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Wednesday, April 26

Wednesday, April 26 9:15 - 9:45

O1: Opening

Wednesday, April 26 9:45 - 10:45

K1: Keynote 1

Title: Ford Otosan R&D activities and Details about Vehicle Communication Projects

Chair: Sinem Coleri (Koc University, Turkey)

Wednesday, April 26 10:45 - 11:15

C1: Networking Break

Wednesday, April 26 11:15 - 12:30

S1: Vehicular Network Applications

Chair: Ana C Aguiar (University of Porto & Instituto de Telecomunicações, Portugal)

11:15 ***Efficient Multi-UAV-Aided Communication Service Deployment in Disaster-Resilient Wireless Networks...1***

Shih-Fan Chou (National Taiwan University of Science and Technology, Taiwan); Chen-Yu Yu and Sok-Ian Sou (National Cheng Kung University, Taiwan)

In times of disaster, a flexible and responsive emergency communication network is essential for saving lives and properties, especially after incidents such as hurricanes and floods when terrestrial base stations are not operational. Under such conditions, using Unmanned Aerial Vehicles (UAVs) as aerial base stations is a promising solution due to their agility, mobility, and flexibility. In this work, we deploy multiple UAVs in 3D space with the goal of maximizing total user service time while satisfying users' Quality-of-Service (QoS) requirements. Our proposed method divides the target area into several regions based on the Voronoi Diagram to effectively serve dynamic user distribution. By moving circles in each region, we can discover the optimal placement of service areas. Then, we deploy UAVs to service areas with maximum total service time. Our simulation results demonstrate the effectiveness of our approach in the total service time while fulfilling the QoS requirements of all served users.

11:40 ***EMS-RTC: LSTM-Based Adaptive Video Streaming for Smart Ambulance...9***

Bo-Wen Wang and Wen-Hsuan Shen (National Taiwan University, Taiwan); Ming-Ju Hsieh (National Taiwan University Hospital, Taiwan); Hsin-Mu Tsai (National Taiwan University, Taiwan)

A smart ambulance continuously shares the patient's vital signs data and video feeds from the ambulance so that the doctors stationed in the hospital can work with the paramedics in the ambulance, performing an

early assessment of the patient or even providing treatment guidelines. One prerequisite to the seamless cooperation between the doctor and the paramedics is high-quality video streaming. Video streaming with bad image quality or high latency would introduce significant difficulty in providing accurate diagnoses of the patient. As the video needs to be delivered from a moving ambulance, the streaming performance is influenced by the fast variation of the service quality of the mobile network. Compared to static scenarios, additional channel impairments, such as the shadowing effect, is introduced in the mobile scenarios. In this case, it is crucial that the bitrate of the video streaming can quickly react to the changes of the service quality and is adjusted accordingly, such that the video quality leverages full available bandwidth, but does not exceed what the channel can support. To this end, we propose EMS-RTC, a real-time video streaming platform specialized for the need for ambulance services. EMS-RTC trains a classifier to infer the optimal bitrate based on features from a range of signal- and network-related metrics, collected in real-world driving scenarios. We compare EMS-RTC to a state-of-the-art ABR algorithm (i.e., Google congestion control, GCC). Evaluation results collected from real-world driving scenarios show that EMS-RTC reduces the total time duration of stall events by a factor of 3.85, at the cost of a neglectable reduction of image quality.

12:05 ***Privacy of Smart Traffic Lights Systems...17***

Artur Hermann, Michael Wolf and Natasa Trkulja (Ulm University, Germany); Ines Ben Jemaa (IRT-SystemX, France); Anis Bkakria (IRT System X, France); Frank Kargl (Ulm University, Germany)

Smart traffic lights systems (STLSs) are a promising approach to improve traffic efficiency at intersections. They rely on the information sent by vehicles via C2X communication (like in cooperative awareness messages (CAMs)) at the managed intersection. While there exists a large body of work on privacy-enhancing technologies (PETs) for cooperative Intelligent Transport Systems (cITS) in general, such PETs like changing pseudonyms often impact the performance of cITS applications. This paper analyzes the extent to which different PETs affect the performance of two types of STLSs, a phase-based and a reservation-based STLS. These are implemented in SUMO and combined with four different PETs. Through extensive simulations we then investigate the impact of those PETs on STLS performance metrics like time loss, waiting time, fuel consumption, and average velocity. Our analysis shows that the impact of PETs on performance varies greatly depending on the type of STLS. Finally, we propose a hybrid STLS which is a combination of the two STLS types as a potential solution for limiting the negative impact of PETs on performance.

Wednesday, April 26 12:30 - 14:00

L1: Lunch

Wednesday, April 26 14:00 - 14:45

I1: Invited Talk 1

Title: Connecting Vehicles with Light

Chair: Takamasa Higuchi (Toyota Motor North America R&D, USA)

Abstract: Connected autonomous vehicles boost a high demand on communication bandwidth in order to timely share the information collected by in-car sensors (e.g., LiDAR). While visible light

communication (VLC) presents itself as a possible solution and has shown its potential to offer Gigabit-level throughput for indoor applications, the throughput drops to only a few Mbps when it is moved outdoor. In this talk, I will first present our solution to address the problem - our recent development of an interference-free outdoor mobile VLC system called RayTrack. The key idea is to build a receiver with a small but real-time adjustable FOV tracking the transmitter, which can effectively repel interference from the environment and from other transmitters and boost the system throughput. This realizes virtual point-to-point links, and eliminates the need of link access control. Real-world driving experiments demonstrate that our prototype is capable of tracking the transmitter with over 90% detection accuracy with 70 - 100 km/hr driving speed. I will also demonstrate our preliminary work of a VLC transmitter prototype with steerable transmission. The beam can track the movement of a moving receiver, and does not produce any interference to neighboring vehicles. In the second part of the talk, I will present our work-in-progress vehicle localization system. This latest work leverages a linear light sensor array and a digital headlight to achieve centimeter-level localization accuracy. The implementation is a cost-effective alternative to modern RADAR or LIDAR and can support sensing for various advanced driving assistance system (ADAS) or autonomous driving applications.

