

Emergency Braking: A Study of Network and Application Performance

Michele Segata Renato Lo Cigno



UNIVERSITY OF TRENTO - Italy

**Department of Information
Engineering and Computer Science**

The Eighth ACM International Workshop on Vehicular
Inter-NETworking (VANET 2011)



Why This Research?

- Literature is either network or application-oriented
 - VANETs analysis needs to consider network and application (and benefits) in a joint way
- Investigate what are the implications of the information diffusion protocol on the application (and vice-versa)
 - Is message re-propagation needed for every safety application?
- Can we quantify the benefits of a safety application given a particular protocol?
 - Protocols' performance are generally investigated in crash-free simulators
- Goals: show that
 - Considering application and network together helps the development and the evaluation of network protocols
 - The choice of a network protocol must not be based only on its network performance



Outline

- 1 Outline of the Work
 - Motivation
 - Approach
 - Simulation
- 2 Results
 - Network Results
 - Application Results
 - Impact of Reverse Direction

The Work

- Joint analysis of a safety application and network protocols
- Application:
 - Emergency Electronic Brake Lights (EEBL)
 - Computer-aided braking (CACC)
 - Human reaction to warnings
- Network:
 - Basic beaconing
 - EEBL messages, different re-propagations
- Scenario:
 - Emergency braking in a highway



Simulator Employed

- ns-3 with embedded IDM and MOBIL¹
 - Characterize driver through random parameters for IDM
 - Simulation of highway with 50 vehicles per lane
- Necessary modifications
 - Allow crashes through max deceleration²
 - Max deceleration randomly set in [5.9, 8.4] m/s²
 - CACC for aided braking
 - Basic human reaction to warnings
 - Curious drivers on reverse direction
- Modified simulator (under continuous development) is available for download: <http://vnt.disi.unitn.it>

¹H. Arbabi and M. C. Weigle, "Highway Mobility and Vehicular Ad-Hoc Networks in ns-3" - 2010

²U.S. Department of Transportation - "Final Report For The Methodology Study Of The Consumer Braking Information Initiative" - 1999

Network

- Network protocols:
 - Basic beaconing: 1Hz update rate (GPS position, speed, acceleration, etc.)
 - Basic EEBL: on braking, warnings at 10Hz
 - EEBL with Re-broadcast (EEBLR): re-propagation using a *weighted p-persistent* mechanism
 - EEBL with Aggregation (EEBLA): EEBLR improved with message buffering
- Stack structure
 - 3) Beaconing/EEBL Application Logic (novel-implemented)
 - 2) 802.11p MAC layer (ns-3 provided)
 - 1) 802.11p PHY layer (ns-3 provided)



Network Protocols - Description

- EEBLR:
 - based on the *weighted p-persistent* broadcast suppression mechanism³
 - upon reception, re-propagate the message with a distance-dependent probability p
- EEBLA:
 - re-propagation criterion same as EEBLR but
 - messages are buffered, aggregated and sent in a single frame
 - messages scheduled for re-propagation are removed from buffer if received again from another re-broadcaster

³Tonguz et. al. "On the Broadcast Storm Problem in Ad hoc Wireless Networks" - 2006

Network Parameters

Parameter	Value	Unit
IEEE standard	802.11p CCH	
AC (beacons)	AC_BK	
AC (EEBL)	AC_VO	
Data rate	6	Mbps
Bandwidth	10	MHz
Tx power	20	dBm
Propagation loss	Three log distance	
d_0, d_1, d_2	1, 200, 500	m
n_0, n_1, n_2	1.9, 3.8, 3.8	#
L_0	46.67	dB

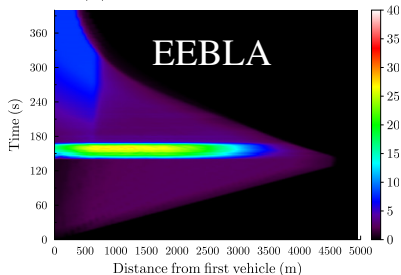
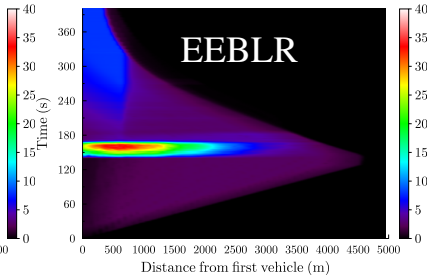
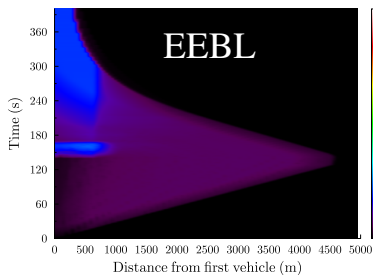
Table: Network parameters



