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Acronyms

Acronyms	Details
3D	Three Dimension
AI	Artificial Intelligence
AR	Augmented Reality
ASIC	Application-Specific Integrated Circuit
BB	Baseband
BiCMOS	Bipolar-Complementary Metal-Oxide-Semiconductor
CMOS	Complementary Metal-Oxide-Semiconductor
EDA	Electronic Design Automation
EFECS	European Forum for Electronic Components and Systems
EG	Experts Group
eNVM	Embedded Non-Volatile Memory
EuCNC	European Conference on Networks and Communications
FDSOI	Fully Depleted Silicon-Oxide-Insulator
FPGA	Field Programmable Gate Array
GaAs	Gallium-Arsenide
GaN	Gallium-Nitride
HBT	Heterojunction Bipolar Transistor
HW	Hardware
III-V	Chemical compounds with at least one group III (IUPAC group 13) element and at least one group V element (IUPAC group 15). In the Mendeleev table: III refers to the boron group (the table columns). V refers to the nitrogen group (the table rows).
InP	Indium-Phosphide
IoT	Internet of Things
IP	Intellectual Property

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ISA	Instruction Set Architecture
LE	Large Enterprise
MAC	Multiply and Accumulate
MCU	Microcontroller Unit
ML	Machine Learning
Mmw	Millimeter Wave
MPSoC	Multiprocessor System on a Chip
MPW	Multi-project wafer
MR	Mixed Reality
NB-IoT	Narrow Band Internet of Things
NVM	Non-volatile Memory
OS	Operating System
PCM	Phase-Change Memory
RAN	Radio Access Network
ReRAM	Resistive Random-Access Memory
RF	Radio Frequency
RFSOI	Radio Frequency circuit over Silicon-Oxide-Insulator
Si	Silicon
SiGe	Silicon-Germanium
SiP	System in Package
SME	Small and Medium-sized Enterprise
SOC	System on Chip
SOI	Silicon on Insulator
SW	Software
THz	Tera-Hertz
VR	Virtual Reality
WLS	Wireless
WRC	World radiocommunication conferences

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1. Introduction

This report presents activities of COREnect expert groups (EG)s in the first year, from the Kick-off meeting. The first action was to define experts' groups in order to cover all the fields. Three expert groups were created: EG1 is dedicated to computing and the storage; EG2 covers connectivity and communication; and EG3 deals with the sensing and the power. Each EG organizes its own workshops, and defines gaps to EU sovereignty and actions to be put in place to prepare the synergy between Telecom and Microelectronics roadmaps in Europe, helping diversify and reduce European dependence on other continents in these domains over global value chains.

2. EG1 Workshops

2.1. Expert Group presentation

Figure 2.1: Distribution of experts from academia, research, large enterprises (LE) and small- and medium-sized enterprises (SME)

EG1 assembles 20 experts on computation and storage from various types of organizations as depicted in figure2.1. Its mission is to investigate what components are needed for trustworthy, yet competitive, solutions with 5G and beyond communications as first key market. The goal is to recommend what components Europe should invest in to keep checks and balances in the supply chain.

The focus is on CMOS-based systems which are programmable by software. Accelerators that are, at most, configurable or that use special process technology are out of scope of this EG. We zoom in mainly on access of intellectual property (IP) and less on access to leading edge process.

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2.2. Description of WS and meetings since EFECS

2.2.1. EFECS Workshop

In the EG1 workshop on November 27, which was held in conjunction with EFECS, EG1 has widened its previously defined scope. The decision was to also include memory/storage, where traditional models are losing relevance, and overall system architecture, where one needs to find the right form for the specific function, instead of the other way around, as further research areas. It was also noted that for an operating system (OS) to separate trusted components, it needs support from both, the multiprocessor system on a chip (MPSoC) and the instruction set architecture (ISA). The workshop and all the subsequent meetings were moderated by the chair of EG1, Gerhard Fettweis.

2.2.2. 2021 kickoff meeting, 23rd of March 2021

The first meeting since the EFECS workshop was on 23rd of March. In the meantime, there had been an open call for new experts which lead to an enlargement of EG1 by several new experts, mainly from SMEs. The newcomers were introduced to the EG and its previous work.

This was followed by a clarifying discussion on the scope of EG1, especially on the status of accelerators. A consensus was reached those accelerators are only included if they are programmable by software.

The topic of EG1 was then divided into several subtopics, mostly as in D3.1. The key-performance indicators were omitted and process technology was added as new topic, led by some newly recruited experts. The agreed-upon topics are thus

- System architecture
- Process Technology
- ISA
- Memory and Storage
- MPSoC
- OS

To each topic, several experts were assigned according to their expertise with one expert appointed as main responsible person. Figure 2.2.2 provides an overview of the distribution of experts in each team. Each of the teams should compose a draft of a section about their respective topic until the next meeting.

