

Optical 6G Cell Free Networks for High Performance Communications and Sensing in Industry 4.0

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Abstract—This paper presents a Photonic near infrared IR Cell Free 5G Network, which provides universal broadband coverage for (1) Smart Transportation Vehicles and (2) Material Handling by Collaborating Mobile robots (3) Motion Control use cases with their required Key Performance and Key Value Indicators in industrial factory buildings from pervasively located optical wireless communications OWC access points.

Keywords—5G Network, Industry 4.0 Communication System; Cell Free Network; IR Optical Wireless Communications; Localisation.

I. INTRODUCTION

Private 5G/6G and enterprise Wi-Fi provide high speeds and device density for Industry 4.0 (I4.0). They have similar costs but suit different use cases, often complementing each other in I4.0 factories without interference [Tea22]. 5G/6G non-public network (NPN) is favored for its security, guaranteed throughput, low latency, and high location accuracy. This new solution offers reliable broadband communication without interference, licensing, or Mobile Network Operators (MNO) permission.

The OPTI-6G project develops a 5G broadband optical wireless communications (OWC) vertical-cavity surface-emitting lasers (VCSELs) phase array solution that operates in near Infrared (IR) 1550nm wavelength which does not suffer from interference because of the propagation characteristics of electromagnetic (EM) waves in this part of the spectrum whilst minimizing interference and harmful EM exposure and provides universal broadband coverage within buildings from a cell free network of OWC access points that are pervasively located within buildings.

This broadband system will provide 1 Gbps data rates up to 5 m over a field of emission of 25° or 3 Gbps with an angle of 15° up to 5 m and pave the way towards a beamsteered OWC system, which will ultimately produce much wider access angles.

Localisation is essential for enabling the Communications-Computing continuum in I4.0 since important use cases such as automated guided vehicles (AGV) Navigation requires it for industrial automation. Therefore, OPTI-6G system will be supplemented with a sub cm location measurement and sensing solution, whose accuracy has already been proven at 3.5 GHz. The performance of near IR OWC solution will be compared with the alternative 3.5 GHz 5G radio solution.

Cell free near IR networks can be configured to implement multi-connectivity with cell free network thereby improving link quality and reliability, whilst obviating the need for

building owners to subdivide their non-public mobile building network into cellular areas, and obviating the need for building owners to request permission from MNOs to use their licensed spectrum since the system operates at the optical unlicensed bands and its AI Based Distributed Scheduler manages any interference between inside and outside access.

The OPTI-6G project provides a solution by developing a safer, more secure, customizable and intelligent building network that reliably delivers increased throughput (up to 3Gbps) from access points pervasively located within buildings, whilst minimizing interference and harmful EM exposure and providing location accuracy of less than 10 cm [COS23]. It thereby shows how to solve the problem of broadband wireless access in buildings and provides a solution to promote the decarbonisation of Europe through innovative communications technology.

II. MANUFACTURING VERTICAL

The European Unions's (EU) manufacturing sector employs close to 30 million people in 2.1 million enterprises and accounts for almost 20% of the total GDP. The challenge for the sector is to work towards the full digitization of manufacturing to promote energy efficient automation and foster sustainable manufacturing. The mix of autonomous applications for I4.0 ranges from Process Automation, Mobile Robots and Motion Control. 3GPP has identified use cases where communication between different AGVs and industrial controllers in large machines is required [Art21], [3GP20], [3GP21].

A. Smart Transportation Vehicles

5G ACIA has identified Mobile robots/AGVs Use Case where mobile robots and AGVs represent mobile systems on a shop floor [ACI20]. In Factory of the Future, AGVs play an important role and take care of such tasks like driverless and autonomous transport of material and goods from and to production lines. They also can carry robot equipment (e.g., a robot or gripper arm) to flexibly support the assembly process. In this use case, we focus on two important features of AGVs:

- Video processing offloading from an AGV camera to the neighbour edge computing node (see Fig. 1) with high requirements on data rate (>500 Mbps),
- Localization of an AGV in different scenarios with high requirements on accuracy for the localization (< 1cm).

