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QoS Enhancements using IEEE 802.11p WLANs for Communication Based Train Control Systems

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Abstract: In near future, communication based train control (CBTC) systems will play a major role in the urban railway networks in the world. CBTC systems are an automated railway signaling system that makes use of telecommunications to ensure safe operation between rail vehicles. For the urban railways Wireless local area networks (WLAN) based CBTC is the best approach because of wide availability of WLAN equipments. In the earlier works, IEEE 802.11a based WLANs are used to provide bidirectional train ground communications. But these WLANs are not suitable for high speed environments with frequent change in network topology, which may result in communication interrupt and long latency. In this paper IEEE802.11p WLANs are used to provide better communication availability in the CBTC environment. In the proposed work Quality of service (QoS) parameter metrics like throughput, delay are analyzed by using NS-2. Simulated results show 802.11p is more suitable than 802.11a for CBTC systems.

Key words: CBTC system, Quality of services, IEEE 802.11p, Vehicular Networks.

I. INTRODUCTION

Recently, developed countries around the world have extensively incorporated rail transit systems to relieve the pressures from already-busy roads to address the need for quick, punctual, and environmental friendly mass transit systems. In the communication based train control (CBTC) system, the safe operation between the rail vehicles must be ensured by using the data communications. It can improve the utilization of railway network infrastructure and enhance the level of safety and service offered to customers. CBTC is a modern successor a traditional railway signaling system using track circuits, and signals [1],[2]. Most CBTC systems use bidirectional wireless train ground communications to transfer control data between trains and wayside equipment.

With the rapid development of wireless communication systems, several wireless technologies have been proposed for CBTC systems, such as Worldwide Interoperability for Microwave Access (WiMAX), Global System for Mobile communications Railway (GSM-R) and wireless local area networks (WLANs). Due to the wide availability of commercial WLAN equipments and open IEEE 802.11 standards [3], WLAN-based CBTC systems are focused in this paper to gain the popularity in the urban rail transit systems.

Communication based train control systems have stringent requirements for wireless communication availability and latency. The less service availability and the long latency in commercial wireless networks lead to poor quality of services (QoS). In CBTC systems, less service availability could cause derailment of train; collision between the vehicles or even catastrophic events like loss of life is likely to takes place. So it is important to ensure the better wireless communications are available when they are needed, and the latency is minimized in CBTC system to provide safe operation between the vehicles.

In the earlier works in train control environment mostly IEEE 802.11a based WLANs are used for communication [1] and authors of [4] shows IEEE 802.11a has certain demerits to adopt the vehicular environments. In this paper we use the IEEE 802.11p to support the better communication in fast changing vehicular environments.

This paper is organized as follows. Section II describes the overview of CBTC system. The IEEE802.11p physical and MAC layer characteristics are discussed in Section III. Then section IV describes about the Implementation of 820.11p in NS-2. Sections V discuss about the simulation results and finally conclusion is drawn in section VI.

II. OVERVIEW OF CBTC SYSTEM

Fig.1 shows a typical view of wireless communication in CBTC system. In this system, continuous bidirectional wireless communication between each station adapter on the train and the wayside access point is adopted, instead of the traditional fixed-block track circuit. The railway line is usually divided into physical areas and these areas are referred as zone controller.

Each area is under the control of a zone controller and has its wireless transmission system to exchange the data. The location, direction and speed of each train are transmitted

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to the Zone controller and the wireless link between each train and the Zone controller must be continuous to ensure the

location, speed, direction of all the trains in each area at all times.

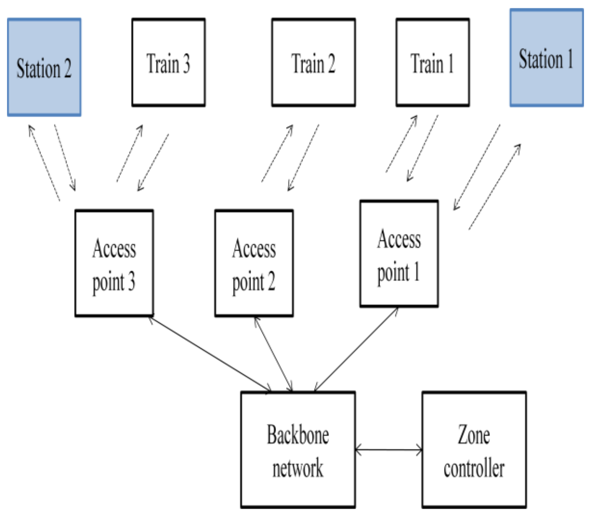

Fig.1 A typical view of wireless communication in CBTC system

The function of Backbone network is to interconnect the several access points and the zone controller unit present in the wireless network.

III. IEEE 802.11p

The IEEE 802.11p, also known as Wireless Access in Vehicular Environment (WAVE), is a draft amendment to the IEEE 802.11 standard that adds applications to fast changing vehicular networks. It includes the exchange of data between high speed vehicles and also vehicle to infrastructure in the licensed ITS (Intelligent transport system) band of 5.9 GHz (5.850-5.925GHz). The IEEE 802.11p supports transmission rates ranging from 3 to 27 Mb/s over a bandwidth of 10 MHz, which is half of the bandwidth in 802.11a [5], [6]. The physical layer and MAC (Medium access control) layer are described in the following section.