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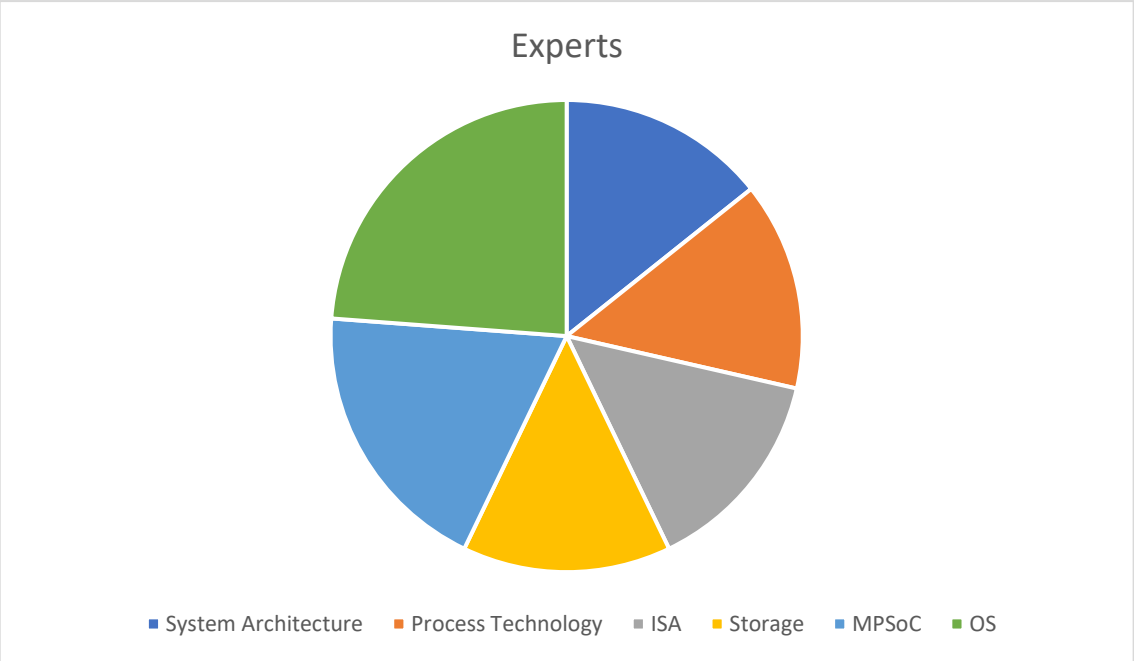

Figure 2.2: Distribution of experts on different topics. Experts could join multiple topics.

2.2.3. D3.3 meetings, 6th and 26th of May 2021

The teams presented the draft of their respective sections. The other experts provided feedback. Based on this the feedback the teams revised their draft. A shared online document was set up where the teams could insert their contributions.

The revised sections were discussed by the entire EG1 in the next meeting. Feedback from other EGs and the editor of D3.3 was also processed. The experts agreed that the sections should contain more cross-references to each other. The teams then finalized their sections which were then submitted to the main editor of D3.3 by 1st of June.

2.2.4. EuCNC workshop, 17th of June 2021

In the week after the EuCNC, EG1 had their 2nd workshop. Here, there was a very active discussion on the envisioned strategic actions that were drafted in D3.3, chapter 4. Several more political or technical strategic actions than the ones provided initially in D3.3 were proposed. Regarding the character of the listed action items, several points were agreed upon:

- They should be consistent (in terms of quantity and quality) across the different EGs
- They should have priorities assigned
- Their actionability should be considered.

The discussion on this will be continued in the second half of 2021 with a revision of the strategic actions in the intermediate and the final industry roadmaps.

2.3. EG first trends and conclusions

Several challenges and recommendations are crystallizing in the main topics of the EG:

- System architecture:
  - Tradeoff between flexibility and performance
  - The need for dynamic, real-time multi-tasking
  - Utilization of novel packaging and interconnect technologies

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- Process technology
    - Three Dimension (3D) packaging of multiple technologies as a possible way out
        - Artificial intelligence (AI) accelerators
        - High performance logic dies
        - Radio Frequency (RF) circuits
        - Memory
    - 2.5 and 3D packaging can enable energy-efficient and trustworthy solutions
    - Increase usage of specialized AI accelerators
- ISA
    - Standard ISA for infrastructure equipment
        - Leverage existing European RISC-V implementations
    - Non-standard ISA for edge devices
- Memory and Storage
    - New packaging technologies
    - (Low power) embedded non-volatile memory (eNVM) for AI
- MPSoC
    - Need for new MPSoC fabric architecture
        - Interface to the OS
        - Enable trusted hardware units
        - Isolate untrusted hardware units
        - Allow trusted transactions between units
        - Independent from the chip network
- OS
    - Recommendation: Operating System framework
        - Module, microkernel based
        - Open-source under governing entity/foundation
        - Formally verified
        - Well documented
        - Compatible
        - Allow for hierarchy and virtualization across hierarchy

3. EG2 Workshops:

3.1. Expert Group presentation

EG2 is dedicated to explore “Connect and Communicate” thematic, with two main missions:

- To support ever growing data rate and capacity demands and requirements at both infrastructure and devices sides
- Maintain and assure Europe’s leadership position.

