Simulation for Analysis of Wireless Can for Time Response

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Abstract – This paper attempts to model and simulate wireless CAN (WCAN) for both constant bit rate (CBR) and variable bit rate (CBR) traffic (VBR). While researchers have presented different ideas on wireless CAN modelling, due to its noted benefits, WCAN is implemented in this study using the token frame scheme. In this work, WCAN simulation done using QualNet, an algorithm is built based on this WCAN using a token scheme. For both constant bit rate traffic (CBR) and variable bit rate traffic (VBR) used for performance measurement, this paper outlines the modelling of wireless CAN (WCAN) using token scheme, the process adopted for simulation using QualNet, and the estimation of parameters such as throughput, end-to-end delay and packet transmission ratio. As response time analysis is more important for safety-critical applications than performance analysis, it is considered appropriate to expand the analysis and to obtain the response times of both frequent and intermittent WCAN communications. Also presented here are the findings of several simple QualNet tests for both WCAN and IEEE 802.11b.

Key Word – CAN, IEEE 802.15.4, Response Time Analysis, WCAN, WCAN Implementation

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I. INTRODUCTION

The Control Area Networks (CAN) are widely used in real-time, distributed and parallel processing systems like manufacturing plants, networking fields, humanoid robots, etc., Robert Bosch GmbH (1991). It is beneficial to expand the usage of CAN to systems where wireless environments are seen and favored in recent times with the introduction of wireless technology. This updated CAN is modelled as Wireless CAN for wireless environment use (WCAN).

The Wireless Controller Area Network (WCAN) is an alternative to using a wireless network interface based on CAN messages. Researchers have suggested different ideas to allow a quick transition from CAN to WCAN. WCAN uses token frames developed by Lun et. al. (2012) and implemented in this analysis to relay messages across the network using token frames. Also, by setting the successor and predecessor fields present in each node, the token determines the ring network. The WCAN is a wireless-based distributed media access control (MAC) protocol for ad-hoc networks, according to the scheme. Having a distributed MAC wirelessly based has the bonus of being resilient against single node failure as it can gracefully recover from it. In comparison, nodes are linked in a loose and partly linked way, since not all nodes need to be linked to each other. The simplicity of its network topology is made possible by allowing nodes to quickly and dynamically join or exit the network.

The WCAN follows the wireless token ring protocol (WTRP) using the token scheme, so WTRP is present in this segment. It is a new Medium Access Control (MAC) protocol for local area wireless networks (WLANs). WTRP promises quality of service (QoS) in terms of reduced latency and allocated bandwidth, which are essential in many real-time implementations, in comparison to IEEE 802.11 networks. WTRP increases reliability by reducing the number of retransmissions due to collisions relative to IEEE 802.11, as it is fairer as the channel is used for the same period of time for both stations. Ergen et al., stations take turns transmitting and give up the right to transmit after a given amount of time (2004). As not all stations need to be linked to each other or to a central station, WTRP is a distributed protocol that supports several topologies. WTRP is stable to failures of single nodes, and gracefully recovers from multiple simultaneous failures. In ITS DSRC, WTRP is ideal for inter-access point communication, Safety-critical vehicle-to-vehicle connections, home networking and other networks and mobile IP extensions are supported.

WTRP is designed for multiple simultaneous faults to rebound from. Partial connectivity, where sporadic connections are required, is a big challenge that WTRP overcomes. WTRP puts management, special tokens, and additional fields in the tokens to solve this problem, and introduces fresh timers. WTRP demands that the joining node be connected to its prospective predecessor and successor when a node joins a ring. By looking up its connectivity graph, the joining node obtains this knowledge. If a node leaves a ring, its predecessor in the ring, by looking up its connectivity table, finds the next available node to close the ring. WTRP uses a special priority classification system for tokens to exclude tokens that cannot be heard by a station. Stations only accept a token that has a higher priority than the token last accepted by the station. To allow the operation of several nearby rings, WTRP also has algorithms for keeping each ring address unique.

