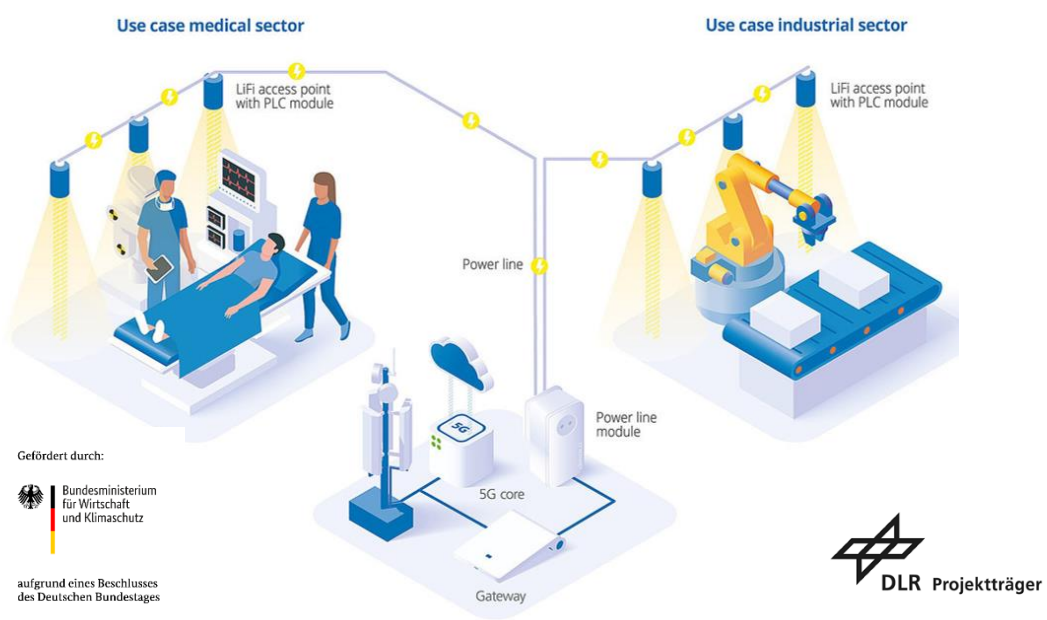


Lincnet

LiFi-Enabled for Industrial and Medical Networks

Dr. Anil Mengi, VP Strategic Positioning, devolo

Li-Fi Conference

26.06.2023

Challenges and Motivation for the LINCNET Project

•Challenges of 5G Communication:

- Heavy attenuation of by walls and thermally insulated windows in indoor settings

•Cable-Like Quality of Service in IoT:

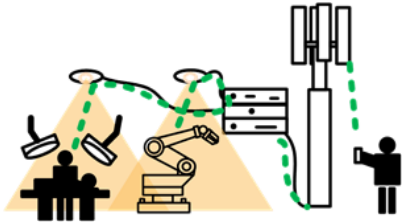
- Increasing demand for reliable wireless communication in IoT applications

•Costly Infrastructure Requirements:

- Expensive installations needed to address 5G limitations indoors

•Existing LiFi Challenges: Affordability and Seamless Integration

- Ensuring cost-effective solutions with seamless integration capabilities



<u>Objective of the LINCNET Project:</u>

•Develop innovative integration of PLC and LiFi technologies

•Provide reliable and high-speed wireless communication in industrial and medical networks

