

# HIGH BANDWIDTH APPLICATION OVER WI-FI CONNECTION WITH IEEE 802.11P, AND IEEE P1609 (WAVE) PROTOCOLS

## Introduction

IEEE 802.11 enabled WiFi devices, present in the personal computing devices, communicate with each other after standard authentication, and association procedures. But, consider deploying these devices in a high speed moving automobile, wherein the communication environment rapidly changes, and the transactions have to be completed in a short time interval. IEEE 802.11p (Wireless Access in Vehicular Environments – WAVE) amendment attempts to solve this problem of deploying WiFi devices in vehicular environments. A block diagram of the WAVE device stack is as given in *Figure 1*. A WAVE device is based on an architecture that supports a Control Channel (CCH) and multiple Service Channels (SCH). The CCH is used to transmit Wave Short Messages (WSMs) and announce WAVE services, and the SCH are used for application interactions and transmissions over IP. To make it cost effective, WAVE devices use a single radio solution. Another challenge in implementing the WAVE stack warrants accurate channel switching between CCH and SCH.

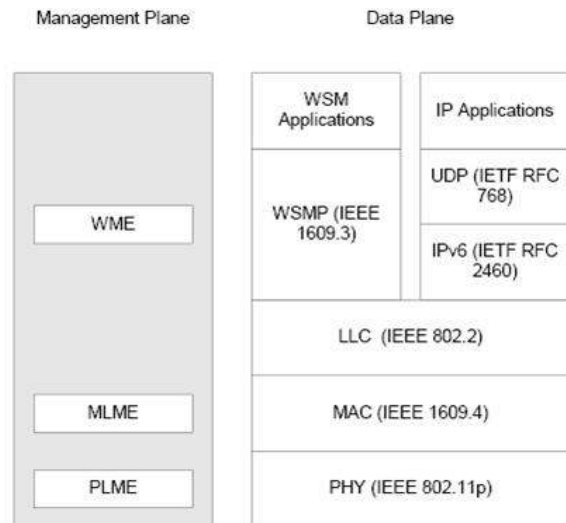
We present here a solution aimed to solve the challenges in physical layer, and MAC layer by demonstrating a high bandwidth required application. It presents the importance of channel utilization efficiency, and synchronization between multiple wireless nodes.

## Physical Layer

The WAVE devices are to operate in 5.85-5.925GHz DSRC frequency band in the USA, with 10MHz channel spacing, and 10MHz of channel bandwidth. Due to the reduced channel bandwidth, the maximum physical data rate will reduce to 27Mbps. This band also supports two 20MHz wide service channels for higher data rates.

## MAC Layer

Coordinated Universal Time (UTC) is time standard defined by International Atomic Time, and is based on the earth's angular rotation. All WAVE devices shall monitor the CCH beginning at the start of a UTC second, and channel switch to SCH at the end of CCH interval. At the beginning of each scheduled channel interval, there shall be a guard interval. This guard interval includes the channel switch time, and is used to account for variations in channel interval time, timing inaccuracies among different devices.



**Figure 1 Wave Radio Stack**

The CCH and SCH intervals are 50msecs each, with Guard Interval as 4msec. Due to the nature of WiFi devices, the time taken to switch between channels is governed by the traffic in progress (transmit or receive). We have seen that the channel switch time can vary between 50 to 300msecs or even more. This factor badly affects the reliability of the vehicular communication device for safety usage.

Vehicular device could also be used for exchanging non-safety messages, which require moving the wireless device to a SCH periodically. A WAVE device with a service provider application, advertises its SCH, and timestamp to enable/synchronize the users. We could achieve this multiple channel communication with two radio solutions. But, we demonstrate the channel coordination using a single radio solution. The CCH, and SCH will have independent channel queues, and access priorities defined. It is required that data integrity is maintained when switching between channels.

The channel time for transmitting safety messages is reduced because of single radio serving two channels. It is also necessary that nodes have to be synchronized for reliable data exchange, especially for safety messages. All the nodes have to switch from CCH to SCH at the same instance, and vice versa as well.

## Our Solution strengths

1. Wi-Fi Radio tuning for FCC Class C Spectral mask
2. Consistent channel switching time of less than 3msec
3. Efficient time synchronization between nodes
4. Low propagation delay from transmit application to receive application
5. Less than 2% loss in broadcast messages used for safety
6. Efficient channel utilization, with high TCP/UDP data throughput used in infotainment applications.

