1. PUBLISHABLE SUMMARY

Summary of the context and overall objectives of the project (For the final period, include the conclusions of the action)

So far, the Internet of Things (IoT) is narrowband with no latency constraints. A wider range of applications is envisioned for industrial manufacturing, augmented reality and autonomous cars. It makes use of artificial intelligence, where compute functions will be offloaded from devices into the cloud. Accordingly, future IoT will need wireless links with high data rates, low latency and reliable connectivity despite the limited radio spectrum. Connected lighting is an interesting infrastructure for IoT services because it enables visible light communication (VLC), i.e. a wireless communication using unlicensed light spectrum. LED luminaires have enough modulation bandwidth for high data rates and each luminaire can be used as a wireless access point. Networked VLC-enhanced luminaires will add new features to build a wireless network for the IoT. ELIoT will start from existing prototypes and develop the support for IoT services. The project will integrate the lighting infrastructure with VLC and add positioning, multicast communications and enhanced security. ELIoT will demonstrate the new infrastructure in real environments at TRL $\geq$6 and mobile IoT devices at TRL $\geq$ 4. Main project goals are to provide an open reference architecture for the support of IoT in the lighting infrastructure, build consensus reflecting the best architectural choices, contribute to standardization of lighting and telecom infrastructures in IEC, IETF, IEEE and ITU-T and provide a roadmap for IoT until 2022 and beyond. ELIoT brings together Europe's key players that cover the whole value chain, i.e. Signify as major component and luminaire makers, Maxlinear as chipmaker, Nokia as a leading network vendor and integrator, Weidmüller working on industrial IoT, Deutsche Telekom and KPN as innovative operators, LightBee an SME for LiFi devices together with Fraunhofer HHI and Fraunhofer FOKUS as a leading research institute and two top universities from Eindhoven and Oxford.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far (For the final period please include an overview of the results and their exploitation and dissemination)

Work package 1, Project Coordination, is the management and administrative work package which is led by Fraunhofer with support of the technical manager Signify. The work is ongoing and is successfully managed.

Work package 2, Use Cases and Requirements, is the foundation of the technical work in ELIoT. So far, initial demonstrators have been showed by the partners and LiFi uses cases have been detailed described. The most promising use cases have been chosen for the final demonstrators in order to target real industrial, office, fixed wireless access and in-home scenarios.

Work package 3, Concepts and Algorithms, is aiming at studies on system concepts and algorithms enabling secure, dynamic and high-capacity LiFi end-to-end links. At this time, system concepts for the different use cases have been developed and integrated into a uniform system architecture. Work on LiFi indoor positioning concepts is ongoing and a Plastic Optical Fiber (POF) based feeder network for the luminaries has be investigated. Furthermore, concepts for handover solutions, based on the Maxliner chipset are under discussion.

Work package 4, IoT Lighting Infrastructure Innovations, is concerned with a wide variety of the underlying technologies necessary for the successful design and construction of the hardware

demonstrators. Concepts initiated in Work Package 3 are translated into a demonstrator setting that can actually show their feasibility. Furthermore, a number of practical aspects and limitations such as scalability are also be studied.

Work package 5, Mobile IoT Device Innovations, focuses in ensuring that mass-market compatible mobile devices become available for the IoT that are LiFi-enabled. For this, the different aspects of light communication systems are being optimized in terms of power consumption and algorithms.

Work package 6, Validation through Demonstration in Real Environments, will officially start in 2021, however preparation work has been started.

All commercial partners started their exploitation activities in work package 7, and the effectiveness of ELIoT to influence the directions and progress in standardization became obvious through active participation and contributions to ITU-T SG 15 (G.vlc), IEEE P802.11bb, as well as in IEEE P802.15.13. Remarkable visibility and awareness of ELIoT among light communication experts were reached through contributions and presentations at the LiFi congress in June 2019 in Paris, the LiFi event at the Photonic Week at the beginning of October 2019 in Eindhoven, and in the general public through a press release at the end of July 2019. Numerous scientific papers were created out of ELIoT mainly by TU Eindhoven, University of Oxford, and Fraunhofer and there is an increasing amount of joint papers, e.g. presented at ICTON and submitted to the GLOBECOM Workshop on Optical Wireless Communications.

Progress beyond the state of the art, expected results until the end of the project and potential impacts (including the socio-economic impact and the wider societal implications of the project so far)

Indoor Positioning: In order to extend the accuracy of existing optical positioning solutions and enhance the capabilities of conventional luminaires with high-speed network connectivity and positioning services simultaneously, ELIoT uses a variation of time-of-flight measurements.

Broadband Data Communication: POF is an attractive medium for wired indoor communication. In ELIoT the ambition is to explore POF as the feeder for the LiFi access points. The data can be brought first in baseband spectrum to the access points, and by O/E/O conversion can then be brought into the optical domain. Within ELIoT, the POF network will be investigated as a versatile feeder network for LiFi, offering delivery of other services in a converged way. First experiments on POF feeder networks for LiFi, with OFDM as modulation format, have shown promising results. Demonstrations in real environments later in the project will further support this.

Multicast Communication: The ELIoT project approaches multicasting in three ways. Firstly, there will be a vertical handover between LiFi and 5G. It will be implemented at the transport layer (IP) by using the non-3GPP Interworking Function (N3IWF). Secondly, one version of the classical horizontal handover will be implemented on top of an existing G.vlc system in order to support mobility between LiFi cells. Thirdly, for IoT applications, which require the highest reliability and lowest latency, ELIoT considers main steps towards implementing a more modern form of multicasting, i.e. soft handover or so-called distributed MIMO link. Current work in ELIoT on multicast is in a conceptual phase with first results expected late in 2020.

Open Architectures: The ELIoT reference architecture document will be designed to allow system and device designers to immediately create an actual working product or system, also before the rather slow international standardization process provides all related standards, and the “how to” knowledge

is part of the common domain. A first version of the open reference architecture has been published by ELIoT in March 2020.

Address (URL) of the project's public website

https://www.eliot-h2020.eu/

ELIoT meeting at Weidmüller in 2019 and newly developed outdoor LiFi modules.