Lincnet: **L**iFi-Enabled for **IN**dustrial and Medi**C**al **NET**works

Project details

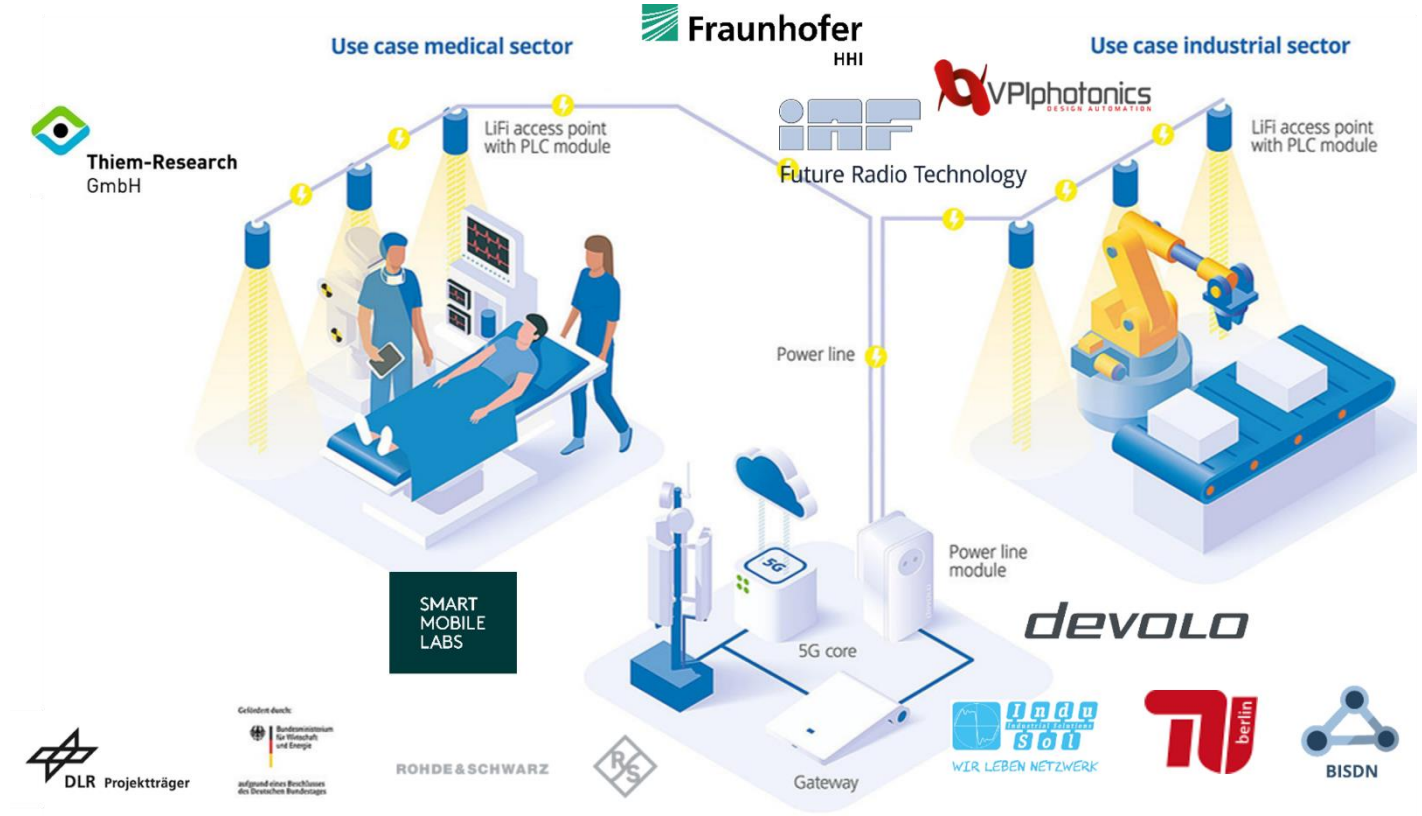
- 15 partners from industry and research
- Duration 01.02.2022-31.12.2024
- Total costs 5,3 Mio. €
- Funding 3,3 Mio. €

Proposed Solution

- **PLC as a backbone for LiFi**: Utilizes existing electrical infrastructure for reducing installation costs.
- **Integrated infrastructure**: Combines LiFi with PLC, effectively addressing industry-specific demands.
- **Unified network management**: Controls communications, enables remote monitoring and maintenance.
- **Requirement analysis**: Focuses on relevant LiFi use cases, such as imaging sensors and mobile robots

