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Interference handling for LiFi

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Optical wireless communication (OWC) could be the answer to meet the increasing demand for wireless connectivity in response to crowded RF networks. OWC suffers less from interference than RF because light does not penetrate through walls and allows for smaller "cells" compared to RF due to better beamforming. Therefore, optical wireless communication enables a much denser reuse of the transmission medium compared to RF.

To realize full optical coverage within a certain area, optical cells need to overlap. That means, like for RF, that interferences may occur between nodes that belong to different cells. Unlike in RF, LiFi nodes dominantly communicate via line-of-sight. This property causes an extra hurdle to handle interference, because nodes do not detect the transmission of neighbouring nodes and may cause unintended interference.

In a typical LiFi system as illustrated by Figure 1, LiFi Access Points (AP) are installed in the ceiling of a (large) room where LiFi user devices / End Points (EP) are located. The coverage areas of APx and APy are indicated in yellow and the ones of the EPx and EPy in blue.

As illustrated by the left part (*A*) of Figure 2, APy may cause unintended interference (red arrow) to the transmission of APx to EPx (white arrow), because it does not detect when APx is transmitting. Similarly, as illustrated by the right part (*B*) of Figure 2, EPx may cause unintended interference (red arrow) to the transmission of EPy to APy (white arrow).

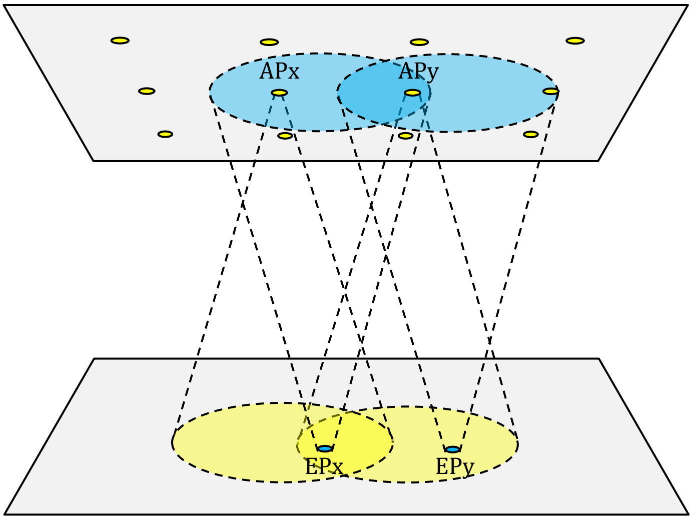

Figure 1 Situation with LiFi Access Points (AP) in ceiling and LiFi End Points (EP)

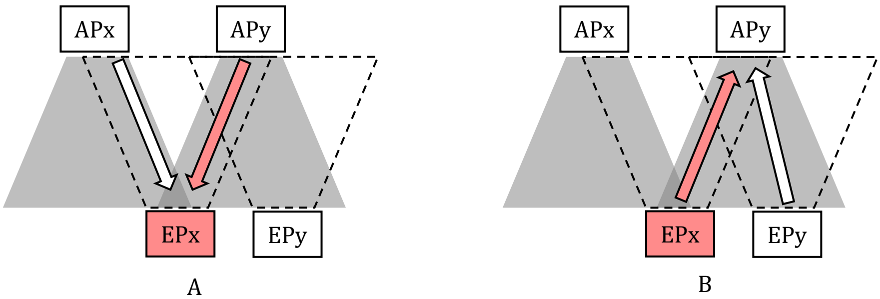

Figure 2 Interference for downlink transmission (*A*) and uplink transmission (*B*)

The unintended interference may cause a significant degradation of the transmission which can be solved by dividing the medium resources over the interfering nodes. Various options can be chosen for that purpose, like time division, frequency division of the baseband, code division and wavelength division (in analogy to frequency division of an RF carrier).

To introduce LiFi products into the mass market, some practical considerations narrow the choice between these options. The main consideration thereby is to make use of existing chips that support OFDM and adaptive bit-loading (allowing the use of LEDs with a low pass frequency response) and a MAC protocol with sufficient flexibility to address the problem of unintended interference.

Different MAC protocols exist to control the access to the medium, whereby two proven techniques dominate: CSMA and TDMA. For the first one, a node checks if the medium is idle before it transmits and for the second one a node follows a scheduled time for its transmissions. To address the unintended interference problem in OWC, CSMA is by nature not favourable, because an OWC node typically does not sense the carrier of the other nodes. A more favourable option is therefore TDMA whereby an AP determines the access of the nodes to the medium according to a schedule. The unintended interference problem can then be solved by coordinating the APs in respect to their time-schedules for the access.

These considerations lead to use the ITU-T G.9991 recommendation that is largely based on ITU-T G.9960/G.9961 for which chips are available.

The following is a summary of proposals to enhance the ITU-T G.9991 recommendation for inter-domain interference handling, which are currently discussed in the Q18/SG15 group of ITU-T.

