BACKBONE TECHNOLOGIES FOR LIFI IN INDUSTRIAL AND MEDICAL APPLICATIONS

Volker Jungnickel, Fraunhofer Heinrich Hertz Institute, Berlin, Germany

Fraunhofer HHI

Industrial and medical use cases

Challenges

Moderate data rates, High QoS

- Data Rates: ≤ 100 Mbit/s
- Latency: ≤10 ms

High user density and parallel connections

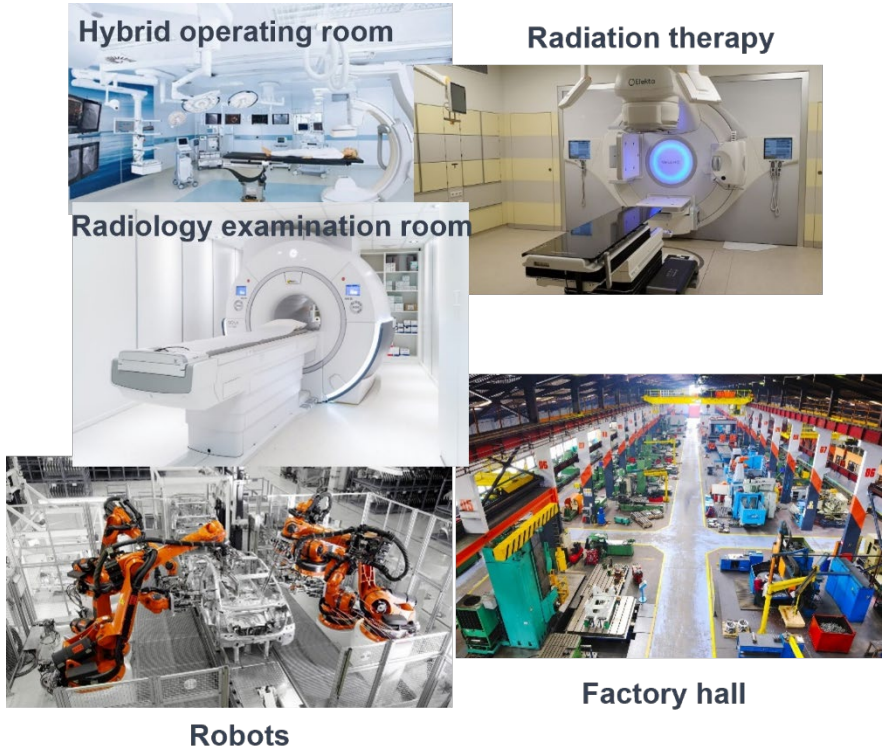
- Simultaneous data transmission to ≥10 devices
- Next service next room

