Geolocation and Wayfinding in Complex Buildings Using Visible Light Communication

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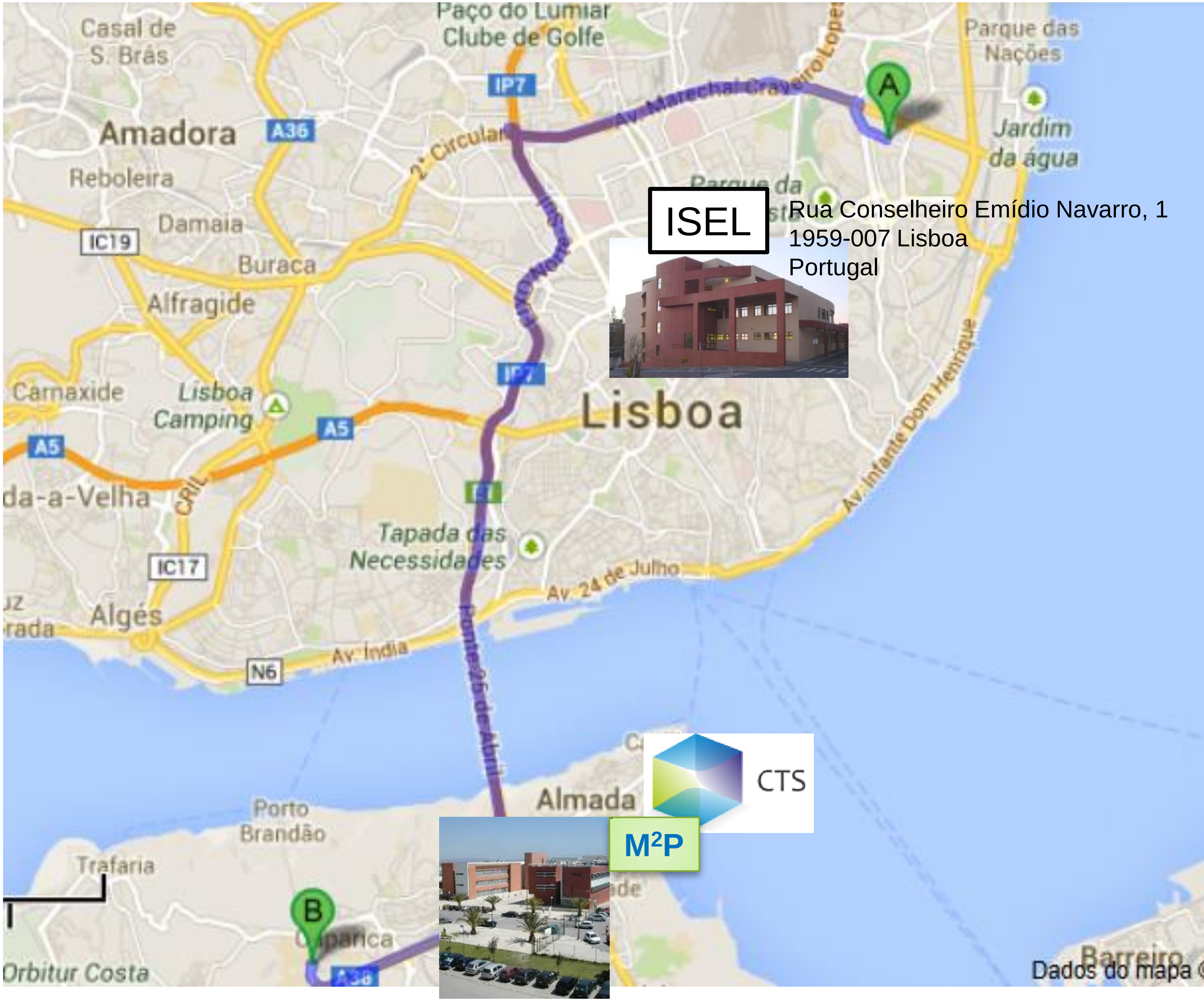
Location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- **Manuela Vieira** was born in Lisbon, Portugal. In 1986, she received the Master of Science in Solid State Physics-Microelectronic and in 1993 the PhD in Semiconductor Materials, both from the New University of Lisbon. She receives the habilitation title in Electronics, in 2003 from New University of Lisbon, Portugal.

- She is a Full Professor, since 2011, in Electronics inside the Department of Electronics Telecommunication and Computers (ISEL-Portugal) and Associated Professor in the New University of Lisbon, School of Sciences and Technology (UNL-FCT, Portugal).

- She is also the Leader of the Research Groups in Applied Research in Microelectronic Optoelectronic and Sensors (GIAMOS / ISEL) and in Microelectronic, Material and Processes (M2P/ CTS-UNINOVA). She has several scientific papers and has participated in many international and national projects, both as a researcher and as a project coordinator. She has 30 years of experience in the field of thin films and devices and on Visible Light Communication.

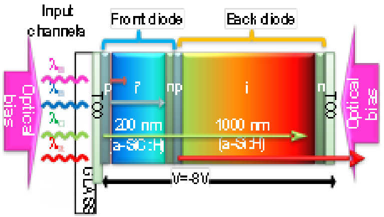
Other scientific activities:

- Referee for international publications such as: Thin Solid Films, Material Research Society, Sensor Magazine, Sensor and Actuators, Material Science Fórum, Solid State Electronics, Vacuum, Applied Surface Science, Sensors and Transducers, Revista Ibersensors, Physica Status Solidi, Sensors, Journal of Nanoscience Nanotechnology, Journal of Sensors, Journal of Signal and Imaging Systems Engineering (IJSISE), etc.
- Evaluator of proposals submitted to several international funding organizations
- Supervision and co-supervision of Master and PhD students
- Examiner for Master and Doctoral degrees.
- Authored and co-authored over than *400* publications in refereed journals and conferences proceedings. Presented more than 500 communications at conferences and seminars most of which with publication in journals and proceedings. She is an IARIA Fellow since 2018.

Objectives (M^2P)

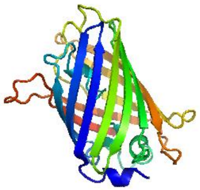
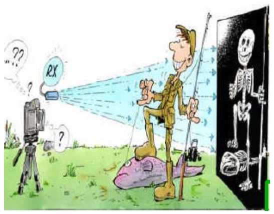
- Development, optimization and application of semiconductor based devices: image and color sensors, optoelectronic devices, solar cells, optical amplifiers, biosensors, VLC devices, nanostructures and UV and IV detectors.

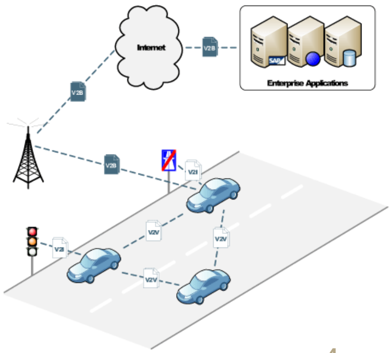
- Design and modeling of optical devices.

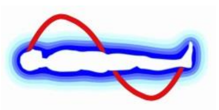
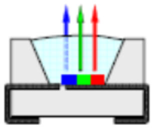
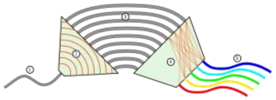


- Electrical and numerical simulation of optical devices.

- Integration of different technologies, namely optical sensors, wavelength-division multiplexing, waveguides, Visible Light Communication, X-ray detectors and full digital medical imaging.




What are we Pursuing/ Aiming

- Generate cross fertilization with other national and international research groups;
- Increment the number of graduation students;
- Participation in European projects;
- Collaboration with industry/companies;
- Increase the number of patents.

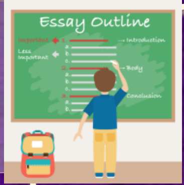
ABSTRACT

- The applicability of an intuitive wayfinding system in complex buildings using Visible Light Communication (VLC) is investigated.

- Data from the sender is encoded, modulated and converted into light signals emitted by the transmitters. Tetra-chromatic white sources are used providing a different data channel for each chip. At the receiver side, the modulated light signal, containing the ID and the 3D geographical position of the transmitter and wayfinding information, is received by SiC photodetector with light filtering and demultiplexing properties.

