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REAL TIME ANALYSIS OF WIRELESS CONTROLLER AREA NETWORK

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Abstract

It is widely known that Control Area Networks (CAN) are used in real-time, distributed and parallel processing which cover manufacture plants, humanoid robots, networking fields, etc., In applications where wireless conditions are encountered it is convenient to continue the exchange of CAN frames within the Wireless CAN (WCAN). The WCAN considered in this research is based on wireless token ring protocol (WTRP); a MAC protocol for wireless networks to reduce the number of retransmissions due to collision and the wired counterpart CAN attribute on message based communication. WCAN uses token frame method to provide channel access to the nodes in the system. This method allow all the nodes to share common broadcast channel by taken turns in transmitting upon receiving the token frame which is circulating within the network for specified amount of time. This method provides high throughput in bounded latency environment, consistent and predictable delays and good packet delivery ratio. The most important factor to consider when evaluating a control network is the end-to-end time delay between sensors, controllers, and actuators. The correct operation of a control system depends on the timeliness of the data coming over the network, and thus, a control network should be able to guarantee message delivery within a bounded transmission time. The proposed WCAN is modeled and simulated using QualNet, and its average end to end delay and packet delivery ratio (PDR) are calculated. The parameters boundaries of WCAN are evaluated to guarantee a maximum throughput and a minimum latency time, in the case of wireless communications, precisely WCAN.

Keywords:

CAN, WCAN, Token Frame, Wireless Token Ring Protocol, Throughput, Latency, Packet Delivery Ratio, QualNet

1. INTRODUCTION

CAN networks, called Controller Area Networks, can be used in the framework of real-time distributed industrial applications. Such applications cover manufactures, the distributed and parallel processing systems in industrial and networking fields, etc [4], [5].

CAN networks guarantee sufficiently short time latency and it has been shown that these systems exceed in performance to the token-based ones. Access to the medium in wired CAN is shared based. It respects the CSMA/CA scheme which is “Arbitration on Message Priority” and “bit-wise Contention” technique. This technique, along with the mechanism of detecting and correcting errors, gives high performance to the protocol CAN to be adopted for real-time applications where multiple access are applied [4], [5].

CAN protocol is a message-based or data-centric protocol, in which, messages are not transmitted from one node to another based on addresses. Instead, all nodes in the network receive the transmitted messages in the bus and decide whether the message received is to be discarded or processed. Depending on the system, a message may destine to either one or many nodes. This has several important consequences such as system flexibility, message routing and filtering, multicast, together with data consistency [2].

Due to the number of advantages, CAN has penetrated into numerous automation industries. However with the lack of standards in wireless methods, it could not be fully utilized in wireless communication models which required data centric environment. Unfortunately, the features of wired CAN cannot be adopted as they are without modification, in the wireless case [4], [5]. Though researchers have proposed several schemes to implement WCAN, the implementation using token scheme has been adopted in this work. The WCAN follows the token approach as shown in [1], [3]. It is proven that using token concept has its own advantages in terms of improving efficiency by reducing number of retransmissions due to collisions and is fairer as all the stations use the channel for the same amount of time. The new model WCAN is proposed to exploit the advantages of CAN and still providing wireless access. It is implemented by modifying the wireless token ring protocol (WTRP). The rest of the paper is organized as follows; section 2 outlines the CAN protocol, section 3 describes WTRP protocol, section 4 briefs on the various approaches to WCAN implementation and explains the modelling and simulation of WCAN using token scheme approach in detail. Section 5 presents the results obtained from the WCAN simulation using QualNet and discusses the performance of WCAN in comparison to IEEE 802.11, section 6 discusses the performance of WCAN for real time applications.

2. CAN PROTOCOL

The controller area network (CAN) was created by Robert Bosch in mid 1980s as a new vehicle bus communication between the control units in automobile industries. In the past the vehicle bus communication used point to point communication wiring systems which caused complexity, bulkiness and heavy and expensive with increasing electronics and controller deployed vehicles [2]. According to Fig.1 the abundance of wiring required makes the whole circuit complicated. CAN solves this complexity by using twisted pair cables that is shared throughout the control units which can be seen in Fig.2. Not only does it reduce the wiring complexity but it also made it possible to interconnect several devices using only single pair of wires and allowing them to have simultaneous data exchange [2], [6].