Wednesday, April 26 14:45 - 16:00

S2: Security in Vehicular Communications 1

Chair: Susmit Shannigrahi (Tennessee Technological University, USA)

14:45 ***A New Approach to Pseudonym Certificate Management in V2X Communication...25***

Takahito Yoshizawa and Bart Preneel (KU Leuven, Belgium)

This paper proposes a new solution to the pseudonym certificate management and usage in Vehicle-to-Everything (V2X) communication. This solution is a result of our critical analysis of the Issue First Activate Later (IFAL) pseudonym certificate management scheme, which is a leading candidate for ETSI Intelligent Transport System (ITS) standardization. While the IFAL scheme improves over the existing ETSI ITS Security Credential Management System (CCMS) for Europe and the Security Credential Management System (SCMS) for the US, it still has significant issues when real-world deployment is considered. To address these issues, we propose a novel activation scheme that improves the security properties by combining the OAuth concept and Authentication Encryption with Associated Data (AEAD) solution to provide confidentiality and authenticity of data. Our analysis and simulation show that our scheme significantly improves the security properties and efficiency of certificate usage. As a result, our solution is more robust, reliable, and efficient. We propose this solution for adoption in the ETSI ITS specifications.

15:10 ***A4MD: Artery for Misbehavior Detection, Reporting, and Reaction in the ETSI C-ITS...33***

Alexander Willecke (Technische Universität Braunschweig, Germany); Bastian Kulke

(Institute of Operating Systems and Computer Networks, Germany); Lars C Wolf (Technische Universität Braunschweig, Germany)

Messages in Cooperative-Intelligent Transportation Systems (C-ITS) are secured using cryptography to ensure authenticity and authorization. However, this cannot prevent the semantical incorrectness of the message, which can be caused by either faulty sensors or malicious intent. This misbehavior must be detected and mitigated by receiving stations to prevent harm. Further, misbehaving stations need to be sanctioned by informing their manufacturer, owner, or evicting them from the C-ITS to protect other systems proactively. This misbehavior detection management process of detection, reporting, and sanctioning will be part of European and American Intelligent Transportation Systems (ITS). For research in this domain, we propose the Artery 4 Misbehavior Detection (A4MD) framework, building on the Artery V2X simulation framework and Framework for Misbehavior Detection (F2MD) for the European C-ITS. The framework's capabilities are shown by an evaluation of the Misbehavior Reporting protocol proposed in ETSI TR 103 460.

15:35 ***Adaptive Cybersecurity Monitoring for Resilient Vehicular Architectures...41***

Daniel Grimm and Moritz Zink (Karlsruhe Institute of Technology, Germany); Marc Schindewolf (KIT, Germany); Eric Sax (Karlsruhe Institute of Technology, Germany)

The use of new technologies in vehicles, such as automation and connectivity, results in the addition of more software components, which in turn increases the potential vulnerabilities and attack surfaces for the vehicle. To address this, cybersecurity monitoring of vehicle fleets is required to detect and respond to potential cyber threats and vulnerabilities. The aim of this research is to explore a technological approach to fleet monitoring using established IT standards and techniques. The approach involves collecting, filtering, and forwarding cybersecurity information from multiple sources within the vehicle by instrumenting the ROS2-based architecture and integrating these data sources with the log management tool syslog-ng. The logging configuration can be adapted at runtime using a ROS2 interface that we developed. The approach is demonstrated with our fleet simulation setup "Fleet in the Loop" and a sophisticated data collection in a Knowledge Graph. The approach at hand can be used to seamlessly integrate ROS2 in common IT monitoring tools and efficiently increase the resilience of vehicles by integrating adaptive security monitoring.

Wednesday, April 26 16:00 - 16:30

C2: Networking Break

Wednesday, April 26 16:30 - 18:00

S3: Short Papers 1

Chair: Seyhan Ucar (Toyota Motor North America R&D, InfoTech Labs, USA)

16:30 ***An Argument for NDN Bridges in Hierarchical In-Vehicle Networks...49***

Zachariah Threet (Tennessee Tech, USA); Christos Papadopoulos (University of Memphis, USA); Susmit Shannigrahi (Tennessee Technological University, USA)

Current automotive architectures with domain controllers and multiple gateways have grown to be very complex due to the added functionality in modern vehicles. Such architecture leads to the addition of significant weight and cost due to the length of the wires. As autonomous driving and multimedia applications become more ubiquitous, the complexity of such an architecture will increase manyfold.

In this paper, we take the position that a data-centric approach suits future automotive networks better. We also argue that a network or application stack built on top of a point-to-point IP paradigm will likely complicate future automotive networks, especially in security, which has always been an afterthought in TCP/IP. Instead, we propose the use of Named Data Networking (NDN) in conjunction with Vehicle Signal Specification (VSS) for the common substrate that unifies various underlying technologies.

16:45 *An ETSI ITS-Compliant Formation Protocol to Support Long Heterogeneous Platoons...53*

Saeid Sabamoniri (CISTER-ISEP, Polytechnic Institute of Porto, Portugal & Islamic Azad University - Sofian Branch, Iran); Pedro Miguel Santos (CISTER Research Unit - Polytechnic Institute of Porto, Portugal); Luis Almeida (Universidade do Porto & Instituto de Telecomunicações, Portugal)

As penetration of autonomous technology grows, vehicular platooning also becomes a reality with clear benefits on efficiency and traffic management. One can consider that platoons may grow to arbitrary lengths, limited solely by the ability of achieving reliable end-to-end communication. We introduce the Long Heterogeneous Platoon (LHP) protocol, meant to handle very long platoons composed of vehicles with different characteristics and facilities. It creates autonomous sub-units, sub-platoons, that facilitate platoon maneuvers and internal communication. Coordination is achieved by newly proposed ETSI ITS-compliant messages or containers; a key message is the Platoon Management Message. In this paper, we describe the platoon formation and subplatoon creation procedures of the LHP protocol.

