INTERCONNECTING PEDESTRIANS, BICYCLE AND SCOOTER DRIVERS WITH CARS

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ABSTRACT

While developing new mobility services (autonomous driving, electromobility, multimodal transport) it is important to address the risks of vulnerable road users by specific measures to foster the comfort and safety of the vehicles selected by VRUs. Pedestrian, bicycle and scooter traffic (referred to as VRU which stands for Vulnerable Road User in ITS terminology) play an essential role in achieving the transition to low emission mobility and the associated climate goals.

In recent years, many new Advanced Driver Assistance Systems (ADAS) have been developed in the automotive industry. Some of these systems would prove even more valuable if available for Vulnerable Road Users (VRU), e.g. Green Light Optimized Speed Advisory (GLOSA), Approaching Emergency Vehicle (AEV), or collision warning.

Based on the ETSI standardization for Cooperative Intelligent Transport Systems (C-ITS) with the focus on vulnerable Road Users (VRUs), projects interconnect passenger vehicles and elements of the traffic infrastructure (traffic lights, St. Andrew's crosses) with vulnerable road users using VRU awareness basic services [1], so that they can optimize their movement and get to their destination safely and comfortably.

Leveraging this technology Continental provides a collision warning service to improve the safety of VRUs (Vulnerable Road Users), while T-Systems provides a traffic light prediction service to bikes and passenger vehicles (GLOSA).

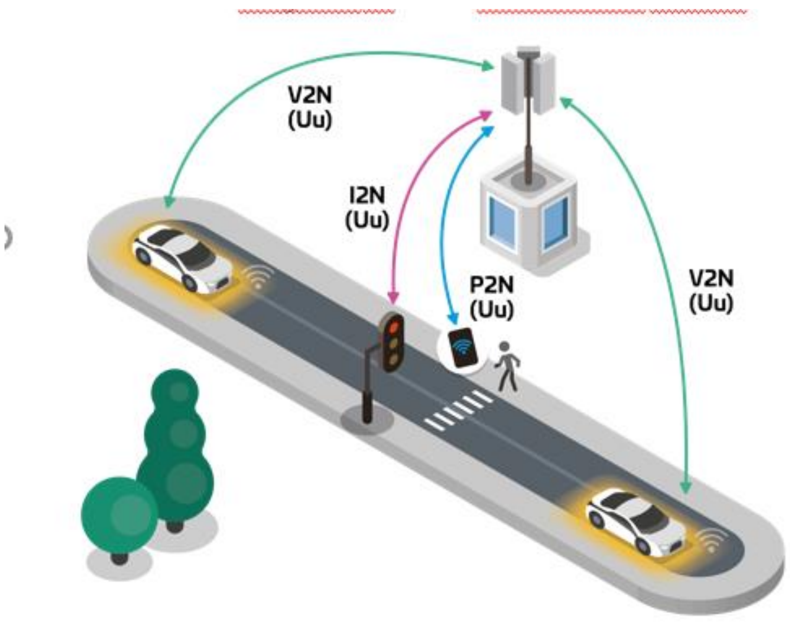

Figure 1: V2X potential for Vulnerable Road Users

All services are based on high precision positioning and low latency technology.

This paper is focusing on the services traffic light assistant and collision warning and detailing trial run results in the RealLab Hamburg.

1 TRAFFIC LIGHT ASSISTANT FOR VRUS

Green Light Optimized Speed Advisory (GLOSA) systems have been shown to be able to reduce both CO2 emissions and fuel consumption [2] by giving drivers speed recommendations when approaching a traffic light. The NPM Subproject 7 will address the GLOSA service for vulnerable road users, especially cyclists and e-scooter drivers. The optimization of traffic efficiency is primarily related to controlled intersections. In a Real Lab test field it will be analyzed how safety can be improved by traffic light information and positioning accuracy. The traffic light status information is provided by an open data interface from the city of Hamburg. The forecast information of the traffic lights, i.e. next phase is available in the test field for automated and connected driving in Hamburg (TAVF). This several kilometers long test track was upgraded to infrastructure-to-vehicle (I2V) and vehicle-to-infrastructure (V2I) communication in 2020 and it enables vehicle manufacturers, technology companies and research institutions to test ITS applications, safety and assistance systems as well as automated and connected driving functions in the real traffic environment on public roads. About 40 traffic lights in the TAVF are equipped with IEEE 802.11p[3] based communication, and a low latency connection to central servers.