Lun et. al. (2013) a new wireless protocol, the so-called wireless controller area network, is introduced in this article. WCAN is an adaptation of its network protocol for the wired cousin, controller field. In providing channel connections to system nodes, the proposed WCAN uses the token frame scheme. This token frame strategy follows the example used in the wireless token ring protocol, which is a protocol for the wireless network that decreases the number of retransmissions due to collisions. This CAN protocol-based scheme allows nodes to share a standard broadcast channel by transmitting for a given length of time after receiving the token frame that circulates across the network. The token frame allows nodes to enter the network one at a time, providing all nodes with an 'equal' chance instead of vying with each other. In a limited latency environment, this approach provides high efficiency. Through the QualNet simulator, the proposed WCAN protocol was generated and simulated. From the viewpoint of throughput, end-to-end delay and packet distribution ratio, the efficiency of this proposed protocol is measured and compared to the IEEE 802.11 protocol. Simulation findings reveal that in terms of throughput, the proposed WCAN outperforms IEEE 802.11 based protocol by 62.5 percent with increasing network size. It also indicates an increase of 6 per cent at a higher data interval rate compared to the IEEE 802.11 standard. Mary et. al. (2013) summarizes the studies on Wireless Controller Area Network Simulation and Interpretation (WCAN). In the standardisation of vehicle bus standards, the controller area network (CAN) has long been recognised as the pioneer. The effect has also been applied to different industrial automation uses, including military, transportation, electronics, among many others. There is also a need for CAN to transition and adapt to its wireless counterpart as wireless technology becomes more prevalent. In the last decade, a few approaches were proposed that used the benefit of CAN in a wireless network system called the wireless controller area network (WCAN). These WCAN methods are reviewed in this article. In Mary (2016), e the necessity and implementations of the Bosch implemented and simplified wireless variant of the common controller area network (CAN) as early as 1990. There are several practical applications where short distances are needed for CAN messages to be transmitted and where cable connections are either impossible or unwelcome. This paper addresses technical information and case studies of the different wireless interface possibilities for the wireless transmission of CAN frames. CAN over Bluetooth, CAN over ZigBee and CAN over UWB applications are presented. For the wireless and control applications of CAN, ZigBee based on IEEE 802.15.4 is recommended among the different wireless choices. The controller area network (CAN) has been long regarded as the pioneer in standardizing vehicle bus standard. Its influence has even been reached out to various applications in industrial automation; which includes military, aviation, electronics and many others. With wireless technology becoming more pervasive, there is a need for CAN too to migrate and evolve to its wireless counterpart. In this paper, a new wireless protocol named wireless controller area network (WCAN) is introduced. WCAN is an adaptation of its wired cousin, controller area network (CAN) protocol which has not being properly defined. The proposed WCAN uses the concept introduced in wireless token ring protocol (WTRP); a MAC protocol for wireless networks and efficient in a sense to reduce the number of retransmission due to collisions. Additionally, it follows most of its wired cousin attributes on message-based communication. Message with higher priority has the first priority in transmitting their message into the medium. In WCAN, stations or nodes take turns in transmitting upon receiving the token frame that are circulating around the network for a specified amount of time. WCAN was tested in a simulation environment and is found that it outperform IEEE 802.11 in a ring network environment (Ng W.L et. al, 2011).

II. EXPERIMENTAL PROCEDURE

Simulation tests are first carried out before attempting to enforce WCAN on the system in question, in order to establish that the related efficiency and response times of the WCAN algorithm are adequate to meet the application's needs. The version of WCAN adopted for simulation in this research is the one proposed by Lun *et al.* (2012) which has the following features:

i) It is based on wireless token ring protocol (WTRP).

ii) A MAC (medium access control) protocol is obtained by changing the FC (frame control) field of the WTRP token frame to contain the CAN message ID, which decreases the number of retransmissions due to collision and also has the wired equivalent CAN attribute on contact dependent messages.

iii) The token frame approach gives channel access to the device nodes, as presented in Section 4.1.1 of Chapter 4. It enables them to share a shared transmitted channel by transmitting turns upon receiving the token frame that for a given period of time circulates within the network.

iv) Delivers high efficiency, reliable and manageable delays and good packet transmission ratios in low latency environments.

Here, WCAN is modeled and simulated using QualNet v5.1, its throughput, average end to end delay and packet delivery ratio (PDR) for constant bit rate traffic (CBR) and variable bit rate traffic (VBR) are calculated and compared with IEEE 802.11. By using these values, the work will be extended to do the response time analysis of WCAN messages and the results will be validated with SAE benchmark for Class C automotive for safety critical control applications.