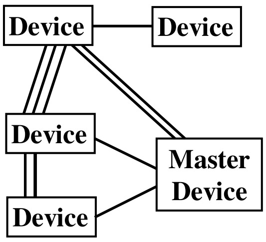


Fig.1. Traditional Wiring Method

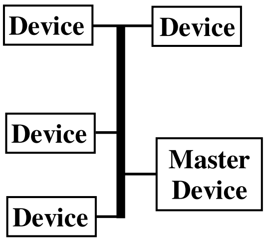


Fig.2. CAN Wire Method

2.1 STANDARD CAN AND EXTENDED CAN

Generally, there are two different standards of CAN, namely standard CAN and Extended CAN. The frame format of both standards can be seen in Fig.3. The standard CAN (CAN 2.0A) with 11-bit identifier, could provide signaling rate of 125kbps to 1Mbps. This standard was later revamped to Extended CAN (CAN 2.0B) that supports 29-bit identifier with a signaling rate of 1 Mbps. The standard 11-bit identifier provides 2^{11} or 2048 different message identifiers whereas the extended version of 29-bit could support up to 2^{29} or 537 million identifiers [2].

S O F	**11-bit Identifier**	**R T E**	**I D E**	**r0**	**DLC**	**0…8 bytes Data**	**CRC**	**ACK**	**E O F**	**I F S**

S O F	**11-bit Identifier**	**S R E**	**I D E**	**18-bit Identifier**	**R T R**	**r1**	**r0**	**DLC**	**0…8 bytes Data**	**CRC**	**ACK**	**E O F**	**I F S**

Fig.3(a). Frame Format of Standard CAN (b). Frame Format of Extended CAN

A message in the standard frame format begins with the start bit or start of frame (SOF). This is followed by the arbitration field which contains the identifier of the CAN frame and is used to arbitrate access to the bus. Also part of the arbitration field is the remote transmission request (RTR) bit, indicating whether the frame is a request frame or a data frame. The control field contains the identifier extension (IDE) bit, denoting whether the frame is a standard format frame or an extended one. The r0 bit is reserved for future extensions.

The four additional bits contain the length of the data field (data length code). The data field can be ranged from zero to eight bytes in length. The cyclic redundancy check (CRC) field contains a 15-bit code that is used to ascertain frame integrity. The acknowledgement (ACK) field comprises an ACK slot bit and an ACK delimiter bit. The ACK slot is transmitted as a recessive bit and the receivers that retrieve the message correctly will then overwrite this field with a dominant. The detection of this dominant bit by the transmitter implies that the message was accepted by at least one node and therefore, error free.

The end of frame (EOF) designates the termination of a frame. Last but not least, the intermission frame space (IFS) represents the minimum number of bit periods that must elapse right before another station is allowed to transmit a message. If there are not any other transmissions trailing the frame, the bus remains in its bus idle state.

3. WIRELESS TOKEN RING PROTOCOL

WTRP is a novel medium access control (MAC) protocol for wireless local area networks (WLANs). In contrast with IEEE 802.11 networks, WTRP guarantees quality of service (QoS) in terms of bounded latency and reserved bandwidth, which are critical in many real-time applications. Compared to 802.11, WTRP improves efficiency by reducing the number of retransmissions due to collisions, and it is fairer as all stations use the channel for the same amount of time. Stations take turns transmitting and give up the right to transmit after a specified amount of time [7], [8]. WTRP is a distributed protocol that supports many topologies, as not all stations need to be connected to each other or to a central station. WTRP is robust against single node failures, and recovers gracefully from multiple simultaneous faults. WTRP is suitable for inter-access point coordination in ITS DSRC, safety-critical vehicle-to-vehicle communications, and home networking, and provides extensions to other networks and Mobile IP.

WTRP is designed to recover from multiple simultaneous failures. One major challenge that WTRP overcomes is that of partial connectivity. To overcome this challenge, WTRP places management, special tokens, and additional fields in the tokens, and adds new timers. When a node joins a ring, WTRP requires the joining node to be connected to its prospective predecessor and successor. The joining node obtains this information by looking up its connectivity table. When a node leaves a ring, its predecessor in the ring, finds the next available node to close the ring by looking up its connectivity table. To delete tokens that a station is unable to hear, WTRP uses a unique priority assignment scheme for tokens. Stations only accept a token that has greater priority than the token the station last accepted. WTRP also has algorithms for keeping each ring address unique, to enable the operation of multiple nearby rings.

3.1 WTRP TOKEN FRAME FORMAT

The Fig.4 shows the token frame format of WTRP.

FC	RA	DA	SA	NoN	Genseq	Seq	
1	6	6	6	2	4	4	bytes

Fig.4. WTRP Token Frame Format

- FC - Frame Control contains the packet type indicator (*token, data, set- successor/predecessor token, soliciting token*)
- RA - Ring Address (Ring which token belongs to = SA)
- DA - Destination Address (determines destination station)
- SA - Source Address (station of packet origination)

- Genseq - incremented after every token rotation by the owner
- Seq - Sequence number (initialized to 0 and incremented as token pass each station)
- NoN - Number of nodes (calculated by diff of sequence numbers in one rotation) [7], [8].

