SINGLE CHANNEL SLOTTED CONTENTION FOR COGNITIVE RADIO VEHICULAR NETWORKS

By

Nada Gamal Ahmed Ibrahim Elgaml

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

SINGLE CHANNEL SLOTTED CONTENTION FOR COGNITIVE RADIO VEHICULAR NETWORKS

By

Nada Gamal Ahmed Ibrahim Elgaml

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

Under the Supervision of

Prof. Dr. **Hebat-Allah M. Mourad**

………………………………..

Professor
Electronics and Communications
Engineering Department
Faculty of Engineering, Cairo University

Dr. **Ahmed K. F. Khattab**

………………………………..

Associate Professor
Electronics and Communications
Engineering Department
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

SINGLE CHANNEL SLOTTED CONTENTION FOR COGNITIVE RADIO VEHICULAR NETWORKS

By

Nada Gamal Ahmed Ibrahim Elgaml

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

Approved by the
Examining Committee

____
Prof. Dr. **Hebat-Allah M. Mourd**, Thesis Main Advisor

____
Associate Prof. Dr. **Ahmed Khattab F. Khattab**, Advisor

____
Prof. Dr. **Magdy M. S. El-Soudani**, Internal Examiner

____
Prof. Dr. **Ahmed Elsayed Alarabi Almahde**, External Examiner
- German University in Cairo

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: Nada Gamal Ahmed Ibrahim
Date of Birth: 18/01/1992
Nationality: Egyptian
E-mail: nadagamalelgaml@gmail.com
Phone: (+02) 01001525829
Address: Block 13, Division 6, Zahraa Elmaadi
Registration Date: 01/03/2018
Awarding Date: 2018
Degree: Master of Science
Department: Electronics and communications Engineering

Supervisors:

Prof. Dr. Hebat-Allah Mourad
Dr. Ahmed Khattab Fathi Khattab

Examiners:

Prof. Dr. Ahmed Elsayed Alarabi (External Examiner)
- German University in Cairo
Prof. Dr. Magdy M. S. El-soudani (Internal Examiner)
Prof. Dr. Hebat-Allah Mourad (Thesis Main Advisor)
Dr. Ahmed Khattab Fathi Khattab (Advisor)

Title of Thesis:
Single Channel Slotted Contention For Cognitive Radio Vehicular Networks

Key Words:
Cognitive Radios; Vehicular Networks; Slotted Contention; IEEE 802.11p.

Summary:
Cognitive Radio Vehicular Ad-hoc Networks (CR-VANETs) exploit the dynamic spectrum capability of cognitive radios to allow the vehicles to access the unused channels in their vicinity. The existing VANETs protocols are not originally designed as enablers for cognitive radios. Therefore, CR-VANETs do not only suffer the traditional CR problems, especially in spectrum sensing, but also suffer new challenges due to the highly dynamic nature of VANETs. This thesis presents a spectrum sensing and reporting protocol for non-safety applications, which counters the deficiencies of typical CR-VANETs in high-density networks. We introduce the Single Channel Slotted Contention $(SC)^2$ protocol for highly dense vehicular traffic on highways. The proposed protocol consists of three main components: random single channel sensing, slotted contention and implicit aggregation. The proposed $(SC)^2$ protocol can be easily incorporated with the IEEE 802.11p. Simulation results show that the proposed protocol increases the secondary throughput and spectrum utilization while significantly decreasing the radio environment map time in high densities when compared to the legacy IEEE 802.11p based protocols. A trade-off between the primary outages and the secondary throughput can be controlled via the contention window size. We also analytically study the collision probability and secondary throughput of the $(SC)^2$ and the IEEE 8021.11p based protocols.

Acknowledgements

I was extremely lucky to have had exceptional mentors, who set the bar so high and to whom I will forever be grateful. I would like to express my very great appreciation to Professor Dr. Heba Mourad for her patient guidance, enthusiastic encouragement and constrictive critiques of this research work.

My deepest and enormous gratitude goes to Associate Professor Dr. Ahmed Khattab who has inspired me to achieve at levels much higher than I ever thought possible. His guidance, leniency, and endless support during the thesis process and the past five years were invaluable. For being my mentor, I have discovered a passion for learning, asking questions, exploring and researching. For that, I am forever thankful.

My very heartfelt and sincere thanks recorded to my friend Mona Fouad. This work would not have been done without her support and help.

Finally, many thanks and love to my family especially mom and dad who have been exceptionally encouraging and caring throughout my life.

