Omniscient Situational Aware Traffic Management System (TMS) for Smart Cities

Iqbal Ahmed
Dept of Computer Science & Engineering,
University of Chittagong, Bangladesh

Riya Biswas
Dept. of Electrical & Electronics Engineering,
University of Chittagong, Bangladesh

ABSTRACT
Modern and efficient modes of transportation play a crucial role in development of any society. Emerging technologies, especially, Internet of Things (IoT) are leading the world towards Smart Cities. However, Smart Cities cannot function without an intelligent and autonomous Traffic Management System (TMS). Smart Cities require such TMS, which is not hindered by issues like, on-road congestion and delays, accidents, inappropriate emergency response, waiting/searching or in extreme cases unavailability of parking. Those all factors also contribute to the wastage of fuel and energy and are the major source of air pollution in urban areas. Vehicular Ad-hoc Network (VANET) can utilize the full potential of the IoT and might provide a comprehensive solution for traffic related problems in Smart Cities. Therefore, we offer a VANET based Novel Quasi Omniscient Situational Aware Traffic Management System (TMS) that expeditiously tends to eliminate all these traffic-related problems. The System acquires user, vehicular and environmental contexts through road- side sensors, then optimally processes and stores it either at edges or at cloud layer (according to the situation) and produces requisite actuations. It recommends the optimal path from source to destination and automatically reserves the (optimal) nearest parking spot to destination while considering the dynamic real-time variables in the environment such as congestions and road-blockages throughout the itinerary. Simultaneously, we have created an analogy between vehicle and packet routing using Particle Swarm Optimization (PSO) method. System routes and manages the vehicles, as packets are (optimally) routed and guided over the IP network.

General Terms
Traffic Management System, IoT, VANET, Smart Cities

Keywords
Omniscient Situational Aware, Parking Management, Optimal Path Algorithm, Particle Swarm Optimization, IP network

1. INTRODUCTION
Internet of Things (IoT) is a platform of smart sensors and computing devices interconnected through Wireless Sensor Networks (WSNs) [1, 2, 3]. IoT is decisive for Smart Cities, because it provides a mechanism to acquire process and communicate information inclusively and expeditiously among multiple computing and sensing devices. Such capability is utilized in Smart Cities to provide (real-time) numerous automated and intelligent services enhancing the aspects relating, but not limited, to the transportation, waste management, crime detection, emergency, school, and other community service, consequently, improving the quality of life tremendously [2,3]. However, transportation may be the most important factor in Smart Cities because most of the favors for example, waste and emergency management, commuting to work/education and parking pins its hope on it. Besides that, it is essential to manage road traffic in such a way that it reduces the air pollution to theminimum.

However, inefficient traffic management is one of the major issues in any metropolitan including on-road congestion and delays, accidents, inappropriate emergency response, waiting/searching or in extreme cases unavailability of parking and resultant air pollution [4, 5]. Mart City's senor rich environment can be utilized to solve all those issues. Therefore, many research works proposed multiple solutions to overcome traffic related problems in Smart Cities by making full use intelligent wireless networks of sensors and digital devices. For instance, Vehicular Ad-hoc Network (VANET) is often utilized in such domain to solve traffic problems and it is a product of IoT [6-8].

Much research has been done on traffic managements system using advanced technologies like Bluetooth devices, Zigbee, sensors, VANETs, wireless sensor devices, and cameras, etc. [9-11]. The researcher started to observe the real-time data for the prevention of accidents, Control congestion, reduced waiting time and fuel usage, emergency responseservices, and violation of traffic rules, etc. Existing traffic Management system is trying to modernize the quality of life by solving the traffic issues and draw back like congestion, response services, Parking Management, optimal path, stress-provoking delays, and carbon emission gases. Although, there are several methods to ameliorate the congestion and select the optimal path, but they still needed improvements to respond in unaware situation actively and suggest best optimal solutions, and alternative solutions. Optimal path selection during the voyage and suggest alternative path in case of unexpected situation, parking the automobile via an optimal path, inform the emergency department in case of an accident and inform the law enforcement department in case of rule violation and reduction in carbon emission are some aspects they are missing in the existingsystem.

