Optimizing road traffic of emergency vehicles

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***Abstract*—In our application, and in the context of optimizing the flow of an emergency vehicle in time, we will rely on two tools (mathematics and computer science) in order to avoid delays and risks that characterize the movement of these vehicles. We will use VANET networks as a transmission system to retrieve information about the road incident, and after that, we shall use the Kalman algorithm for tracking our vehicle clarify to specify its position on the predefined path in order to intervene and change its direction towards a safer driving at the same point.**

Keywords- VANET; Kalman; SUMO;

I. INTRODUCTION

In recent years, Intelligent Transportation Systems (ITS) have emerged as an effective way to improve the performance of traffic on the roads, and allow users to consume less energy whilst traveling a less distance to reach the desired destination with a benefit of time and money, while respecting nature. But unfortunately this is not always the case, due to the congestion caused by accidents, construction work, vehicle breakdowns, illegal parking, the weather the bad behavior of drivers, etc.

There are a lot of procedures and algorithms developed to identify the optimal path for a vehicle according to its constraints, but when there is an incident blocking traffic, the road considered optimal is no longer so and may even be the longest path becoming optimal as the shortest route or the more expensive becomes more optimal than the least expensive route, because in this case the optimality is based on the minimization of losses more than maximizing gains. it is in this context where our application comes, which aims to respond at any time to optimize the flow despite the problems encountered in the path, based on the necessary information such as location of the incident and position of the vehicle at the time of the incident, we will find ourselves with advanced methods.

They are a lot of ITS applications that are related to the communication between vehicles and systems that require reliable positioning, with high precision and high speed bandwidth. But each has its own advantages and limitations;

Technique for satellite positioning, the most widely used sensor is the GPS (Global Positioning System), which calculates the position using the signals emitted by a constellation of 27 satellites (including 3 spare) terminals fitted positioning a chip. So this satellite system requires visibility of at least four satellites by GPS receivers, plus a telecommunications medium allowing the dissemination of information, knowing that these receptors have a localization error of plus or minus 10 to 100 meters.

For the technique Location cellular networks, it is based on the information provided by the base station equipment which is connected with a SIM card, such as mobile phones. Among the existing methods to detect the position we find RSSI (Received Signal Strength Indicator) [1,2] EOTD (Enhanced Observed Time Difference) [3] ToA (Time of Arrival) [4] AoA (Angle of Arrival) [5] and TDoA (Time Difference of Arrivel) [6,7], It is true that these methods provide connectivity to 4G over the transmission of data with high speed, but it may decrease due to the existence of trafficking in his voice, and most of these methods are very expensive and lack of precision in the location (differences of 200 meters to several kilometers depending on the number of cellular base stations distributed in the area).

For the localization technique for RFID (Radio Frequency ID entification), it is based on the number of tags detecting the RFID chip in a vehicle, by positioning a series of RFID readers equipped with different types of antennas, so as to cover the entire area wished. The accuracy of this technique results in depend number of readers deployed implying a very high investment cost.

Technique for locating Vanet networks, it is based on Manet networks and does not require a large investment. It is based in particular on the positions designed access points Wi-Fi and even the positions of other vehicles in the case of a relative location. So Vanet offering broadband connectivity includes communication vehicle to vehicle (V2V) and vehicle to infrastructure communication (V2I), which requires no charge for the data transmission, unlike cellular networks.

In our application, we will use the vehicular ad-hoc networks (VANETs) to obtain relevant information in real time on the road, and after that, we shall use the Kalman algorithm for tracking our vehicle in order to intervene at the right moment and change its direction to another path of the same destination, however to one that is smoother and more secure.

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II. WHY USE VANET?

Inter-Vehicle Communication (IVC) is a promising technology for the next generation of ITS, offering new opportunities focused on improving the movement of vehicles on the roads.

VANETs are based on Mobile Ad-Hoc Networks (MANET) that are designed to ensure communication between vehicles (V2V) or communication between vehicles and the road infrastructure (V2I), thus play a crucial role in providing applications [8,9,10,11] to improve safety Road, to effectively increase the use of road infrastructure, to reduce traffic congestion, to reduce the waiting time of vehicles at intersections and reduce the impact of vehicles on the environment.

VANETs using Dedicated Short Range Communication (DSRC) [12,13] to disseminate messages in multiple directions [14,15] because its latency is low , but the coverage will be very limited, so to overcome this problem, researchers have proposed solutions based on V2V communication[16,17] such that vehicles farther can communicate with Road Side Units (RSU).

Unlike other techniques already mentioned above, networks Vanet are more profitable and less expensive, because they offer both a reliable data transfer at high speed, plus a tracking system in several forms with high accuracy.

In our proposal, we will use the Kalman filter in order to provide relevant information in real time to determine the position of the vehicle in a given moment, to change the path before the vehicle arrives at this point.

