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Kalman Filter for Local Optimum Problem of Geographic Routing Protocol in VANETs

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***Abstract:** Vehicular communication has diverse set of applications and has procured ubiquity in automotive industry these days. To perpetuate robust communication among vehicles amid progressively changing street topology is one of the difficulties of vehicular communication. Traffic density and its estimated progress information will assist in combating the urban vehicular difficulties. Although geographic routing renders best route selection for vehicles in VANET environment but it has few constraints like Local optimum problem. To resolve this problem, the paper presents a novel approach to predict proper location of vehicle in future wielding Kalman filter. Also, the real world scenario of Bengaluru city is simulated by SUMO tool for VANET network. Thus, Kalman filter precisely estimates the future location of vehicle and assists in proper information dissemination in VANETs wielding MATLAB and SUMO tool together.*

***Keywords:** Kalman filter, LOP, V2V Communication, VANET*

I. INTRODUCTION

Various analyses have shown that in-advance notification to the drivers and commuters regarding unexpected risks may decrease nearly 60% of vehicle fatalities [1–3]. In order to upgrade the street security, traffic stream control, traffic observing and infotainment administrations, VANET has engrossed concern in the automotive field, transportation and scholarly class. Therefore, to expedite the correspondence among associated vehicles, recent and subsequent renditions of automobiles are intended to be furnished with VANET installed gadgets. For instance, recent BMW automobiles are outfitted with correspondence frameworks and actuators that facilitate their clients to wield the allocated applications viz. BMW Connected Drive [4]. Due to high mobility and diversified ambience (sparse and non-sparse), the essence of VANET is exceptionally exigent. Thus information conveyance in such an exigent system demands routing protocol to be streamlined, authentic and resilient to network modifications. In order to upgrade the operational competence of ITS (Intelligent Transportation System), a compendious study on enhancing traffic prerequisites by wiping out the issues of geographic/location based routing conventions is presented in this paper. By 2023, there will be approximately 70 million vehicles enabled with internet service [5].

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This persistent increment in the quantity of vehicles in both sparse and non-sparse environment has lead to several issues like medical problems, traffic jams and congestion, on-road casualties, fuel consumption, pollution etc in the transportation framework. Amid aforesaid issues, traffic congestion is the predominant impediment in non-sparse environment, which leads to the emanation of destructive carbon monoxide (CO) and CO_2 (carbon di-oxide) in the atmosphere. Consequently, it escalates the menace to general wellbeing and thus prompts an expansion in clinical treatment cost. According to the report of location technology company TomTom [6], for 2020 year, Bengaluru takes the title of highest congested city in the world. The TomTom traffic index report delineates traffic condition of 416 cities in 57 countries of the world. This report depicts that commuter of Bengaluru city reckoning to consume nearly 71% additional movement time jammed in rush hour gridlock. Manila (71%) is second in the worldwide ranking, which is subsequently followed by Bogota in Colombia (68%); Mumbai (65%) and Pune (59%) building up the five most clogged urban cities on the planet. Fig. 1 depicts the worldwide ranking of top 10 congested cities [6].

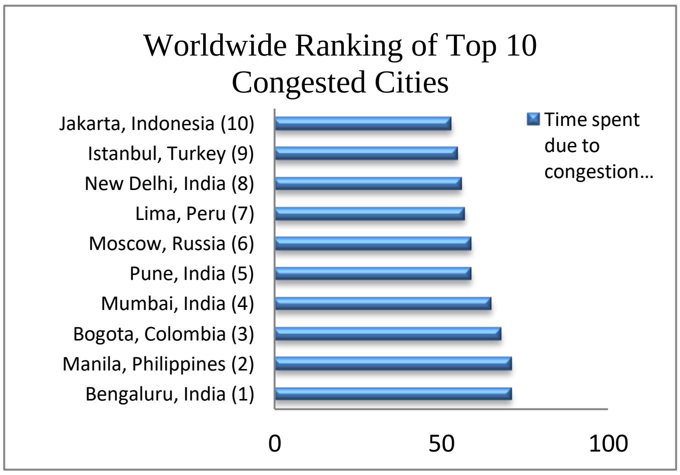


Fig. 1.Worldwide ranking of top 10 congested cities [6].

As indicated by [7], traffic blockage diminishes the yearly worldwide economy to the pace of $1.4 trillion due to air contamination, time ravage, diminished profitability and wastage of fuel. In 2017, traffic blockage cost almost $300 billion to the USA [8]. In addition, the worldwide move to urbanization will substandard the traffic situation in the subsequent years. The primary cause behind blockage is the current street structure which is incompetent to sustain vehicles expansion. One way to deal with deliberately expanding traffic is to recreate prevailing street framework by growing the quantity of streets.

