An IoT approach for optimizing routing and safety*

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Abstract. This paper presents an IoT approach that aims to provide routing optimization and navigation as well as to improve safety of commercial vehicles. The proposed approach utilizes static information and data to generate an efficient overall delivery sequence of customers for the whole fleet of the company and real-time traffic information to assist drivers in making more efficiently a particular point-to-point trip. With regard to safety, improvements could simply be achieved by easing driver mental workload and reducing their exposure to higher-risk roads of heavy traffic.

Keywords: urban goods movement · routing optimization and navigation · safety improvement

1 Introduction

As markets tend to become increasingly competitive, efficient urban goods movement turns out essential and necessary to expand profit margins for companies and improve customer services. As such, companies plan, implement and control their flows of goods utilizing related information from the point of origin to the point of consumption in order to satisfy customer requirements [1] and a possible area of improvement is determined in the context of vehicle management and monitoring. The development of modern technologies such as Internet of Things (IoT), Vehicle to Infrastructure (V2I) and Vehicle to Vehicle (V2V) [2] communication constitute automatic routing and navigation a feasible approach

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beyond the common practices for efficient and safer distribution of urban goods [3].

The high frequency of deliveries in the urban environment often lead to substantial negative externalities such as increased congestion, energy consumption and other safety impacts. In other words, routing and navigation constitute complicated processes for companies that try not only to serve their customers minimizing their travel costs but also to minimize fuel consumption and equipment repairs. Technological advances could offer improved services aiming to safety, capable to monitor real-time road conditions and communicate them with drivers in order to avoid roads of high congestion and risk. The effective planning and management of delivery schemes may impose a significant impact on current distribution operations optimizing the logistics of the produce supply chain thus minimizing several of the relevant externalities.

The aforementioned considerations form the background of this paper, which aims to develop an IoT approach that utilizes V2I communication to optimize vehicle navigation with emphasis on safety. The availability of real-time information provided by modern technology (i.e. traffic cameras, traffic sensors etc.) is considered to provide dynamic navigation that avoid exposure to higher-risk roads that are congested with traffic. The main focus is given on a modification of the well-known Vehicle Routing Problem with Time Windows (VRPTW) [4] in which vehicles communicate in a wireless manner with traffic lights to allow efficient road navigation from a point A to a point B based on the dynamic traffic volume of the road network (i.e. queues, waiting time).

The remainder of the paper is structured as follows: section 2 describes the proposed IoT approach for efficient and safe routing optimization and navigation of commercial vehicles utilizing modern technologies and then, section 3 presents a discussion of the results obtained of a real case study. Finally, in section 4 conclusions are drawn.

2 IoT approach

This paper presents an IoT approach for efficient routing optimization and navigation of commercial vehicles based on V2I communication in an attempt to avoid traffic and enhance safety. The proposed solution (Fig. 1) consists of two main phases: (1) routing phase and (2) navigation phase.

Routing phase aims to provide an efficient overall delivery sequence of customers for the whole fleet of the company taking into consideration customer's information about their location, earliest and latest time windows, their service times and demand. The VRPTW is used to model a variety of aspects for distributing goods to customers based on static information and a metaheuristic algorithm is utilized based on a memory-based Tabu Search [5] which is enhanced with a probabilistic mechanism similar to greedy randomized adaptive search procedures [6] and [7] to further improve the solutions utilizing a mechanism for properly switching between local search and modifying the current solution, ensuring that the algorithm balance between intensification and differentiation.