EG2 has categorized four main connectivity areas:

- Data center infrastructure for cloud centric applications
- Wireless infrastructure
- Industrial grade connectivity
- Consumer grade connectivity

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The expert group is composed by 59 experts coming from University, Research institutes, and Industry, and they cover the connectivity areas and all the value chain, from the microelectronics material to the operators.

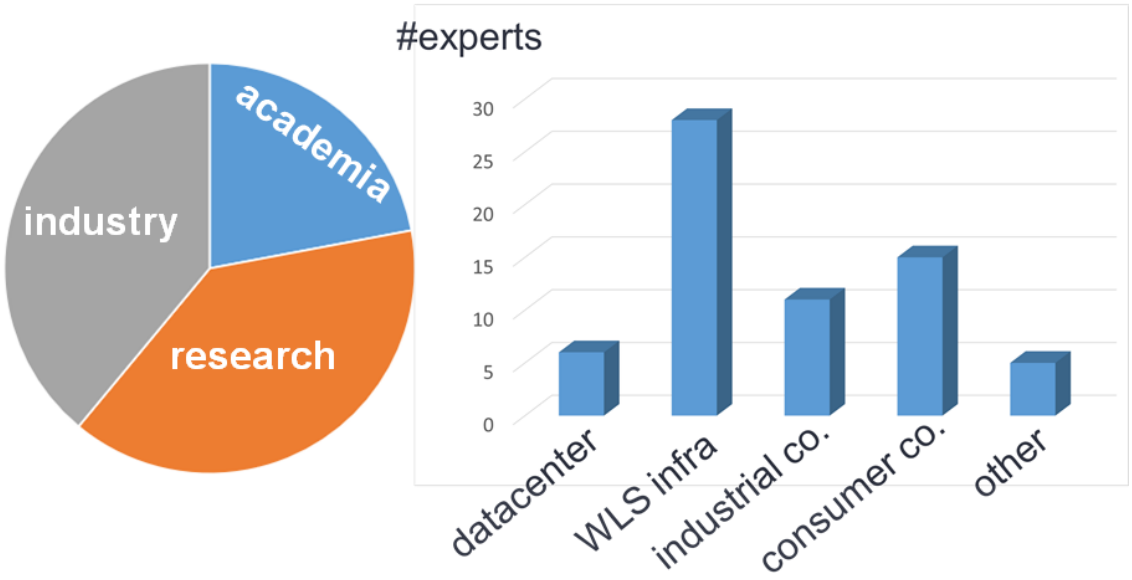

Figure 3.3: Distribution of experts from academia, research, industry and their fields

3.2. Description of Workshops and meetings since EFECS

The Expert group was firstly invited to EFECS Workshop in November 2020, and a second time on the 29th of March 2021. Finally, a third appointment coupled with EuCNC-6G summit beginning of June 2021 has been organized.

3.2.1. EFECS Workshop:

Presentation of the Key challenges for connectivity by the Chair (Piet Wambacq):

- Quest for ever increasing data rates
  - Both in wireless and wireline
- Quest for decrease of latency
  - Cyber Physical Systems for Industry 4.0, Smart mobility, Telehealth…
- Quest for computing power
  - Network virtualization, Smart Networks
- Connecting heterogeneous devices
  - Sensors, Internet of Things (IoT), other novel devices...
- Increase of power efficiency
  - Communication links, data centers, edge computing...
- AI is becoming omnipresent
  - 6G ~ AI enabled more efficient and higher-performance connectivity
- Improvement of software (SW) and hardware (HW) interoperability
  - E.g. OpenRAN, system-of-systems
- Security
  - A default requirement

We proposed four questions to be discussed:

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- Q1: What is missing to grow EU value chain coverage and how can this be realized?
    - Value chains examples:
        - Telecom; Automotive; Industrial; Computers; Health; Audio-Video; Aerospace/security/Defense; Home…
    - Coverage example in Telecom/Cellular/radio frequency (RF)/TX-RX submarket

