IoT Enabled Intra-Vehicular Wireless Sensor Networks for Reliable Communicatio

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Abstract: The concept of Internet of Things (IoT) (i.e., large number of nodes are interconnected each others) can be utilized in vehicle, since the number of sensor nodes has increased significantly due to the uplifting demand of various safety and convenience applications. The controller area network is a widespread system of communication between sensor nodes inside a vehicle with wired connections, however, the wired architecture is not scalable and flexible due to the complex architecture inside the vehicle. Therefore, there is an increasing level of appeal to design a reliable system in which the wired connections to the sensor nodes are replaced with wireless links. In this paper, we design a wireless sensor network for reliable intra-vehicular communications based on concept of IoT. Firstly, we study the design of single link between a base station and a sensor node. Then we design a complete scenario, where more sensor nodes transmit their packets, to generalize the design for a larger intra-vehicle wireless sensor network. For achieving reliable communications, we define two different levels of reliability: one is single link reliability and other is network reliability. Finally, the performance is evaluated in terms of network reliability. The simulation results assist to design a robust system for intra-vehicular communications.

Key–Words: Controller Area Network, Reliability, Intra-vehicle communication, Wireless Sensor Network (WSN)

1 Introduction

The concept of Internet of Things (IoT) can be utilized in vehicle, since the number of sensor nodes has increased significantly due to the uplifting demand of various safety and convenience applications. IoT in vehicle enables the objects (e.g., parts of the vehicle) to be active participants, i.e., they share information with others through sensor nodes. In this way the objects are capable of recognizing events and changes in their surroundings and are acting and reacting autonomously without human intervention in an appropriate way.

Controller Area Network (CAN) is one of the widely used communication protocol especially for wired intra-vehicle communications. It is a serial communication protocol capable of managing high efficiency distributed realtime control with a high level of security. A CAN network is composed of two or more nodes connected through a linear bus made with a twisted pair of wires, and supporting CAN protocol. The CAN protocol defines a set of aspects for serial transfer of data through the bus. CAN protocol data unit is a frame, with mainly 4 types of frames such as, data, remote, error and overload. The data and remote frames are used during normal operation: data frames have a payload field, carrying a piece of user-level information; the remote frames do not possess such field. Conversely, error frames are issued upon bus error detection and overload frames are intended to delay the start of a data or remote frame transmission. In CAN protocol, one node transmitting a frame on bus and all other nodes can see that frame. Nodes are able to distinguish between frames using their frame IDs. For more information about CAN, we refer to [1, 2].

The wired architecture is not scalable and flexible because of the increasing number of sensor nodes and the internal structure of the vehicle [3]. Therefore, there is an increasing level of appeal to design a system in which the wired connections to the sensor nodes are replaced with wireless links. To this end, several technologies, such as Radio Frequency IDentification (RFID) and Zigbee, have been investigated in literature [4, 5, 6].

Wireless channels are by nature extremely complex and unpredictable systems. Several models and parameters are used to characterize wireless channel, whereas many of them are backed up by intuition and physical theory [8, 9]. However, no single concrete method for determining the characteristics of a wire-

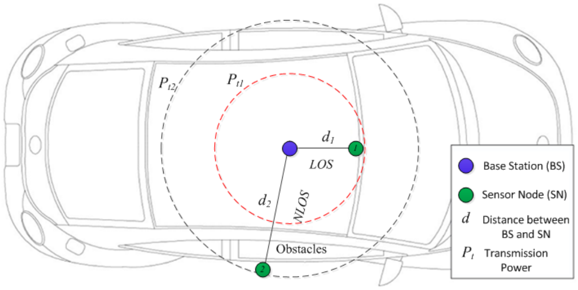

Figure 1: Scenario is changed with the varying of communication parameters.

less channel has been established. Therefore, the most accurate method of characterizing a particular wireless channel is experimental measurements, particularly for practical purposes.

