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

Submission Title: Proposal for the Next Generation Optical Camera Communication Standard

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Re:

Abstract: Proposal for the Next Generation Optical Camera Communication Standard

Purpose: Proposal for the Next Generation Optical Camera Communication Standard

Proposal for the Next Generation Optical Camera Communication Standard

1. Current status of IEEE 802.15.7a TG

➢ Scope of task group

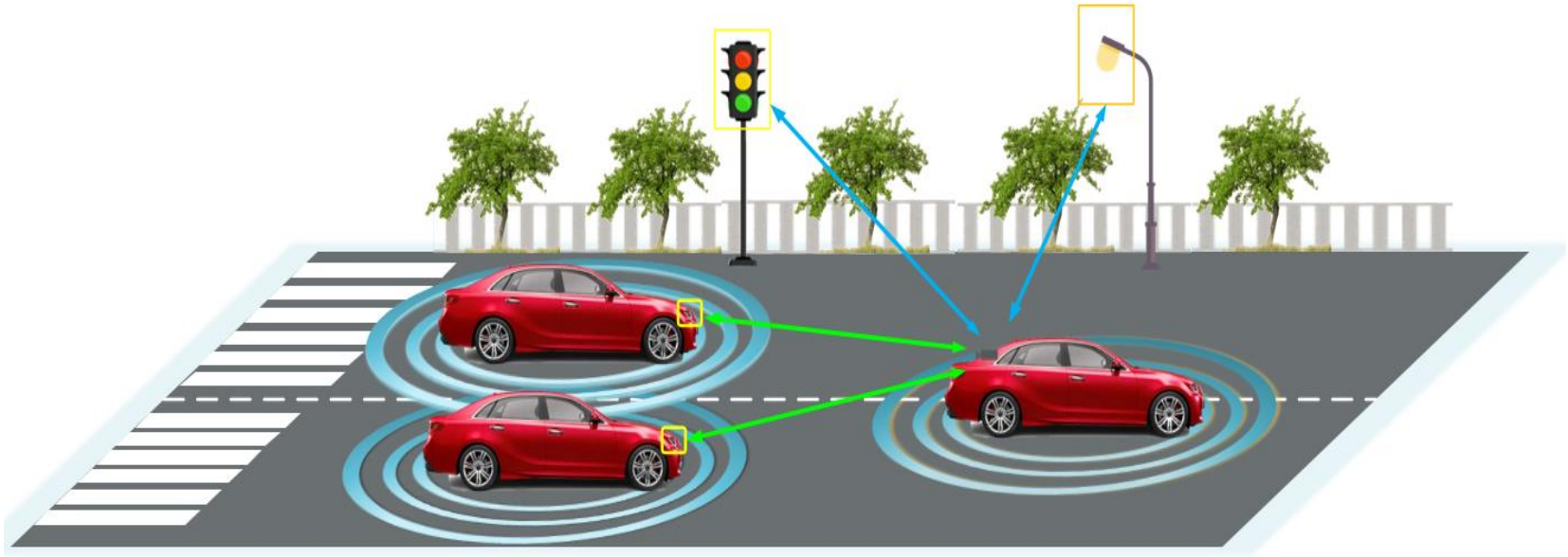
- IEEE 802.15.7a Task Group amendment specifies a high-rate Optical Camera Communications (OCC) Physical Layer (PHY) using light wavelengths from 10.000 nm to 190 nm in optically transparent media.
- It is capable of delivering data rates and is designed for point-to-point and point-to-multipoint communication.
- Maintaining connectivity during high mobility.
- Flicker mitigation.
- Radio Frequency (RF) co-existence, and a communication range.
- Multiple-Input-Multiple-Output (MIMO) is utilized to deal with high-levels of optical interference while maintaining high-rate data transmission.

1. Current status of IEEE 802.15.7a TG

➢ Purpose of task group

- IEEE 802.15.7a standard provides:
  - Access to unlicensed spectrum.
  - Inherent communication security due to inability to penetrate through optically opaque walls.
  - Data delivery without using RF spectrum.
  - Apply MIMO and Artificial Intelligence (AI)-based PHY and MAC layers.
  - Communication augmenting and complementing existing services (such as illumination, indication, localization, etc.)