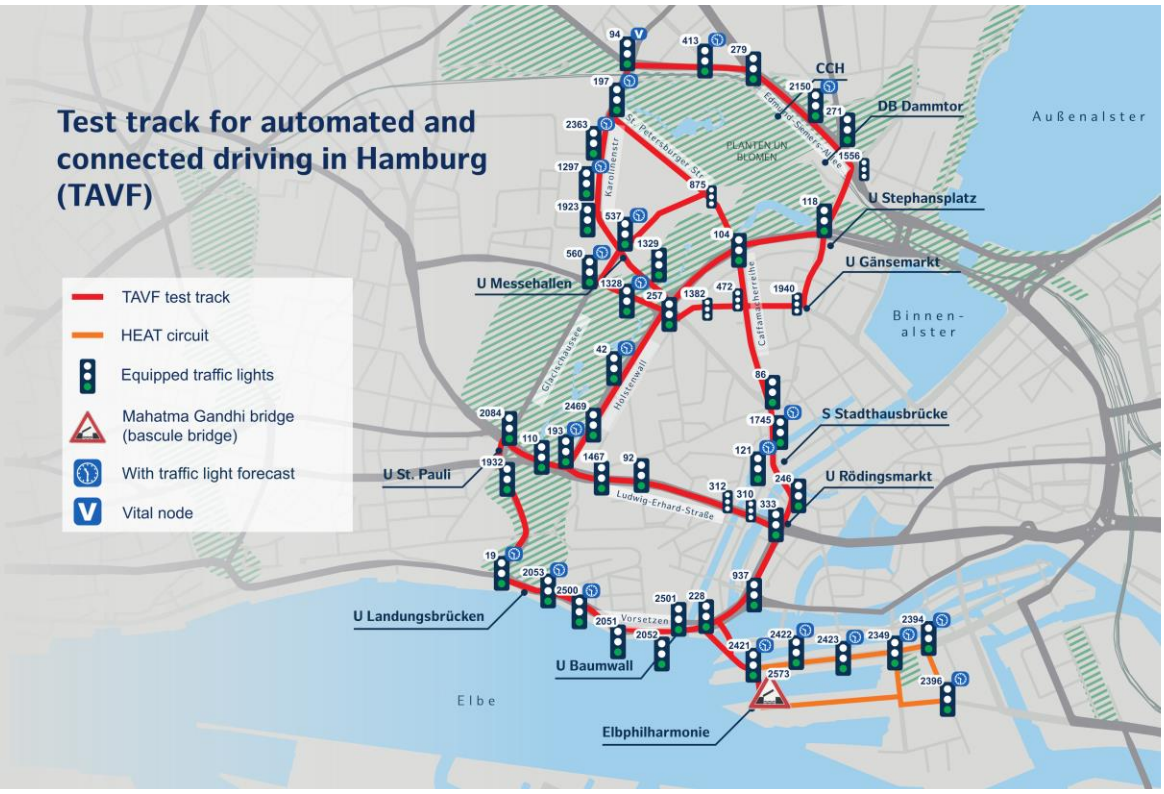

Figure 2: Test field Hamburg

The data will be provided by the central servers (e.g. supplier of the traffic controller) to Deutsche Telekom's 5G Edge Compute servers. The edge servers are deeply integrated into the mobile network to enable a short connection between the mobile user device (car, bicycle, user phone, etc.) and the data which is provided by the city. Several edge servers are located over Germany delivering short connections between user devices and applications operated on the edge cloud. As platform as a service (PaaS) layer, MobiledgeX PaaS is provided on the edge infrastructure, to provide an easy to handle PaaS layer for application developers and operators. MobiledgeX provides standard deployment mechanisms such as docker, kubernetes, etc.