These functions require a wireless communication network for data transfer and localization purposes to be processed in a local or remote data centre. The localisation of

an AGV using time of arrival (ToA) and Angle of Arrival (AoA) from one or more 6G NodeB (NB) AP to identify position and a high definition (HD) camera observing the AGV environment to avoid collision with moving objects is an example of a Mobile AGV application in industry, as shown in Fig. 1.

An AGV fleet provides intra-logistic transportation and traversing in the factory. An AGV can also be part of an assembly process by picking and placing parts using a gripper arm with sensors mounted on the AGV.

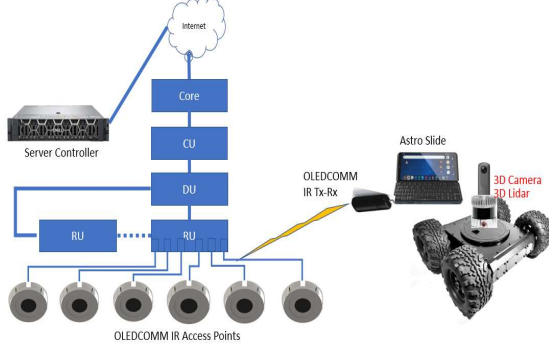


Fig. 1. AGV Navigation - Localisation and Video Processing Offloading for Collision Avoidance

Wireless high-quality video cameras and co-located light detection and ranging (LIDAR) are easily deployed on mobile platforms like AGVs. The video from these cameras can be used to send high-quality and high frame rate video to an image analysing system located at the “factory edge”. By this, a new level of production monitoring is unleashed enabling a long list of new features such as accurate object detection and tracking around AGVs, anomaly detection on the shop floor, improved safety, process tracking and logging, etc. This use case has high requirements on the data rate consuming up to 3 Gbps per camera in case of state-of-the-art industrial three-dimensional (3D) camera systems (130 uncompressed HD frames per second: $130 \times 1280 \times 720 \times 24 = 2.8$ Gbps). In this project, however, we consider lower data rate of up to 600 Mbps for only 30 frames per second ($30 \times 1280 \times 720 \times 24 = 632$ Mbps). Since the compression is very time-consuming process, we consider an uncompressed video stream. A 128 channel Ouster OS1 LIDAR bit rate can be as high as 254.3 Mbps.

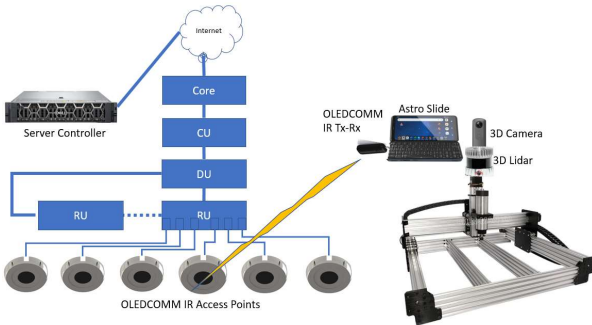


Fig. 2. Voice Controlled Ooznest Flatbed Plotter

Whilst the AGVs are being built, an already constructed and operational voice controlled Ooznest 3D flatbed plotter with a co-located Ouster OS1 LIDAR and a Ricoh Theta V XYZ 3D Camera is used as a mobile platform whose moving head can be positioned with millimeter accuracy, as shown in Fig. 2.

B. Material Handling by Collaborating Mobile robots

5G ACIA identified use cases for mobile robots in material handling at warehouses and production plants [ACI20]. In the Factory of the Future, picking robots retrieve items from storage and deliver them to destinations like packing stations. At production plants, mobile robots move products between production steps.

The interaction between a robot actuator and parts on a conveyor belt observed from HD cameras is an example of material handling by robots use case which will be considered in the OPTI-6G project, as shown in Fig. 3. In this use case, we focus on two important features:

- Video processing offloading from a robot and conveyor belt cameras to the neighbour edge computing node (see Fig. 3) with high requirements on data rate (>500 Mbps),
- Coordination of two collaborating autonomous systems i.e., robot and conveyor belt from the edge.

