Smart System for Busy Roads Using Short Range Wireless Technologies

Muneer Bani Yassein, Mohamed Al-Maolegi, Yaser Khamayseh, Dragana Krstic, Shadi Aljawarneh

***Abstract*—**The vast advancements in wireless networks led to an increased interest in the development of smart transportation systems which permit vehicles to exchange important information between them and deployed fixed stations. The main goal of these systems is to assist the drivers on the roads and providing them with the necessary information about the driving conditions so they can avoid the accidents and the crowded streets. An intelligent transportation system which notifies the drivers about the crowded streets is proposed in this paper. Once the driver receives this information, it can search for the best path to their destination. The underlying wireless network used in the proposed system is ZigBee, it is preferred for it is low power and low cost compared to other short range wireless technologies. The proposed system decreases the overall cost of such systems which makes it applicable in any country. The performance of the proposed system is evaluated using two competing technologies: ZigBee and Wi-Fi. In terms of end to end delay and packet delivery ratio, Wi-Fi outperforms ZigBee, while ZigBee outperforms Wi-Fi in terms of energy consumption.

***Keywords*—**Intelligent transportation system, crowded street, ZigBee, Wi-Fi.

I. Introduction

THE Intelligent Transportation System [1] (ITS) is advanced application that aims to apply Information and Communication Technologies (ICT) to transports. These intelligent systems include all types of communications that can be used between vehicles such as car to car communication and between vehicles and specific location such as train to railway station. ITS's are not exclusive to road transports but they also include air and water transports. Generally, the different kinds of ITS depend on radio services for communication. Many specialized wireless technologies can be used for ITS's such as Wi-Fi, WI-MAX, Bluetooth or ZigBee. Our proposed approach focuses on using ZigBee wireless network in ITS [6].

Muneer Bani Yasein is with the Department of Computer Science, Jordan University of Science and Technology, Irbid, Jordan, masadeh@just.edu.jo.

Mohamed Al-Maolgi is with the Department of Computer Science, Jordan University of Science and Technology, Irbid, Jordan, mqalmaolegi11@just.edu.jo.

Yaser Khamayseh is with the Department of Computer Science, Jordan University of Science and Technology, Irbid, Jordan, yaser@just.edu.jo.

Dragana Krstic is with the Department of Telecommunications, Faculty of Electronic Engineering, University of Nis, Serbia, dragana.krstic@elfak.ni.ac.rs.

Shadi Aljawarneh is with the Department of Software Engineering, Jordan University of Science and Technology, Irbid, Jordan, shadi.jawarneh@yahoo.com.

ZigBee is a short range and a high level communication technology which depends on wireless technology. It is based on IEEE 802.15.4 standard [2]. Additionally, it is developed for working with very low power consumption so battery life can be expanded from many months to several years. The data rate used in ZigBee is not a high as Bluetooth or Wi-Fi because of that it is used in applications that require low data rate and low power consumption [11-12]. We prefer using ZigBee with ITS because it is low power, low cost and inexpensive as compared to other short range wireless technologies of its class. Furthermore, the data rate that is used in ZigBee is good enough for communications and transfer information in our proposed approach.

Wireless Fidelity (Wi-Fi) [10] is a wireless technology that is considered as alternative to wired technology that is usually used to connect many devices to each other wirelessly. Wi-Fi is based on IEEE 802.11 communications standard that is used in wireless local area networks. Wi-Fi technology can be used to connect devices to each other, to the wired network or to the internet. It comes with many protocols such as IEEE 802.11 b, a, g and n. These protocols differ from each other by the used frequency, data rate and transmission range. The elements of Wi-Fi network are access point for connecting to internet, Wi-Fi cards that allow relying information wirelessly and safeguards that protect networks from attacks [3].

Most of the accidents on the roads occur today because the streets are crowded with many vehicles such as cars and buses. Sometimes, when somebody delayed for his work, university or anything else, and as he is driving his car, he may go through a crowded street which leads to further delay. If anybody knows that the street is crowded, he will never go through it and he will search for another road which leads him to his location and avoiding the delay. So to not be stuck in any crowded street, we want to propose an intelligent system to inform the drivers with the crowded street before going through it. The notification should be early enough to provide the driver by enough time to react and not moving through any crowded street. An efficient system is required using a wireless technology such as ZigBee which is low power and low cost as compared to other short range wireless technologies.