The data exchange format is the European ETSI ITS [4] standard for Signal Phase and Timing (SPaT) and MAP (Topology Information of the Intersection) messages [5], and CAM messages [6]. T-Systems is developing the GLOSA (Green Light Optimum Speed Advice) service with the major aim to provide “traffic light assistance” for bicycle, ebikes and e-scooter drivers. The focus is on vulnerable road users using smartphones but the same data will also be provided to vehicle manufacturer clouds and car drivers. The GLOSA app provides the VRU with real-time information (time to green) about the traffic light phases. The end user sees the next traffic light and a countdown to the next green or red phase on the display. In simulations and field tests the project will analyze to which extent the throughput of bicycles per hour can be improved and if there is an overall improvement of travel time for cyclists. In E2E tests the latency and the position accuracy will be tested and analyzed. A large scale user trial is planned with the GLOSA app before and at the ITS world congress with the focus on user experience.

In addition, anonymized movement profiles of VRU groups, e.g. of cyclists will be sent back to the traffic management center. In a simulation, the prioritization of groups of cyclists will be calculated for a specific bicycle track. This will help to provide guidance for traffic planning and in the future a prioritization of cyclists on fast lane cycle tracks.

2 COLLISION WARNING SERVICE

Continental is developing a collision warning service that can be deployed to locations defined as geofences with a significant risk of accidents (hotspots), e.g. intersections. Vulnerable road users (VRUs), especially bicyclists, have a high risk of being seriously and even fatally injured at intersections by vehicles, especially trucks, turning left or right. A hotspot can be flexibly configured at a geographically bounded area, e.g., 50m around an intersection. When a road user carrying a registered client device (e.g., a smartphone) enters the configured hotspot, then the client automatically starts to send CAM messages specified according to the ETSI ITS standard to the collision warning backend. The CAM messages contain information about the position, classification, accuracy and dimensions of the road user. The backend then analyses the resulting trajectories and calculates the probabilities of collisions between different road users. Road users potentially affected by a collision are warned by the backend via DENM messages, which contain the future collision point, a collision probability and the current position of the road user as well as the type and position of the collision partner. This information can be processed and visualized by clients (e.g., smartphone / smartwatch). Geographical distribution and possible communication with low latency is supported by mobile edge cloud computing over 5G or LTE. The aim of Continental is to increase the safety of all road users, especially VRUs, using networked collision warning. For this purpose, an open interface for the integration of a large number of device classes (ECU, smartphone, smartwatch, OBU) is offered by Continental.

The overall architecture relies on MQTT protocol. Let us briefly describe the various components.

1. **Hotspots:** This component is deployed centrally to the public cloud and it administers central functions such as hotspot definition, user management and authentication/authorization. This component is not directly relevant to latency measurements.
2. **Message Broker:** This component resides in the cloudlet of some telecommunication provider and it is in charge of brokering MQTT messages among the different elements such as client devices and collision warning backend as well as distributing event messages to other cloudlets.
3. **Collision Warning**: This component is the actual backend calculating collision probabilities and generating warning messages (DEMN) based on sensor data (CAM) received from the client devices directly or indirectly via the local message broker.
4. **Mobile Client**: This component is a client device like a smartphone that must be registered with the collision warning backend. As soon as such a client device is within the hotspot

boundaries, it starts to send CAM messages to the corresponding collision warning backend via the message broker.

3 INTERCONNECTING GLOSA, COLLISION WARNING AND CLIENTS

Since Green Light Optimized Speed Advisory (GLOSA) and Collision Warning are deployed within the system boundaries of the companies that developed the applications, both systems are connected by a MQTT based routing application (NPM TP7 Router).

This way a GLOSA focused smartphone application can log into the user management of T-Systems and gain access to the Continental collision warning system without separately accessing the Continental user management.