- Since lighting and wireless data communication is combined, each luminaire for downlink transmission become a single cell, in which the optical access point (AP) is located in the ceiling and the mobile users are scattered within the overlap discs of each cells underneath. The effect of the location of the Aps is evaluated and a model for the different cellular networks is analyzed. Orthogonal topologies are tested, and a 3D localization design, demonstrated by a prototype implementation, is presented. Uplink transmission is implemented and the 3D best route to navigate through venue calculated. Buddy wayfinding services are also implemented.

- The results showed that the system make possible to determine the position of a mobile target inside the network, to infer the travel direction along the time and to interact with information received and to optimize the route towards a static or dynamic destination.



OUTLINE

✓ MOTIVATION

- VLC – Transmission of data using light
- Multilayered a-SiC:H heterostructures as optical filters

✓ SYSTEM DESIGN

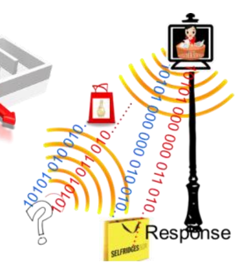
- The VLC Scenario
- The VLC emitters for large environments
- The OOK modulation scheme
- The VLC receivers

✓ RESULTS AND DISCUSSION

- Coding/decoding techniques
- VLC System evaluation

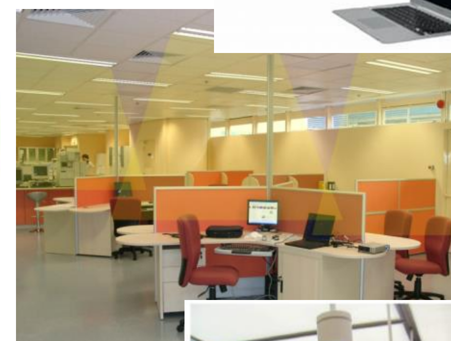
✓ APPLICATIONS

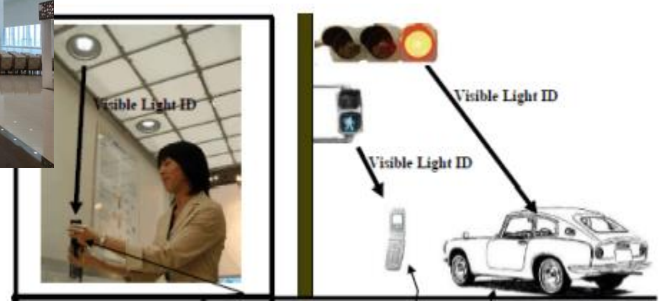
- Navigation data bits
- Bi-directional Communication
- LED-aided Navigation System



✓ CONCLUSIONS/FUTURE WORK

VLC – Visible Light Communication





Wi-Fi will begin to become limited

Indoors environments

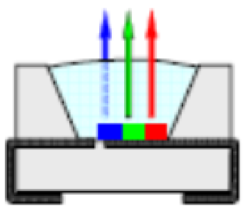
- Light atmospheric absorption
- Shadows
- Light dispersion
- Influence of other light sources

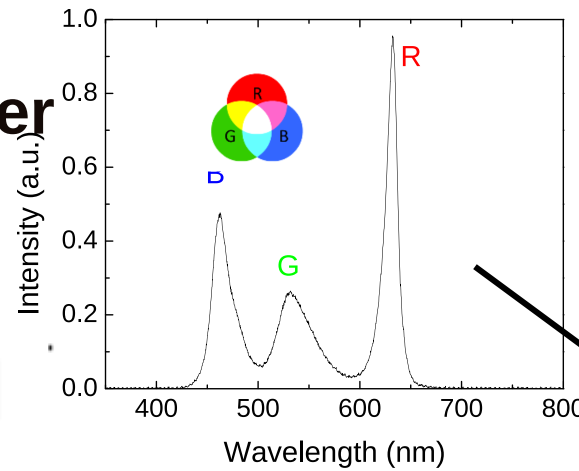
MOTIVATION

VLC SYSTEM

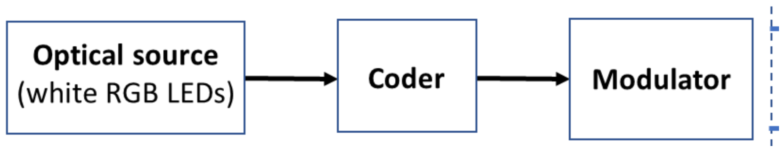
- The system is a self-positioning system in which the measuring unit is mobile.
- This unit receives the signals from several transmitters in known locations, and has the capability to compute its location based on the measured signals.

Transmitter

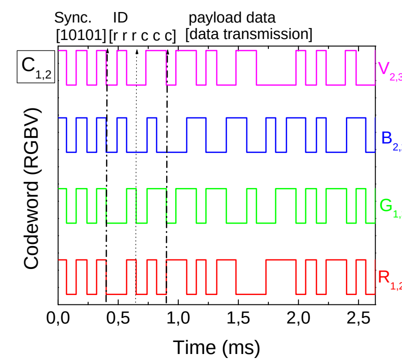




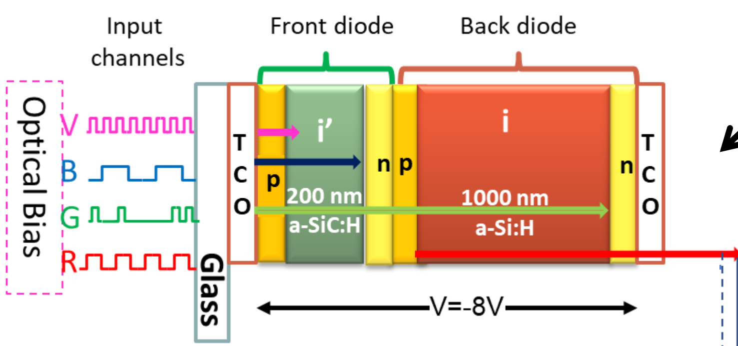
- Red, Green and Blue white LED



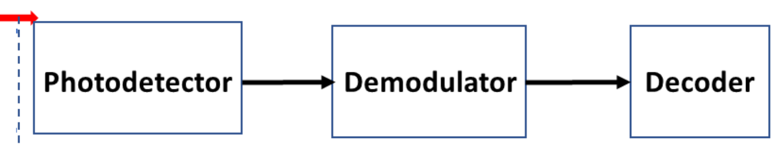
Line of Sight channel



Receiver

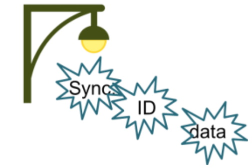


- p-i'(a-SiC:H)-n/p-i(a-Si:H)-n heterostructure produced by PECVD.