A. Physical Layer

The IEEE 802.11p physical layer implementation specifies the use of dedicated short range communications (DSRC), defined by the Federal Communications Commission (FCC)**.**The DSRC technology operates at a 75 MHz bandwidth , Positioned in the spectrum range of 5.9 GHz. These 75 MHz are divided into seven 10 MHZ channels each, the center channel is the control channel (CCH) and the rest of the channels are the service channels (SCH) [5], as shown in Fig. 2.

Control channel (CCH) usage is limited to broadcast of safety related data and transmission of control and management

messages. The remaining channels are Service Channels (SCHs) available for non-safety related data transmission, including general Internet service.

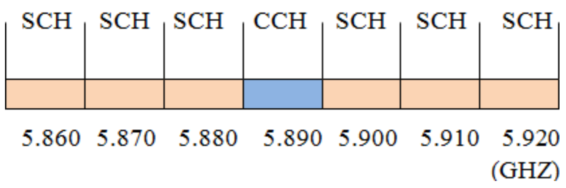

Fig.2 The channels of IEEE802.11p

In this different channels cannot be used simultaneously, so each station can make the constant change between the control channel and the service channels. To ensure the minimum delay, especially when safety related data are sent, the changing time cannot be more than 100 *m*s.

During the data transmissions, the signals are sent by using orthogonal frequency division multiplexing (OFDM) technique to increase the data transmission rate and overcome the signal fading in wireless communications, which divides each channel in several sub-carriers spaced by 0.15625 MHz from each other [6].

The IEEE 802.11p, made formal changes to physical (PHY) and medium access control (MAC) layers, which is a modification to IEEE 802.11a for applying in the unstable vehicular environment. In the physical PHY layer, minor changes made in number of channels, bandwidth and coding scheme.

B. MAC Layer

The Medium access control (MAC) layer functions are related to the IEEE 802.11e standard, enhanced distributed channel access (EDCA), which adds quality of service to IEEE 802.11 networks and prioritizing the safety messages. In this messages are categorized into four different Access Categories (AC0, AC1, AC2 and AC3), where AC3 has the lowest priority range and AC0 has the lowest priority range [9].

When a particular message is selected, its contained parameters are sent to the transmitter. First the arbitrary inter frame space (AIFS), previously set for each AC. As each slot time is 16 µs, the AIFS time is equal to AIFS x 16 µs. The contention window time is calculated subsequently.

If there is any collision occurs, then the window time is recalculated by $2(CW + 1) - 1$, and a new attempt is done. This operation is continued until the window size

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(CWmax) is reached maximum or the packet is sent successfully [5].

IV. IMPLEMENTATION OF 802.11p IN NETWORK SIMULATOR (NS-2)

As represented in [8], none of the current standards (802.11a) have completely adapted the VANET (Vehicular adhoc network) technology. So IEEE had a 802.11p new protocol developed which can adapt properties of vehicular network and also support safety, quality and reliable data transmission in rapidly changing vehicular environments.

Table 1 Setting of 802.11a and 802.11p

For 802.11a	*For 802.11p*
set val(netif)	set val(netif)
Phy/WirelessPhy	Phy/WirelessPhyExt
set val(mac)Mac/802_11	setval(mac)Mac/802_11Ext

For implementation we are using NS (Network Simulator) version 2.34. NS-2 is a general purpose networks simulator developed by Berkley University [7] [8]. The two versions of network simulator 2.33 and 2.34 only support the simulation work for the 802.11p.

Its implementation is done by applying the IEEE 802.11p physical and MAC layers features in the TCL simulation code, defined by two native modules: ***WirelessPhyExt*** and ***Mac/802-11Ext*** as shown in Table 1**.**

V. SIMULATION RESULTS

Using NS-2.34 VANETS's support, performance evaluation experiments were realized. However, it was necessary to check whether this implementations was sufficient to obtain consistent results because, as described in Section IV, the NS-2 IEEE 802.11p modules are present only in the last two versions of the simulator.

We are considering simulation scenario containing the nodes (transmitter and receiver) which were defined, in which the nodes are consider as vehicles. The nodes movement was done in both directions and in each simulation the speed of each node was variable.

In this paper, an IEEE 802.11a and IEEE 802.1p comparison scenario was simulated, where the quality of service parameter metrics like End to End delay, data throughput and packets delay were compared.

