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 ≥6 and mobile IoT devices at TRL ≥ 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

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. Important results are a refined system concept for the different ELIoT use cases, LiFi-based indoor positioning with cm accuracy, Plastic Optical Fiber (POF) based feeder networks for the luminaries concepts for handover solutions.

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. WP4 was successfully completed in 2021 and a lot of conceptual work on current and future LiFi systems was carried out. This includes, for example, the development of detailed channel models, the establishment of specifications for different LiFi use cases, work on the necessary infrastructure and the integration of LiFi into radio technologies such as 5G.

Work Package 5 looks to ensure that mass market compatible mobile devices become available for
the IoT that are VLC enabled. For this, the different aspects of light communication systems are being optimized, especially in terms of power consumption. Ongoing work in WP5 includes many aspects, like fronthaul optimization for power efficiency, investigation of suitable modulation schemes, advances signal processing to address the optical wireless channel, system models for the LED and recommendation for LiFi communication standards.

Work package 6, Validation through Demonstration in Real Environments, will demonstrate new features like positioning, handover and broadband data communication in LiFi system in real environments. Several use cases like outdoor, office or industry are targeted. Another highlight is ELIoT’s effectiveness to influence the directions and progress in standardization through active participation and contributions to ITU-T SG 15 (G.vlc) IEEE P802.11bb as well as in IEEE P802.15.13.

Progress beyond the state of the art and expected potential impact (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. Demonstrations of the investigated approach have shown accuracies in the range of 1-2 cm, based on a ITU-T G.9991 signal structure. Furthermore, investigations on how to bring this feature into future LiFi chip set, have shown promising results.

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. Experiments on POF feeder networks for LiFi, with OFDM as modulation format, have shown promising results. Ongoing demonstrations in real environments support this. To realize distributed MIMO functions over POF, we used WDM concept. Therefore we have developed 4 prototypes of WDM (de)Mux for bidirectional 2x2 MIMO concept which can be used for spatial diversity and spatial multiplexing.

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). This has been successfully demonstrated in the laboratory and will now be implemented in the industrial use case of ELIoT. 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. Initial tests for this approach have already been successfully completed. 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. The conceptual background has been developed in the last 18 months and implementation in the laboratory are ongoing.
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 and a refined version will be published in March 2022.

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

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