Lincnet: LiFi-Enabled for INdustrial and MediCal NETworks

15 partners from industry and research



Detailed Use Case and Performance Requirements

Medicine and Industry Use Cases

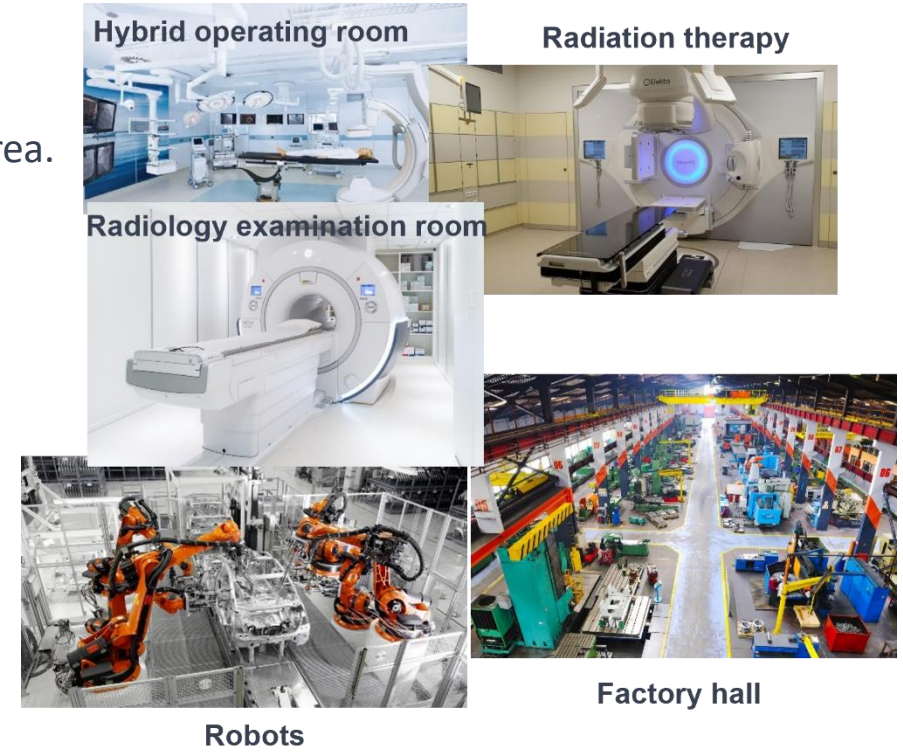
- Moderate data rates, highest quality of service.
- Data Rate Requirement: ≥100 Mbit/s for 6-8 m² area.
- Latency Requirement: ≤10 ms.

High User Density and Parallel Connections:

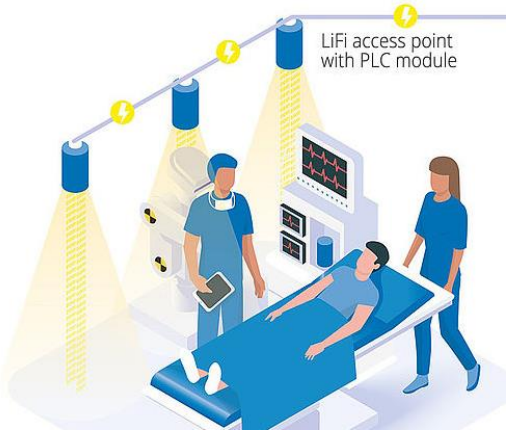
- Simultaneous data transmission from ≥10 devices.
- Industrial: Optical data transmission range ≥10 meters.

Hybrid Operating Room :

- Optical data transmission range ≥3 meters
- Area Coverage: ~40 m².
- LiFi Modules: 5-6 modules deployed.



Why Powerline as a backbone of LiFi?



- LiFi can have many cells per room
  - Installation of new cabling increases cost
  - PLC backbone is intuitive, BPLC → > 2 Gbit/s with 2x2 MIMO

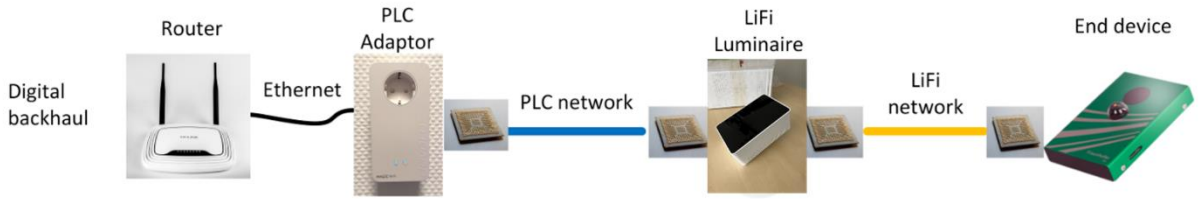
- Literature describes **multiple possible solutions of PLC+LiFi**
- There is a need of cost-effective solutions with seamless integration capabilities