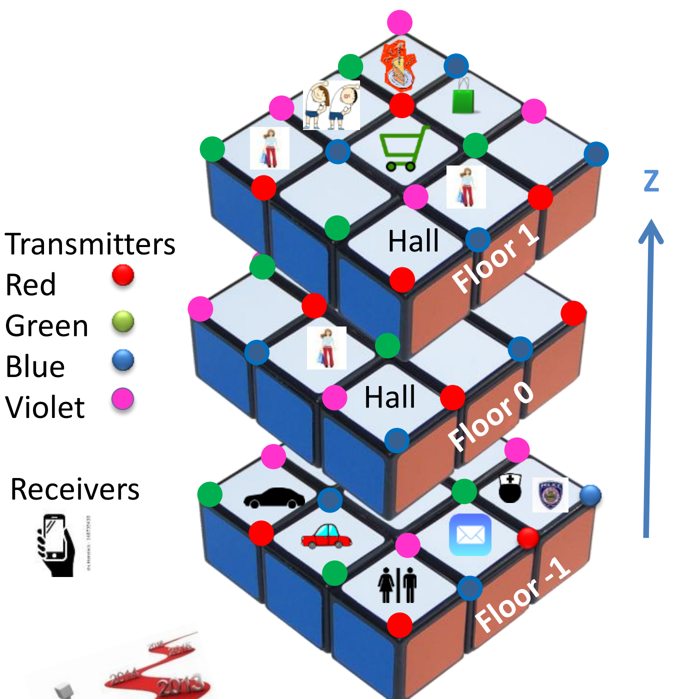
DYNAMIC NAVIGATION SYSTEM

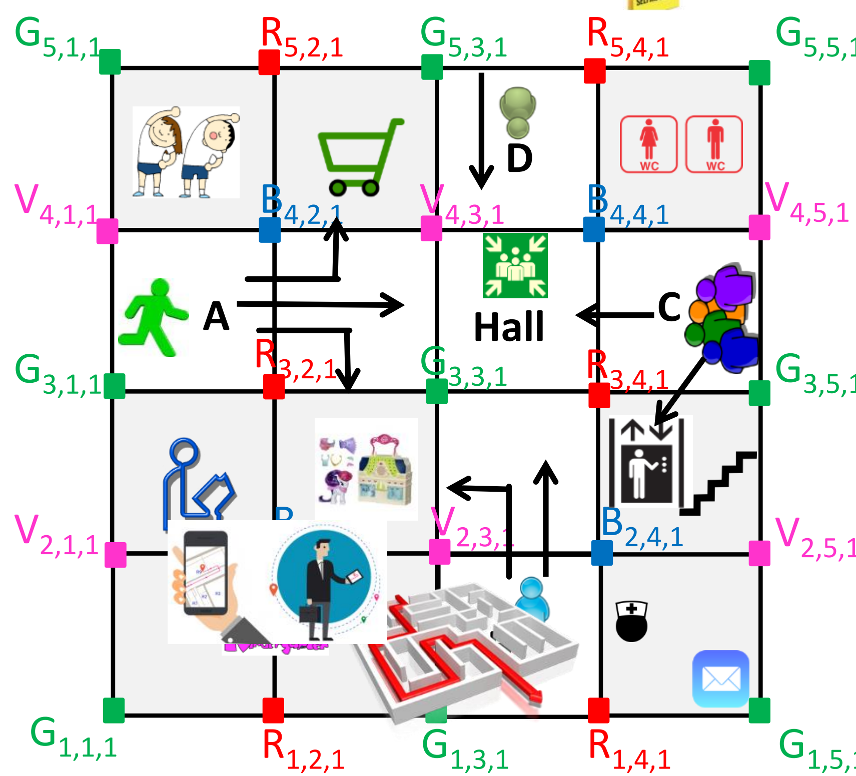
- The system is composed of several transmitters (LEDs ceiling luminaries) which send the map information and path messages required to wayfinding.



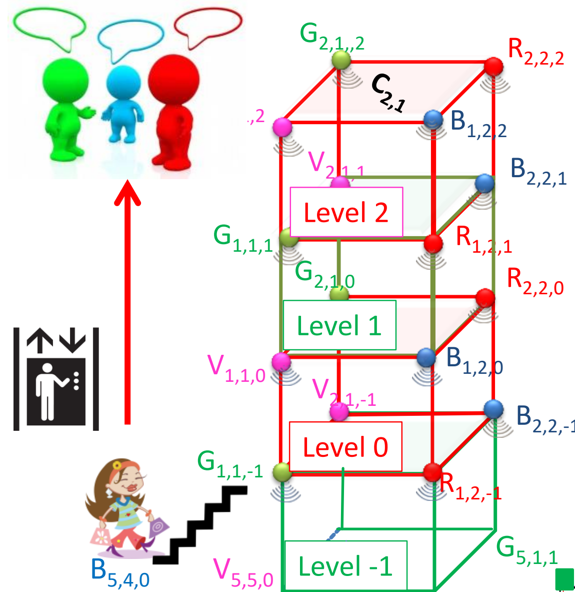
- Mobile optical receivers extracts theirs location to perform positioning and, concomitantly, the transmitted data from each transmitter.

- Bidirectional communication between the emitters and the receivers is available in strategic optical access point (Li-Fi zone).

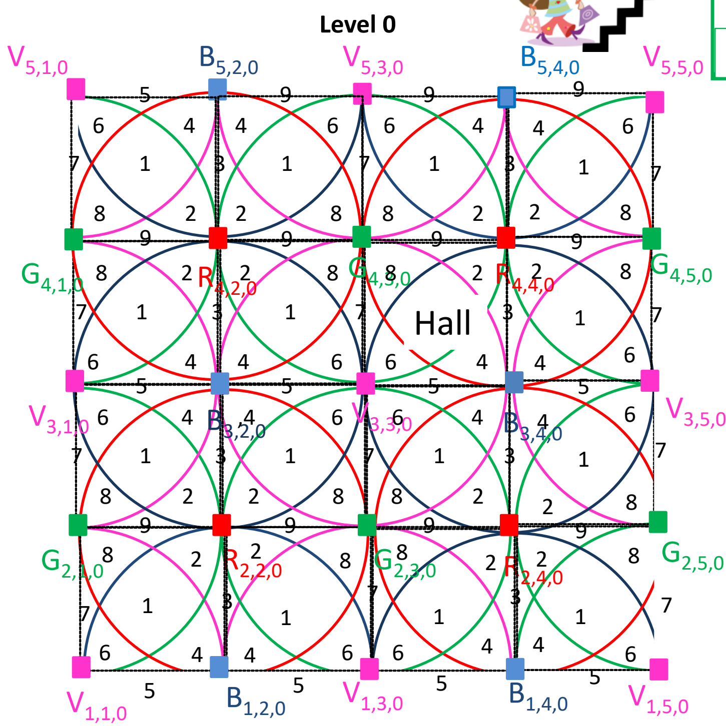


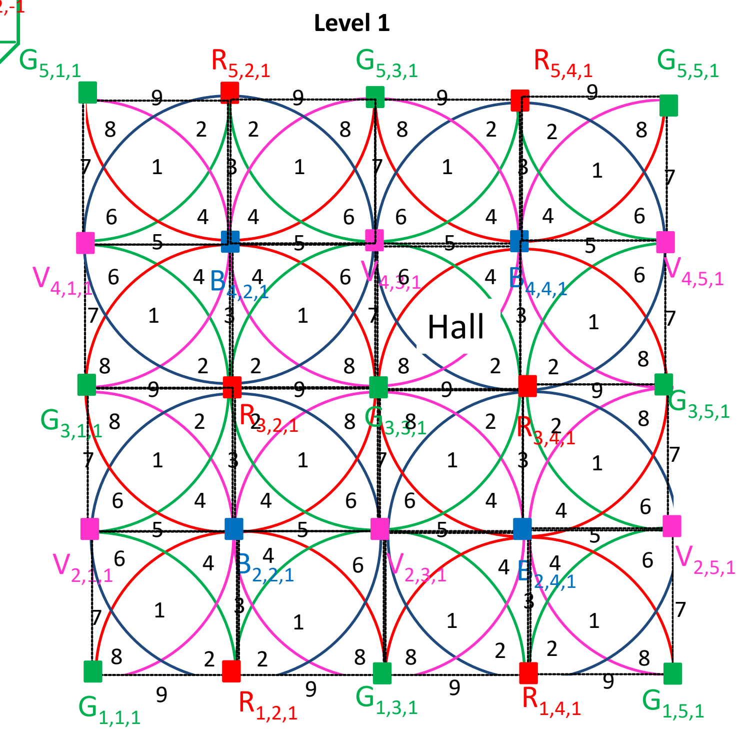


VLC SCENARIO



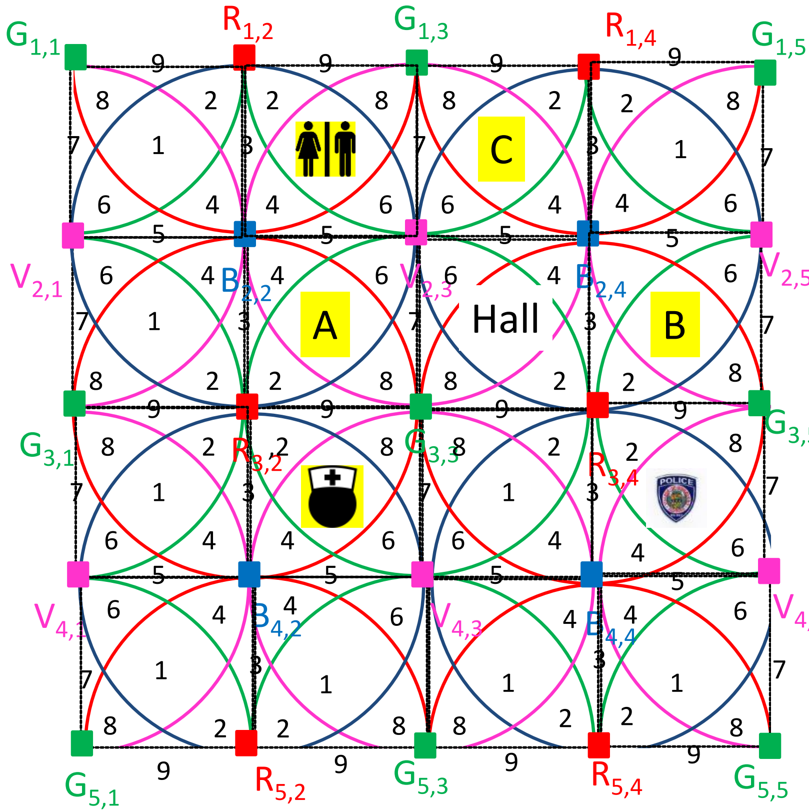
Footprint	Overlap
#1	R+G+B+V
#2	R+G+B
#3	R+B
#4	R+B+V
#5	B+V
#6	G+B+V
#7	G+V
#8	R+G+V
#9	R+G