ITU-T G.9960/G.9961 describes the concept of domains, which basically are regarded as separately operating networks. For powerline communication, the standard describes how interference between multiple domains can be mitigated. The concept of multiple domains fits well for LiFi, whereby a domain should be regarded as a part of a larger LiFi network. A LiFi domain could also be regarded as a BSS in IEEE 802.11 terms.

Where for PLC the inter-domain interference is handled by a distributed protocol whereby all management messages are transferred over the same medium as the data, for LiFi this can be organized differently as illustrated by the architecture of Figure 3. In this architecture, each domain is connected to a backbone via their AP to exchange inter-domain management messages. Moreover, a separate LiFi controller (LC) is introduced to utilize the inter-domain interference handling. The LC can be implemented as a central entity, but its functionality (or part of) may also be distributed among the APs. This architecture allows for a faster and more efficient control on handling inter-domain interference compared to that for PLC.

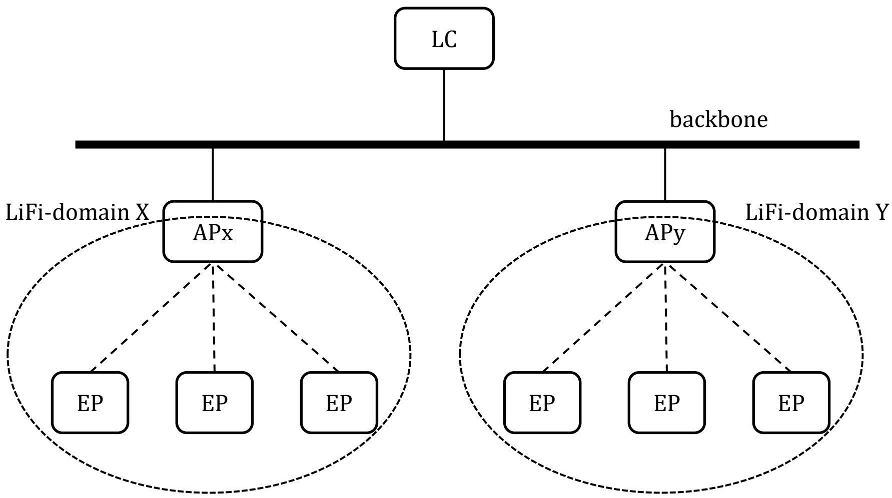

Figure 3 LiFi network architecture

The concept of the advanced inter-domain handling for LiFi is to collect inter-domain interference occurrences and to coordinate the APs by setting constraints on their access schedules to resolve these interferences.

A pre-requisite for coordinated time division over multiple domains, is to apply a common time-base among the domains. As illustrated Figure 4 APs are synchronized with a common clock to align their MAC-cycles. Such synchronization can for example be realized by applying IEEE 1588 over the backbone. To detect, which nodes of neighbouring domains potentially interfere, a common channel (CC) is proposed in which APs and EPs advertise their presence.

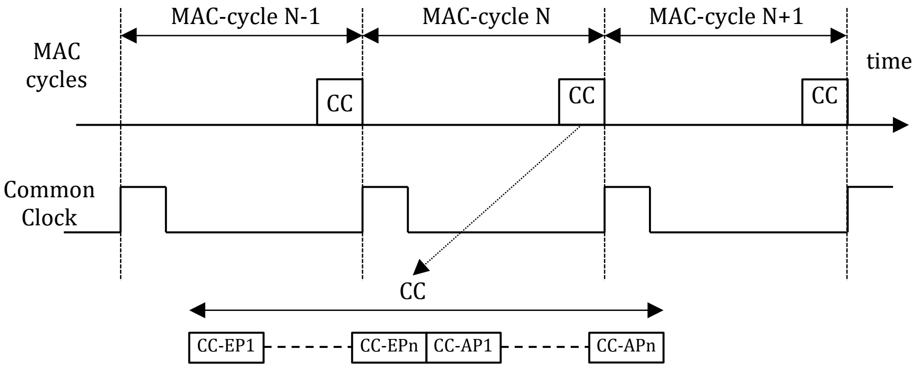

Figure 4 MAC cycle alignment to common clock and CC

Each AP keeps track on the detection of neighbouring nodes and reports interference occurrences to the LC. Based on the reporting derived from the APs, the LC calculates scheduling constraints for each AP to resolve the interferences. Taking the example of Figure 2, and the domains of Figure 3, the core part of this procedure works as follows.

EPx, belonging to the domain X detects the advertisements of APy belonging to domain Y and reports the detection to APx. APx informs the LC on interference of APy to APx. To resolve the interference situation, the LC imposes constraints to APx by restricting its communication with EPx to a set of timeslots and imposes constraints to APy by restricting its communication with its EPs by excluding this set of timeslots.

There are various possibilities to calculate these time-division constrains, which are currently out-of-scope for ITU-T G.9991. However, to aim at interoperability of the elements (LC, AP, EP) in a LiFi system whereby these elements may be produced by different vendors, further proposals may be expected for ITU-T G.9991 and for a LiFi consortium that ensures interoperability through a certification process.

References

[1] ITU-T G.9991 03/2019
[2] ITU-T G.9961 11/2018
[3] ITU-T G.9960 11/2018