Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: High Mobility V2X PHY Functional Requirements for High Data Rate OCC
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Abstract: This document introduces the functional requirements for High Mobility V2X PHY to be used in IEEE802.15.7a High Data Rate OCC (Optical Camera Communication) TG. The proposed High Mobility V2X PHY functional requirements considered to use with varying channel conditions and maintaining connectivity during high mobility (speeds up to 350 km/h), flicker mitigation, Radio Frequency (RF) co-existence, and a communication range of up to 200m in on-road mobility scenario.

Purpose: To provided High Mobility V2X PHY design functional requirements for IEEE802.15.7a High Data Rate OCC.

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Contents

Needs for High Mobility OCC V2X Technology

- Vehicle-to-Everything (V2X) is a Vehicle Communication Technology, which involves vehicles exchanging data with each other and the infrastructure on the road, and has proven to improve traffic safety and increase the efficiency of transportation systems.
- Potential On-Road OCC V2X Applications
  - Powering Next-Generation Automotive Solutions - Advanced driver-assistance systems (ADAS), autonomous vehicles (AVs) as well as in drones and robotics
  - Collision avoidance
  - Autonomous driving and safety
  - Distance measurement between multiple vehicles
  - Autonomous robot navigation
  - Forward/rear collision warning
  - Blind-spot monitoring
  - Cross traffic alert
  - Parking assistance
  - Distance measurement and high-speed optical link
  - Multi-Vehicle Speed Measurement
  - Precise localization

IEEE802.11 Next Generation V2X (NGV) Use Cases

- **Basic Safety Messages (BSM)**
  - Broadcast a message containing their basic information
  - Based on received messages, driver is alerted of an upcoming safety risk
- **Sensor Information Sharing**
  - Broadcast all detected objects from all sensors, and receive objects
- **Infrastructure Applications**
  - Transmission of safety and non-safety data from infrastructure to vehicles
- **Vehicular Positioning & Location**
  - Positioning of the vehicle w.r.t other road-users
- **Automated Driving Assistance**
  - Coordinated vehicle maneuvers like Vehicle shares their future path, etc.
- **Vehicle ITS Application**
  - Vehicles provide road safety and traffic violation monitoring functions

5G V2X Use Cases (1)

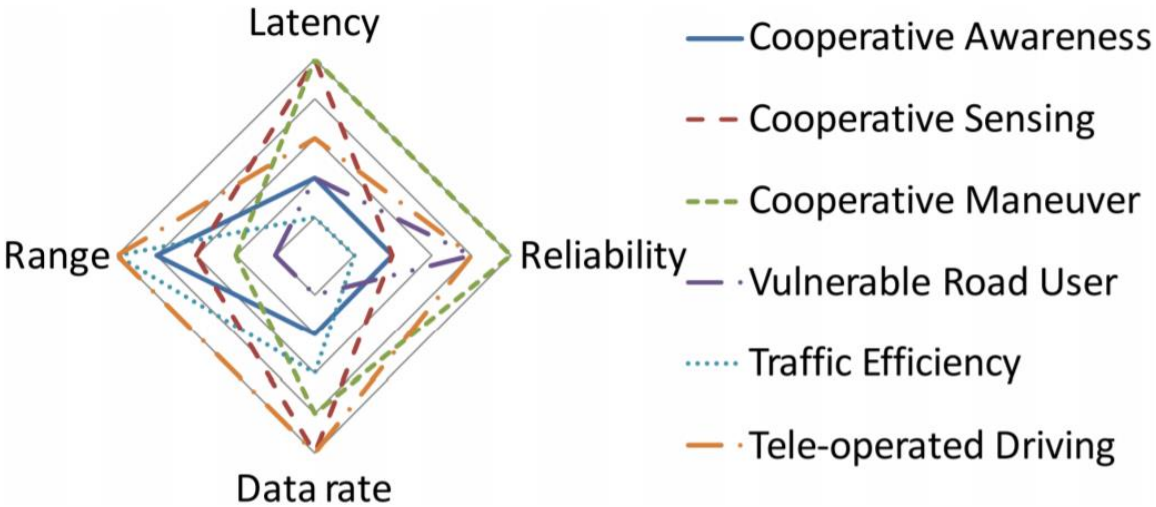
- **Cooperative Awareness**
  - Warning and increase of environmental awareness (e.g., Emergency Vehicle Warning, emergency electronic brake light, etc.).
- **Cooperative Sensing**
  - Exchange of sensor data and Object information that increase vehicles environmental perception
- **Cooperative Maneuver**
  - Includes use cases for the coordination of the trajectories among vehicles (e.g., lane change, platooning, CACC, and cooperative intersection control).
- **Vulnerable Road User (VRU)**
  - Notification of pedestrians, cyclists etc.
- **Traffic Efficiency**
  - Update of routes and dynamic digital map update
- **Tele-operated Driving**
  - Enables operation of a vehicle by a remote driver