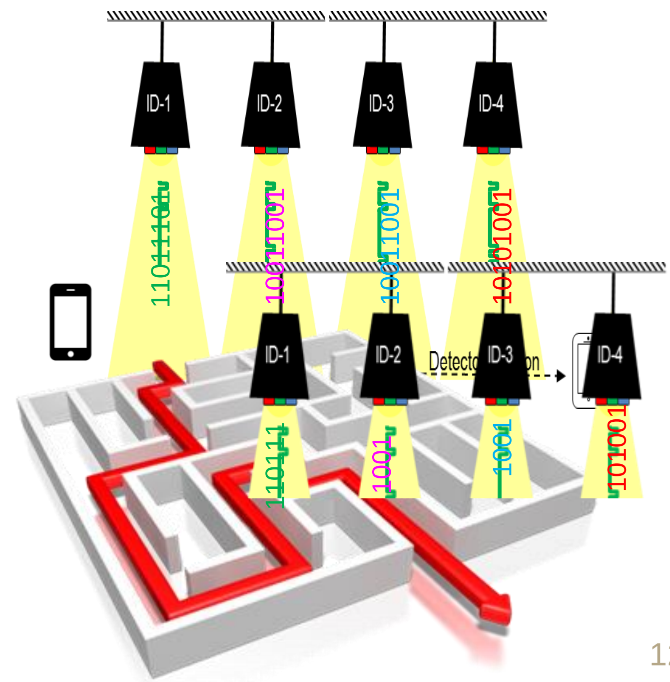


- Ceiling plans for the LED array layout in a 3D building, for even and odd floors (R,G,B,V are the modulated color spots for data transmission in each level). The footprint regions assigned to the overlaps are pointed out.

The Emitters for Large Environments



Clusters of cell in an orthogonal topology (square).



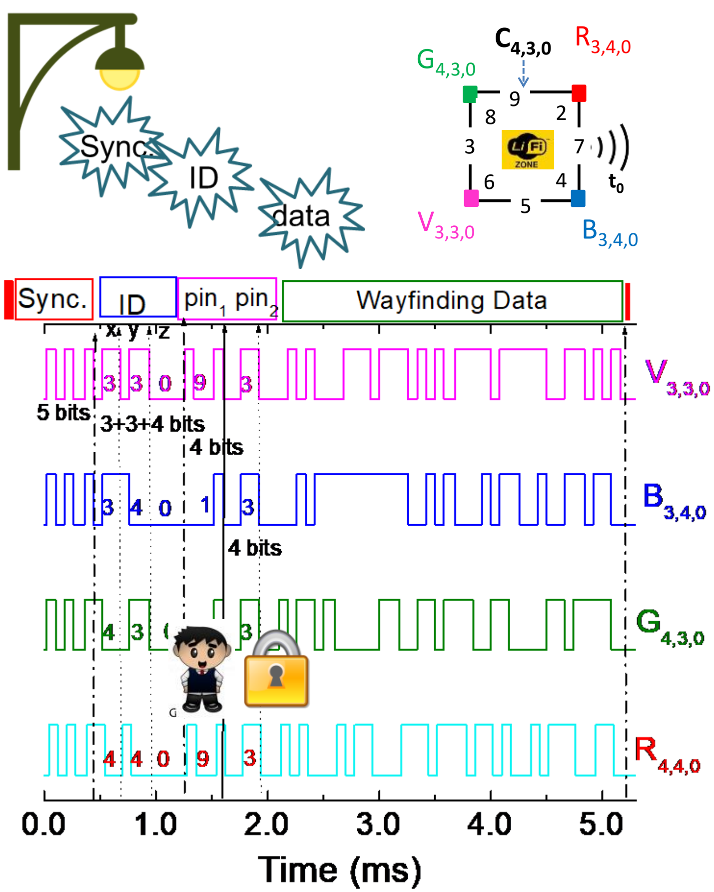
- Each node, $X_{i,j}$, carries its own color, X, (RGBV) as well as its ID position in the network.

Coding / Decoding

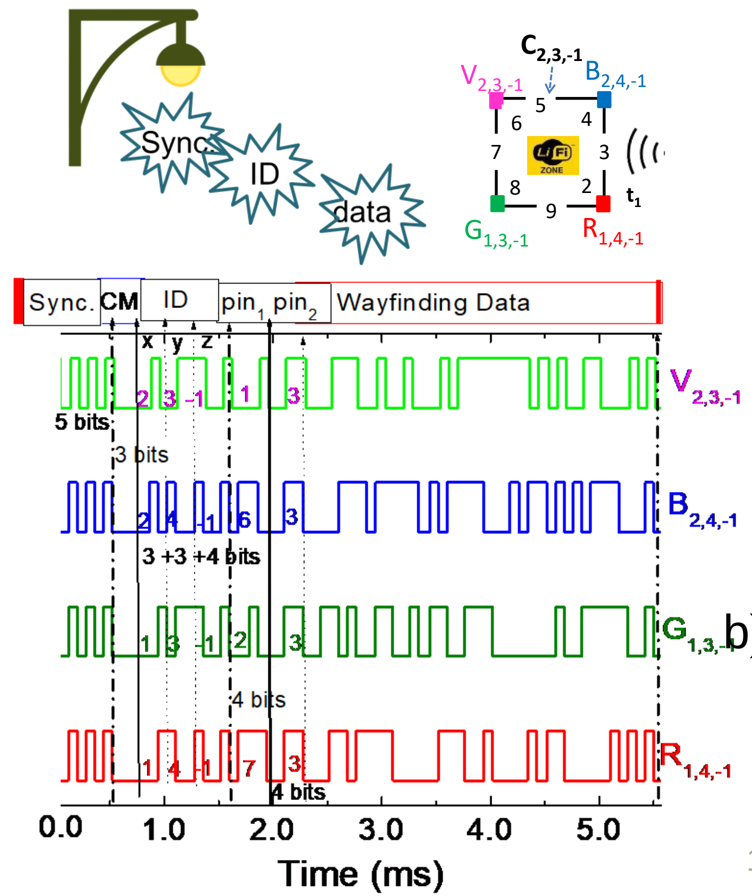
- An on-off keying modulation scheme was used to code the information. To create a communication protocol and overcome the technology constraints, a 64 bits data frame was designed.

Representation of one original encoded message, in a time slot:

- a) $R_{4,4,0}$; $G_{4,3,0}$; $B_{3,4,0}$ and $V_{3,3,0}$ are the transmitted node packet from the unit cell $C_{4,3,0}$ in the network.
- b) $R_{1,4,-1}$; $G_{1,3,-1}$; $B_{2,4,-1}$ and $V_{2,3,-1}$ are a transmitted node packet from the CM at the unit cell $C_{2,3,1}$.



a)



b)