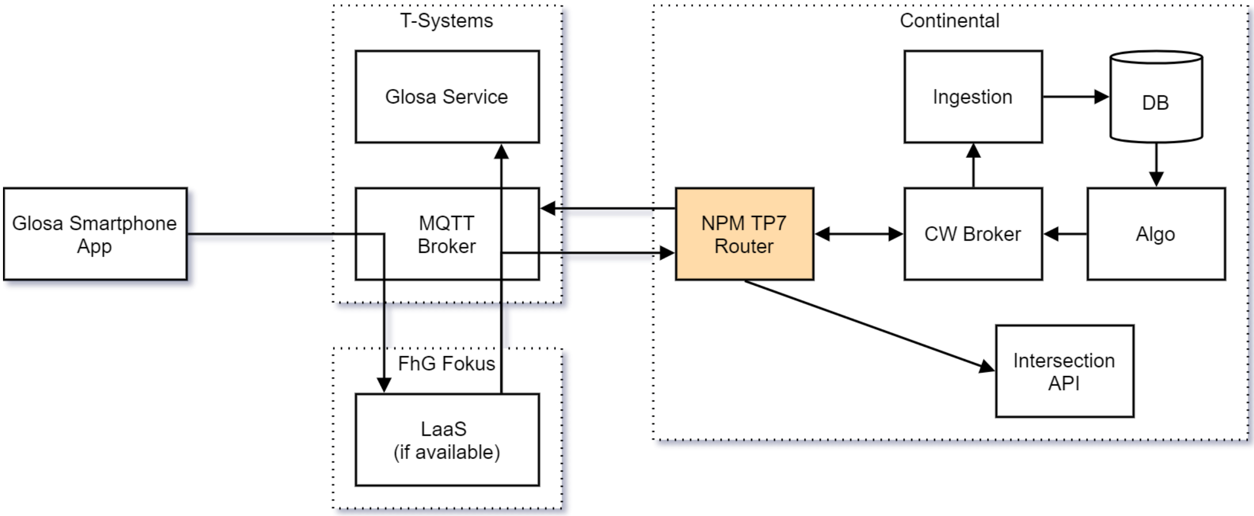

Figure 3: Architecture Client / Server

In detail, tasks performed by the TP7 router are:

CAM
- retrieve all intersections, periodically update the cache
- connect to the T-Systems broker
- subscribe for the external CAM messages (from the T-Systems broker)
- convert CAM messages to Continental internal format and re-publish the messages to the CW broker in a specified manner

DENM
- connect to the CW broker and the T-Systems broker
- subscribe on the CW broker for the specified DENM topics
- re-publish DENM messages in the format expected by the T-Systems environment to the T-Systems broker

LaaS (Location as a Service) improves location (position and heading) by looking at individual smartphone traces as well as combining location information from other smartphones.

3.1 Collision Warning Open API

It is also possible to develop a client that can directly communicate with the Continental Collision Warning service without interacting with any other system.

Since the API is defined as a lightweight Open API, users can gain access to collision warning by authenticating against the Authentication API (TLS and JWT based user authorization).

After logging in, a ContextData API is providing methods for:

- Finding hotspots in the proximity of the client location
- Fetching a session ID to uniquely identify the client within a hotspot
- Grabbing result messages encoded in JSON / GeoJSON

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With this information a client can directly stream his position information (CAMs) as soon as he enters the geofence (defined by the hotspot) and in the case of a probable collision receive a DENM encoded protobuf message. The warning can then be displayed to the client.