However, it requires sufficient land assets which aren't feasible for urban regions. Thus, the most ideal strategy is to configure traffic organization approach to oversee prevailing traffic conditions. A proficient routing approach to anticipate vehicular position is one of the solutions for traffic configuration. Although geographic routing renders best route selection for vehicles in VANET environment but it has few constraints like Local optimum problem (LOP). When greedy advancing strategy becomes inefficacious to relay information packets due to prevailing correspondence gaps, then local optimum problem appears [9]. This issue persuades constantly in sporadic area i.e. there are few vehicles lying in the vicinity of source vehicle. In such situations, store and carry forward strategy is generally exerted. The information that has to be forwarded is held up by the forwarder until a good relaying node is found [10]. In case if a good relaying node is not found, the information transmission gets delayed leading to deterioration of quality. This LOP issue may occur in either sparse or non-sparse environment. In non-sparse network, LOP occurs due to irregular vehicular positioning. Most of the geographic routing protocols wields greedy forwarding strategy, which results into LOP issue. This paper presents a novel approach to predict proper location of vehicle in future wielding kalman filter. Thus, this filter properly estimates the future location and helps in proper information dissemination in DTNs (Delay Tolerant Networks) and non-DTNs (Delay Tolerant Networks). The rest of the paper is arranged in various sections. Section 2 illustrates the real world scenario of Bengaluru city obtained via SUMO simulator. Section 3 presents kalman filter approach in order to overcome LOP problem and simulation results, at last conclusion is drawn in section 4.

II. SUMO NETWORK

In order to predict the future location of vehicles properly in a VANET network, firstly SUMO (Simulation of Urban Mobility) simulator is wielded in order to create a real world scenario. SUMO imitates the street traffic ambience and vehicular motion whereas network counterfeit is provided by kalman filter developed in MATLAB R 2018a version. TraCI (Traffic Control Interface) provides access to road traffic simulation in SUMO and let it run in MATLAB software. As per TomTom report, Bengaluru city is highly congested. Therefore, kalman filter provide V2V communication in such a congested city and subsequently overcome this congestion issue. Thus, OSM (Open Street Map) of Bengaluru city is downloaded and then SUMO configuration file is created by setting different QoS variables namely arrival rate, vehicle type, departure rate, routes etc. Thus, SUMO provides the real street environment of Bengaluru city which is depicted in Fig. 2.

Fig. 2.SUMO scenario of Bengaluru streets.

Moreover, general system attributes of the network are illustrated in Table-I.

Table- I: General attributes of the network.

Attributes	Specification
Simulation Software	SUMO 1.3.1 and MATLAB R 2018a
Simulation Time	500 s
Number of Vehicles	10, 20, 30,…, 100
Vehicle Length	5 m
Simulation Area (X*Y)	4000*2400 m
Maximum and Minimum Speed of Vehicles	5.5 and 22.5 m/s
Maximum Acceleration	2.5 m/s^2
Transmission Range	350 m
Error Bounds (θ)	10 m
MAC Protocol	IEEE 802.11 p

III. KALMAN FILTER APPROACH AND SIMULATION RESULTS

After creating the scenario, Kalman filter (KF) in MATLAB is utilized to predict the future location of vehicles in the network. In order to design discrete-time linear KF, the trackingKF class [11] is wielded to track velocity as well as location of vehicles. KF is an iterative algorithm which estimates the future location of vehicles. Initially, SUMO interfacing and recording of vehicle parameters is done by TraCI. Total 100 vehicles are considered for V2V communication. In order to predict the location of neighboring vehicles, following steps are followed: 1 Step: Initially SUMO simulator is wielded to imitate the real world road traffic from Bengaluru city.

Then, TraCI provides access to road traffic simulation from SUMO in MATLAB software, therefore yields vehicle ID and other parameters to MATLAB simulator by Fig. 3.

```
initialVhclID=[];
initialPos=[];
for i = 1: simTime   % simulation time
          traci.simulation.step();
          vehicleID=traci.vehicle.getIDList();
```

Fig. 3.TraCI to simulate street scenario from SUMO to MATLAB software.

2 Step: After that VANET processing takes place in which distance between vehicles is estimated to predict future location of vehicle. Let there are two vehicles V_1 and V_2, if V_1 is in range of V_2, i.e. both vehicles are within the radius of 350m, then V_1 can transmit information to V_2, otherwise trackingKF class of kalman filter is utilized to predict the future location of vehicle V_2, such that information can be transmitted successfully from V_1 to V_2. The expression for estimating state of neighboring vehicle using trackingKF class is as follows:

For ii=1:nume(initialVhclID) (1)
KF{ii}=trackingKF
('MotionModel','2DConstantVelocity','State'...)
[initialPos(ii,1);0;initialPos(ii,2);0]); (2)

Kalman filter predicts almost all the locations of the vehicles accurately. The Fig. 4, which is a flowchart, illustrates the process of vehicle state estimation in a lucid way. Initially when position of vehicle (vehPos) is in range (350m) of neighboring vehicle (neighbrPos), then information can be easily transmitted from one vehicle to other, else kalman filter is used for state estimation of neighboring vehicle.