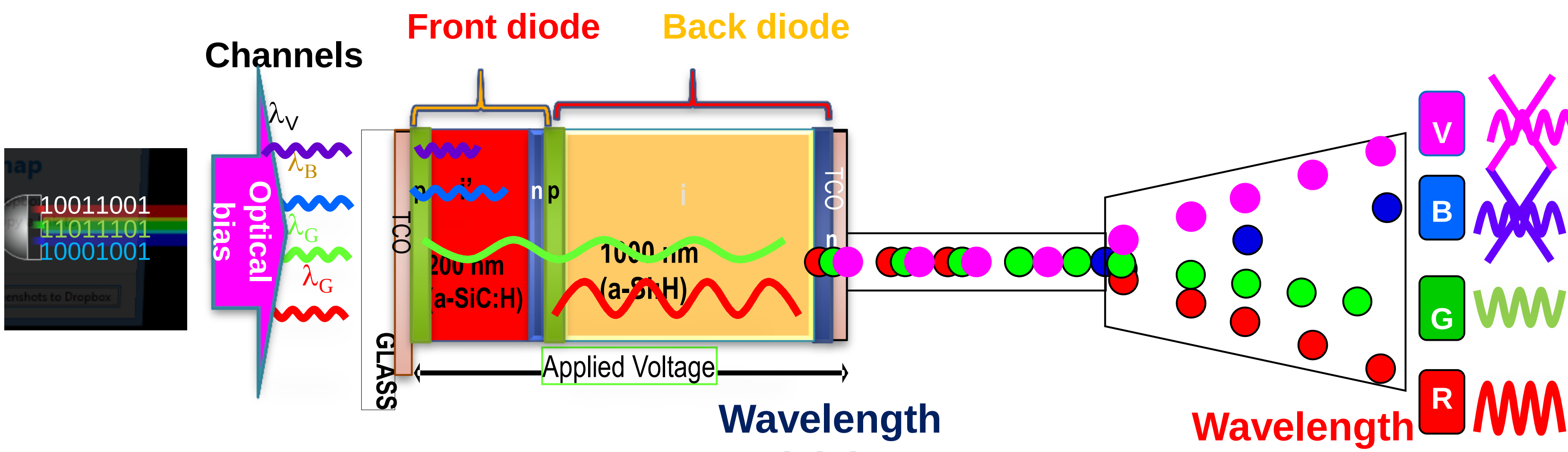
Transmitter / Receiver of VLC

SYSTEM OPERATION

LED
ID data transmit with fast blinking

Coder/decoder device

Bit decode

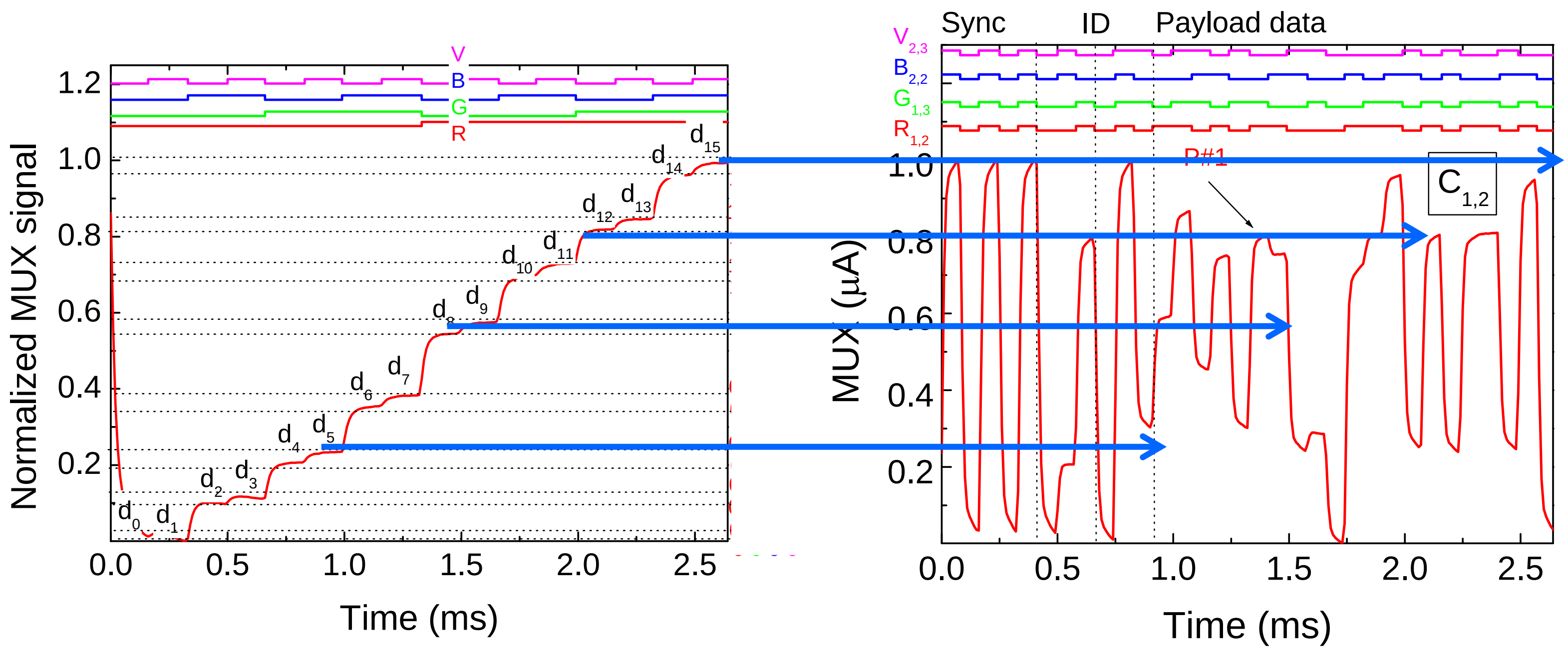


Wavelength Division Multiplexing

Wavelength Division Demultiplexing

- The device acts as an active filter, under irradiation.
- The gain is higher than the unity for wavelengths above 500 nm and lower for wavelengths below, resulting in an amplification of the **green** and **red** spectral ranges and quenching of the **violet**/**blue** ones.
- As the wavelength increases, the signal strongly increases. This nonlinearity is the main idea for the decoding of the MUX signal at the receiver.

DECODING ALGORITHM

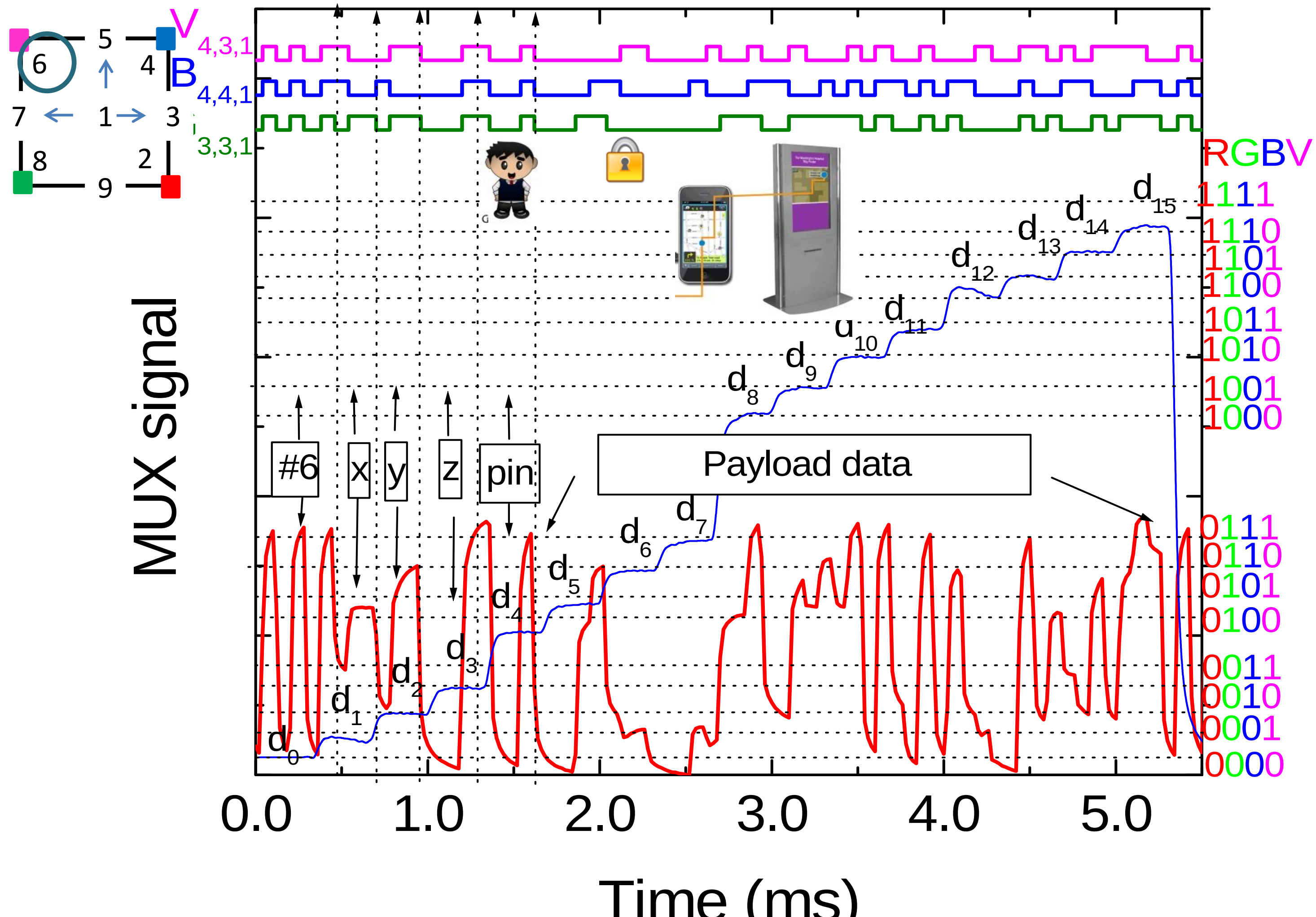


- 2^4 ordered levels pondered by their optical gains are detected and correspond to all the possible combinations of the *on/off* states.

