An Efficient Message Dissemination Technique in Platooning Applications

HALMSTAD UNIVERSITY

Le-Nam Hoang, Elisabeth Uhlemann, Magnus Jonsson

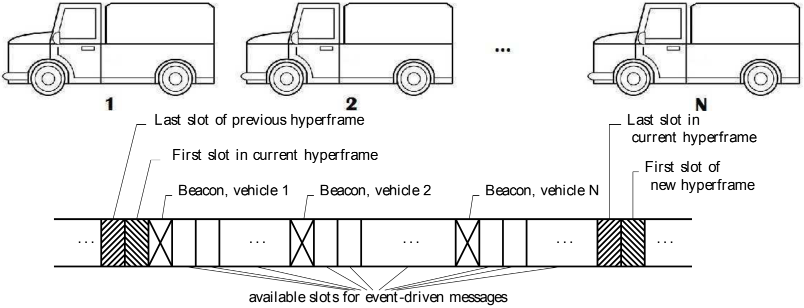
November 13, 2014

INTRODUCTION

- Objective:
  - *Delay*-sensitive data traffics are sent with high *reliability*
  - Considering the *co-existence* of both time-triggered and event-driven control messages
- Current approach:
  - CSMA IEEE 802.11p: unbounded channel access delay and multiple consecutive packet drops
  - Time-triggered messages: congestion control, rate control
  - Event-triggered messages: algorithms to mitigate broadcast storms
  - Collision-free phase together with contention-based phase, using a separate SCH

HALMSTAD UNIVERSITY

System Model



- A platoon consisting of N nodes communicating through an *ad hoc* network, using a separate SCH
- Time is slotted (TDMA) and every packet is transmitted in exactly one time-slot
- In each superframe, a subset of the available time-slots are dedicated to periodic time-triggered messages

System Model (Cont'd)

- Channels between nodes are characterized by an $N \times N$ stationary matrix $\mathbf{P}$
- Each event-driven message is assigned a set of $K+1$ time-slots
- Time-slot 0 is always allocated to the source R_0 and the remaining K time-slots to a set of K *distinct* relayers $R_1, R_2, ..., R_K$
- After overhearing in time-slots numbered $0, 1, \ldots, k-1$, relay R_k will transmit at time-slot k or being quiet
- How to choose an optimal combination of R_k, $i = 1, 2, \ldots, K$?

ANALYTICAL EXPRESSIONS

- Defining

$$e_i = \begin{cases} T & \text{if } R_i \text{ transmits at time-slot } i \\ Q & \text{if } R_i \text{ remains quiet at time-slot } i, \end{cases}$$

- For a specific sequence $\mathbf{e} = \{e_i\}_{i=0}^{K} \in \{T, Q\}^K$, defining

  $\Phi_T(\mathbf{e}) = \{i | e_i = T\}$: the set of time-slots where transmissions occur
  $\Theta_Q(\mathbf{e}) = \{j | e_j = Q\}$: the complimentary set of time slots where the corresponding relay nodes remain quiet

- The probability that the destination cannot receive the packet after K transmission attempts

$$\Pr\{e_{K+1} = Q\} = \sum_{\forall \mathbf{e} \in \{T,Q\}^K} \Pr\{e_{K+1} = Q | \mathbf{e}\} \Pr\{\mathbf{e}\} \quad (1)$$

HALMSTAD UNIVERSITY

ANALYTICAL EXPRESSIONS (CONT'D)

- Applying the chain rule

$$\Pr\left\{\cap_{i=0}^{K} e_i\right\} = \Pr\left\{e_0\right\} \prod_{k=1}^{K} \Pr\left\{e_k \middle| \cap_{i=0}^{k-1} e_i\right\} \tag{2}$$

- in which

$$\Pr\left\{e_k = T \middle| \cap_{i=0}^{k-1} e_i\right\} = 1 - \prod_{\substack{l \in \Phi_T(\mathbf{e}) \\ l<k}} P_{R_l \to R_k}, \tag{3}$$

$$\Pr\left\{e_k = Q \middle| \cap_{i=0}^{k-1} e_i\right\} = \prod_{\substack{l \in \Phi_T(\mathbf{e}) \\ l<k}} P_{R_l \to R_k}. \tag{4}$$

- Assuming that $P_{R_u \to R_l} = 0$ when $l = 0, u < l$

$$\Pr\left\{\mathbf{e}\right\} = \prod_{\substack{\forall l \in \Phi_T(\mathbf{e}) \\ k \in \Theta_Q(\mathbf{e}) \\ k>l}} P_{R_l \to R_k} \left(1 - \prod_{\substack{u \in \Phi_T(\mathbf{e}) \\ u<l}} P_{R_u \to R_l}\right) \tag{5}$$