The remainder of this paper is structured as follows: Section 2 discusses the related work that design intelligent transportation systems. Section 3 presents ZigBee sensor and its components. Section 4 shows the system description and the flow of information. Section 5 shows the methodology of this paper. Section 6 presents the performance evaluation. Finally, Section 7 draws the conclusions of the entire study and mentions and discusses further potentials of follow up research.

II. Literature Review

Many systems are proposed to notify the driver of the upcoming traffic, road under maintenance, hospital, university, school, a blind upcoming corner and many other conditions. Furthermore, these systems can be used to inform the driver of existence of road signs and simple advertisements such as the menu of a nearby drive-in restaurant.

In [3], the authors proposed a system to alert the drivers to approaching traffic hurdle before a safe distance so that drivers can avoid these hurdles. This system uses a short wireless technology by installing ZigBee sensors on the traffic hurdles and ZigBee hosts on the cars. The ZigBee sensor and ZigBee host start communication whenever the ZigBee host reaches the range of the ZigBee sensor on the traffic hurdle. The traffic hurdles used are road stops, railway tracks, no entry roads, traffic signals, curves and brake indicators.

In [4] the authors proposed a system to notify and inform the drivers of upcoming a preset waypoint on the road. ZigBee sensor is installed on each waypoint and equipped on each car. The system gives the driver information about road condition before choosing the route, upcoming fuel pump, upcoming railway crossing or traffic signals. The location of all waypoint must allow the notification message to be sent out early enough to provide the driver enough time to react.

In [5], the authors proposed a system uses ZigBee modules for traffic management and surveillance. The system includes a ZigBee module installed in the vehicle and other ZigBee module installed at checkpoints that are placed at regular intervals along the road. Whenever the vehicles close from the range of checkpoints, the checkpoints receive the information about vehicles then forward this information to central traffic control room. The information in central traffic control room is processed to form a database containing of records for each vehicle. The communication happens also between vehicles to avoid the accidents.

In [6], the Flexible Bus Systems (FBS) are proposed to fulfill the demands of the passengers in a way that the passenger will not wait on the bus stop for long time. The bus stops and buses will communicate with each other using ZigBee. The bus stop receives information about the incoming buses and the number of passengers on each one of them. The buses receive information about the next bus stop and the number of passengers who are waiting for the buses. So, when there are passengers waiting for the buses in bus stop, the bus stop sends a message to the closest bus in the bus stop's coverage area. Therefore, the bus drivers are notified by the passengers who are waiting for the bus. The usage of Zigbee for communication between the bus stops and the buses decreases the overall cost of the system significantly.

Many systems are proposed to notify the driver of the upcoming traffic, road under maintenance, hospital, university, school, a blind upcoming corner and many other conditions. Furthermore these systems can be used to notify the driver of existence of road signs and simple advertisements such as the menu of a nearby drive-in restaurant. Some of these systems use vehicle to vehicle communication and some other uses vehicle to infrastructure communication and others use hybrid architecture that combines vehicle to vehicle communication and vehicle to infrastructure communication to prevent accident as important future services [4].

III. ZigBee Sensor Network

ZigBee [7] is a high level communication technology that depends on wireless technology. ZigBee is easy to implement and can be used in any place, and it is designed to appropriate with low power, low cost and easy for control the network. ZigBee covers a small area and transmits data over short distance that reaches up to 100 m almost. ZigBee wireless network used in residential and commercial applications, and used for control and automation. It is used for low data rate networks, and it is slower than Wi-Fi and Bluetooth, with a maximum speed of 250Kbps at 2.4 GHz. ZigBee [2] can be used in a lot of applications that require a low data rate, secure networking, and long battery life.

The most promising application are home control such as access control and security, personal health care such as patient monitoring, building automation such as security and lighting, personal computers and peripherals such as mouse or keyboard, and environment such as environment monitoring [3].