Therefore, we propose a VANETs Embedded Novel Quasi Omniscient Situational Aware Traffic Management System that can assess, predict, and take appropriate measures to improve traffic situation. System is based on IoT, utilizes its resources proactively, significant reduction in the problems such as, on-road congestion and delays, accidents and improves in-time and appropriate emergency response.

2. RELATED RESEARCH WORK
Many authors suggested IoT based system for road traffic monitoring, aware message and accident avoidance based on mobile sensor information processing. A GSM/GPRS/GPS TK103 used to collected Speed information and Geo-location. Tracker based system fixed in automobiles and sent to an Open GTS Server that stores them in an exceedingly SQL database, providing a real time OpenStreetMap visualization of trafficsituations [12]. In [13], researcher introduced a smart

traffic management control system which based on real time video processing technique used to measure the traffic intensity. Object detection is used for analyzed video sequence by a camera. RFID sensors used to ensure enforcement by system has advantage.

The authors recommended cloud computing to resolve theproblemsassociatedwithrealtime.Theycanincreasethe use of virtual strips in DTMon for tracking and detecting the end of the line, due to congestion. They proposed fuzzy logic and wireless sensors network controllers for detection of emergencyvehicle [14]. In [15], they offered a software defined network (SDN)- enabled method, named a software-defined network (SDN) enabled method, named SeDaTiVe. In VCPS situation to control the incoming stream of traffic in the network based on deep learning structural design. In traffic flow control Network, deep learning absorbs the secreted forms in information packets and produces an ideal route based on the discovered features. A. Aledegheishem *et.al* [16], represents an intelligent road traffic accident-avoidance approach based on intelligent transportation systems (TARs). It forecast probability about the occurrence of an accident in advance. It also provides the alternative paths to the vehicle traffics to avoid the congestions on roads that may cause of accidents. POVRP routing protocols used for messagedelivery. [17], the author proposed architecture in internet of vehicles for fog infrastructure. Modern technologies have allowed linked vehicles model that suggests a variety of real time protection and more products. The VCC (vehicular could computing) have the intelligence of a traditional centralized cloud that enables it to deal with the management, storage of big dataanalytics. The researchers in [18] represented a model that used context aware guidelines and DNN (Deep neural Network) methods, it can reproduce various vessel traffic conditions to successfully show intellectual data and to fit in linked structures with a VTS system under single window monitoring by linking vessel trafficdatabases. Vehicular cloud computing provides an effective improvement to congestion control, message dissemination etc. [19]. Vehicular cloud infrastructure and its classification extend the services by exploring the communication of vehicular clouds with additional clouds. Cloud computing distribute facilities that provide transportation security and effectiveness to vehicles. Cloud formation, integration type defined by a taxonomy of vehicular cloud. The VCC allows customers to use the services and resources of a coordinated vehicle group dynamically. Vehicle resources are shared in the VCC, such as storage and computing identities, to make decisions in the traffic management system [19]. The authors introduced online parking slot booking techniques to solve the parking problems in busy areas [20]. User can easily check the available parking slot and booked online using Androidmobileapplication.IOTusedtomaketheparking system more intelligent. In presented work Node MCU, IR sensors are hardware component and software components are Cloud access, Cryptographic techniques used for online parking system. IR sensor used to sense the object. Node MCU contain onboard Wi-Fi Module that used to host an application or for importing network functions from other application. Cryptographic algorithm used for secure data from unauthorized users. Finally, in [21], researchers proposed a system in which an optical wireless sensor network used in parking garage as counting the vehicles. They installed all wireless sensor nodes at all entrance, exit points and at other key points for count the vehicles. This system collects this data at near server and used to count the available and occupied parking spots. Parking guide information system used to provide the information about the available parking spot by using vehicles detectors. Common detectors contain, machine vision, loop detectors, infrared, ultrasonic, lasers and microwave. Transit based information system used to inform about parking space information and public transportationschedule.