17:00 *Application of 10BASE-T1S Ethernet in Delay-Sensitive Vehicular Networks...57*

Jihyeon Min and Youngil Park (Kookmin University, Korea (South))

10BASE-T1S, one of the automotive Ethernets, provides all nodes the transmission opportunity in sequence by using the Physical Layer Collision Avoidance (PLCA) Reconciliation Sublayer (RS) in a half-duplex multidrop mode. However, its maximum delay approaches several milliseconds, and therefore, cannot be used in the time-sensitive communications that require delay of less than a few micro-seconds. In this study, an expanded PLCA algorithm is proposed that assigns a high priority to the time-sensitive packets and transmit them with a small delay by employing the concept of transmission interrupt. An implementation scheme for the proposed algorithm is suggested and the performance is estimated by simulation.

17:15 *Automotive Container Orchestration: Requirements, Challenges and Open Directions...61*

Naresh Nayak and Dennis Grewe (Robert Bosch GmbH, Germany); Sebastian Schildt (Robert Bosch Corporate Research, Germany)

After having changed the landscape of software development and operations in cloud computing, virtualization technologies such as containers have now become a technology of interest for in-vehicular E/E architectures. Packaging software components and all their dependencies into portable containers is promising to simplify the deployments on modern in-vehicle platforms. A key component to distribute and manage containerized applications within a computing system is the orchestrator. As a logically centralized component, it is responsible to deploy, manage and monitor containerized applications and their health state and migrate them if necessary, e.g., in event of failures. However, the design of the existing orchestration solutions, such as Kubernetes (k8s), is mainly driven by cloud or IoT applications, not addressing the requirements of automotive applications such as heterogeneous communication networks or functional safety. In this paper, we discuss the functions of an automotive grade container orchestrator in an in-vehicular network and elicit its requirements. We explore k3s, a specialized orchestration framework for edge computing, and highlight its shortcomings for usage in automotive networks. Finally, we conclude with a set of open challenges and directions towards the development of an automotive grade container orchestrator.

17:30 *Context-Aware Reinforcement Learning for Supporting WiFi Connectivity for Connected Vehicles...65*

Mushahid Hussain (University of Porto, Portugal); Felipe M. G. França (Universidade Federal do Rio de Janeiro, Brazil); Ana C Aguiar (University of Porto & Instituto de Telecomunicações, Portugal)

The continuously rising number of mobile users and applications drives spectrum scarcity. Wi-Fi connectivity can help to reduce the load on cellular networks in urban areas even for slow moving commuters if supported by adequate network management. This research explores reinforcement learning from context and network data to deal with the stochastic and dynamic nature of WiFi and provide continuous connectivity to a moving vehicle. We formulate the access point handoff problem as a Markov Decision Process (MDP) and solve it using a Deep Q Network (DQN) applied to a real-world dataset. The observed pattern of learning in preliminary results indicates that the agent can learn from the real world dataset.

17:45 *Evaluating Intent Sharing Communication Using Real Connected Vehicles...69*

Hao M. Wang (University of Michigan, USA); Sergei Avedisov and Onur Altintas (Toyota Motor North America R&D, InfoTech Labs, USA); Gábor Orosz (University of Michigan, USA)

In this paper we experimentally evaluate intent sharing, an emerging vehicle-to-everything (V2X) communication class that allows vehicles to share their intended future motion. Using commercially available radios, we implement intent sharing messages according to two different realizations of vehicle intent: (i) bounds of kinematic variables over a time horizon; (ii) expected trajectory specified as target road segments. We test intent messages using real vehicles on highways both in rural and urban environments. The collected data is used to evaluate the performance in terms of packet delivery ratio. Furthermore, using numerical simulations, we reveal the benefits of intent sharing in resolving conflicts during cooperative maneuvers and investigate the effects of packet delivery ratio on the gained benefits.

Thursday, April 27

Thursday, April 27 8:30 - 9:30

K2: Keynote 2

Title: V2X Deployment in Europe - Challenges and Opportunities

Chair: Onur Altintas (Toyota Motor North America R&D, InfoTech Labs, USA)

Thursday, April 27 9:30 - 10:45

S4: Simulation & Modeling

Chair: Michele Segata (University of Trento, Italy)

9:30 *Free-Floating Micro-Mobility Smart Redistribution Using Spatio-Temporal Demand Forecasting...73*

Zeineb El khalfi (LINEACT CESI & Campus de Bordeaux, France); Imen Jemili (Faculty of Sciences of Bizerte, University of Carthage & HANA Research Group, University of Mannouba, Tunisia); Mohamed Mosbah (CNRS-LaBRI UMR 5800, University Bordeaux, Bordeaux-INP, France); Rania Swessi (University of Carthage, Tunisia)

Micro-mobility refers to a variety of small and lightweight vehicles designed for individual use. These new vehicles are inexpensive, simple to operate and enjoyable to ride, making them the easiest and most suitable mode of transportation for trips of less than five miles. They have become extremely popular, especially with the advent of free-floating systems that offer users flexible parking in order to facilitate the rental process. However, the problem of imbalance and maldistribution is among the major challenges of these systems, causing dissatisfaction and customer loss. Therefore, to ensure the balancing of the fleet and to make the best decision for its reorganization, we must consider strategic locations that are accessible to all. In this paper, we propose a machine learning model for spatio-temporal demand forecasting using a multi-output regression technique. The main goal of the paper is to help to pick the ideal areas for fleet deployment and balance the system according to user needs. Our solution, designed for public electric scooters, is based on the estimation of user demand over a grid-based service area. In addition, we propose an enhanced solution that outperforms other baseline models, including the Random Forest, Gradient Boosting, and Stacking Regressor.