III. WHY KALMAN ALGORITHM?

In our case, it is true that if we specify our vehicle a path to follow with a certain speed, commencing with a starting point, we can easily clarify its position at any time since we have vehicle's speed, the starting point and the route being followed. But this does not allow us to make a good estimate of the vehicle position at a given moment because we have no guarantee that the vehicle will truly respect the speed specified, so we will always have an estimation error which may adversely affect our temptation optimization.

What characterizes the Kalman algorithm is that it minimizes the maximum error of estimate, which gives a good estimate very close to the actual state, and it is for this reason that we have chosen it as a means to clarify the position of our vehicle at the time of the incident, to detect the paths closest and more secure to the vehicle.

A. *Summary of the Kalman filter*

The Kalman filter is very useful for the realization of a trajectory tracking of a moving target [18]. it allows to estimate the state $x(k)$, of a system that changes over a limited period of time, based on partial and noisy observations.

The Kalman filter is based on a schema type prediction-correction, and it has the advantage of minimizing the variance of the estimation error.

We note:

- x_k is the state vector of the process,
- z_k is the measurement vector at time k,
- ϕ_k is the state transition matrix, which describes the dynamics x_k
- w_k is the model error of the process,
- v_k is the measurement error,
- H_k is the matrix of observations Kalman filtering relies on a set of two equations:
- The state equation that models the random process x_k.
- The process of observation equation z_k .

The system is described by the following two equations:

$$\begin{cases} x_{k+1} = \phi_k x_k + w_k & (1) \\ z_k = H_k x_k + v_k & (2) \end{cases}$$

We believe that the measurement noise and state noise are both white, of known and not correlated covariance.

Their respective covariance matrices are Q_w and Q_v.

At iteration k we get a measure z_k , which has information on the state of the system at time k with measurement noise. We want to find an estimator of x_k to be as efficient as possible that would enable us to know the measurement during the time of k and the moments that precedes it and measures at all times that precede k, which minimizes the mean square deviation between the estimator and the true value x_k .

We note this gap P(k) and we have : $P(k) = E(|x(k) - \hat{x}(k)|^2)$ knowing that $\hat{x}(k)$ is the estimator of x_k .

We can summarize the procedure as follows Kalman [2]:

- Step 1: (Prediction)

$$\hat{x}(k) = \phi\hat{x}(k-1) \qquad (3)$$

$$P(k) = \phi P(k-1)\phi^t + Q_w \qquad (4)$$

- Step 2: (Correction)

$$Q_I(k) = HP(k)H^t + Q_v \qquad (5)$$

$$K(k) = P(k)H^t * Q_I(k)^{-1} \qquad (6)$$

$$\hat{x}(k+1) = \hat{x}(k) + K(k) * (z(k) - H\hat{x}(k)) \qquad (7)$$

$$P(k+1) = (Id - K(k)H) * P(k) \qquad (8)$$

$Q_I(k)$ is the covariance matrix of the innovation that innovation is knowing the difference between the measurement at time k and state estimated a priori. This is the term $z(k) - H\hat{x}(k)$
and K (k) is the Kalman gain, in the sense of mean square error, that is to say, which causes a minimum a posteriori.

B. Modeling case study

Our vehicle travels on the path at a constant speed v.

At time k, the position of the vehicle is $d(k) = d_0 + v_k, d_0$ is the initial position. Then we have $d(k+1) = d(k)+v(k)$and $v(n+1) = v(n)$, because the speed is constant.
But we are not sure that the vehicle will really keep the same speed, it can slow down as it can accelerate, and this uncertainty will influence the certainty of the estimated position of the vehicle. For this reason we added a noise b(k) which is a random process, and we obtain the following system:

$$\begin{cases} d(k+1) = d(k) + v(k) & (9) \\ v(k+1) = v(k) + b(k) & (10) \end{cases}$$

Matrix form:

$$\begin{pmatrix} d(k+1) \\ v(k+1) \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} d(k) \\ v(k) \end{pmatrix} + \begin{pmatrix} 0 \\ b(k) \end{pmatrix} \qquad (11)$$

We set $z(k)$ the observation at time k, we have $z(k) = d(k) + u(k)$, $u(k)$ is a random process representing the measurement noise.

We then have:

$$\begin{cases} \begin{pmatrix} d(k+1) \\ v(k+1) \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} d(k) \\ v(k) \end{pmatrix} + \begin{pmatrix} 0 \\ b(k) \end{pmatrix} & (12) \\ z(k) = [1 \quad 0] \begin{pmatrix} d(k) \\ v(k) \end{pmatrix} + u(k) & (13) \end{cases}$$

We note:

$$x(k) = [d(k) \quad v(k)]^T \qquad (14)$$

Our equation of state is:

$$x(k+1) = \phi(k)x(k) + b(k) \qquad (15)$$

And the measurement equation:

$$z(k) = H(k)x(k) + u(k) \qquad (16)$$

IV. SIMULATION

Many applications have emerged to stimulate VANET and each has its own peculiarities. In our case we need a simulator which can dynamically change the paths of vehicles during the simulation; this traffic model is developed on the platform of Simulation of Urban MObility (SUMO).

