

**MILLIMETER WAVE FOR VEHICULAR COMMUNICATION
USING EFFICIENT CODING TECHNIQUE**



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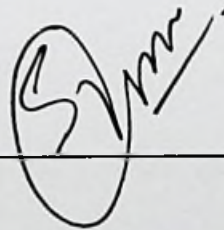
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ABSTRACT

A promising technology for vehicular ad-Hoc Networks (VANETs) is Millimeter-wave (mmWave). mmWave is, however, susceptible to path loss and fading, which degrades system performance. Error-free data between Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) in the context of fading and mobility of vehicles calls for in-depth research.

In addition to the above-mentioned limitations, challenging issues degrading the reliability of VANET are the problems of high penetration loss and blocking. To establish effective communication in mmWave networks in context of vehicles, a detailed understanding of the VANET communication channel is necessary, which differs significantly from those explored at frequencies lower than 6 GHz. When a vehicle's speed exceeds 50 km/h, Doppler shifts can have adverse affects on the reliability of V2V communication. The transmission becomes impossible in VANET because of the increasing mobility of the nodes.

This research presents three tractable channel models for VANET in which system performance degradation due to error is addressed. The operating frequency is 60 GHz. In the first model, concatenated Bose–Chaudhuri–Hocquenghem (BCH) and Alamouti Space-Time Block Coding (ASTBC) and coding are used. The two Bit Error Rate (BER) closed-form approximations, one for BCH in Rayleigh fading and the other for BCH with ASTBC, are obtained. Signal to Noise Ratio (SNR) and code rate are included in these expressions, which can be used to create VANET systems. The findings demonstrate that the BER obtained by concatenating ASTBC and

BCH is 10^{-5} thus outperforming the traditional BER obtained by ASTBC expression. The code rate (127,36), (127,64) and (255,251) are used to evaluate the performance of the proposed expressions.

The second model is designing a comprehensive tractable model for VANET over millimeter waves that combines Reed Solomon (RS) coding with Space-Time Block Coding (STBC). The closed-form approximations for BER of RS in the Additive White Gaussian Noise (AWGN) channel and Rayleigh fading are derived. The performance of RS closed-form expressions is compared with previous BER computation approaches. The results shows that the BER lies between 10^{-7} to 10^{-6} . Furthermore, the model's performance has been compared with the current VANET communication systems, specifically the IEEE 802.11bd and 3GPP V2X communication systems. Results are comparable with V2X NR and demonstrate that our suggested approach works better than IEEE 802.11bd. As metrics for performance, throughput, Packet Error Rate (PER) and Packet Reception Ratio (PRR) are employed. The model has also been evaluated with vehicles moving at faster velocities. Further, the simulation and numerical findings show that the AWGN approximation for STBC-RS model outperforms Reed Solomon - Mary Phase Shift Keying (RS-MPSK) traditional system i.e. the achieving the BER of 10^{-7} . These derived expressions can be adopted in designing various VANET architectures targeting reliability in the network. The path loss and fading are reduced since the directivity of the transmitter has increased using beamforming.

The analytical and numerical results are compared, demonstrating the accuracy of our closed-form expressions. In the third model, the impact of the Doppler shift using BCH and RS coding is also analyzed in VANET communication. Since Orthogonal Frequency Division Multiplexing (OFDM), which is highly susceptible to Doppler shift, is used by the IEEE 802.11p PHY layer. It is seen that the results of the suggested model surpass those of earlier models, including 802.11p.

Considering there exhibits a strong dependence of 5G/6G communication on both the molecular composition of the medium and the transmission distance. The closed-form expressions of BER are simulated in the Terahertz (THz) channel. A detailed analysis of relative humidity dependency on code rate is conducted. Further, the relation between code rate and relative humidity is analyzed. The results are analyzed at different code rates. Moreover, we have compared our results with the performance of existing ASTBC technique in the THz channel. The results depict that the proposed model surpasses the behavior of the ASTBC equation in THz. The findings presented here are expected to pave the way for ultra-reliable vehicular communication networks.

