IoRL Deliverable D7.1

Techno-economics study for IoRL case applications – Initial version

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Abstract

This deliverable presents the techno-economics assessment of the proposed IoRL solutions, focusing on the targeted scenarios and use case applications. The document provides a very high level description of the technical solution as a starting point. It also provides an initial version of an inventory of the necessary software and other components and licensing schemes to assure consistency.

Furthermore, this document addresses IoRL future strategy and methodology for project results exploitation. To this end, it identifies the clear potential impact of the system based on the technical description and s the methodology that will be assessed to build a successful exploitation plan for the project and the proposed technology, taking into account the defined scenarios and use cases.

This is the first version of the document, it will be superseded later with a more complete and final version of the techno-economics study (reported on deliverable D7.6).

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Executive summary

According to Internet World Stats, the use of the internet is more and more important in the whole world touching almost 4 billion of people with a penetration rate that has passed the half of the overall population[1].

Moreover, these figures passed 80% in Europe and are next to 90% in North America, while the penetration rate of smartphones of most developed countries is between 60% and 70%, making clear that an efficient broadband is absolutely necessary.

The potential for VLC is being driven by the increasing demand for adoption of mobile electronic devices and wireless communications for indoors. In this continuously growing market, WiFi is not always a solution, particularly on internal spaces, making LiFi a good answer, particularly while it will be matched with the upcoming 5G. VLC can provide significant benefits over RF investigated in the project:

- VLC does not interfere with RF, and thus can be added to an existing network without introducing new interference;
- Very high data rates, in the order of Gb/s[2], when used in line-of-sight;
- Are not perceived as hazard to health and thus can be used in hospitals, airplanes etc. ;
- VLC is confined by opaque walls and thus improve security and enhance channel re-use in smaller cells;
- Light based positioning and localization.

IoRL positions itself in this framework engaging a wide number of stakeholders on 4 specific scenarios:

- Homes (UK)
- Museums (France)
- Metro/Train tunnels (Spain)
- Supermarket (China)

The chosen scenarios and the related countries will be considered a starting point to analyse market conditions to the immature status of this market that is today still not structured, but that shows a really high potential for the coming years.

This deliverable explains how this will be studied by the project, starting with an overview of technical and non-technical elements, including an overview on IPR management process within the project, which can be identified at this stage to be exploited after the project lifecycle to ensure maximum sustainability of IoRL results.

[1] Internet World Stats, 2017, Miniwatt Marketing Group

[2] "WDM MIMO Visible Light Communication System Employing OFDM Modulation", Cheng et al., OFC 2017 W2A.39

Moreover, the overall methodology and different methods that will be used to carry out market and competitors analysis are described in the next sections, accompanied also by a clear presentation of key stakeholders at this stage.

Finally, conclusions provide a clear picture of the next steps to be taken by the consortium to drive the project to a complete and concrete sustainability plan.

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Issy Média	Matteo Satta	Table of contents, overall structure, coordination, consolidation, overall writing
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NCSRD	Harilaos Koumaras	Review

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Abbreviations

A list of abbreviations is strongly recommended

5G	Fifth Generation (mobile/cellular networks)
CAGR	Compound Annual Growth Rate
HeNB	3GPP's term for an LTE femtocell or Small Cell
IoRL	Internet of Radio Light (project)
LiFi	Light Fidelity
mmWave	Millimeter Wave
MS-Stream	Multiple-Source Streaming
NFV system	Network Functions Virtualization
R&D	Research and Development
SDN	Software-defined networking
SWOT	Strengths, Weaknesses, Opportunities, and Threats analysis
UE	User Equipment
VLC	Visible Light Communication

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1 Introduction

This document contains the methodology of the techno-economics study and the different activities and actions that will be taken during the 3 years of the project by partners.

The aim of this task and related reports is to identify a viable sustainability model or models for the IoRL solutions in the post-funding period, which will help the project, continue to further continue to sustain the project achievements.

This deliverable is developed as part of the IoRL project Work Package 7 (Dissemination and Exploitation).

The report is structured into the following parts:

- The 1st section provides an overview of the technical elements and the innovative findings developed within the projects.
- The 2nd section provides the project vision and methodology about exploitation of technical achievements.
- The 3rd part is dedicated to define the overall project strategy and stakeholders to introduce the methodology of IoRL competitors and market analysis.
- The 4th section is an overview of future steps and actions about exploitation.

It has to be underlined that this is an initial version of this document, which is still a living document that will be superseded by the final version, D7.5, which will complete the work of this task.

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2 Technical solutions and related Intellectual Property Rights

This section explains in an easy-to-read way the technical solutions, reported in other deliverables (mainly D2.1 and D2.2), to allow to better understand the following sections and the whole methodology defined in this document.

It has to be noticed that the architecture, at the time of this writing, is still in a phase of definition, consequently any improvements will be reported in the following deliverables.

2.1 Technical elements to be exploited

Our ambition in the IoRL project is to develop and exhibit the operation of an mmWave duplex transceiver and VLC imaging receiver in a wide range of consumer electronic digital media user equipment.

We address key user equipment's (UE's) such as 4G/5G smartphones, tablets, laptops, AR Glasses VR headsets and TVs, thereby incentivising consumer electronic media user equipment manufacturers to initially develop mmWave and VLC interfaces and drivers that can connect to media devices via a USB port but eventually to integrate these interfaces as a standard feature in their products.

MS-Stream is a completely new way of distributing the media content, video in particular, to mobile devices, which considers all the capabilities of the client device from one side and of the "multiple" different networks from the other side, in order to benefit from all the potential content sources.

This ambition will be realised in four scenarios (reported in detail in D2.1) that have been defined to reflect the range of size of properties, the number and behavior of occupants using the property and the type of media that is usually being used in the property. The following presents the main characteristics of the project scenarios, which are also summarized in table 1.

Private Homes

Many homes can often have constraints due to lack of availability of high quality connection in all rooms, limiting the experience of users that might need to have, particularly on multimedia contents that are privately more and more used, a full experience. This is clearly a limitation that LiFi can solve.

In this case, LiFi solution on a home scenario targets a market of millions of small sized properties with low number of occupants, whose identity rarely changes unless they are guests, and who mainly consume very high quality media from external providers.

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Public Buildings

Public buildings are a natural choice on this kind of technology as they often have a clear and logical need of high demand of internet connections, being often crowded, being often difficult to meet due to the crowd, and with wireless signal reception due to the size and age of the buildings. It often happens to anyone who goes to a public office is unable to obtain a good wireless internet connection. Moreover, many public buildings, such as museums or entertainment centers struggle to offer good services due to this kind of problem.

The project chose the museum scenario as it targets a market of thousands of medium sized properties with medium sized number of occupants, whose identity regularly changes daily or half daily unless they are staff, who consume high quality media internally created by the museum.