The selected standard for ZigBee is IEEE 802.15.4. The ZigBee identifies three types of devices, the first one is the ZigBee Coordinator (ZC) that forms the root of the network tree, controls the network and creates the routing tables, the second one is the ZigBee Router (ZR) that acts as an intermediate router by passing data from devices to others, and can speak to the three devices: the coordinator, the other routers and the end devices, the third one is ZigBee End devices (ZED) that control functions and can talk to either routers or the coordinator, but not to each other, and it cannot relay data from other devices. The ZigBee is composed if several sensors, processor, nodes, and computer. The ZigBee network runs as the following: the sensors collects the information and sends it to the ZigBee node; after that the ZigBee node in its turn resends the collected information to the coordinator. Once the coordinator receives the collected information, it resends it to the processor.

As soon as the coordinator gets the sensor information, it sends the same information to the processor by the wired connection. The processor receives the collected information, manipulates and save it.

When the host computer queries the ZigBee network, all of the collected information will be provided by the processor.

Table 1 [9] shows the comparison between ZigBee, Bluetooth and Wi-Fi and why we choose the ZigBee instead of the other wireless technologies.

Table 1 Comparison between wireless communication technologies

Standard	ZigBee 802.15.4	Bluetooth 802.15.1	Wi-Fi 802.11g
Automotive application	Inter-vehicle and vehicle to infrastructure communication	In-vehicle communication and device connectivity	Inter-vehicle and vehicle to infrastructure communication
Network range	Up to 100m	Up to 70m	Up to 100m
Network method	Mesh	P2P	P2P
Bandwidth	250 kbps	12Mbps	54Mbps
Frequency	2.4 GHz	2.4 GHz	2.4 GHz
Advantages	Low power Many devices Low overhead	Dominating PAN Easy synchronisation	Dominating WLAN Widely available
Disadvantages	Low bandwidth	Consume medium power	Consume high power

IV. System Description and Flow of Information

Figure 1 explains the general idea of this paper [10]. When you are driving and you want to reach to your specific location fast, you wish to avoid the crowded streets. In the crowded streets, you may wait for a long while in case you were stuck. The concept of this paper is to notify the drivers with the crowded streets before reaching them. The figure below shows the intelligent system that used to inform the driver about crowded cars on the streets.

This system is designed so that a ZigBee host is provided to each car and ZigBee sensor to the main streets or to the streets that are probably crowded. When the cars approach to the crowded street, the ZigBee sensors start registering the surrounded cars through a communication between ZigBee sensors in cars and ZigBee host in streets. The ZigBee sensor sends messages to each car near to it in distance up to 100 m telling them about the number of the cars in the street.

After that, the ZigBee host in the car receives the information about the number of the cars on the street and displays this information on screen. The drivers have a choice to move through this street or find another one.

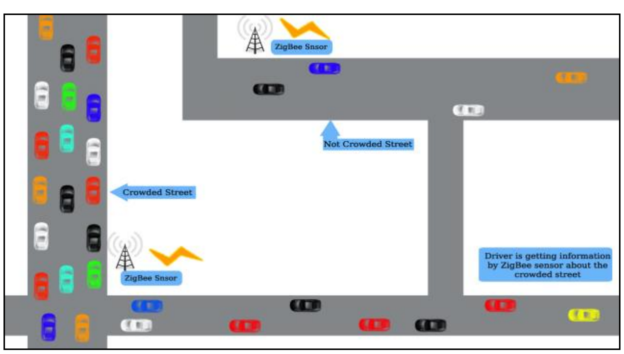

Fig. 1 ITS for crowded street using ZigBee sensors

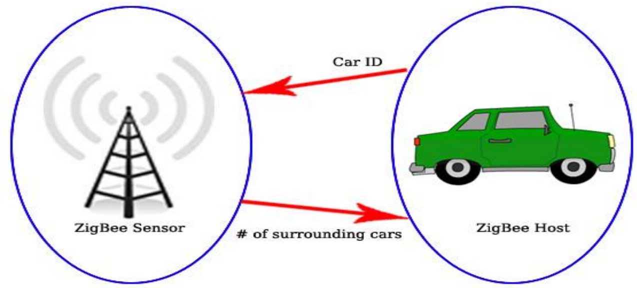

Fig. 2 Flow of Information between ZigBee sensor and ZigBee host

The ZigBee sensor covers a distance up to 100 m. Each car in the transmission range of the ZigBee sensor communicates with it by sending its ID and asking for the number of cars existing in the transmission range. The ZigBee sensor gathers the car's IDs and sends the number of these cars in a message to each one as clearly in Figure 2. Because of that, the drivers will be informed about the crowded street before an enough long distance so that the driver can avoid these streets.