Ring owner is the station with the same MAC address as the ring address. A station can claim to be the ring owner by changing the ring address of the token that is being passed around. To ensure that the ring owner is present in the ring, when the ring owner leaves the ring, the successor of the owner claims the ring address and becomes the ring owner.

4. WIRELESS CONTROLLER AREA NETWORK

There are several schemes by which WCAN has been implemented by researchers.

4.1 WCAN USING RTS/CTS SCHEME

Dridi et al. proposed to apply contention based WCAN protocol using RTS/CTS mechanisms that are used in IEEE 802.11 protocol. The RTS/CTS mechanism is used to reduce frame collisions introduced by the hidden node problem. Dridi et al. uses RTS/CTS mechanism in managing priority considerations between nodes. Changes are done to the standard RTS/CTS frame that allows message identifier. The MAC-addresses in RTS and CTS frame are replaced by the 29-bit CAN message identifier to allow message-based protocol. Additionally, RTS/CTS mechanism is used to enable a station or node to reserve the medium for a specified amount of time by specifying the duration field that the station/node requires for a subsequent transmission. This reservation information is stored in all stations in a variable called Network Allocation Variable (NAV) and represents the Virtual Carrier Sense. Inter-Frame Space (IFS) are used to control the priority access of the station to the wireless medium and it represents the time interval between each transmission of frames with Short IFS (SIFS) as the smallest type of IFS [6]. The main modification of the RTS/CTS scheme in the WCAN case is that the MAC address is substituted by the Arbitration field. This characteristic means that the WCAN protocol is Data-Centric and is based on total diffusion or directed diffusion. However, the RTS/CTS mechanism cannot be used for MPDUs with broadcast and multicast immediate address because there are multiple destinations for the RTS, and thus potentially multiple concurrent senders of the CTS in response. The RTS/CTS mechanism need not be used for every data frame transmission. Because the additional RTS and CTS frames add overhead inefficiency, the mechanism is not always justified, especially for short data frames.

4.2 WCAN WITH RFMAC ACCESS METHOD

The RFMAC protocol is operated in the centralised WCAN network that consists of one master (base) node and slave nodes in the range of master node. In such centralised wireless networks, an assessment of the numbers of contention-based channel access protocols such, as ALOHA, PRMA (packet Reservation Multiple Access), ISMA (Idle Signal Multiple Access), etc. has been made. The ISMA access protocol is the one that is partially adopted as a reference method for centralised WCAN. It enables upstream (to central node) and downstream (to terminals) traffic to be transmitted on a shared channel. Basically when the shared channel is idle the base station broadcast short idle signal to terminals. In response to the idle signal, a terminal may transmit its messages with some transmission probability [9], [10].

Similarly, as can be seen from the previous section; CAN supports on demand transmission of messages. Instead of sending periodic messages from slave nodes to the master node, remote frames can be used to have the same periodic messages without any contention of data frames. Therefore the master node schedules all periods of data frames. If the master node wishes to have data from channel, all nodes on the network receive the remote frame and decide whether the remote frame belongs to the node by using acceptance filtering. If the remote frame identifier does not match with the acceptance filter, the slave node stays idle. A data frame is only sent when the remote frame identifier matches with the data frame identifier [10]. It is possible that more than one data frame is requested by the master node. In that case the master node decides which remote frame is sent first according to messages priority defined by the user. Message traffic is shown in Fig.5.

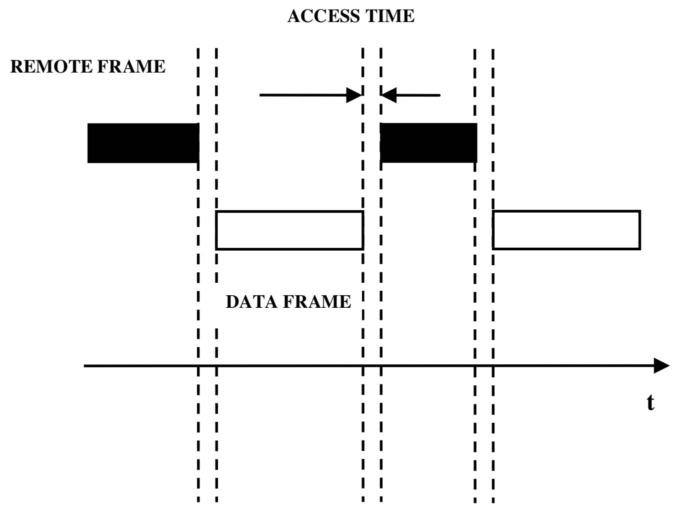


Fig.5. Remote Frame Message Traffic

4.3 WCAN WITH WMAC ACCESS METHOD

In a distributed WCAN network, several nodes may act together and communicate with each other without the assistance of a central node. The proposed WMAC protocol has been designed to support sporadic and periodic messages. Hence any node can broadcast a message at any time they desire. The contention situation is solved by using different PIFS (Priority Inter frame Space) delay times for each message. In a comparable study, the priority levels with CSMA/CA Access procedure have been presented to IEEE 802.11 for a wireless medium access control protocol by W. Diepstraten.

