data to make decisions that will enhance the future of the autonomous vehicle experience for everyone who uses this type of advance vehicles. In this study [22], AUTOSAR architecture has been used for optimizing the overall system that can also integrated with our approach for enhancement of the designed architecture.

3.3 Security and Privacy in Mobile Crowdsourcing

Crowdsourcing is a critical platform for gathering data from crowds, autonomous cars, and addressing complicated challenges connected to autonomous vehicles and smart cities. Privacy and security are critical components of the crowdsourcing platform. The privacy of a user's profile and data is especially crucial since an attacker can take information from a user while they are undertaking crowdsourcing activities. To secure sensitive data transferred across mobile devices, car infotainment systems, and crowdsourcing platforms, data encryption techniques like end-to-end encryption are deployed. To protect the confidentiality of users' personal information and data obtained during the crowdsourcing process. Data anonymization drops all personally identifying information from users and assures that the data cannot be traced back to the user. The most important aspect of crowdsourcing procedures is user authentication. Any unauthorized user executes tasks and gains access to the crowdsourcing platform's sensitive data. A strong user authentication mechanism checks users' identities as they take part in crowdsourcing activities. Protect the communication channels between mobile devices, the vehicle's infotainment system, and the crowdsourcing platform. Strong secure protocols are used to protect communication channels, and the security of secure protocols is continually updated to address any new vulnerabilities [23]. These are the critical aspects to preserve user data privacy and the security of crowdsourcing operations.

4 Advanced Spatial Crowdsourcing for Autonomous Vehicle

4.1 Data Optimization for Crowdsourcing

To fulfil the tasks assigned through spatial crowdsourcing, employees must physically be at those places. This kind of crowd intelligence involves people gathering, analyzing, and disseminating geographical and/or social understanding in the actual environment. Geo-crowdsourcing or location-aware crowdsourcing are other terms used to describe SC. However, even though SC, from which many applications may substantially benefit, has received far less attention, there has been a lot of study on crowdsourcing. For example, the government must gather data on the city's air quality at various intervals (e.g., per hour, day, every month, and yearly), and each site needs a number of people to provide the information. Due to the geographically distributed nature of the employees in the city, a standard crowdsourcing method where participants just submit the data in their immediate area at the time of their choosing would not give an accurate representation of the city's air quality situation. Due to a lack of employees in some regions at some times, not enough data may be reported from those places or periods. On the other hand, this problem will be solved by a Spatial Crowdsourcing system that sends workers in an anticipatory way. Typically, some challenges in spatial crowdsourcing:

These challenges frequently interact rather than being in isolation from one another:

- Task formulation
- Task assignment or worker selection
- Task assignment
- Incentive mechanism

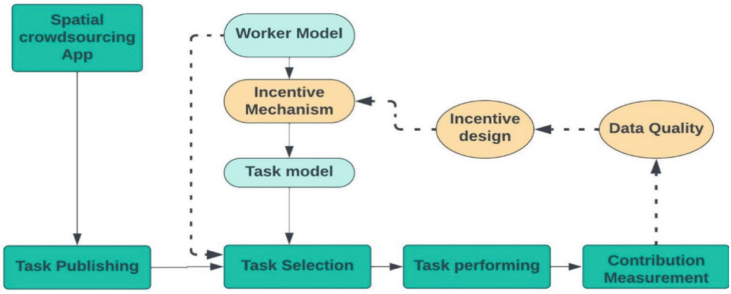

Fig. 6. Generalized block diagram of (SMC) Spatial Mobile Crowdsourcing.

- Scalability

The geographical crowdsourcing flow is Showing in Fig. 6. At first, each employee downloads the SC app and has access to all the assignments posted by task publishers. If the server is assigning jobs, the server gets information about all the employees and hires suitable workers; if the worker is picking tasks, the worker chooses the right task set to maximize model and the worker model are used to inform both worker selection and job selection. To encourage employees to complete their duties, an incentive structure is created. When the assignment is finished, the task publisher receives the information from the employees. The system evaluates user contributions based on factors such as user dependability and contribution quality. Further adjustments to the incentives are made using the results. For instance, after the assignment is publicized, the worker's dependability and timeliness may vary, necessitating the updating of the incentive for this worker. If there are open jobs, this process will continue to be repeated.

The priorities of various Spatial Crowdsourcing systems might change depending on the viewpoint of the employees or the systems. A worker's objective is often to maximize total net reward, which is the sum of the reward he receives from the system and any costs (such as travel expenses). Task scheduling and path selection need to be taken into consideration together when choosing tasks since the worker may choose the optimum way to complete all the jobs to decrease costs. From a system's viewpoint, the objectives are frequently to achieve maximal job coverage at the lowest possible cost [24].

There are some benefits after data Optimization:

- Optimize the expenses for the system.
- Maximize the accuracy of data and quality.
- Increase the task scope.

Each worker w_j has a dependability p_i, j for task z_i (worker reliability). Worker wj completes job tj before the conclusion of the cycle with probability pi, j if he or she is given the task, which is:

$$y_{i,j} = \begin{cases} 1 & with\,probability\,p_{i,j} \\ 0 & otherwise \end{cases} \tag{1}$$

Assume that $p_{i,j}$ (0, 1) without losing generality. Worker w_j's dependability on task z_i relies on the task, the worker, and the environment in which they work.