- By assigning each output level to a 4-digit binary code (weighted by the optical gain of the each channel), [X_R, X_G, X_B, X_V], with X=1 if the channel is *on* and X=0 if it is *off*, the signal can be decoded.

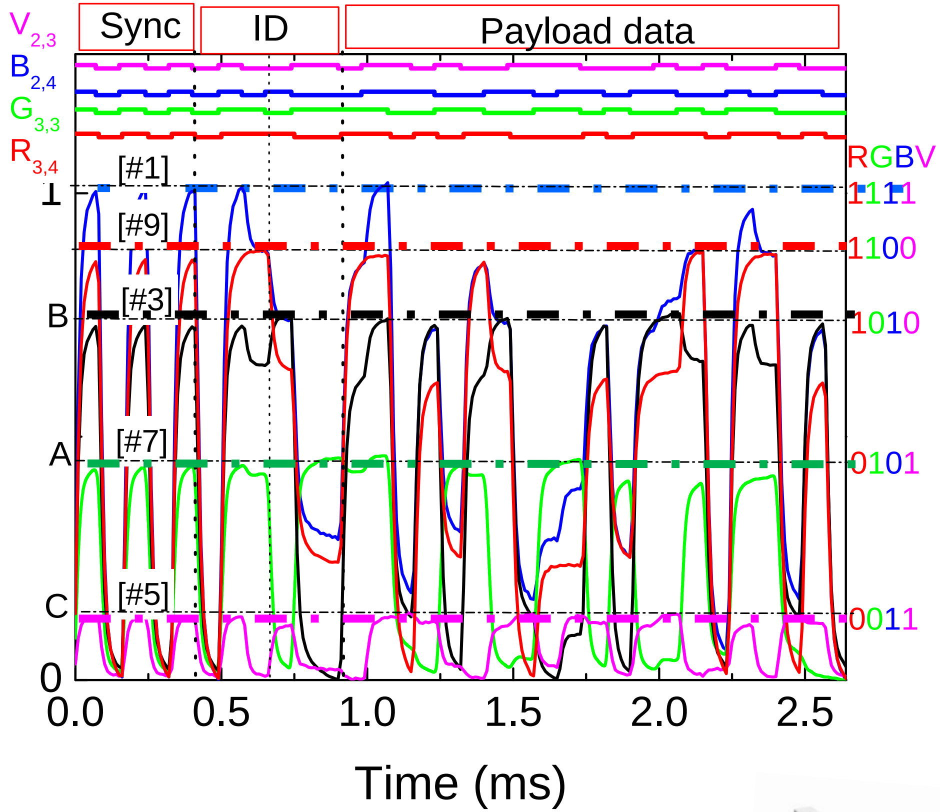
- Comparing the calibrated levels with the different generation levels in the same frame of time, a simple algorithm was used to perform 1-to-32 demultiplexer function and to decode the multiplex signals.

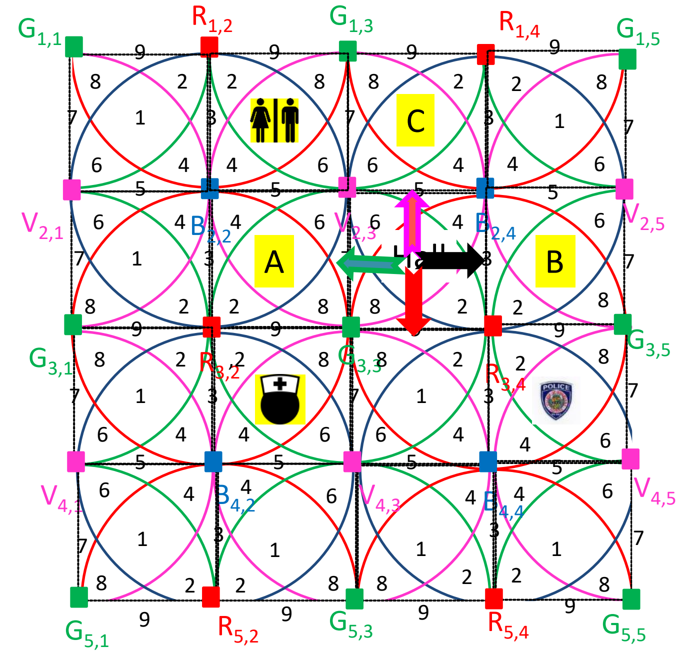
MUX-DEMUX

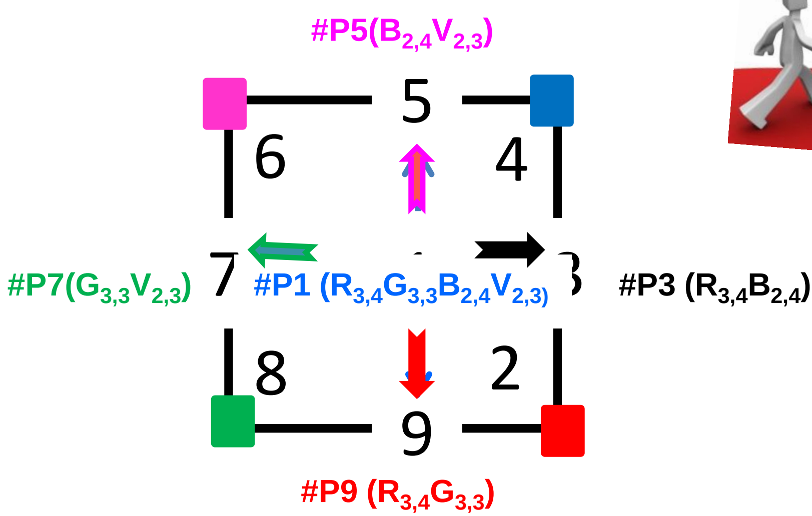


- A binary code of 4 bits (RGBV) is assigned to each level position.
- Comparing the calibrated levels with the different levels, in the same frame of time, a simple algorithm was used to perform 1-to-64 demultiplexer function and to decode the multiplex signals.