Considering Possible Integrations of PLC and LiFi

Analog forwarding vs. digital recovery and forwarding

- **Two main approaches**:
  - Digital forwarding → Signal is decoded and retransmitted between PLC and light
  - Analog forwarding → Same signal is sent over PLC and light without recovery

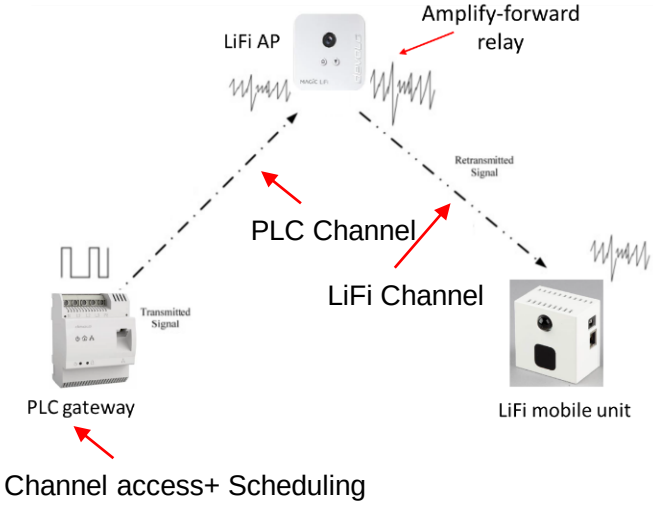
- **Digital:**
  - more chipsets needed
  - higher energy use
  - the use of MIMO PLC
  - Latency 2,3-**13,2 ms** ✗



- **Analog:**
  - less chipsets
  - smaller, less energy used
  - spatial diversity possible
  - SISO PLC

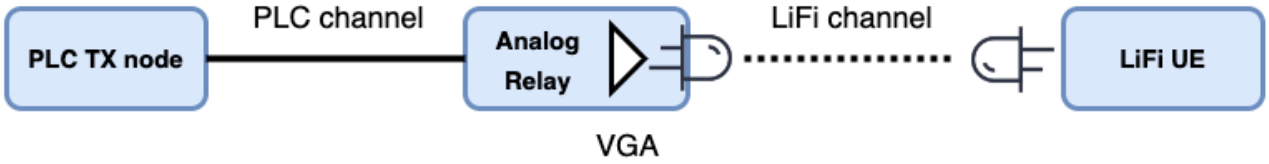
Anolog Forwarding PLC-LiFi

- LiFi-APs operate as ***analog Amplify-Forward Relays***:
  - **Downlink**: PLC signal is not decoded but only amplified by the relay and directly transmitted via LiFi (conversion of electrical signal to optical signal)
  - **Uplink**: the LiFi-received signal is only amplified and directed into the PLC network (conversion of optical signal to electrical signal)
  - Analog relay facilitates transmission from one medium to another: PLC<->LiFi
- <u>Technical details & parameters:</u>
  - Utilization of a single PHY/MAC for transmission over the LiFi and PLC channel ITU-T G.Hn
  - Channel access and scheduling are realized by the PLC gateway for both DL+UL => TDMA-TDD
  - Spectrum LiFi: 200MHz (Coax Mode), 80MHz (PLC)