9:55 *Simulation of Tele-Operated Driving over 5G Using CARLA and OMNeT++...81*

Valerio Cislaghi (University of MIlan, Italy); Christian Quadri (Università degli Studi di Milano, Italy); Vincenzo Mancuso and Marco G Ajmone Marsan (IMDEA Networks Institute, Spain)

Tele-Operated Driving (ToD) allows a remote operator to drive a vehicle through the services provided by a mobile network. ToD can replace on-board driving in many different occasions, such as dangerous environments, but can also provide assistance to autonomous driving systems in difficult and unexpected situations. ToD is a bandwidth-demanding and latency-sensitive service, which requires transmitting a large

amount of sensor data from vehicle to operator, and driving instructions from operator to vehicle. The data exchange must comply with strict real-time requirements. The low latency and high bandwidth offered by 5G Radio Access Networks (RANs) open new opportunities for an effective deployment of ToD services in different contexts. However, the rapidly changing channel quality and network conditions can raise many challenges in meeting bandwidth and latency requirements.

In this paper, we report on the development of an elaborate simulation framework combining the realism of vehicle dynamics simulated by CARLA and the detailed network models provided by OMNeT++. We demonstrate the capabilities of the simulation framework by describing results about the feasibility of ToD services in a simple scenario under different network and application configurations. We simulate the implementation of the ToD service in a slice of a 5G RAN, with varying application and network parameters, also considering a variable amount of background traffic. Our simulation results show that the ToD service performance is heavily impacted by the amount and shape (i.e., the selected 5G NR numerology) of radio resources allocated to the 5G slice.

10:20 *Towards Net-Zero Goal Through Altruistic Prosumer Based Energy Trading Among Connected Electric Vehicles...89*

Ferheen Ayaz and Maziar Nekovee (University of Sussex, United Kingdom (Great Britain))

The motivation to protect environment and reduce CO2 emissions has resulted in increase in number of electric vehicle (EV) users. However, the rising number of EVs leads to increasing electricity demands and aggravates the burden on existing energy distribution systems. Therefore, the distributed energy systems, where consumers can also sell their surplus energy are required to overcome the potential challenges of high energy demands predicted in future. Furthermore, the consumers are now inclined towards buying energy from a renewable source to reduce environmental damage. Therefore, the sellers willing to contribute towards environmental sustainability also need to be encouraged to generate energy at a small scale through renewable sources and offer them at cheap prices. This paper proposes an energy trading system where both EVs and immobile users, such as houses and buildings, act as prosumers. They can buy or sell energy for both monetary incentives as well as for altruistic aim of environmental sustainability. A 5G-enabled aggregator is proposed to manage the energy trading system through blockchain and smart contracts for maintaining security and immutability in transactions and verify energy sources. Stackelberg non-cooperative and cooperative games are formulated to strategize incentives of prosumers reflecting both altruism and monetary incentives. Complexity analysis and probabilistic calculations are performed to theoretically analyze the proposed system. Simulation results show more than 90% and 60% successful energy transactions when only seller is EV and when both buyers and sellers are EVs, respectively.

Thursday, April 27 10:45 - 11:15

C3: Networking Break

Thursday, April 27 11:15 - 12:30

S5: Vehicular Edge Computing

Chair: Raphael Frank (University of Luxembourg, Luxembourg)

11:15 ***A Novel Design for Advanced 5G Deployment Environments with Virtualized Resources at Vehicular and MEC Nodes…97***

Angelo Feraudo, Alessandro Calvio, Armir Bujari and Paolo Bellavista (University of Bologna, Italy)

IoT and edge computing are profoundly changing the information era, bringing a hyper-connected and context-aware computing environment to reality. Connected vehicles are a critical outcome of this synergy, allowing for the seamless interconnection of autonomous mobile/fixed objects, giving rise to a decentralized vehicle-to-everything (V2X) paradigm. On this front, the European Telecommunications Standards Institute (ETSI) proposed the Multi-Access Edge Computing (MEC) standard, addressing the execution of cloud-like services at the very edge of the infrastructure, thus facilitating the support of low-latency services at the far-edge. In this article, we go a step further and propose a novel ETSI MEC-compliant architecture that fully exploits the synergies between the edge and far-edge, extending the pool of virtualized resources available at MEC nodes with those found at both fixed and mobile nodes in the vicinity. In particular, our approach allows vehicle owners to access and partake in reward(s) schemes, by addressing resource volatility as vehicles join and leave the resource pool. To demonstrate the viability and flexibility of our proposed approach, we have built an ETSI MEC-compliant simulation model, which could be tailored to distribute application requests based on the availability of both local and remote resources, also managing their transparent migration and execution. In addition, the paper reports on the experimental validation of our proposal in a 5G network setting, contrasting different service delivery modes, by highlighting the potential of the dynamic exploitation of far-edge vehicular resources.

11:40 ***Data Sharing in Virtual Edge Computing Using Coded Caching…104***

Gurjashan Singh Pannu (TU Berlin, Germany); Seyhan Ucar (Toyota Motor North America R&D, InfoTech Labs, USA); Takamasa Higuchi (Toyota Motor North America R&D, USA); Onur Altintas (Toyota Motor North America R&D, InfoTech Labs, USA); Falko Dressler (TU Berlin, Germany)

Multi-access edge computing (MEC) has been identified as a powerful concept for offloading computational tasks and for storing popular data in close proximity of end users; avoiding frequent communication to a back-end cloud server. In the context of vehicular applications, similar functionality can be provided by vehicles collaboratively offering storage and computational resources on-board, i.e., a virtual MEC concept. Data management in a virtual edge is particularly challenging due to the high degree of mobility. Coded caching is a concept to store data on distributed systems in form of fragments. When needed, these fragments are transmitted to the requesting node in a coded form so that the total number of transmissions is reduced (i.e., optimizing for reduced download times and reduced resource utilization). In this paper, we introduce a new protocol for data sharing among vehicles participating in virtual edge computing using coded caching. Our results show that coded caching improve the efficiency of data sharing by up to 50% in a virtual edge computing environment.