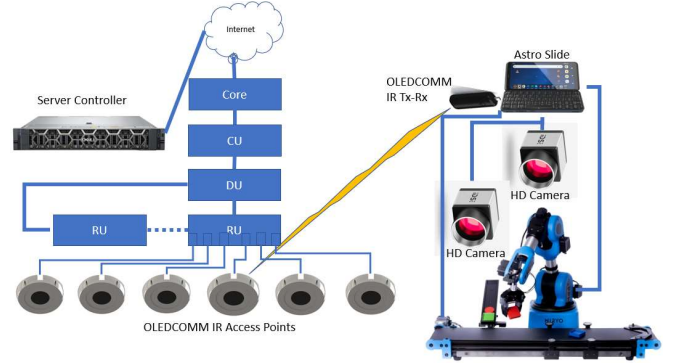


Fig. 3. Niryo Ned 2, a 6-axis robotic arm and Conveyor belt

C. Motion Control - Offloading of the PLC Control Function to the Edge

Factory of the Future requires very high level of flexibility of the involved software and hardware components. For this, “soft” controllers running in a virtualized environment are going to replace solid and fixed machine controllers like programmable logic controllers (PLC). The communication networks between “soft” controllers and machine components get an important role in realization of the new control methods.

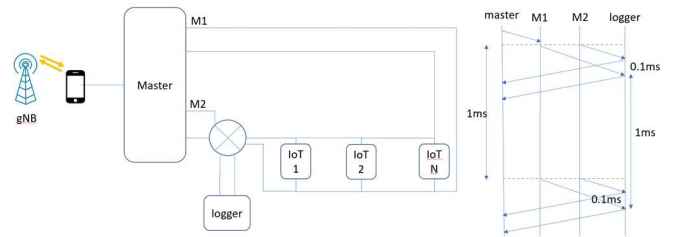


Fig. 4. “hard” industrial controller

A “soft” industrial controller is an evolution from a “hard” industrial controller, which is shown in Fig. 4, consists of a Master controller and a doubly wired Ethernet loop connected to industrial IoT devices. The Master controller generates two Ethernet packets every 1ms, which are transmitted around the doubly wired Ethernet loop in opposite directions.

The Probability Distribution of the Interarrival times of Ethernet packets measured at the logger is shown in Fig. 5. It

shows that the Ethernet packs interarrival times are 0.1 ms and 0.9ms as also illustrated in Fig. 5.

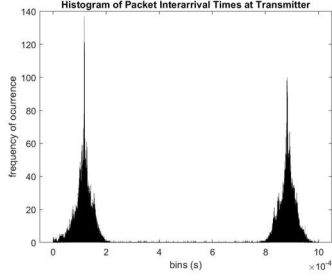


Fig. 5. Probability Distribution of the Interarrival times measured at the logger of Ethernet packets

Offloading of the PLC control function to a neighbour data centre such as Multiaccess Edge Computer (MEC) servers provides a lot of benefits for controlling the production process in a most flexible way. Such “soft” controllers can run as containers or virtual machines on a classical IT infrastructure. The communication between these “soft” controllers and the machine components requires high quality of service (QoS) provisioning. To enable the ease of product line modification, the communication should include wireless segments.

A “soft” industrial controller consists of Master Controller located at Multiaccess Edge Computer (MEC) servers, as shown in Fig. 6. This requires latency to be small and minimally variable.

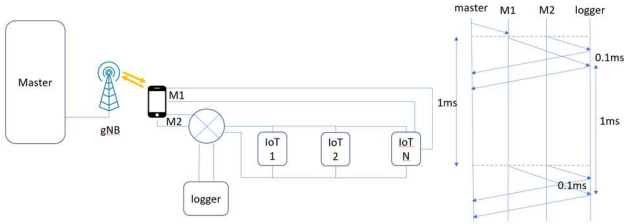


Fig. 6. “soft” industrial controller

A more centralized approach, where all controllers (real or virtualized) are placed in the same area significantly increases the flexibility of the production process by introducing the possibility of seamless function update and reduce the cost for example to control the stepper motor of an inverted pendulum controller (see Fig. 7). Connecting the production cells through the OPTI-6G communication system to the “factory edge” shall enable the ease of reconfiguration of hardware and software components on demand. This use case sets very high expectations on the guaranteed latency and deterministic communication that should support low industrial application cycle times and very precise synchronicity.

With this use case, we want to analyse the requirements on the transmission latency and jitter with respect to the current state of the art in communication between PLCs and machine components.