Industrial manufacturing

- 6-8 m² area, range ≥10 meters

Hybrid Operating Room

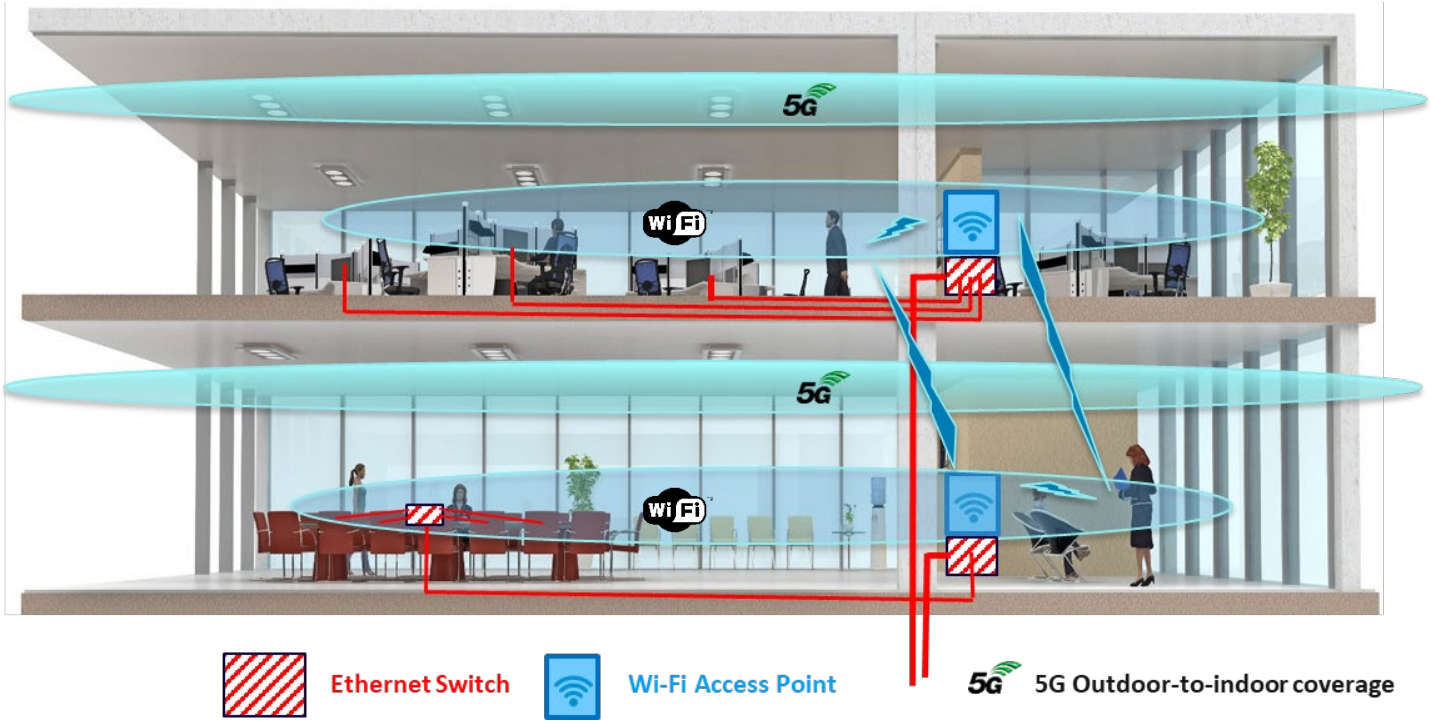
- 20-40 m² area, range ≥3 meters



Source: A. Mengi, devolo

In-building network in 2024

5G and WAN from outside, LAN and WLAN inside the building



Problem statement

LAN und WLAN vs. 5G

LAN: high speed, high QoS

- Ethernet: 1 Gb/s per user
- Coax-/PLC: 1-2 Gb/s shared between 1…16 users (G.hn)

WLAN: high speed but limited QoS

- **Shared spectrum**: up to 10 Gb/s for multiple users
- "Listen-before-Talk" random channel access to combat interference
- a) by other technologies, b) by other access points and stations

5G: High QoS but limited indoor capacity

- **Licensed spectrum**: deterministic channel access enables high QoS
- poor energy efficiency: large distance to base station, outdoor-to-indoor penetration loss

How to reach "wire-like wireless" QoS inside buildings?