V. Methodology

In this section, we present a detailed description of the main steps that we will go through to perform this paper. The first step is developing a scenario of ZigBee sensor network by using QualNet 5.2 simulator. The experiments are conducted to check the suitability of using ZigBee with ITSs. According to the communication between ZigBee host on the cars and ZigBee sensor on the street, we evaluate the network performance in terms of the delivery ratio and end to end. We also compare the network performance of the ITS using ZigBee network with the same system but by using Wi-Fi technology.

VI. Performance Evaluation

This section presents the simulation tool, simulation setting and the simulation results. The performance of the proposed intelligent system using ZigBee is evaluated in terms of packet delivery ratio and end to end delay. Additionally, we conduct a comparison between ZigBee and Wi-Fi when they applied in the proposed intelligent system. The following sections give a brief description of the experiments and detailed description of the results.

A. *QualNet Simulator*

The QualNet 5.2 simulation platform is a planning, evaluating and training tool [8]. It is used to simulate the behavior of a real communications network. Through this simulator, the users can evaluate the basic behavior of a network, provide universal environment for designing protocols, and analyze their performance. QualNet is useful and understandable tool which supports both command line interface and graphical user interface.

B. *Simulation Settings*

We have assumed a 200m×200m for network region which contains different numbers of cars. We run the scenarios experiments with 10, 25 and 50 cars. There are two limitations that should be considered to perform the experiments. Firstly, 100 m is the maximum distance between ZigBee sensor and ZigBee host. Secondly, the height of the antenna should be 2m for ZigBee host and ZigBee sensor [3]. The rest of simulation parameters are recorded in Table 2.

Table 2 The simulation parameters

The Parameters	The Values
Deployment Field	200 x 200 m
Data Packet Size	50 bytes
Number of nodes	10, 25, 50
Simulation time	30 m
Radio type	IEEE 802.15.4 radio
Antenna model	Omnidirectional
Antenna type	Traditional
Antenna height	2 m
Energy model	MicaZ
Device type (ZigBee host)	FFD
Device type (ZigBee sensors)	RFD
Routing protocol	AODV
Beacon order	3
Super Frame order	3

The results of our proposed approach are the average of 20 experiments. We conduct a performance evaluation in terms of packet delivery ratio and end to end delay. Packet delivery ratio is the rate between numbers of data packets received by the destination and the number sent by the source. End to end delay is time taken for a packet to be transmitted across a network from source to destination.

Figure 3 shows the design of network in Qualnet 5.2 simulator where the ZigBee host is placed in the center of intersection of two roads.

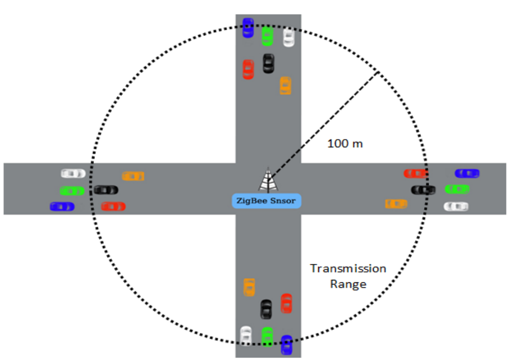

Fig. 3 The design of the network in Qualnet simulator

The cars coming from the four directions communicate with ZigBee host. ZigBee host registers each car that communicates with it and sends a message to each one about the number of surrounding cars.

C. Results and Discussions

Figure 4 shows the packet delivery ratio for the proposed ITS for different numbers of cars located at 100 m from ZigBee sensor. As shown in the figure, there are different values for delivery ratio with different numbers of cars.

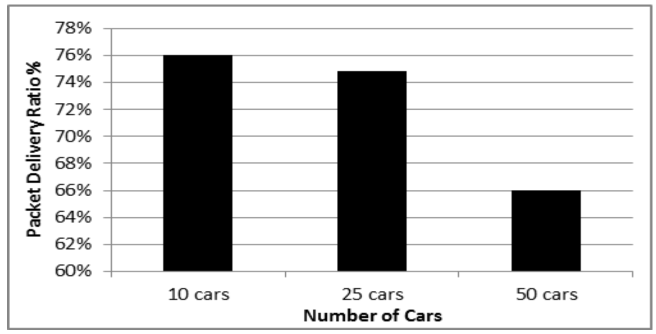

Fig. 4 Packet delivery ratio for different numbers of cars

We notice that there is a slight difference in delivery ratio between 10 and 25 cars. Additionally, the delivery ratio decreases with 50 cars and this is because of the collision between packets sent by cars and ZigBee sensor.