The current production machines do not allow wireless communication networks to be part of the control loop, because current wireless network technologies do not support very low latency and jitter required in bus systems. The majority of the PLCs in production support cycle times below 1 ms and expect jitter in data transmission as low as 100 ns or lower, as shown in Fig. 6. Within a single cycle time, data

exchange among hundreds of machine components. However, cabling is one of the most popular pain points in the production and costs a lot of effort.

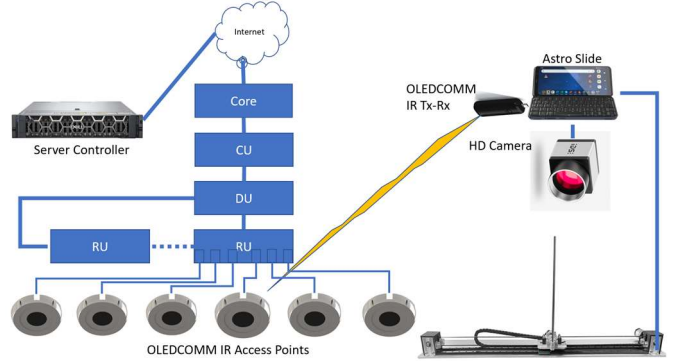


Fig. 7. Programmable Logic Controller - Remote Control Function

III. TECHNOLOGY MIX OF INTEREST

A. Optical Wireless Communications (OWC)

From an industrial point of view, it was not until the end of the 2010s that the first light fidelity (LiFi) standards were actually published and implemented into commercialized products. The ITU-T G.9991 recommendations, published from 2019 by the ITU [ITU19], are now the basis of a majority of LiFi products put on the market, whereas the IEEE 802.11bb task group is currently developing a WiFi-based LiFi standard that should open new markets. At the same time, industrials are working on the miniaturization of the electronic components, and in particular, of the optical antennas, in order to reduce their size and cost while increasing their performance, which would then facilitate their integration in consumer equipment (e.g., smart phone, tablets etc.).

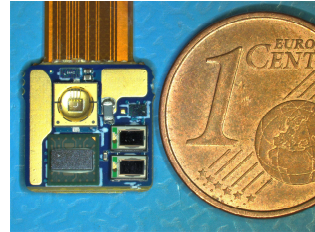


Fig. 8. Current optical antenna in cell-based LiFi systems

Fig. 8 shows for example an optical antenna developed by Oledcomm, embedding a VCSEL infrared source and high-speed PIN photodiodes receivers and that supports 1 Gbps data rates up to 5 m over a field of emission of 25° or 3 Gbps with an angle of 15° up to 5 m.

LiFi is therefore an already existing reality, both at the academic and industrial levels. Nevertheless, for the large-scale use of LiFi to be correlated with the deployment of 6G networks, many challenges remain to be solved. In particular, most of the current LiFi products and academic demonstrators rely on the concept of cells, generated by multiple APs installed at regular intervals on the ceiling to ensure complete coverage of the room and thus continuous connectivity for the user. Such a topology then requires conventional interference management and handover mechanisms to ensure that all user equipment (UE) is continuously connected to the network. Although functional, this cell-based topology has several limitations, similar to that experienced in the radio frequency (RF) world. First, it is preferable to have cells large enough to

avoid too frequent handovers, which would reduce the time dedicated to traffic transmission in favour of signalling transmissions. At the same time, it is difficult to provide coverage of more than a few square meters with a conventional light source. The signal-to-noise ratio (SNR), and therefore the QoS, degrades rapidly as the receiver moves away from the transmitter's transmission axis, and is therefore generally relatively low at the edge of the cell. In addition, each change of cell results in a short loss of connection, which contributes to further degradation of QoS.

To overcome these problems, cell-free LiFi topologies have been theoretically proved to be a promising solution [ALSatai23].

