A Mobile Agent based Autonomous Partial Green Corridor Discovery and Maintenance Mechanism for Emergency Services amidst Urban Traffic

Manoj Bode
Department of Computer Science and Engineering,
Indian Institute of Technology
Guwahati, India
m.bode@iitg.ernet.in

Shashi Shekhar Jha
Department of Computer Science and Engineering,
Indian Institute of Technology
Guwahati, India
j.shashi@iitg.ernet.in

Shivashankar B. Nair
Department of Computer Science and Engineering,
Indian Institute of Technology
Guwahati, India
sbnair@iitg.ernet.in

ABSTRACT

Traffic management in urban areas is a challenging task. Provisioning of traffic moving on the roads becomes crucial especially when emergency services such as an ambulance or fire-fighting team need to make their way to the hospital or to the point where the problem is. With the advent of networking technologies, the traffic signals can now be equipped with sensing and communicating equipment facilitating the diversion of such vehicles along shorter and less crowded paths towards their respective destinations. This paper exploits the concept of an Internet of Things comprising the various traffic signaling equipments, and proposes a distributed mobile agent based mechanism to autonomously discover, create and manage a *partial green corridor* just ahead of the emergency vehicle along the least crowded path to its destination. The proposed mechanism assumes a network of equipment used for traffic signaling as its base and makes use of intelligent mobile software agents to facilitate the smooth movement of an emergency service vehicle. We have implemented the proposed mechanism by emulating the network of traffic signals and mobile agents using a mobile agent platform. The movement of the ambulance and the traffic flowing on the roads has been at the moment simulated. Our implementation and results obtained emphasize that the proposed mechanism can prove to be a viable solution for the movement of emergency vehicles in urban traffic.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems; C.2.4 [**Distributed Systems**]: Distributed applications

General Terms

Design, Experimentation

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Mobile Agents, Traffic Management, Autonomous Movement, Urban Traffic, SWI-Prolog, Emulation, Internet of Things

1. INTRODUCTION

With cities becoming bigger and denser, managing traffic in urban areas is becoming a complex task. The traffic infrastructure in urban spaces which ideally should include real-time sensing and processing capabilities can be looked upon as a highly dynamic and distributed system. The increased number of vehicles on the roads often creates traffic problems due to unforeseen incidents. For instance a sudden surge of vehicles inflow into a lane can create traffic jams or congestions. These problems can impose uncertainties in the estimated time of travel from a source to a destination. When it comes to emergency services such as Ambulances and Fire-Fighters, these uncertainties could lead a service onto a congested area. Such delays in the traversal of emergency services may thus lead to heavy damages or even loss of life. Traditionally, these emergency services use sirens to alerts their surroundings and create an on-the-fly transitory free passage towards their respective destinations. Though the siren model of movement of emergency services has been in use for ages across the globe, it does not ensure a seamless hassle-free movement of the emergency vehicle amidst the current uncertain traffic scenarios. A proactive mechanism which can disseminate the information on the movement of such emergency vehicles, *a priori* to all concerned traffic signal points or junctions along the expected route envisaged to be taken, may constitute to be a better alternative to the old siren model. However, availability of such *a priori* information *throughout* the envisaged route of this vehicle may have adverse impact on the traffic flowing along and on the adjoining routes [2]. A proactive mechanism which could ensure the seamless and virtually uninterrupted movement of emergency services using an established traffic infrastructure while also avoiding further congestions or inconvenience to the current traffic, may be deemed to be a viable and acceptable solution.