3. METHODOLOGY

We propose quasi-intelligent TMS that expeditiously diminishes traffic pertinent problems inclusively and smartly. It operates to achieve common objectives that are rapid, secure, comfortable, and optimal routes. System includes optimal parking reservation, route selection, accident, and congestion avoidance and most especially the reduction in consequent carbon emissions. The proposed system is its analogy with the packet routing over IP network. System maintains such architecture where each vehicle is considered as packet and routed over a virtual circuit (real-time vehicular and roadside information) towards destination, however, driven by human.

3.1 Basic Factors

Traffic Management system involves following factors, as demonstrated in Figure 1.

- Smart vehicles
- Optimal path selection
- Emergency management
- Weather management
- Law enforcement department
- Toll collection management
- Parking management

Fig1: Smart Traffic Management System

Smart Vehicles

Smart vehicle is an intelligent mobile node that can drive itself and communicate with other automobiles or roadside units for sharing the information between them. VANET includes the roadside units that provide internet access to the Vehicles. [22, 23]. Smart vehicle can detect the pedestrians, animals or other objects via embedded sensors and can track the other vehicles and gives response in real time. It also has the ability of auto braking and assists the driver throughout the journey.

Emergency Department

Emergency department is responsible for management of any emergency that happen in transport system that Side Road Accident, etc. It also known as accident department. When an accident happened in a region, smart vehicles embedded sensors or smart phones by sensing the noise, gravity force, acceleration or speed etc. inform the emergency depart and asking for provide emergency care immediately

Law Enforcement Department

Law enforcement department is in charge for monitoring and taking some appropriate act against vehicles that violate law i.e., speed limitation etc. when a vehicle violates any traffic rule e.g. traffic signals, over speed, overtaking etc. Then Law enforcement department start to monitorthatvehicle and take appropriate action against the vehicle. Enforcement agencies also monitor the criminal or unregister vehicles that enter in the city and provide safety to citizens.

Optimal Path Selection

System creates an analogy with packet routing and guides the vehicles, as packets are disseminated over the network. Such proposed approach is novel and intended to solve prevailing traffic management issues expeditiously. Roadside sensors implant the system with the capability of real-time vehicular context acquiring and decision making. Such refined context is disseminated to concerned entities of the TMS to estimate an optimal path for each induvial vehicle. System is aware of positions and ordinations of all the individual vehicles and proactively decides the optimal itineraries for them and avoids the congestions and accidents.

Toll Collection Management

Electronic toll collection is a wireless system that will collect the charges online without the intervention of human. When a car will be passed from a toll point sensor will detect the car and get the necessary information e.g., V_ID, V_ Type and Vehicle number then charge the user. A major advantage is that driver does not have to stop for pay the dues. Consequently, it reduced the congestion and carbon emission.

Parking Management

Smart parking management system is most essential aspect of smart city. Driver has wasted a lot of time and fuel in searching available parking slot. This smart parking system help the driver to reserve their parking slot before reached to their destination and online pay for that parking.

Weather Management

A weather system is responsible for updating the vehicle about weather condition and assists the driver in hard conditions. This system gets the weather information from weather sensors and stations and provides suggestion to tackle this situation.

3.2 Three Layer Model

The following 3 layer has been used for Traffic Management System.

- Internet of things(IoT)
- EdgeComputing
- Cloud Computing

Internet of Things (IoT)

The internet of thing is a system of interconnected computing devises that will be participating in communication. This layer includes the Vehicles, RSUs, and Mobiles etc. This layer is responsible for sensing data and communicates to other devices. Mobile applications will be used as user interface.

Edge Computing

Edge computing layer is responsible for real time processing of the information close to the edge of network, where the data is generated. This layer includes device to device communication, buffering etc. Edge computing reduced the volume of data and consequent traffic and the distance. It provides lower latency and reduced transmission cost.

Cloud Layer

Cloud layer is used to perform city level monitoring. Cloud layers store the information of each vehicles that enter in the city e.g. vehicle id, location, registration etc. This information use by the trusted authorities and traffic management system to act appropriately. This layer includes cloud data center, cloud storage etc.

