SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127 "Resilient Communication Services Protecting End-user Applications from Disaster-based Failures" (RECODIS)
STSM title: Resilient communications for safe autonomous platooning
STSM start and end date: 25/02/2020 to 29/02/2020
Grantee name: Alexey Vinel

PURPOSE OF THE STSM:

The focus of this STSM was on the safety analysis of autonomous vehicular platooning. Vehicle-to-infrastructure (V2I) communication is one of platooning enablers. We have focused on the interconnection between the communication resilience and the safety of autonomous vehicles. For prospective infrastructure-based platooning solutions like the ones based on LTE or 5G in particular, which are technologies that are inherently prone to disaster-based failures, it is important to assure the functional safety of the platooning.

This was a continuation of the STSM carried by Daniel Plöger from Hamburg University of Technology to Halmstad University in 2018 and which was the first collaboration experience between these two institutions. The areas of expertise of the research group at the home institution and the host institution complement each other perfectly: the research group at the School of Information Technology, Halmstad University focuses on the data age behavior of vehicular communication standards and networks such as 5G, IEEE 802.11p, and ETSI ITS-G5. On the other hand, the latest research at the Institute of Communication Networks from Hamburg University of Technology analyses the impact of such data age behavior of intra-platoon communication on the reliability of platooning in terms of risk of collision and string stability of connected systems.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

The work was dedicated to the state-of-the-art standardisation activities and research projects in vehicular communications for cooperative automated driving including autonomous platooning.

Alexey Vinel provided an overview of ongoing projects at Halmstad University and presented the work J. Thunberg, N. Lyamin, K. Sjöberg and A. Vinel, "Vehicle-to-Vehicle Communications for Platooning: Safety Analysis," in *IEEE Networking Letters*, vol. 1, no. 4, pp. 168-172, Dec. 2019.

Possible extensions of braking dynamics e.g. more realistic time-dependent deceleration models were considered. Vehicle speed prediction extension of adaptive sensor weighting for PATH CACC were discussed.

To enable further work in this direction the following automotive radar properties are to be figured out:
* Types of distance sensors
* Update Rate
* Sensor output delay
* Accuracy / measurement error distribution

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Daniel Plöger has presented the work
D. Plöger, M. Segata, R. Lo Cigno, and A. Timm-Giel, “Markov-modulated Models to Estimate the Age of Information in Cooperative Driving”, in *10th IEEE Vehicular Networking Conference (VNC 2019)*, Los Angeles, CA, Dec. 2019.

Alexey Vinel suggested to design analytical model for 11p CAM packet losses as function of number of stations, CAM rate and interferer distances.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The development of the analytical model for 11p CAM packet losses as function of number of stations, CAM rate and interferer distances has been started.

Matab script has been prepared to replicate the reference approach from A. Vinel, Y. Koucheryavy, S. Andreev, D. Staehle, “Estimation of a successful beacon reception probability in vehicular ad-hoc networks”, Proceedings of the 2009 international conference on wireless communications and mobile computing: Connecting the world wirelessly.

Following parameters serve as an input to the model:

```
f = 30; % Generation frequency in Hz (CAM/second at ITS-s)
L = 400*8 % CAM length in bits
R = 6e6; % Datarate in bit per seconds (802.11p)

e = 0;     % channel BER (we currently exclude BER)

%802.11 MAC parameters
sig = 13e-6; %aSlottime in seconds
W = 7;     % Contention window
AIFS = 32e-6+2*sig;
EIFS = AIFS;

%Number of vehicles in the network
N=10;

%MAC collision probability p
%MAC access delay [sec]

[p,delay]=MAC11p(N,f,sig,W,e,L,R,AIFS,EIFS)
```

The function MAC11p implements 2-dimensional embedded Markov chain where the first state is the current number of active vehicles and the second state is the situation in the 802.11p channel. It appears to be possible to take into interferer distances by modifying Markov chain transition probabilities of the reference approach.

FUTURE COLLABORATIONS

Prof. Dr. Andreas Timm-Giel and Dr. Koojana Kuladinithi, Hamburg University of Technology, Germany and Prof. Dr. Alexey Vinel, Halmstad University, Sweden will be demo co-chairs for the Conference on Networked Systems (NetSys 2021) to be held in Lübeck, Germany next year. Further interaction with TUHH in terms of future short visits is foreseen.