Table 1 Variable Feature versus Scenario

	Home	**Museum**	**Train/Metro Tunnel**	**Supermarket**
Size of Properties	*Small*	*Medium*	*Medium- Large*	*Small - Large*
Number of Properties per country	1.000.000s	1.000s	1.000s	100.000s
Number of occupants	1s to 10s	10s – 100s	100s – 1.000s	10s – 100s
Type of Media Quality	High Quality	High Quality	Medium Quality	Medium Quality
Latency Requirements of Media	10ms or more	20ms or more	20ms or more	20ms or more
No. of Media Items	10s	1000,000s	100s	100,000s

Train/Metro Tunnels

In most major Cities in Europe, millions of commuters make urban journeys all around their cities thereby crowding train stations. Most of those are underground and not covered, or not sufficiently well covered by 3G/4G signal and the installation of antennas is often not possible. This does not allow commuters to have an acceptable connectivity, thereby impacting congestion as passengers cannot often have real time information to help them find their destination A clear example is in Paris, where although the Public transport company (RATP)

is investing on 3G/4G antennas[3], but this is not always allowing users to have an high quality connection as the speed is just 512 kbits/s and time is limited to 20 minutes per user[4].

IoRL technology then targets a market of thousands of medium to very large sized properties with thousands of occupants, whose identity regularly changes by the minute and hour unless they are staff, and who mainly consume medium quality media from transport operators and external service providers.

The potential uses of IoRL technology can be applied to broaden the services offered to passengers along with the improvement of working conditions from maintenance workers. Passengers will be able not only to access the same services that could allow any 3G/4G connection, but they will benefit as well from the indoor positioning system that IoRL technology allow for. This way, depending on the place where the passenger is located, they can access different type of data.

At the same time, this additional indoor location system provides real time information of the platform occupancy at different times and how passengers are distributed within it, allowing operators that analyze it to improve the frequency of trains and even provide messages to passengers to optimize their distribution within the platform.

For maintenance operators, which usually do not have access to 3G/4G connections, IoRL technologies could bring a significant advantage for their daily basis operations and also an improvement in their health and safety procedures. Furthermore, maintenance operators could be located at all times, reducing the risks associated with maintenance engines circulating inside the tunnels while workers are performing operations. Additionally, they could make use of videoconference communications with control operators and record them, allowing them to access any previous works performed in the area.

Supermarkets and Retailers

In addition to the previous scenarios, it has been decided to propose one in a more complex situation: grouping together small to large properties. To this end, it was defined to propose a scenario on commercial stores that can be adapted to small markets to big retailers.

It has to be noticed that this decision was made also taking into consideration how IoRL solutions may give the advantage to such premises to provide useful and targeted services to customers. In this case, IoRL targets a market of hundreds of thousands of small to very large sized properties with hundreds of occupants, whose identity regularly changes, unless for staffs that are a tiny portion of the crowd, and who mainly consume medium quality media from supermarket and external providers.

[3] https://www.iledefrance.fr/sites/default/files/cr_137-16.pdf

[4] https://www.ratp.fr/en/visite-paris/english/services-available-our-metro-and-rer-stations

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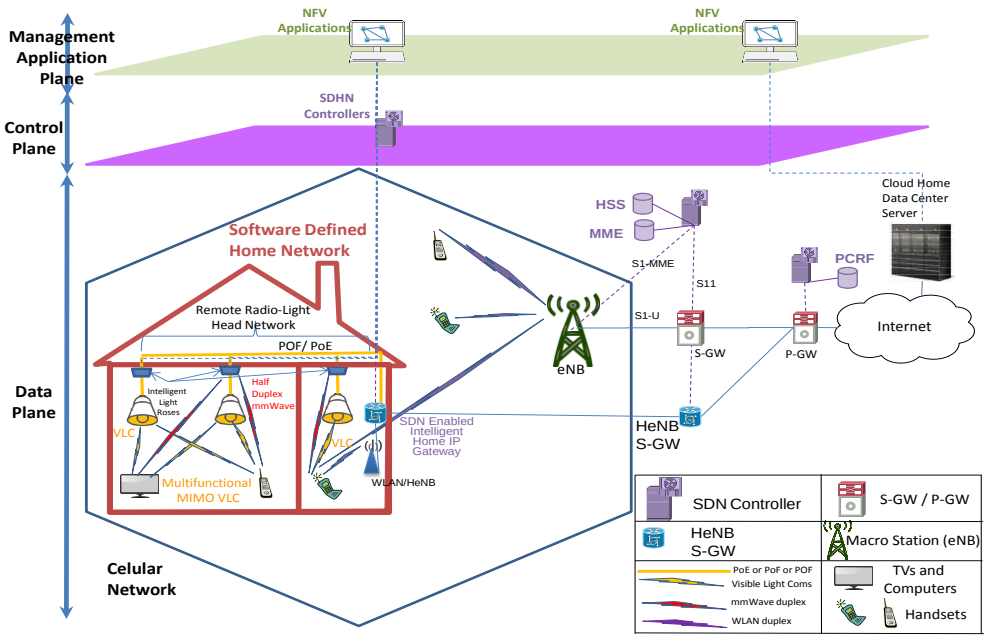
Figure 1 Internet of Radio Light Network Architecture



Starting from these scenarios, the objective of IoRL is to design an architecture that can meet the requirements of all the scenarios:

- flexible enough to be easily expanded to support properties that vary in size;
- adequately large bandwidth to support small to large number of users;
- appropriately flexible to support varying duration of occupancy in buildings;
- suitably flexible to support the different dynamics of the changing identity of occupants;
- operating in unlicensed spectrum so that there are no restrictions to deploying it;
- simple enough to allow the ordinary electrician to install it.

The below table reports a summary of the potential of this solution and the related architecture. It can be easily noticed how the risks are all related to needed investment, but it has to be considered that the solution would be royalty and license free, consequently the risk is considered low.

Figure 2 Summary table of potential of IoRL solutions

2.2 Process of Intellectual Property Rights management

The introduction of a commercial network solution in the unlicensed spectrum for mobile networks could have an enormous impact on the market, thus it is necessary, to have a sustainable solution, to define a proper management of existing Intellectual Property Rights.

IoRL management of IP Rights will start defining the background that will be necessary to define, implement and deploy the architecture and the solutions of the project, taking in consideration:

- **IPR held by partners**. The IoRL solutions are also based to existing rights of some partners, particularly Arcelik, Cobham Wireless, Oledcomm and RunEL, but all partners will be requested to give feedback on their rights, filling a table that will be updated time-to-time, defining hardware and software components. A final and exhaustive table will be included on D7.5 as part of the final sustainability and exploitation plan of the project.
- **IPR held by third parties**. The IoRL project doesn't plan to use components held by third parties, but the quick evolution of the LiFi market obliges partners to have a look to this aspect and to be aware of any evolution. Therefore, research techniques will be conducted, also in accordance to market and competitors' analysis.

Referring to the IPR held by partners, those have to fill a table in proposing various information as reported in table 2 below.