5G V2X Use Cases (2)

Use Case Type	V2X Mode	End-to-End Latency	Reliability	Data Rate per veh. (kbps)	Comm. Range†
Cooperative Awareness	V2V/V2I	100ms-1sec	90-95%	5-96	Short to medium
Cooperative Sensing	V2V/V2I	3ms-1sec	>95%	5-25000	Short
Cooperative Maneuver	V2V/V2I	<3ms-100ms	>99%	10-5000	Short to medium
Vulnerable Road User	V2P	100ms-1sec	95%	5-10	Short
Traffic Efficiency	V2N/V2I	>1sec	<90%	10-2000	Long
Teleoperated Driving	V2N	5-20ms	>99%	>25000	Long

†Communication range is qualitatively described as "short" for less than 200 meters, "medium" from 200 meters to 500 meters, and "long" for more than 500 meters.

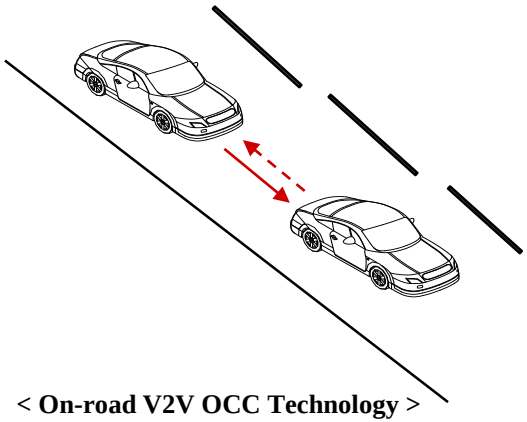
< Use Cases and Key Performance Requirements for 5G V2X >



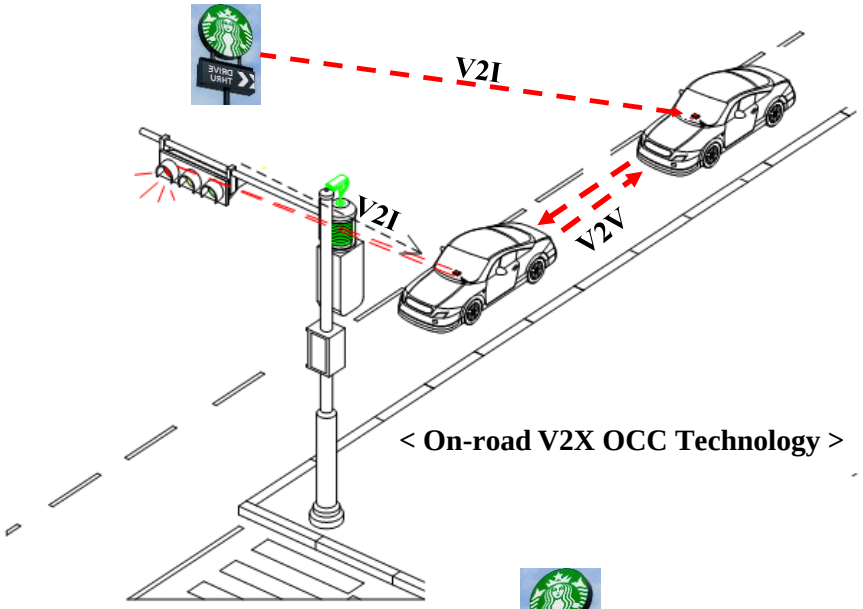
< Use Cases categories and the stringency of Requirements for 5G V2X >

Mate Boban, et al., "Use Cases Requirements, and Design Considerations for 5G V2X", IEEE Vehicular Technology Magazine, 2018.

