EXPERIMENTAL EVALUATION OF INTEGRATED DSRC AND WI-FI SYSTEMS FOR INTELLIGENT TRANSPORTATION SYSTEMS

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DECLARATION

I declare that this is my work, and this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or institute of higher learning, and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

The high initial and maintenance costs of standard Dedicated Short-Range Communications (DSRC) and cellular V2X systems pose a significant barrier to the implementation of Intelligent Transportation Systems (ITS), particularly in low- and middle-income countries where road safety is a critical requirement. This thesis addresses the necessity for cost-effective V2X solutions by developing and experimentally evaluating a DSRC/Wi-Fi integrated communication system. The system leverages low-cost Wi-Fi (IEEE 802.11 n) technology, which shares protocol similarities with DSRC, utilizing economic devices such as the ESP32 System-on-Chip (SoC). The cost of integrating the Wi-Fi subsystem is less than 30 USD.

The proposed architecture integrates commercial DSRC devices with the low-cost Wi-Fi subsystems, connected via an Ethernet link, to deliver information for applications such as Active Road Signs (ARS). System performance was evaluated using critical vehicular communication metrics:

- Packet Delivery Ratio (PDR)
- Maximum Range (MR)
- Effective Range (ER)
- Packet Interarrival Time (PIT)

Empirical evaluation demonstrated that the system is a viable solution for many ITS applications, confirming a MR above 300m and an Effective Range (ER), defined as the range where PDR is above 50%, of approximately 200m. Crucially, the probability of situation awareness blackouts (PIT > 1s) was found to be negligibly small. To assist designers in selecting optimal parameters, a model was developed using a Bi-directional Long Short-Term Memory (Bi-LSTM) neural network to predict system performance (PIT) based on variables such as distance, speed, RSSI, and beacon interval. This work confirms that the novel dual communication system offers a practical, low-cost pathway for extending V2X capabilities.

Keywords: Integrated Communications for ITS Applications, Intelligent Transportation Systems, Active Road Signs, Dedicated Short-Range Communications, DSRC / Wi-Fi Integrated Systems, Vehicle-to-Everything (V2X) communications

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List of Abbreviations

AODV Ad hoc On-Demand Distance Vector
ARS Active Road Signs
AU Application Unit
BSM Basic Safety Message
C-ITS Cooperative Intelligent Transport Systems
C-V2X Cellular Vehicle-to-Everything
CCH Control Channel
COTS Commercial Off-The-Shelf
CSMA/CA Carrier Sense Multiple Access with Collision Avoidance
D-OBU DSRC On-Board Unit
DSRC Dedicated Short-Range Communications
ER Effective Range
ETSI European Telecommunications Standards Institute
FTP File Transfer Protocol
GPRS General Packet Radio Service
GPS Global Positioning System
H-RSU Hybrid Roadside Unit
I-I2V Integrated Infrastructure-to-Vehicle
I-V2V Integrated Vehicle-to-Vehicle
I^2C Inter-Integrated Circuit
ICA Intersection Collision Avoidance
IP Internet Protocol
IPv6 Internet Protocol Version 6
ITS Intelligent Transport System
LTE Long Term Evolution
MAC Media Access Control
MCU Microcontroller Unit
MR Maximum Range
NGV New Generation V2X
NLOS Non-Line-of-Sight
NoW Network on Wheels
OBU On-Board Unit
OCB Outside the Context of the Basic Service Set
PCB Printed Circuit Board
PDR Packet Delivery Ratio
PIT Packet Interarrival Time
PPDU Physical Protocol Data Unit
PSK Pre-Shared Key
RF Radio Frequency
RSA Roadside Alert
RSSI Received Signal Strength Indicator
RSU Roadside Unit
SBC Single-Board Computer
SCH Service Channel
SoC System-on-Chip
SPI Serial Peripheral Interface
SUMO Simulation of Urban Mobility
TCP Transmission Control Protocol
UART Universal Asynchronous Receiver-Transmitter
UDP User Datagram Protocol
USB Universal Serial Bus
UTC Coordinated Universal Time
V2I Vehicle-to-Infrastructure
V2V Vehicle-to-Vehicle
V2X Vehicle-to-Everything
VANET Vehicular Ad Hoc Network
W-Beacons Wi-Fi Beacons
W-OBU Wi-Fi On-Board Unit
WAVE Wireless Access in Vehicular Environments
WLAN Wireless Local Area Network
WSMP WAVE Short Message Protocol