Anolog Forwarding PLC-LiFi

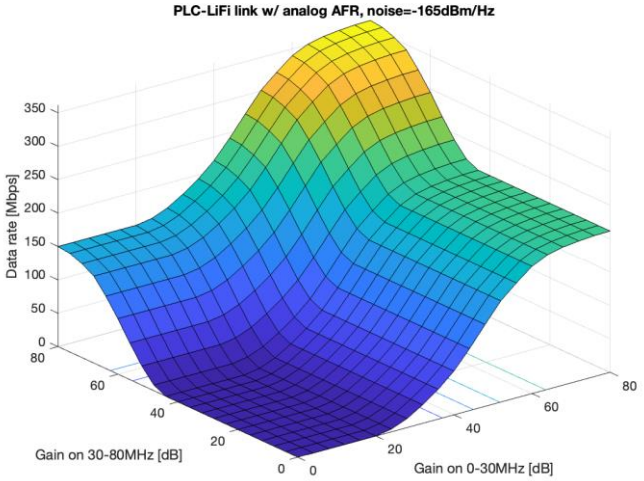
Single-Channel Approach



VGA in the analog relay: adjustable from 0 to 80 dB

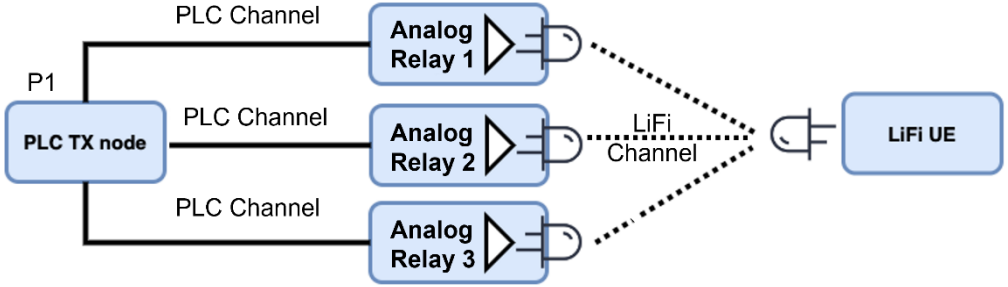
transmit power in the PLC:
higher power can be transmitted on the first 30 MHz compared to the range of 30-80 MHz,

the impact of VGA on both ranges:
the maximum data rate of 360 Mbps can be achieved in both ranges with a VGA of 60 dB.

