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

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**Abstract:** This slide presents the definition of asynchronous communication in Image Sensor based Receiver (OCC) and explains the importance of asynchronous communication mode.

**Purpose:** Call for Application Response

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# Asynchronous OCC: Definition, benefits and consideration.

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# Definition of Asynchronous OCC

In OCC, especially in unidirectional OCC, the ratio of frame rates between light source transmitter and camera receiver are **mismatched**. Mismatched frame rates happens when the ratio of frame rate is unstable.

$$\frac{\text{Camera frame rate}}{\text{Transmitter clock rate}} = \text{varying}$$

## Reasons can be:

- (i) the frame rate of camera is unstable [1-2]
- (ii) the camera frame rate is fixed but the pulse rate of light source transmitter is varying/ or fixed but unknown

## Definition:

Asynchronous OCC is OCC under presence of mismatched frame rates between transmitter and camera receiver.

[1] **Kookmin contribution:** [Synchronization and Flickering Issues of OCC] [Kookmin University]- 20-Jan-2014. Available at: <https://mentor.ieee.org/802.15/dcn/14/15-14-0041-00-007a-synchronization-and-flickering-issues-of-occ.ppt>

[2] **Microsoft:** Wenjun Hu, Hao Gu, and Qifan Pu, "LightSync: Unsynchronized Visual Communication over Scenen-Camera Links," *MobiCom '13 Proceedings of the 19th Annual International Conference on Mobile Computing & Networking*, pp. 15-26, Oct. 2013.

# Example

**Transmitter clock rate:** 200 Hz

**Camera frame rate:** varying from 20fps to 40fps for 30fps camera.

$$\frac{\textit{Camera frame rate}}{\textit{Transmitter clock rate}} = \textit{varying}$$

In this case, frame rates between transmitter and receiver are mismatched. And Asynchronous Communication Mode is needed.

# Why Asynchronous OCC is needed?

- The camera frame rate can be setup. However, between the setup value and practical recorded value of camera frame rate are different. In addition, it is practically recorded that the camera frame rate is unstable (the variation of camera frame rate) [1, 2]. This causes the mismatching frame rates between transmitter and receiver. There is one way to fix frame rate of camera is hacking firmware. However, the result clearly shows that a fixed rate may be undesirable, for breaking the camera's adaptive lighting compensation algorithm and potentially producing low-quality images, according to Microsoft work [2].
- Asynchronous communication is still required even though the frame rate of camera is fixed. It happens when the pulse rate of transmitter is unknown or varying. In fact, the frequency range can be varied at low range [2] or high range.

[1] **Kookmin contribution:** [Synchronization and Flickering Issues of OCC] [Kookmin University]- 20-Jan-2014. Available at:

<https://mentor.ieee.org/802.15/dcn/14/15-14-0041-00-007a-synchronization-and-flickering-issues-of-occ.ppt>

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# Benefits of Asynchronous OCC

	<b>Synchronized OCC</b>	<b>Asynchronous OCC</b>
<b>Scenarios flexibility</b>	<ul style="list-style-type: none"><li>- Only matched frame rates between transmitter and fixed camera frame rate</li><li>- Frame rates between camera and transmitter are harmonic</li></ul>	<ul style="list-style-type: none"><li>- All types of cameras with varying frame rate in acceptable range, including fixed frame rate camera.</li><li>- Frame rates between camera and transmitter do not require to be matched.</li></ul>
<b>Implement complexity and video quality consideration</b>	<ul style="list-style-type: none"><li>- Hacking existing camera firmware to fix frame rate[1]</li><li>- The video quality should be considered while the auto brightness adjustment mode is off.</li></ul>	<ul style="list-style-type: none"><li>- Software programming based on existing camera firmware</li><li>- Thus video quality is maintained while integrating OCC into video (eg. Augmented reality).</li></ul>
<b>Data rate</b>	<ul style="list-style-type: none"><li>- Fixed camera frame rate can achieve high performance of transmission</li></ul>	<ul style="list-style-type: none"><li>- A frame structure may need to be considered to support variation of camera frame rate.</li></ul>