NAVIGATION DATA BITS



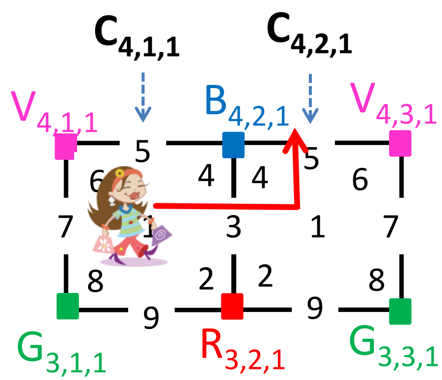


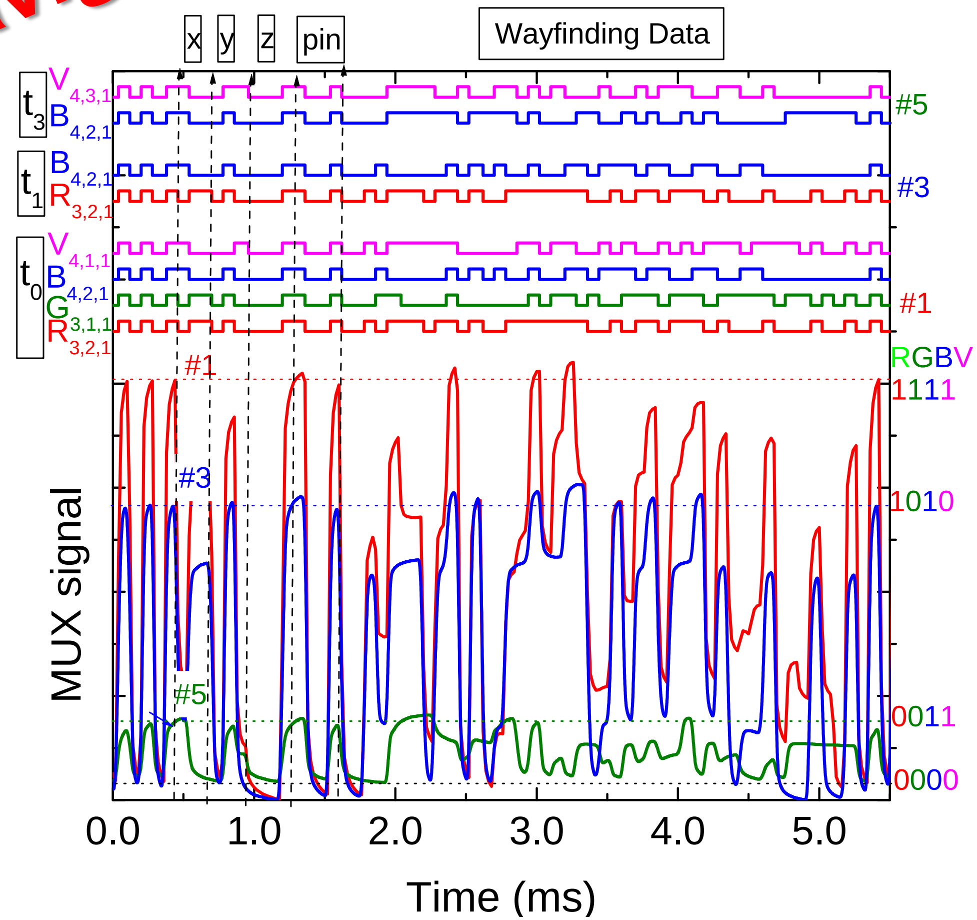


- As the receiver moves between generated point regions, the received information pattern changes. The transition actions are correlated by calculating the ID position codes in successive instants.

WAYFINDING SERVICES

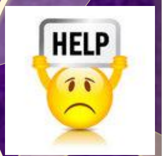
Aided dynamic navigation

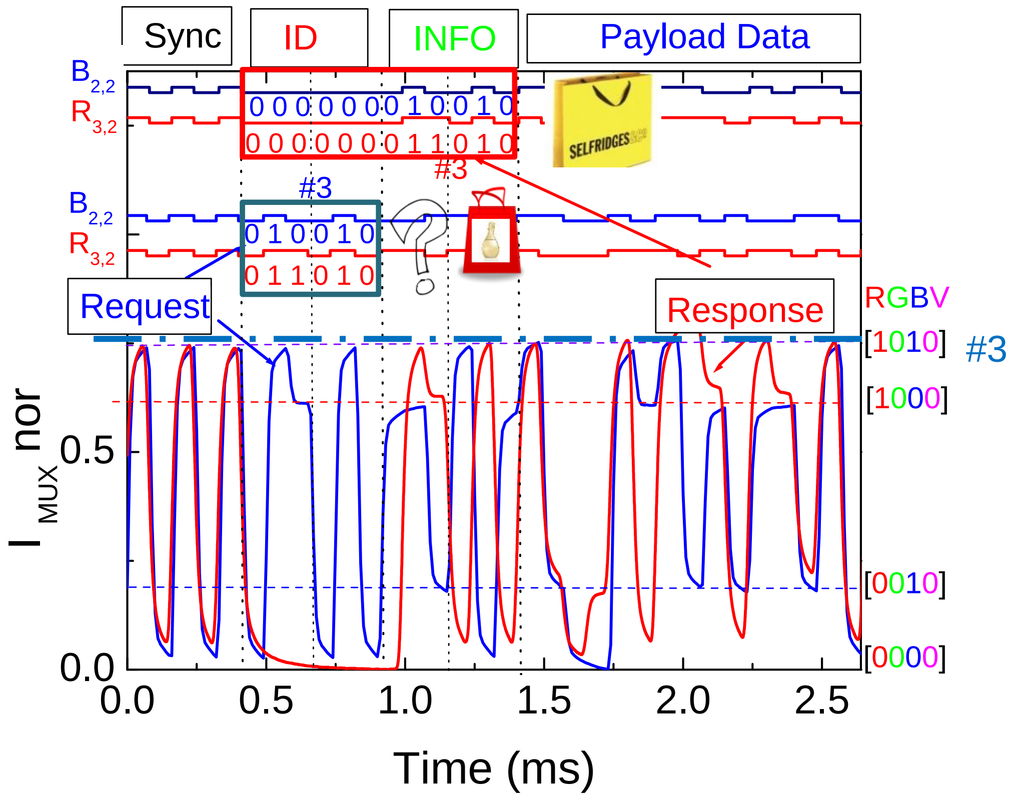


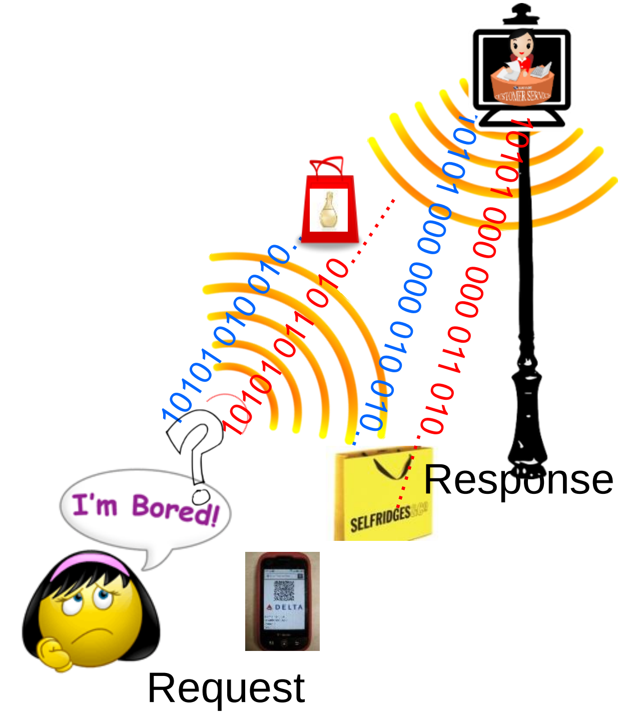


Fine-grained indoor localization and navigation in successive instants. On the top the received channels packets are decoded at each time step [R, G, B, V].