III. DESIGN OF WIRELESS CAN USING TOKEN SCHEME

The token is a core component of the WCAN network, since it enables packets to be exchanged seamlessly between nodes. In addition, it determines the actual operating mode that is running on the network. The token format used in this WCAN is illustrated in Figure 3.1. In the token frame, a total of five fields are defined: frame control, ring address, destination address, source address and number of the series. The Frame Control (FC) provides the CAN format for the frame sort indication and message identifier. The type of frame specifies the type of token that a node gets, such as Token, Successor Order, Data Token, Token Erase Token, Tacit Acknowledgment, Successor Set and Predecessor Set. The token's message identifier follows the same message broadcasting concept as used in the CAN protocol. The ring address (RA), the destination address (DA), and the source address (SA) for which the path and flow of the token frame is specified. Refers to RA.

To the ring to which belongs the token frame. To construct an ordered list and decide the number of stations or nodes present in the ring, the sequence number is used.

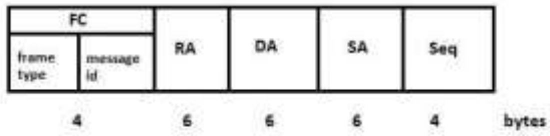


Figure 3.1 WCAN Token format

In order to obtain access to the medium, the node must first catch the token that circulates across the network. In the beginning, the token is generated by a ring master assigned to the network. A node wins the arbitration by matching the message identifier located in FC until a token is captured. When the arbitration is won by a node, its message identifier is put in the FC field and its data is sent to the predecessor, which is the next node in the list. Otherwise, the said node will be at the receiving end and will relay the token before a lower-priority message identifier token is received.

An overview of how token transfer operates inside the network is seen in Figure 3.2 and Table 3.1. Before the token comes back to E, Station D tracks the sequential token transmission from B to C. D transmits the token with the sequence number 0.0 at time 0. At time 1, with the series number 1 and so on, E transmits the token. D may not detect the transmission from F and A, but it will find that the sequence number has been raised by 3 instead of 1, as it detects the transmission from B, which means that there were two stations that could not be heard between A and F. Station D will create an ordered list of nodes available in the ring with this knowledge, as seen in the D connectivity table (refer Table 3.1).

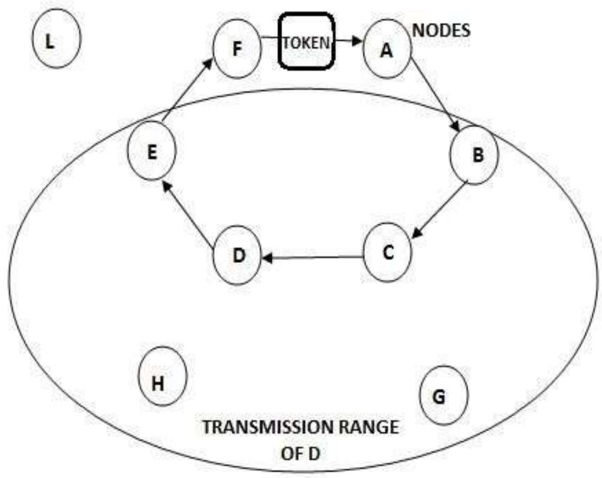


Figure 3.2 Token Passing within the Ring

Table 3.1 Connectivity Table of Node 'D'

WITHIN RANGE OF 'D'		OUTOF RANGE
Seq=1	Address=E	Address=H
Seq=2	Unknown	Address=G
Seq=3	Unknown	
Seq=4	Address=B	
Seq=5	Address=C	

► **ALGORITHM**

The WCAN system adopted in this thesis is a hybrid property between WTRP and CAN. The algorithm and the pseudo code are presented here.

► It must first grab the token that is circulated in the ring and put its message identifier in the FC field in order for a station or node to win the arbitration and obtain access to the medium.

- The token is then transferred on the basis of the ordered list that the station has to the next station in the ring.
- The next station catches the token and first checks the identifier for the letter. If the message identifier has a higher priority, the station will send the same token on the ordered list to the next station.
- Otherwise, the message identifier in the token is replaced with its own and its data is sent to the next station.
- When the token it receives next holds the same message identifier it has, a station or node can only know if its transmission is successful.
- Otherwise, once it gets the token back with a lower priority message identifier, it will be in receiving mode.
- It transforms the token frame into a data frame for transmission when a station needs to transfer data. It transforms the frame back into a token until the sending station gets its own data frame.
- When a token or data frame with a priority less than or equal to the requested priority of the station is issued by the station wanting to send, it sets the priority bits to the intended priority. The station does not transmit immediately; until it returns to the station, the token circulates throughout the media. The station downgrades the token priority back to the initial priority until it sends and receives its own data frame.