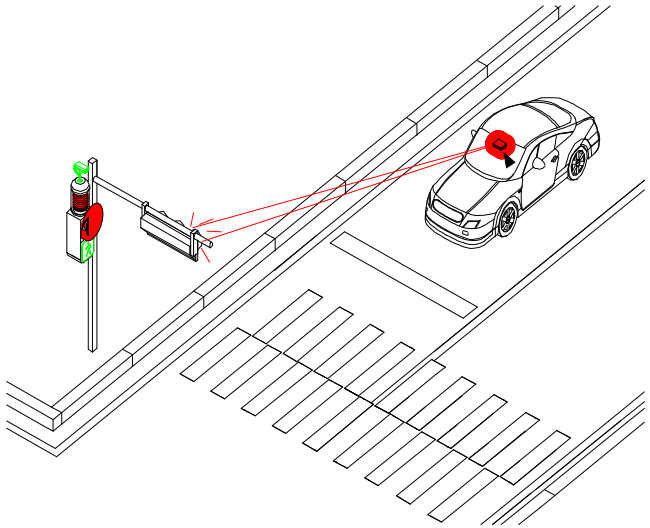
High Mobility OCC V2X Use Case Model



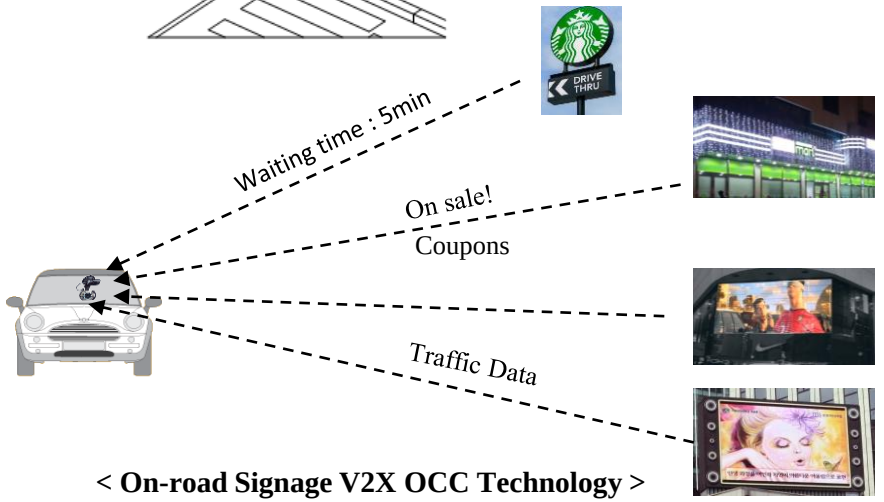
< On-road V2V OCC Technology >



< On-road V2X OCC Technology >

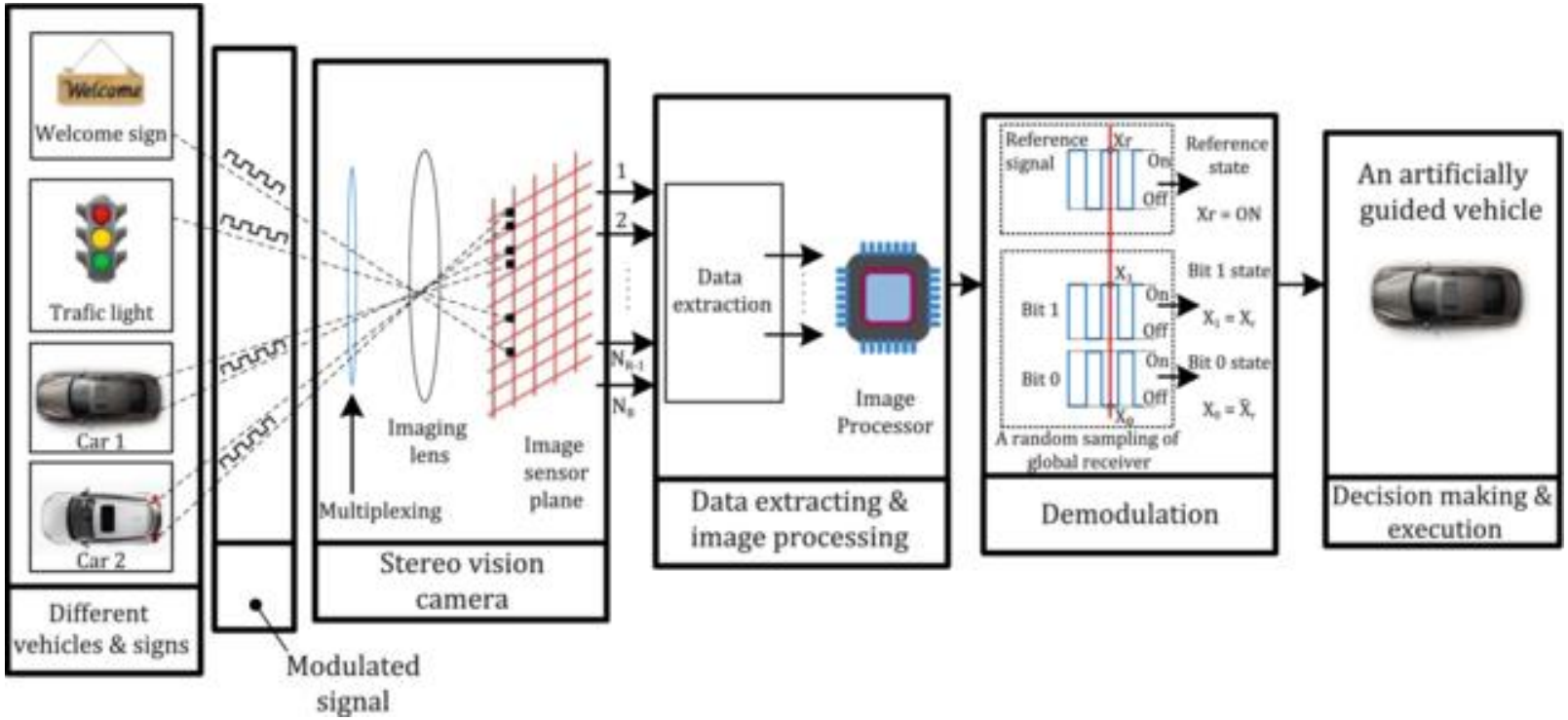


< On-road V2I OCC Technology >



< On-road Signage V2X OCC Technology >

High Mobility V2X Technical Considerations (1)



< Vehicle-centric Data Flow in OCC >

ISO 22738:2020 : Intelligent transport systems — Localized communications — Optical camera communication

High Mobility V2X Technical Considerations (2)

- Major challenges of OCC are dependent on the structure of the receivers (cameras), diverse modulation and coding schemes, and different synchronization techniques.
- Ambient Light is one of the primary sources which interference OCC and degrade the performance of the OCC system, so need to address the Modeling of Ambient light effectively.
- Optical channels are needed to modeled by additive white Gaussian noise (AWGN) consisting of both signals dependent noise and signal independent noise.
- OCC V2X is required to develop a unified system model and performance bounds to analyze the performance of different specifications of OCC.

High Mobility V2X Technical Considerations (3)

- **High-Speed Image Sensor**
  - Demodulation process is composed of two units: an image processing unit and an OCC data decoding unit.
  - The characteristic portion of the ISC receiver lies in the image processing unit, which detects and tracks the transmitters (LED/Signage).
  - The maximum supported frame per second (fps) of the Image Sensor is important increase the data rate of OCC System.