The advent of technology has driven the cities to become smarter. The use of sensor networks and advanced wireless and wired communication infrastructure have evolved capabilities to gather and process the real-time data and take informed decisions. The traffic management in urban spaces provides a real-world platform to apply the advancements in Information and Communication Technology (ICT) to ease the life of general masses [12]. The state-of-art traffic management systems [15] use various approaches to manage traffic within a city. These approaches can be broadly classified into centralized and distributed approaches [18]. In the centralized approach, the traffic information of the whole city is gathered at a control station. The control station centrally looks into the management of traffic by possible re-routing or blocking the traffic flow at various routes. Such an approach imposes high computational and communication complexities as also heavy expenditure in setting up the system. Since the traffic infrastructure is inherently distributed in nature, distributed approaches seem more appropriate to realize an intelligent traffic management system. Multi-agent based systems provide a fitting solution to model a near decentralized dynamically varying traffic infrastructure of a city.

Most of the traffic management approaches proposed in the literature [4] focus on the movements of all kinds of vehicles on the roads without giving any specific attention to emergency service vehicles. In this paper, we endeavour to provide a mechanism for the seamless movement of emergency services amidst dynamically varying traffic conditions. We envisage the digital infrastructure of the various traffic signals and their related sensing and processing entities within a city as an Internet of Things (IoT) to realize a distributed and autonomous mechanism to discover the least crowded routes from a source to a destination. Such routes can thus be used by vehicles catering to emergency services. The proposed approach makes use of a Mobile Agent platform nicknamed *Tartarus* which is an enhanced version of its predecessor *Typhon* [10]. This platform supports rapid prototyping and emulation of intelligent mobile agent systems.

In the next section we discuss the related work in the context of agent based traffic management system. We present our proposed approach in Section 3. The emulation of the same using the mobile agent based framework is provided in Section 4 while Section 5 discusses the results obtained. Section 6 concludes the paper.

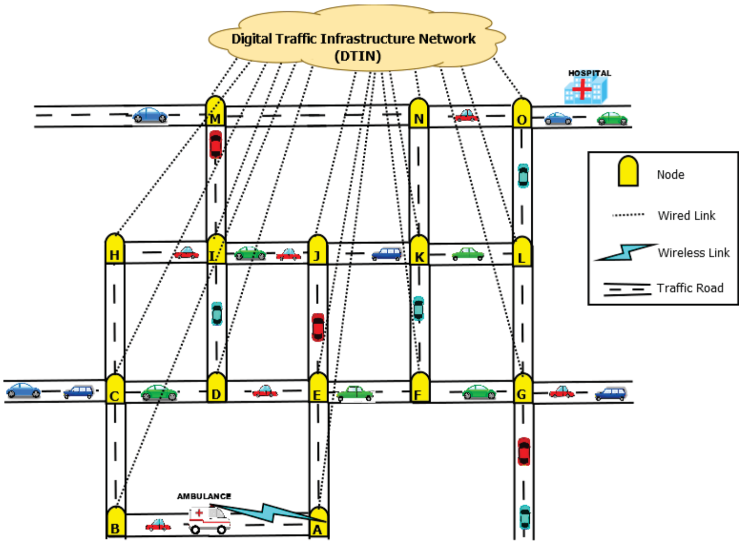
2. AGENT BASED APPROACHES FOR TRAFFIC MANAGEMENT