This algorithm is presented as psuedo code given below;

<u>Step 1: initialization</u>

◦ Ring owner produces the token. From the e.g. in Figure 4.2, Say node 'D'

◦ An empty token is generated to recognize the no. of nodes within the particular ring (sequence number).

◦ All the nodes within the ring know its successor and predecessor.

◦ Requirement: transfer sensor data from automobile parts.

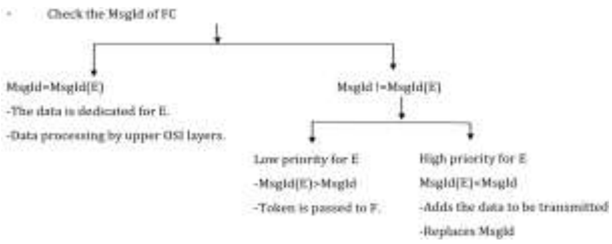
◦ Set frame type=data.

◦ Other nodes are in idle state.

<u>Step 2: Token Passing</u>

◦ Token is passed to next node say 'E'.

◦ Ensure FT= data frame and proceed.



<u>Step 3: Acknowledgement</u>

◦ E sends ACK signal back to the predecessor D.

◦ E Goes into Monitoring mode waiting for ACK reply from D.

◦ Then E goes back to idle state.

Step 4: Token kill

- It uses the same algorithm for all other nodes.
- If the token enters the destination node, depending on the query, it is either destroyed or recirculated.
- If data collection from the same sensor node is needed, then the token will be recirculated with the priorities set.
- Node priorities are allocated in conjunction with the operation of the vehicle.
- For parallel processing, different tokens may also be used.

IV. METHOD OF SIMULATION

The WCAN protocol modelled in Section 4.1 is simulated and deployed using QualNet simulator, http://web.scalable-networks.com/content/qualnet. This simulator allows addition of new protocol with the help of simple C++ programming. The details of using QualNet for simulation are elaborated in this Section.

The first task is to create a new network scenario by changing the default .cfg, .nodes, .app files contained in the /bin folder, with each of these input files having the name <expt-name >.extension.

(i) The necessary numbers of nodes are given in the .config file to deploy the nodes in the network scenario.

(ii) Twenty nodes, representing a medium sized network, are used in this simulation.

(iii) The location of the nodes in the network scenario is determined in the .nodes register, whereas the ring configuration of the nodes is used for the implementation of WCAN nodes using the token scheme, while the nodes in IEEE 802.11b are arbitrarily placed in this thesis. The nodes in the .config file are provided with applications and connections.

(iii) In both cases, the type of network is defined as a wireless network in the .cfg format.

(iv) The next step is to establish application layer links between the nodes in the .app file after setting up the network. There could be multiple links operating concurrently in the network at any moment. There'll be a source and a destination node for each connection. The traffic is generated by the source node and transmitted to the destination node.

(v) Next, pick the traffic source in the .app file from the predefined applications available, such as CBR (Constant Bit Rate) and VBR (Variable Bit Rate) for the simple workload.

(vi) Create a connection by choosing the source node and the destination node. This generates the chosen traffic generating application between the source and the destination node.

(vii) The next step is to select the parameter values for this link: the Poisson data packet mechanism is generated at the source and the packet length is spread exponentially with a mean packet length of 512 bytes. The default value is deterministically set to 512 bytes, so the size of the data is modified from Exponential to Deterministic.

(viii) Letting the source generate traffic according to the Poisson process; deterministically generating traffic per 1 second by necessity, this is altered. The interval distribution of successive packets has been changed to exponential and the mean interval has been changed to 0.5 seconds (recall that the inter-arrival times for a Poisson process are exponentially distributed). In addition, the communication start time is set to exponential with an average of 0.5 seconds, and the length is set to deterministic with an optimal fixed duration of 50 seconds.

(ix) The default MAC protocol is the 802.11 format, which defines how the nodes enter the physical channel to relay their packets. The /mac directory has common and commonly used MAC layer protocols such as IEEE 802.11, CSMA, MACA, ALOHA, TDMA, IEEE 802.3, and the latest MAC layer protocol is coded using C++ according to the algorithm in section 4.11 and stored in this directory and selected during simulation in the path.