IoT Enabled Intra-Vehicle Wireless Sensor Networks (IVWSNs) refers the network where large number of sensors are connected each other for sharing the car status information in order to develop a smart car system. The design of a IVWSN can not be separated from the study on the link between the different sensor nodes distributed in the vehicle. Therefore, link designing between BS an SN is an important issue in IVWSNs. The network performance varies in IVWSNs with different communication parameters such as distance between Base Station (BS) and SN, transmission power and channel fading. From Fig. 1, we can see that the transmission power of the BS is set P_{t1} if the distance between BS and SN is d_1. When the distance is increased from d_1 to d_2 then the transmit power needs to be increased from P_{t1} to P_{t2} for receiving the same level of received signal by the SN. We also notice that due to the increasing of distance between BS and SN, the obstacles may come in the propagation path that changes the line-of-sight (LOS) to non LOS (NLOS). As a result, the fading distribution of a channel will be changed. For achieving the better performance in IVWSNs, the above parameters need to be adjusted. In fact, design a wireless sensor network inside the vehicle is more challenging to other networks, e.g., wireless, sensor and computer networks, because of the complex environment created by a large number of parts inside the vehicle. Therefore, it is an active research area to design a network for intra-vehicle communications.

In this paper, we design a wireless sensor network for reliable intra-vehicular communications based on the concept of IoT by utilizing ZigBee standard instead of the traditional CAN technology. More in details, firstly, we study the design of single link between a base station and a sensor node. Then we design a complete scenario, where more sensor nodes transmit their packets, to generalize the design for a larger intra-vehicle wireless sensor network. For achieving reliable communications, we define two different levels of reliability: one is single link reliability and other is network reliability. Finally, the performance is evaluated in terms of network reliability. The simulation results assist to design a robust system for intra-vehicular communications.

The rest of the paper is organized as follows. In Section 2, we provide the related works, while in Section 3, we present the theoretical background. In Section 4, we describe the design of IVWSNs, while in Section 5, we present the simulation results. Finally, in Section. 6, we conclude the paper.

2 Related Works

There have been active researches on the design of wireless and sensor networks [15]-[23]. For example, In [15], the authors present an empirical study based reliability estimation in wireless networks. However, there are less numbers of work have addressed particularly the design of network for intra-vehicular communications [3, 7, 11], [24]-[27]. In [26], the authors present the viability of the optical wireless channel for use in intra-vehicular communications applications. In [27], the authors investigate the coverage area performance of multi band orthogonal frequency division multiplex ultra wide band intra-vehicular communication in the presence of plural mobile terminals.

The ZigBee is a key technology to design a wireless sensor network for various purposes. In [28, 29], the authors design a monitoring and control system based on ZigBee wireless sensor network. In addition, it plays an important role in the intra-vehicle networks. However, few works have addressed this technology for intra-vehicular communications. In [3], the authors report the statistical characteristics of 4 representative intra-vehicle wireless channels on the basis of the results of received power measurements and verify the level of reliability of the channels. In [11], the authors propose another work to characterize the wireless channel for intra-vehicle wireless communication. In [24], the authors design and analysis a robust broad-cast scheme for the safety related services of the vehicular networks. In [25], the authors study the performance of ZigBee sensor networks for intra-vehicle communications, in the presence of blue-tooth interference. In [7], the authors evaluate the ZigBee standard specially for cyber-physical systems, which is a class of engineered systems that features the integration of computation, communications, and control.

Unlike all the aforementioned works, in this paper we design a IoT based wireless sensor network for intra-vehicular communications and evaluate its performance in terms of network reliability.

3 Theoretical Background

This paper studies the internet of things in vehicle and the design of a wireless sensor network for reliable intra-vehicular communications. In this section, we provide the theoretical background of the work.

The Internet of Things (IoT) paradigm denotes the pervasive and ubiquitous interconnection of large number of devices that can be uniquely identified, localized, and communicated [12]. The concept of IoT can be implemented as either *internet centric* or *object centric*. The former aims at provisioning services within the Internet, where data are contributed by the objects. On the other hand, the latter aims at purveying services via network of smart objects [13], such as Intra-Vehicle Wireless Sensor Networks where numbers of sensor communicate each other for collecting real-time information about the vehicle to perform identification, locating, tracking, monitoring, and intelligent controlling.

The internal structure of a vehicle is comples where the time variations of the received power are usually caused by the changes in the transmission channels due to the fading effects. There are two kinds of fading: i) large-scale fading and ii) small-scale fading.