3.3 Assumptions need to consider

Before going to the Setup of the framework we proposed, we will be discussing some assumed aspects of the framework for the efficient and smoother execution of the system that are**:**

- VANETs have different types of communication, so VANETs to infrastructure and infrastructure to infrastructure modes should beconsidered.
- Vehicles used in this system are smart and have the GPS system to known about the location of the vehicle for execution of thesystem.
- Each vehicle must register to the confidential parties.

3.4 Operational Diagram of the System

The complete operational diagram of our system is shown in figure 2. This system helps the driver to complete their journey in less time with optimal path and efficient fuel consumption ultimately it will cause less greenhouse gasses emission that can decrease the pollution of airsmartly.

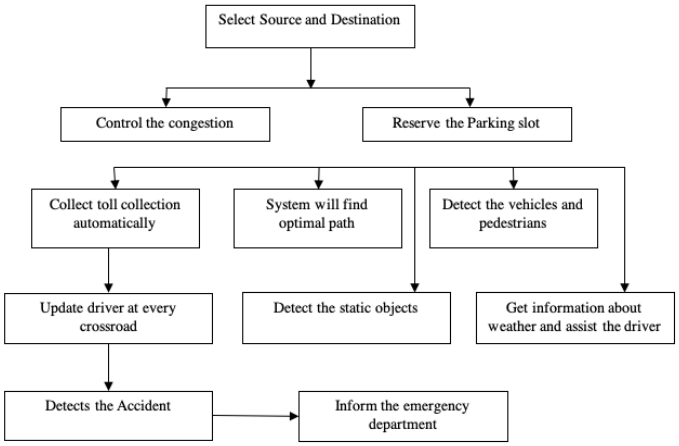

Fig 2: Overall OperationalDiagram

3.5 Algorithm Implementation

3.5.1 Parking Management

Parking unavailability is a major cause of congestion. Traffic becomes congested when vehicles roaming on roads for searching parking slots, results in an exponential carbon emission rate. Research have proposed many solutions to solve the problem of parking system. The online booking of the parking slots before reach to the destination is a good solution for this problem so that before reach to the destination driver knows where to park the car. In our proposed work, the driver firstly selects the destination and reserve the parking slot before reached to the destination then system guide the vehicle with the optimal path to destination. When vehicles will be reached near the parking area system will guide it to the parking slot via an optimal path. Figure 3 represents the algorithm for parking management.