There has been discussion of being able to provide prioritisation of frames using a non-TDMA (Time Division Multiple Access) based Medium Access Control Protocol. In CSMA/CA protocol; prioritisation is accomplished by timing the inter frame gap. In other words, the longer the channel is idle, the lower the priority of the frame as can be seen in Fig.6. Different priority levels have been implemented for different purposes. For example, for all immediate response actions, the short priority inter frame space (SIFS) is defined as the highest priority.

In the WMAC protocol, each node must wait the messages PIFS time before sending their messages. PIFS times provide message priority to each message and are derived from the scheduling method which is performed by the user application. The shortest priority interframe space (PIFS) takes the highest message priority which means shortest delay before accessing the channel. After waiting PIFS times, each node checks the channel for the second time to be sure that the channel is available for access. Hence, a message with lower PIFS will access the channel before any massage with higher PIFS.

Each node has a timer called Priority Timer. Setting the Priority Timer as soon as the message is received from the channel prevents the nodes from the channel access during the PIFS time [10]. This is essential since a node may wish to transmit a message during the PIFS time and sense the medium is free although there could be a node waiting its PIFS. The Priority Timer also is set when the collision situation occurs. After a collision situation, the nodes involved in the collision stop their transmissions and wait their messages' PIFS times to access the channel. The value of the Priority Timer varies according to amount of messages used in the network. It takes the PIFS time of the message that has the lowest priority. The timing diagram of the WMAC protocol is given in Fig.6.

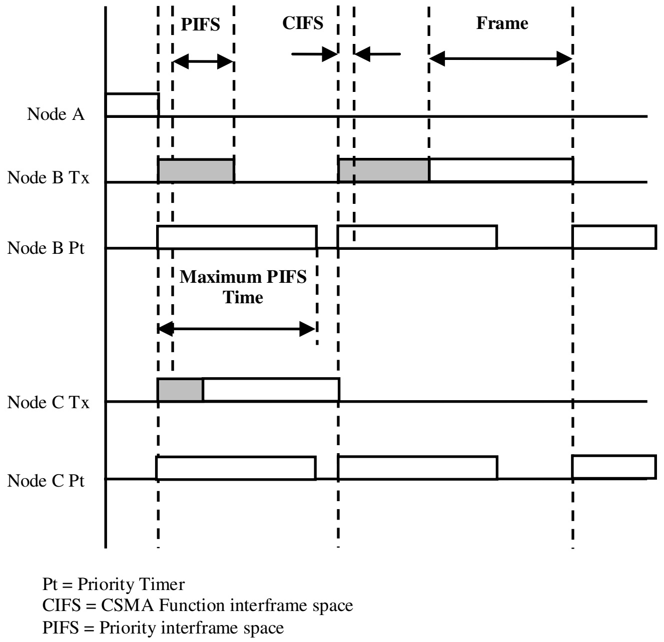


Fig.6. WMAC Timing Diagram

Node "B" and node "C" in the Fig.6, try to access the channel while it is busy. Node "C" sends a message while "B" waits the PIFS time. "B" sense the channel busy after PIFS time and defers the transmission of the message until the next idle channel situation. In turn, waits its PIFS time to gain the access. CIFS time represents the time requirements of carrier sensing.

4.4 WCAN USING TOKEN FRAME SCHEME

Inspired by the token frame scheme introduced in [1], [3], WCAN uses token frame in transmitting messages around the network. Also, the token defines the ring network by setting the successor and predecessor field present in each node. Following the scheme, the proposed WCAN is a wireless based distributed medium access control (MAC) protocol for ad-hoc network. Having a wireless based distributed MAC has its advantageous of being robust against single node failure as it can recover gracefully from it. Additionally, nodes are connected in a loose and partially connected manner.

4.4.1 WCAN Token Frame Format:

Transmission of messages proceeds in one direction along the ring network of WCAN. As such, each node requires a unique successor and predecessor present in the network. The token is the crucial part in WCAN network as it allows a smooth transmission of packet between nodes. Furthermore, it defines the current mode of operation running in the network. Fig.7 shows the proposed token format used in WCAN. A total of five fields are defined in the token frame: frame control, ring address, destination address, source address and sequence number.