Large-scale fading includes path losses and shadowing effects. The path loss is generally modeled through empirical evaluations specially for WSN. The expression of path loss can be written as follows [10]:

$$PL(d)[dB] = PL(d_0)[dB] + 10\gamma \log_{10}(\frac{d}{d_0}) + X_\sigma \tag{1}$$

where X_σ is a Gaussian random variable, $\mathcal{N}(0, \sigma^2)$, with zero mean and variance σ^2, also known as log-normal shadowing, $PL(d_0)$ is the path loss in dB at the reference distance d_0 and γ is the path loss exponent.

The performance of this model not only depends on the distance between transmitter and receiver, but also the path loss exponent and the variance of the log-normal shadowing.

On the other hand, small-scale fading is caused by the interference between multiple versions of the transmitted signal, which arrive at the receiver at slightly different times. Three different propagation mechanisms can happen between the antennas of the transmitter and receiver in the vehicle such as reflection, diffraction and scattering [3]. Reflection occurs when the signal impinges on objects whose dimensions are larger than λ (signal wavelength). Diffraction occurs when the signal impinges on objects with sharp edges. Scattering occurs when the signal impinges on several objects whose dimensions are smaller than or comparable to λ.

The fading distributions of wireless channels can be characterized into two distribution functions, such as Ricean and Rayleigh distributions. The Ricean distribution occurs when there is a presence of dominant stationary signal component, such as a line-of-sight propagation path. In this case, the random multipath components arriving at different angles are superimposed on a stationary dominant signal. Because of the large number of multipath components, central limit theorem can be applied and the sum of these random components can be approximated by the Gaussian distribution. The Ricean distribution is given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2+A^2}{2\sigma^2}} I_0(\frac{Ar}{\sigma^2}) \tag{2}$$

where r is the received signal amplitude, A is the peak amplitude of the stationary dominant signal, and $I_0(.)$ is the modified Bessel function of the first kind and zero-order.

On the other hand, the Rayleigh distribution occurs, when the dominant signal becomes weaker and comparable to other random multipath components. The Rayleigh distribution is given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} \tag{3}$$

The Ricean distribution can be described in terms of a parameter K which is defined as the ratio between the deterministic signal power and the variance of the multipath and is given by [3]:

$$K[dB] = 10 \log(\frac{A^2}{2\sigma^2}) \tag{4}$$

The Rayleigh distribution can be considered as a special case of the Ricean distribution with $K = -\infty$.

It could expect that the intra-vehicle wireless channels with strong LOS signals to follow the Ricean distributions while the others NLOS signals to follow the Rayleigh distributions. However, these conventional ideas may not work properly, due to the complex environment created by a large number of parts inside the vehicle. Consequently, the actual distributions need to be obtained by analyzing the experimental data, as discussed in [3, 11].

In this paper, we analyse the level of reliability in intra-vehicle wireless communication with the varying of communication parameters, which are suitable for IVWSNs. We define two different levels of reliability: one is single link reliability and other is network reliability. These definitions are as follows:

Definition 1 (**Link Reliability**). *The level of reliability for single link between a BS and a SN depends on the function of Throughput, Packet Loss Ratio (PLR) and Valid Packet (VP).*

where the parameters of the function are defined as follows:

Definition 2 (**Throughput**). *Throughput is the total data traffic (bits/s) successfully delivered to the 802.15.4 MAC layer of the receiver and sent to the higher levels.*

Definition 3 (**Packet Loss Ratio**). *Packet Loss Ratio (PLR) is the ratio of Dropped Packets (DPs), i.e., packets that are affected by a number of bit errors and can not be corrected by the Cyclic Redundancy Check (CRC), and Arrived Packets (APs), i.e., packets arriving at the BS with a power greater than the receiver sensitivity.*

Definition 4 (**Valid Packet**). *Valid Packet (VP) is the percentage of packets that arrive at the receiver with power greater than the receiver sensitivity.*

Remark 5. *All the parameters of the function are defined according to the OPNET simulator, since the experimental results are obtained by utilizing this simulator. The level of reliability will be presented in terms of these three parameters.*

Definition 6 (**Network Reliability** R). *Network reliability is defined as the ability to deliver the packets to the destination (BS) within a certain time limit (called Deadline). The expression of the reliability can be written:*

$$R = P_r(D_{ete} \leq D) \tag{5}$$

were R_{cs} is the network reliability for complete scenario, D_{ete} is the end to end delay (i.e., the overall delay between the time instant when it creates a package from the application layer and the time instant when it is received) and D is the deadline (i.e., the limits on the chosen end-to-end delay of the packet).