Therefore, an OWC cell-free topology for LiFi applications could be realized by developing compact, fast and wide range optical antennas. Such a light source would thus ensure a high SNR link that would be hard to eavesdrop for an attacker who would not be in the line of sight and would thus be more secure than in the usual cell-based topology. A UE could in turn be served by several APs simultaneously, thus making its connection more robust to obstacles. Each AP could also provide several parallel links through wavelength division multiplexing (WDM) to support multiple input multiple output (MIMO) modes of operation and thus provide an even greater QoS. The resulting LiFi network could operate alongside RF networks by using similar, if not the same, physical layer (PHY) and medium access control (MAC) layers, generated by a unique remote unit (RU). At the same time, the combination of several Active Optical Units (AOUs) will enable trilateration methods to be used, which will be of great interest to implement optical localization and orientation methods. Therefore, the proposed network topology would be in line with the overall 6G requirements, as it would be very flexible to adapt to the dynamic user environment and yet provide high QoS and secure service while ensuring sensing at the same time.

B. Cell Free Network Architecture

1. Cell Free networks in 3GPP

Cell Free network comprises a plurality of distributed APs which simultaneously serve a smaller number of users over the same time/frequency resources based on directly measured channel characteristics. All APs are randomly located in a large area. Furthermore, all APs connect to a central processing unit via a backhaul network, see Fig. 9. All APs simultaneously serve all user equipment using the same time-frequency resource. The APs acquire channel state information through time-division duplex operation and the reception of uplink pilot signals transmitted by the users. The APs perform multiplexing/de-multiplexing through conjugate links on the downlink and matched filtering on the uplink. Closed-form expressions for individual user uplink and downlink throughputs lead to max-min power control algorithms. Max-min power control ensures uniformly good service throughout the area of coverage. A pilot assignment algorithm helps in mitigating the effects of pilots contamination, but power control is far more important in that regard. Cell-Free has considerably improved performance with respect to a conventional small-cell scheme, whereby each user is served by a dedicated AP, in terms of both 95%-likely per-user throughput and immunity to shadow fading spatial correlation. Under uncorrelated shadow fading conditions, the cell-free scheme provides nearly 5-fold improvement in 95%-likelihood per-user throughput over the

conventional small-cell scheme, and 10-fold improvement when shadow fading is correlated [NAY17].

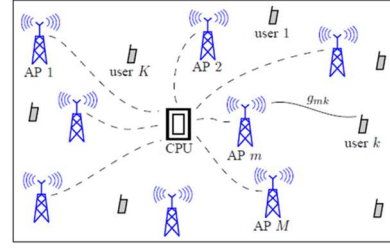


Fig. 9. Cell Free Network Architecture

Despite the clear theoretical advantages that Cell Free systems show in simulations to substantially outperform small-cell systems in terms of throughput and robustness to shadow fading correlation, the reality shows that presently there are no reported commercial deployments of Cell Free networks for the following reasons:

- Implementation complexity related to the need to synchronously combine the signal from the UEs received by multiple APs;
- Implementation complexity due to the need for a Central Network Scheduler to manage packets in the Time-Frequency and Spatial domains, as multiple APs synchronously transmit and receive with single UEs in their coverage area;
- Cell Free Networks require a higher front-haul bandwidth compared to regular cellular networks that connect each UE to a single AP;

The standardization process of Cell free networks is still ongoing in the recent 3GPP releases (Release 18 and 19).

2. Application of Cell Free Networks in OWC

Overall architecture access ITU G.9991 provides access for up to 6 antennas. Although OWC networks are inherently cell-free within this cluster of 6 OWC photonic antennas controlled by a single OWC access point to typically support a 4x5 meters coverage area, handover is required between clusters of 6 OWC photonic antennas controlled by different OWC access points, see Fig. 10.

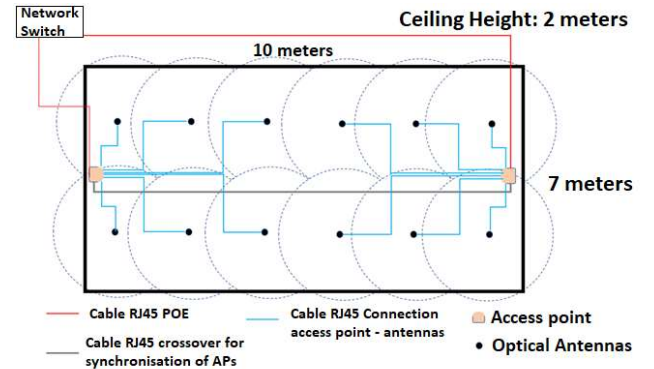


Fig. 10. OWC Network with 2 access points

Clearly this poses a challenge for a large factory such as Bosch's I4.0 factory in Feuerbach (The Bosch plant in Feuerbach – where tradition meets high-tech - Bosch Media Service (bosch-presse.de)) with a floor space area of 109,100m² since not only would require 5455 OWC access

point clusters, but also the mobility of user equipment within the coverage area would incur excessive number of handovers and signalling.