(x) Likewise, /phy directory has samples of common and commonly used wireless physical layer & propagation models such as IEEE 802.11a, IEEE 802.11b, which are accessible for adjustment to get the required design, IEEE 802.11b is used as the physical layer for this study.

(xi) By selecting Gaussian fading, fading is integrated into the wireless channel. Bellman-Ford The routing protocol is (a Distance Vector routing algorithm). Through sharing routing packets, the nodes periodically change their routing tables. Both nodes are one hop apart from each other in a single wireless subnet, so there is no routing, but nodes will periodically send routing packets. In Table4.2, these parameter choices are presented as Simulation Parameters.

(xii) The next move is to run a network simulation. If the simulation has been finished, the data obtained during the simulation can be accessed from the .stat file with statistical data description and from the .trace file with Packet Traces that can be read by QualNet Tracer.

4.1.1 ANALYSIS OF PERFORMANCE OF WIRELESS CAN

As the algorithm for WCAN in Section 4.1.1 is simulated, the performance of WCAN is evaluated on basis of

- Throughput.
- Packet delivery ratio.
- End to end delay.

These parameters of the assessment are determined using equations (1), (2) and (3). The timing diagram of the WCAN token is seen in figure 4.3. As seen in Table 4.2, the simulation parameters include the traffic type, the number of nodes, the simulation time, the protocols to be simulated, the size of the payload packet and the location of the nodes. As previously discussed, both constant and variable data interval rates are the traffic type, the number of nodes is 20, reflecting the standard medium network, Simulation Time is optimal 50 sec. MAC Layer protocols are the protocols to be simulated: WCAN & IEEE 802.11b, packet payload is 512 bytes by design, and node location is WCAN simulation ring network and IEEE 802.11b mesh network. For both WCAN, the simulation scenario is created using the token scheme and IEEE 802.11b for comparison. Figures 4.4 and 4.5 provide a snapshot of all scenarios. Chapter 6 describes and addresses the consequences of the simulation.

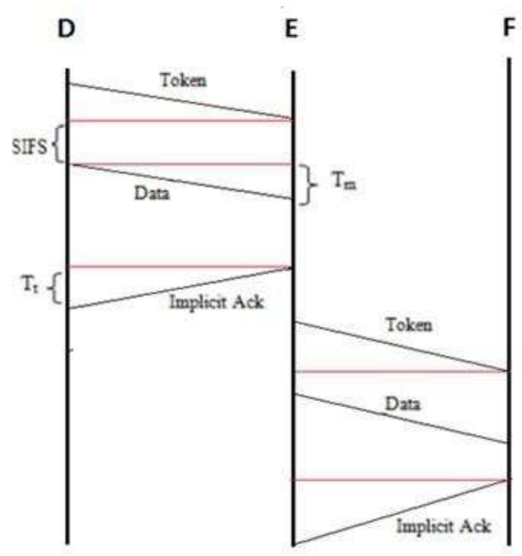


Figure 4.3 WCAN Token Timing Diagram

► **Token Rotation Time (TRT):**

TRT = n x Tm + N x (Tt + DIFS) (1)

- Tm = transmission time of data packets
- Tt = transmission time of token
- n = active nodes
- N = total nodes
- DIFS = DCF interframe space – period of time when channel is available

► Throughput :

S/R = (n x Tm)/ TRT (2)

► Transmission delay, D: time required for data packet to wait for the token to successfully transmit.

◦ Average, D = TRT/2 => S/R = (n x Tm)/ 2D. (3)

4.1.2 DIFFERENCE BETWEEN WIRELESS CAN USING IEEE 802.11b AND TOKEN SCHEME

QualNet was used to simulate the scenarios for both the simple IEEE 802.11 MAC layer protocol and WCAN using the MAC layer token scheme, as defined in Section 4.2 and shown in Figures 4.4 and 4.5.