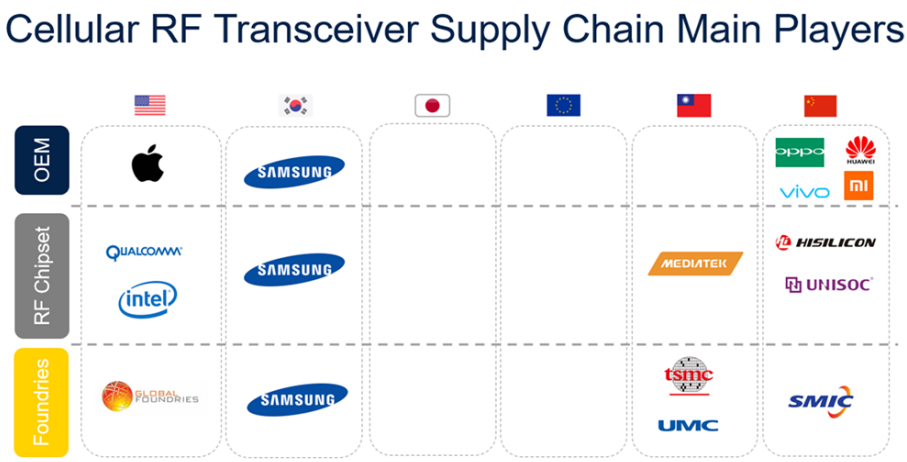

Figure 3.2: RF Transceiver chain case

- Q2: What must be EU's prime focus to strengthen its current leadership in the value chain & why? How can this be achieved?
    - As An Example, EU Foundries:
        - Europe's differentiated semiconductor technologies should be both preserved and improved upon to secure European leadership in connectivity.
        - How maintaining Eu leading edge in:
            - Semiconductors as Silicon-Germanium (SiGe) Bipolar-Complementary Metal-Oxide-Semiconductor (BiCMOS); Radio Frequency circuit over Silicon-Oxide-Insulator (RFSOI); Gallium-Nitride (GaN); Fully Depleted Silicon-Oxide-Insulator (FDSOI); Gallium-Arsenide (GaAs)/ Indium-Phosphide (InP)
            - Packaging: Advanced Package / Assembly technologies
            - Measurement capabilities at RF frequencies
            - Production testing capabilities at RF frequencies
- Q3: From a strategic sovereignty point of view, what should be EU owned and why?
    - As an Example:
        - Artificial Intelligence strategy for EU Sovereignty:
            - Big Data AI, a google like?
            - Focused applicative AI, Automotive, connectivity, security …?
            - Edge AI, smart IoT, smart sensors …?
            - Software Based / Hardware & Software?
            - Which Hardware, Which semiconductor process?
- Q4: How to keep design capabilities using technologies from non-EU foundries?
    - For example: Hardware design:
        - Trust foundries from Trust countries?

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        - How to track HW Trojan Horse?
    - For example: Software design:
        - Trust Sub-soft from Trust countries?
        - How to track malware in sub-soft?

Methodology:

The game rules were given for the answers, in a short time, (5 minutes) experts place different sticks with comment on different areas, the size of the stick presents the importance, the position left (technical) right (non-technical) represents the topic:

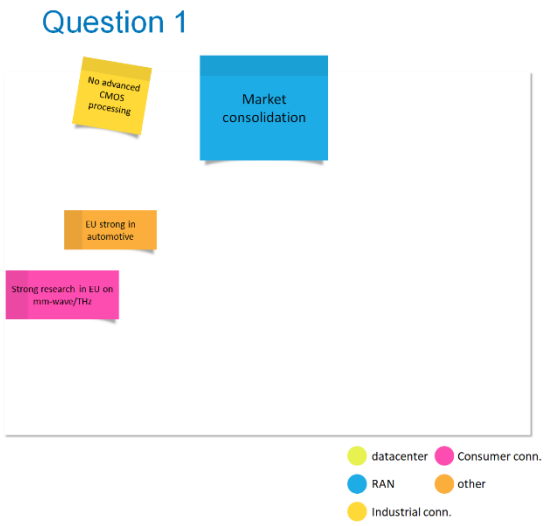

Figure 3.3: EG2 Brainstorm methodology

After exploitation of all the obtained graphs, a presentation of the early results of EG2 was done at the second Workshop on the 29th of March 2021.

3.2.2. 29th of March 2021 Workshop:

Piet Wambacq presented the feedback from the EFECS Workshop, giving the first trends of EG2 Think Tank:

What must be EU's prime focus to strengthen its current leadership in the value chain & why? How can this be achieved?

- Technical inputs:
    - Many answers about processing facilities
        - Advanced CMOS, III-V, GaN, 3D, alliances between foundries, ...
    - Strengthen position in RF component design
        - Tera-Hertz (THz): research, measurement & test capabilities, processing technologies
        - Catch up with US & China in data centers
        - Incl. opto-electronics, more investments, photonic chip factory in EU
    - Grow EU Electronic Design Automation (EDA)
    - Grow digital design capabilities
- Non-technical inputs:
    - Invest more in education and training
    - More recognition for technical careers

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- Support out-of-the-box thinking
- Don't let EU's openness be our trap
- Precautions against uncontrolled globalization
- More EC funding for hardware
- More funding for fabs and create technology hubs to host innovative solutions with fast time to market aim
- Funding for academia to design in EU fab technologies and create design IP
- Be more influential in standardization
- Harmonize standardization, frequency allocations, ...
- Help sales overseas
- Stimulate creation of vertical companies like Samsung, Huawei, Apple
- EU system providers should give priority to EU foundries (that should offer competitive technologies)
- Promote a federating 6G initiative
- Foster collaboration between companies, universities and research centers
- Political support for "made in Europe"

How to keep design capabilities using technologies from non-EU foundries?