FC		RA	DA	SA	Seq	
Frame type	Message id					
4		6	6	6	4	bytes

Fig.7. WCAN Token Frame Format

The Frame Control (FC) contains the frame type indicator and message identifier CAN format. Frame type indicates the type of token received by a node; such as Token, Soliciting Successor, Data Token, Token Delete Token, Implicit Acknowledgement, Set Successor and Set Predecessor. The message identifier of the token follows the same principal as used in CAN protocol, which is a message broadcast.

The ring address (RA), destination address (DA), and the source address (SA) that defines the direction and the flow of the token frame. RA refers to the ring which the token frame belongs to. The sequence number is used to build an ordered list and determine the number of stations or nodes that present in the ring.

In order for a node to gain access to the medium, the node must first capture the token that circulates around the network. The token is generated first by a ring master assigned in the network. Once a token is captured, a node wins the arbitration by comparing the message identifier located in FC. Once a node wins the arbitration, it will place its message identifier into the FC field and starts transmitting its data to the next node on its list, which is the predecessor. Otherwise, the said node will be in the receiving end and relays the token until it receives a token with lower message identifier priority.

4.5 WCAN MODELLING

4.5.1 Algorithm:

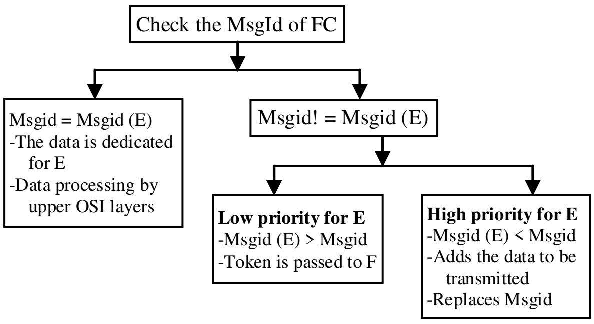
Step 1: Initialization.

- Ring owner produces the token. With the above example. Say node 'D'.

- An empty token is generated to recognize the no. of nodes within the particular ring (seq number).
- All the nodes within the ring knows its successor and predecessor.
- Requirement: transfer sensor data from automobile parts.
- Set frametype = data.
- Other nodes are in idle state.

Step 2: Token Passing.

- Token is passed to next node say ‘E’.
- Ensure FT= data frame and proceed.
- Check the MsgId of FC.



Step 3: Acknowledgement.

- 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.

- Same algorithm is followed for all other nodes.
- Once the token reaches the destination node it is either killed or recirculated depending on the requirement.
- If the data collection is needed from the same sensor node then the token is recirculated with the set priorities.
- The priorities of nodes are assigned in accordance with the automobile operation.
- Multiple token can also be employed for parallel processing.

4.5.2 Performance Evaluation:

The performance of WCAN is evaluated on basis of

- Throughput.
- Packet delivery ratio.
- End to end delay.
- **Token Rotation Time (TRT):**

$$TRT = n \times Tm + N \times (Tt + DIFS) \tag{1}$$

- 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:**

$$S/R = (n \times Tm)/TRT \tag{2}$$

Transmission delay D, is the time required for data packet to wait for the token to successfully transmit, and Average $D = TRT/2$, Hence,

$$S/\mathrm{R} = (n \times Tm)/2D \tag{3}$$

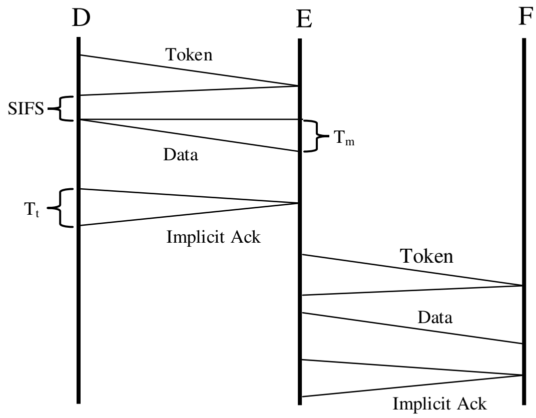


Fig.8. WCAN Token Timing Diagram

4.5.3 WCAN Simulation:

The proposed WCAN protocol is simulated and deployed using QualNet simulator. This simulator allows addition of new protocol with the help of simple C++ programming. The Simulation Parameters are given in Table.1. A snapshot of the scenario is given in Fig.9. The performances of WCAN are evaluated in terms of its Throughput, Average end-to-end delay and Packet delivery ratio, for the two types of traffic namely, constant bit rate (CBR) traffic and variable bit rate (VBR) traffic.

During the variable bit rate traffic, the source is made to generate traffic according to a Poisson process, the distribution of the interval between successive packets is Exponential with the Mean Interval of 0.5 seconds (recall that the inter-arrival times for a Poisson process are exponentially distributed). The Start Time of the connection is exponential with mean 0.5 seconds, and the Duration is Deterministic with fixed duration of 30 seconds.

