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Submission Title: [VLC Application: Image Sensor Communication (ISC)]

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Abstract:[VLC Application using Image Sensors discussed in VLCC Japan.]

Purpose:[Contribution to IEEE 802.15 TG7]

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VLC Application: Image Sensor Communication (ISC)

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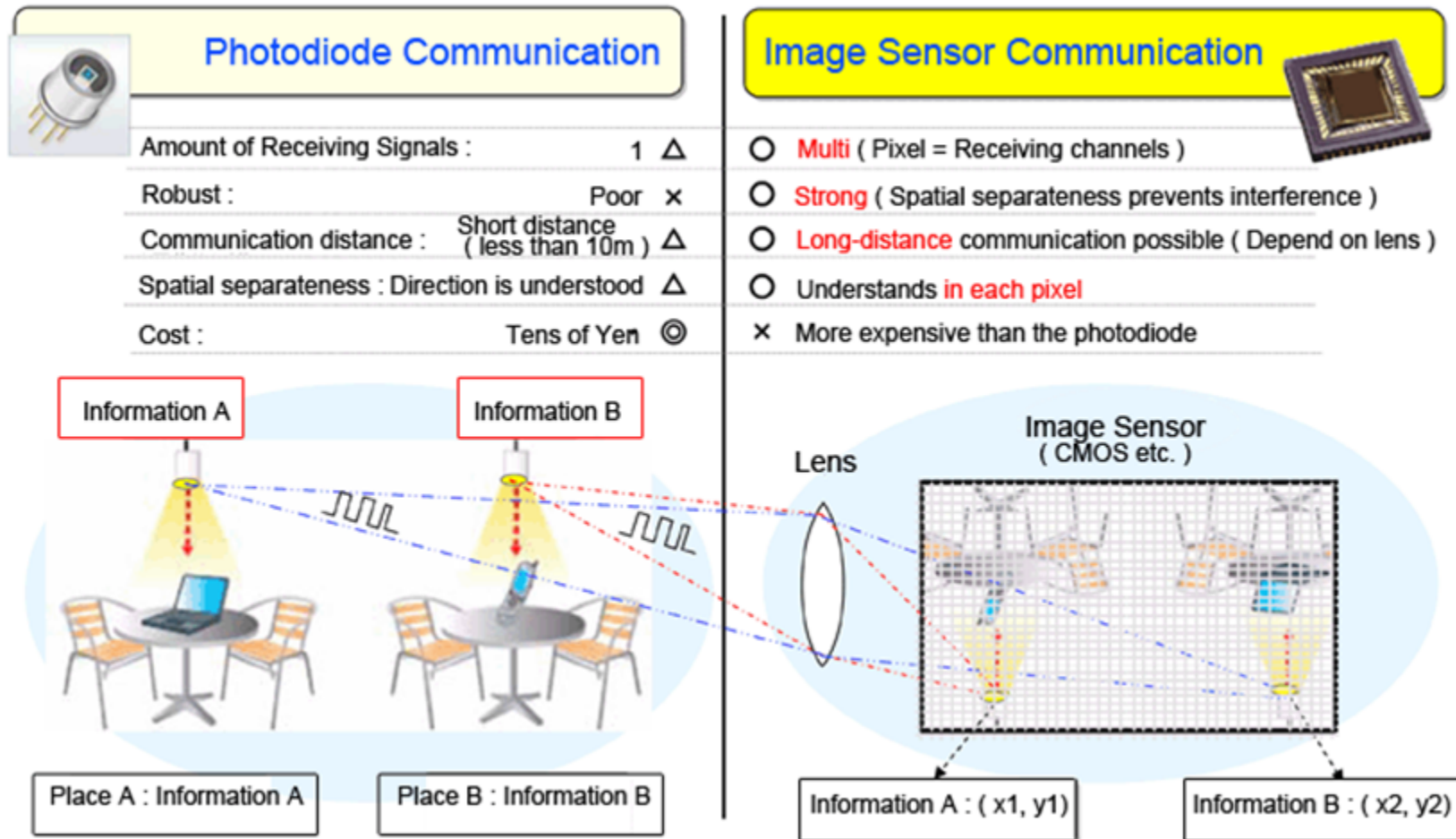
Visible Light Communications
Consortium(VLCC)
(Fundamental Device Technology WG)

Tokyo, Japan

- **Purpose:**
- This document is made to examine the applications and the technologies of the **Image Sensor Communications** (Hereafter, we call “**ISC**”).
- In this document, some comments refer to the document: 802.15.09-0111-00-0007 of Mr. Rick Roberts and Mr. Praveen Gopalakrishnan of Intel.
- There are two fields about VLC technologies and its applications of Visible Light Communication; one based on the “Photodiode (PDC)” and the other based on the “Image sensor (ISC).” In this document, we put some comments for the technologies and the applications especially about ISC.