12:05 ***Edge-Assisted Service Allocation and Delivery for Connected Vehicles with Variable Velocities…112***

Yi Hung, Liang-Kuan Chou, Hsu-Huai Tsai, Hsi-Chuang Wang and Chung-Wei Lin (National Taiwan University, Taiwan); BaekGyu Kim (DGIST, Korea (South))

Edge computing can support many services, such as driving assistance, autonomous driving, high-definition mapping, and entertainment, to connected vehicles. Compared with cloud computing, edge computing provides lower latency and better locality, but its more distributed architecture needs a delicate design to deliver services to moving vehicles at the right time at the right place. In this paper, we focus on service allocation and delivery at edge servers, featuring vehicles with variable but bounded velocities as well as shared services with timing and freshness constraints. To solve the problem, we propose two types of diagrams to encode the timing when services should be allocated to edge servers to satisfy the requests generated by vehicles. We then develop an approach which iteratively selects requests, allocates services, updates the status of requests, and refines solutions. One novel feature of the approach is that, if there is no feasible solution, the approach computes and suggests the velocities of vehicles so that vehicles can follow the suggestions to slow down and guarantee to receive the services. Experimental results demonstrate the effectiveness and the real-time applicability of the approach with different methods for request selection and service allocation.

Thursday, April 27 12:30 - 13:45

L2: Lunch

Thursday, April 27 13:45 - 14:30

I2: Invited Talk 2

Title: Sensing with Communication Signals: Protecting Privacy, and Perspectives for Cooperative Perception

Chair: Michele Segata (University of Trento, Italy)

Abstract: Joint communication and sensing (JCS) received a lot of attention in the past ten years or so, specially with regard to people localization and activities. As AI signal analysis techniques evolved, the opportunities for a new generation of personalized services emerged and attracted the attention of standardization bodies, so that it is now a staple for both 6G and evolved Wi-Fi systems. What instead received far less attention is the unprecedented threat to people privacy, security and safety that this technology poses, as the sensitive information is embedded within the physical signal and cannot be protected with any cryptographic means, nor can it be removed from the signal as it is imprinted during the propagation. This talk will make the point in the state of the art of JCS, quickly discussing the different methodologies that have been proposed and the real understanding we have of the phenomenon. Then it will tackle the possible countermeasures that our group and few others have proposed to obfuscate the information imprinted by the environment in the signal to prevent illegitimate sensing. Finally, it will discuss the research challenges the community has to tackle to exploit JCS for cooperative perception in vehicular and smart mobility scenarios.

Thursday, April 27 14:30 - 14:45

C4: Networking Break

Thursday, April 27 14:45 - 16:25

S6: Cooperative Driving

Chair: Lars C Wolf (Technische Universität Braunschweig, Germany)

14:45 ***Cooperative Perception Based on Intent Sharing Messages…120***

Sergei Avedisov (Toyota Motor North America R&D, InfoTech Labs, USA); Ahmed Hamdi Sakr (University of Windsor, Canada); Takamasa Higuchi (Toyota Motor North America R&D, USA); Onur Altintas (Toyota Motor North America R&D, InfoTech Labs, USA)

This paper proposes and investigates the concept of intent-based cooperative perception (IBCP) for connected vehicles. In IBCP, a connected ego vehicle shares its intended path and maneuver with remote connected road users, e.g., other connected vehicles and infrastructure. The remote road users then process the intent of the ego vehicle and use their on-board sensors to detect critical road users which may come into conflict with the ego vehicle. Once a potential conflict is detected, the remote road users send a notification to share information about the critical road users with the ego vehicle. IBCP supplements traditional cooperative perception in which messages are sent at a periodic rate without distinguishing critical road users from other detected objects. In IBCP, conflicts between connected vehicles and critical road users are anticipated so that the connected vehicles can react in advance. We use experimental data and simulation to evaluate the benefits of the proposed protocol compared to the non-cooperative case for an ego vehicle making a left turn through an intersection with an occlusion.

15:10 ***Evaluating Protocols for Cooperative Maneuvers Among Connected and Automated Vehicles…128***

Bernhard Häfner (Technical University of Munich & BMW Group, Germany); Jörg Ott (Technische Universität München, Germany); Georg Schmitt (BMW Group, Germany)

Future automated vehicles will also cooperatively perform maneuvers. Researchers have recently proposed diverse application-layer protocols to enable such cooperative maneuvers via vehicle-to-everything communication. However, every study uses its own set of metrics, making the results hard to compare. In this paper, we propose a framework comprising existing and new metrics for cooperation protocols that enables researchers to examine their protocols in comparable ways. Some of them are based on simulation, others on real-world implementation. We also evaluate two example protocols according to the framework to show its applicability. We hope to initiate a discussion on relevant and suitable metrics for cooperation protocols and to contribute to making future research on cooperation protocols more objectively comparable.

15:35 *On the Coexistence of Maneuver Coordination Service with Use-Case Specific Applications...136*

Edmir Xhoxhi and Shule Li (Leibniz Universität Hannover, Germany)

Cooperative Autonomous Vehicles (CAVs), like their human-driven counterpart, need to coordinate their maneuvers with other traffic participants in order to increase comfort and traffic efficiency. The development and standardization of the Maneuver Coordination Service (MCS) aim to offer CAVs these capabilities. Meanwhile, there are also other applications which are being developed that will allow vehicles to coordinate maneuvers for specific use cases, i.e. Cooperative Adaptive Cruise Controller, Platooning Application or Cooperative Lane Change Assistance. In this work we extend MCS so that it supports the coordination and negotiation needed by these applications, without being intrusive in the existing structure of the Maneuver Coordination Message. Furthermore we also propose an on-demand message generation rule combined with a keep-alive function for MCS. We implement the proposed service and test it on a highway merging scenario. The results show that with this method we have a more efficient channel usage, higher position tracking accuracy and successful merging rate.