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Table 2 IPR partners table

IoRL component	Owner	Type	Platform framework	Dependency (owner)	IoRL functionality
Pre 5G PHY and MAC	RunCOM	Software	Proprietary	None	5G mm Wave solution
SDN Network	Brunel	Software	OpenDaylight OpenvSwitch	None	Intelligent Home IP Gateway
NFV Orchestrator	NCSRD	Software	Openstack OpenBaton	None	Intelligent Home IP Gateway
Home Apps	Brunel	Software	Linux	Python	Home Apps
Museum Apps	Brunel	Software	Linux	Python	Museum Apps
Station Apps	Brunel	Software	Linux	Python	Station Apps
5G UE PHY and L2	Cobham	Software	Linux	None	5G test UE solution
5G L2 software	Cobham	Software	Linux	None	5G L2 solution
5G L1 software	MTEK	Software	Rsoft/GI-POF simulation	None	IoRL indoor use cases
5G L1 software	MTEK	Software	Rsoft/RGB mux/demux PCF	None	IoRL L1 solution
5G L1 software	MTEK	Software	Rsoft GaN 10Gbps LED	None	IoRL L1 solution
SW-tool for planning the distribution of RRLHs in an indoor environment with respect to the quality of positioning services	FhG	Software	Matlab/Pyton	Matlab/Python	Installation of RRLH
mmWave module containing up/down and antenna	FhG	Hardware	-	-	RF front end for RRLHs
Algorithms for reliable and accurate combined VLC and mmWave location sensing within IoRL communication system	FhG	Software	Matlab/C	Matlab/C	Location sensing

All partners will need to update their information before the preparation of D7.6, to allow having a list useful also to be included in the market and competitors' analysis, and they will need to provide a final one in D7.5.

Moreover, the partners that will indicate some IPR will be requested to give all the due information about their rights. Therefore, they will be requested to give, to any concerned partner, a non-exclusive license at the best conditions allowed, while some licensing programs exist.

Finally, any right held by third parties will be duly analysed and treated carefully as it is due on matters of this kind. Particularly, it will be discussed by the General Assembly taking into consideration whether the patent (or any other right) would be absolutely necessary for the successful deployment of the IoRL solutions.

Where absolutely necessary, an agreement will be negotiated with the interested party, discussing also the right project partner that might need to get engaged.

Although this is an unlikely situation, the consortium will anyway work to avoid any risks and/or bottleneck effects related to any third parties' IPR being IoRL solutions proposed as license-free.

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3 Study Methodology

When detailing the primary objectives of this particular study, it is important to go back to IoRL's Description of Work (DoW) to be reminded of the overall key objective that this deliverable contributes to find the clear potential impact of the system based on the technical description. This will identify the methodology that will be followed to clearly build a successful exploitation for the project and the proposed technology, taking into account the proposed use cases.

To this end, it is necessary to identify a sustainable model that will continue to deliver benefits long after the end of the project.

This deliverable will mainly focus on 2 objectives that will be chased through a 3 stage process during the next 3 years:

(a) to define the potential market opportunities of IoRL in a non-yet mature and well-known market such as the LiFi one;

(b) to identify an exploitation model to allow IoRL to support its findings and achievements after this 3 year process.

To achieve these objectives IoRL, with the support of all partners, will go through a process divided into 3 stages following the 3 deliverables that will be produced during the funding phase of the project.

- **Stage one – Methodology and LiFi stakeholders**: definition and identification of a methodology necessary to achieve a useful and clear market analysis, necessary to define a project exploitation plan. In this stage, using partners' backgrounds and skills, it will define and describe a list of potential stakeholders. This will be defined also taking into consideration the project scenarios. This stage will be defined and explained in this deliverable.
- **Stage two – Market and competitors analysis**: involved use of primary research techniques, namely an online questionnaire and structured interviews, and secondary research and literature reviews to define the perimeter of the LiFi market that, being not yet mature and in a development phase, has to be better defined. This will be fully reported and defined on D7.6, although some details, also methodologies will be reported in this deliverable.
- **The final stage – sustainability plan**: will define a model to allow partners to keep working together making possible to create a working structure allowing exploitation of the project findings as a consortium and as an individual body. It will be then necessary to define all partners' roles and commercial relationships. This will defined in deliverable D7.5.

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Moreover, some sub-objectives will be put in place to deliver the required plans and studies related to these reports, particularly:

- Define the LiFi potential demand;
- Understand the barriers blocking the demand of this technology;
- Find out the real needs of users;
- Understand business models of potential competitors in LiFi market, as well as their IPR;
- Propose several options for IoRL sustainability model that can be adopted either individually or collectively once the initial project funding ends.

Most of these points will be defined with targeted surveys and interviews that will be submitted on project countries.

To address this process, as indicated in Description of Work (DoW), IoRL will adopt radical innovation strategies useful to stimulate the creation of new markets around new technologies. The project appoints an innovation manager whose role includes to:

- create culture for innovation in the project;
- report on innovation figures in the project;
- monitor project activities and results to enhance the innovation potential;
- relate the project work to market development;
- arrange workshops/sessions to facilitate and enhance innovation in the project.

The innovation manager is not directly related to the execution of the project. The innovation manager assumes an advisory role for the partners to act when potential innovation opportunities are identified through the innovation management process.

The activities related to innovation management will be led by Dr. Moshe Ran (MostlyTek Ltd), appointed as the innovation manager of the project.

3.1 Market analysis

According to Global Market Insights, “LiFi market size was valued at USD 630 million in 2015, and is likely to grow at 80.8% CAGR from 2016 to 2023.”[5], this is a clear confirmation that during the next 3 years, the market will show all its potential for all the actors that will participate in it.

[5] “(Light Fidelity) LiFi Market Size By Component (Microcontroller, Photodetector, LED), By Application (Indoor Networking, Aerospace, Automotive, Healthcare, Location Based Services, Underwater Communication, Defense & Security, Intrinsically Safe Environments), Industry Analysis Report, Regional Outlook (U.S., UK, Germany), Application Potential, Price Trends, Competitive Market Share & Forecast, 2016 – 2023”

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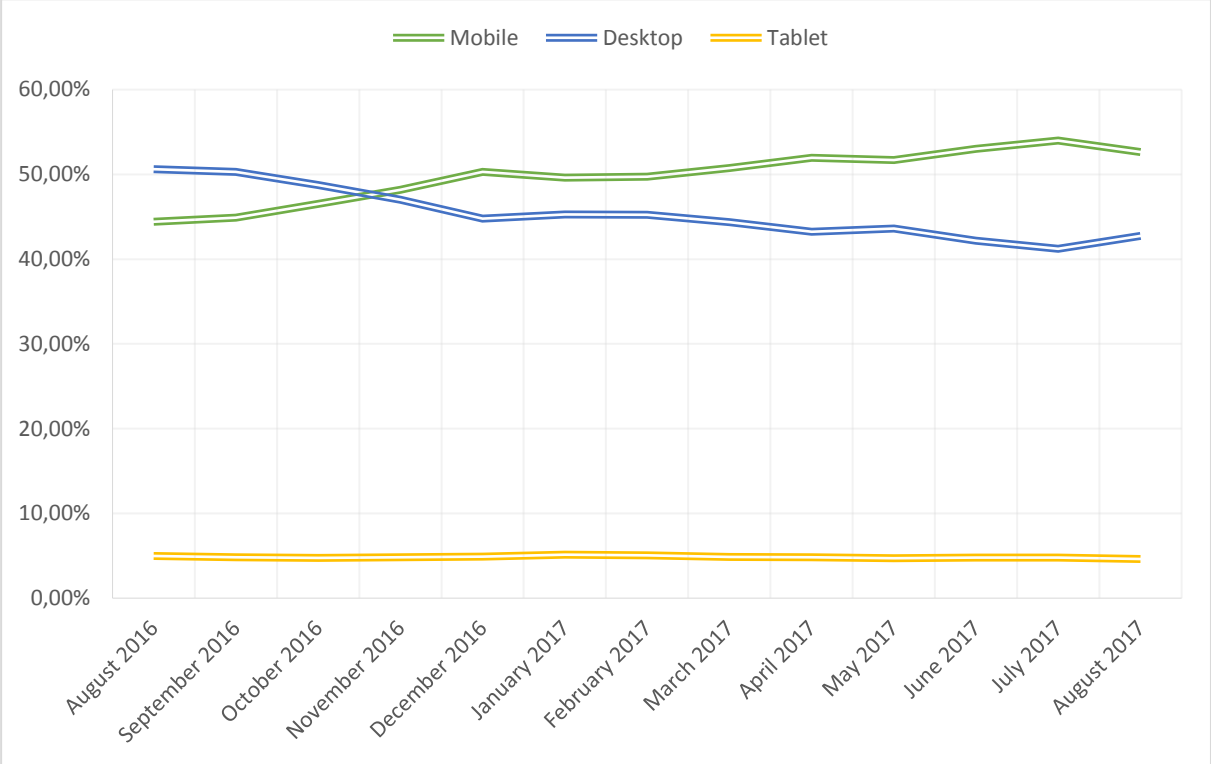
Moreover, the sales of mobile phones have today surpassed the sales of desktops, making the sales of mobile phones and tablets touching almost 60% of the overall sales (see figure 2). This is confirmed also by the statistics on use of operating systems that clearly underline that more than 50% of uses are related to Android and iOS systems[6].