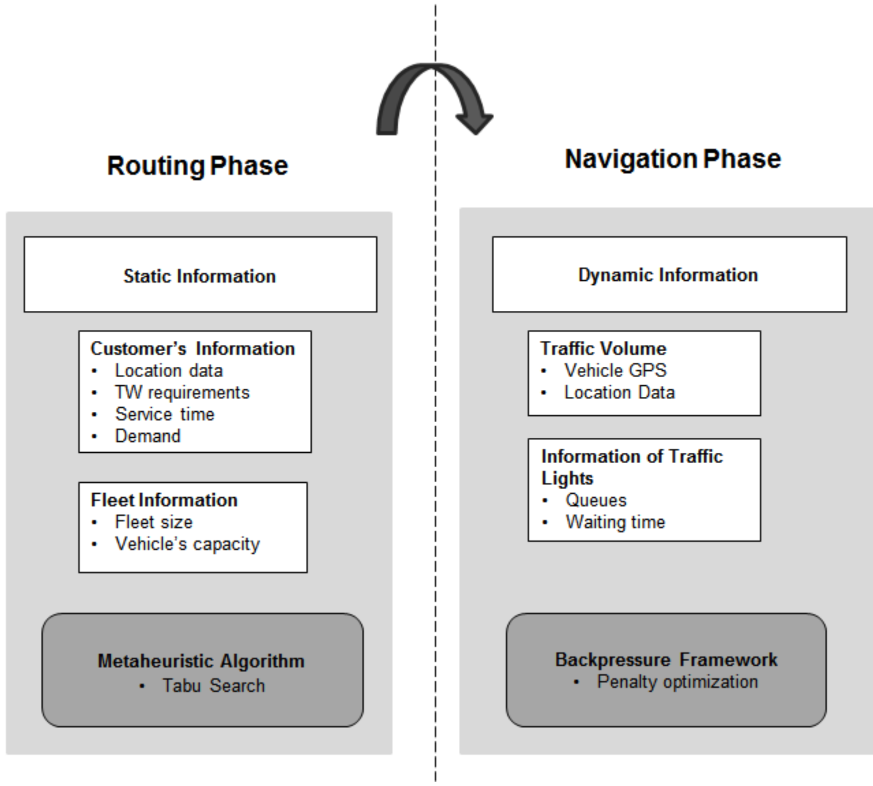

Fig. 1. IoT approach

On the other hand, navigation phase aims to support drivers to follow roads without traffic and avoid high risk roads. This diversion practice enhances safety as guides drivers to safer road conditions and reduces crash risks. For this reason, modern road networks utilize modern technology (i.e. traffic cameras, traffic sensors etc.) to calculate travel times and the number of vehicles on a road [8]. Based on these collected real-time information and data, a backpressure algorithm [9] is implemented to calculate for each outgoing road a backpressure weight which represents the localized queue and link state information [10] and [11]. It acts dynamically based on the network information provided by traffic cameras following a dynamic update process. In particular, for each vehicle a weight is calculated based on the localized queue (i.e. queue backpressure) and link state information (i.e. backlogs at junctions).

3 Empirical study

An empirical study is executed following the proposed IoT approach and a real data set is provided by a transportation company based in Thessaloniki city in

Greece where there are blue-tooth sensors and optical light cameras in infrared-sensors. Given a set of depot-returning capacitated vehicles, each customer is visited only once by exactly one vehicle in order to receive products, as shipments are initially located at the depot. The data set contains 35 customers and their addresses (by latitude and longitude), the corresponding time windows and demands.

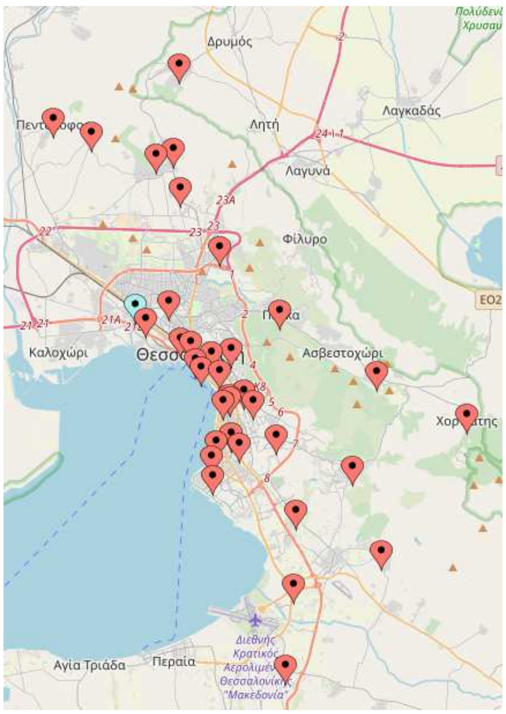

Fig. 2. Customers to be served

The spatial distribution of customers is depicted in Fig. 2 and Euclidean distances are calculated considering a constant speed of the vehicle equal to 50 km/h. The service time varies for each customer and depends on customer demand and the time for unloading. The depot is open from 06:00 to 16:00, and the maximum route duration should be up to 8 h.

