International Journal of Engineering

Journal Homepage: www.ije.ir

TECHNICAL NOTE

Intelligent Traffic Management System for Prioritizing Emergency Vehicles in a Smart City

L. Sumia, V. Ranga*

Department of Computer Engineering, National Institute of Technology, Kurukshetra, India

P A P E R I N F O

Paper history:
Received 01 August 2017
Received in revised form 22 October 2017
Accepted 30 November 2017

Keywords:
Intelligent Traffic Management System
Emergency Vehicles
Road Side Units
Smart Cities

A B S T R A C T

Traffic congestion worldwide has led to loss of human lives due to failure in transporting accident victims, critical patients, medical, equipments and medicines on time. With the unending growth in vehicular traffic everywhere, the fusion of Internet of Things (IoT) and Vehicular Ad Hoc Network (VANET) has embarked as a promising platform for an Intelligent Traffic Management System (ITMS). In the literature, researchers have suggested various solutions, but without taking into consideration how to prioritize emergency vehicles when traffic system is collapsed due to hacking. This paper proposes a novel intelligent traffic management system for a smart city after considering the research gaps which are yet to be explored in the current scenario. Our proposed solution, not only navigates ambulances to find the shortest possible paths till their destination, but also presents a counter measure to get rid the problem of the traffic light system when it is hacked during its operation. To show the advantages of our proposed solution over already proposed solutions, a simulated environment (CupCarbon simulator) is used to model various scenarios which shows the actual roads and vehicle movements in the implementation. The observed results exhibit the superiority of our proposed solution over state-of-the-art solutions.

***doi**: 10.5829/ije.2018.31.02b.11*

1. INTRODUCTION

Rapid growth in the world population has resulted in tremendous demand for smart city initiatives; however, there are many issues for smart cities [1]. Government as well as private sectors has to contribute in finding sustainable solutions for these overwhelming issues. Monitoring traffic is a prominent issue in the current scenario. It has become a global issue with the escalation of vehicular density and population growth since last few decades. Road traffic has not only resulted in wastage of time, property damage or environmental pollution, but also caused loss of lives as accident victims. Sometimes medical equipment, critical patients and necessary medicines are not transported in time. Controlling of traffic with a traffic light is an integral part of any intelligent traffic management system. The two important aspects to be considered are green light duration and its sequence. Several traffic systems, practices fixed duration of light length and sequences which is desirable only for regular and stable traffic, but not for dynamic traffic situations. Most countries, at the current state of practice, decide the green light sequence without considering the emergency vehicles such as ambulances, police cars, fire engines, etc., thereby leaving emergency vehicles to wait and cause loss of lives and assets [2]. Additionally, vehicular population increases the "response time" of emergency vehicles which is defined as nothing but the period between the time whenever a call is received by an emergency service provider and the arrival time of an ambulance to an emergency site [2]. Reducing the response time by just one minute increases the survival rate of the patients with sudden cardiac arrest by 24% [2]. Taking these issues under consideration, we introduce a methodology in this paper to estimate the distance between an intersection and emergency vehicle through wireless technologies like, video surveillances and sensor devices deployed at strategic locations. A solution is proposed to reduce the travelling time by

*Corresponding Author's Email: *virender.ranga@nitkkr.ac.in* (V. Ranga)

Please cite this article as: L. Sumia, V. Ranga, Intelligent Traffic Management System for Prioritizing Emergency Vehicles in a Smart City, International Journal of Engineering (IJE), IJE TRANSACTIONS B: Applications Vol. 31, No. 2, (February 2018) 278-283

organizing both the green light duration and green light sequence on the basis of distance measured with less delay and response time. At the outset, we propose an ITMS based on the type of an incident and hacking of traffic signals. It is inspired by the principles of VANET and IoT where every vehicle in a VANET system share information with one another within a certain range through wireless technology and every device (such as vehicles, Road Side Units (RSUs), users, mobile, traffic control server, etc.) are interconnected to exchange information among themselves.

The remainder of the paper is structured as follows: section 2 presents a brief review of related works. Section 3 introduces our proposed methodology with its algorithm. The performance and evaluation of the proposed work are discussed in section 4. Finally, section 5 concludes the paper and gives future work.