So, the first motivation is to design a cell-free network where handover between AP clusters are no longer needed for mobile users. This paves the way towards a beamsteered OWC system, which will ultimately produce much wider access angles, which would subsequently require much fewer OWC APs. Increasing the radius by a factor of 4 with a field of emission angle of 70° , which provides a coverage area from one access point of $16 \times 20 \text{ m} = 320 \text{ m}^2$ which would require 340 OWC AP clusters for a factory with a floor space area of $109,100 \text{ m}^2$. This is much more commercially viable.

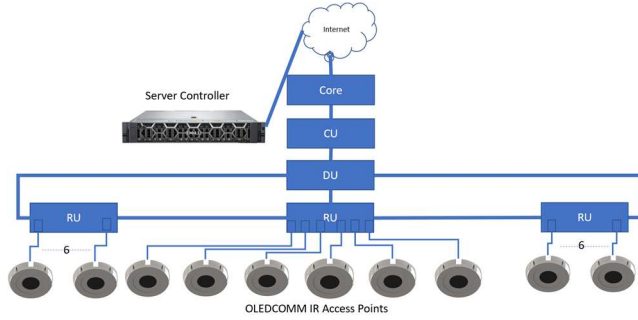


Fig. 11. Runel 6G Network

The Runel 5G Network distributed unit (DU) supports up to three RUs which for usual mobile radio use provides access to four horizontally and vertically polarised antennas or up to eight optical antennas Fig. 11.

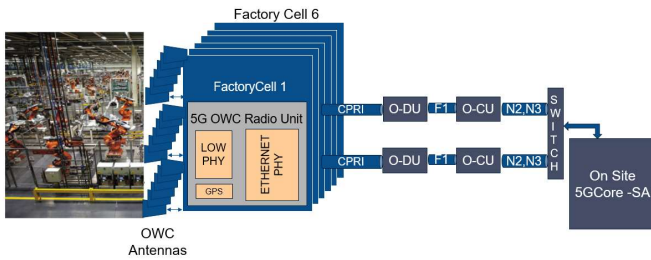


Fig. 12. 5G Private Network with Optical Air Interface

Extending the network in and I4.0 factory involves adding more centralised unit (CU) and DU to the Core as shown in Fig. 12.

IV. 5G RAN ARCHITECTURE

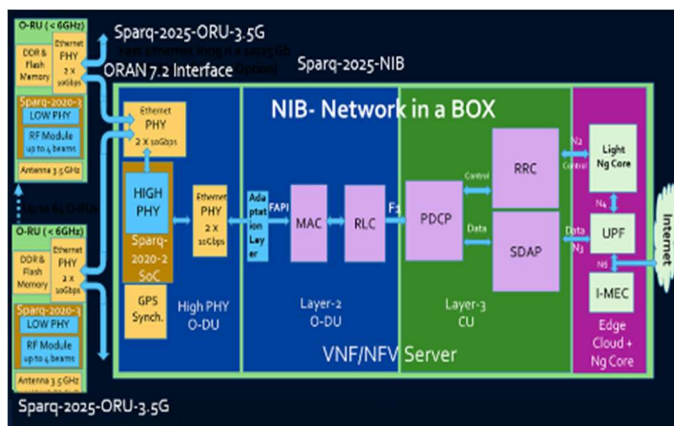


Fig. 13. 5G RAN Architecture

The current state of the art for 5G Private Network architecture is described in Fig. 13. The system is based on two types of modules, the NIB (Network In a Box) that includes the next generation (Ng) Core the CU and the DU units in one server that is connected through Ethernet over fibre or wireless front-haul to a set of beamforming-capable RUs that wirelessly connect via four dual polarized beams with commercial 5G end devices such as smart phones or any other termination devices. The network achieves a 2 Gbps (0.5 Gbps/beam) aggregate data rate per 100 MHz channel in each RU.