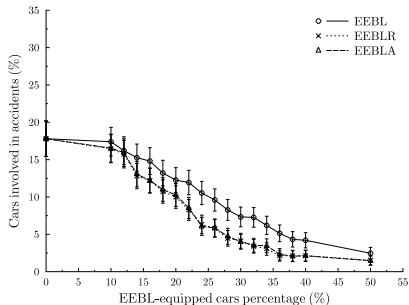
Network Load Definition

- Network load: fraction of time a vehicle observes the channel busy over 1 second
- For plotting:
 - Divide the road into “slots” of 50 m, starting from platoon’s head
 - Compute the load as the average load of the vehicles in each slot
 - Repeat for each second of the simulation
- Graphical example

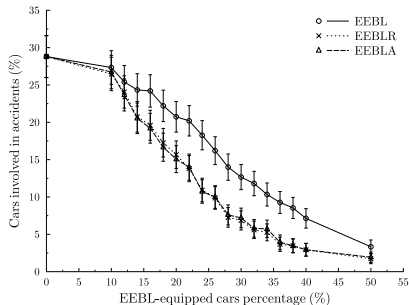
Network Load - 5 lanes - Single Direction



Market Penetration Rate - Single Lane

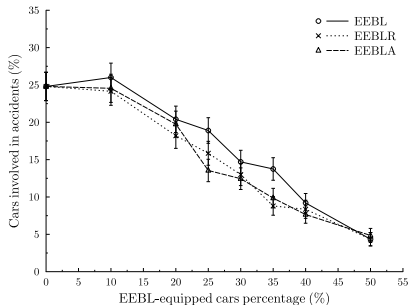


130 km/h - 80 mi/h

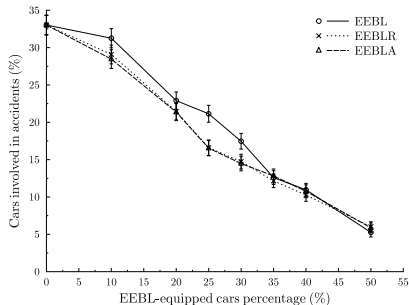


150 km/h - 93 mi/h

Market Penetration Rate - Multi Lane



2 lanes @ 130 km/h - 80 mi/h



5 lanes @ 130 km/h - 80 mi/h

Market Penetration Rate - Equipped vs. Non-Equipped

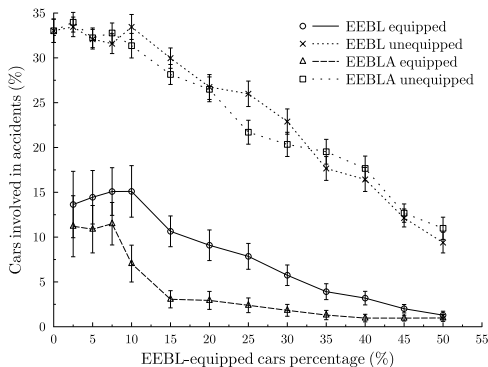
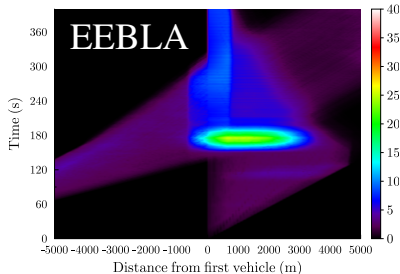
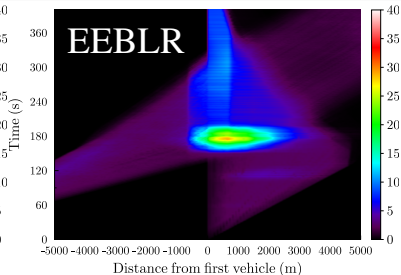
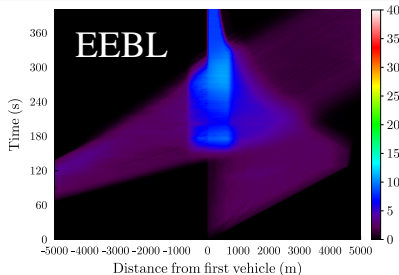