  - Need High Speed image sensor with image processing capability like background removal algorithm will help to increase the data rate of the OCC system.

High Mobility V2X Technical Considerations (4)

- **Defocusing**
  - Significant challenges faced by OCC where the size of the transmitting source and the camera pixels mismatches, even if the source is placed at the camera focus.
  - Defocusing of image sensors are inevitable, especially with handheld cameras which are not stable and can cause distortion to each pixel.
  - Defocusing of image sensors are exist in stationary cases as well, which distorts the pixels in the form of mixed frames and blur.
  - Impact of blur has been well investigated in the area of computer vision yet on the subject of the combined effect of defocus and blur is an open research problem for OCC.
  - Need to be addressed the methods to handle defocusing dynamically

High Mobility V2X Technical Considerations (5)

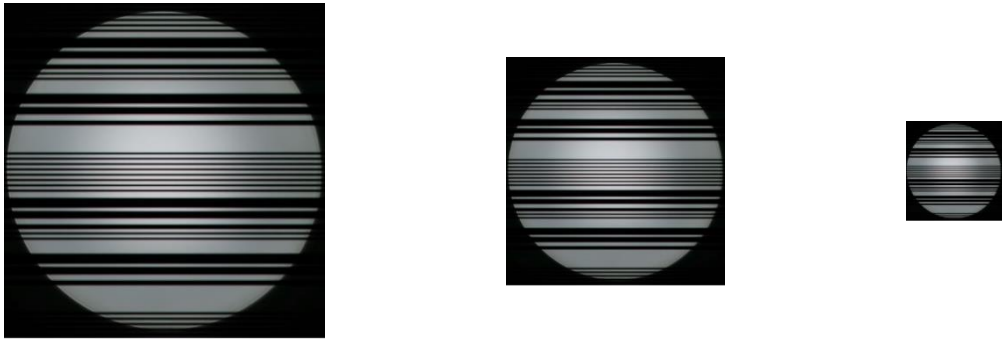
- **Synchronization**
  - Commercially available cameras have low and diverse frame rates and are unstable, therefore, if the frame rates of the transmitter and the receiver mismatches, the problem of synchronization arises.
    - For example, the frame rate of a typical smartphone camera is 30 frames per second while the conventional LCD has the frame rate of 30-60 frames per second.
    - Similarly, the frame rates of LED and screen-based transmitters varies and that results in losing the frames or mixing the frames at the receiver.
  - Effective and Fast synchronization techniques are necessary for the development of OCC systems.