- More Data Signal Processing skills
- Techniques to detect malicious hardware added by foundry
- Establish trusted cooperation based on mutual benefit. Foresee 2nd source, also in Times of heavy consolidation for very advanced CMOS
- have non-EU foundry company setting a site in EU
- Make EE attractive to many engineers/researchers
- Joint EU multi-project wafer (MPW)s in non-EU foundries
- Use only IP from trusted suppliers with regular audits
- Reduced EU bureaucracy

From a strategic sovereignty point of view, what should be EU owned and why?

- Ideally the whole chain but this is not realistic
- Data acquisition/processing/storage; an EU big data company
- Security technologies, both HW and SW
- Hardware developments (no backdoors)
- Quantum computing
- Fabs: a 5nm CMOS, GaN & InP, BiCMOS, 3D, photonics
- A player at the top of 6G value chain
- Leader in standardization of AI/ML hard- & software
- Invest more in systems & algorithms; AI algorithms
- Data center & wireless infrastructure for security reasons
- A future smartphone company; more fabless players

In order to illustrate this feedback, an example of EU Failure was presented, where EU funding and Researches were present and at the worldwide leading edge, and where the industrial transfer has failed.

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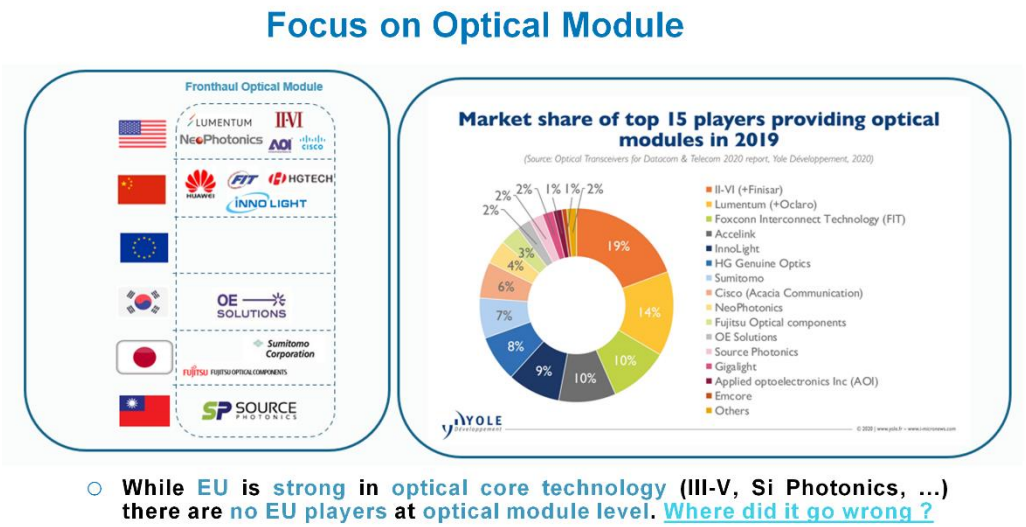

Figure 3.4: Optical Module case

To frame the discussions most proposal so far have been very technical, in order now to perform a higher-level analysis and propose a global vision/strategy some basics figures on targeted markets were recalled:

Figure 3.5: Targeted Markets

Europe is present on small to medium volume markets but has left high volume ones in wireless connectivity.

The second part of the Workshop was dedicated to a Brainstorm sequence with the Experts, in order to propose a strategic plan for short term (<3years), mid-term (4-7years) and long term (10years and more) roadmap, with a first direct feedback:

Short term (1-3y) EG2 Inputs:

- More dynamic, more aggressive ex Narrow Band Internet of Things (NB-IoT)
- 20-30GHz EU position for Cell Infrastructure?
- Sub 6GHz band deployment.
- Wireless Infrastructure is an asset.
- 2023 World radiocommunication conferences (WRC) to be influenced by EU. Countries, Major companies.
- Manufacturing semiconductor sovereignty.
- Will be an acceleration of investment from Network and operators

Mid-term (4-7y) EG2 inputs:

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- AGV: ACV autonomous and connected vehicles: 5.9GHz coexistence with cellular and wireless 802.11p/bd Research to be invested in this connectivity. Ranges 1Km to 2Km, 500m for 5GNR.
- Design of System on Chip (SoC) including accelerators baseband (BB) and RF to prepare 6G. Ecosystem in EU for SoC area. CMOS Design, for Wireless and Wireline. Some AI and AI accelerator embedded (edge or not) extending the Moore law. ASIC will be bought by Infrastructure providers. EU Design House (fabless). System in Package (SiP) if available, could be interesting too.
- RF design in mmW above 100GHz; antenna-package couple, 3D packaging for mmW. New integrated passives for mmW.