2. RELATED WORKS

Shekher et al. [3] introduced an efficient navigation system based on VANET for ambulances that addresses the problem of ascertaining the shortest path to the destination to get rid of unexpected congestions based on real time traffic information updates and historical data. A dynamic routing system was suggested by integrating real time traffic scenario and Global Positioning System (GPS). The system also includes a metro rail network with road transport system to guide ambulances in real time scenarios. Similarly, Djahel et al. [4] also presented an adaptive framework for an efficient traffic management of emergency vehicles that not only adjusts the traffic signals dynamically, but also recommend drivers required behavior changes, driving policy changes and exercise necessary security controls. Sundar et al. [5] proposed a smart way of controlling traffic for clearing ambulances, detect stolen vehicles and control congestions. This is done by attaching Radio Frequency Identification (RFID) tags on vehicles that assists it to count the number of vehicles passing on a particular path, detect stolen vehicle and broadcast message to the police control room. Additionally, it communicates with traffic controller to prioritize ambulances with the help of ZigBee modules.

The author in reference [6] initiated an intelligent traffic management system which prioritizes emergency vehicles using a different approach, i.e. by categorizing them based on priority levels and incident type occurred. They also proposed a secure method to detect and respond hacking of traffic signals. An ITS has been introduced based on Green Wave system in reference [7] that allows a traffic signal system to turn green whenever it encounters an emergency vehicle, thereby allowing it to acquire all green signals in its pathway. The traffic signal system in this project also identifies stolen vehicle that bypasses the green signal. The main drawback of the Green Wave is that it can create a heavy traffic jam when the synchronization of the signals is disturbed.

Although several researchers have projected many approaches to offer clear pathways to emergency vehicles after assuming a single emergency vehicle coming from a single direction. So far, very few of the existing ITMS considered the case of possible attacks that a traffic signal system may be vulnerable too. Some researchers investigated the possible cyber-attacks on autonomous vehicle and listed the type of attack(s) that can be performed on these vehicles. Autonomous vehicles are capable of identifying its environment using multiple sensors [8].

Significant researches focused on reducing collision or accidents on roads [9, 10] and managing traffic congestions using various concepts like Machine-to-Machine (M2M), IoT and VANET [11, 12]. Optimal route planning for providing shortest traveling time were presented in [13, 14], while transmiting traffic information such as traffic statistics, vehicle density and weather conditions, etc. were proposed in references [11, 15]. Therefore, it is pertinent to say that several works have been done for traffic management system, but not many concentrated on prioritizing emercency vehicles.

3. PROPOSED METHODOLOGY

3. 1. Architecture of the Proposed Solution

This section presents our proposed architecture for an ITMS inspired by the fused concepts of VANET and IoT that prioritizes the emergency vehicles on roads. The system firstly measures the gap between an intersection and the emergency vehicle, then dispatched EV from that particular intersection with the consideration that either the traffic signals are hacked or non-hacked, the type of incident and emergency car type. Our main motivation is to allow the emergency cars to bypass heavy traffic and reach their destinations on time as well as ensuring minimum transmission delay for emergency messages. Figure 1 demonstrates our proposed model comprising of Traffic Management Server (TMS), vehicles, RSUs, sensors deployed at strategic locations, all interconnected in a VANET system exchanging with one another. Every emergency vehicle has a unique identity that distinguishes it from the rest of the vehicles on the road. As depicted in Figure 1, the TMS maintains the database of the traffic conditions globally. Once the information of emergency vehicles is obtained from sensors, it estimates the distance of emergency vehicles from an intersection and delivers access to the emergency vehicle on that particular road segment immediately. An RSU of the

current intersection (RSU-A) informs the RSU of neighboring intersections (RSU-B) with the details of velocity of emergency car and number of vehicles which is moving towards the same intersection-B. On receipt of information from RSU-A, RSU-B will estimate its arrival time at the intersection-B. RSU-B will then regulate both the green light sequence and duration on the basis of expected time of arrival of the same and the received vehicle details from RSU-A. Additionally, the TMS also keeps a check on the response time of emergency vehicles for both normal and hacked traffic signals. If it observes that the traffic signals are hacked or some malicious entities are trying to impersonate emergency car to gain road clearance, it will immediately terminate its access. As soon as the emergency vehicles clear the road, the traffic system continues to function normally. Hence, with no or little delay, emergency vehicles can bypass through the intersections and save lives and property.