Table of Contents

Chapter	Title	Page
	TITLE PAGE	i
	APPROVAL FOR EXAMINATION	ii
	AUTHOR’s DECLARATION	iii
	PLAGIARISM UNDERTAKING	iv
	ACKNOWLEDGMENT	vi
	ABSTRACT	viii
	TABLE OF CONTENTS	xi
	LIST OF FIGURES	xviii
	LIST OF TABLES	xxii
	LIST OF ABBREVIATIONS	xxiv
	LIST OF SYMBOLS	xxviii
1	INTRODUCTION	1
	1.1 Vehicular Ad-Hoc Network (VANET) Overview	2
	1.1.1 Communication in VANET	3
	1.2 VANET Challenges	4
	1.3 Motivation	6

1.4	Problem Statement	9
1.5	Aims and Objecives of Research	11
1.5.1	Aims of Thesis	11
1.5.2	Objectives of Dissertation	11
1.6	Scope, Assumptions and Limitations	12
1.7	Contributions	12
1.8	Thesis Outline	14
2	THEORETICAL FRAMEWORK	16
2.1	VANET Applications	17
2.1.1	Road Safety Applications	17
2.1.2	Efficiency Applications	21
2.1.3	Comfort Applications	22
2.2	Role in Urban Sensing	23
2.3	Potential Applications of Gbps in mmWave VANET Communications	24
2.3.1	Cooperative Perception	24
2.3.2	Sensor Data Sharing	24
2.3.3	Map Download	25
2.3.4	Live Perceptual Data	25
2.4	VANET Characteristics	26
2.5	Intelligent Transportation System	28
2.6	VANET Communication Technologies	28

2.6.1	Dedicated Short Range Communication (DSRC)/ IEEE 802.11p	32
2.6.2	Cellular system (2G/3G/4G)	35
2.6.3	Worldwide Interoperability for Microwave Ac- cess (WiMax) 4G	36
2.6.4	Microwave (4G)	36
2.6.5	Long Term Evolution LTE-V2V	37
2.6.6	Continuous Air-interface, Long And Medium Range (CALM)	38
2.7	Protocol Stack for VANET	39
2.7.1	Physical Layer	39
2.7.2	MAC Layer	40
2.7.3	Network Layer	41
2.7.4	Application and Transport Layers	41
2.8	Millimeter Wave Communication	43
2.8.1	Millimeter Wave Spectrum	44
2.8.2	Millimeter Wave Channel Properties	45
2.8.2.1	The Friis Free Space Path Loss Formula	46
2.8.2.2	Blockage	47
2.8.2.3	Doppler Spread and Delay Spread	48
2.8.2.4	Weather and Atmospheric Effects	52
2.9	Standards and systems in VANET	52
2.9.1	Additive White Gaussian Noise and Rayleigh Channel	54
2.9.2	VANET Literature Review	56

2.10 Channel Coding	62
2.10.1 Automatic Repeat Request	63
2.10.2 Error Control Coding	63
2.10.3 Forward Error Control	65
2.10.3.1 BCH Coding	66
2.10.3.2 RS Coding	67
2.11 Beamforming	68
2.11.1 Benefits of Beamforming in MIMO systems	70
2.11.1.1 Enhanced Energy Efficiency	70
2.11.1.2 Improved Spectral Efficiency	70
2.11.1.3 Increased System Security	70
2.12 Diversity Techniques	70
2.12.1 Space Diversity	71
2.13 Space Time Block Coding	71
2.14 Current VANET Communication Systems	75
2.15 Research Gap	77
2.16 MIMO Communications in VANET	77
2.17 Terahertz Communication in VANET	78
3 METHODOLOGY	81
3.1 Introduction	81
3.2 Alamouti Space-Time Block Coding and Bose-Chaudhri-Hocquenghem Channel Model	83

3.2.1	Bose-Chadhuri- Hocquenghem (BCH) Coding in Rayleigh Fading on Node i	84
3.2.2	BER in Concatenated ASTBC and BCH on Node j	87
3.3	Reed Solomon – Space Time Block Coding Channel Model	88
3.3.1	Transmit Beamforming	91
3.3.2	Maximal Ratio Combining at Receiver End	92
3.3.3	Maximum Likelihood Estimator	93
3.3.4	Reed Solomon Error Probability in Rayleigh Fading	94
3.3.5	Reed Solomon Error Probability in AWGN Channel	96
3.4	Doppler Effect in Millimeter-Wave Communication	97
3.4.1	Reed Solomon under Doppler Effect	98
3.4.2	BCH Coding under Doppler Effect	100
3.5	Relative Humidity and Code Rate Relation in BER in 6G Communication	102
3.5.1	System Model	103
4	RESULTS AND DISCUSSION	107
4.1	Alamouti Space-Time Block Coding and Bose-Chaudhri- Hocquenghem Channel Model: Results and Discussion	107
4.2	Space Time Block Coding - Reed Solomon Channel Model: Results and Discussion	110
4.2.1	Comparison Analysis of proposed approach with IEEE 802.11bd and 3GPP V2X Communication	120
4.3	Doppler Effect in Millimeter-Wave Communication: Re- sults and Discussion	125