1. Current status of IEEE 802.15.7a TG

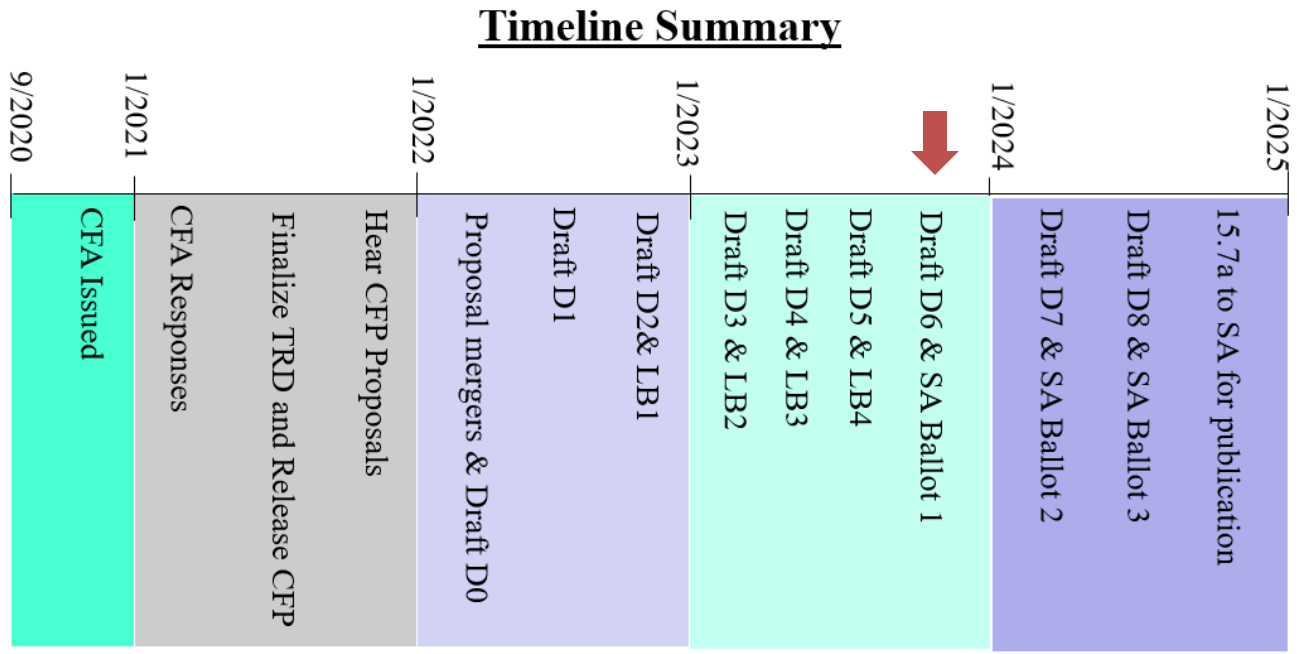


- **Technologies applied to IEEE 802.15.7a TG:**
  - OFDM technology
  - MIMO and NOMA technologies
  - Deep Learning based OCC
  - Hybrid technology

1. Current status of IEEE 802.15.7a TG

➢ Current status of IEEE 802.15.7a Higher Rate, Longer Range OCC TG:

- Currently, the Draft standard (D6) is in stage the 4th Letter Ballot Recirculation and is expected to start SA Ballot on November 2023
- It is hoped that the standard will be finalized by the middle of 2024



Suggested 15.7a Schedule and Milestones (May 2023)

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Why we need new standard?

- Now a days automotive vehicles have been considered as one of the upcoming technologies in the world. There are many researchers and companies who are studying and trying to provide the best solution through their research.

- Many automotive companies are working to improve safety with other technologies besides unmanned vehicles. Due to the limitation of the current technologies, it is necessary to develop an image sensor communication system for the vehicular environment to communicate with each other.