The primary objective of the proposed work is to deliver importance emergency messages quickly and lessen the broadcast delay. Four different types of vehicles are considered in our paper: ambulance, police car, fire brigade and ordinary cars. The following sub-sections show the flow of our proposed solution:

3. 1. 1. Determination of Incident Type

Emergency situations can be broadly classified into three categories:

i. Life-threatening issues such as situations requiring medical assistance during a road accident.
ii. Fire threats such as burning houses.
iii. Crowd control problems such as fights or other criminal activities requiring the presence of police.

The incident type can be quickly analyzed and determined through video surveillances.

3. 1. 2. Determination of Priority Level

Determination of priority levels based on the urgency of the situation is necessary. The priority levels assigned to different types of vehicle on the basis of an incident are given in Table 1. In order to appropriately determine the priority levels of emergency vehicles on the basis of incidents, three cases have been considered:

In case 1, an ambulance is given the topmost priority for a situation when medical assistance is more important, for instance, road accidents or transporting critical patients.

Fire brigades and police can follow after ambulances as they have little or no role to play. In case of fire accidents, fire brigades will be given the priority as paramedics cannot rescue people from fire. Here, case 2 will be considered. Ambulance and police cars will be assigned priorities consequently. In the case 3, Police cars will be given the priority for situations like riots or, fights or crowd controlling situations.

3. 2. Algorithm for Prioritizing Emergency Vehicles

In Table 2, the symbols and descriptions, used in our proposed solution, are shown. When an EV plying on the road send out emergency notifications for priority, its V_{id} will be checked in the database to find out if the vehicle is an authentic EV. On finding the matched id, TMS will schedule EVs on the basis of incident type and priority levels. When more than one EVs are plying on the same road simultaneously, they will be given priority on the basis of their classified cases (case 1, 2, 3) in sequence.

Now, when an RSU is hacked (for instance, DDOS attack) or is compromised by some malicious entity, the entire traffic of the attacked RSU will be shifted to a handler (i.e., another uncompromised RSU). To address such an issue, the handler tries to find the source of packet from which the malicious traffic is disseminated. If the number of packets coming from one source has exceeded the threshold (Th) or the set limit of a normal traffic system, then it will be considered as malicious and the source S of the incoming malicious packets will be immediately blocked by the handler.

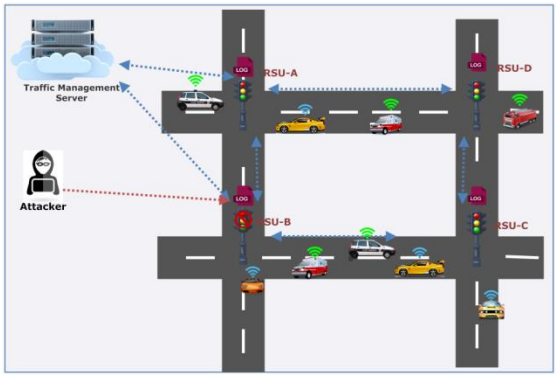

Figure 1. An architecture of an Intelligent Traffic Management System Prioritizing Emergency Vehicles

TABLE 1. Priority levels for different cases of incidents

Case No.	Emergency Medical assistance?	Fire Threat?	Fire Control needed?	Crowd control or Criminal investigati-ons?	Priority
1	Yes	Yes	No	No	Ambulance>Fire Brigade> Police
2	Yes	Yes	Yes	No	FireBrigade<Ambulance<Police
3	Yes	Yes	No	Yes	Police<Ambulance<Fire Brigade

TABLE 2. Symbols and their descriptions

Symbols	Description
V_{id}	Vehicle id
V_{A_i}	Ambulance id of vehicle *i*
P_r	Priority
P_{A_i}	Priority of ambulance *i*
D	Distance of vehicle from RSU
Th	Threshold for normal traffic
Handler	RSU which handles attack
C	Cases, where c=1,2,3
I_s	Counter for each source S
p_s	Packet from source *S*

Once the situation is handled, the traffic resumes to its normal way of functioning. A flowchart of the proposed step is shown in Figure 2.