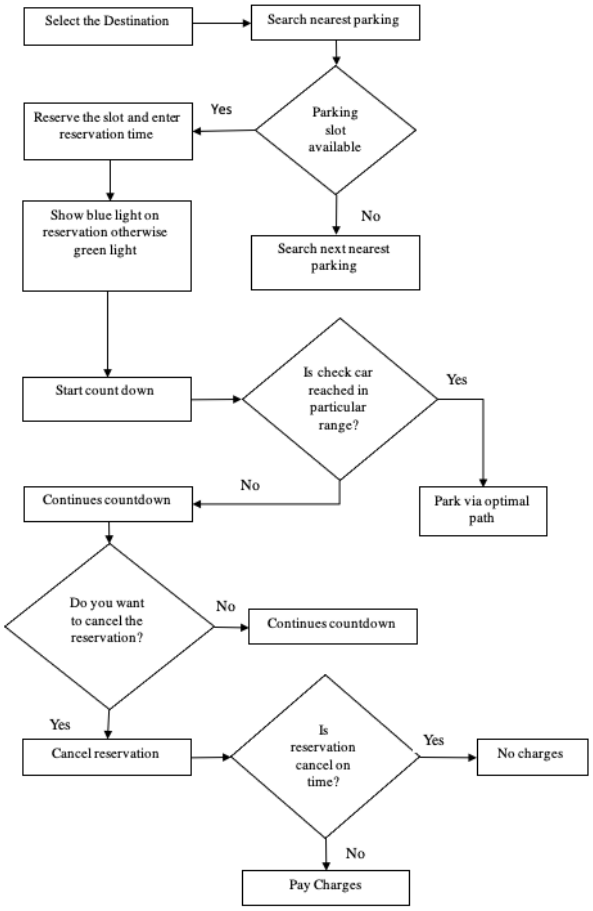

Fig 3: Flow graph for Parking Management

3.5.2 Optimal Path Selection

Optimal path finding is our prior task. All the major problems that we face in traffic are due to the congestion. That's why we try to overcome the congestion. We got congested traffic when the vehicles do not follow the optimal path. Here we used the swarm optimization algorithm to find the optimal path for each vehicle during the journey. When a vehicle starts their journey, the system will suggest the optimal path according to the destination, after that system also guide the vehicle at each carrefour according to the traffic on road throughout the journey if the system detects any problem on the road e.g., road blockage and accident etc. then it will suggest the alternative path to reach the destination. We route the vehicle according to the packet routing to avoid the congestion. The optimal path algorithm for proposed system is shown in next fig 4.

3.5.3 Swarm Optimization Algorithm

Particle swarm optimization (PSO) is a computational method, in computational science that iteratively optimizes the problem and seeks to improve the candidate solution according to the given measure of quality [24]. It solves issues by having a population of solutions, referred to as particles and moving these particles round the search area in keeping with the mathematical formulas over the particle's position and velocity. Each particle influenced by its local best value, however conjointly guided to the best-known best position in the search area, which are updated as better-quality best positions is founded by other particles. This is expected to move the swarm near to the bestanswers.

Typically, an algorithm following PSO is based on the reputation of these three steps until the termination conditionreached.

- Initialization
- Updating
- Termination condition

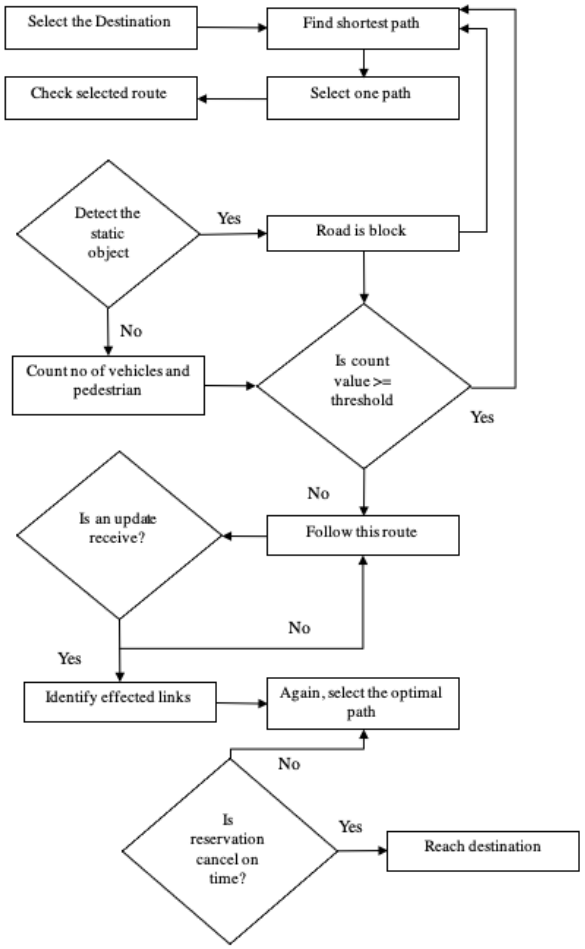

Fig 4:Flow graph for Optimal Path Selection

3.5.3.1 Mathematical Model of PSO

This method refers to searching for the optimal solution via agent mention as particles. Each particle *i* is distinct by its velocity vector, v_i and its position vector, x_i,. With each repetition, each particle changes its position according to the new velocity.

$$V_i^{t+1} = wv_i^t + c_1 r_{1^*}(xBext_i^t - x_i^t) + c_2 r_{2^*}(gBext_i^t - x_i^t)$$

$$X_i^{t+1} = x_i^t + v_i^t * t$$

where xBest and gBest are respectively particle local best position and particle global best position and 'r1', 'r2'are two random parameters within [0, 1], 'w' represents as inertia weight or 'c1', 'c2' are two positive constants [25].