Having a look to "Ericsson Mobility Report"[7], the number of mobile broadband subscriptions worldwide on quarter 1 of 2017 is about 5,2 billion, while they expect this figure to grow up to 8,3 billion in 2022 (0,5 on 5G) and more than 6,2 billion of unique broadband subscribers. This report looks also to 5G subscriptions that should reach the 500 million of subscriptions by 2022.

Figure 3 Sale of desktop vs mobile vs tablet worldwide in 2016/2017[8]



According to this report, use of mobile data grew of about 70% between the beginning of 2016 and the same period of 2017. Today, North America shows the biggest use of mobile data with a monthly average of 6,9 GB per user, while Europe reaches 3,9 GB, but this figures will quickly grow as North American users will use about 26 GB every month making smartphones about

[6] The actual number is 53,5% according to Statcounter as reported at the following link: http://gs.statcounter.com/os-market-share

[7] Ericsson Mobility Report, June 2017

[8] Data produced by Statcounter

90% of mobile data traffic in 2022. Moreover, 495 million of broadband subscriptions are expected in China between 2016 and 2022.

Additionally, it is highly interesting to notice how today multimedia contents are taking the lead on use of smartphones, as 50% of data is used for videos (42% on smartphones) and it is expected to grow to 75% in 2022.

All these figures clearly underline that IoRL technical findings will come in a market that will be highly expanding.

3.1.1 LiFi potential stakeholders

In an immature market, the first step is to define the potential stakeholders' profiles to allow the project to define later on the potential competitors and market players.

IoRL has already defined 4 scenarios that allow identification of some potential stakeholders, but it is necessary to go beyond it to have a clear overall picture allowing the creation of a real sustainable plan before the end of the project.

To this end, it has been possible to create a first list and description of bodies, public and private, that will have an interest and an impact on LiFi technology and, consequently, on IoRL solutions.

This list will be updated, from time to time, and reported in the following deliverables (D7.6 and D7.5).

3.1.1.1 Manufacturers

Equipment manufacturers' main concern is the costs incurred on their products related to integrating VLC and mmWave technology relative to the benefits that these technologies can provide for their product capabilities.

One of the advantages of LiFi technology is higher data transfer rate. It enables manufacturers to serve video in better quality to TV users. Moreover LiFi technology is bandwidth friendly.

Users will not cause more network traffic for the same content since data will be transmitted to everywhere. Users can watch the same video from TV and tablet without any additional bandwidth usage. Another benefit of LiFi is to be a technology not working licensed radio frequencies. Wider connectivity area can be reached in some areas where WiFis not allowed like hospitals.

IoRL is now composed of a consortium including various manufacturers working in various fields from a lighting and an electronics consumers' and professionals' point of view:

- Lighting: many partners play a role on lighting manufacturing, each one of them with different strategies and specialisation. This will lead to a natural collaboration wbetween them as reference partner, SFY, will work on a strategy focused to create a product range of lighting systems within the IoRL project to incorporate VLC and

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mmWave technology and make it available to the market to define whether the research community and the home networking product development community might show any interest in it. The suppliers to SFY intelligent lighting system will be the sub-system manufacturers of the system, namely: FhG for the mmWave transceivers, Oledcom/Tsinghua for the VLC transmitters, Runel for the L1 processing, Cobham for the L2/L3 processing, Brunel for the SDN, NCSRD for the NFV system and the various partners for the applications running on the network servers.

- Electronics consumer and professional market: the main concerned partner in this case will be Arçelik. Its main goal is to create a radio-light external interface that can be interfaced to the TV of their main product range and make it available to the market to see if there is any interest firstly from the research community and then secondly from the consumer product development community. As an example, Arçelik is manufacturing two million television sets per a year including smart TV sets, smart-slim TV sets, Ultra-HD (UHD) TVs, OLED TVs, Quantum Dot TV sets in several types of panel sizes and with different type of functionalities. One of the main targets in the scope of this project is to integrate the IoRL technology into consumer electronics product such as television sets. By achieving this aim of the project will result to create new products that can be interfaced with VLC and mmWave technology in the consumer electronics market. Moreover it will provide extra features for consumers in the consumer electronics market such as television market. Besides the integration of LiFi / 5G technology into the product range, this will increase the brand value of TV manufacturers as early adopters in the market. In the future, the integration of IoRL technology to consumer electronic products such as TV sets will conclude to develop innovative and pioneering products using LiFi / 5G technology in its other products.

Clearly these network and consumer product systems need to coexist for a full communications system to operate and so a collaborative promotion strategy from the two systems needs to be adopted.

The success of this process will dictate the progress to the next stage which is the process of production engineering the systems into the consumer product themselves.

3.1.1.2 Home owners

One of the principal potential stakeholders of LiFi solutions has been identified in the Home owners and, more in general, anyone that lives in a home.

A traditional family consists of 3-4 people or more that might want to watch different videos or channels at the same time. By VLC technology, multiple contents from different service providers can be downloaded and displayed by different users and by more than one user simultaneously at home very rapidly. Record ability for the multi channels by multi end-users at home will be supported too e.g. Olympic Games. During the season of the Olympic Games the different programs of sports are displayed during the same time-slot. The end-users at home can watch or record the different sports programs at the same time. By VLC system

integrated to TV, end-users will be able to download and display the multiple contents much faster than wired/wireless networking system.

According to the population and housing census conducted in 2011, there were 495.6 million people in the EU-28 living in a private household. According to the EU's labour force survey (EU-LFS), the total number of private households within the EU-28 rose from 195 million in 2005 to 214 million by 2013, equivalent to average growth of 1.2 % per annum. This represents around 2.6 billion light access points. This is a very large potential market of households that can be upgraded to radio-light broadband. In China, new areas are 16 national level new areas, which are new urban districts that have been given special economic and development support from the central or regional government, that have been designated since 2010[9]. This is equivalent to the new build construction of over 10 cities the size of Greater London, in case the urban population density is similar to that of Greater London, then these new areas will be the future homes of 100 million Chinese people or approximately 30 – 40 million households with over half a billion light access points in their households.