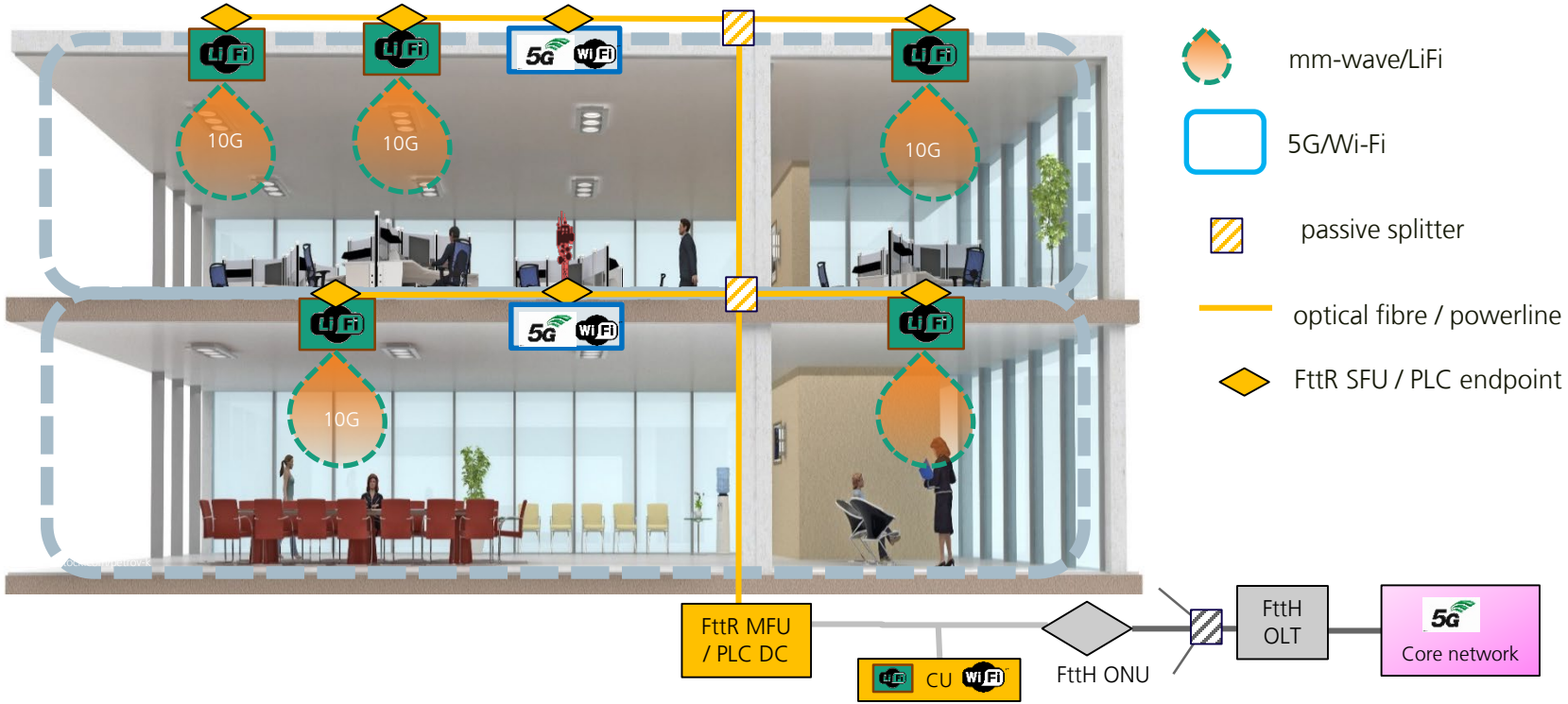
- further develop LAN and WLAN technologies, complement 5G inside buildings

In-building network technologies

	rate	QoS	cost
LAN	high	high	high
WLAN	high	limited	low
5G	limited	high	high

Future in-building network

Overall system concept



Overview of main R&D topics

Optical access and in-building networks

Empower optical access

- develop PON as mainstream (GPON, XGS, HSP)
- keep coax, FWA and NTN as alternatives

Promote fiber to replace copper in buildings

- fibre-to-the-room (FttR): P2P vs. PON approaches (10 years for B2B, 30 years for B2C)
- keep Ethernet, coax and PLC as alternatives

Make Wi-Fi more reliable

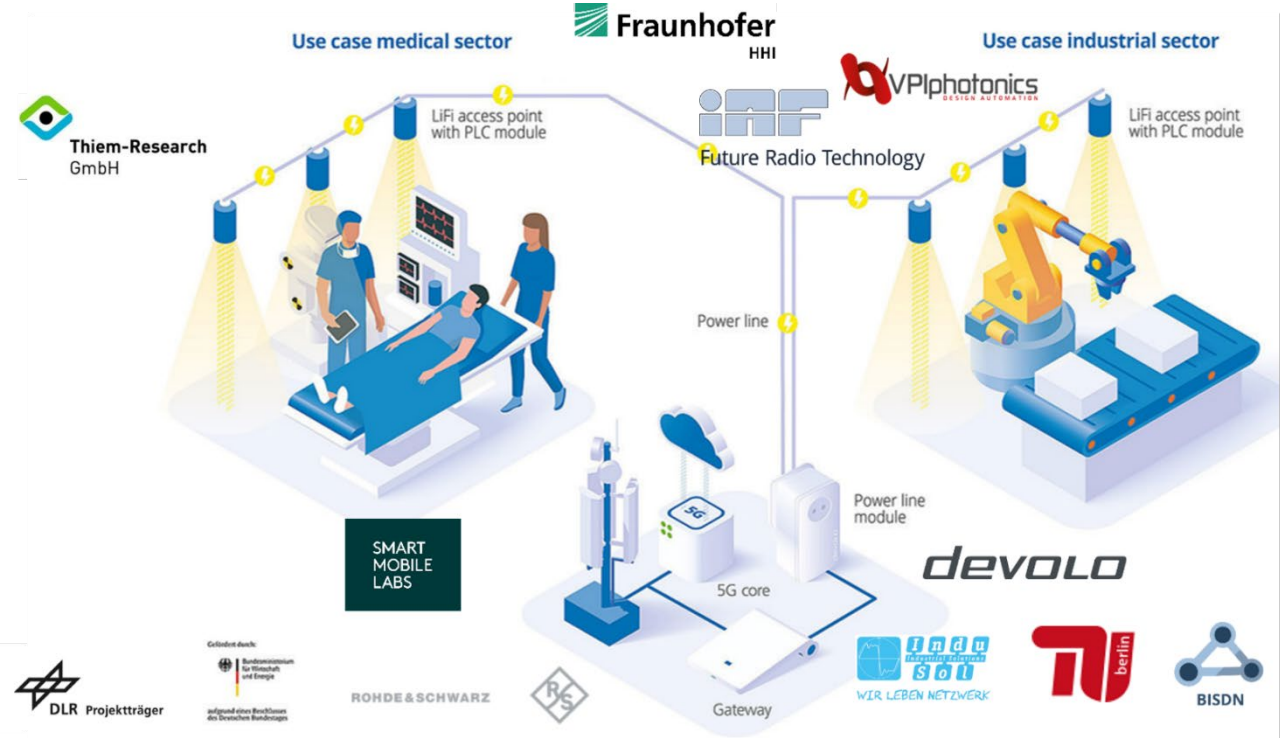
- coexistence between different radio access technologies
- coordination of multiple access points
- use of higher frequency bands: mm-wave/LiFi