As it is shown in Table 3, The ZigBee sensor can register approximately 8 cars of 10 cars located at 100 m from it. After that, it will send messages to all cars to inform them that the street contains only 8 cars with error of 20%.

Table 3 The registered and not registered cars in 100 m

Distance	Actual no. of cars	No. of registered cars	Error
100 m	10	8	20%
100 m	25	19	24%
100 m	50	33	34%

With 25 cars, approximately 19 cars are registered with error of 24%. With 50 cars, approximately 33 cars are registered with error of 34%. We conclude that as the number of cars increases, packet delivery ratio will decrease. The main factors which effect on the packet delivery ratio are the long distance and the overhead on ZigBee sensor.

Figure 5 reveals the average end to end delay for different numbers of cars. With 10 cars the delay becomes 14 second. With 25 and 50 cars the delay time increases to be 70 and 212 seconds respectively. The delay increases as the number of cars increases. The delay time is caused by the long distance between cars and ZigBee sensor and the large overhead on ZigBee sensor. The delay time for this system is critical factor because cars move fast.

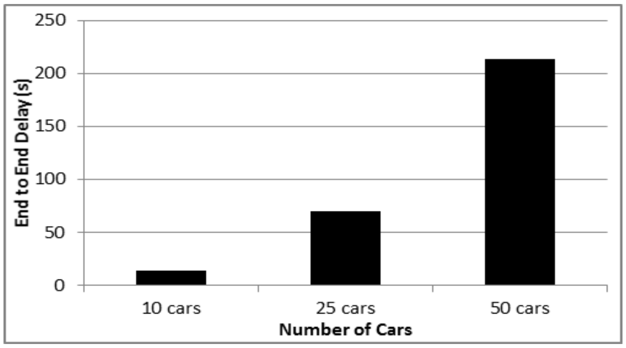

Fig. 5 End to end delay for different numbers of cars

So, using ZigBee with this type of intelligent system is not effective. Because of that, we evaluate the proposed system by using Wi-Fi and compare it with ZigBee.

D. ZigBee and Wi-Fi Comparison with ITS

In this section, we conduct a comparison between ZigBee and Wi-Fi with the same intelligent system in terms of packet delivery ratio, end to end delay and energy consumption. The same simulation setting is assumed for Wi-Fi with a little difference. We assume that the deployment field is 1000 x 1000 m and the radio type is IEEE 802.11.

Figure 6 shows the packet delivery ratio in the ITS using ZigBee and Wi-Fi for different number of cars. We notice that delivery ratio of ITS using Wi-Fi is approximately stable with different number of cars.

In the other side, the delivery ratio of ITS using ZigBee deceases as the number of the cars increases. For the ITS, Wi-Fi outperforms ZigBee for 10, 25 and 50 cars by approximately 7%, 7% and 25% respectively in terms of packet delivery ratio.

Figure 7 shows the average end to end delay in the ITS using ZigBee and Wi-Fi for different number of cars. We can notice from this figure that the delay of ITS using Wi-Fi is approximately stable with different number of cars.