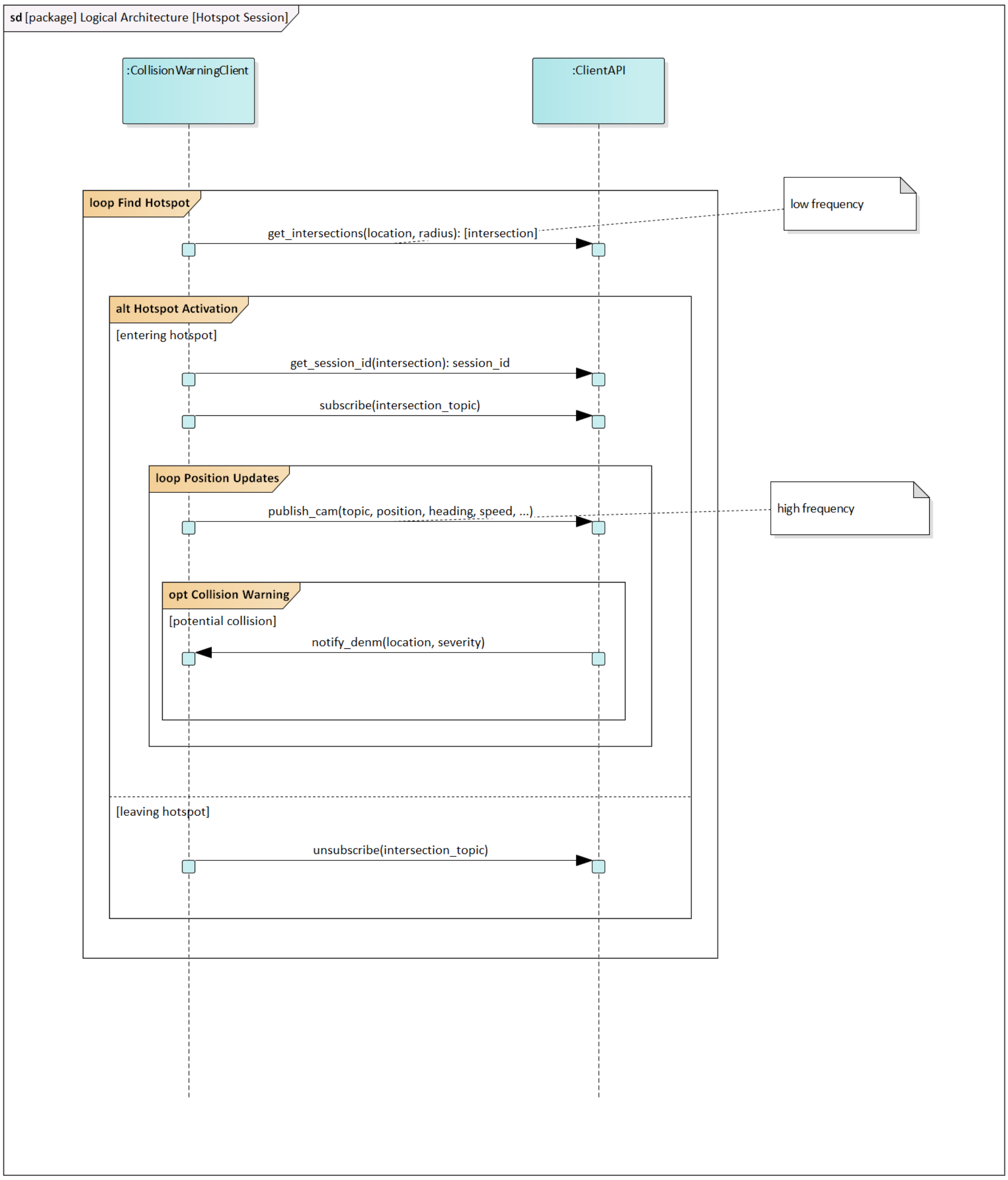

Figure 4: Client communicating with Open API

4 COLLISION WARNING TEST RESULTS REALLAB HAMBURG

To validate the most prominent use cases Continental set up a list of test cases to confirm the functionality of the Collision Warning algorithm. In this test setup the GLOSA app was used as client application.

Many tests were performed with SPaT/MAP features (Signal Phase and Timing) of the algorithm turned off and on to validate that Collision Warning performs better if the algorithm knows the status of the traffic lights at the moment in time where the calculation takes place.

Additional used features of the Collision Warning algorithm were HD map integration and the utilization of AI methods to predict passenger car behavior even earlier due to machine learning techniques. The deployed algorithm was calculating the probable collisions in real-time (<20 ms).

Here is an excerpt of the test cases:

a) Test without collision with pedestrian and bike. No warning was expected.