Integrate LAN+WLAN into 5G/6G network

- in-building network as non-3GPP RAN in 5G/6G core: from N3IWF to trusted non-3GPP access

LincNet project (BMWK, 2022-2025)

Focus on PLC and LiFi



VOLKSWAGEN AKTIENGESELLSCHAFT

SIEMENS

MHP A PORSCHE COMPANY

DB Systel GmbH

Weidmüller

LincNet project (BMWK, 2022-2025)

Focus on PLC and LiFi

VOLKSWAGEN AKTIENGESELLSCHAFT

SIEMENS

MHP A PORSCHE COMPANY

DB Systel GmbH

Weidmüller

Analog forwarding

Concatenate PLC and LiFi channels

LiFi can have multiple APs per room

- cabling increases cost (dominates TCO)
- PLC as backbone for LiFi: up to 2 Gbit/s with 2x2 MIMO

Multiple possible solutions for PLC+LiFi

- decode-and-forward, amplify-and-forward (analog forwarding)
- cost-effective solution: **Single PHY/MAC for PLC+LiFi channel**
  - channel access and scheduling are realized by the PLC gateway
  - current technologies match available BWs: 80 MHz for PLC/LEDs

Connect multiple LiFi APs via the same PLC network

- use dual diversity in optical and PLC channels to improve performance

Sources: devolo, HHI, TU Berlin

Analog forwarding

Concatenate PLC and LiFi channels

LiFi can have multiple APs per room

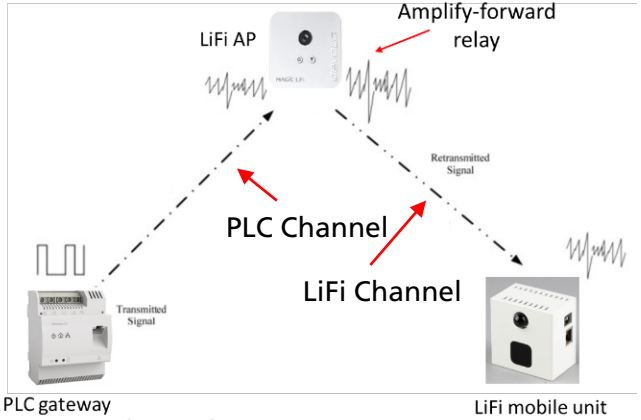
- cabling increases cost (dominates TCO)
- PLC as backbone for LiFi: up to 2 Gbit/s with 2x2 MIMO

Multiple possible solutions for PLC+LiFi

- decode-and-forward, amplify-and-forward (analog forwarding)
- cost-effective solution: **Single PHY/MAC for PLC+LiFi channel**
  - channel access and scheduling are realized by the PLC gateway
  - current technologies match available BWs: 80 MHz for PLC/LEDs