Many researchers have applied agent based approaches to model traffic control and its management in urban spaces [4]. Agent technology, due to its inherent distributed characteristics, provides a natural solution to the highly distributed and dynamically changing problem of traffic management and control. In [4], the authors have discussed the application of agents to different modes of transport by road, rail and air. They emphasize the power of agent based systems to regulate and improve the performance of traffic and transportation systems. Weyns *et al.* [17] present an agent-based approach using delegate Multi-Agent Systems for anticipatory vehicle routing to avoid traffic congestion. They extend their approach in [6] with an environment-centric coordination model. In their approach, individual vehicles dispatch lightweight mobile agents for exploring alternate routes to find the shortest path to the destination, based on current traffic conditions. They further use *intention* agents to confirm the intended travel route on the road infrastructure. This information was used by the situated agents to estimate the future traffic so that they can alter the route of the approaching vehicles. In [13], the author proposes an intelligent traveling-assistant system based on a distributed model. They use *Personal* agents for each individual traveler to communicate with the driver and the system to provide optimal advice to the former and update stored traffic information in the system. Katwijk and Koningsbruggen [16] present an agent-based model for the coordination of traffic-control and management of instruments. They modeled the traffic instruments as individual intelligent agents to tune their actions at a local level. They demonstrate that traffic management instruments can coordinate their actions to attain a common goal at the network-level using agent based concepts. Balaji *et al.* [1] attempt to exploit the advantage of evolutionary techniques for traffic management operations and congestion avoidance in Intelligent Transportation Systems. They propose a multi-agent based real-time centralized evolutionary optimization technique for urban traffic management using an evolutionary strategy for the control of traffic signals. Chen *et al.* [5] have proposed a model to integrate mobile agent technology with multi-agent systems. They have designed a model to enhance the ability of traffic management systems to deal with the uncertainty in a dynamic environment. They use a mobile agent system called Mobile-C to design agent-based real-time traffic detection and management system. They argue that the use of mobile agents allows the deployment of new control algorithms and operations on-the-fly to respond to unforeseen events and conditions in urban traffic scenarios.

The agent based traffic management and control approaches discussed so far focus on the city traffic as a whole. They seem to ignore the manner of movement of emergency services amidst general traffic. Handling the seamless flow of such emergency services constitutes a vital requirement in urban traffic. Discovering, managing and maintaining a *partial green corridor* towards the destination for such high priority services is mandatory in today's ever increasing traffic scenarios. In this paper, we present a concerted effort to prioritize the movement of emergency services within the general traffic flow using a mobile agent based mechanism. The succeeding sections discuss the proposed mechanism in detail.

3. MOBILE AGENTS FOR A GREEN CORRIDOR

In our proposed approach, we consider a Digital Traffic Infrastructure Network (DTIN) constituting an Internet of Things (IoT) of various traffic junctions and traffic signals referred hereinafter as nodes. Figure 1(a) depicts a conceptual DTIN, the nodes within and its mapping along with the traffic infrastructure. Each node is assumed to be equipped with local sensing capabilities to capture the information of the current traffic flow under its purview. The management of the local information at each node in a DTIN is done by a local situated static agent termed the *Node Agent* (NA) residing at each node. The node-to-node communication is assumed to be a part of the wired network backbone in the DTIN. The emergency service vehicle is managed by another situated or static agent termed the *Vehicle Agent* (VA). The communication between the VA and the NA is assumed to be wireless.



(a)

Node	GPS Coordinates	Neighbouring Nodes (NN)	Distance to NN (in km)	Traffic load towards NN	Time-Stamp
A	$\langle lat_a, long_a \rangle$	**B**	**8**	**5**	$\langle T_1 \rangle$
		E	**10**	**2**	$\langle T_2 \rangle$
B	$\langle lat_b, long_b \rangle$	**A**	**8**	**3**	$\langle T_3 \rangle$
		C	**7**	**4**	$\langle T_4 \rangle$
D	$\langle lat_d, long_d \rangle$	**C**	**3**	**7**	$\langle T_5 \rangle$
		E	**5**	**7**	$\langle T_6 \rangle$
		I	**11**	**5**	$\langle T_7 \rangle$
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.

(b)

Figure 1: (a) A Snapshot of an Urban traffic scenario along with the manifestation of a Digital Traffic Infrastructure Network (DTIN) (b) A typical traffic flow map stored at a node.