Table.1. Simulation Parameters

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

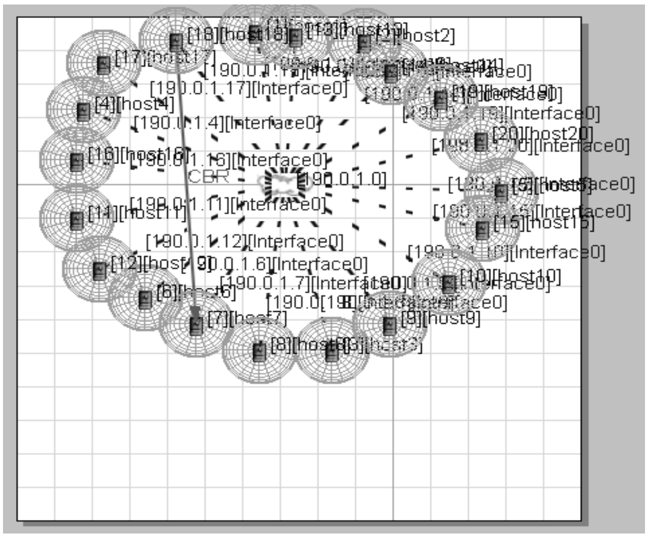


Fig.9. WCAN Simulation Scenario

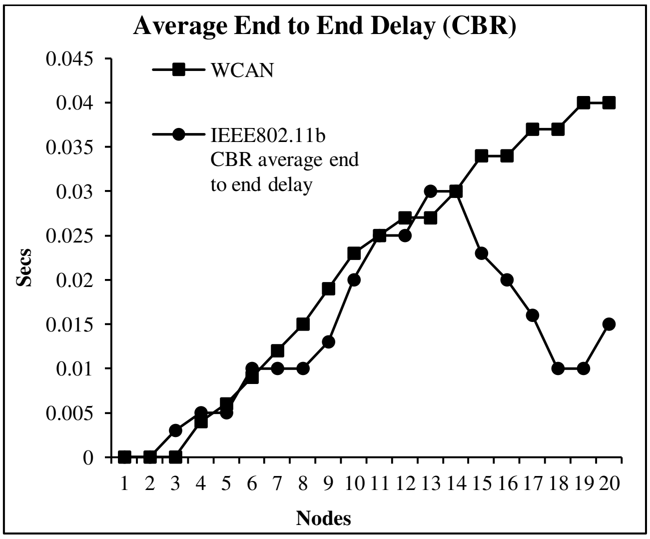


Fig.10. Average End to End Delays in WCAN and IEEE 802.11 for Constant Bit Rate Traffic

5. WCAN PERFORMANCE ANALYSIS

The most important factor to consider when evaluating a control network is the end-to-end time delay between sensors, controllers, and actuators. The correct operation of a control system depends on the timeliness of the data coming over the network, and thus, a control network should be able to guarantee message delivery within a bounded transmission time [5].

Table.1 shows the simulation scenario parameters, in terms of network size, the simulation is done for 20 nodes which covers scenario from small to large networks. As for the node placement, the nodes are all placed in a ring manner. The IEEE 802.11b has been chosen as the physical layer. In this paper, the performance of WCAN is compared to that of IEEE 802.11 Dynamic Coordination Function (DCF) mode. The IEEE 802.11 is selected due to the fact that the token frame idea was first derived from the Request to Send and Clear to Send (RTS/CTS) frame. The proposed WCAN protocol is compared with the standard IEEE 802.11, for the same simulation parameters as given in Table.1.

5.1 AVERAGE END TO END DELAY

The average end-to-end delay is defined as the time taken for a particular packet transmitting from the source to destination and the discrepancy is computed between send times and received time. The delay metric includes delays due to transfer time, queuing, route discovery, propagation and so on; meaning that it is regarded as how long it took for a packet to travel across a network from source node to destination node. This parameter is calculated only for the CBR traffic.

5.1.1 Inference from Fig.10:

- It can be seen that the average end-to-end delay of WCAN increases linearly with increasing number of nodes in a ring network.
- IEEE 802.11 shows a lower value for its average end-to-end delay. This is because the packet in WCAN environment is passed through each of the nodes present in the ring network in a circular motion.
- While in IEEE 802.11, the packets are directly transmitted to the destination node using mesh network capability.

5.2 THROUGHPUT

5.2.1 Constant Data Interval Rate:

Throughput is defined as the average rate of data packets received at destination successfully. It is often measured as bits/sec or bps and occasionally in data packets per second. In other words, throughput is the total amount of data that a receiver receives from the sender divided by the time it takes for the receiver to get the last packet. Lower throughput is obtained with a high delay in the network. Throughput provides the ratio of the channel capacity utilized for positive transmission and is one of the useful network dimensional parameters.