High Mobility V2X Technical Considerations (6)

- **Robust OCC Luminary RoI Extraction and Data Extraction Imaging Algorithm**
  - OCC Receiver demodulates the data is in the shape of the captured frame from LED lights and Signage images and therefore it requires reliable and robust image processing techniques to extract the useful data.
  - Recently, Machine learning, neural networks and deep networks have been used to solve the complex problems of image recognition and classification.
  - OCC V2X systems depend on image processing tools, therefore sophisticated algorithms need to be devised to improve the OCC V2X performance of on-road vehicle applications.

High Mobility V2X Technical Considerations (7)

- **Demodulation**
  - OCC Receiver detects the LED Stripe or Display Coded Color pattern size differs according to the distance.
  - Inter-symbol bit sampling need to be done with distance and mobility and this can be achieved by dynamically adjusting camera zooming or sampling according to V2V and V2I distance.
  - Need to provide distance adaptive inter-symbol bit sampling method.



< OCC Receiver LED Stripe in Different Distance Level >

High Mobility V2X Technical Considerations (8)

- **Handover**
  - IEEE802.15.7-2018 is focusing only on modulation, coding, and synchronization of OCC in static environment both Transmitter and Receiver.
  - Research on the handover for OCC systems does not exist yet and therefore require attention.
  - Need to provide effective and fast handover mechanism for the on-road high mobility OCC systems.

High Mobility V2X Technical Considerations (9)

- **Blockage**
  - Blockage of the Line-of-Sight link is a critical issue for OCC systems due to the mobility of users or obstruction of objects
  - Received optical intensity is dramatically reduced in such cases which consequently degrades the performance of OCC systems.
  - Research on the blockage issue for OCC systems does not exist yet and therefore require attention.
  - Mobility of vehicles is random movements can be explicitly tracked by using adaptive signal processing approaches like Kalman filters to predict the blockage and Markov chain can be used to estimate the probability of blockage in LoS conditions.
  - Need to be addressed the blockage as a one of the parameters for high mobility OCC V2X PHY design.

High Mobility V2X Technical Considerations (10)

- **RF Co-Existence**
  - VLC, Li-Fi and OCC use LED as a transmitter, however the receiver is different in case of OCC (camera).
  - The existing VLC and Li-Fi systems provide high data rate and secure communication but suffers from low SNR and short transmission range.
  - However, OCC can provide long range communication with high SNR, but suffers from low data rate and long-lost connectivity on-road conditions.
  - Therefore, the OCC can also be integrated with RF systems to support OCC V2X on-road vehicle applications.
  - Needs to be addressed to switch between the OCC and RF wireless communications technologies.

High Mobility V2X Technical Considerations (11)

- **Medium Access Control (MAC)**
  - IEEE802.15.7-2018 OCC is focusing only on physical layer issues such as modulation, coding, and synchronization.
  - IEEE802.15.7-2018 OCC systems are based on the MAC layer protocols of VLC; however, unlike VLC, the OCC systems support mainly unidirectional communication which requires a re-examination of the MAC protocols.
  - The scope of the projects says that “Radio Frequency (RF) co-existence” with High Rate OCC
  - Need to be developed the MAC protocols which can address the different challenges of OCC systems such as low frame rate, defocusing, visual MIMO support, and mobility, etc.

Conclusion

- Proposed the High Mobility V2X PHY Functional Requirements for IEEE802.15.7a High Data Rate OCC TG.
- Discussed the needs for High Mobility OCC V2X Technology with IEEE802.11 Next Generation V2X (NGV) Use Cases, 5G V2X Use Cases, and High Mobility OCC V2X Use Case Model.
- Proposed the necessary technical considerations need to be addressed in High Mobility V2X OCC PHY design.
- This proposed High Mobility V2X PHY design consideration helps to provide the flexible, secure, and safety user network OCC access link.