2. Proposal of Next Generation Optical Camera Communication Standard

➢ **Why we need new standard?**

- Also, autonomous vehicular uses a combination of sensor, including LiDAR (light detection and ranging), RADAR (radio detection and ranging), cameras, ultrasonic, and infrared. A combination of sensors can complement each other and prove them as a weak candidate for the collection of sensors data. So, it has become hardest challenges to develop an ultra-reliable autonomous vehicular system.
- Currently, we have a lot of High-Speed rail, which achieve the speed more than 400 km/h: next generation KTX train (HEMU-430X) in Korea, Maglev Train (CRRC) in China

  ➔ TG7a just apply for lower mobility with 200 km/h and 200 m communication distance, then, new standard for higher mobility and longer-range OCC should be considered

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Targets of task group

- We proposed new task group to amendment specifies a high-mobility Optical Wireless Communications (OWC) Physical Layer (PHY) using light wavelengths from 10.000 nm to 190 nm in optically transparent media.
- Data rates: up to 200 Mbps
- Designed for point-to-point and point-to-multipoint communication
- Maintaining connectivity during high mobility: mobility support up to 400 km/h
- Higher localization resolution: below 1 cm
- Radio Frequency (RF) co-existence
- Communication range: up to 1 km
- Bidirectional communications

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Channel model of OCC

❖ Transmitter:

1. Circular LED (Seaside Communication)
2. LED Signage (Digital Signage)

❖ Channel Medium:

We have considered only Line of Sight (LOS) communication channel. The reflected portion of light **(**NLOS channel) is discarded by using image processing method.

❖ Receiver:

1. Rolling Shutter Camera
2. Global Shutter Camera

We use extra zoom functionality for long distance communication in sea communication.

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Channel model of OCC in foggy condition

- Fog attenuation coefficient

$$\alpha_{fog}(\lambda) \cong \beta_a(\lambda) = \frac{ln\tau_{th}}{V}\left(\frac{\lambda}{500}\right)^{-q} = \frac{3.912}{V}\left(\frac{\lambda}{550}\right)^{-q}$$

- Fog attenuation coefficient after considering 5% transmission threshold

$$\alpha_{fog}(\lambda) \cong \beta_a(\lambda) = \frac{ln\tau_{th}}{V}\left(\frac{\lambda}{500}\right)^{-q} = \frac{13}{V}\left(\frac{\lambda}{550}\right)^{-q}$$

here,

V = visibility range in km

λ = transmission wavelength in nm

q = size distribution coefficient

τ_{th} = transmittance threshold

$$q = \begin{cases} 1.6 & (V > 50\ km) \\ 1.3 & (6km < V < 50\ km \\ 0.16V + 0.34 & (1km < V < 6\ km \\ V - 0.5 & (0.5km < V < 1\ km) \\ 0 & (V < 0.5\ km) \end{cases}$$

Reference: Muhammad Saleem Awan *et al.*"Characterization of Fog and Snow Attenuations for Free-Space Optical Propagation" http://ojs.academypublisher.com/index.php/jcm/article/view/0408533545/491

2. Proposal of Next Generation Optical Camera Communication Standard

- **Channel model of OCC in the condition of rain and snow**
  - The snow attenuation coefficient

$$\alpha_{Snow} = \frac{58}{V}$$

  - The rain attenuation coefficient

$$\alpha_{rain} = \frac{2.9}{V}$$

It is seen that snow condition attenuate light source more than other. So, for channel modelling snow and rain condition should be considered.