Moreover, the number of people working from home has risen to its highest level since records began, according to the International Labour Organization (2015)[10]. This study reports that around 7% of EU employees are home-based and mobile telework as well as self-employed teleworkers in SOHOs, while, on the same basis, this figure is around 3% in the US. Although, these figures do not count all self-employed people that work from home that, according to SIBIS - Statistical Indicators Benchmarking the Information Society (2002)[11], represent around 21% of self-employed workers.

A survey of the opinions of 200 building owners on the importance of advanced broadband communications services has found that 90% of building owners and managers say that access to advanced communications services is the most important selling point behind only price, parking and location and that 61% of respondents report that having advanced communications in their buildings provides them with a competitive advantage.

One of the growing problems in buildings is interference due to congestion in WLANs. This has been due to an ever increasing capacity demand for data traffic from Smartphones, mobile PCs and Tablets with voice traffic occupying only a fraction of the total capacity demand.

This interference has been compounded by the range of different wireless systems in homes and businesses, namely: electronic equipment such as microwave ovens, cordless phones, wireless headsets, Zigbee, ZWave, Bluetooth devices, surveillance cameras and other wireless

[9] Liangjiang, Zhoushan Archipelago, Lanzhou, Nansha, Xixian, Guian, Xihaian, Jinpu, Tianfu, Xiangjiang, Jiangbei, Fuzhou, Dianzhong, Harbin, Changchun and Ganjiang; consisting of 16,663 Km2 of new build urban areas

[10] "Challenges and Opportunities of Teleworking for Workers and Employers in the ICTS and Financial Services Sectors", 2015, International Labour Organization

[11] http://www.sibis-eu.org/statistics/data/4-40.htm

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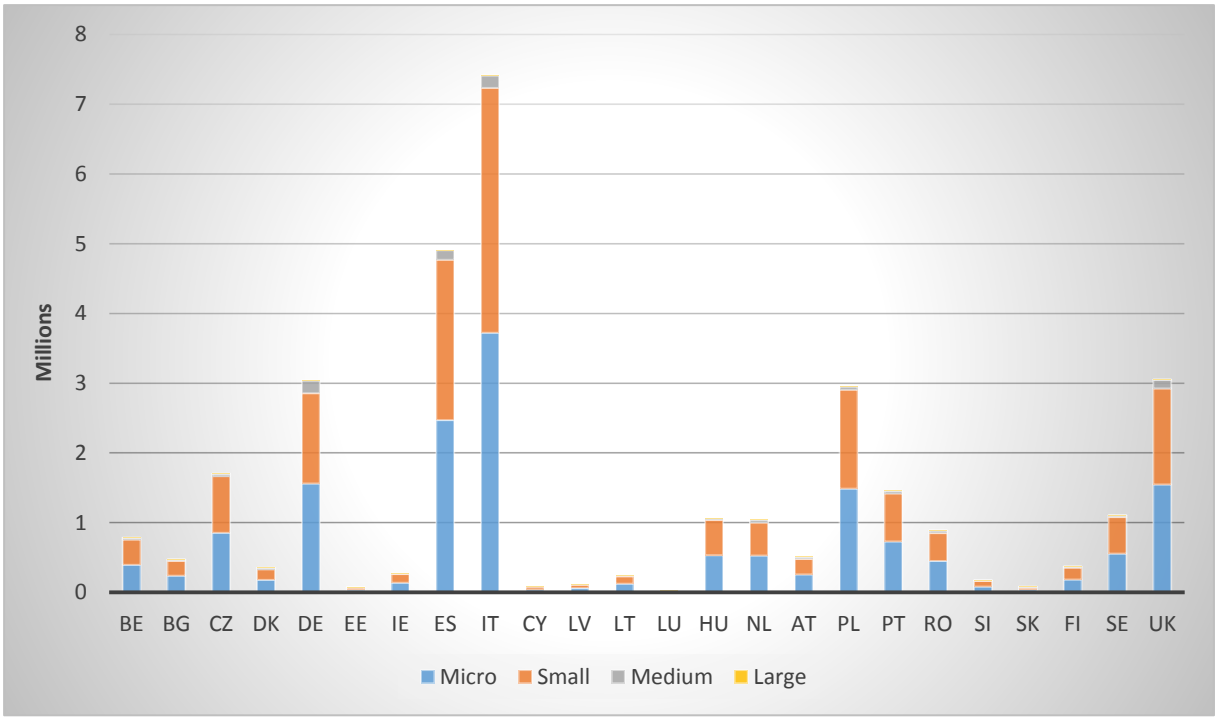
radio networks. Thus the main motivation for homes and businesses has been to switch to home networks that use regulated spectrum such as HeNB to avoid interference problems.

Furthermore, many modern buildings are built with thermal metal clad insulation that severely restricts the propagation of RF waves and with metallized windows, which restrict the propagation of RF waves within and to/from outside the building. Therefore the introduction of modern building materials is making it increasingly difficult for the radio signal from wireless transceivers to provide sufficient coverage inside buildings and so many organizations are attempting to deploy HeNB on their premises.

According to Eurostat, in 2011 in EU we could count almost 21 million of businesses[12], while 92% are microbusinesses (less than 10 people) and 6,7% small businesses (less than 50)[13], as reported in figure 2.

Figure 4 Number of Business against size in Europe[14]



Then, next to the private households, we can count on a large number of micro businesses who are highly concerned as well by the same issues. Actually, those are struggling to deploy HeNB small cells in buildings as network operators do not have enough resources to analyze

[12] It has to be noticed that France, Malta and Greece are not part of those figures, it is than reasonable to consider that numbers are sensibly higher.

[13] For statistical purposes, structural business statistics are broken by Eurostat on: large (250 or more employees); medium-sized (50 to 249); small (10 to 49); and micro enterprises (less than 10).

[14] "Key figures on European business with a special feature on SMEs", Eurostat

the interference they would incur to the outside mobile network, but they are clearly and by far the largest group in the market place. These smaller clients are returning to using WiFi, a trend that is being experienced worldwide.

Finally, as reported on section 3.3, the mobile traffic data will be growing quickly in the next few years, resulting in a real need as 80% of this traffic is generated indoors and it is growing 20% faster each year than outdoor wireless traffic.

However, fewer than 2% of commercial and public buildings are currently covered by dedicated wireless indoor solutions therefore the introduction of a commercial network solution in the unlicensed spectrum for mobile networks could have an enormous impact on this market.

3.1.1.3 Public building

Public buildings are well known to struggle with connectivity as, often, these buildings are old, highly crowded and need exceptionally good security measures.

Since many of those buildings are used for entertainment and cultural activities, then IoRL has decided mainly to propose two scenarios, one related to a museum and one to a conference center. It has to be noticed that public buildings of this kind also include:

- Public libraries;
- Entertainment centers;
- Community centers;
- Music halls.

Moreover, in France, WiFi in kindergartens[15] and schools[16] is not allowed by law[17], making those potential stakeholders.

The choice of the project was although to concentrate to a museum, as this was defined as a perfect location and example of the possible use cases that might be demonstrated with IoRL solutions, also because of the various types of stakeholders visiting them and the wide spectrum of activities that can be conducted there. The Museums Association (UK) agreed a definition in 1998, which states: “Museums enable people to explore collections for inspiration, learning and enjoyment. They are institutions that collect, safeguard and make accessible artefacts and specimens, which they hold in trust for society.” This definition

[15] Figures at national level not available

[16] 52.580 nursery and primary schools in France according to “ Enquête dans les écoles publiques et privées de l’enseignement préélémentaire et élémentaire », MENESR DEPP

[17] This defined by the law called “Loi Abeille” voted in May 2015 by the French National Assembly

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includes art galleries with collections of works of art, as well as museums with historical collections of objects.