Remark 7. *In this paper, we consider two deadlines: one is called restrictive deadline denoted as D_1 and other is called less restrictive deadline denoted as D_2. Note that D_1 and D_2 represent 25% and 50% of the maximum SN transmission period, i.e., 120 ms.*

4 Design of IVWSNs

The main design of the intra-vehicle wireless sensor networks including two parts: link design between BS and SN, and network scenario design. The link design presents the suitability of the communication parameters for single link in IVWSNs, such as transmit power and the distance between BS and SN. The network scenario design part presents the detailed description about IVWSNs. We are explaining them in the following.

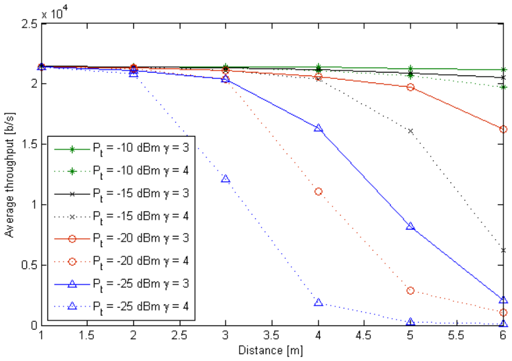

Figure 2: Average throughput versus Distance between BS and SN with the varying of Transmit power.

4.1 Link Design between BS and SN

In this sub-section, we study about the analysis of single link between BS and SN, since the design of a IVWSNs can not be separated from the study on the link between the different sensor nodes distributed in the vehicle. In order to do that, we have carried out a simulation through a discrete event simulation software, OPNET, with the relative packages for the ZigBee module. A pair of transmitter (i.e., SN) and receiver (i.e., BS) communicates each other within a vehicle. The BS collects the packets that are transmitting periodically by the SN. The BS and the SN are placed at a distance d. The Transmit Power set: $\{$-10, -15, -20, -25$\}$ dBm, which is suitable for ZigBee, such as the Crossbow MICAz MPR2400 [31]. The Carrier frequency is 2.4 GHz (ISM band). There are two channels 1 (a, b), which are for NLOS paths with Rayleigh fading. The path loss exponent γ for channel 1(a) 3 and for channel 1(b) is 4. The values of shadowing deviation $\sigma[dB]$ is 8. The suitability of the considered parameters has been discussed elaborately in our previous work [30].

Fig. 2 shows the behavior of the average throughput with the variation of distance between BS and SN for Channel 1 (a, b). The figure clearly shows a decreasing trend of the average throughput with increasing distance. The cause of this trend is due to the low power level of the packets arriving to the antenna of BS. We know that the path loss increases with distance and the effect of the log-normal shadowing involves a fluctuation in time of the received power, which can further degrade the performance of the communica-

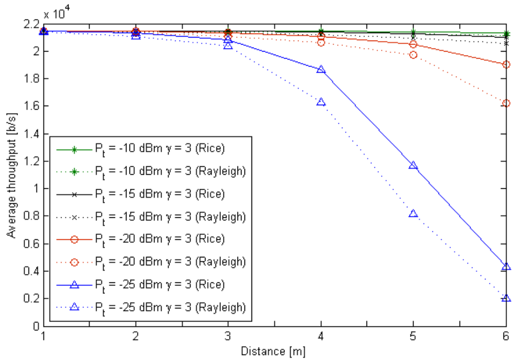

Figure 3: Comparison of the average throughput experienced by the channel 1(a) and 2(a).