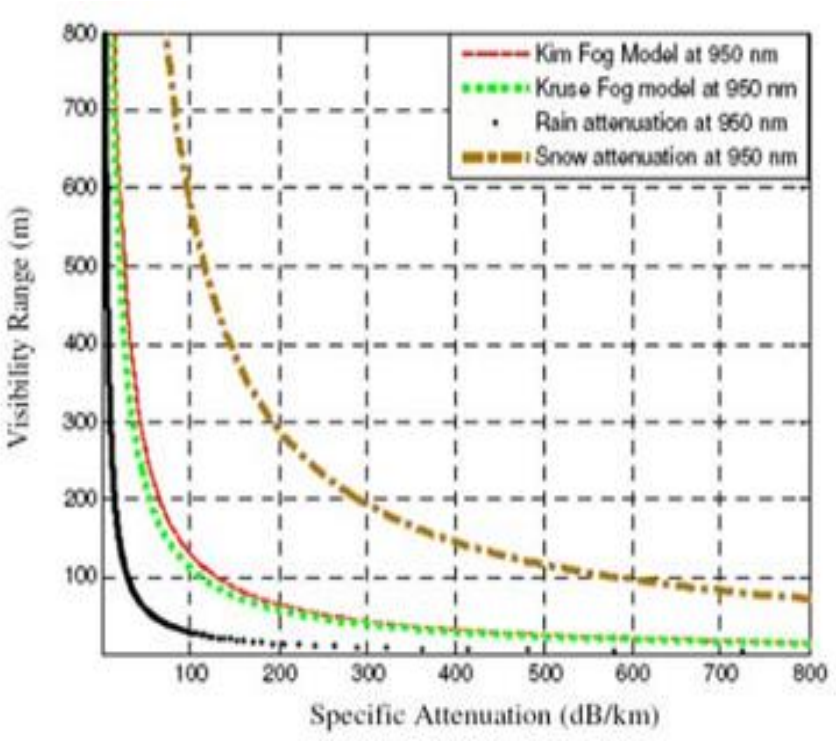


Fig 1: Simulation of empirical models for a FSO link operating at 950nm

Reference: Muhammad Saleem Awan *et al.***“**Characterization of Fog and Snow Attenuations for Free-Space Optical Propagation” http://ojs.academypublisher.com/index.php/jcm/article/view/0408533545/491

2. Proposal of Next Generation Optical Camera Communication Standard

- **Proposed technologies for new OCC standard**
  - Longer range communication (telescope etc.)
  - Joint communications and sensing (LiDAR, RADAR, etc.)
  - High-mobility 3D communication applications
  - Bidirectional communication
  - MAC protocol for full duplex operation
  - Quantum technology
  - Etc.

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Proposed technologies for new OCC standard