Long term (7-10y) EG2 Inputs:

- Which technologies are needed?
  - RF Technology: Up to 300GHz and more.
  - Optical and RF in a mixt technology.
  - Advanced CMOS and/or Beyond CMOS Techno.
  - Photonics integrated technology.
  - Heterogeneous technologies packaging. (Antenna's integration, III-V & Silicon)
  - Advanced PCB
- Which systems
  - Data exchanges and connectivity control by AI
  - AI for security (HW-SW)

3.2.3. EuCNC Workshop:

Piet Wambacq, the EG2 chair, have presented at EuCNC the first conclusions of EG2 after one year of work. Title of the presentation was “Future core technologies and integration”. After an overview of what could be 6G applications, the presentation highlights the limits of CMOS downscaling: it becomes more and more complex, and the cost exponentially increases with the complexity; reducing gate length doesn’t mean increasing Ft and Fmax, as the active layers are at the limit of atomic layers, and it means reducing the power output available per transistor. For this point, the limit of the exercise is somewhere around D-Band, with a lot of difficulty to provide power output. Heterogeneous integration seems to be a good alternative as exotic processes based on GaN or InP can provide Power in the same frequency range as CMOS, and high frequency operation respectively. Another alternative is the research axe on SiGe HBT processes which deliver medium power with 0.7 THz Fmax. Both alternatives, Heterogeneous integration and SiGe HBT, process and circuit design, (for wireless and Radar), are European strengths, in research for the integration, and in Research to Industry for SiGe HBT. These two axes must be reenforced, either at research level and technology transfer to industry. One objective should be to have integrated solution to achieve >>100Gbaud in a cost-effective, densely integrated and energy-efficient way against background of slowing optics and electronics:

- cost-effective and industrially scalable method to integrate the laser?
- Scalable approach needed for heterogeneous integration of electronics and optics.

Concerning industry, Europe doesn’t have a world champion in heterogeneous integration, even if European research is strong in this domain.

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Key world for research & Developments are:

- Silicon Photonics
- Heterogeneous integration with
    - InP for optics and THz
    - GaN for mmW Power
    - SiGe HBT for THz?
    - Industry in Heterogeneous Integration
- All of this with sub nm CMOS processes.

3.2.4. EG first trends and conclusions:

The EG2 workshops have exhibited needs to prepare the next decades in the following three key axes:

- European leadership and Independence
    - Strengths and Weaknesses: What are the gaps?
    - Technical & Non-Technical
- Geopolitics Evolution
    - Treats and Opportunities: How to deal with?
    - Technical & Non-Technical
- Connectivity value chains exploration
    - HW: Semiconductor, Circuits (RF; Analog; processors…), Packaging, Modules, Antennas …
    - SW: EDA, Physical-Medium-applicative layers …
    - Applications: Infrastructure; Automotive; Factory 4.0; E-Health; consumer …

With these inputs, EG2 is preparing a roadmap for the next decade in three steps:

- Short term (1-3y) => 5G implementation
    - Probably more emphasis on policies and way of working than for mid and long term
    - What is needed today for existing technologies?
- Mid-term (4-7y) => Beyond 5G
    - Evolution of existing technologies
- Long term (10y) => 6G
    - New technologies, types of company, ways of working, policies

4. EG3 Workshops

4.1. General Introduction

In addition to computing and communications core technologies, future networks require the development of supplementary core technologies that support the design of computing components (EG1) and communications components (EG2) and are essential for controlling the telecommunication and vertical value chain. During an internal meeting held in February 2021, the expert groups 2 and 3 realigned their topics and thus, decided to rename the Expert Group 3 to “Sense & Power”, which was previously named “Peripheral Technologies”. This way, a clearer distinguishment and stronger focus can be kept within each working group. The goal of

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Expert Group 3 (EG3) is to identify key challenges for innovation and sovereignty in the areas of sensing and power for future network. This will encompass the following key domains to focus upon:

- Sensor Processing in 5G and beyond
- Power Management
- Core Process Technologies
- System and Component Architectures

Overall, EG3 aims to define the overall European strengths for maintaining and developing our strongholds in the domain of sensing and power. It targets to address selected weak points that are critical yet can be realistically achieved.

The Expert Group 3 consists of 20 experts, with 11 consortium-internal experts and 9 external experts, which have been recruited from outside the consortium. Coming from University, Research institutes, and Industry, they cover a broad spectrum of the area related to power and sensing.

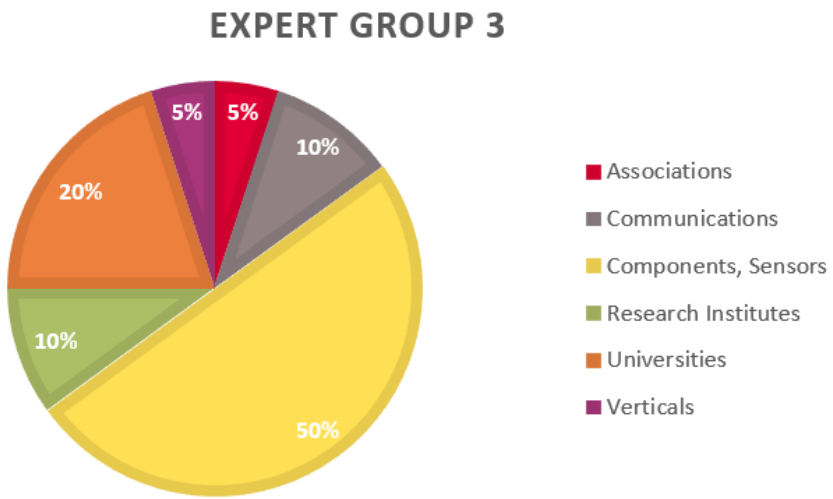

Figure 4.1: Expert Group 3 "Sense and Power" repartition.