Image Sensor Communication (ISC)

- Up to now, photodiode (PDC) has been used as for the optical communication device, and the Image Sensor is used as a communication device in the ISC.
- The photodiode has been used overall unconditionally in the optical communication, and it seems to have to think separately by PDC and ISC.



Opinion for 802.15.09-0111-00-0007

- We agree completely with the Opinion 1. And we believe that ISC develops a truly new market.
- Why can ISC create a new market?

You referred to the possibility for the function of SDM in Opinion 11 . We agree with it. We think it is important for the applications, and the following functions bring additional viewpoints other than SDM.

1. It is extremely strong in jamming and interference because it is separated spatially.
2. It is possible to know the position of each source in high accuracy stabilizing.
3. It is possible to be associated with the scene and multi information.
4. It is possible to be used a source of light for person and an existing lighting infrastructure for the long-distance communications .
5. It is possible to be able to stick data in the object by an indirect light irradiation.
6. It is possible to be obtained the scalability of distance very easily with the optical system technology (e.g. lens exchange, zoom).

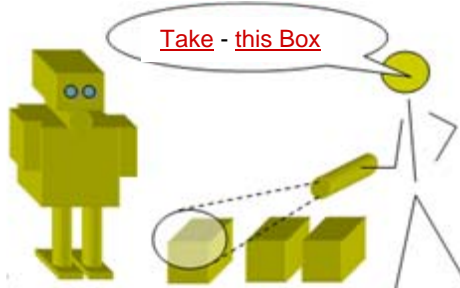
...etc

Application for ISC

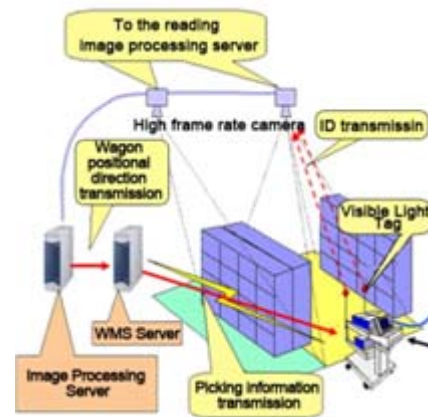
- The new applications for ISC will be separately announced as proposals from VLCC.
- The following application is unable to be realized with the existing telecommunication technology or the image-recognition.
- The proving test and a lot of application ideas have been already opened and discussed by the members of VLCC.



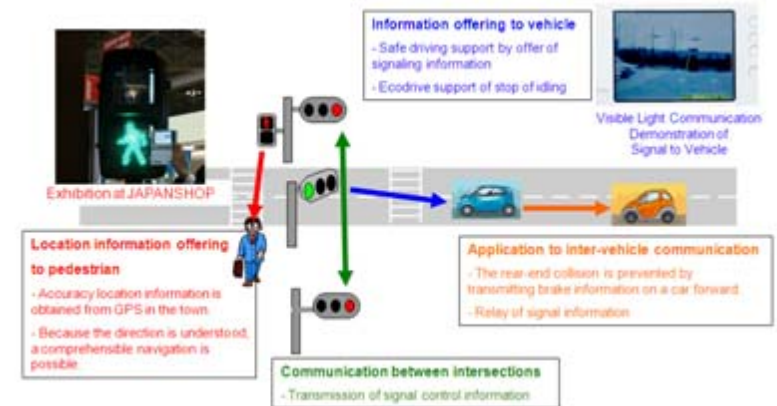
A. Positional grasp sensor net



D. Robotics Object + command



B. Positional measurement at Factory and warehouse



C. Application of visible optical communication around intersection



E. Indirect irradiation at art and museum



F. Photograph with balloon message (Transmit from Cellular phone LED)



G. Guiding in spectacle outdoor long distance



H. ITS Navigation

Applications for ISC

- A summary of our interest for ISC is shown below.
- All applications are Pt-to-MultiPoint and Uni-Directional.