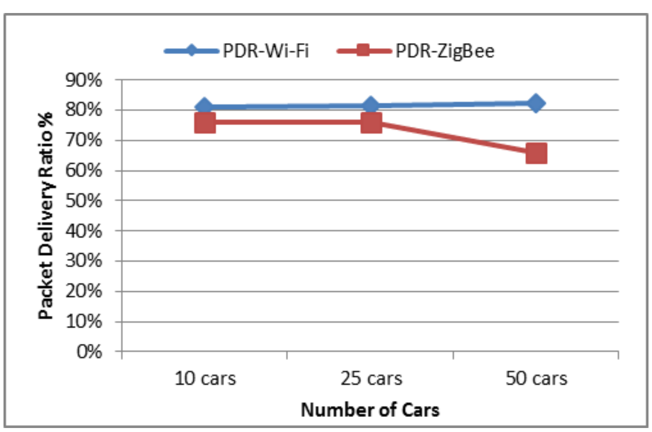

Fig. 6 The packet delivery ratio of ITS using ZigBee and Wi-Fi

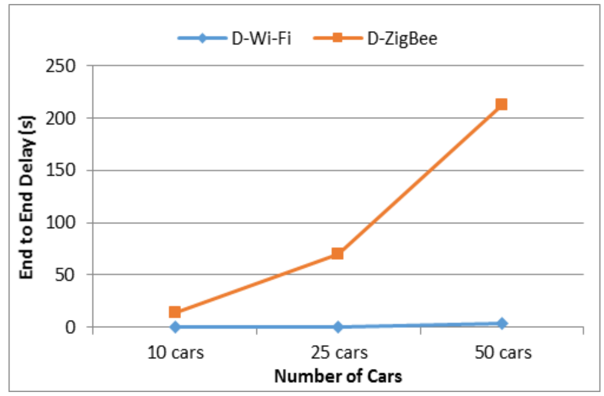

Fig. 7 The end to end delay of ITS using ZigBee and Wi-Fi

In the other side, the delay of ITS using ZigBee deceases as the number of the cars increases. In addition to that, the end to end delay using ZigBee is much higher than end to end delay using Wi-Fi especially with the increasing number of cars. In other words, Wi-Fi outperforms ZigBee for 10, 25 and 50 cars by approximately 99%, 99% and 98% respectively in terms of end to end delay.

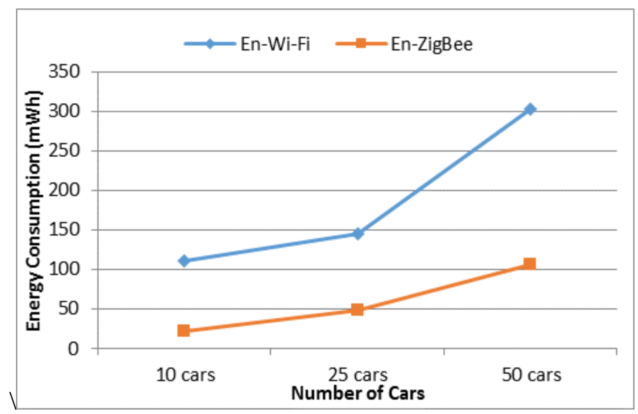

Fig. 8 The energy consumed in ITS by using ZigBee and Wi-Fi

Figure 8 shows the energy consumed in the ITS by ZigBee and Wi-Fi with different number of cars. We notice that the energy consumed by using Wi-Fi network increases whenever the number of cars increases.

The same thing is with ZigBee where the energy consumed increases also whenever the number of the cars increases. However, the amount of energy consumed by Wi-Fi is very higher than the amount of energy consumed by ZigBee. In other words, ZigBee outperforms Wi-Fi for 10, 25 and 50 cars by approximately 390%, 197% and 187% respectively in terms of energy consumption.

VII. Conclusions

In crowded streets, there are many factors that affect the communication between cars and ZigBee sensor. These factors increase the average end to end delay and decrease the packet delivery ratio. The first factor is the long distance between ZigBee sensor and cars where the ZigBee network performance reduces over distance. Thus, the ZigBee sensor and cars should be very close to each other for a good quality communication.

The second factor is the large overhead caused by the large number of cars that send packets to ZigBee sensor and that lead to collision. From the experimental results, we conclude that the intelligent system using Wi-Fi outperforms the same system using ZigBee in terms of the packet delivery ratio and the average end to end delay. Wi-Fi outperforms ZigBee for long distance and high data rate while ZigBee outperforms Wi-Fi in terms of energy consumption. The critical factors for choosing either ZigBee or Wi-Fi are cost and energy consumption. ZigBee is low cost and require low power to operate. If we ignore the cost and the energy consumption, then the intelligent system using Wi-Fi is very efficient and effective.

Though considerable effort has been made on this research, many solutions regarding the subject are still not investigated. Here we outline and present some of our future plans to be conducted in order to improve this work. The main goal here is to increase the effectiveness and efficiency of the intelligent system using ZigBee by decreasing the delay and increasing the delivery ratio. One of these solutions is to allow car to car communication.