3. 3. Identification of Hacking and its Countering

Hacking of traffic signals can interrupt the entire normal functioning of the traffic system. There is a typical pattern of signals in a traffic system during peak and off-peak hours. Any form of intrusion in the system can be deduced as hacking. Once hacking is confirmed, the compromised RSU's traffic is handled by a handler (by another RSU). The malicious source of the packet is traced and blocked from communicating further with the traffic system. Thus, hacking is handled efficiently. This is depicted in Figure 3 of the proposed solution.

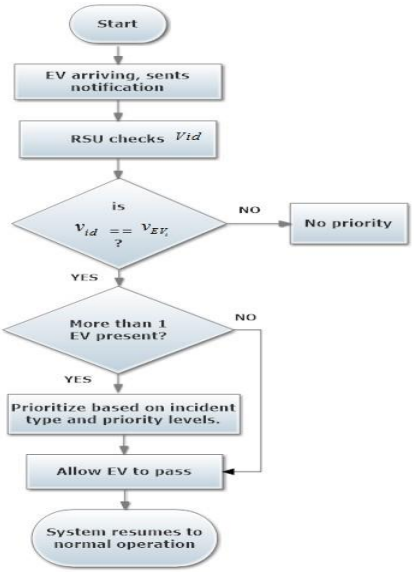

Figure 2. Flowchart for Prioritizing EmergencyVehicles

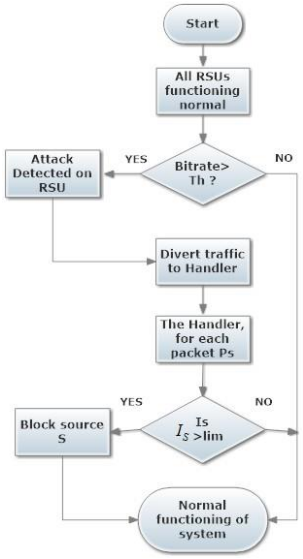

Figure 3. Identification of hacking and its countering

Algorithm 1. ITMS for Prioritizing Emergency Vehicle algorithm

When an EV and normal vehicles are present
for each vehicle *i* passing through RSU in D distance
if (V_{id}==V_{EV_i})
if (N(V_{EV})>1)
Switch(c)
Case 1:
P_max=P_A
Allow $V_{EV_A}$to pass
(P_F>P_P)
Allow V_{EV_F} to pass
Allow $V_{EV_P}$to pass
Case 2:
P_max=P_F
Allow V_{EV_F} to pass
(P_A>P_P)
Allow $V_{EV_A}$to pass
Allow $V_{EV_P}$to pass
Case 3:
P_max=P_P
Allow $V_{EV_P}$to pass
(P_A>P_F)
Allow $V_{EV_A}$to pass
Allow V_{EV_F} to pass
End if
End if
End

To detect attacks on RSU:
if (bitrate>Th)
Attack Detected
Divert attack traffic to Handler
In Handler
for each packet p_s
I_s++
if I_s>lim
Block S
End if
End if

4. PERFORMANCE AND EVALUATION

For simulation, we have implemented our proposed solution on CupCarbon U-One simulator, which is an open source and free network simulator for the simulation of smart city and IoT applications. In this section, performance of our system is evaluated by comparison with previous proposed works, i.e., EPCS [6] and Green Wave [7] system. A total of 20 vehicles and eight intersections between each RSUs have been considered. We have taken 10 vehicles between the starting point of EV and the incident location (destination) during simulations. The average speed of the vehicle is set at 15 km/hr and distance between two successive vehicles is taken at 1 meter. The simulation results, in Figure 4, show that Green Wave, EPCS and our proposed system require 17.5 minutes, 12.7 and 11.2 minutes, respectively to meet the set target. In order to examine the proficiency of handling hacking in the system, we have considered that 10% of hacked traffic signals are hacked. When traffic systems are compromised, Green Wave and EPCS show 19.2 minutes and 14 minutes respectively, while our proposed work shows 11.8 minutes to meet the target even in a hacked scenario. This shows the superiority of our proposed solution over Green Wave method and EPCS. At the outset our proposed solution shows 12% improvement over EPCS system and 17% over Green Wave.

Figure 5 shows bit rate of packets of traffic signals per seconds.

