Bi-Directional Communication Between Infra-Structure and Mobile Device Based on Visible Light Communication

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OUTLINE

• Introduction

• Optoelectronic characterization
  • Transmitters
  • Receivers

• Results and discussion
  • I2V channel
  • V2I channel

• Conclusions
GLOBAL INTERNET GROWTH AND TRENDS

Key Digital Transformers

By 2021

By 2021, 63% of total IP traffic will be wireless *

Source: Cisco VNI Global IP Traffic Forecast, 2016-2021
5G COMMUNICATIONS

Speed
Latency
Capacity

The Internet of Things
VR, AR and holograms
TECHNOLOGY INTEGRATION

Source: pureLiFi

Sensor Devices 2020
The Eleventh International Conference on Sensor Device Technologies
COMMUNICATION SPECTRUM

Radio
- Radio navigation
- Shortwave emission
- Citizen band

Microwaves
- Walkie-talkie
- FM Radio

Infrared

Visible

Ultra violet

X rays

Radio frequencies

Radio frequencies

100 kHz
1 MHz
10 MHz
100 MHz
1 GHz
10 GHz
100 GHz
f (Hz)

Adapted from "Física 11", C. Fiolhais et al.
OPTICAL COMMUNICATION SPECTRUM

**OWC** Optical wireless communications

**FSO** Free space optical comm

**VLC** Visible Light communication

**INFRARED**
- 1 mm
- 15 μm
- 8 μm
- 3 μm
- 1.4 μm
- 700 nm
- Far
- Long
- Mid
- Short
- Near

**VISIBLE**
- 400 nm
- 700 nm
- 1.4 μm
- 30 μm
- 300 μm
- 850 nm
- 1310 nm
- 1550 nm

**ULTRAVIOLET**
- 430 THz
- 700 nm
- 750 THz
- 400 nm
- 3 PHz

**Optical wired communications**

**FO** Fiber optics communication

SENSORDEVICES 2020
nth International Conference on Sensor Device Technologies
VISIBLE LIGHT COMMUNICATION

- Dual operation: light + comm
- Infrastructure advantage
- Increased bandwidth
- Negligible power
- Inexpensive
- Free and non-regulated spectrum
- Security
- Harmless to human health
- No EM interference
- Line of sight condition
MOTIVATION

- Use of autonomous vehicles to grab goods and carry them to the packaging station
- Navigation along pre-defined routes
- COOPERATIVE APPROACH: bidirectional communication
COMMUNICATION LINKS

- I2V lamps to autonomous robots
- V2I: robots to lamps
- V2V: robots to robots
**OPTOELECTRONIC CHARACTERIZATION: TRANSMITTERS**

**White RGB LEDs**

**Spectral output**

- 470 nm, $\Delta \lambda = 22$ nm
- 532 nm, $\Delta \lambda = 48$ nm
- 635 nm, $\Delta \lambda = 13$ nm

**Viewing angle**

$\theta = 2 \times 60^\circ = 120^\circ$
OPTOELECTRONIC CHARACTERIZATION: RECEIVER

Violet LED (400 nm)

White LEDs

Steady state light

Long λ - amplification

Modulated light

Front contact

Back contact

Front PD
a-SiC:H
200 nm

Back PD
a-Si:H
1000 nm

Glass substrate
Increased accuracy
NAVIGATION CELLS

Unit navigation cell: #1
- LED Lamps
  - Reverse lane
  - Forward lane
- Racks
  - a
  - b
  - c
- Photodetector
  - Reverse lane
  - Forward lane
R'
B'

Unit navigation cell: #2
- LED Lamps
  - Reverse lane
  - Forward lane
- Racks
  - a
  - b
  - c
- Photodetector
  - Reverse lane
  - Forward lane
R'
B'

Unit navigation cell: #3
- LED Lamps
  - Reverse lane
  - Forward lane
- Racks
  - a
  - b
  - c
- Photodetector
  - Reverse lane
  - Forward lane
R'
B'
Simultaneous modulation of 4 emitters

The resultant optical signal is a combination of 4, 3, 2 or 1 optical signals → 16 possible photocurrent levels

(The driving current of each LED emitter was adjusted to provide different levels of photo excitation)
I2V CHANNEL

Photocurrent (a. u.)

Time (ms)

Top emitters: 111 0
Bottom emitters: 101 1

CELL ID: 001010000100
Line: 0101_{12} (5_{10})
Column: 0010_{12} (2_{10})

TRANSMITTED INFORMATION

CELL ID: 001010000100
Line: 0101_{12} (5_{10})
Column: 0010_{12} (2_{10})

Top emitters: 111 0
Bottom emitters: 101 1
P1 = R + R' + B'
P2 = R' + B + B'
P3 = R + B + B'

Parity Check Bits

Calibration signal
Control signal

Photocurrent (a.u.)
Time (ms)

R
B
R'
B'

Parity check bits standard bits (16 states)

L00: OFF
L01: B'
L02: B
L03: BB'
L04: R'
L05: R'
L06: R
L07: RB'
L08: R
L09: RB'
L10: RB
L11: RBB'
L12: R
L13: RR'B'
L14: RR'B
L15: RR'BB'
L16: RR''
L17: RR''B'
L18: RR''B
L19: RR''BB'
L20: OFF

0 1 2 3 4 5 6 7
standard bits (16 states)
Parity check bits
V2I CHANNEL

ID of both partners

➢ ROBOT ID: 01100110₁₂ (118₁₀)
➢ CELL ID: 1100₁₂ (5₁₀) & 0010₁₂ (2₁₀)
➢ RACK: items from rack a and c located at the south direction (forward lane) were removed

Photocurrent (a.u.)

Time (ms)

V2I Channel

ROBOT ID (8 bits)
CELL ID (12 bits)
RACK (4 bits)
MESSAGE (820 bits)

SoT
EoT
CONCLUSIONS

✓ Bi-directional communication using VLC has been addressed in a robot navigation system inside a warehouse.

✓ Different links were proposed to establish I2V and V2I communication.

✓ Definition of specific codes for each link using 64 bits word. ON-OFF Keying modulation.

✓ I2V link – positioning and navigation information using 4 emitters.

✓ V2V link - data transmission using a single emitter.

✓ Flickering effects were addressed by suitable control of the amount of transitions to zero.

✓ Implementation of bit error control schemes.

✓ Future work
  ✓ Analysis of the system under other background illumination sources (noise, photodiode saturation...).