As in most of Museums are open and visited by a wide spectrum of people, although it has to be noticed that some groups are more present than others:

- Normal citizens;
- Tourists (national and tourists);
- Schools (including after school activities);
- Local associations with an interest in exhibitions;
- Professionals with an interest in exhibitions.

Furthermore, museums are often a place useful for important events, such as the "European Heritage Days" that bring millions of people in a really short time.

To give an idea of the potential impact, it is necessary also to have a look to figures. The most comprehensive directory of the museums of the world, which is published by De Gruyter, lists more than 55.000 museums in 202 countries[18].

Taking into consideration the countries of the project, we can see how just UK and France represent almost 4.000 museums (3.718). Next to this, it is hard to find total number of visitors, but, just considering the British Museum and The Louvre, we can count on more than 15 million of visitors in 2011.

In this context, multimedia contents help visitors understand what they are viewing and well prepared media is appreciated by the public. As a simple example, the British Museum has a guide that provides 260 expert commentaries on highlight objects from the Museum, with audio, video, text and images providing in-depth information, self-guided tours for exploring the Museum, from ancient Egypt to China, an interactive map to help you find your way around, a digital souvenir you can send to yourself with a list of what you visited.

According to Trip Advisor reviews on the multimedia in the British Museum, the multimedia Tour guide provides: "*an effective and exciting ways to learn about the things you see both for adults and kids*" and "You have to get the audio guide because it makes the experience so much better!". However they are not without problems. The popularity of the audio guides meant that they were not always available: "*By 10:30 am on a Tuesday all of the audio devices were gone. We were told none would be available until 1pm*". Some guides were affected by interference: "*I would NOT recommend getting the audio guides, they switch channels, languages, and just randomly jump all the time. Hoping they'll fix it soon*". Some users complained that they were required to clumsily "punch in the exhibit number and get a brief explanation of the exhibit" and that: "*The multimedia guide cost £10 for two adults and a child*

[18] "Museums of the World", DE GRUYTER SAUR, 2012

and did not work at all well. The equipment was poor and it lacked appeal for children. It was not as good as Buckingham Palace guide".

The museum defined for the demonstrator of the project, the playing card Museum of Issy-les-Moulineaux, which is a medium sized city on the outskirts of Paris (France) that is recognized as one of the most important innovation hubs in Europe, consists of two buildings: the Modern and the Old. The museum also acts as a community center for local residents, frequently hosting children's activities driven by a professional entertainer, such as Magical Tours.

Figure 5 screenshot of video about LiFI at the Playing Card Museum in Issy-les-Moulineaux

The Modern Museum building was built on the side of a hill and the basement areas suffered from an underground water course running through the building causing dampness. For this reason the basement areas of this modern building was encased in stainless steel container to keep out the water but this also acts as a Faraday Cage that prohibits outside wireless signals from entering the building and vice versa.

This case study will allow to have a proof of concept demonstrator in the field with a genuine interest in the use of IoRL solutions for a wide spectrum of uses and users in an old and modern public building, which will have a clear and useful impact on market analysis and sustainability plan.

3.1.1.4 Building designers

Building Services Engineers are in charge of designing, installing and maintaining a number of services within the building's interior. In general, the building services engineer will write a performance specification for the particular needs of his client and then look at different technological options and recommend different systems that meet the needs of his client.

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The type of considerations that a client may have is the level of Electromagnetic Radiation, wireless coverage, the bits/second per square meter, the signal latency, the building and network security, the energy usage of the wireless transmission system and user equipment, the number of network operators that can be supported, the accuracy of location tracking of people and things, the size positioning of the electrical infrastructure, the routing of electrical and optical cabling, the positioning of transmission antennas.

Once the Building Services Engineering designer has defined the performance requirements of his client's needs he will then recommend how the building should be designed and what electrical facilities should be installed to meet the needs of his clients.

Building Services Engineers are responsible for keeping abreast of the latest technological advances in order to recommend different technological options to his client. Since IoRL technology has the potential to meet the requirements of many business, industrial and domestic buildings, it will be a very attractive option for wireless networks in buildings.

3.1.1.5 Retailers

We can count, just in the UK, 55,000 supermarkets[19] and 47,000 convenience stores[20] with a range of different sizes, thus a scalable architecture is required to allow an ordinary electrician to install it and to be flexible enough to be easily expanded if required.

This is roughly 1 supermarket and convenience store per 1000 people. Extrapolating these figures proportionally for EU, where there are 510 Million people then there are about 510,000 supermarkets and the same number of convenience stores and for China where there are 1.2 Billion people then then there are about 1.2 Million supermarkets and the same number of convenience stores. Furthermore an architecture that operates in unlicensed spectrum is required so that there are no restrictions to deploying it (i.e. does not require the permission of MNOs). This is a considerable sized market that is immediately available.

On the high street, price is no longer a competitive differentiator for retailers due to the advent of on-line retailers such as Amazon.com, rather, selling services, solutions and stellar shopping experiences is what is used to deepen emotional connections with shoppers and encourage consumers to shop longer, spend more money and stay loyal.

However according to PriceWaterHouseCoopers[21], who performed a survey from about 24.000 shoppers around the world, mobile and digital communication technologies in social media are playing a bigger role in influencing shopping decisions, while traditional marketing continues to decrease, whilst 79% still buys products on site, but, at the same time, 39% is

[19] "Number of supermarkets in the UK now greater than pubs" The Morning Advertiser, 2011

[20] "Number of convenience stores in the UK remains stable, reports IGD", Retail Times, Fiona Briggs, 2016

[21] Total Retail Survey 2017, PriceWaterHouseCoopers

inspired by social media, 35% by price comparison websites and 32% by multi-brand websites on purchases.

Moreover, 66% of retailers state that they struggle to give a single view to customers and have a lot to do yet on this matter.

Furthermore, transparency throughout the supply chain food manufacturers and retailers is likely to embrace technology as well as available transparency tools to ensure their brands are accurately represented[22]. Additionally, utilizing technologies like big data analysis to mine loyalty programs allows retailers to quickly identify product purchases and alert shoppers of food safety issues or product recalls.

Furthermore personalization is enabled by Big Data and analytics, allowing more personalized grocery shopping experiences, which in turn could translate into increased sales and repeat visits by loyal customers, is the focus of retailers.

This makes retailers as a potential user of IoRL solutions, while they would have a royalty-free solution allowing them to provide to their customers useful information about products, availability and position, matched with an excellent broadband and any additional useful information.

Moreover, the solution may also allow them to get important data, useful to improve their services and make their offer more adapted to their customers, with a clear positive impact on turnover.

3.1.1.6 Transport companies

According to UITP[23], about 10 billion of people travelled on metro, tram and urban trains on one single year. This figure needs to take into consideration that metro travels are around 75% of total, making it clear that the most of passengers spend most of time in tunnels in which broadband is low or absent.

These are very large numbers of people who flow through the train station system that requires an Information system that has the capacity to support such large numbers and whose behaviour and habits are valuable information in marketing through big data analysis.