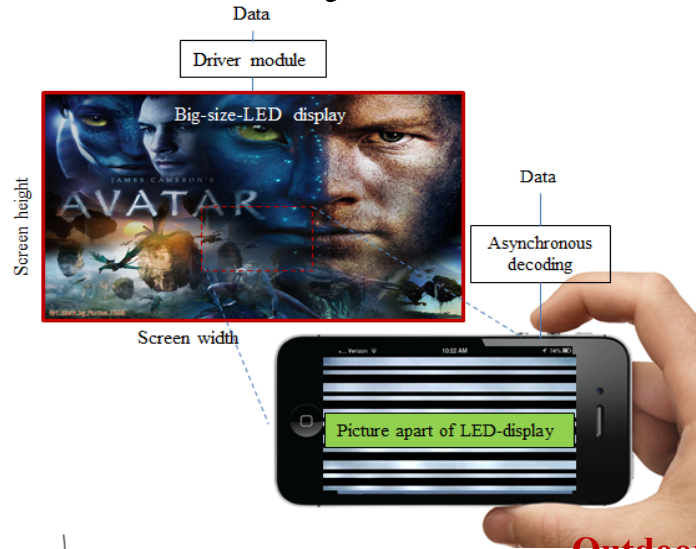
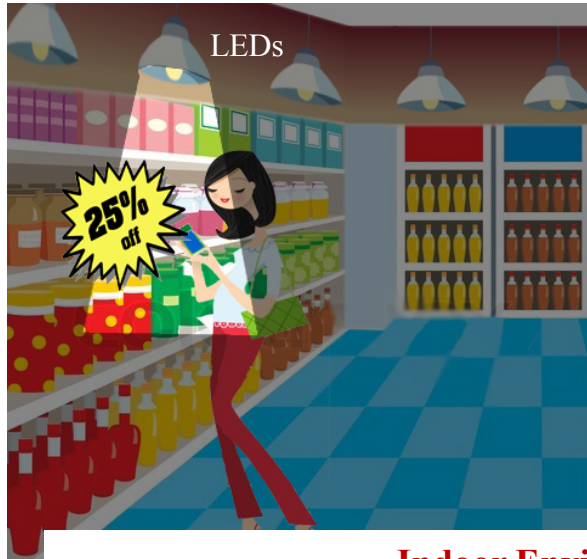
[1] **Microsoft:** Wenjun Hu, Hao Gu, and Qifan Pu, "LightSync: Unsynchronized Visual Communication over Scen-Camera Links," *MobiCom '13 Proceedings of the 19th Annual International Conference on Mobile Computing & Networking*, pp. 15-26, Oct. 2013.

# Benefits of Asynchronous OCC

- **Flexibility**
  - All types of camera can be used, including fixed frame rate or varying frame rate cameras.
  - Flexible frame rate/frequency for transmitter
  
- **Simplicity**
  - Once the protocol is provided, every programmer can make their own program based on existing camera firmware.



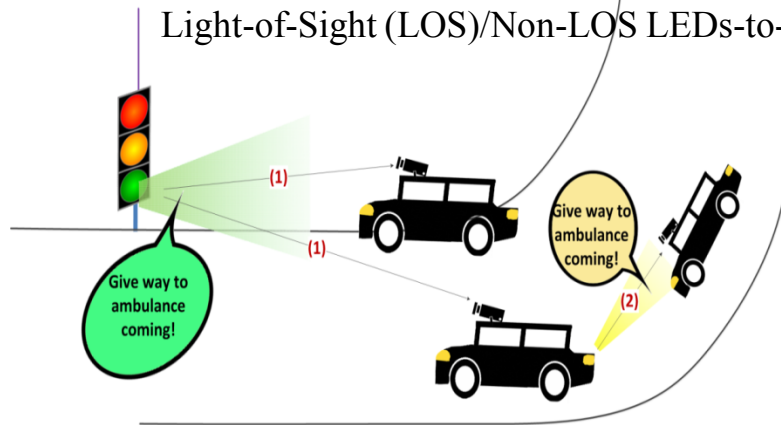
# Scenarios of Asynchronous OCC



**Indoor Environment**

**Outdoor Environment**

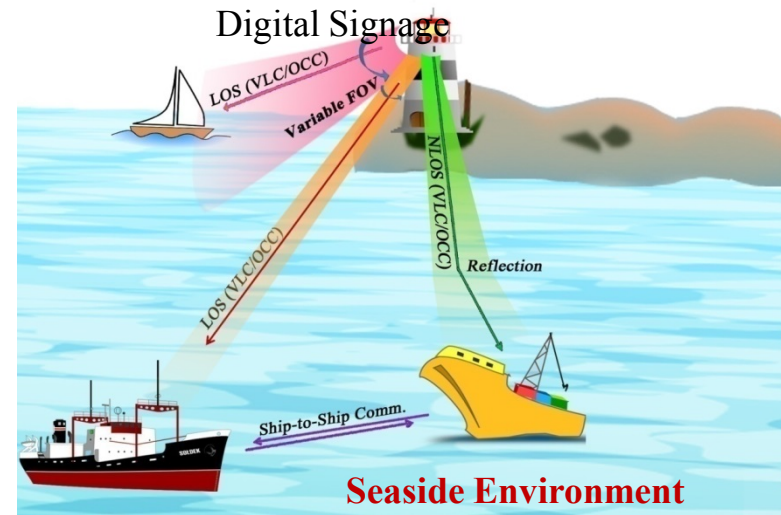
Light-of-Sight (LOS)/Non-LOS LEDs-to-camera