- Longer range communication

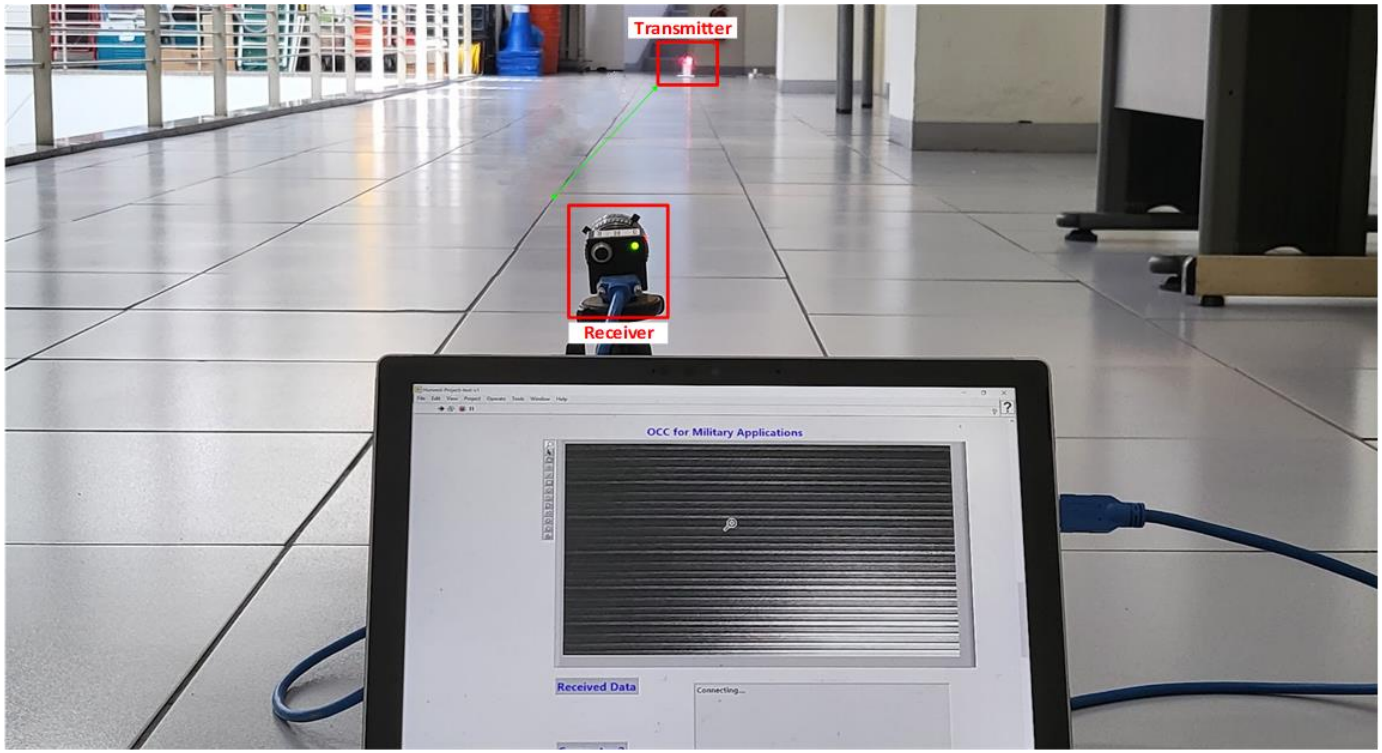


Fig 2: Longer range OCC concept for outdoor environment

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Proposed technologies for new OCC standard

- Joint communications and sensing (LiDAR, RADAR, etc.)