In addition there are two kinds of *mobile* agents used in the proposed approach named: (a) Monitoring Agent (MA) (b) Path-Finding Agent (PFA). The MAs serve the sole purpose of disseminating and updating traffic information to all the NAs. In the proposed DTIN, there can be n number of MAs deployed by the traffic systems administrator. These MAs migrate from one node to another within the DTIN and update the NAs about the current traffic conditions at other nodes in their surroundings. The MAs thus patrol and aid in building a map comprising the current traffic conditions across all the nodes. These traffic flow maps consist of the information of the estimated traffic flow over each lane in the traffic road infrastructure within the city along with the respective GPS coordinates of the nodes, the distance to the neighbours of a node and the time-stamp of the records. Figure 1(b) depicts the snapshot of a traffic flow map stored at a node. These traffic flow maps get updated whenever an MA visits a node in the DTIN. On arriving at a node, the MA communicates with the local NA and queries the current traffic information at the location in the node's proximity. Since the NA constantly senses and updates traffic flow within its proximity, it replies with its estimates of the recent and expected traffic to the MA. The MA in turn updates this new information in its traffic map. Further, the MA delivers the traffic map having such information of other nodes within DTIN to the NA. The NA matches the time-stamps of the traffic flow at different lanes within the traffic map and updates any information having old timestamps. Thus the MA forms the basic unit of the flow of traffic information within the DTIN. The number of MAs within a DTIN could vary as per the need and size of the DTIN. Further the MAs could communicate with each other as and when they meet at a node to mutually share and update their traffic flow maps so that any critical information such as road accidents, flash crowds, etc. can be communicated at a faster pace. One may note that the use of such *mobile* MAs greatly reduces the communication overheads required to spread the traffic information among the large set of nodes in the DTIN. In addition, these agents put a lower bound on the pairs of nodes communicating at any moment of time thus reducing precious bandwidth utilization [9].

The Path-Finding Agent (PFA) is a mobile agent that has the responsibility to construct a *partial green corridor* along the least crowded path for the emergency service vehicle on the move. As soon as the emergency service vehicle decides a destination to travel to, its VA situated within the vehicle spawns a PFA encapsulated with the knowledge of vehicle's current position and destination. The VA connects to a node in its vicinity and releases the PFA onto it wirelessly. As soon as the PFA lands on a node, it acquires the traffic flow map from the resident NA at that node. The PFA then calculates a plausible route, R, to the destination from the current position of the vehicle based on the information available within the traffic flow map. This calculation can be performed using an algorithm such as [3] based on the nature and demand of the traffic infrastructure as also the historical data. The calculated route thus forms an estimated least crowded path for the emergency vehicle to travel to its destination. Further, the PFA traverses within the DTIN towards the succeeding nodes under the ambit of the calculated route (R) and deposits the information of the approaching emergency service vehicle onto those nodes. The forward movement of the PFA towards its destination is restricted to a limited number of nodes on the route R which is decided based on the distances among the nodes. The PFA only informs the subsequent nodes within a predetermined distance (λ) from the current position of the emergency vehicle, regarding the approaching of this vehicle. To maintain such a distance, the PFA initially moves up to a node (η) whose distance, d, from the node which was closest to the emergency vehicle is such that $d \geq \lambda$. If the distance to the destination is less than d then η is set to the destination node and the PFA ceases its forward movement.

After arriving at η, the PFA backtracks on the route till the initial node which was the last known location of the emergency service vehicle. Meanwhile, an NA, after receiving the information of the approaching emergency service vehicle, starts to wirelessly broadcast the intended route that the emergency service vehicle needs to take from the location of that node as provided by the PFA. As and when the emergency service vehicle reaches the vicinity of the NA, the VA receives the information of the route to follow from that node's location as a result of the NA message broadcast. The NA also registers the passage of the emergency vehicle and terminates the broadcast of the information as soon as the vehicle has crossed its vicinity. Thus, when the PFA backtracks to a node (say ρ) in the vicinity of which the vehicle was last reported to be, it discovers that the vehicle has moved over to the next node along the path to the destination. After discovering ρ, the PFA moves further in the calculated route to a new, η, satisfying the criteria of $d \geq \lambda$. The PFA oscillates in between the next node to ρ and the new η until the emergency vehicle crosses a new ρ node. Such oscillations aid in keeping track of the segment of the route R up to a distance d from the current location of the emergency vehicle and ensures that it remains to be a *partial green corridor* along the path to its destination. If an NA is apprised of a sudden increase in nearby traffic by an MA within this *partial green corridor*, then the PFA on reaching this node, recalculates the route R from the expected *next* ρ of the emergency vehicle to the destination and then starts moving back and forth in this new route *R'* along the expected ρ and the newly discovered η. This process of maintaining a partial green corridor ahead of the emergency vehicle continues until the vehicle eventually reaches its destination. As soon as the PFA finds that the emergency vehicle has crossed the node nearest to the destination, it terminates itself.