The aim of this study is to observe and measure the impact of the proposed IoT approach in practice. The routing phase generates the delivery sequence of customers for the whole fleet of the company minimizing the total vehicles used and the total traveled distance. Table 1 summarizes the results obtained on the empirical study and the CNR and CTD stand for cumulative number of routes and cumulative traveled distance (without considering traffic).

Table 1. Results of Routing Phase

CNR		2
CTD		180.24 km
Route	**Traveled Distance**	**Route Duration**
1	95.88 km	5h 28min
2	84.36 km	7h 52min

The navigation phase utilizes dynamic information and aims to support drivers for following the path with lower risk and avoid traffic. Fig. 3 depicts the final solution obtained for this case study and table 2 summarizes the results derived in practice. The results of the navigation phase appears a weighting factor of 1.43 regarding the distance metric [12] comparing to the routing phase which means a 30% increase. This indicates the efficiency of the proposed IoT approach and allows determining the qualitative feature of planning for real conditions.

Table 2. Results of Navigation Phase

CNR		2
CTD		258.4 km
Route	**Traveled Distance**	**Route Duration**
1	141.5 km	6h 20min
2	116.9 km	8h 17min

4 Conclusions

Trends in advanced technologies render the development of more sophisticated solutions that allow efficient routing optimization and navigation of commercial vehicles with emphasis on safety. This paper presents how an IoT approach could guide vehicles based on real-time information achieving cost efficiency in terms of travel time and improving safety. The proposed approach is based on the communication among vehicles and infrastructure which is a key for improving transportation process of companies delivering goods in urban areas. This allows dynamic updates on navigation phase comparing to the state of practice *Google Maps* that requires more time to gain information for an incident or increased traffic presenting a more periodic update process. To this end, this paper presents the applicability and the importance of the proposed IoT approach for advanced management of city logistics and especially in servicing customers in case of emergency due to unexpected events.

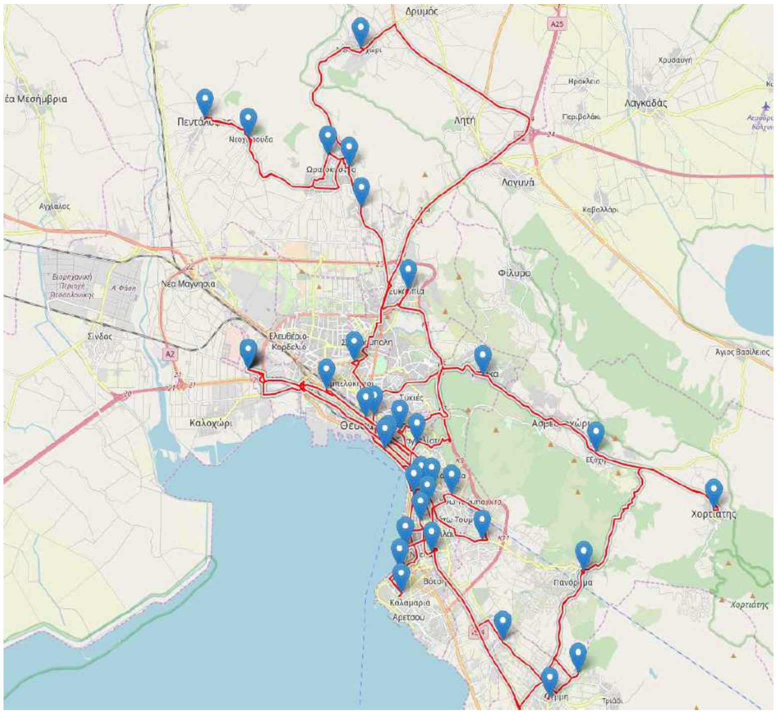

Fig. 3. Final routes

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