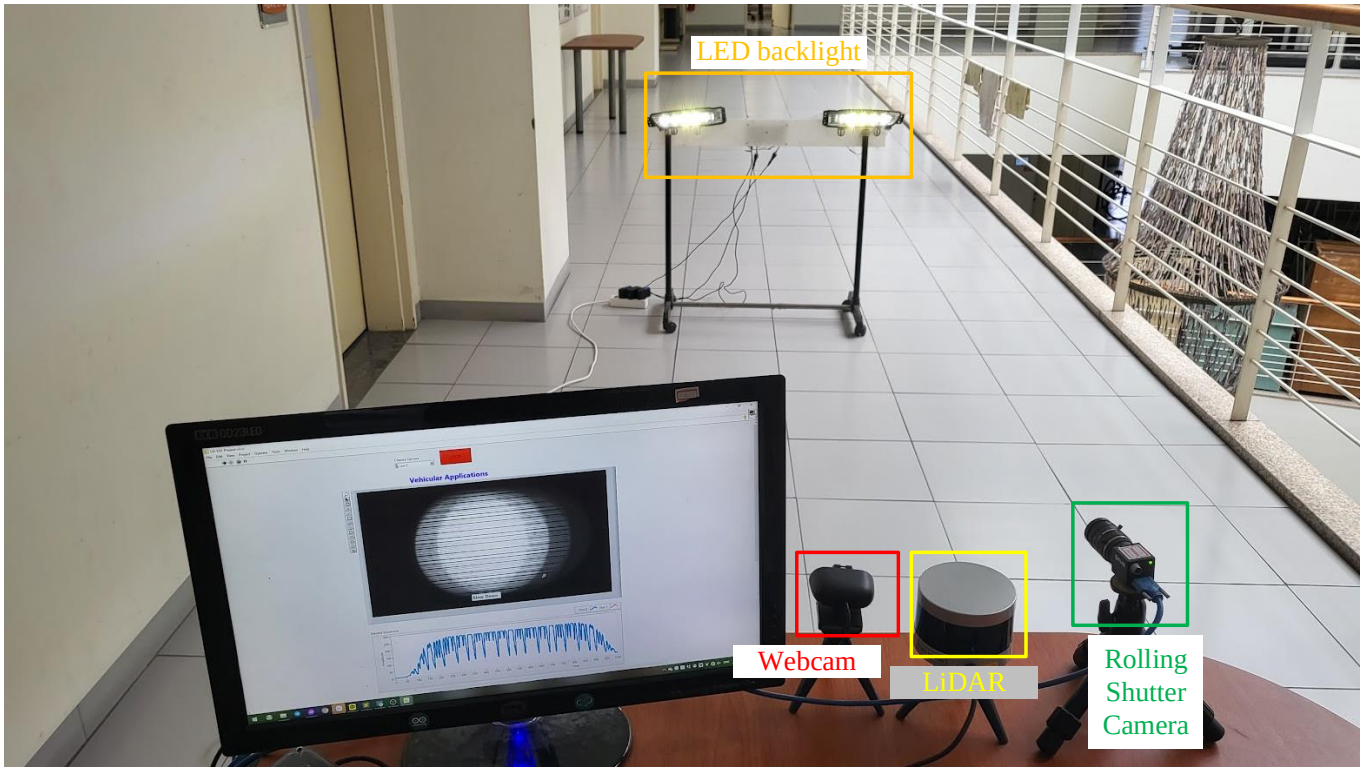


Fig 3: Outdoor scenario of multi-sensor fusion supported-OCC

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Proposed technologies for new OCC standard

- High-mobility 3D communication applications

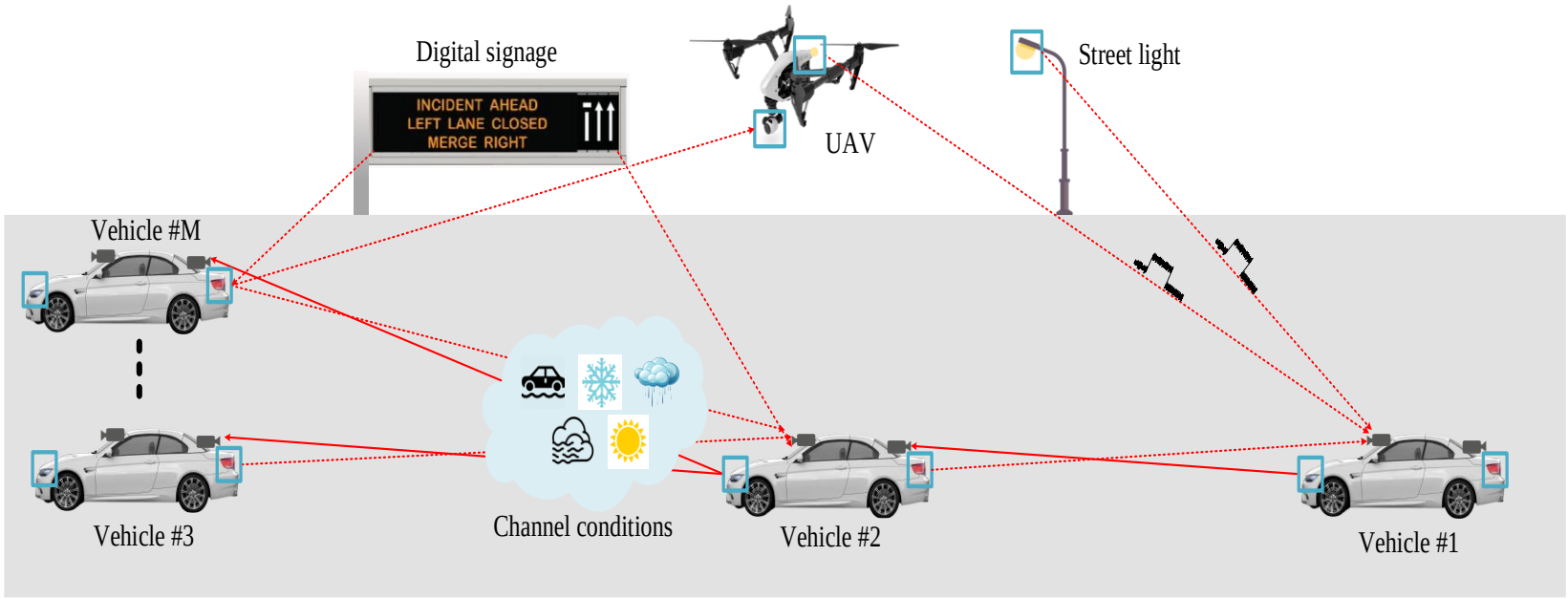


Fig 4: Scenario of 3D communication applications

2. Proposal of Next Generation Optical Camera Communication Standard

➢ Proposed technologies for new OCC standard

- Multi-user applications for long distance

Fig 5: Multiple links OCC architecture

3. Conclusion

Motion to 802.15 Interest Group

Recommendations