The basic architecture includes a 5G radio access network (RAN) PHY Split (Open RAN ORAN Option 7.2) that enables maximum virtualisation of the base station functions creating a local edge cloud that facilitates the advantages of centralized computing and keeps the fronthaul connection with the edge using limited data overhead and delay (microseconds). The split point protects the data that runs over the fronthaul by taking advantage of the 5G powerful Low Density Parity Check (LDPC) embedded Forward Error Correction (FEC). The beamforming antenna weights are calculated and optimized in the DU unit but activate the precoding matrix in the RU units along with the (Inverse) Fast Fourier Transforms (FFT/IFFTs) demodulators and modulators, and the radio front end. In addition, each RU includes a high performance 64 (8x4x2) active hybrid digital/analogue weighted beam forming antenna at 3.5GHz (n78 time division duplex frequency range 1 (TDD FR1) 5G NR band) with 4 dual polarized streams, with low side-lobes and with high antenna gain.

The Opti-6G project team plans substantial progress beyond the current state-of-the-art of Cell-Free Networks including:

- Actual lab implementation of a Cell-Free network at a lab environment with the ability to perform and meet critical KPIs measurements such as throughput, latency, coverage, robustness, UE location accuracy, etc.
- Implementation of the Cell-Free network in near IR optical domain to demonstrate the potential use in indoor applications and services and to evaluate the advantages and disadvantages of such implementations.
- Taking advantage of the Cell-Free network architecture that simultaneously and synchronously connects the UEs to multiple APs to facilitate sub cm accurate UE location measurements.
- Upgrade the DU central scheduler in the Network in the Box (NIB) Module into a disruptive Artificial Intelligence (AI) based cell-free scheduler, responsible of user-centric cluster formation and dynamic optimal packet scheduling in the presence of user mobility, and implementing multi-connectivity using near IR multipoint transmissions. The new cell-free scheduler will centrally control the RUs that will simultaneously communicate with the end devices in the coverage area over the proposed Photonic air interface.

V. LOCALISATION AND ORIENTATION

A. in OWC bands

The main technique of localization with OWC is mainly the use of the received signal strength (RSS), the TOA or time or phase difference of arrival (TDoA/PDoA) and the AOA to extract position information, either by trilateration or by triangulation [ZHY18]. The RSS method is the most popular and algorithms coupled with Kalman filters have been proposed to improve the positioning resolution and responsiveness to motion [ZWZ20]. Furthermore, precise round trip (RT) TOA measurements are possible, which are based on several APs and can be implemented using existing fields in the physical layer preamble [KKM21], together with fine timing measurement (FTM) available in the MAC layer of IEEE Std. 802.11 (Wi-Fi).

However, most of these works are based on simulations or experiments in simple or size limited environments [ZHY18], [THA22]. Only few of them address 3D positioning or information about orientation of the receiver with experimental part in large environment. Inclusion of the altitude parameter requires more complex equations and/or additional sensors like inertial sensors or camera [YHV14], [MCP15].

The Opti-6G project aims to achieve sub-centimetre accuracy in 3D including the information of orientation angle of the target, based on several improvements: a) develop a combined method with RSS and RT TOA, which, to our knowledge, has not been addressed yet; b) combine this first sensing approach with AOA measurements in a different approach than in the literature [THA22] and [YHV14], and based on previous work on beam steering [MCP15]. We propose to modulate the angle of emission of the source and, thus, simplify the receiver which is an important point in the case of simple embedded receivers

B. in MMW Cellular Bands

Localization of UEs using ToA from sub-6 GHz wireless and RSS from Optical Wireless Infrared techniques can be used to obtain an accuracy of less than 1 cm, however it is highly dependent on the continuous direct line of sight access between the gNB access points and the UE [ACZ22]. In the 5G-PPP 6G BRAINS project it has been shown in a laboratory experiment that 2 to 3 mm localization accuracy can be achieved using TDoA in a sub 6 GHz 5G [Orthogonal Frequency Division Multiplexing \(OFDM\)](#) Network [MKG23] [MES23].