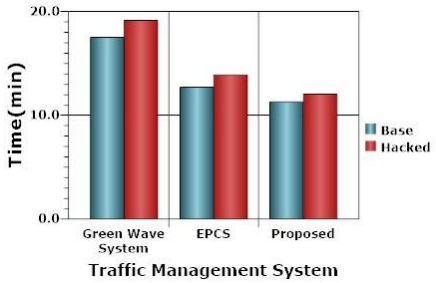

Figure 4. Time comparison of different traffic management systems

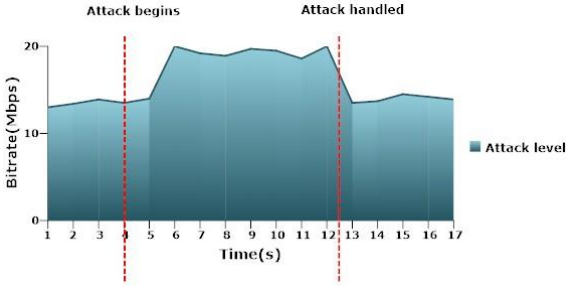

Figure 5. Bitrate of packets where attack starts after 4 seconds

It is observed from the plotted graph that during a normal working of RSUs, the average bit rate is 12.5 Mbps. When an attack begins at 4th sec after a few seconds, the bit rate rises to 20 Mbps leading to heavy congestion in a few minutes and eventually collapses the traffic system. The traffic is then shifted to a handler to handle and normalize the flow of bit rates. We witness here that there is a drop in bit rates of 12.5-13 Mbps on the compromised road.

5. CONCLUSION AND FUTURE SCOPE

Several researches have been carried out on intelligent traffic monitoring system, but a secure and efficient solution for emergency vehicles is yet to discuss. Therefore, an ITMS has been proposed to prioritize emergency vehicle by fusing the concept of VANET and IoT with an effort to ease the flow for ambulances in urban areas. It also presents a method to detect and counter hacking of traffic signals which is a very common problem nowadays. The distance between intersections and emergency cars were estimated to achieve the target travel time of emergency vehicles with minimal delay time, considering both hacked and non-hacked traffic signals. The proposed model not only distinguishes emergency messages with several priorities, but also prevents false warnings from malicious entities. The experimental results show that our system outperformed others in terms of time constraints, thereby achieving the goal of allowing emergency services to be met at the shortest possible time. The proposed system eliminates the time delay in medical assistance for accident victims, transporting critical patients and medicines.

For future directions, different priority levels for multiple incidents and scenarios can be considered. The main issue with IoT is that the security of the entire system have to be concentrated on and not a particular IoT layer, device or software. Hence, integrating the entire traffic management system with multiple layer security for various data generated from various sources can be another subject of future scope.

6. REFERENCES

1. Sumi, L. and Ranga, V., "Sensor enabled internet of things for smart cities", in Parallel, Distributed and Grid Computing (PDGC), 2016 Fourth International Conference on, IEEE., (2016), 295-300.
2. Nellore, K. and Hancke, G.P., "Traffic management for emergency vehicle priority based on visual sensing", ***Sensors***, Vol. 16, No. 11, (2016), 1892.
3. SmithaShekar, B., Divyashree, C., George, G., Rani, H.U., Murali, A. and Kumar, G.N., "Gps based shortest path for ambulances using vanets", in Proc. International Conference on Wireless Networks (ICWN 2012). Vol. 49, (2012).