Figure: Split-down of equipped an unequipped cars involved in accidents vs. MPR; five lanes @ 130 km/h - 80 mi/h

Network Load - 5 lanes - With Reverse Direction





Conclusion

- Joint network and application analysis helps in protocol design and evaluation
- EEBLA is a good compromise between application and network performance (for EEBL)
- Re-propagation plays a fundamental role during the initial diffusion
- Unequipped vehicles benefit from the introduction of this safety application



Future Work

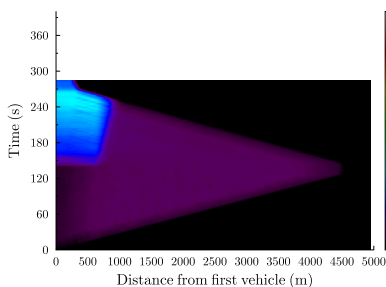
- Analysis of different transmission powers
- Analysis with a more realistic PHY layer
 - Consider fading conditions
- Analysis of different scenarios and applications together
 - Brake and start, full CACC, density diversification
- EEBLA protocol improvement
 - Analyze different re-broadcast policies
 - Reduce re-propagation range, without harming the application
- Improvement of driver reaction to warnings
 - Distance weighted
 - Amount weighted

That's all!
Thanks for your attention!
Questions?

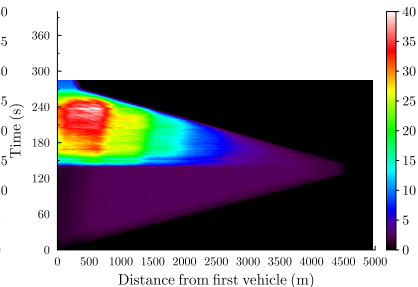
Contacts:

`{msegata, locigno}@disi.unitn.it`

“Open Loop” Network Load

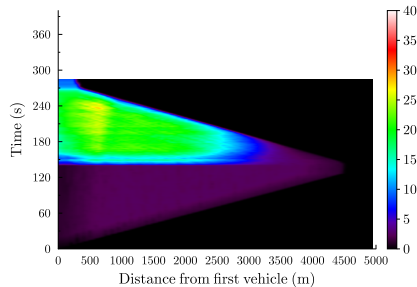


EEBL



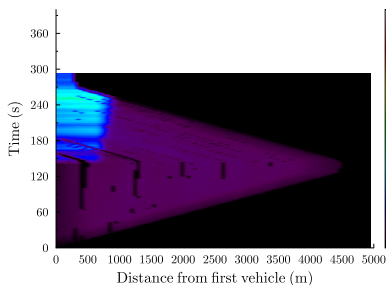
EEBLR

“Open Loop” Network Load

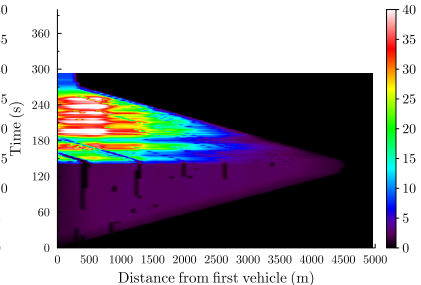


EEBLA

“Open Loop” Single Simulation Examples

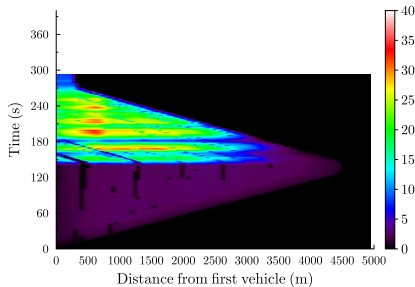


EEBL



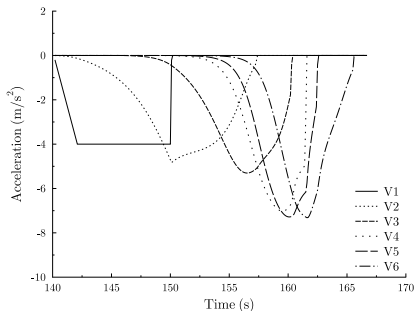
EEBLR

“Open Loop” Single Simulation Examples

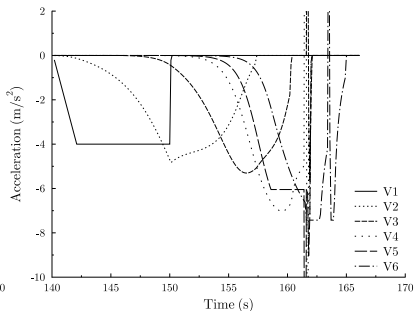


EEBLA

Acceleration Traces

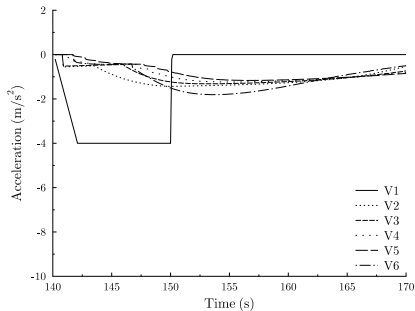


IDM



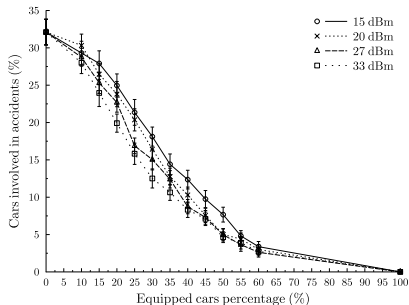
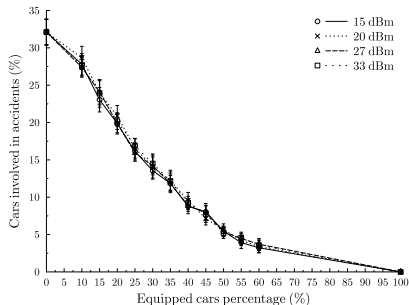
Limited-IDM

Acceleration Traces

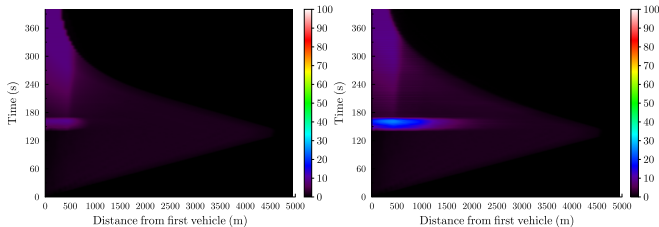


EEBLA

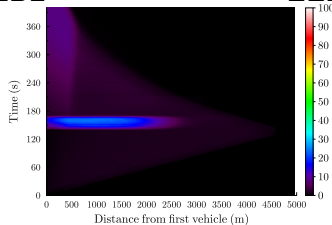
Transmission Power - Application

**EEBL****EEBLA**

Transmission Power - Network - 15 dBm



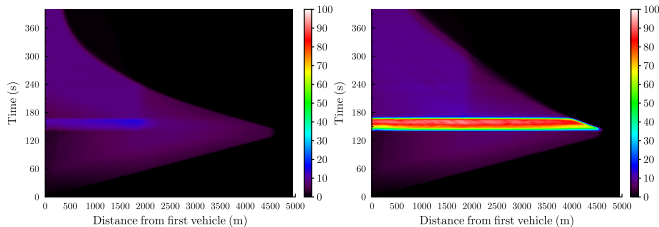
EEBL



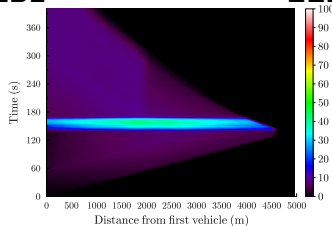
EEBLR

EEBLA

Transmission Power - Network - 37 dBm



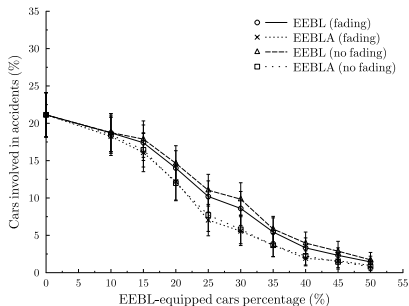
EEBL



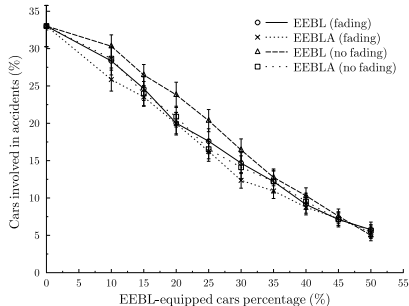
EEBLR

EEBLA

Nakagami Fading - $m = 3$



1 lane



5 lanes