In this simulation environment the vehicles i.e trains are considered as nodes and processed .The quality of service (QoS) performance metrics like End to end delay, packet delay and data throughput of 802.11a and 802.11p are analyzed and the results are shown in the Fig. 3, Fig. 4, Fig. 5 respectively

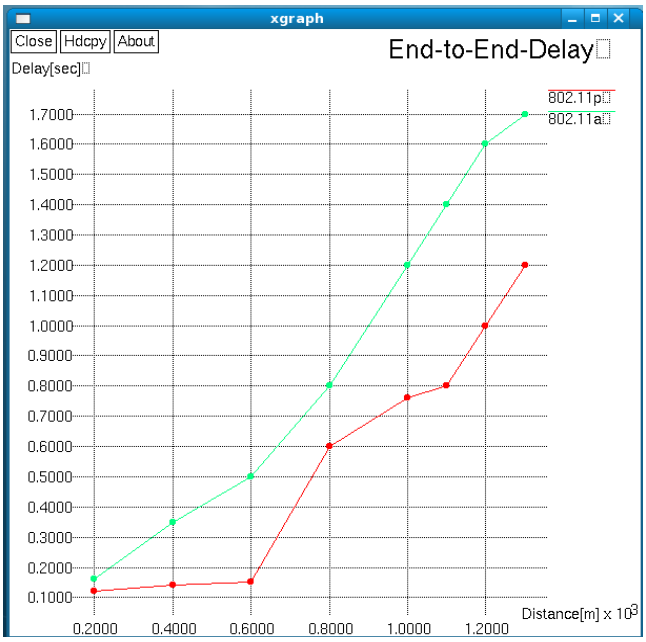

Fig 3 End to End delay comparison

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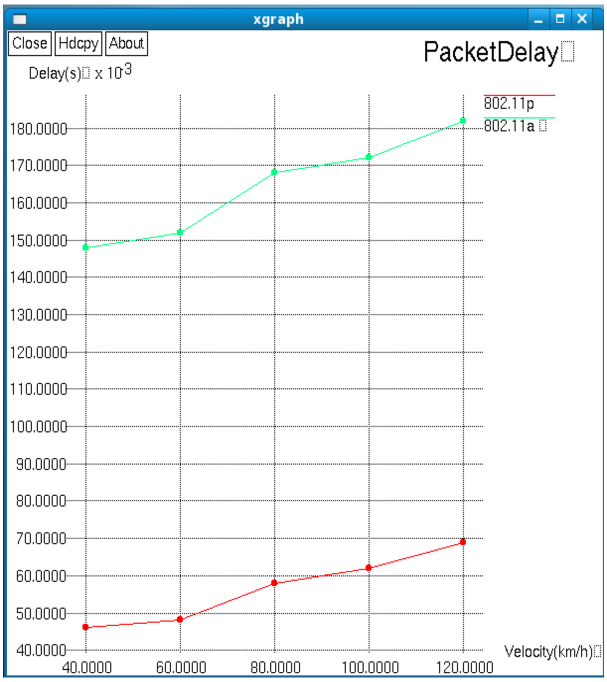

Fig. 4 Packet delay comparison

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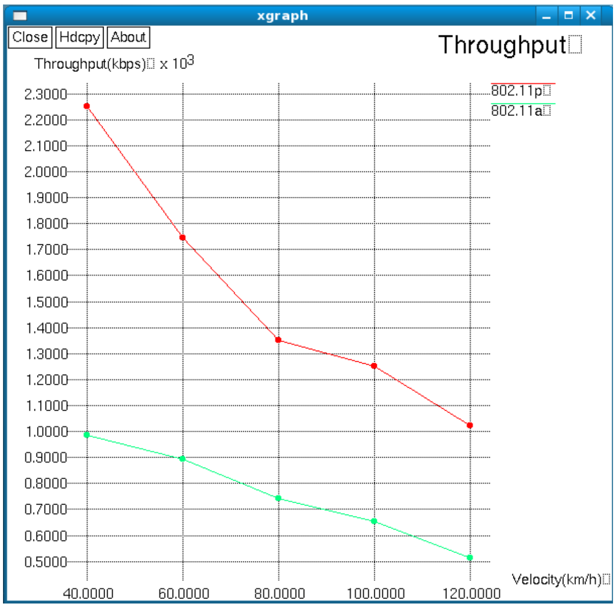

Fig .5 Throughput comparison

The End to End delay is calculated as inter arrival of first data packet and second packet to the total packet delivery time. The delay is calculated in seconds, and the fig shows as the distance increases end to end delay of 802.11p is minimum value compared to the 802.11a.

The nodes changing the velocity, starting at an initial speed of 40 km/h and increased by 20 km/h until the final speed of 120 km/h, it was possible to obtain the packets delay and the transmitted data throughput and is shown in Fig 4 and Fig 5.

Initially packet delay is minimum for low speeds, as the speed increases gradually delay also increases. The graph shows IEEE 802.11p has the minimum packet delay compared to IEEE802.11a represented in Fig 4.

Throughput is the average rate of successful message deliver over a communication channel. The graph is plotted against velocity and the data rate in kbps. Fig. 5 shows that the performance of IEEE 802.11p is better than the IEEE 802.11a when the speed of the node is increased.

VI. CONCLUSION

Communication based train control systems have strict requirements for wireless communication availability to ensure better performance and providing safety. This paper describes computer based simulations, using NS 2.34, the performance metrics such as End to End delay, packet delay and data throughputs, for vehicular networks are analyzed. Simulation results show that 802.11p provides effective service in the vehicular networks compared to the 802.11a.

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