4. Djahel, S., Salehie, M., Tal, I. and Jamshidi, P., "Adaptive traffic management for secure and efficient emergency services in smart cities", in Pervasive Computing and Communications Workshops (PERCOM Workshops), 2013 IEEE International Conference on, IEEE., (2013), 340-343.
5. Sundar, R., Hebbar, S. and Golla, V., "Implementing intelligent traffic control system for congestion control, ambulance clearance, and stolen vehicle detection", ***IEEE Sensors Journal***, Vol. 15, No. 2, (2015), 1109-1113.
6. Chowdhury, A., "Priority based and secured traffic management system for emergency vehicle using iot", in Engineering & MIS (ICEMIS), International Conference on, IEEE., (2016), 1-6.
7. Mittal, A.K. and Bhandari, D., "A novel approach to implement green wave system and detection of stolen vehicles", in Advance Computing Conference (IACC), 2013 IEEE 3rd International, IEEE., (2013), 1055-1059.
8. Garip, M.T., Gursoy, M.E., Reiher, P. and Gerla, M., "Congestion attacks to autonomous cars using vehicular botnets", in NDSS Workshop on Security of Emerging Networking Technologies (SENT), San Diego, CA., (2015).
9. Milanes, V., Villagra, J., Godoy, J., Simo, J., Pérez, J. and Onieva, E., "An intelligent v2i-based traffic management system", ***IEEE Transactions on Intelligent Transportation Systems***, Vol. 13, No. 1, (2012), 49-58.
10. Jayapal, C. and Roy, S.S., "Road traffic congestion management using vanet", in Advances in Human Machine Interaction (HMI), 2016 International Conference on, IEEE., (2016), 1-7.
11. Foschini, L., Taleb, T., Corradi, A. and Bottazzi, D., "M2m-based metropolitan platform for ims-enabled road traffic management in iot", ***IEEE Communications Magazine***, Vol. 49, No. 11, (2011).
12. Chatrapathi, C., Rajkumar, M.N. and Venkatesakumar, V., "Vanet based integrated framework for smart accident management system", in Soft-Computing and Networks Security (ICSNS), 2015 International Conference on, IEEE., (2015), 1-7.
13. Wang, M., Shan, H., Lu, R., Zhang, R., Shen, X. and Bai, F., "Real-time path planning based on hybrid-vanet-enhanced transportation system", ***IEEE Transactions on Vehicular Technology***, Vol. 64, No. 5, (2015), 1664-1678.
14. Al-Sakran, H.O., "Intelligent traffic information system based on integration of internet of things and agent technology", ***International Journal of Advanced Computer Science and Applications (IJACSA)***, Vol. 6, No. 2, (2015), 37-43.
15. Chang, I.-C., Tai, H.-T., Yeh, F.-H., Hsieh, D.-L. and Chang, S.-H., "A vanet-based a* route planning algorithm for travelling time-and energy-efficient gps navigation app", ***International Journal of Distributed Sensor Networks***, Vol. 9, No. 7, (2013), 794521.

Intelligent Traffic Management System for Prioritizing Emergency Vehicles in a Smart City

TECHNICAL NOTE

L. Sumia, V. Ranga

Department of Computer Engineering, National Institute of Technology, Kurukshetra, India

P A P E R I N F O

Paper history:
Received 01 August 2017
Received in revised form 22 October 2017
Accepted 30 November 2017

Keywords:
Intelligent Traffic Management System
Emergency Vehicles
Road Side Units
Smart Cities

چکیده

تراکم ترافیک در سراسر جهان به از دست دادن زندگی انسان ها به علت شکست در حمل و نقل به موقع قربانیان حادثه، بیماران با وضعیت بحرانی، پزشکی، تجهیزات و دارو منجر می شود. با رشد بی پایان در ترافیک وسیله نقلیه در همه جا، همپوشانی اینترنت چیزها (IoT) و شبکه حمل و نقل ویژه (VANET) به عنوان یک پلت فرم امیدوار کننده برای سیستم مدیریت هوشمند ترافیک (ITMS) آغاز شده است. در ادبیات، محققان راه حل های مختلفی را پیشنهاد کرده اند، اما به نحوه اولویت بندی وسایل نقلیه اضطراری، زمانی که سیستم ترافیک به دلیل هک شدن سقوط می کند، توجهی نشده است. این مقاله پس از در نظر گرفتن شکاف تحقیقاتی که هنوز در سناریو فعلی مورد بررسی قرار نگرفته است، یک سیستم مدیریت ترافیک هوشمند را برای یک شهر هوشمند پیشنهاد می دهد. راه حل پیشنهادی ما نه تنها آمبولانس را هدایت می کند تا کوتاه ترین مسیر ممکن را تا مقصد خود پیدا کند، بلکه یک اقدام مقابله ای برای رفع مشکل سیستم چراغ راهنمایی که در طول عملیات آن هک شده است، ارائه می دهد. برای نشان دادن مزایای راه حل پیشنهادی ما در مقایسه با راه حل های پیشنهادی موجود، یک محیط شبیه سازی شده (Simulator CupCarbon) برای مدل سازی سناریوهای مختلفی استفاده می شود که جاده ها و حرکات واقعی خودرو را در پیاده سازی نشان می دهد. نتایج مشاهده شده برتر بودن راه حل پیشنهاد شده ما را در مقایسه با راه حل های موجود نشان می دهد.

***doi**: 10.5829/ije.2018.31.02b.11*