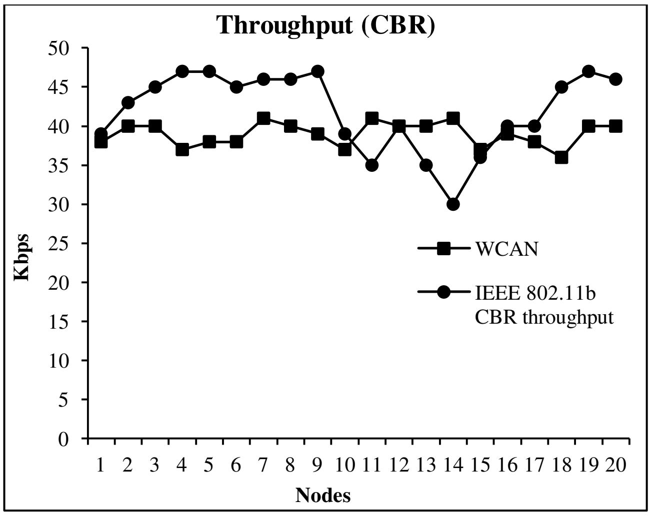


Fig.11. Throughput Performances between WCAN and IEEE 802.11 for Constant Bit Rate Traffic

5.2.1.1 Inference from Fig.11

- WCAN slightly maintain the throughput variation but the variation in IEEE 802.11 is irregular in the same environment.
- Average throughput of 802.11 is very slightly lesser than WCAN. This might be due to random arrangement of nodes causing contentions with neighboring nodes.

5.2.2 Variable Data Rate:

5.2.2.1 Inference from Fig.12

- Throughput decreases exponentially with increasing data interval rate.
- Throughput variation is rather gradual in WCAN.
- For a data interval rate of 100ms Throughput of WCAN = 40.3 kbps and of IEEE 802.11 = 38kbps.
- WCAN out performs IEEE 802.11 by 7.04%.
- Throughput deterioration in IEEE 802.11 is due to packet collision.

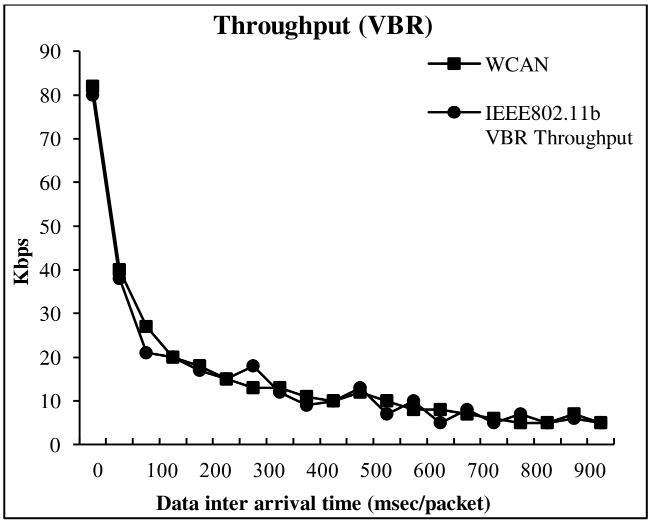


Fig.12. Throughput Performances between WCAN and IEEE 802.11 for Variable Bit Rate Traffic

5.3 PACKET DELIVERY RATIO

Packet delivery ratio (PDR) indicates successful transmission of data in the system.

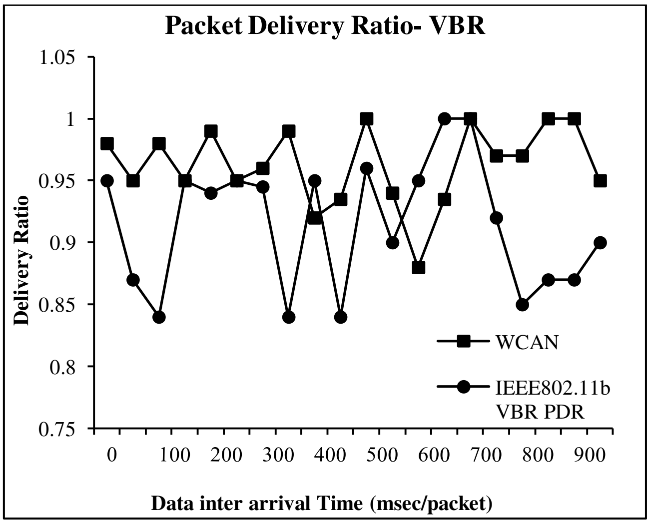


Fig.13. Packet Delivery Ratio for WCAN and IEEE 802.11

5.3.1 Inference from Fig.13:

- IEEE 802.11 suffers slightly on the delivery ratio caused by the collision of packet data.
- The consistency in PDR of WCAN is better than that of IEEE 802.11 on average PDR of WCAN = 0.963 and of 802.11 = 0.915.