The following table 1 represents the parameters for PSO.

Table 1. PSO Parameters

Parameters	Values
Population	500
No. of Iterations	150
Inertia Factor (W_{min},W_{max})	[0.98, 1]
Acceleration Rate (C_1 , C_2)	[1.5, 1.5]

3.5.4 Path Optimization Problem

To formulate the problem that represents the situation where the driver wants to find the optimal path moving toward the destination for avoiding the congestion and hazards. We need to consider these points:

- Starting position
- Destination position

Our aim is to solve the problem by finding the optimal path from the place where from the driver start their journey toward the destination, that take minimum distance, least number of vehicles on road and avoid hazards.

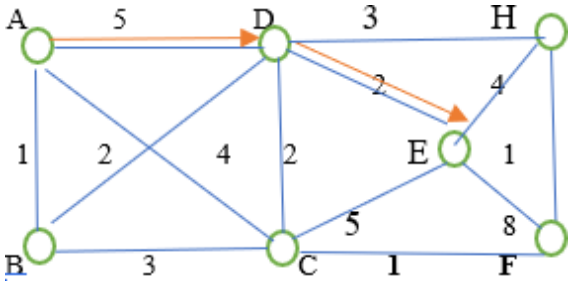

Fig 5:Graph for Optimal Path

In term of the graph that we built in this figure 5, this corresponds to find a path, from starting position where from driver start their journey to the destination where they want to be reached with minimum cost over theedges.

4. RESULTS

The proposed work tried to give the solution according to the situation and route the vehicle like packet routing. At the start of their journey vehicle will add their source and destination and will request for parking slot booking. The simulation has been made using Bayonet software from AIST, Japan and JMP statistical tools from SAS corporation, USA. The simulation has been run for two times in two different object obstacles or congestions over an analogy of IP network.

Our system will guide the vehicle and suggest the optimal path for automobile. After reached at destination, our system again checks the optimal path and gives alternative path if they detect some problem like accident or congestion etc. when vehicle will be reached to the destination our system will guide to parking slot via optimal path. Figure 6 represents how proposed system find optimal path among the hazards and figure 7 depicts the best cost (Best cost = 7.5492) and iteration (iteration value = 492) that our proposed system takes to find the optimal path in the first run of the simulation.

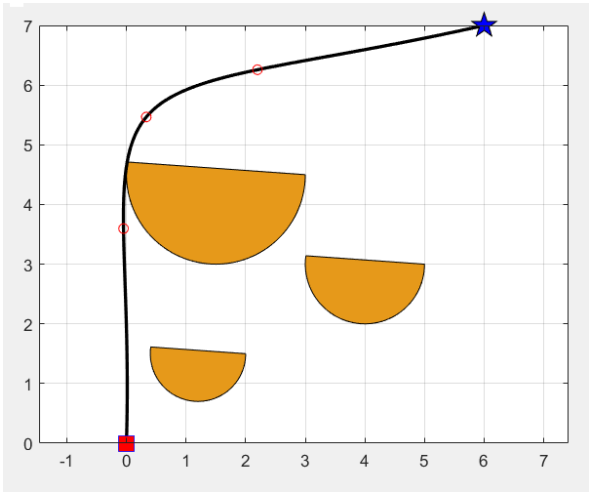

Fig 6:Results for Optimal Path finding among the hazards

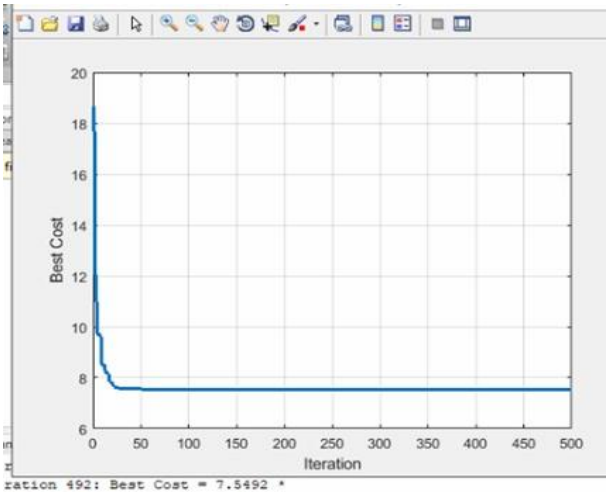

Fig 7: Result for Optimal path cost (7.5492) in first simulation

Next in the figure 8 represents the scenario for not finding the path for destination. In our second simulation run finds the best cost of 7.8543 whereas the iteration value is 496 (figure 9).