16:00 *On the Feasibility of RIS-Enabled Cooperative Driving...143*

Michele Segata and Paolo Casari (University of Trento, Italy); Marios Lestas (Frederick University, Cyprus); Dimitrios Tyrovolas (Aristotle University of Thessaloniki & Technical University of Chania, Greece); Taqwa Saeed (Halmstad University, Sweden); George K. Karagiannidis (Aristotle University of Thessaloniki, Greece); Christos Liaskos (University of Ioannina, Greece & Foundation of Research and Technology Hellas, Greece)

Future cooperative autonomous vehicles will require high performance communication means to support functions such as cooperative maneuvering and cooperative perception. Such high-bandwidth needs find a natural solution in mmWave communications, but the harsh conditions typical of vehicular environments easily cause signal blockage, making it especially difficult to establish reliable channels. One solution is the use of reconfigurable intelligent surfaces (RISs), a technology that permits the reflection of signals towards a configurable direction. So far, RISs have been envisaged mainly for mmWave communications in cellular networks, but they have recently gained attention in the vehicular domain as well. In this paper we provide an initial feasibility study, showing what are the challenges ahead and the performance required by RISs to enable this type of communication. We do so with the help of CoopeRIS, a simulation framework for RISs integrated in the Plexe/Veins/SUMO ecosystem that we developed and that we plan to release to the public.

Thursday, April 27 16:25 - 18:00

D1: Poster / Demo

Poster: A Case for Heterogenous Co-Simulation of Cooperative and Autonomous Driving...151

Tobias Hardes (Technische Universität Dresden, Germany & Paderborn University /

suggest utilizing ultra-wide-band outdoor localization to detect cyclists and motorcyclists in blind spots. Our proposed method provides a cost-effective solution that does not require additional hardware, as we assume that vulnerable users' mobile phones can support UWB communication. In this demo, we both show simulation results comparing different localization techniques and architect a simple test-bed using COTS hardware supporting UWB links with Android devices.

Demo: Vehicular Micro Cloud Assisted Collaborative High-Definition Map Downloading...177

Seyhan Ucar (Toyota Motor North America R&D, InfoTech Labs, USA); Takamasa Higuchi (Toyota Motor North America R&D, USA); Onur Altintas (Toyota Motor North America R&D, InfoTech Labs, USA)

Vehicular Micro Cloud (VMC) is a group of connected vehicles where they collaborate over vehicular networks. One potential use case of a VMC is a collaborative downloading service in which vehicles download data contents from a remote server and form VMCs to share them with other vehicles. In this paper, we study the feasibility of collaboratively downloading high-definition (HD) maps among VMC members. We demonstrate the benefits through field trials with multiple test vehicles. Our outdoor experiments showed that VMC-assisted collaborative downloading could reduce the communication overhead associated with HD map updates.

Thursday, April 27 18:30 - 21:00

B1: Banquet

Friday, April 28

Friday, April 28 8:30 - 9:30

K3: Keynote 3

Title: Wireless Systems for Sustainable and Active Mobility

Chair: Sinem Coleri (Koc University, Turkey)

Friday, April 28 9:30 - 10:45

S7: Short Papers 2

Chair: Sergei Avedisov (Toyota Motor North America R&D, InfoTech Labs, USA)

9:30 ***FraST: Frankfurter Kreuz SUMO Traffic Scenario...179***

Alexander Willecke, Keno Garlichs, Fynn Schulze and Lars C Wolf (Technische Universität Braunschweig, Germany)

Various traffic scenarios, whether synthetic or realistic, have been published for the traffic simulator

SUMO. Many realistic scenarios containing various traffic situations were used in simulation studies on Cooperative-Intelligent Transportation Systems applications, such as Cooperative Awareness and Collective Perception. However, new applications like Maneuver Coordination (MC) are used in different traffic situations, like on-ramp merging and high-speed overtaking, which are not the focus of present realistic scenarios. To facilitate research in the field of MC, we present and showcase the Frankfurter Kreuz SUMO Traffic (FraST) scenario in this paper. This scenario models highway intersections according to actual usage statistics, presenting a challenging environment for MC.

9:45 ***Machine Learning Aided NR-V2X Quality of Service Predictions...183***

Aslihan Reyhanoglu, Feyzi Ege Kumec, Yahya Sukur Can Kara, Emrah Kar, Bugra Turan and Sinem Coleri (Koc University, Turkey); Sercan Karaagac (Ford Otosan, Turkey)

Vehicle-to-Everything Communication (V2X) technologies aim to meet strict quality-of-service (QoS) requirements of vehicular connectivity applications such as safety message exchange, remote driving, and sensor data sharing. The high reliability requirement is particularly important to enable safety relevant applications. Thus, predicting QoS levels becomes key to ensure the reliability of the connected vehicle applications. Recently, machine learning (ML) algorithms are demonstrated to provide dependable predictions to plan, simulate, and evaluate the performance of vehicular networks. In this paper, we propose ML aided NR-V2X QoS predictions scheme to provide Packet Delivery Ratio (PDR) and throughput predictions with the input of Modulation and Coding Schemes (MCS), distance-to-base station, Signal to Interference plus Noise Ratio (SINR), and packet size. Seven different ML algorithms based prediction models are trained and evaluated by using NR-V2X simulation data. We provide performance comparisons between Support Vector Regression (SVR), Deep Neural Network (DNN), Random Forest (RF), Gradient Boosting Machine (GBM), Extreme Gradient Boosting (XGBoost), Categorical Boosting (CatBoost), and Light GBM (LGBM) for predicting throughput and PDR. We demonstrate that CatBoost and RF are the best performing algorithms to predict throughput and PDR of NR-V2X networks, respectively.