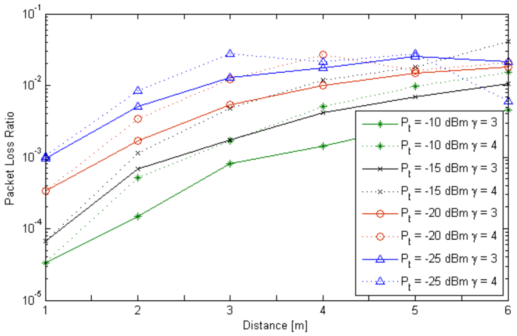

Figure 4: Packet loss ratio versus distance between BS and SN.

tion. These fluctuations may lead the level of received power below the receiver sensitivity (-95 dBm). Then, the BS evaluates the received packet as noise and consequently, the packet is lost.

In Fig. 3, it shows the comparison of the average throughput experienced by the channel 1(a) (Rayleigh fading) and 2(a) (Rice fading). From the figure, we see that, as expected, the channel 2 (a) is the favorable case because of the presence of dominant signal component in Rice fading. We also (as similar in Fig. 2) note that a dramatic decrease of average throughput when the distance between BS and SN passes from 4 to 5 meters, in the case of Rice fading with -25 dBm, it is about 12 Kb/s, while in the case of Rayleigh fading, it is about 8 Kb/s. This trend is due to the decreasing of received power below the receiver sensitivity.

In terms of PLR, we analyse how the PLR behaves with the variation of distance between BS and SN, and transmission power, as shown in Fig. 4. The PLR increases with the increasing of distance between BS and SN. As the distance increases, the power level at which packets are received by the BS decreases, and consequently, it decreases the SNR. This causes the increasing of the BER that may discard the packets. We note that, for low values of the transmission power, for example $P_t = -25\ dBm$ with $\gamma = 4$, and $P_t = -20\ dBm$ with $\gamma = 4$, seem to improve the performance, as in Fig. 4 one can observe a decrease of PLR. In fact, this trend is not for the improvement of performance, but the fact is the number of packets arriving at the BS, with a low power than the receiver sensitivity, increases to this point that distorts the performance, as the PLR is calculated from the packets arriving at reception with a power greater than the receiver sensitivity. In the case of Rice fading, the PLR can be considered equal to zero, since the performance in terms of Bit Error Rate (BER) are very good so that there is no packet discarded after the error control check CRC.

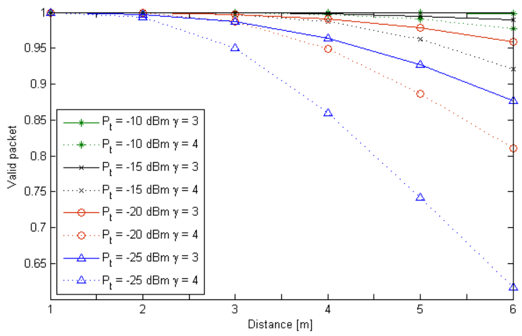

Figure 5: Comparison of valid packets experienced by the Channel 1 (a, b).

In terms of VP, we analyse how the VP behaves with the variation of distance between BS and SN, transmission power, and also the effect of Rice and Rayleigh fading.

Fig. 5 shows the percentage of valid packets for channel 1 (a, b), the function of the distance between BS and SN, and for different transmission power. As expected, the figure shows a decreasing trend with the distance, Similar to Fig. 2, the cause of this trend is due to the low power level of the packets arriving to the antenna of BS.

In Fig. 6, it is shown the comparison of valid packets experienced by the channel 1(a) (Rayleigh fading) and 2(a) (Rice fading). Similarly in Fig. 3, the channel is affected by Rayleigh fading provides the worst performance with respect to Rice fading. The difference of the valid packets in two cases is more noticed by increasing the distance between BS and SN; in fact, within 3 meters of distance the performance are almost same. This trend can be explained by considering that multipath effects are as more as the difference between the propagation paths; obviously, the less is the distance between transmitter and receiver, the less will be the propagation paths and the distance

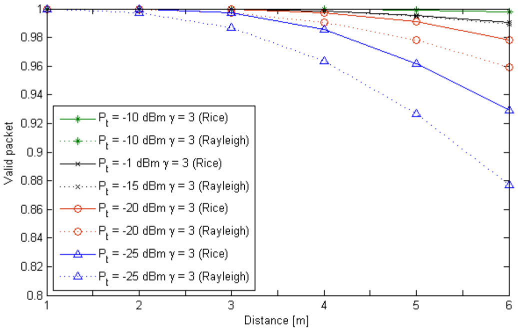

Figure 6: Comparison of valid packets experienced by the channel 1(a) and 2(a).

between them will be decreased.