For illustration, consider the emergency vehicle i.e. an ambulance shown in Figure 1(a) near to the node A. As can be seen, the destination of the ambulance is towards node O (near the HOSPITAL). Initially, the ambulance releases a PFA into the DTIN via node A using the wireless link. The PFA calculates the route R to the destination i.e. node O using the traffic flow map available at node A. Suppose the PFA finds the route R as $A \rightarrow E \rightarrow F \rightarrow G \rightarrow L \rightarrow O$. Further, assume that λ for the PFA is set to the distance in between three consecutive nodes. Hence, the PFA initially moves up to the node F (initial η) from node A to inform these nodes about the approaching vehicle. It then oscillates on the $A \rightarrow E \rightarrow F$ nodes to ensure a *partial green corridor* on this route. Once the ambulance crosses node A (ρ here), the PFA moves forward to node G and starts to move back and forth along the $E \rightarrow F \rightarrow G$ nodes. The PFA then keeps expanding by one node towards the destination in the calculated route until the ambulance crosses the node O which is its destination. The oscillations performed by the PFA on the route R helps to keep track of the current condition of the route and modify the traffic or route in this limited part of the whole path to the destination. Suppose while the ambulance moves to the node E, the traffic between nodes G and L suddenly increases. Since the MAs are continuously updating the traffic map within the nodes, this information will be encountered by the PFA when it is oscillating in the sub-route $E \rightarrow F \rightarrow G$. After finding about the new traffic conditions, the PFA re-calculates the route now from node E to node O to find the least crowded path. Such a route could be for instance $E \rightarrow F \rightarrow K \rightarrow L \rightarrow O$. The PFA would thus start oscillating in this new sub-route comprising $E \rightarrow F \rightarrow K$ nodes.

As can be observed, the PFA acts as a guide to the VA and provides a route to the emergency vehicle through the least crowded traffic nodes. It also utilizes its inherent capability to take local decisions based on the current traffic conditions at nodes along the path. The *a priori* knowledge of the approaching emergency vehicle provided by the PFA to the NA helps the latter to regulate the local traffic within its vicinity. This can be done either by altering the traffic signal pulse duration or by possible re-routing of the traffic flow in such a manner so as to create the required space for the seamless passage of the approaching emergency vehicle. The proposed approach thus provides an autonomous, distributed and self-organizing framework to realize and maintain a *partial green corridor* within a stretch in the path between the emergency service vehicle and its destination. Further, the proposed approach in no way over utilizes the DTIN by trying to create a continuous *green corridor* right up to the destination for an emergency vehicle to pass through. For instance, a reservation based scheme [7] to reserve all the nodes in the route R to create and ensure a green corridor right up to the destination would choke up the existing traffic flowing on the other routes. The proposed approach does not affect the adjoining traffic adversely as it only ensures a *limited* or *partial green corridor* directed towards the destination along the least crowded path. While this allows the emergency service vehicle to move forward without hindrance, it also ensures minimal inconvenience to other vehicles that constitute the traffic in the entire route R to the destination. In the next section we present a very brief description of *Tartarus* followed by the manner in which the proposed mechanism was emulated.

