Internet of Radio-Light - EU Horizon 2020 Project

First Year's Main Achievements

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***Abstract*—This paper presents the major innovation achievements of the EU Horizon 2020 project Internet of Radio-Light in its first year. The achievements have been categorized into (1) Overall Architecture, (2) Remote Radio-Light Head Architecture, (3) Radio Access Network Architecture, (4) NFV / SDN Architecture, (5) Lighting System Architecture. It then identifies the planned demonstrations for the final year of the project and expected key performance indicators.**

Keywords—5G, Visible Light Communications; millimetre Wave Communications; Radio Access Network, Remote Radio-Light Head, Network Function Virtualisation, Software Defined Networks.

I. Introduction

The Internet of Radio-Light (IoRL) project develops a safer, more secure, customizable and intelligent in building network using millimetre Wave (mmWave) and Visible Light Communications (VLC). The conceived solution reliably delivers increased throughput (greater than 10Gbps) from access points pervasively located within buildings. It does so, whilst minimizing interference and electromagnetic exposure and providing location accuracy of less than 10 cm at the same time. Thereby IoRL's ambition is to show how to solve the problem of broadband wireless access in buildings and promote ITU's 5G global standard. Further aspects of the project and more full description of its architecture and scenarios can be found in [1], [2], [3], [4] and [5].

II. Major Achievements in First Year of Project

The major achievements in the first year of the project are the elaboration of the use case scenarios and the extraction of the user and technical requirements, the development of the system architecture as shown in Figure 1, the implementation plan for the benchtop demonstrators and the first steps towards their implementation. Use case scenarios were developed for private homes, public buildings including a museum and a transportation hub and buildings hosting commercial operations.

A. Overall Architecture

IoRL devised a layered architecture consisting of three layers: Service, Network Function Virtualisation (NFV) / Software Defined Network (SDN) and Access; and as such our architecture is well aligned to the overall 5G architecture.

The next generation 5G Home eNodeB architecture was developed, which we are calling Home gNB (HgNB). It introduces the concept of indoor room/floor cellular coverage areas, which is suitable to the bimodal nature of visible light and mmWave channels depending on the presence or absence of line-of-sight. Furthermore, it introduces the concept of intra-handover between indoor coverage areas within the same building and inter-handover between building HgNB and outside gNB. This is a totally new concept, which increases the total bit rate that can be delivered to a building network.

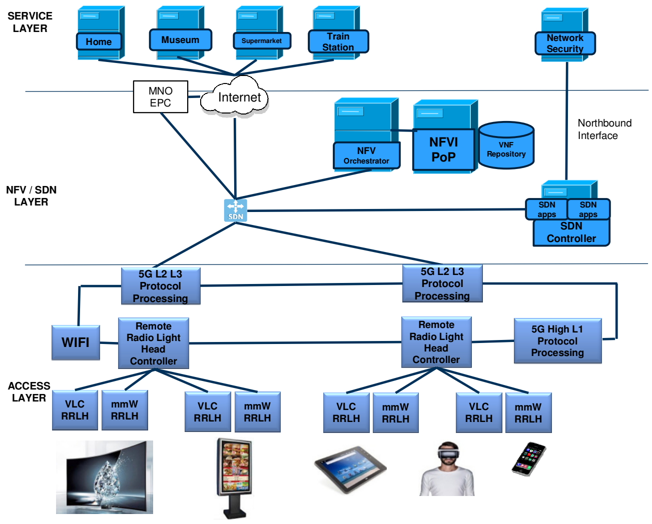

Figure 1: IoRL Layered Architecture

The 5G Home gNB can act both as an extension to the outside cellular network or as a standalone WLAN network operating independently from the 5G outside network. The impact of this is that ultra-low latency communications can be obtained by selecting the appropriate path through the network.

B. Eemote Radio-Light Head Architecture

Improvements to the 5G remote radio head architecture were made by including a VLC module, which we a calling Remote Radio-Light Head (RRLH), as shown in Figure 2. It uses the multi-component carrier feature of 5G architecture to transmit at these two different parts of the EM spectrum. The impact of this is that the total throughput to a building can potentially be dramatically increased.

The RRLH architecture uses DC offset Orthogonal Frequency Division Multiplexing (DC-OFDM) as VLC modulation, which combines modulation efficiency and compatibility with existing 3G PPP's 5G OFDM modulation. The impact of this is that it can readily integrated into a future 5G standard.

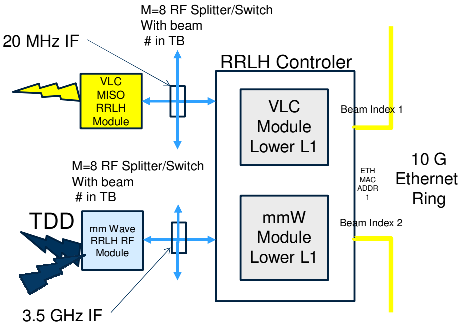

Figure 2: RRLH Architecture

C. Radio Access Network Architecture

A Distributed Radio Access Network (DRAN) architecture was developed that processes the 5G Lower Layer 1, Upper Layer 1, Layer 2 and 3 protocol stack in a parallel pipeline interconnected by a 10Gbit/s Ethernet ring. The impact of this is a reduction in processing delay and building network latency.

Algorithms estimating the location of User Equipment (UE) were developed using a combination of the Received Signal Strength of VLC OFDM reference symbols and using Round Trip Times of mmWave OFDM reference symbols. We expect to contribute with this to the development and improvement of indoor location based services.

D. NFV / SDN Architecture

A NFV - SDN architecture was developed that routes IP packets to different building room/floor coverage areas and performs intra building room/floor coverage area handover. The impact of this is the total bitrate that can be delivered to a building is increased by the number of coverage areas within the building. Since VLC and mmWave frequencies in adjacent room/floor coverage areas do not interfere with each other, the frequency reuse factor is always 1.

The NFV-SDN architecture can also increase the connection reliability of video services by Multi Source Streaming (MSS) offering different quality versions of the same content through RRLH and WLAN. The impact of this is that it overcomes the bimodal nature of visible light and mmWave channels by always ensuring a low quality – low bit rate video by WLAN. This principle can also be extended to multipath TCP protocols. The impact of this is reliable mmWave and VLC communications in buildings with a Quality of Service feedback to users on whether there is line of sight connectivity to the RRLH access points.

The envisaged Intelligent Home IP Gateway (IHIPG) provides the NFV/SDN functionality, which can be located within the building premises, but also in the Cloud. The impact of this is flexible OPEX/ CAPEX trade-off choices for Mobile Network Operators (MNO) depending on type of customer building network being provisioned.

E. Lighting System Architecture

The concept of light systems acting as an Electromagnetic access points in a room was introduced through the adaptation of the physical architecture of spot (as shown in Figure 3), pendant, strip, giotto visible light systems to include both a VLC transmitter and a mmWave transceiver torch. The impact of this is that a completely new disruptive market of radio-light EM access systems might complement the WLAN market.

Figure 3: Spot Light with External mmWave Torch

III. Demonstrations

Demonstrations of UHDTV (live and from streaming server), 360^{o} AV, location based monitoring, guiding and data access, AV communications, interactive Internet, home video security surveillance and network security applications related to the use case scenarios are planned.

IV. Key Performance Indicators

Key performance indicators considered are: Location accuracy of less than 10 cm, building network latency of less than 10ms and Peak data rate of 732.16Mbit/s per room/floor with a potential of increasing this up to 3.4Gbit/s per room/floor depending on the NR Sub-carrier Spacing and Bandwidths selected.

References

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