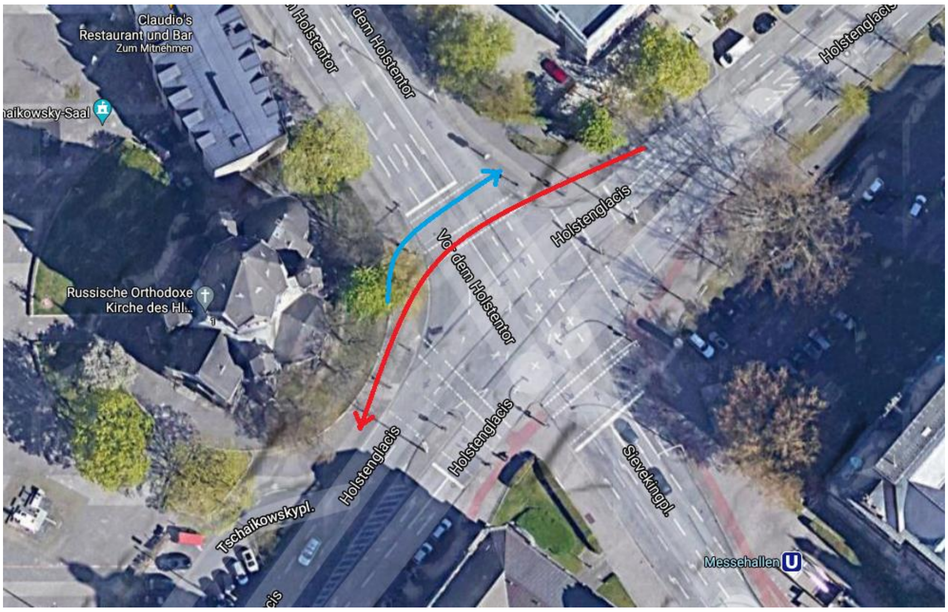

Figure 5: Test Case No Warning Pedestrian / Bike

Results:

- CAM messages are arriving at CW algo
- The CAM latency is below 200ms
- A DENM message is not published because the bike is passing before the pedestrian

b) Test with collision with car and bike, turn right. The test should issue a warning to both car and bike in a timely manner.

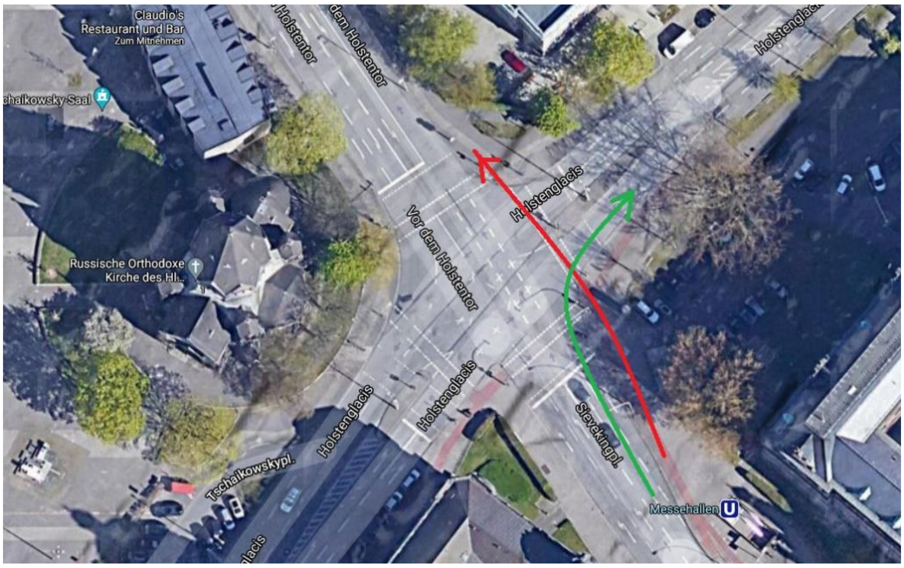

Figure 6: Test Case Warning Between Turning Car / Bike

Results:

- CAM messages are arriving at CW algo
- The CAM latency is below 200ms
- A DENM message is published
- The reception of a DENM message is indicated on the GLOSA app of both users
- Quality level was 2 and higher (this indicates a Collision probability of more than 20 percent – the time to collision was more than 3.5 seconds)

c) Test with collision with car and pedestrian, straight on. The expected results were depending on the activation of the SPaT/MAP feature.