Bi-directional Communication



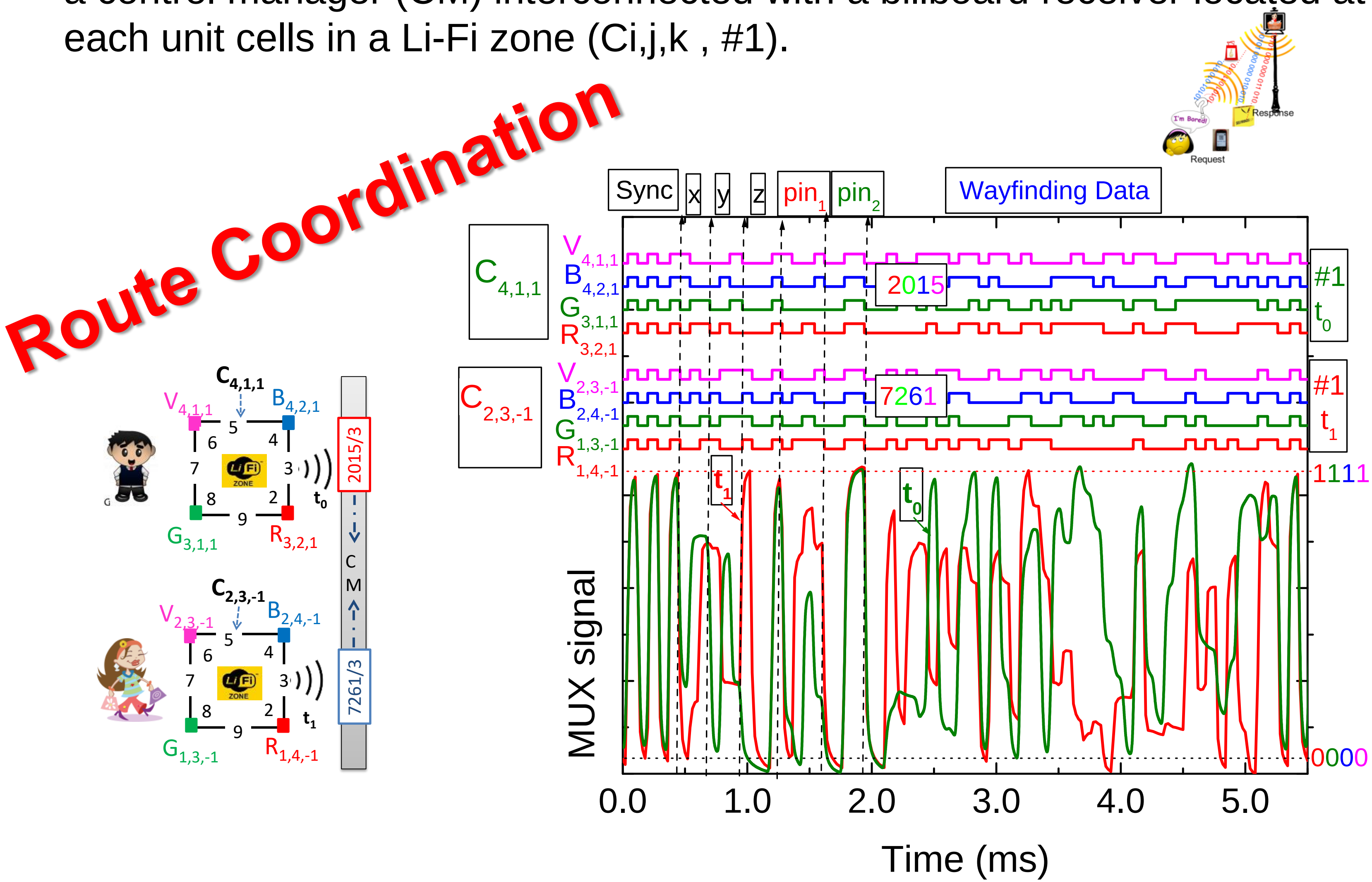




- Bi-directional communication between VLC emitters and receivers at a handheld device can be established through a control manager linked to an indoor billboard.
- Using a white polychromatic LED as transmitter, the receptor sends to the local controller a “request” message with its location (ID) and adds its needs for the available time. For route coordination, the local controller emitter sends the “response” message.
- Each ceiling lamp broadcasts a message with its ID and advertising which is received and processed by the receiver.

WAYFINDING SERVICES

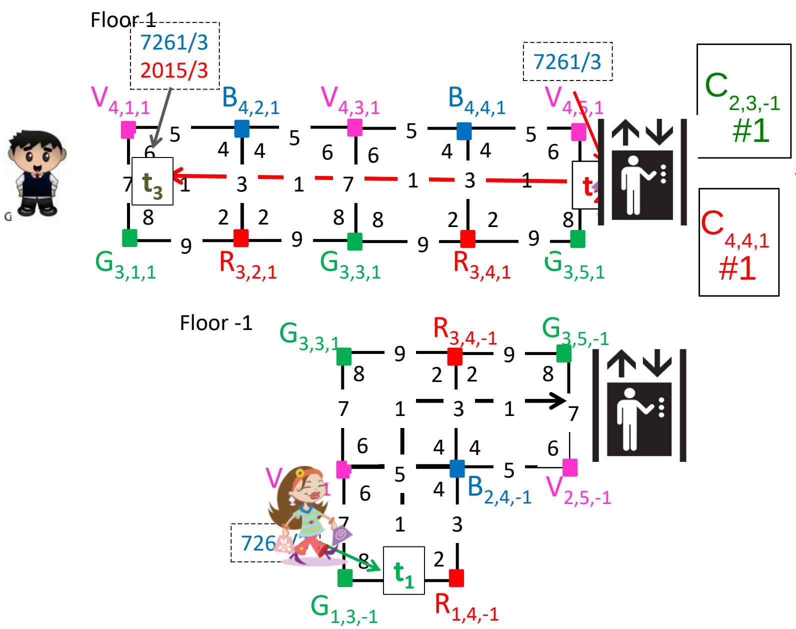
- Bi-directional communication is available at ready handheld device through a control manager (CM) interconnected with a billboard receiver located at each unit cells in a Li-Fi zone (Ci,j,k , #1).

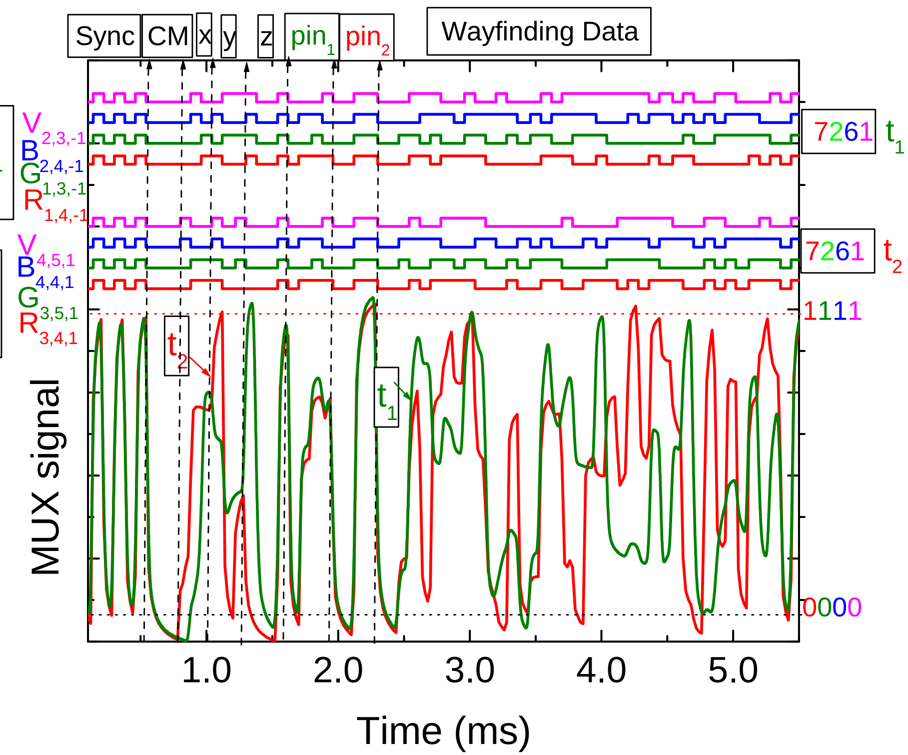


- MUX/DEMUX signals assigned to a “request”. MUX signal received by the CM receiver from two users (“2015” and “7261”) at different locations ($C_{4,1,1}$; #1 and $C_{2,3,-1}$; #1) in successive instants (t_0 and t_1). On the top the transmitted channels packets are decoded [$X_{i,j}$].

Responses sent by the CM to user “7261” the moment she arrives for the scheduled meeting (t_1) and when she is in the vicinity of the chosen location (t_2).

Buddy wayfinding





MUX/DEMUX signals assigned to a “response”. MUX signal received by user “7261”, pin_1, during his path, beginning at t_1 from $C_{2,3,-1}$; #1, changing floor at t_2 in $C_{4,4,1}$; #1 and when arriving ($C_{4,1,1}$; #1) at t_3 for the arranged meeting ([0011]; pin_2). On the top the transmitted channels packets are decoded [$X_{i,j}$].

CONCLUSIONS

- A generating method of ceiling landmark route instructions using VLC was proposed.
- For lighting, data transmission and positioning, white LEDs were used. A SiC optical MUX/DEMUX mobile receiver decodes the data and infers its path location, timing and user flows.
- A 3D building model for large indoor environments was presented, and a VLC scenario in a three level building was established. The communication protocol was presented. Bi-directional communication was analysed.
- Global results show that the location of a mobile receiver, concomitant with data transmission is achieved. The dynamic LED-aided VLC navigation system enables to determine the position of a mobile target inside the network, to infer the travel direction along the time and to interact with received information.
- The VLC system can help to find the shortest path to a place, guiding the users on a direct, shortest path to their destinations.
- Research is still necessary to optimize the coverage; effects as synchronization, shadowing and ambient light could be minimized through MIMO techniques.

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FOR YOUR ATTENTION