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**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	NoW Network on Wheels
ARS Active Road Signs	OBU On-Board Unit
AU Application Unit	OCB Outside the Context of the Basic Service Set
BSM Basic Safety Message	PCB Printed Circuit Board
C-ITS Cooperative Intelligent Transport Systems	PDR Packet Delivery Ratio
C-V2X Cellular Vehicle-to-Everything	PIT Packet Interarrival Time
CCH Control Channel	PPDU Physical Protocol Data Unit
COTS Commercial Off-The-Shelf	PSK Pre-Shared Key
CSMA/CA Carrier Sense Multiple Access with Collision Avoidance	RF Radio Frequency
D-OBU DSRC On-Board Unit	RSA Roadside Alert
DSRC Dedicated Short-Range Communications	RSSI Received Signal Strength Indicator
ER Effective Range	RSU Roadside Unit
ETSI European Telecommunications Standards Institute	SBC Single-Board Computer
FTP File Transfer Protocol	SCH Service Channel
GPRS General Packet Radio Service	SoC System-on-Chip
GPS Global Positioning System	SPI Serial Peripheral Interface
H-RSU Hybrid Roadside Unit	SUMO Simulation of Urban Mobility
I-I2V Integrated Infrastructure-to-Vehicle	TCP Transmission Control Protocol
I-V2V Integrated Vehicle-to-Vehicle	UART Universal Asynchronous Receiver-Transmitter
I²C Inter-Integrated Circuit	UDP User Datagram Protocol
ICA Intersection Collision Avoidance	USB Universal Serial Bus
IP Internet Protocol	UTC Coordinated Universal Time
IPv6 Internet Protocol Version 6	V2I Vehicle-to-Infrastructure
ITS Intelligent Transport System	V2V Vehicle-to-Vehicle
LTE Long Term Evolution	V2X Vehicle-to-Everything
MAC Media Access Control	VANET Vehicular Ad Hoc Network
MCU Microcontroller Unit	W-Beacons Wi-Fi Beacons
MR Maximum Range	W-OBU Wi-Fi On-Board Unit
NGV New Generation V2X	WAVE Wireless Access in Vehicular Environments
NLOS Non-Line-of-Sight	WLAN Wireless Local Area Network
	WSMP WAVE Short Message Protocol