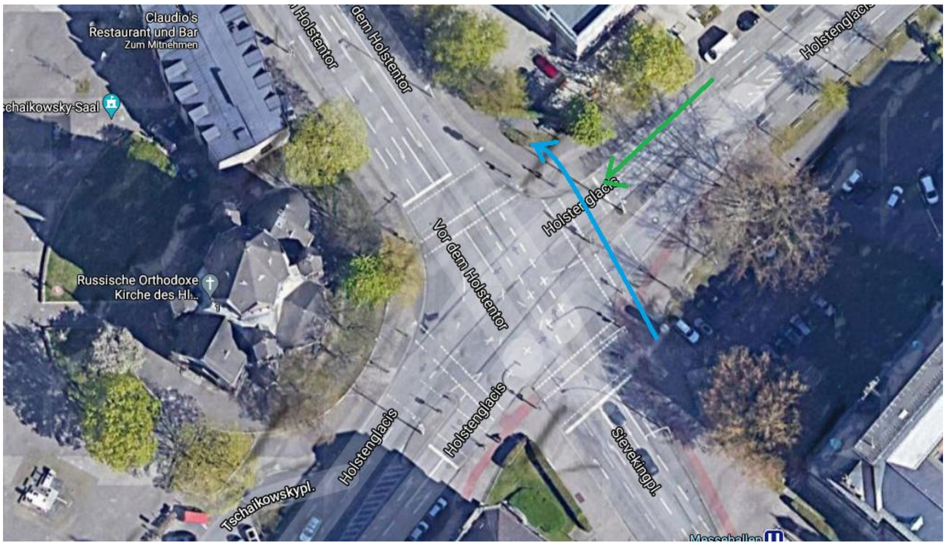

Figure 7: Test Case Between Car / Pedestrian, straight on

This test case was performed with SPaT/MAP features off and on to determine if the signal phases of the traffic lights are a valuable add-on to the Collision Warning algorithm.

With SPaT/MAP turned off clients received collision warning messages because the algorithm did not know that their trajectories would stop at the traffic light and therefore predicted a collision with a low probability on the road. Since the probability of the warning was very low the client could have ignored the warning (to avoid false positives) but this is an undesired result, nonetheless.

With SPaT/MAP turned on clients did not receive any collision warning messages since the Collision Warning algorithm did know exactly where the road user (in this test case the car) would stop and did therefore shorten and reposition the trajectory to avoid collisions on the road since the car had reduced his speed to stand rather still at a red traffic light.

This and further test cases proved that additional information provided by a traffic intersection infrastructure will reduce false positive warnings and strengthen true positive warnings provided by a Collision Warning system.

5 CONCLUSIONS

Cellular V2X does provide a great potential for interconnecting pedestrians, bicycle and scooter drivers with passenger cars and intelligent infrastructure. 5G mobile edge computing is used to reduce latency and and latency jitter (stability of latency) of ITS services in comparison to standard internet communication.

B2B interfaces can be easily realized and work well in first trial runs. This allows users from various system domains to access the applications from partnering companies.

Tests prove that Collision Warning provides an additional security layer for all pedestrians, bicycles and scooter drivers but also warns other road users such as passenger cars before a collision in a timely manner.

In addition to positioning/sensor data provided by an end-user client application the Collision Warning service algorithm improves its prediction by ingesting infrastructure data like SPaT/MAP in addition to digital HD maps and other high precision information.

GLOSA is also an important value add on since it provides a well estimated traffic light prediction directly to the client application which can be used to save fuel and therefore reduce energy consumption and CO2 emissions on the road.

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