From the above analysis, it can be concluded that the BS should be placed in the center of the vehicle specially for the less transmission power. In the hostile scenario (where fading = Rayleigh, $\gamma = 4$, $\sigma = 8$ dB, $P_t = -25$dBm, distance between BS and SN = 2m), the level of reliability is: 97% of the maximum achievable throughput, PLR $< 10^{-2}$ and 99% of VP. In the less hostile scenario (where fading = Rice, $\gamma = 3$, $\sigma = 8$ dB, $P_t = -25$dBm, distance between BS and SN = 3m) the level of reliability is: 97.2.3% of the maximum achievable throughput, PLR is zero and 99% of VP. In the considered scenario (where fading = Rayleigh/Race, $\gamma = 3/\ 4$, $\sigma = 8$ dB, $P_t = -15$ dBm, distance between BS and SN $< 4m$) the level of reliability is: 98.5% of the maximum achievable throughput, PLR is 1.2 x 10^2 and 99% of VP. Indeed, the performance will be more better while the power will increase, however the life time of the SN will be reduced.

4.2 Network Scenario Design

There is only on BS that is placed in the center of the vehicle and several number of SNs are placed around it, as shown in Fig. 7. In this way, the distance between SN and BS will be less than any other scenarios where BS is set at any palace in the vehicle, as a result the BS can receive packets from the SNs with better signal strength. There are two different SNs: one is Green (G) and other is Yellow (Y), whose transmission period is 120 ms and 60 ms, respectively. We consider four different cases according to traffic load in the networks. This consideration will help to measure the performance of the network while the traffic load is high. In case I, 100% Green, in case II, 70% Green and 30% Yellow, in case III, 50% Green and 50% Yellow and in case IV, 30% Green and 70% Yellow SNs will be from the total sensor nodes, see Table 1. The more number of Yellow SNs means the more traffic in the network because of its less transmission period. The number of sensor node set is {10, 30, 50, 70, 90, 110}. The communication parameters of the networks are as follows:

Number of NS	Case I		Case II		Case III		Case IV	
	G	Y	G	Y	G	Y	G	Y
10	10	0	7	3	5	5	3	7
30	30	0	21	9	15	15	9	21
50	50	0	35	15	25	25	15	35
70	70	0	49	21	35	35	21	49
90	90	0	63	27	45	45	27	63
110	110	0	77	33	55	55	33	77

Table 1: Considered Cases

- Transmit Power: -15 dBM, as discussed in the previous subsections;
- Carrier frequency: 2.4 GHz (ISM band), which is used on ZigBee sensor node [31]
- Receiver sensitivity: The reception threshold of the BS is set equal to -95 dBm, typical for ZigBee [31];
- Transmission Period: 120 ms and 60 ms for Green and Yellow SN, respectively ;
- Channel: The channel is for NLOS paths with Rayleigh fading. The path loss exponent γ is 4. The values of shadowing deviation $\sigma[dB]$ is 8. These values are suitable for intra-vehicle communication [3, 11].
- Packet size: 210 bits (ZigBee packet header 120 bits + data 90 bits);

  Remark 8. *90 bits for data is selected with the reference of CAN message used in [14].*

- Parameters MAC:
  - ACK Mechanism:
    - ∗ ACK Wait Duration: 0.05 second;
    - ∗ Number of retransmissions: 5.
  - CSMA-CA Parameters:
    - ∗ Minimum Backoff Exponent: 3;
    - ∗ Maximum Number of Backoffs: 4;
    - ∗ Channel Sensig Duration: 0.1 second.

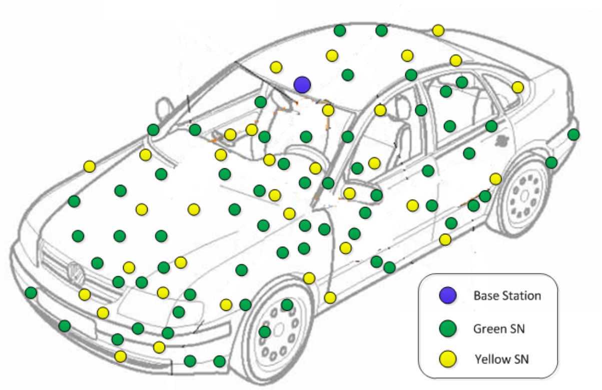

Figure 7: Example of SNs distribution inside the vehicle.