Railways are playing an increasingly important role in alleviating problems such as road congestion and air pollution and new plans for high-speed intercity railway links are being initiated around the world[24]. The objective of transport centres such as train stations and airports is the efficient management of the flow of very large numbers of people through the station to their destination safely, punctually and enjoyably.

[22] Gerhard Schiefer, Jivka Deiters, "Transparency in the Food Chain," Universität Bonn-ILB, Germany, 22nd July 2013.

[23] "Metro, light rail and tram systems in Europe", 2009, UITP

[24] "Railway Systems for Smart City Development" (Yosho Ishida), 2011, Hitachi Review Vol. 60 , No. 3

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The pursuit of customer satisfaction has led to the provision of more retail areas in stations. Inside railway stations, restaurants, book stores, convenience stores, fashion boutiques, and other retailers vie for attention, while station neighbourhoods are well provided with hotels, shopping, and similar facilities. When passengers arrive at a station either at the start or end of their journey, they are often unfamiliar with its surroundings and so incorporating advanced information systems into stations and other parts of the railway network is important contributor to the free flow of people by informing them how to get to where they want to go. Additionally, utilizing technologies like big data analysis to mine loyalty programs allows retailers to quickly identify product purchases and alert shoppers of food safety issues or product recalls.

The Mobile Internet is playing an increasingly important role in informing people but particularly important for passengers who do not have Mobile Internet access is digital signage to display service status, news, and guides to the station and surrounding areas of railway stations.

In addition to information systems for passengers, more sophisticated information systems are required for train operation management for ticketing, for maintenance, to enhance security and for disasters and emergencies to maximize operational efficiency.

The pursuit of customer satisfaction has led to making access to station buildings barrier-free. Integration of smart card ticketing systems between different railway companies allows cards to be used interchangeably over a wide area of a country and improving the flow of passengers through train stations.

Next to this, many transport companies tried, or are trying, to provide 3G/4G broadband, but this is often highly costly and complicated as it shows the example of French transport company RATP that could actually provide it in a limited number of stations[25] and giving just a broadband of 512 kb/s. Actually, this company found itself to have to cover around 320 stations, installing an antenna every 500 metres and being obliged to deploy 300 kilometres of fibre cables.

Thus, IoRL will provide a solution allowing these companies to have a much easier to install solution, royalty-free, making easier to provide services to customers. Consequently, they clearly represent a potential stakeholder of these solutions.

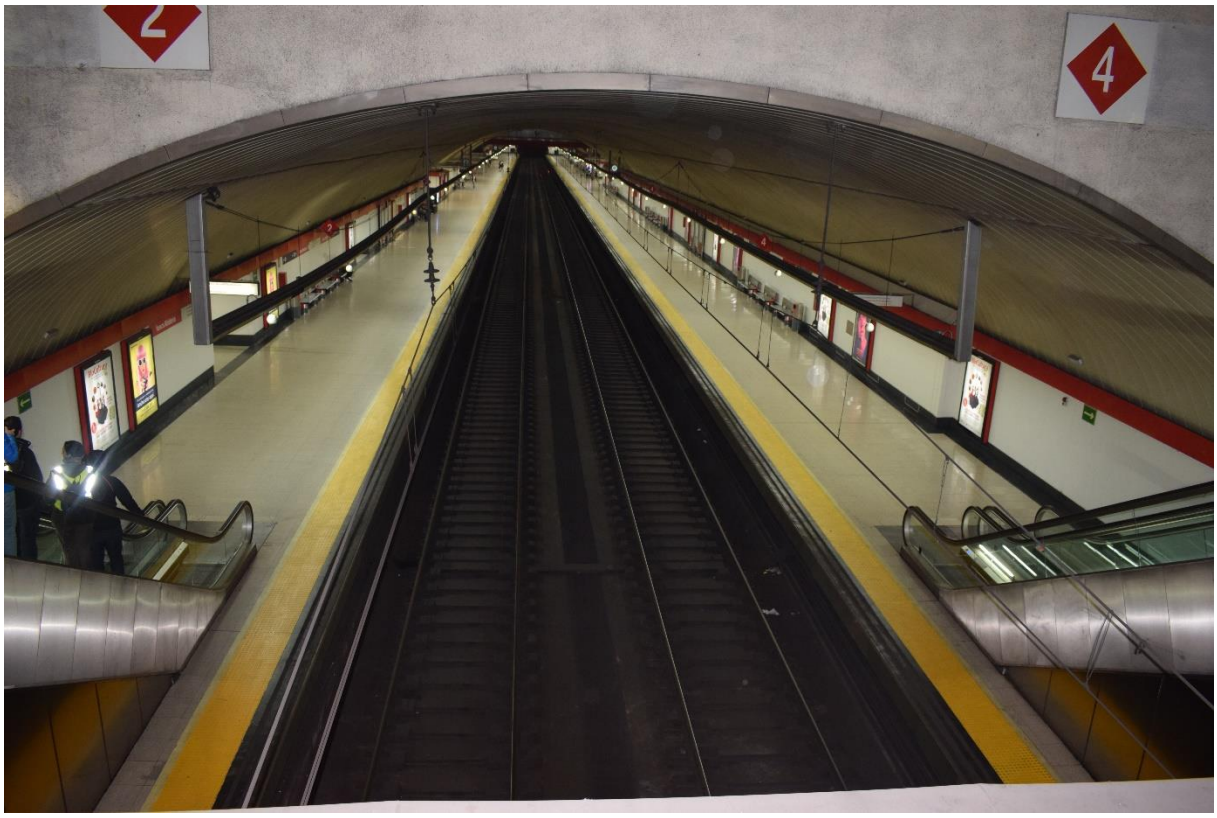
3.1.1.7 Infrastructure Construction companies

Within the infrastructure construction sector, IoRL technologies are disruptive and can drastically change the way that tunnels, roads, bridges, and other major infrastructures are designed, constructed and operated.

[25] Wenbo Ding, Fang Yang, Hui Yang, Jintao Wang, Xiaofei Wang, Xun Zhang and Jian Song, “A hybrid power line and visible light communication system for indoor hospital applications, Computers in Industry”, 2015.

Infrastructures all over the world are becoming obsolete and are in need for constant maintenance, as well as alternative retrofitting solutions. As an example, in the US one out of every five miles of highway pavement is in poor condition and roads have a significant and increasing backlog of rehabilitation needs[26]. In Europe, in addition to the retrofitting of existing infrastructures, new designs and solutions requiring outrageous investments, which are setting the future of infrastructures, are becoming a reality. Some of these projects are: a $25 billion construction of the first fully submerged, floating tunnel beneath the Sognefjord (Norway), a body of water more than 4,000 feet deep and 3,000 feet wide; a massive upgrade to the existing Underground system in London (Crossrail project), being the largest construction project ever undertaken in Europe with 10 new train lines and connecting 30 existing stations via 73 miles of track and 26 miles of tunnels; a 13 miles of underground roadway tunnel in Stockholm that will cost about $3.5 billion and will be the largest tunnel near a city ever constructed.

Figure 6 Tunnel of Madrid Metro network



In all these cases, IoRL technologies could be adopted providing improved solutions to communications infrastructure. An example of a potential use would be a lighting system directly connected to cars obtaining real time data for traffic improvement, or the potential

[26] ASCE- Infrastructure Report Card 2017

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for taking advantage of existing lighting infrastructure for setting up communications inside tunnels.