- (1) - Broadcasting Service using Asynchronous OCC
- (2) - Relaying Car-to-Car using Asynchronous OCC

**Vehicular Environment**

V2V/V2X

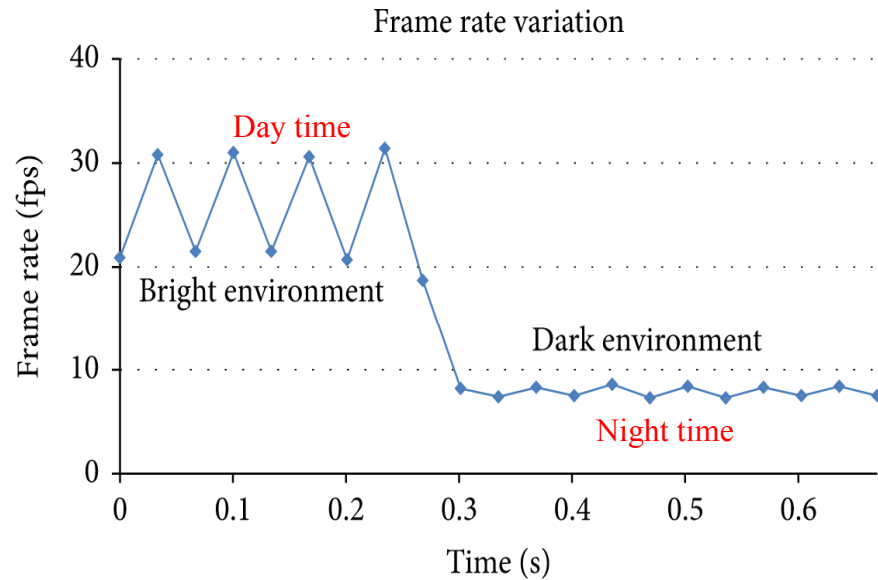


**Seaside Environment**

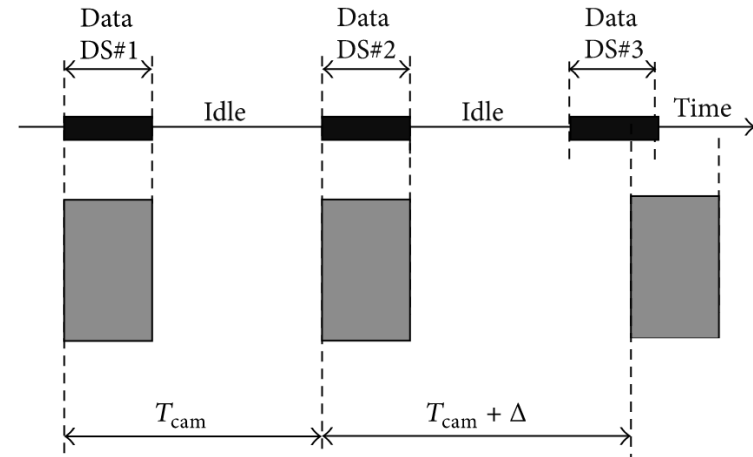
Lighthouse-to-Ship/Ship-to-Ship

# Technical considerations

- **The acceptable range for varying frame rate**



**Experiment of variation in camera frame rate by measuring inter-frame interval**



$$T_{cam}(t) = T_{cam} \pm \Delta(T_{cam}),$$

**Model of variation in camera frame rate**

- The variation range of camera frame rate should be considered. How much it varies may affect to the communications. When the frame rate drops under a accepted threshold, the data frame might be lost.

## Conclusion

- ❖ Beside synchronized OCC, asynchronous OCC should be considered and allowed in some situations in which frame rates between transmitters and receivers are mismatched.
- ❖ Asynchronous OCC can bring various benefits including flexibility and simplicity.
- ❖ Some Asynchronous OCC scenarios are promising
- ❖ **Need PHY support Asynchronous Communication Mode as well as Synchronized Mode**