The ZigBee sensor sends messages to the cars in its transmission range about the number of surrounding cars. After that, the surrounding cars send messages to the closer cars which are out of the transmission range of the ZigBee sensor and so on.

This solution will decrease the load on the ZigBee sensor because each car will communicate with other cars rather than communicate with the ZigBee sensor. Other benefit is to cover long distance and hence the driver will be informed by the crowded street before reaching them. Other solution is to distribute many ZigBee sensors along the street. Thus, the cars will communicate with the closest sensor and the ZigBee sensors will communicate with each other. This solution also covers long distance and distributes the load over all sensors.

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Muneer M. Bani Yassein, is an associate professor at the Department of Computer science at Jordan University of Science and Technology (JUST), He received his PhD degrees in Computer Science from the University of Glasgow, U.K., in 2007 and M. Sc. in Computer Science, from Al Al-bayt, University, Jordan in 2001 and his B.Sc in Computing Science and Mathematics from Yarmouk University, Jordan in 1985. Bani Yassein served as chairman of the department of computer science from 2008 to 2010, as Vice Dean of the Faculty of Computer and Information Technology from 2010 to 2012, and from 2013-2014. Bani Yassein is currently conducting research in Mobile Ad hoc Networks, Wireless sensors Networks, Cloud Computing, Simulation and Modelling, Bani Yassein, has published over 60 technical papers in well reputed international journals and conferences. During his career, he has supervised more than 50 graduate and undergraduate students. Bani Yassein is a member of the technical programs of several international journals and conferences. In academic year 2014/15 he is spending his sabbatical year at Edinburgh Napier university, Edinburgh, U.K.

Mohammed Al-Maolegi obtained his M.Sc. degree in computer science from Jordan University of Science and Technology, Jordan in 2015. He received his B.Sc. in computer information system from Mutah University, Jordan in 2010. His research interests include: wireless sensor networks, data mining and software engineering.

Yaser Khamayseh is an associate professor in Computer Science Dept. at Jordan University of Science and Technology. He received Bachelor's degree in Computer Science from Yarmouk University, Irbid, Jordan, in 1998. He finished his Master's in Computer Science at the University of New Brunswick, Canada in 2001. Ph.D. in Computer Science at University of Alberta, Canada, in 2007. Dr. Khamayseh joined Jordan University of Science and Technology in 2007. Dr. Khamayseh has more than 15 years of experience in research and teaching in the field of data communication and computer networks in different institutions. He worked at TR Labs for testing high speed network devices. His research interests include simulation and modeling, wireless networks, performance evaluation, security, next generation Internet, and evolutionary computation. Dr. Khamayseh has more than 40 published articles in international journals and conferences. Dr. Khamayseh is member of IEEE and has received several awards.

Dragana S. Krstić received the B.Sc, M.Sc and PhD. degrees in Electrical Engineering from Faculty of Electronic Engineering, University of Nis, Serbia

in 1990, 1998. and 2006, respectively. She is with Faculty of Electronic Engineering, University of Nis, since 1990. Her field of interest includes telecommunications theory, optical communication systems, wireless, mobile and satellite communication systems, etc. As author/co-author, she wrote about 200 scientific research papers, of which over 30 are printed in international journals, several in national journals, approximately 100 are referred at international symposia and conferences, while over 30 are presented at national professional conferences. Dr Krstic had several plenary and keynote lectures, panels and tutorials by invitation at international conferences. She is also the member of editorial boards of a few international journals and reviewer for many. Dr Krstic is a member of the technical program committees or reviewer for more than 50 conferences.

Shadi Aljawarneh is an ACM senior member and an associate professor, Software Engineering Dept, at Jordan University of Science and Technology. He holds a BSc degree in Computer Science from Jordan Yarmouk University, a MSc degree in Information Technology from Western Sydney University and a PhD in Software Engineering from Northumbria University-England. His research is centered in web and network security, e-learning, software engineering, Cloud Computing and ICT fields. Aljawarneh has presented at and been on the organizing committees for a number of international conferences and is a board member of the International Community for ACM, ACS, and others. A number of his papers have been selected as "Best Papers" in conferences and journals.