10:00 ***On Time Constraints for Internet-Connected Multi-User Real-Time Traffic Simulation...187***

Marie-Christin H. Oczko and Lukas Stratmann (TU Berlin, Germany); Florian Klingler (TU Ilmenau & Paderborn University, Germany); Falko Dressler (TU Berlin, Germany)

In recent years, the inclusion of vulnerable road users (VRUs) such as bicyclists in road traffic systems has become a topic of general interest. However, the development and testing with humans in the loop are complicated. Co-simulation of cyclists on a training stand together with road traffic and vehicular networking simulation helps to get more insights into traffic interactions. This approach is currently limited as that only one real-time cycling stand can be supported. Therefore, we extend a centralized intelligent transportation systems (ITS) simulation to allow multiple real-time users simultaneously. We developed an architecture building upon new extrapolation and convergence algorithms to deal with communication lags. Our proof-of-concept for internet-connected multi-user real-time simulation confirms the general feasibility and allows us to gain insights into its technical limitations.

10:15 ***Remote Vehicular Micro Clouds...191***

Seyhan Ucar (Toyota Motor North America R&D, InfoTech Labs, USA); Takamasa

Higuchi (Toyota Motor North America R&D, USA); Onur Altintas and Kentaro Oguchi (Toyota Motor North America R&D, InfoTech Labs, USA)

Vehicular Micro Cloud (VMC) is a group of connected vehicles where vehicles collaborate on tasks through vehicular networks. The formation strategy of VMC generally relies on local communication in which the first vehicle (i.e., the micro cloud leader) communicates with other nearby cars (i.e., micro cloud members) and forms the VMC. Such a forming strategy is practical, but it may limit the benefits of VMC. Micro cloud leaders must be in the communication range of other vehicles to form VMCs and lead the collaboration. However, in some situations, there may be a need to initiate micro clouds remotely. In this paper, we focus on remote VMCs. In remote VMCs, micro cloud leaders can form VMCs at remote locations and lead the collaboration remotely. We test the feasibility of remote VMCs through a simulation study in a risk reasoning use case. Extensive simulations demonstrate that remote VMCs could help vehicles to reduce collision risk.

10:30 *SuperDriverAI: Towards Design and Implementation for End-To-End Learning-Based Autonomous Driving…195*

Shunsuke Aoki (National Institute of Informatics, Japan); Issei Yamamoto, Daiki Shiotsuka, Yuichi Inoue, Kento Tokuhiro and Keita Miwa (TURING, Japan)

Fully autonomous driving has been widely studied and is becoming increasingly feasible. However, such autonomous driving has yet to be achieved on public roads, because of various uncertainties due to surrounding human drivers and pedestrians. In this paper, we present an end-to-end learning-based autonomous driving system named \textit{SuperDriver AI}, where Deep Neural Networks (DNNs) learn the driving actions and policies from the experienced human drivers and determine the driving maneuvers to take while guaranteeing road safety. In addition, to improve robustness and interpretability, we present a \textit{slit model} and a visual attention module. We build a data-collection system and emulator with real-world hardware, and we also test the SuperDriver AI system with real-world driving scenarios. Finally, we have collected 150 runs for one driving scenario in Tokyo, Japan, and have shown the demonstration of SuperDriver AI with the real-world vehicle.

Friday, April 28 10:45 - 11:15

C5: Networking Break

Friday, April 28 11:15 - 12:30

S8: Security in Vehicular Communications 2

Chair: Takahito Yoshizawa (KU Leuven, Belgium)

11:15 *Comparative Evaluation of PKI and DAA-Based Architectures for V2X Communication Security…199*

Anna Angelogianni (University of Piraeus, Greece); Ioannis Krontiris (Huawei Technologies, Germany); Thanassis Giannetsos (Ubitech Ltd., Greece)

The emerging Cooperative Intelligent Transportation Systems (C-ITS) landscape is expanding in terms of security and trust requirements, to provide the necessary enablers for the safety of critical operations (i.e., collision avoidance). To this extend, Public Key Infrastructure (PKIs) and Direct Anonymous Attestation (DAA) schemes have been proposed by the literature, in order to provide authenticity over the exchanged messages. DAA schemes can help address several challenges of centralized PKIs by offering a more scalable solution for pseudonym certificate reloading and revocation. This paper is the first to implement a DAA-based solution and then do a methodological comparison of the two schemes side-by-side based on an experimental evaluation. The acquired results do not directly dictate one prevailing solution, but rather suggest the need for an integrated approach converging concepts from both schemes, in order to better accommodate the needs of future C-ITS systems.

11:40 *Source Linking Framework in Vehicular Networks for Security of Electric Vehicles Using Machine Learning...207*

Farzan Majeed Noori (University of Oslo, Norway); Azeem Hafeez (University of Michigan - Dearborn, USA); Hafiz Malik (University of Michigan, USA); Md Zia Uddin (SINTEF Digital, Norway); Jim Tørresen (University of Oslo, Norway)

Fully connected autonomous vehicles are more vulnerable than ever to hacking and data theft. The controller area network (CAN) protocol is an effective means of communication between in-vehicle control networks. However, the absence of basic security features of this protocol, like message authentication, makes it quite vulnerable to a wide range of attacks including spoofing attacks. As traditional cyber-security methods impose limitations in ensuring confidentiality and integrity of transmitted messages via CAN bus, a new technique has emerged among others to approve its reliability in fully authenticating the in-vehicle communication messages. At the physical layer of the communication system, the method of fingerprinting the messages is being implemented to connect the received signal to the transmitting Engine Control Unit (ECU). This paper introduces a new method to enhance the security of modern fully autonomous electric vehicles. Errors due to digital to analogue converter (DAC) are used to estimate ECU specific distortion distributions, which are utilized for transmitting node identification. A dataset collected from a CAN network with seven ECUs is used to evaluate the efficient performance of the suggested method. The experimental results indicate that kNNs achieved the 99.2% accuracy in ECU detection and outperformed the rest of the classifiers.