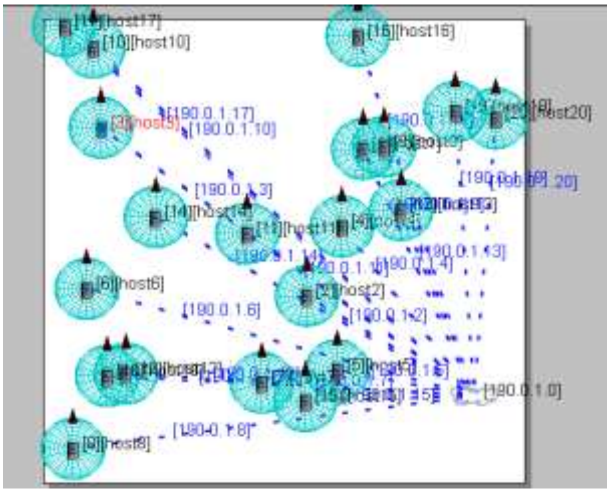


Figure 4.4 IEEE 802.11b Simulation Scenario in QualNet

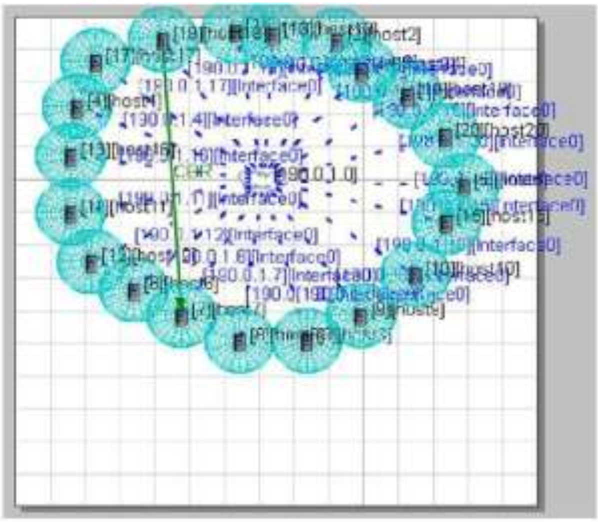


Figure 4.5 WCAN using Token Scheme Simulation Scenario in QualNet

Table 4.2 Simulation Parameters in QualNet

PARAMETER	VALUE
Traffic Type	Constant/variable data interval rates
Node	20
Simulation Time	50 sec
Protocols	MAC Layer protocol- WCAN & IEEE 802.11b
Packet payload	512 bytes
Node placement	Ring network

Basic experiments are performed in QualNet for both the scenarios and the graphical analysis shown in Figures 4.6 to 4.11 follows the legend as given

- ► WCAN
- ► IEEE 80.11b

Channel Utilisation

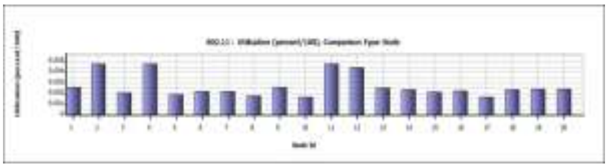


Figure 4.6 Channel Utilization for IEEE802.11b

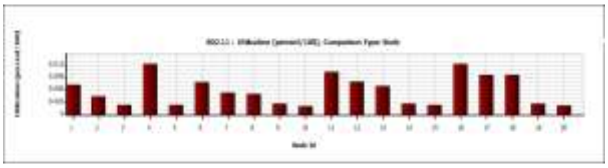


Figure 4.7 Channel Utilization for CAN

From Figures 4.6 and 4.7 it clear that channel utilization is more with WCAN than with IEEE802.11b as all the nodes of the WCAN using token ring scheme is involved in passing the token which is not so in IEEE802.11b

Time Delay

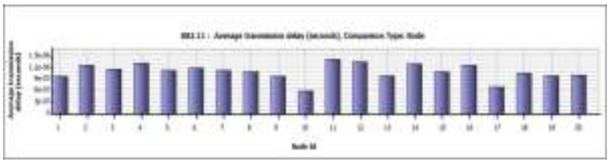


Figure 4.8 Time Delay for IEEE802.11b

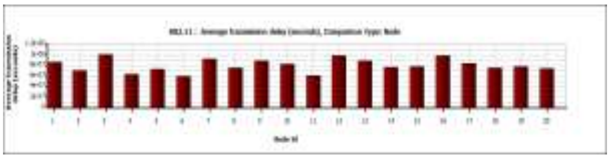


Figure 4.9 Time Delay for WCAN

While the total transmission time for WCAN is more than IEEE802.11b from Figures 4.8 and 4.9, so the data needs to go through all the nodes in the WCAN loop, because the data transmission in IEEE802.11b is through mesh networking.