	A. Positional sensor net	B. Positional measurement at Factory and warehouse	C. Application for visible optical communication around intersection	D. Robotics (Object + command)	E. Indirect irradiation at art and museum	F. Photograph with balloon message	G. Guiding in spectacle outdoor long distance	H. ITS Navigation
Environment	Outdoor / Indoor	Indoor (Outdoor)	Outdoor	Outdoor / Indoor	Indoor	Outdoor / Indoor	Outdoor	Outdoor
Simultaneous number of receptions	Typ.< 10 (Perhaps < 100)	Typ.< 10 (Perhaps < 100)	Typ.< 10	Typ.< 10	Typ.< 10	Typ.< 10	Typ.< 10 (Perhaps < 100)	Typ.< 10
Data Rate	< 1kbps	< 1kbps	< 1kbps	< 1kbps	< 1kbps	< 1kbps	< 1kbps	< 10kbps
Distance	< 100m	< 100m	< 300m	< 10m	< 10m	< 10m	< 500m	< 300m
Multiple Device Discovery	Auto	Auto	Auto Pre adjust @Signal to Signal	Auto	Auto	Auto	Auto	Auto
Mobility (Multiple beam tracking)	None	4KPH (walk)	150KPH @Signal to Vehicle None@Signal to Signal)	None Or 4KPH (robot move)	None	None	None	150KPH

ISC Technology

- The image sensor (camera) keeps extending to all the applications. The S/N performance and the frame rate keep developing greatly.
- It might be inevitable to catch the Image Sensor as a device of the communication at the present time.
- ISC will be able to develop the application at the early stage by utilizing the mass production technology of the Image Sensor.
- Moreover, the following points might be necessary for more careful discussions of the standardization.
 - Data Rate
 - (Multi Point) Device Discovery
 - (Multi Point) Beam Tracking

- At Opinion10, it mentioned that the field of under 10 kbps should not be used for VLC because it is ambient interference. However, we think that we should positively use the low data rate band when thinking about early practical use of ISC.
 - Although the problem of ambient interference is found, it is extremely few for ISC by an advanced spatial separateness. It is possible to use ISC without any troubles even by a low-data rate.
 - Even if it is the same frequency and the same modulation, the light that spatially becomes another position is never interrupted when the optics system is used for ISC.
 - Moreover, the observation experiment using the LED signal that VLCC had done in 2008 and 2009, we confirmed that the sudden change of a surrounding illumination such as day and night didn't exert a big influence on the communication when paying attention to a single source of light.
 - Because ISC depends on the frame rate, it is not suitable for the high-speed communication.
 - The frame rate is greatly controlled by the field angle and the spatial resolution (number of pixels for the sensor).
 - The bit rate (It depends on the field angle of the search space and the resolution. And it is different because of the demonstration at various applied patterns) that VLCC member companies announce from 150 bps (600 fps)
 - To 1.2 kbps (4800 fps) as results now.
 - We think that we should start from easy and practical use such as the tag first.
- Because ISC has a lot of new functions and characteristics, it is likely to make a clear distinction with the speed-up competition of the data rate.
- If it considers a data rate necessary for ISC applications, it is very useful even in the low data rate.

Effective application even using low data rate

- Frankly speaking, it is o.k. that a reactive time is very slow for the ID recognition.
 - For instance, it is only 160 bps bit rate needed for the application to identify ID of 16 bit within 0.1 seconds.
 - The ISC function of “positional grasp” brings important information more than the bit rate.

- Because ISC is a parallel communication without interference, you don't have to assume the maximum and simultaneous number of communications and secure the band as many as the number of single channels.
 - It is not jammed (ambient interference). And time sharing is not necessary, either.
 - You don't need the rate to be adjusted to 100 kbps because there is 100 tag of 1 kbps.
 - A 100 tags of 1kbps is received simultaneously , and, in parallel, even 1 piece or 100 of 1 kbps are easily recognized.

(Multi Point) Device Discovery

- “Device discovery” (and Tracking too) mentioned in Opinion 12 is very essential fact in the ISC.
 - Because the same brightness and the same color of light from a signal source can be existed , it is very necessary to solve the interference.
- The member companies of VLCC have already created the filter for useful device to discover the specific light signal source among the ambient interference lights.
 - CASIO has announced the trial prototype that discovered using the three dimensions processing (= time * spatial) filters on the time order image between the time and spaces.
 - NEC also has announced the filters that discover a specific light signal.
- The “device discovery method” is very important for the decision of the data format of the ISC.

- In many applications, the signal moves independently, and the sensor causes the blurring so that a relative position always changes.
- - It is difficult to do the higher correspondence to chase for your mentioned Option 13, if the ISC beam tracking is not corrected at the real time basis.
 - The process might be more complicated when the transmission lights become many sources in the application.
- The trial prototypes which can track the many moving objects are already announced by VLCC.
- It is quite possible to use ISC for the vehicle networking.
 - It mentioned “Vehicle to Infrastructure” in the table of Opinion 7, “Infrastructure to Vehicle” has been also discussed in VLCC/Japan.