12:05 *Feasibility and Benchmarking of Post-Quantum Cryptography in the Cooperative ITS Ecosystem...215*

Brigitte Lonc (IRT SystemX, France); Alexandre Aubry (Stellantis, France); Hafeda Bakhti (Atos, France); Maria Christofi (Oppida, France); Aissaoui-Mehrez Hassane (Mines-Telecom Institute - Telecom-Paris - Institut Polytechnique de Paris, France & Laboratoire Traitement Et Communication de l'Information Paris Saclay (LTCI), France)

Localized communication between vehicles and their surrounding environment (V2X) is a key technology to enable Cooperative Intelligent Transportation Systems (C-ITS) aiming at road safety, traffic flow and driving comfort. Security services based on Elliptic Curve Cryptography (ECC) for authenticity and confidentiality (mostly application-dependent) have been chosen to meet the hard constraints of low latency safety

communications and limited bandwidth radio communication in dense traffic conditions. Due to threats raised by Quantum Computers (QC), the classical asymmetric cryptographic algorithms could be broken impacting the Public Key Infrastructure (PKI)-based security solutions, with negative safety consequences on the (semi)-autonomous vehicles and road users. Our project (TAM: Trusted Autonomous Mobility) [18] is focusing on end-to-end cybersecurity and privacy for innovative services in the field of cooperative, connected and automated mobility (CCAM). TAM's main objective is to find suitable quantum safe schemes to replace the current cryptographic standards based on ECC which are used in V2X communications.
After defining the main requirements and key performance indicators for C-ITS, a benchmarking of current NIST pre-standards PQC algorithms was performed to assess the feasibility and performances in C-ITS applications and based on the results a best fit solution is selected.

Friday, April 28 12:30 - 14:00

L3: Lunch

Friday, April 28 14:00 - 15:00

P1: Panel

Title: Edge Computing - what role will it play in V2X communication?

Friday, April 28 15:00 - 15:30

C6: Networking Break

Friday, April 28 15:30 - 16:45

S9: In-vehicle Communications

Chair: Renato Lo Cigno (University of Brescia & CNIT - Consorzio Nazionale Interuniversitario Telecomunicazioni, Italy)

15:30 ***Assessing the Impact of Attacks on an Automotive Ethernet Time Synchronization Testbed...223***

Alessio Buscemi, Mahdi Fotouhi and Abdelwahab Boualouache (University of Luxembourg, Luxembourg); Christian Köbel (Honda R&D Europe, Germany); Florian Jomrich (Honda R&D Europe Germany, Germany); Thomas Engel (University of Luxemburg, Luxembourg)

Time Sensitive Network (TSN) standards are gaining traction in the scientific community and automotive Original Equipment Manufacturers (OEMs) due their promise of deterministic Ethernet networking. Among these standards, Generalized Precision Time Protocol (gPTP) - IEEE 802.1AS - allows network devices to be synchronized with a precision far higher than other Ethernet synchronization standards like Network Time Protocol (NTP). gPTP is a profile of Precision Time Protocol (PTP) which, due to its robustness to delay variations, has been designated for automotive applications. Nonetheless, gPTP was designed without security controls, which makes it vulnerable to a number of attacks. This work reveals a critical vulnerability

caused by a common implementation practice that opens the door to spoofing attacks on gPTP. To assess the impact of this vulnerability, we built two real gPTP-capable testbeds. Our results show high risks of this vulnerability destabilizing the system functionality.

15:55 ***Authenticated and Secure Automotive Service Discovery with DNSSEC and DANE…231***

Mehmet Mueller, Timo Häckel, Philipp Meyer, Franz Korf and Thomas C. Schmidt (Hamburg University of Applied Sciences, Germany)

Automotive softwarization is progressing and future cars are expected to operate a Service-Oriented Architecture on multipurpose compute units, which are interconnected via a high-speed Ethernet backbone. The AUTOSAR architecture foresees a universal middleware called SOME/IP that provides the service primitives, interfaces, and application protocols on top of Ethernet and IP. SOME/IP lacks a robust security architecture, even though security is an essential in future Internet-connected vehicles. In this paper, we augment the SOME/IP service discovery with an authentication and certificate management scheme based on DNSSEC and DANE. We argue that the deployment of well-proven, widely tested standard protocols should serve as an appropriate basis for a robust and reliable security infrastructure in cars. Our solution enables on-demand service authentication in offline scenarios, easy online updates, and remains free of attestation collisions. We evaluate our extension of the common vsomeip stack and find performance values that fully comply with car operations.

16:20 ***On the Resilience of Machine Learning-Based IDS for Automotive Networks…239***

Ivo Zenden, Han Wang and Alfonso Iacovazzi (RISE Research Institutes of Sweden, Sweden); Arash Vahidi (RISE Research Institutes of Sweden & Volvo Cars Corp, Sweden); Rolf Blom and Shahid Raza (RISE Research Institutes of Sweden, Sweden)

Modern automotive functions are controlled by a large number of small computers called electronic control units (ECUs). These functions span from safety-critical autonomous driving to comfort and infotainment. ECUs communicate with one another over multiple internal networks using different technologies. Some, such as Controller Area Network (CAN), are very simple and provide minimal or no security services. Machine learning techniques can be used to detect anomalous activities in such networks. However, it is necessary that these machine learning techniques are not prone to adversarial attacks.

In this paper, we investigate adversarial sample vulnerabilities in four different machine learning-based intrusion detection systems for automotive networks. We show that adversarial samples negatively impact three of the four studied solutions. Furthermore, we analyze transferability of adversarial samples between different systems. We also investigate detection performance and the attack success rate after using adversarial samples in the training. After analyzing these results, we discuss whether current solutions are mature enough for a use in modern vehicles.

Friday, April 28 16:45 - 17:00

O2: Closing