4.4	BER in 6 th Generation: Relative Humidity and Code Rate Relation: Results and Discussions	132
4.5	Environmental Conditions and Effect on Results	135
5	CONCLUSION AND FUTURE WORK	136
5.1	Future Work	138
5.2	Future Recommendations	140
	References	142
	Appendix A: Path loss and BER of 20 vehicles in Proposed Model	155
	Appendix B: List of Publications	157
	B.1 List of Publications	157
	B.2 Ph.D Symposium Presentation	158
	B.3 Other Scholarly Contribution	158
	Appendix C: ASTBC and MIMO 4*4 STBC	159
	C.1 2*1 ASTBC	159
	C.2 MIMO 4*4 STBC	160
	Appendix D: Adopting Long-Short Term Memory (LSTM) to predict reliability in different use cases in autonomous vehicles in 6G	161
	D.1 Deep Learning	162
	D.1.1 Long Short-Term Memory LSTM	164
	D.2 Activation Function tanh	167
	D.3 Background	168

Appendix E: The Designed Framework for Reliability Assessment using LSTM in different use cases in autonomous vehicles in 6G	171
E.1 Fuzzy Logic	173
E.2 Rectified Linear Unit, ReLU	174
E.3 PRF's Conditions	175
E.4 The Fuzzy Arithmetic-Based System	177
E.5 Results and Discussion	178

List of Figures

Figure	Title	Page
1.1	VANET Architecture	3
2.1	VANET Safety Applications	22
2.2	Data Downloaded in Millimeter Wave Communication	26
2.3	DSRC in VANET	33
2.4	Millimeter Wave Spectrum	44
2.5	Logarithmic Plot of Calculated Values of Attenuation by Rain dB/km	47
2.6	Direct and Multipath Propagation in VANET	49
2.7	Beamforming in VANET	69
2.8	Beamforming-STBC	71
3.1	Methodology Flowchart	82
3.2	BCH-ASTBC System Model	83
3.3	System Model for RS-STBC	89
3.4	VANET Communication Process	89
3.5	STBC Encoder and Decoder	90
3.6	Transmit Beamforming	91

3.7	Relative Speed in VANET	97
3.8	VANET Terahertz Channel Model	103
4.1	Pathloss in Presence of Vehicles	108
4.2	BER of BCH in Rayleigh Fading (Simulation)	109
4.3	Simulation Result of BER of BCH-ASTBC	109
4.4	Signal received after Beamforming when number of elements are increasing	111
4.5	Signal received after Beamforming when distance between elements is increasing	112
4.6	Maximal Ratio Combiner for 4 number of receiving antennas	113
4.7	SNR per symbol in Maximal Likelihood Detector	113
4.8	System Capacity	114
4.9	BER of RS-STBC in AWGN Channel for $N_t=3$	114
4.10	BER of RS-STBC in AWGN Channel for $N_t=4$	115
4.11	BER Comparison of RS-8PSK system with Proposed Approximation in AWGN Channel	115
4.12	BER of RS in Rayleigh Fading	116
4.13	BER Comparison of RS in Rayleigh and AWGN Channel	116
4.14	BER Comparison of RS-STBC with BCH-ASTBC	117
4.15	BER Comparison of STBC-RS with previous work in terms of coding type	120
4.16	BER Comparison of STBC-RS with previous work in terms of AWGN/Rayleigh Channel	121
4.17	PER (Packet size = 100 Bytes) of RS in AWGN Channel	122

4.18	PER (Packet size = 100 Bytes) of RS in Rayleigh Fading	123
4.19	Throughput of MIMO-RS (Packet size = 100 Bytes) in Rayleigh Fading	124
4.20	Packet Reception Ratio (PRR) of MIMO-RS in AWGN Channel (Packet size = 100 Bytes)	124
4.21	Packet Reception Ratio (PRR) of MIMO-RS in Rayleigh fading (Packet size = 100 Bytes)	125
4.22	BER of RS code under Doppler Shift with relative velocity of 25 km/h to 250 km/h	126
4.23	BER of BCH code under Doppler Shift with relative velocity of 80 km/h	126
4.24	BER of BCH code under Doppler Shift with relative velocity of 250 km/h	127
4.25	BER of BCH code under Doppler Shift with relative velocity of 25 km/h	127
4.26	BER and Doppler Shift relation in BCH coding at 60 GHz under 250 km/h	129
4.27	BER and Doppler Shift relation in BCH coding at 60 GHz under 30 km/h	130
4.28	BER and Doppler Shift relation in BCH coding at 30 GHz under 250 km/h	130
4.29	Doppler Shift under 5.9 GHz	131
4.30	Comparison Analysis of Doppler Shift on 60 GHz	131
4.31	BER of Proposed Equation in THz	133
4.32	BER of Concatenated ASTBC-BCH	134
4.33	Concatenated ASTBC-BCH BER v/s Relative Humidity	134
A.1	BER of BCH in Rayleigh Fading for 20 vehicular nodes	156