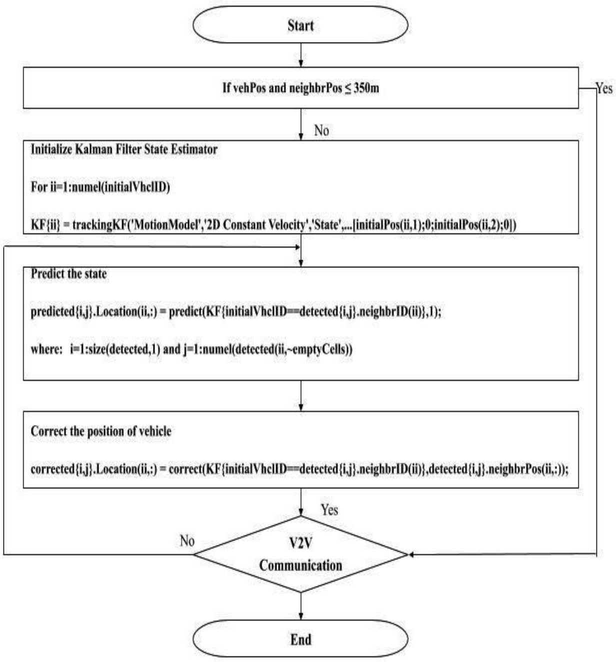
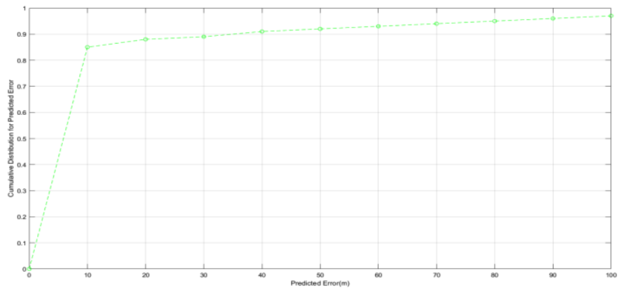


Fig. 4.Flowchart for position evaluation of vehicles in VANET network.

IV. SIMULATION RESULTS

The simulation is performed for 100 vehicles and simulation time is set to 500 seconds. The experiment was performed by considering the real world traces of Bengaluru city and kalman filter was employed for state estimation of vehicles, which assists in proper V2V communication and eliminated the LOP issue of geographic routing protocols. The error bounds (D_{err}) for predicting vehicle location is given by equation 3 [12]:

$$D_{err} = \|(x_t, y_t) - (\hat{x}_t, \hat{y}_t)\| \quad (3)$$



Flowchart for position evaluation of vehicles in VANET network.

The error bound is determined by a preset threshold θ. The kalman filter will determine the error among real-time and predicted location as soon as the vehicular node (V_n) in time slot t attain its real-time state x_t. If $D_{err} > \theta$, then V_n will disseminate information regarding its speed and location. For very small value of θ, the rate of information would be excessively high. Fig. 5 illustrates the CDF (Cumulative Distribution Function) of D_{err} of Bengaluru city in which random mobility model was utilized. The vehicle acceleration is $2.5 m/s^2$. The maximum and minimum speeds are 5.5 and 22.5 m/s respectively. Utilizing Kalman filter model illustrates that only 2.5% values have $D_{err} > 50m$, whereas 85% of the values have $D_{err} < 10m$. Thus, for non-DTN applications of VANETs, $\theta < 10m$ is suitable because higher position precision is requisite for these applications.

Fig. 6 depicts the Predicted and Corrected Locations of Bengaluru City. The green circles are the estimated position by kalman filter and + symbols indicates the corrected position of vehicles and these both positions nearly overlap which indicates that kalman filter predicts vehicular position properly.

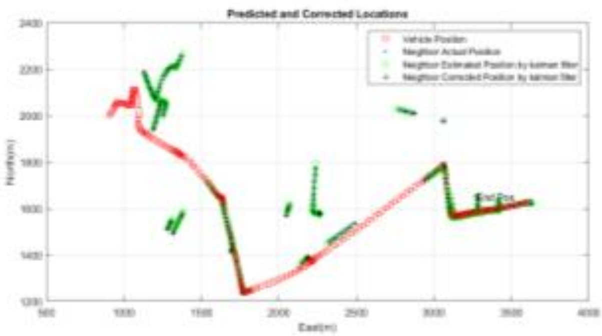


Fig. 5.Predicted and Corrected Locations of Bengaluru City.

V. CONCLUSION

The key to different VANET applications like information transmission, driving safety etc is the discovery of adjacent vehicles in the network. Mobility is the major issue of neighbor discovery, as the speed of vehicle increases; its location estimation becomes an issue, which subsequently results in the loss of information packet in the network. Various location based routing scheme employ greedy strategy to transmit information, but these schemes encounter LOP issue, which is resolved by novel technique proposed in this paper which is Kalman filter employment to predict the future location of vehicles. This technique renders less than 10m error bounds for 85% of the values which is requisite for non-DTN applications. Thus, Kalman filter precisely estimates the future location of vehicle and assists in proper information dissemination in VANETs.

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