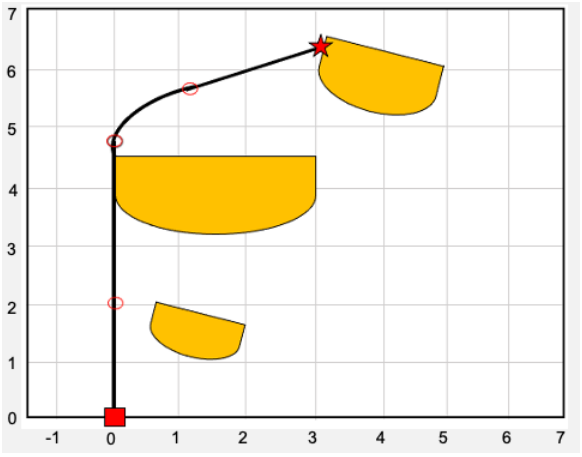

Fig8: Results for not finding Optimal Path finding among the hazards

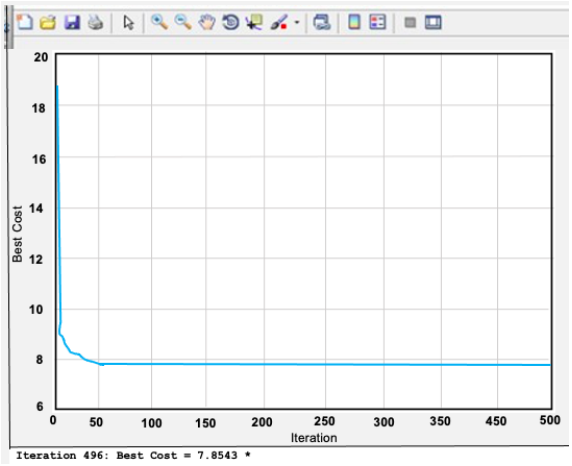

Fig9: Result for Optimal path cost (7.8543) in second simulation

We believe due to the Bayonet simulation tool's limitation the second run did not match with our first simulation run for best cost (7.5492). In future, we will look for the updated version of the simulation tool and check the current value of it. Additionally, we will embed various sensors and IoT for giving the solution of the smart traffic management system of figure 1. However, using PSO model for finding the optimal path and best cost for traffic management using Bayonet tool is the first work in this field, which is the main achievement of our research.

5. CONCLUSION

Evolution of the modern cities have increased the number of vehicles on roads that caused major traffic issues such as congestion, parking management, toll collection system and carbon emission etc. It is found that most of the problems that we face in vehicular environment are caused by congestion, that may cause accidents, difficulty in finding parking slots, wastage of fuel and increased carbon emission. All these problems can be solved if vehicles will follow the optimal path, which leads to a reduced carbon emission rate. Vehicular Ad-hoc Network (VANET) can utilize the full potential of the IoT and might provide a comprehensive solution for traffic related problems in Smart Cities. This research offered VANET based Novel Quasi Omniscient Situational Aware Traffic Management System (TMS) that expeditiously tends to eliminate all these traffic-related problems. It recommends the optimal path from source to destination and automatically reserves the (optimal) nearest parking spot to destination. We used swarm optimization algorithm for optimal path finding and got the best cost value of 7.5492 is the achievement of this research. Therefore, the probability to reach good solution using PSO is high and give results faster than other algorithms in traffic management system. In conclusion, the optimal path/parking and proactive utilization of system's resources are to bring of through situational awareness imbued by IoT and contributes to reduce the traffic congestions, accidents, delays, fuel consumption and eventually aids in diminishing the air pollution in future.

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