Connect multiple LiFi APs via the same PLC network

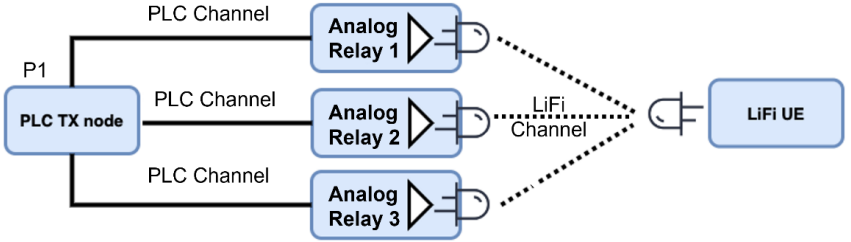
- use dual diversity in optical and PLC channels to improve performance



Sources: devolo, HHI, TU Berlin

Analog forwarding

Concatenate PLC and LiFi channels

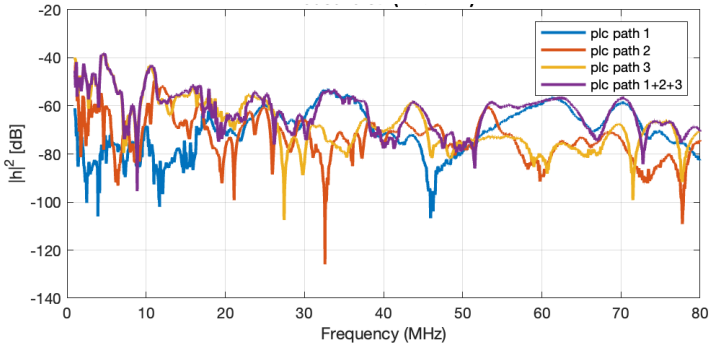


LiFi can have multiple APs per room

- cabling increases cost (dominates TCO)
- PLC as backbone for LiFi: up to 2 Gbit/s with 2x2 MIMO

Multiple possible solutions for PLC+LiFi

- decode-and-forward, amplify-and-forward (analog forwarding)
- cost-effective solution: **Single PHY/MAC for PLC+LiFi channel**
  - channel access and scheduling are realized by the PLC gateway
  - current technologies match available BWs: 80 MHz for PLC/LEDs



Connect multiple LiFi APs via the same PLC network

- use dual diversity in optical and PLC channels to improve performance

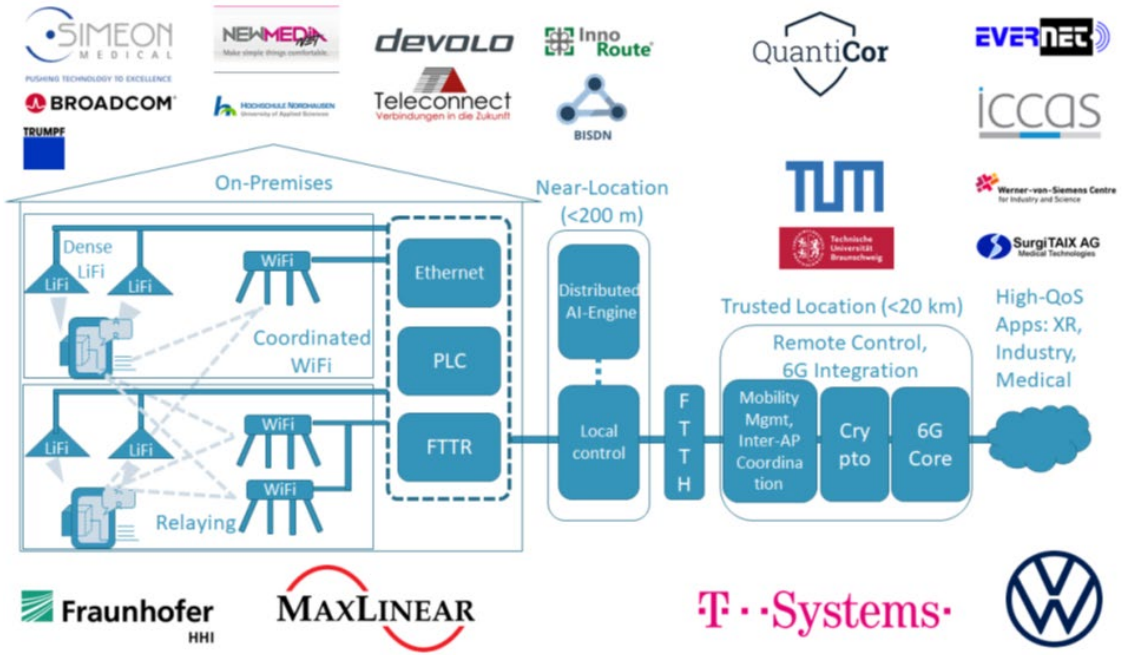
Sources: devolo, HHI, TU Berlin

5G-COMPASS project (BMDV, 2023-2024)