6. WCAN REAL TIME ANALYSIS

In this section the WCAN is analyzed for real time performance. It is seen from Fig.14 that for the constant bit rate traffic in WCAN there is not much variation in the throughput performance as the number of nodes increases, while the average end to end delay increases linearly with increase in number of nodes. In the optimized case of 16 nodes, the throughput is 39 kbps for an average end to end delay of 0.034.

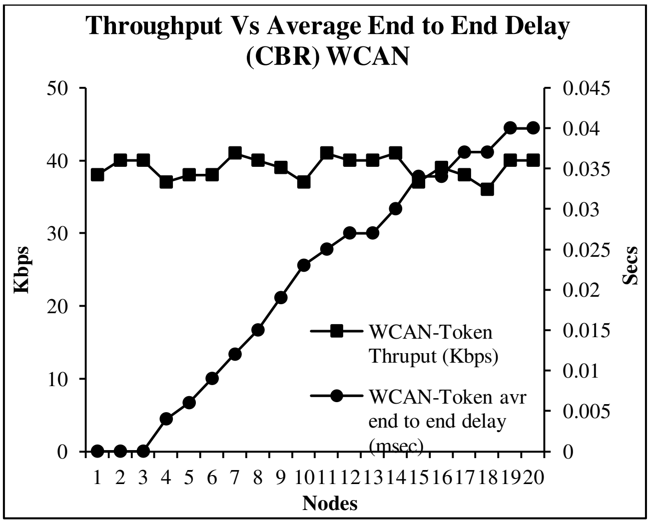


Fig.14. Throughput Vs Average End to End Delay of WCAN for Constant Bit Rate Traffic

While varaible bit rate traffic is considered, as shown in Fig.15, the throughput of WCAN decreases with increase in data arrival rate and the packet delivery ratio fluctuates about an average of 0.9635.

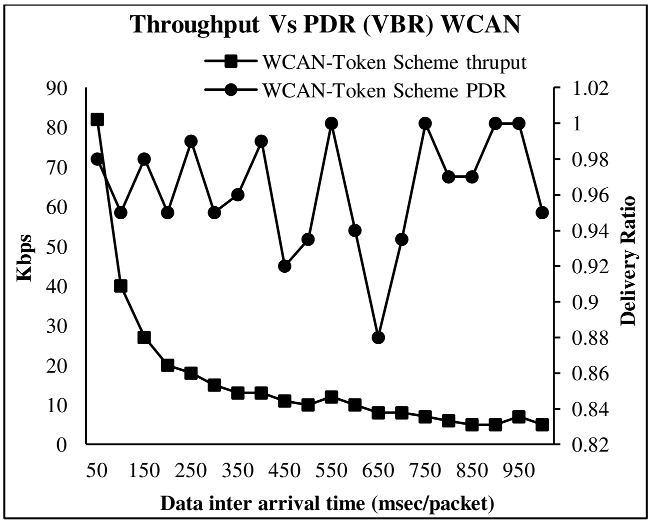


Fig.15. Throughput Vs Packet Delivery Ratio of WCAN for Variable Bit Rate Traffic

7. CONCLUSION

Thus WCAN was deployed using QualNet simulator and compared with IEEE 802.11 standard for wireless communication. WCAN uses the token frame scheme with some modification on the token format and its operation. Furthermore, the flexibility of topologies allows nodes to join and leave the network dynamically. This characteristic determines the versatile design of a home automation and industrial automation. The developed WCAN is built on the MAC layer as a wireless based distributed MAC protocol for ad-hoc network.

Simulation results show that WCAN outperform IEEE 802.11 in terms of throughput in a ring network environment. However, in terms of average end-to-end delay, WCAN increases linearly with increasing number of nodes and is slightly higher than IEEE 802.11. This is due to the fact that every node takes turn in transmitting the token around the ring network causing the overall delay to increase.

From the results, it is shown that WCAN provide 'fair' share for all nodes by scheduling the transmission with token reception. Additionally, WCAN is advantageous by reducing collision probability, by distributing the resource fairly among each node. Further the results show that the proposed WCAN is suited for real time control applications giving maximum throughput for minimal latency for an optimized number of nodes. In the absence of real-time constraints and the need for an important payload that would give a more important throughput, IEEE 802.11 is the best choice. On the other hand, in the presence of real-time constraints and the need to extend a wired CAN network, the WCAN is the best choice.

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