C.1	ASTBC 2*1 Number of Antennas	159
E.1	Different Steps of Proposed Framework	171
E.2	LSTM Network	173
E.3	Trained and Predicted Values	179
E.4	RMSE of the proposed DL model compared with other ML methods	180
E.5	Reliability of System on all Sub-activities	180
E.6	Reliability of System excluding last two activities (Driver's behavior and reaction)	181
E.7	Reliability of System excluding PRF, Coding and last two activities (Driver's behavior and reaction)	181

List of Tables

Table	Title	Page
2.1	Safety and Non-Safety Applications	20
2.2	VANET Communication Technologies	31
2.3	Properties of BCH Code	67
4.1	SNR Simulation Parameters	107
4.2	Beamforming Simulation Parameters	110
4.3	Simulation Parameters	112
4.4	RS BER Computation Approaches I	118
4.5	RS BER Computation Approaches II	119
4.6	PER Analysis of Proposed Approach (Modulation) with IEEE 802.11p and NR V2X	122
4.7	PER Analysis of Proposed Approach (Coding) with IEEE 802.11p and NR V2X	123
4.8	Throughput Analysis of Proposed Approach with IEEE 802.11p and NR V2X	124
4.9	Parameters Used for Comparative Analysis	128
4.10	Comparative Analysis of Proposed Approach	129
4.11	Performance Evaluation Parameters for Channel Model on 6G	132

A.1	Path loss Simulation Parameters	155
E.1	Simulation Parameters for the Proposed LSTM Framework	178

List of Abbreviations

ALOHA	Advocates of Linux Open-source Hawaii Association
AP	Access Point
ARQ	Automatic Repeat request
BI	Beacon Intervals
BSS	Basic Service Set
CAM	Cooperative Awareness Messages
CALM	Communication Access for Land Mobile (CALM)
C-ITS	Cooperative Intelligent Transportation Systems
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier-Sense Multiple Access with Collision Avoidance
DCF	Distribution Coordination Function
DMG	Directional Multi-Gigabit
DENM	Decentralised Environmental Notification Messages
ECC	Error Correction Code
EDGE	Enhanced Data Rates for GSM Evolution
EGPRS	Enhanced GPRS

EIRP	Average Equivalent Isotropic Radiated Power
ETCS	Electronic Toll Collection Systems ETCS
FCC	Federal Communications Commission
FSO	Free Space Optical
FST	Fast Session Transfer
GPRS	General Packet Radio Service
GSRRS	Global Status Report on Road Safety
ISO	International Standardization Organization
ITS	Intelligent Transport Systems
LSTM	Long-Short Term Memory
LDPC	Low Density Parity Check
LRR	Long Range Radar
LTE	Long Term Evolution
MDS	Maximum Distance Separable
MMSE	Minimum Mean Squared Error
mmWave	Millimeter Wave
MPSK	M-ary Phase Shift Key-ing (MPSK)
MQAM	M-ary Quadrature Amplitude Modulation
NGV	Next-Generation V2X
NSCC	Non-Systematic Convolutional Codes (NSCC)

PCP	Personal Basic Service Set Control Point
PRF	Prime Reliability Factor
R	Correlation Coefficient
RMSE	Root Mean Square Error
RS	Reed Solomon
RSU	Road-Side Unit
sRLNC	Systematic Random Linear Network Coding
SCC	Systematic Convolutional Codes
SRR	Short Range Radar
UFMC	Universal Filtered Multi-Carrier
URLLC	Ultrareliable and Low-Latency communication
UWB	Ultra Wide Band
VC-MAC	Vehicular Cooperative Media Access Control
VSC	Vehicular Safety Communication
V2V	Vehicle to Vehicle
V2I	Vehicle to Infrastructure
VITP	Vehicular Information Transfer Protocol
VTL	Virtual Traffic Light (VTL)
Wi-Fi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access

WLAN	Wireless Local Area Networks
WPAN	Wireless Personal Area Networks
WHO	World Health Organization
ZF	Zero Forcing

List of Symbols

STA	IEEE 802.11 device a station
$Gbps$	Giga bits per second
Mph	Miles per hour
km/h	Kilo meter per hour
EB	Exabyte
γ	Signal-to -Noise Ratio
P_t	Transmitter power
G_{tx}	Transmitter array gain
G_{rx}	Receiver array gain
PL	Path loss
α	Path loss exponent
β	Model parameter for the different number of blockers
RH	Relative humidity
L_f	Free space path loss
L_a	Absorption loss
P_{ei}	Probability of error on node i

P_{BCH}	Probability of error in BCH coding
R_c	Code rate
θ	Angle of arrival
ϕ	Angle of reflection
f_d	Doppler shift
n	Number of coded bits
M	Modulation order