4.2. Workshops and Meetings

The Expert group was firstly invited to EFECS Workshop in November 2020 with a parallel Expert Group Workshop on the 27th of November. In 2021, an expert group plenary meeting was held on the 29th of March and a preparation meeting regarding the upcoming Initial Roadmap (D3.3) on the 30th of April 2021. Finally, the third appointment, the 2nd expert group workshop, was coupled with EuCNC-6G summit on the 9th of June 2021.

4.2.1. EFECS Workshop:

During the EFECS Workshop, the EG3 Vice-Chair Jochen Koszescha first introduced the scope of Expert Group 3 and then defined the clusters, which will be discussed further within the upcoming work of the experts:

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- Core Process Technologies including heterogeneous integration, assembly, packaging, all with a key aspect of how to balance sovereignty and autarky.
- Manufacturing and Technology Access.
- System and component architectures including AI and ML approaches.
- Hardware and Software (co-)design and validation methods and tools from device to component and system.
- Power and Power Management for the whole infrastructure and new devices in the next generation.

Specific topics that were planned to discussed are:

- Production sovereignty – critical production issues beyond 5G/6G peripheral components
- Multi-design wafer for high volumes
- Split-foundry approach
- Technologies to focus on (CMOS, GaN, BiCMOS, RF-SOI, FD-SOI, InP/Silicon (Si), Chip2Chip)
- Edge systems & hardware accelerators
- Safety, security & reliability
- Where have control and where allow dependencies
- Out of scope focus areas

4.2.2. 1st EG Meeting Workshop, 27th of November 2020

In the following workshop, which was then held on one day after EFECS, on the 27th of November 2020, the expert group was gathered for an open brainstorming session. The goal of the session was to clarify administrative aspects, to receive input on the WP2 deliverable D2.1 “Strategy, Vision, and Requirements”, as well as to collect and align on the major research areas that COREnect is addressing as EG3 in the industry roadmap. The motivation behind the topic discussion was to define the areas in which Europe is strong and able to hold or gain leadership, but also not trying to catch up in the areas where Europe is too far behind already.

The results from the brainstorming session are demonstrated below [Figure 4.2].

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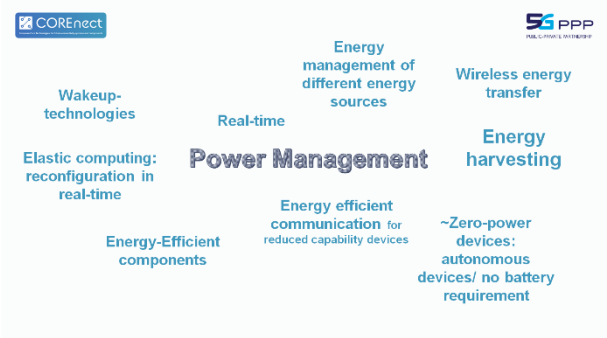

Figure 4.2: Expert Group Brainstorm results of the 1st Expert Group 3 Workshop, on the 27th of November 2020

Based on the defined main research gaps and the expertise of the experts, working groups were formed and the input collection process kicked off. Therefore, the responsibilities and each main research gap was further concretized.

4.2.3. Technical Input Meeting, 23rd of March 2021

During the Technical Input Meeting, the EG3 started to collect detailed input to each of the defined Main Research Gaps and its' subtopics.F The technical discussion was guided in a way that the experts provided state of the art of the technology, but also short-term, medium-term and long-term challenges within their argumentation. Within the discussion, many crucial insights from the experts were added and augmented, while being viewed from different angles due to the broad expert-pool of EG3. Based on those inputs, a collection in table format could be derived by the EG3 team and distributed among the experts.

4.2.4. Initial Roadmap Preparation Meeting, 30th of April 2021

For the preparation of the workshop, the Chair and Vice-Chair gathered company-internal input to the previously developed topic collection in timeline-format. Then, the pre-filled table was distributed among the experts and already partly filled with gaps and challenges. The goal of the meeting was then to discuss the already existing input and complete the timeline, where possible. Due to size and detail, a selection is demonstrated below:

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Domain	Technology	Current SotA	Target 2025	Target 2030	Beyond 2030
Sensor Processing	Low latency	>50ms for industrial and other use cases (mobile control, robots, process automation) - defined as cycle time	1 ms for Industrail use case (motion control, mobile robots) - defined as cycle time	<0.5ms for Industrial use cases (motion control) - defined as cycle time end to end	
Power Management	Heterogeneous energy sources & transfer	Several options available: use different energy sources to charge a storage element or seamless transition from source to source for immediate usage	Development of converters and algorithms for combining several power sources for mobile devices	30% of power of mobile devices coming from heterogenous sources	
Core Process Technologies	GaN	RF GaN: GaN/SiC fT=25GHZ	GaN/SiC fT=50GHz	improved III/V Epi material, fT>100GHZ	2D devices
	0.4				
	0.5				
	1.0				

Figure 4.3: Example from EG3-internal roadmap preparation material with focus topics split into different targets.