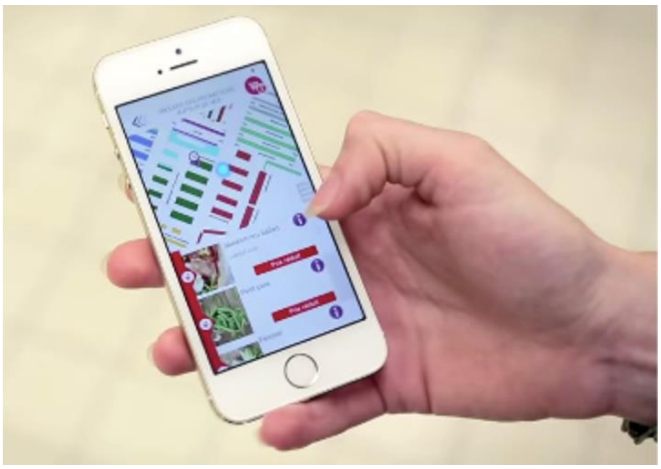
IoRL developments bring to infrastructure construction companies a new set of technologies improving health and safety during infrastructure construction and optimizing communications once the infrastructure is under operation.

3.1.1 Competitors analysis

The third part of market research is related to the study of competitors carried out by the project to better understand IoRL's position in the LiFI landscape. A horizon scan of available solutions will be performed using Boolean search[27].

To give a larger spectrum to this study and reduce the risk not to include important competitors, desktop research and benchmarking will be performed, also considering potential competitors not yet on the market. To this purpose, all partners will be asked to contribute to detect potential competitors on their field and country. This will allow to detect more competitors and the solutions that they are putting in place.

Figure 7 application proposed by Carrefour in joint project with Philips



We already know for sure that various big companies are moving on this solution, as an example, Carrefour, in a joint project with Philips, proposed in Lille (France) an application, called *Promo C-Où*, allowing customers, through LiFi, to have more information on the store and the products.

Moreover, a French city, Courbevoie, next to Paris has equipped some youth centers with LiFi, thanks to the technical support of Lucibel, another potential competitor.

[27] Parameters will be defined and explained in D7.6

Figure 8 Lucibel promotional picture of proposed solutions

Those solutions will be studied in depth to understand how they could compete with IoRL and the individual exploitation plans to be able to include these elements in the final sustainability plan.

Finally, also 5G operators will be taken into consideration as they will surely play a role in the next years around LiFI, being totally part of the process. The most of the attention will be on the operators that hold infrastructures, such as Orange or SFR in France, Vodafone and O2 in the UK, Telefonica in Spain, but some other operators will be closely followed and studied.

3.1.2 Inquiries and surveys

Due to the immaturity of the LiFi market and to better define expectations of partners for the coming years, they will also work on inquiries that will employ primary research methods to deepen all the findings of secondary research.

This will be conducted through the use of surveys and interviews based on two tracks:

- An external stakeholder survey will be designed with a different goal in mind. Unlike the partner survey, its main aims are to find out the needs of potential stakeholders in their day to day job and what features could encourage them to use LiFi. Included in the sample will be managers, decision makers, consultants and developers from municipalities, transport authorities, governments, retailers, building designers and owners, specialised agencies and technology companies. With some of these stakeholders semi-structured interviews will be conducted via skype.
- A partners' survey, designed to determine the most appropriate sustainability model for IoRL after the project's lifetime has elapsed. Consortium members will receive an

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online questionnaire asking them to identify IoRL target market, post-funding management team, pricing model, associated costs, potential revenue streams and avenues for the exploitation of project results during the sustainability phase.

The first survey, proposed to entities external to the project and scenario holders in IoRL, will be prepared between month 6 to 10 and it will be offered to external stakeholders, following the categorisation defined in this deliverable, up to month 19 to allow the inclusion of results in the D7.6. To allow a smoother procedure, questions will be proposed as a survey and/or an interview, taking into consideration that interviews will be prioritised as they will allow a deeper look into expectations of potential actors. This action will be performed with the support of all partners and it will be integrated in market and competitors researches, obtaining a good and deep vision on LiFi market.

The second survey, also mentioned in the following section (3.2), will need to define individual exploitation plans, consequently all partners will need to answer and to explain what they will be expecting to do after the project. This will be used also to define the consortium plan for the future. This will be proposed in the final year to allow a clear sustainability plan on D7.5.

3.2 Sustainability model

Sustainability plan for IoRL will need to give a clear response to a simple question: what should become of the project after it comes to a close in June 2020?

To define an answer to this question, partners will work together to give a clear answer, allowing the provision of crucial information: value proposition, market size, market players, individual and collective revenue model and a related management structure and marketing strategy.

To have a complete and well-structured sustainability model, various activities, involving all partners, will be conducted:

- Individual plans: all partners will have to answer to an individual exploitation survey (as indicated in section 3.1.2)
- Consortium plan: an internal SWOT analysis will be performed, and various propositions considered and compared with a comparison matrix. This will allow a plan to be defined which also considers individual partner plans and all the market research findings.

Following the analysis of individual plans, these potential consortium plans will be presented to the partners in year 3, allowing a discussion to take place that usefully creates a sustainability plan with a mid-long term vision. This will define how IoRL solution will be able to be further developed after the end of the funding period.

A complete sustainability model, individual and collective, will be presented in D7.5.

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4 Conclusions and next steps

As reported in this deliverable, IoRL will propose new technical solutions to propose services to distribute the media content, video in particular, to mobile devices in buildings.

This ambition will make real the development and exhibition of a mmWave duplex transceiver and VLC imaging receiver in a wide range of consumer electronic digital media user equipment, such as 4G/5G smartphones, tablets, TVs, laptops, AR Glasses and VR headsets, thereby incentivising consumer electronic media user equipment manufacturers to initially develop mmWave and VLC interfaces and drivers that can connect to media devices via a USB port but eventually to integrate these interfaces as a standard feature in their products.

As reported in section 2.1 and 3.1.1, this ambition will be demonstrated in 4 scenarios and various use cases to make possible to showcase and test the solutions to the various stakeholders that will play a role in this growing market.

Since the market data available doesn't allow a complete and clear view of the potential of the solution, consequently the IoRL consortium will be working all along 2018 and the first month of 2019 to deepen its knowledge of this market and better define the role that it might play in it. This research will be based on secondary investigations, considering all the existing research not just on LiFi, but also on 5G and consumer electronics products market, and an *primary* research based on partners' countries and networks to make possible to have feedbacks (surveys and interviews) by stakeholders identified in this deliverable.

Later on, from 2019 to the end of the project, this market research, including also an up-to-date stakeholders' analysis, a competitors' analysis will be used to derive a complete and clear plan for sustainability after 2020, with individual and collective plans.

The collective plan will be developed taking into consideration the individual plans and with the support of all partners to make it possible to have a sustainability plan in line with the various business models of the consortium. Moreover, this should lead to feed also the individual plans that might become more effective thanks to the support of an overall plan in the medium and long period.

Finally, it has to be noticed that all partners will collaborate on exploitation and sustainability to make possible to have a complete and consistent plan, taking into consideration the roles played in it by techno-economics analysis and dissemination.

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