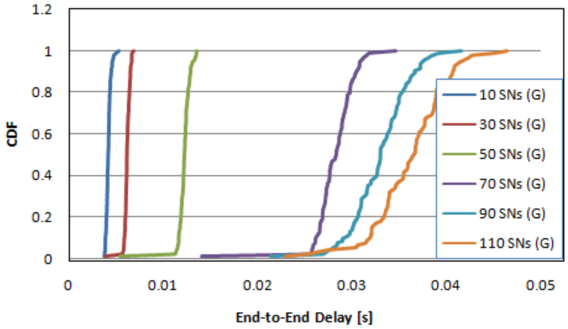

Figure 8: CDF of end-to-end delays Vs the number of nodes in the case I.

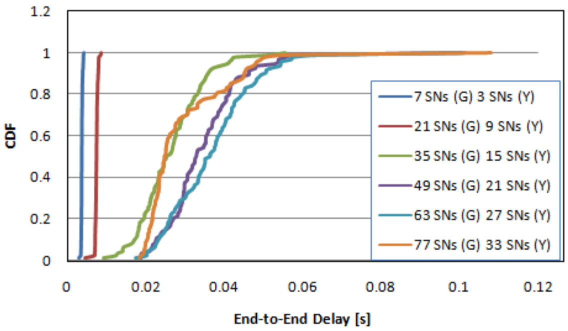

Figure 9: CDF of end-to-end delays Vs the number of nodes in the case II.

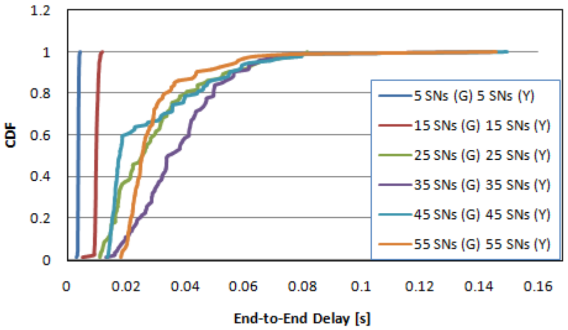

Figure 10: CDF of end-to-end delays Vs the number of nodes in the case III.

5 Simulation Results

In this section, we analyse the reliability of the network, varying of traffic load, by taking account of Definition 6. Due to the increasing of traffic load, the intra-vehicle network becomes congested. The effect of congestion on the network is also investigated. In order to assess the level of reliability, we have carried out a series of simulations through a discrete event simulation software, OPNET, with the relative packages for the ZigBee module. The performance of the network is measured based on this network reliability.

In Fig. 8, we report the CDF of the end-to-end delay versus the number of nodes for analyzing the reliability in the case I. From the figure, we notice that as the number of SN increases in IVWSN, the CDF shift to the right. The cause of this performance is due to the collisions among the packets, which increases with the increasing number of SN in the network. In fact, after the collision SN waits for a certain period of time (Backoff + sensing period) and then if the channel is free, it retransmits the packet that already caused collision previously. The new re-transmissions can be subjected to other collision. The repetition of the procedures is explained under the CSMA-CA protocol. It is easy to understand at this point that the increasing number of collisions results the increasing end-to-end delay experienced by the packets.

As in the first case there is only Green SN and the considered deadlines are $D_1 = 30ms$ and $D_2 = 60ms$. As it can be seen in Fig. 8, the condition on less restrictive deadline, D_2, is fully satisfied, as shown in Table 2. On the other hand, the restrictive condition, $D_1 = 30ms$, it is satisfied in the case of 10, 30, 50 and 70 SNs, while in other cases (90, 110 SNs) are satisfied with a probability not adequate (about 16% in best case) in terms of reliability.