4.2.5. 2nd EG Workshop, 9th of June 2021

During the 2nd EG3 workshop, which was conducted parallel to the EuCNC conference, the previously distributed draft of the Initial Industry Roadmap (D3.3) was discussed in a Webex call. Prior to that, organizational aspects were covered and feedback regarding the working approach collected. Based on the feedback, the EG3 management team will focus on enabling a better experience in co-editing the upcoming roadmap versions. In that sense, the established Microsoft Teams platform will be further deployed.

Next, the topics, that were covered within the Initial Roadmap, were discussed in the plenary session and additional technical areas added, which will be covered in the Intermediate Industry Roadmap with state of the art, challenges and goals to be achieved within different time frames. Contributors were already assigned to the proposed topics. Receiving the D3.3 reviewers' comments, the chapters will be adjusted as needed and further developed after submission of the deliverable by the end of June, in regards to the next roadmap version. There, each chapter will be co-edited by an assigned group of experts. The discussed and adjusted topic focus areas are listed below in 3.2.6.

4.2.6. EG first trends and conclusions:

- Sensor Processing in 5G and beyond
  - System and Architecture for Sensor Processing
    - Edge, Cloud, Sensor Fusion, Privacy, Security, Reliability
  - Hardware for Sensor Processing

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        - Field Programmable Gate Arrays (FPGA)s, Application-Specific Integrated Circuits (ASIC)s, Neuromorphic computing
        - Possible extension: Accelerators, Microcontroller Units (MCU)s with embedded AI, tiny Machine Learning(ML), Analog Computing as bridge for RF, Quantum Computing, architecture of edge computing
    - Process/Core Technologies
        - Technologies applied to sensors; AI, Analog Computing; Non-volatile Memory (NVM) (Phase-Change Memory (PCM), Resistive Random-Access Memory (ReRAM), etc …) for Analog Multiply and Accumulate (MAC), etc.
    - Application (Mona, Raphael)
        - Radar, User Interface, Augmented Reality (AR)/ Mixed Reality (MR)/ Virtual Reality (VR)
        - Possible extension: Robotics, autonomous driving
- Power Management
    - Wireless Energy Transfer
    - Heterogeneous energy sources & transfer
    - Energy harvesting systems
    - Energy efficient components and communication
    - Extension: Energy Storage
- Core Process Technologies
    - Heterogeneous Integration
    - Low-power, no-charge based memory
    - Silicon on Insulators (SOI)s
    - RF CMOS
    - RF BiCMOS
    - Advanced Semiconductor Materials
        - RF GaN, etc.
- System and Component Architectures
    - Beamforming for 5G
    - Open Standardization

5. Conclusion

Global first trends and conclusions

Concluding, since the EFECS conference in November 2020 the work within the expert groups brought insightful results throughout the past seven months. From a broad idea and scope, each group was able to concretize its focus areas, identify valid gaps within each specific area and generally regarding Europe's path towards technological sovereignty. Therefore, the expert groups 1 "Compute and Store", 2 "Connect and Communicate", and 3 "Sense and Power" defined the state of the art of their identified major challenges and, with thorough internal and external consultation of experts, were able to structure and derive short-term, medium-term, and long-term technical and non-technical goals that Europe and its technological players need to address to foster and evolve its strongholds.

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Since the telecommunication and component players are cooperatively developing a strategic R&I roadmap for future European connectivity systems and components, there are common topics that, to be covered comprehensively, are cooperatively coordinated by the expert group chairs and vice-chairs:

- **Security and energy efficiency** are cross-cutting design considerations in the COREnect technical vision and inherently the common work of Expert Groups.
- Regarding 5G/6G application areas, security and trustworthiness are focus for several stakeholders. Thus, the expert groups are contributing to the question of how to derive **Electronics for trustworthy communication** in 6G and beyond. Regarding the technical aspects of the European sovereignty and its ecosystem, the key question is whether a whole European value chain including the tools and knowledge is feasible, required, and how it can be realized.
- An integrated approach of **future core-technologies and integration** throughout all three expert group chapters is going to highlight the areas in packaging, materials, semiconductor, production, and assembly that can bring Europe forward towards a more inclusive and carbon-neutral society.

As a result, the synergies within each EG and its generated knowledge from the expert group workshop and meetings will be further concretized towards the next step – the Intermediate Industry Roadmap.

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