HALMSTAD UNIVERSITY

ANALYTICAL EXPRESSIONS (CONT'D)

$$\begin{aligned}\Pr\{e_{K+1}=Q\} &= \sum_{\forall \mathbf{e}\in\{T,Q\}^K} \Pr\{e_{K+1}=Q|\mathbf{e}\}\Pr\{\mathbf{e}\} \\ &= \sum_{\forall \mathbf{e}\in\{T,Q\}^K} \prod_{\substack{\forall l\in\Phi_T(\mathbf{e}) \\ k\in\Theta_Q(\mathbf{e})\cup\{K+1\} \\ k>l}} P_{R_l\to R_k}\left(1-\prod_{\substack{u\in\Phi_T(\mathbf{e}) \\ u<l}} P_{R_u\to R_l}\right)\end{aligned} \qquad (6)$$

HALMSTAD UNIVERSITY

NUMERICAL RESULTS

Simulation parameters, $N = 12, D = 20m$

Parameter m in Nakagami-m distribution, $PL = 2.32$

Distance between vehicles (meter)	Parameter m
20	1.94
40 to 60	1.86
80 to 160	0.45
180 to 240	0.32

Description	Value
Transmit Power	20 dBm
Antenna gain	4.5 dB
Cable loss	3.4 dB
Noise floor	−99 dBm
SNR decoding threshold	8 dB

IEEE Std 802.11-2012, *IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, 2012.

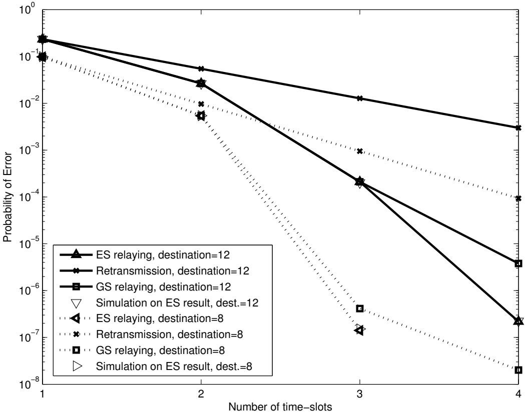
D. Jiang, Q. Chen, and L. Delgrossi, "Optimal data rate selection for vehicle safety communications," in *Proc. ACM Int. Wksp. VANET*, San Francisco, CA, Sep. 2008, pp. 30–38.

L. Cheng, B. E. Henty, D. D. Stancil, F. Bai, and P. Mudalige, "Mobile vehicle-to-vehicle narrow-band channel measurement and characterization of the 5.9 GHz dedicated short range communication (DSRC) frequency band," *IEEE J. Sel. Areas Commun.*, vol. 25, pp. 1501–1516, Aug. 2007.

HALMSTAD UNIVERSITY

NUMERICAL RESULTS (CONT'D)

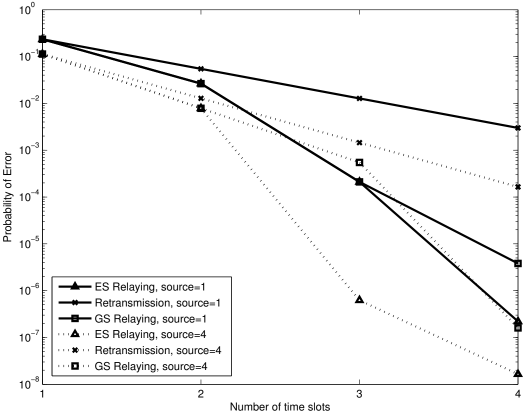
A message that needs to be propagated to a specific receiver



ES = Exhaustive Search, GS = Greedy Search

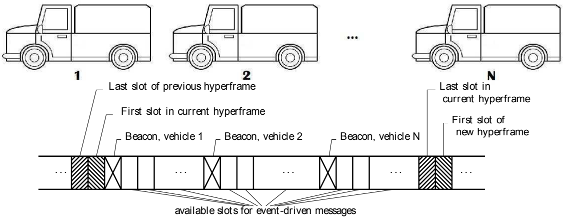
NUMERICAL RESULTS (CONT'D)

A message that originates from one node and needs to be received by the entire platoon, minimising the largest error rate in the platoon



ES = Exhaustive Search, GS = Greedy Search

CONCLUSIONS I



- Provide a centralized TDMA approach where dissemination of event-driven messages is assisted by a set of relay nodes
- Give full analysis on the targeted error probability which also includes the best set of relay nodes for a specific dissemination model

Conclusions II

- Verified by Monte Carlo simulation using the channel model as suggested from literature.
- Evaluate the performance of the proposed scheme, it is useful to determine how a message should be spread within a platoon given a strict time-limit
- Future works
  - Generalize the probability analysis, not only for distinct relayers
  - Consider other channel models instead of using a stationary matrix **P**

HALMSTAD UNIVERSITY

Thank you for your attention

HALMSTAD UNIVERSITY