### LocoMate - mini

*LocoMate - mini* is an embedded device powered by MIPS, along with Ethernet, and high powered PCI based Atheros Wireless device. It also integrates the GPS device, which can enable *LocoMate - mini* to act as both 'Passive' probe or 'Active' probe device. 'Passive' probe device sends location information to another vehicle that has an On Board Unit (OBU) or Road Side Unit (RSU). In an 'Active' probe device the *LocoMate - mini* can be inter-networked with other automotive components, and information can be extracted from vehicle, or controlled based on the received messages. *LocoMate - mini* could be used by vehicle designers for evaluation purposes.

### LocoMate - ez

*LocoMate - mini* employs a PCI based Atheros WiFi device, and is very good for evaluation. But to consider a WiFi device in a large scale production would force vehicle manufacturers to rethink on cost, and easy deployment. Most of the present automobiles with an embedded system does not have PCI interface. It is learnt that SDIO and CAN bus are the most common interfaces available. We provided SDIO based solution in addition to PCI based solution. *LocoMate - ez* would help in large scale deployment in many ways. For certain automobile applications, it would only require upgradation of the software and providing SDIO based WiFi add-on card.

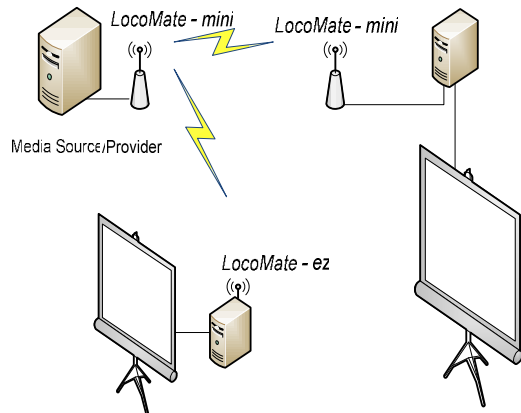


Figure 2 Components of the Video demo setup

## Demonstration Setup

Wireless Networked automobiles can exchange safety messages in CCH, and infotainment data in SCH. In this setup we show that each of the nodes exchange their data relating to safety in CCH. In addition, they also transmit/receive video data in the SCH. We have one video service provider, and two video clients. The safety messages are transmitted in CCH using Wave Short Message Protocol (WSMP) application, for every 100msec.

The video data is transmitted in SCH using IP application. All the wireless nodes in the setup continuously switch between CCH, and SCH every 50msec. Different components of the demonstration are as shown in Figure 2. We use two *LocoMate - mini* units and one *LocoMate - ez*, with interoperable software stacks.

## Data Throughput Analysis

Throughput measurement has been the popular way of evaluating the device for its data handling capabilities. We present here TCP/UDP throughput of an IP application, using standard applications iperf/chariot. Table 1 gives the TCP/UDP throughput in different channels. These numbers can be used to evaluate the throughput for data sent through WSMP as well, wherein the safety messages will be unicast. Until today studies have been made only to use broadcast mechanism for safety messages, and several evaluation metrics are still being studied. We are also in the process of proposing different WAVE device evaluation metrics, which evaluates the reliability of safety messages and benchmark the requirement for infotainment data.

Table 1 TCP/UDP throughput in different channels

	TCP (Mbps)	UDP (Mbps)
WAVE operation in 20MHz (max. phy rate = 54Mbps)	27.782	32.231
WAVE operation in 10MHz (max. phy rate = 27Mbps)	14.75	17.32
WAVE operation in 10MHz, with periodic channel switch	6.9	8.6

## Future Work

- We are engaging with several vehicle designers for large scale vehicle deployment, and evaluation. Mutually working with vehicle designers would help in a fully distributed V2V and V2I applications.
- WAVE Device evaluation mechanisms, to consider unicast, broadcast packets encapsulated by IP or WSMP
- Redesign the software architecture to enable easy deployment in multiple Operating Systems
- High power capable SDIO based wireless card

## References

1. IEEE 802.11-REVMa/D7.0, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications IEEE, Jun 2006
2. IEEE Draft P802.11p/D2.0, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications IEEE, Nov 2006
3. IEEE P1609.4/D08, IEEE P1609.4 Trial-use Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-Channel Operation, Jul 2006
4. IEEE P1609.3/D21, IEEE P1609.4 Trial-use Standard for Wireless Access in Vehicular Environments (WAVE) - Networking services, Sept 2006