We also report the CDF of the end-to-end delay versus the number of nodes for analyzing the reliability in other cases, as shown in Fig. 9 - 11. The above figures show that the introducing of more Yellow SNs in the network, the end-to-end delay is increasing i.e., the reliability of the network decreases. In fact, in the case I with 70 NS, the reliability is 100% for less restrictive deadline. D_2, whereas in case II, this falls to about 96% and continuously falling while increasing in the number of Yellow SNs in the network.

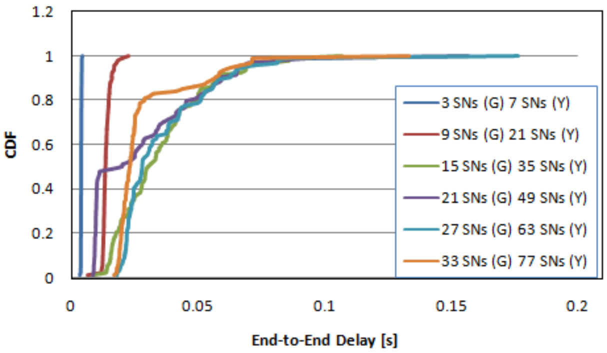

Figure 11: CDF of end-to-end delays Vs the number of nodes in the case IV.

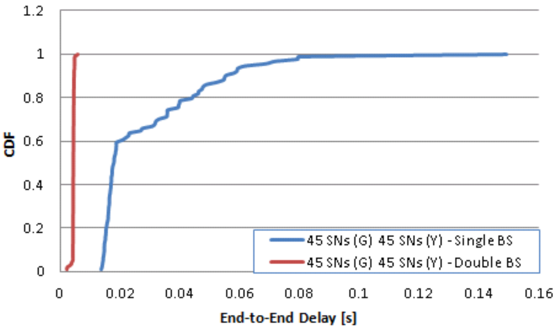

Figure 12: Comparison between CDF in the case of single BS and double BSs.

In addition, the increasing number of SN, in particular when it increases the number of Yellow SN, in the intra-vehicle WSN is subjected to the phenomenon of congestion. In fact, increasing the traffic up to a certain point where the network is no longer able to handle the traffic then it enters into congestion. As a result a number of transmitted packets (including retransmitted packets) by SN never reaches its destination. Higher the degree of congestion of the network, the greater will be the number of packets that never arrives at the destination. The Table 2 summarizes the results obtained in four cases, the results highlighted in bold are ”distorted” due to congestion of the network. The phenomenon of congestion decreases the end-to-end delay that causes the distortion of the results, since in OPNET the end-to-end delay is calculated on the basis of packets that reach to their destination.

To mitigate the problem of congestion, we introduce two BSs in the network. Each BS is consisting of 50% SNs from the total SNs. In Fig. 12, there is 90 SNs with half Green and half Yellow SNs in case of both single and double BS. We note, in case of single BS, initially the result is distorted due to the large number of packets that do not reach to the destination because of the congestion in the network. In case of double BS, there is no congestion effects because of the proper traffic load distribution. However, introducing additional BS increases the design complexity of the networks. Therefore, a new MAC strategy can be designed for congestion network that will be the future direction of this work.

6 Conclusion

In this paper, we design a wireless sensor network for reliable intra-vehicular communication based on the concept of IoT. The design has two phases: one is the design of single link between a base station and a sensor node in terms of link reliability; and other is the design of a complete scenario to generalize the design for a larger intra-vehicle wireless sensor network. The performance is analyzed in terms of network reliability. After the analysis, we note that, the phenomenon of congestion plays an important role in the network while the traffic load is high. To mitigate the congestion problem, we could increase the number of BS in the network. In fact, introducing additional BS increases the design complexity of the networks. Therefore, a new MAC strategy can be designed for congestion network that will be the future direction of this work. The simulation results assist to design a robust system for intra vehicular communications.

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Number of NS	R in case I		R in case II		R in case III		R in case IV	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
10	100%	100%	100%	100%	100%	100%	100%	100%
30	100%	100%	100%	100%	100%	100%	100%	100%
50	100%	100%	72%	97%	52%	90%	45%	87%
70	92%	100%	40%	96%	25%	88%	**66**%	86%
90	16%	100%	30%	95%	**62**%	**89**%	**63**%	**87**%
110	6%	100%	**65**%	75%	**77**%	**92**%	**82**%	**89**%

Table 2: Reliability in Different Cases

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