4.2 Real-Time Intelligent Decisions with Spatial Crowdsourcing

The information that is intake from the roads by different smart sensors may be utilized for monitoring traffic systems in real-time and other major applications that makes the system more intelligent. Mobile phones, reliable high-bandwidth technology for communication, and Smart sensor-equipped cars may be utilized for uploading large amounts of data on congestion, average speeds, accidents etc. This data information, for instance, may be utilized by a real-time GPS navigation system to redirect cars away from a particular road section and reduce systemwide time to travel by detecting anomalous interruptions in the flow of traffic or other reasons. Figure 7 represents constructed approach as the high-level system architecture of autonomous vehicle with the integration of advanced crowdsourcing. In Fig. 7, There are two environments which include internal and external sensors, internal sensors are in-vehicle sensors which all sensors are established in vehicle and for external there are some smart sensors which are contributing as a crowdsourcing. At other sides data is going in cloud for analysis and post processing to improve decisions. Having to spot service interruptions in their initial place is a barrier in putting this into practice. Though accidents are often unanticipated incidents and may be avoided by redirecting traffic, congestion in the roadways is generally recurring (such as rush hour times at school or office timings) and can be predicted from previous information or any other sources.

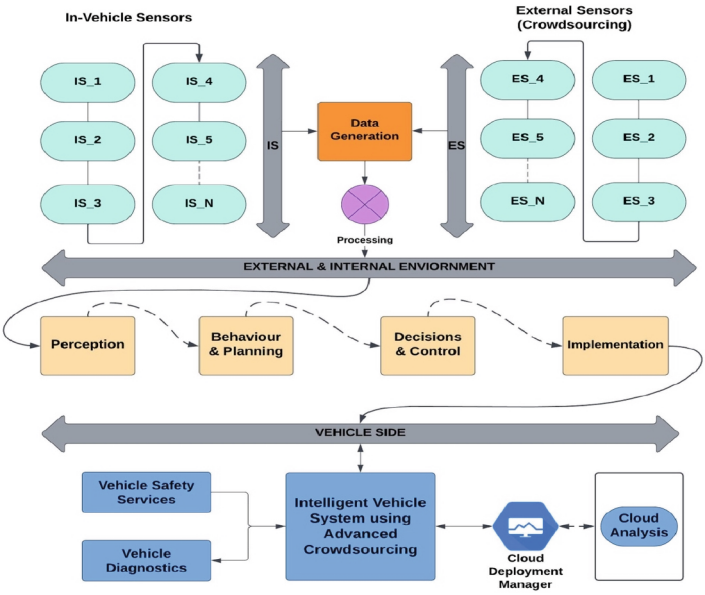

Fig. 7. Suggested approach via constructing the overall Intelligent System Architecture (ISA).

Autonomous incident identification must also result in changes or updates as quickly as feasible so that anyone intending to go over the restricted path can do so without incident and locate an alternate path in a fair period. This information might be utilized to

resolve a user balancing issue and direct traffic routing, supposing some sort of controlled mechanism which is controlled by the integration of smart sensors and advanced software etc.

4.3 Advanced Applications

When doing crowdsourcing activities, advanced applications for mobile devices, automobile infotainment systems, and certain automated sensor technology are necessary for greater input to the crowdsourcing platform. Advanced applications, such as reporting and assigning free parking slots using a crowdsourcing platform for smart cities, are required to identify a free spot in smart cities. The framework based on mobile devices and car infotainment systems provides services for a user to report a free parking place in the traffic network. This application displays real-time availability of parking spaces from registered crowdsourcing users and automobiles. A significant component is improved autonomous vehicle high resolution map performance. Enhancing the resolution of a map [25] on a regular basis is an expensive and time-consuming operation for OEMs, but enhancing the resolution of a map utilizing a crowdsourcing platform is less expensive and takes less time. Some automated sensing technologies have been fitted on public transport vehicles such as buses and capture real-time road data to improve map resolution for autonomous cars. Using this innovative application, vast volumes of data may be collected in less time and provide greater input for enhancing map resolution from crowdsourcing platform. One of the advanced uses for crowdsourcing systems is traffic prediction based on crowdsourced social media data. Advanced transportation tracking using crowdsourcing-based automated sensing technologies [26, 27]. These are some sophisticated crowdsourcing platform applications.

5 Conclusion

In this research study, existing work for IoT crowdsourcing has been demonstrated by covering all the efforts of researchers and developers. IoT technologies, and employing cloud technologies for gathering real-time data, as well as the concept and logic behind crowdsourcing in brief has been showcased by different methods. Also explained, how crowdsourcing structure with features helps the system correct and precise, and analyzed a new branch of crowdsourcing i.e., Spatial crowdsourcing - to safeguard user data privacy and the security of crowdsourcing operations. Mobile crowd sensing is a developing field with a wide range of potential applications. The evaluation also includes advanced spatial crowdsourcing topics such as data optimization in Autonomous Vehicle, maximizing data accuracy, quality, and Task of scope with real-time intelligent environment making use of in-vehicle and external sensors. High-level system architecture has been constructed in this research study by adding the approaches to make the system of Autonomous Vehicle more intelligent and advanced with the capabilities of Advanced Spatial Crowdsourcing. For future aspects, robust output can be seen in the system for crowdsourcing by integrating with artificial intelligence and machine learning.

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