SUMO has the possibility to be run as a server to provide dynamic simulation through Traffic Control Interface (TraCI) which uses the TCP protocol.

In our scenario, we consider the map in ”Fig. 1” and two ambulances (the red vehicle and the vehicle green) moving from point A to point B, to get from point A. To point B, we determine the shortest path (yellow path) using Dijkstra algorithm already implemented in SUMO.

During the simulation, and 70 min after the departure of ambulances from point A, there is an accident on yellow path the in the point C ”Fig. 2”.

This leads to congestion in adjacent roads, before the ambulance arrives at point C, consequently, increase the wait time traveling between A and B using the yellow path, and increasing the risk. For this we define another path (bleu path) ”Fig. 2” to avoid blockages and incidents at point C.

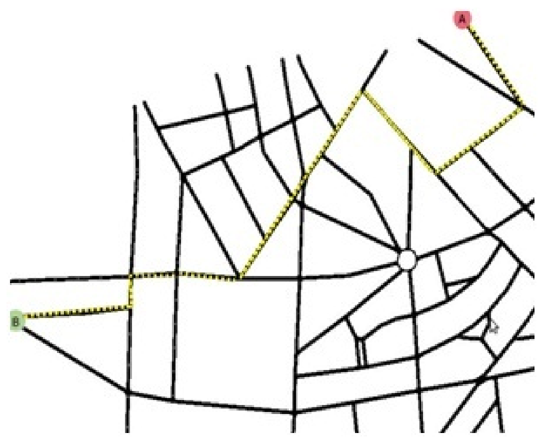

Fig. 1. The shortest path from A to B.

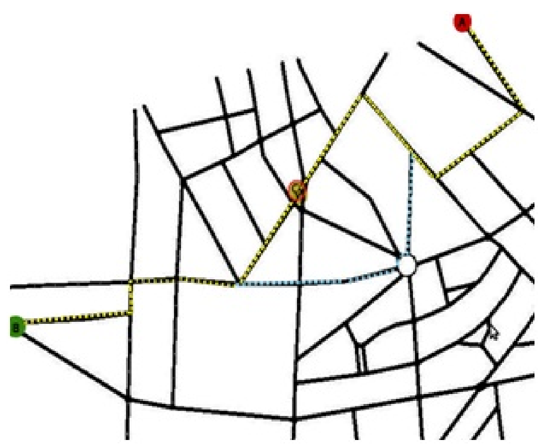

Fig. 2. The point of the accident on the shortest path from A to B.

For this we require the ambulance (green vehicle) to change the path ”Fig. 3”, and take blue path before arrival in the congestion caused by the accident.

The simulation shows that changing the way helped to avoid delays and thus gaining time ”Fig. 4” to go to point B even if it takes on a different longer path.

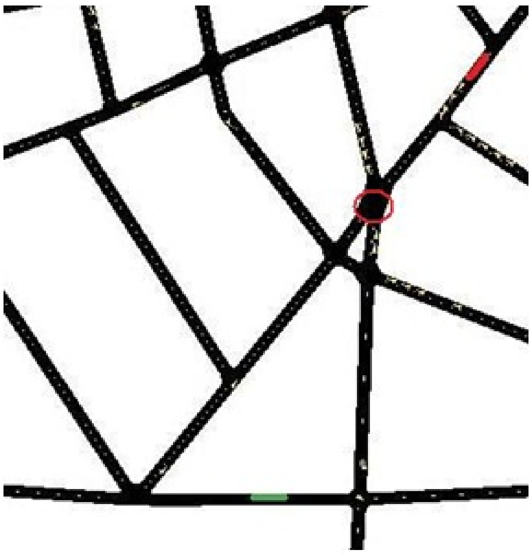

Fig. 3. Change the path of the green vehicle from A to B.

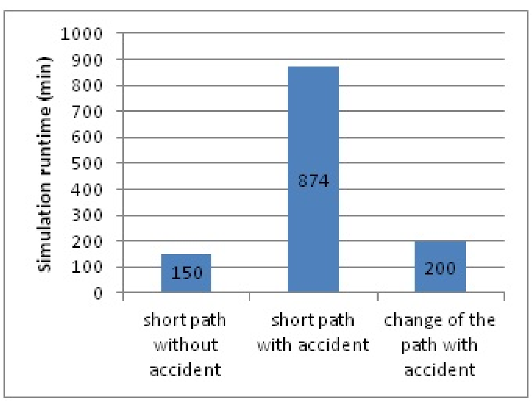

Fig. 4. The time needed to going from A to B.

V. Conclusion

In this paper, we developed a technique combining Kalman and VANETs efficiently to avoid congestion and incidents on the roads by the transmission of warning messages at the right time.

The simulation results show that the use of this technique can not only reduce the waiting time in case of congestion, but also improve traffic flow and road safety.

In the future, we aim at the development and validation of our technique by comparing the results with field data different.

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