Integration and PoCs

Bundesministerium für Digitales und Verkehr

INNOVANT INNOVATIVE NETZTECHNOLOGIEN



Covering all network layers

- **FttH/FttR:** BISDN, Maxlinear, Fraunhofer HHI, devolo, InnoRoute (UA)
- **PLC:** devolo, Teleconnect
- **Wi-Fi:** Maxlinear, devolo, Fraunhofer HHI, TU Braunschweig, NewMediaNet, HS Nordhausen
- **LiFi:** Fraunhofer HHI, Maxlinear, devolo, Teleconnect, Trumpf (UA), Broadcom (UA)
- **Security:** T-Systems, Quanticor, TUM
- **Applications**
  - Medical: ICAAS, KLSMartin, SurgiTaix
  - Industry: Werner-von-Siemens-Centre
  - SOHO: EverNet, Fraunhofer HHI

Focus on integration and demonstration at higher TRL

5G-COMPASS project (BMDV, 2023-2024)

Integration and PoCs

Bundesministerium für Digitales und Verkehr

INNOVANT INNOVATIVE NETZTECHNOLOGIEN

Covering all network layers

- **FttH/FttR:** BISDN, Maxlinear, Fraunhofer HHI, devolo, InnoRoute (UA)

ct

o, Fraunhofer HHI, MediaNet, HS

axlinear, devolo, A), Broadcom (UA)

uanticor, TUM

SMartin, SurgiTaix

n-Siemens-Centre

- SOHO: EverNet, Fraunhofer HHI

Focus on integration and demonstration at higher TRL

Next generation LiFi

VCSEL- and PD-arrays for >1 GHz bandwidth

Bandwidth

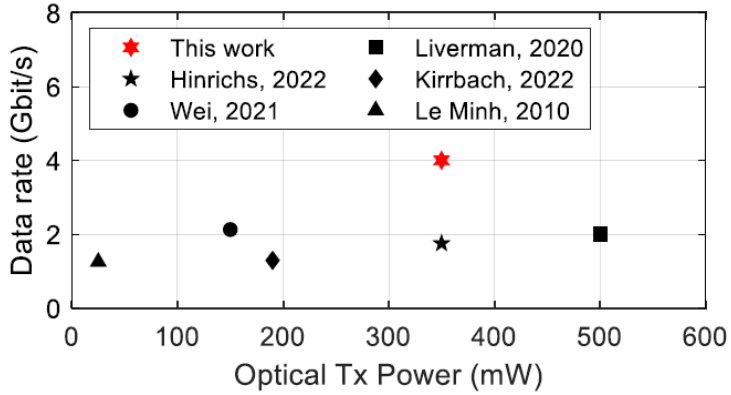
- Today: 1 Gbit/s with high-power LEDs
- Future: 10 Gbit/s with VCSEL-arrays (developed for LIDAR)

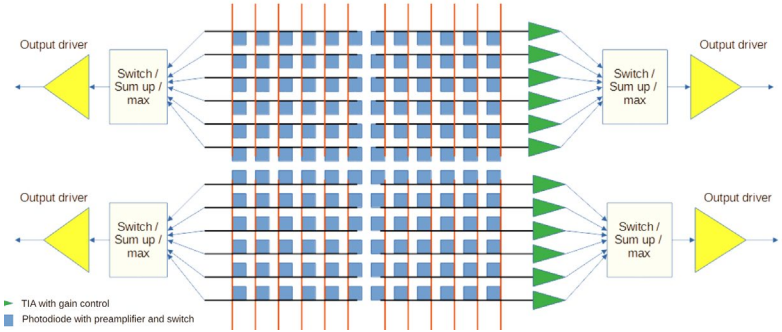
Fast PDs have small area: keep wide FOV

- Today: Large-area photodiodes for non-aligned indoor links
- Future: Arrays of small photodiodes with switching matrix

Rx alignment is realized by switching

- Select-and-combine the best photodiodes on the array
- Chip is designed, tape-out soon, > 1 GHz BW, same FOV