If there is no direct line of sight access to four or more gNB access points then location ambiguity is introduced, and so other techniques can be used to maintain localization such as dead reckoning from Inertial Measurement Units (IMU) or AoA from received radio signatures. In 6G BRAINS project, it has been shown that a 2 - 3 degrees orientation accuracy can in principle be obtained in a simulation experiment using Matlab's Siteviewer 3D radio propagation model [ECS22] [CSB22].

If the received radio signatures estimate AoA from more than two access points or AoA and distance from one access point, then some form of interim measure for obtaining location can continue to be made. Distance and speed of user equipment can be estimated using Orthogonal Time Frequency Space (OTFS) modulation from one access point due to its operation in the delay and doppler domain as

opposed to using OFDM which operates in the time and frequency domain.

In the Opti-6G project, we propose to test if more accurate localization of UEs can be obtained using ToA from near IR OWC because of the greater system bandwidth that can be used to lower the levels of noise which are expected.

VI. KEY PERFORMANCE AND VALUE INDICATORS

A. Key Performance Indicators

An overview of the key performance requirements as a result of the use case analysis is presented in TABLE 1

TABLE 1: KPIs RELATED TO INDUSTRIAL USE CASES

	Offloading of the PLC Control Function to the Edge	Smart Transportation Vehicles		Material Handling
		Localization	Video Processing Offloading	
Round trip time (sensor to controller to actuator)	< 10 ms (250 μ s - 10 ms)	50 ms	50 ms	10 ms
Reliability (packet error rate within latency reqs.)	10-8	10-6	10-4	10-6
Data rate	kbit/s-Mbit/s	kbit/s-Mbit/s	Mbit/s-Gbit/s	Mbit/s-Gbit/s
Packet size	up to 1500 Byte	20-50 Byte	1500 Byte	>200 Byte
Covered distance (from an access point)	within the facility	within the facility	within the facility	<100 m
Movement speed of the user	< 1 m/s	<10 m/s	<10 m/s	< 3 m/s
Time critical handover support	Yes	Yes	Yes	No
User equipment density	0.33-3 per m ²	0.001 per m ²	0.001 per m ²	0.03-0.02 per m ²
Energy efficiency (user equipment battery lifetime)	n/a	n/a	n/a	1 day
Location detection accuracy	<50 cm	1 cm	n/a	< 1 cm
Service availability	99.999 %	99.999 %	99.999 %	99.9 %
Slice config. / re-config. time	1 s	1 s	1 s	1 s

B. Key Value Indicators

Key Values (KVs) are important to people and society and should be considered for 6G technology. Examples of societal KVs, such as Environmental, Social, and Economic, and their assessment methods are discussed in [WIK22] and considered for the OPTI-6G project. TABLE 2 provides an overview of key value requirements from the use case analysis.

TABLE 2: KVIs RELATED TO INDUSTRIAL USE CASES

Type of KVIs	KVI	Offloading of the PLC Control Function to the Edge	Smart Transportation Vehicles		Material Handling
			Localiza tion	Video Processing Offloading	
Environmental	Carbon Footprint Reduction	1%	2%		2%
	Energy Efficiency	0%	10%		20%
	Resource Consumption	5%	5%		10%
Social	Employee Safety and Well-being	100%	100%		100%
	Skills Development	AI + Programmable Control	AI + AGV		AI + Robot
	Job Creation vs. Automation Balance	50:50	50:50		50:50
	Community Engagement and Impact	High	High		Very High
Economic	Productivity Growth	100%	100%		100%
	Market Share	Disruptive technology enhancing existing solutions	Disruptive technology enhancing existing solutions		Disruptive technology enhancing existing solutions
	Cost Efficiency	20% Reduction in personal costs	90% Reduction in personal costs		90% Reduction in personal costs
	Supply Chain Resilience	50% enhanced	50% enhanced		50% enhanced

VII. CONCLUSIONS

This paper presents a photonic near IR Cell Free 5G Network, which does not suffer from interference because of propagation characteristics of EM waves in this part of spectrum and provides universal broadband coverage within buildings from pervasively located OWC access points. The solution also caters for sub cm accuracy location measurement and sensing. The next steps in the project are to build a 5G broadband optical wireless communications (OWC) to test and validate KPIs and KVIs. Future direction is to steer the OWC antennas using photonic processors.

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