Average Path Loss

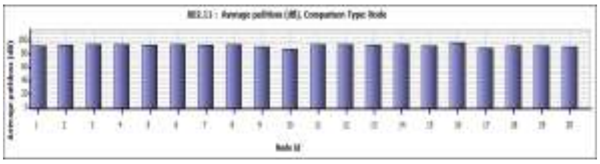


Figure 4.10 Path Loss for IEEE802.11b

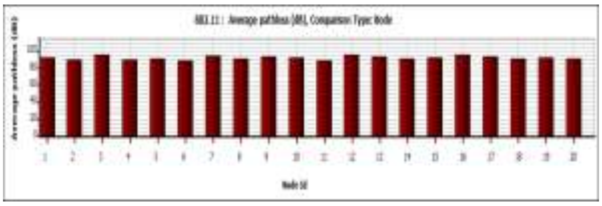


Figure 4.11 Path Loss for WCAN

Figures 4.10 and 4.11 indicate that the average path loss for both WCAN and IEEE802.11b is nearly the same, since the physical layer for the MAC protocol is the same for both. For both WCAN and IEEE802.11b, this leads to comparable throughput results.

V. CONCLUSION

Unlike IEEE 802.11 networks, the use of token schemes by WCAN guarantees service efficiency (QoS) in terms of restricted latency and allocated bandwidth, which are important in many real-time applications. Compared to IEEE 802.11b, the token method of WCAN increases reliability by reducing the number of retransmissions due to collisions, which is fairer when the channel is used for the same period of time for both stations. WCAN is a distributed protocol that supports many topologies using the token scheme, since not all stations need to be linked to each other or to a central station. WCAN is stable to single node errors using a token scheme, and gracefully recovers from several simultaneous faults. It is concluded that in ITS DSRC, safety-critical vehicle-to-vehicle communications, WCAN using the token scheme is sufficient for inter-access point synchronization. This explains the modelling of WCAN built by the modification of the Wireless Token Ring Protocol (WTRP) and the specifics of the simulation of the token device performance study of WCAN relative to IEEE 802.11b using QualNet. In terms of latency and packet transmission ratio, WCAN using token scheme is found to outperform, although in terms of end-to-end latency, message latencies in WCAN using token scheme are increased as nodes increase due to token passing.

VI. REFERENCES

1) Lun Ng, Nor K. Noordin, Md. Ali Borhanuddin (2012) Performance analysis of WCAN using Token Frame Scheme, In the proceedings of Third International Conference on Intelligent Systems Modelling and Simulation, pp. 695-699.

2) Ergen M., D. Lee, R. Sengupta, P. Varaiya (2004), WTRP - wireless token ring protocol. IEEE Transactions on Vehicular Technology 53(6), pp. 1863–1881.

3) Gerardine Immaculate Mary, Z. C. Alex, Lawrence Jenkins (2013). Modeling and Analysis of Wireless Controller Area Network—A Review. Communications and Network, 5, pp. 126-133.

4) Dr. Gerardine Immaculate Mary (2016). Wireless Controller Area Network Implementations And Applications: Technical Details And Case Study, International Journal Of Engineering Sciences & Research Technology, 5(8): pp. 365-371.

5) Ng W.L., Ng C.K., Mohd. Ali B., Noordin N.K. (2011) Wireless Controller Area Network Using Token Frame Scheme. In: Abd Manaf A., Sahibuddin S., Ahmad R., Mohd Daud S., El-Qawasmeh E. (eds) Informatics Engineering and Information Science. ICIEIS 2011. Communications in Computer and Information Science, vol 253. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-25462-8_49.

6) Callaway E., P. Gorday, L. Hester, Jose A. Gutierrez, M. Naeve, B. Heile, V. Bahl (2002), Home Networking with IEEE 802.15.4: A Developing Standard for LowRate Wireless Personal Area Networks, IEEE Communications Magazine.

7) Chen H. and J. Tian (2009), Research on the Controller Area Network, International conference on Networking and Digital Society, pp. 251 -254.

8) Davis R.I., A. Burns, R.J. Bril, J.J. Lukkien (2007), Controller Area Network (CAN) schedulability analysis: Refuted, revisited and revised. Real-Time Systems, 35(3): pp. 239–272.

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