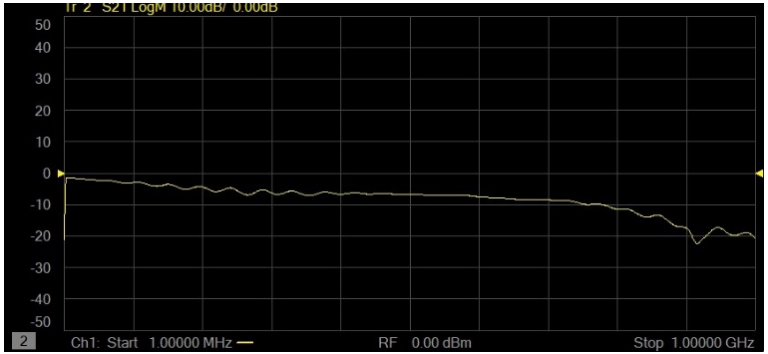


OWIN6G project (EU MSCA, 2023-2027)

Next generation PLC+LiFi

FttR deployment is costly

- alternatives: Coax in the U.S., DSL/PLC in Europe
- next-gen. LiFi has 10-20x higher bandwidth



Next generation PLC

- wider bandwidth is available: noise and sharing are tbd.
- more MIMO: handle every room as a separate PLC domain

Analog forwarding maybe interesting for FttR, too

- keep simplicity and low cost but increase bandwidth: FttR is ideal backbone for LiFi
- However, LiFi is mobile : 20-40 dB gain variations → previous research using LiFi over POF (HHI, TU/E, Signify)

OWIN6G project (EU MSCA, 2023-2027)

Next generation backbone for LiFi

FttR deploy

- alternative
- next-gen.

Next gener

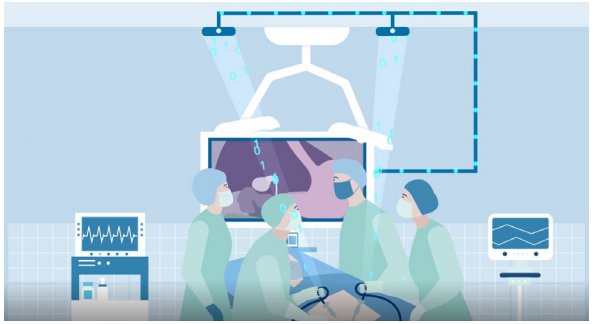
- wider ban
- more MIM

Analog for

- keep simplicity and low cost but increase bandwidth: FttR channel is ideal
- However, LiFi is mobile : 20-40 dB gain variations → previous research using LiFi over POF (HHI, TU Eindhoven)

Conclusions

Backbone technologies for LiFi in industrial and medical applications

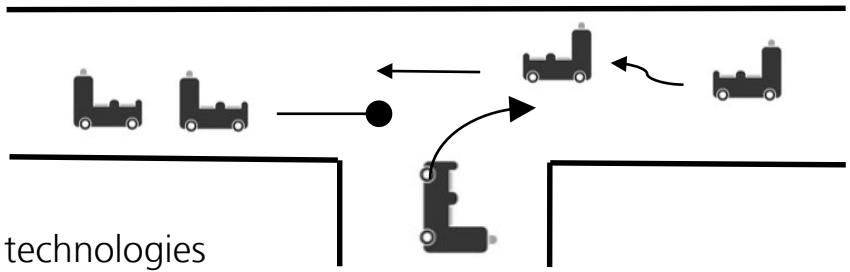


Analysis of current in-building technologies

- limited QoS due to random access in Wi-Fi is a major issue

Future network concept to complement 5G/6G inside buildings

- use FttH+FttR besides copper for higher bandwidth
- use LiFi and mm-wave besides sub-7GHz Wi-Fi



Next-generation backbone technologies

- mature analog forwarding concept for existing PLC+LiFi technologies
- wider bandwidth for LiFi is likely to create the need for more bandwidth in the backbone
- next generation PLC+LiFi, consider analog forwarding also for FttR+LiFi

Sources: ICAAS, WvSC

Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI

WE PUT SCIENCE INTO ACTION.

Contact:

Prof. Dr. Volker Jungnickel
volker.jungnickel@hhi.fraunhofer.de
+49 (0)30 31002 - 768

Einsteinufer 37
10587 Berlin

www.hhi.fraunhofer.de

Fraunhofer HHI