4. IMPLEMENTATION

Considering the distributed nature of the problem and the proposed solution approach, an inherently sequential simulation could have undermined its effectiveness. Hence, we tried to emulate the proposed approach using an SWI-Prolog based mobile agent platform nicknamed, *Tartarus*, developed at our lab. *Tartarus* provides all agent based functionalities such as autonomy, mobility, independent and autonomous execution, payload carrying capability, etc. *Tartarus* is a modified version of *Typhon* [10] and can be used to realize an Internet of Things just as described in [8]. Unlike *Typhon*, it features threaded agents for better and more realistic emulation. It is also equipped with a hardware interface to Mindstorm® NXT® robots so that the agents can perform real actions and sense the environment using the real hardware. Since *Tartarus* has been developed over an open Prolog based environment, it also provides the inherent features of Prolog such as the use of off-the-shelf artificial intelligence techniques. Further Prolog as a computer language supports code mutation and evolution during the execution of a program. Such a feature can be used to evolve the agents and their programs in a dynamically varying environment.

An instantiation of *Tartarus* can emulate a node in a network. These instantiations can exist in a single computer or in different computers connected within a LAN. We created a 100 node DTIN using 100 *Tartarus* instantiations. These nodes were connected to one-another in a mesh topology

Table 1: Comparative durations (Average of 10 runs) required to reach the respective destinations by the vehicles under different traffic loads

Average Traffic Load	Normal approach		Full Corridor approach		Proposed Partial Corridor approach	
	Type of Vehicle		Type of Vehicle		Type of Vehicle	
	Emergency (in units)	Others (in units)	Emergency (in units)	Others (in units)	Emergency (in units)	Others (in units)
3	78.67	59.51	48.76	64.71	48.75	61.95
6	105.49	77.97	47.37	82.51	47.36	79.23
9	137.54	99.38	48.46	103.88	48.46	100.47
12	166.95	120.48	48.16	124.00	48.17	122.15

Table 2: Delays caused to Other Vehicles due to the green corridor

Average Traffic Load	Normal approach (in units)	Full Corridor approach (in units)	Proposed Partial Corridor approach (in units)
3	0	5.30	2.17
6	0	5.21	1.60
9	0	4.43	1.63
12	0	3.49	2.29

using TCP-IP links. The communication among the nodes within the DTIN was completely asynchronous without any global synchronizing clock. The traffic flowing in between each pair of nodes in both directions was initialized randomly during the creation of the DTIN network and was continuously updated based on the movement of a set of simulated vehicles. An NA populates every *Tartarus* node. A single MA was found to be sufficient to update the traffic flow across the 100-node DTIN at the rate of approximately 20-22 times per minute. MA in our implementation uses a *conscientious migration strategy* [11] to move from one node to another. This strategy ensures a uniform distribution of the frequency of the MA visits at the nodes within DTIN. In the current implementation, the movement of emergency service vehicle along with the auxiliary traffic is simulated using SWI-Prolog. The VA within the emergency service vehicle runs as an independent entity in simulation and keeps track of the nodes in the emulated DTIN as it moves towards its destination. In the present case we equipped the PFA with an A* [14] based algorithm to calculate the plausible route to the destination from the traffic flow maps available at a node within the DTIN. Evidently, there can be k different paths going towards the destination from a node n within the DTIN. We have used a heuristic to minimize our search space. As mentioned earlier, a node keeps the estimates of the current traffic at its location. To calculate a route R towards the destination θ from a node n, the PFA evaluates all the plausible routes and selects the one which currently requires minimum time to traverse. Hence, R is chosen as:

$$R = \min\{\forall i \in k, t(i) + h(i)\} \quad (1)$$

where, *t(i)* is the estimated time to reach to the next node $\tilde{n}$ from node n and *h(i)* is the heuristic to calculate the time from node $\tilde{n}$ to the destination θ.