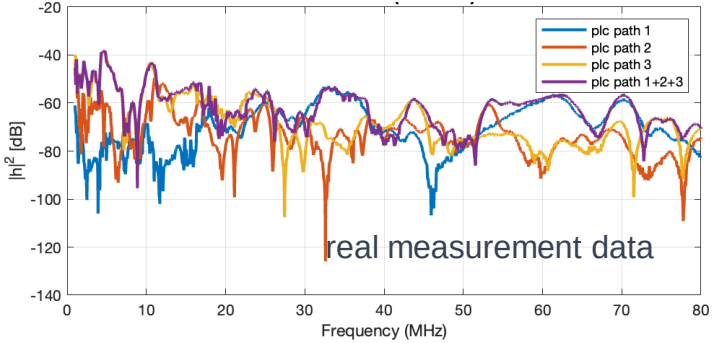


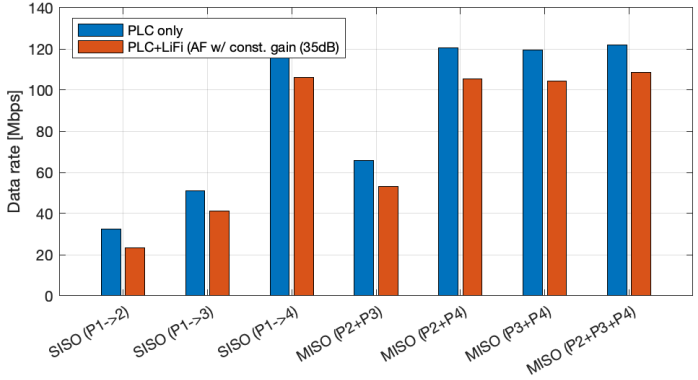
Anolog Forwarding PLC-LiFi

Multi-Channel Approach



Attenuation in the PLC channel to the 3 relays



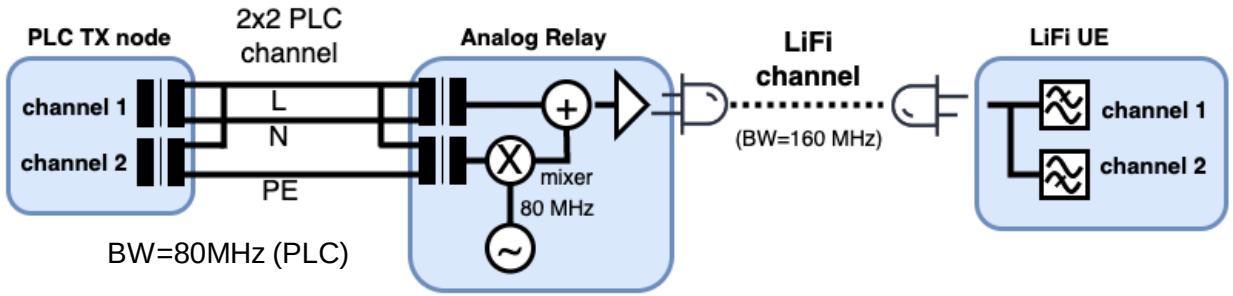


The PLC channel matrix was obtained from real measured traces.

Advantages of multi-channel: Higher data rate, shadowing robustness, low complexity

Possible System Optimization PLC- LiFi

Support of PLC-MIMO



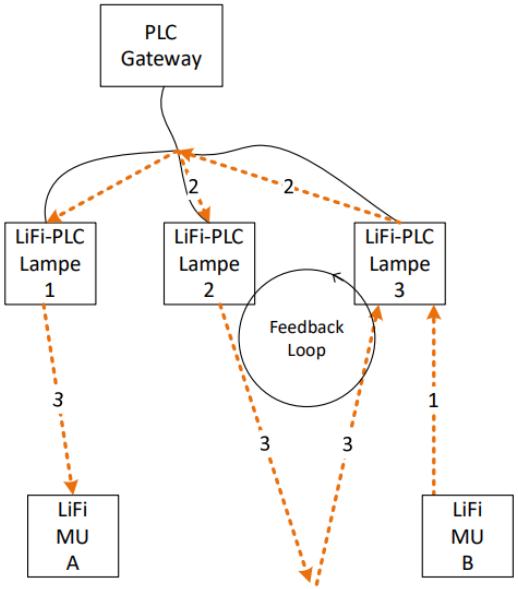
MIMO PLC→ utilization all three conductors of a power cable

Idea: convert the two MIMO signals transmitted over the power cable, each with a low bandwidth, into a single SISO signal with higher bandwidth transmitted over the light channel.

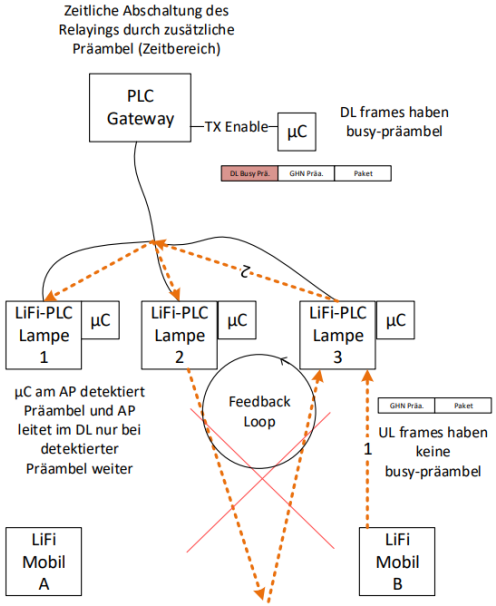
The implementation remains cost-effective, requiring only an RF mixer in the LiFi AP and a bandpass filter in the LiFi UE.

Possible System Optimization PLC-LiFi

Problem: Feedback loops can occur due to the amplification at the LiFi AP (lamp).



Solution: Adding additional preamble before the actual frame



Conclusion

Combining PLC and LiFi is viable today

Summary:

- LiFi and PLC complement each other & can be integrated in multiple ways
- “Analog forwarding” approach has economic advantages
- **Technical feasibility** was **demonstrated**
- Prototypes are currently being developed and will be deployed in medical and industrial scenarios.
- **Outlook:**
- Investigate improved integration (regulatory compliance, performance improvements)
- Make optical signals an extension of PLC to address a diverse set of (niche) applications?

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Thank you for your attention!

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