Dedication

To my beloved parents,
Gamal Elgaml & **Sahar Saad**

My dear siblings,
Sara, Ali & **Mostafa**

My beautiful nieces,
Bisan & **Nuria**

Table of Contents

List of Tables

List of Figures

List of Abbreviations

1G	**1**st **G**eneration
2G	**2**nd **G**eneration
3G	**3**rd **G**eneration
4G	**4**th **G**eneration
AC	**A**ccess **C**ategories
AC_BE	**A**ccess **C**ategories- **B**est **E**ffort
AC_BK	**A**ccess **C**ategories- **B**ackground
AC_VO	**A**ccess **C**ategories- **V**oice
AC_VI	**A**ccess **C**ategories- **V**ideo
ADC	**A**nalog to **D**igital **C**onverter
AIFS	**A**rbitrary **I**nter-**F**rame **S**pacing
AIFSN	**A**rbitrary **I**nter-**F**rame **S**pacing **N**umber
AODV	**A**d-Hoc On **D**emand **D**istance **V**ector
ANPR	**A**utomatic **N**umber **P**late **R**ecognition
AU	**A**Application **U**nit
ASIRD	**A**ssociation for **S**afe **I**nternational **R**oad **D**rive
AWGN	**A**dditive **W**hite **G**aussian **N**oise
argmax	**A**rguments of **M**axima
argmix	**A**rguments of **M**inima
BP	**B**elief **P**ropagation
CCH	**C**ontrol **C**hannel
CCCH	**C**ommon **C**ontrol **C**hannel

CH	**C**luster **H**ead
CoVANET	**C**ognitive **V**ehicular **A**d-hoc **N**etworks
Cog-V2V	**C**ognitive **V**ehicular-to-**V**ehicular
CR	**C**ognitive **R**adio
CR-VANET	**C**ognitive **R**adio- **V**ehicular **A**d-hoc **N**etworks
CSMA/CA	**C**arrier **S**ensing **M**ultiple **A**ccess/ **C**ollision **A**voidance
CW	**C**ontention **W**indow
DCF	**D**istributed **C**oordination **F**unction
DIFS	**DCF** **I**nter-**F**rame **S**pace
DSA	**D**ynamic **S**pectrum **A**ccess
DSR	**D**ynamic **S**ource **R**outing
DSRC	**D**edicated **S**hort **R**ange **C**ommunication
DTN	**D**elay-**T**olerant **N**etworking
EDCA	**E**nhanced **D**istributed **C**hannel **A**ccess
FC	**F**usion **C**enter
FCC	**F**ederal **C**ommunication **C**ommission
FFT	**F**ast **F**ourier **T**ransform
FIFO	**F**irst-**I**n-**F**irst-**O**ut
GPS	**G**lobal **P**ositioning **S**ystem
GSM	**G**lobal **S**ystem for **M**obile-communication
GNSS	**G**lobal **N**avigation **S**atellite **S**ystem
HCM	**H**ighway **C**apacity **M**anual
IEEE	**I**nstitute of **E**lectrical and **E**lectronics **E**ngineers
IFS	**I**nter-**F**rame **S**pacing
ISM	**I**ndustrial, **S**cientific and **M**edical

ITS	**I**ntelligent **T**ransport **S**ystem
LOS	**L**ine **O**f **S**ight
LTE	**L**ong **T**erm **E**Evolution
MAC	**M**edium **A**ccess **C**ontrol
MLR	**M**aximum **L**ikelihood **R**atio
NHTSA	**N**ational **H**ighway **T**raffic **S**afety **A**dministration
OBU	**O**n **B**oard **U**nit
OFDM	**O**rthogonal **F**requency **D**ivision **M**ultiplexing
OSA	**O**pportunistic **S**pectrum **A**ccess
PCF	**P**oint **C**oordination **F**unction
PDF	**P**robability **D**ensity **F**unction
PN	**P**rimary **N**etwork
PU	**P**rimary **U**ser
PHY	**Ph**ysical
QoS	**Q**uality of **S**ervices
REM	**R**adio **E**nvironment **M**ap
RSU	**R**oad **S**ide **U**nit
SCH	**S**ervices **C**hannels
$(SC)^2$	**S**ingle **C**hannel **S**lotted **C**ontention
SIFS	**S**hort **I**nter-**F**rame **S**pacing
SIO	**S**ense-**In**-**O**rder
SNR	**S**ignal to **N**oise **R**atio
SU	**S**econdary **U**ser
TORA	**T**emporally-**O**rdered **R**outing **A**lgorithm
TXOP	**T**ransmission **O**pportunities