The heuristic function *h(.)* is defined as the distance between any two nodes multiplied by the average time to travel a unit distance in the city. For instance, suppose that the emergency vehicle has to move from a node X to the destination node Z, and node X has 3 routes leading to nodes U, V and W along the paths to Z. As per the current traffic estimates at node X, suppose it takes *t(U), t(V)* and *t(W)* units of time to reach the nodes U, V and W respectively from the node X. Let δ be the average time to travel a unit distance in the city and $\beta(;)$ be the function which return the distance between two nodes then,

$$R = \min\{t(U) + h(U), t(V) + h(V), t(W) + h(W)\}$$

where, $h(x) = \beta(x, Z)\delta$

In the current implementation the PFA builds the route to the destination of the emergency vehicle using the above technique. Better and more adaptable ways of this estimation may however be envisaged in practical implementations.

5. RESULTS AND DISCUSSIONS

Experiments were performed using the proposed partial corridor approach as also the normal and Full-Corridor cases. In the normal case, all the vehicles move without any supervisory system in place. This would mean the ambulance needs to fight its way through normal traffic. In the Full-Corridor case, as soon as the PFA calculates the route R to the destination, it traverses through all the nodes in R and informs each of them about the approaching emergency vehicle. Hence, all the nodes within this route R alter their local traffic to ensure a full *green corridor* for the approaching emergency vehicle and hold it so till this vehicle is past its vicinity. The experiments were performed under different traffic loads over the emulated traffic infrastructure. To avoid any undesired stochastic effects that could bias the experiments, 10 runs were performed for each of the cases and their averages were used to portray the results. The traffic load is considered as a numeric quantity with a lower number indicating low traffic on the roads and hence resulting in a smooth movement of the vehicles. On the contrary a higher value for the same represents heavy traffic which hinders the movement of the vehicle.

Table 1 shows the times taken for the various vehicles to reach their respective destinations. The column *Others* represents the average time taken by the remaining or other (non-emergency service) vehicles to reach their respective destinations. For other vehicles, we have chosen 10 source - destination pairs. These pairs are constant throughout all results.

The Normal approach obviously induces large delays in reaching the respective destinations for both the emergency service vehicle as also the others. The Full and Partial Corridor approaches seem to allow the emergency vehicle to reach faster. However the remaining (Others) vehicular traffic seem to be fairly significantly effected in case of the Full Corridor approach which is not the case in the Partial Corridor approach. This gives an edge to the Partial Corridor approach as it eases the other traffic while at the same time does not comprise on the emergency vehicle travel times.

Table 2 shows the waiting times of the other vehicles while the emergency service vehicle traverses the *green corridor* for both the partial and full approaches. It can be clearly observed that the waiting periods of the other vehicles in the partial corridor model are greatly reduced as compared to those when the full corridor approach is followed. It may be observed that the waiting time for other vehicles in Table 2 are decreasing with increase in traffic load in case of full corridor approach while the deviation is least in the proposed partial corridor approach. This occurs due to the fact that other vehicles take more time to reach to the *green corridor* due to the high traffic load and by that time the emergency vehicle already passes beyond the concerned nodes.

6. CONCLUSIONS

With increased population densities and hence vehicular traffic in urban spaces, the need for Intelligent Traffic Management is becoming imperative. While there have been attempts at realizing this, focus on the seamless movement for high priority emergency service related vehicles seems to be missing. Such movement should at the same time ensure that the normal traffic is only minimally affected. In this paper we proposed a technique to monitor, enhance and create a partial green corridor for the seamless movement of emergency service vehicles with limited effect on the normal traffic flow using the concept of a network of traffic controller nodes constituting an Internet of Things. The proposed technique is fully distributed and autonomous and makes use of mobile agent technology for continuous sensing and intelligent decision-making. *Tartarus*, an SWI-Prolog based mobile agent platform has been used for emulation of the same. The results obtained from the emulated experiments show the practical viability of the proposed approach. In future, we endeavour to model the traffic flow infrastructure using real sensory data of a city's traffic. We plan to calculate the traffic conditions based on real sensor reported parameters including traffic speeds, the length and number of parallel lanes their capacity, speed limits, traffic regulations, etc.

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