Workshop Report

Smart Networks and Services Partnership

Stakeholder Workshop

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Executive Summary

The next Research and Innovation (R&I) programme proposed by the European Commission, i.e., Horizon Europe, has currently entered into its preparatory phase. One important aspect to be considered in the development of Smart Networks and Services (SNS) Partnership, building on activities and results of 5G PPP in Horizon 2020, is "Opportunity for Components and Devices" that targets to reinforce and leverage European strongholds in connectivity and revive and build missing yet critical technology competence in Europe for enabling future networks and achieving digital autonomy in the connectivity domain.

To support such a vision and goals, a Networld2020 stakeholder workshop on "Opportunity for Components and Devices" was held in Dresden, on 2 October, 2019. With around 50 attendees from academia, industry and public agencies, this workshop brought key stakeholders from both microelectronics and telecommunications sectors, e.g. Ericsson, Nokia, Infineon, LETI, IMEC, Amazon (Edge computing), ADVA together with SME's like Cyberus that is specialised on security. In addition to Future Connectivity Unit of the European Commission, the ECSEL JU was also represented at the event, which was very interactive with highly relevant discussions in the context of the preparation of the future proposed partnership under the Horizon Europe programme, and notably for the Key Digital Technologies (KDT) Partnership and SNS Partnership.

With 13 presentations and 4 cross-domain extensive panel discussions, the workshop concluded with following take-away points:

- **Compared to 7 years ago when Horizon 2020 was under preparation**, **the collaboration opportunities between the telecommunications sector and the microelectronics sector seem to be much better.** Several speakers noted the need for Europe to have a strong component offer to support the implementation of future smart networks, especially if autonomy becomes an important criterion.
- Adding a new dimension to the discussion, **the speakers noted a need to address the processor aspects more systematically for future generations of connected devices, or for edge computing.** Europe has strong competence at RF level, antennas, PA or passive devices. However, mastering the complete device value chain would require to also address at the baseband processor level. This may be hard, considering the required level of investments and the strategic choices of currently established players.
- **Relatively new drivers for developing components and devices include sustainability and security**. Whilst these requirements have always been part of the research concerns, they today take an accrued importance. For sustainability, integration and packaging play an important role, which may incentivise further the need to look at the issue from an integrated system perspective. For security, it was indicated that current generation of processors are designed for performance, not for security. Architectural aspects such as caching or memory access are currently weak links in terms of security. Also, security requires a comprehensive approach including the OS, the firmware, the microcode, the silicon design. This is seen as a completely new field of activities that open the door for Europe to promote design "according to EU values".
- **5G is already today raising quite some interests in the microelectronic sector.** The ECSEL representative reported about a high number of 5G large scale projects of several 10's of M€. However, these projects are now appearing in "reactive mode", after the first batch of industrial discussion on 5G technologies have taken place and the radio standard is already well established. During the discussion, it was indicated that **it would have been better to have the microelectronics industry involved in 5G developments from the start, to stimulate**

a better impact of EU industry on the lower layer standards. This is a domain where work on new generation of networks with new radio challenges (e.g. THz communications) could highly benefit from early collaboration between the network and enabling technologies communities.

- All speakers agreed that **5G and work towards 6G are opening industrial opportunities for a renewed EU presence on the processor and devices value chains.** The discussion highlighted that General Purpose Processors are not the way to go, due to the complexity of the various application fields. On the other hand, technology needs volume to be commercially successful. This entails a strategy to have as much common hardware as possible for different applications, whilst the differentiation can be developed through software. This requires a strong co-design approach including both HW and SW.
- Regarding the market access barriers, **speakers indicated that Europe has the know-how to move in this domain, including at the processor level**. It was noted that the AMD successful chipset implementation was actually invented in Europe 10 years ago, though the technology was unfortunately not further taken up by European players. In that context, several players indicated that an alternative approach could be to bet on smaller players and support them to scale up across applications.
- As a follow up, **the CSA on components opened under the current 5G PPP workprogramme is seen as an opportunity**. Participants agreed that at this stage, a top-down approach is not likely to work. A bottom up approach is then proposed, with industrial players developing a roadmap for future telecom/device/edge computing needs. This roadmap, if successful, could then become the seed of a European initiative in the field. As a starting point, the SNS community will establish the link with the KDT community to progress the issue further at SRIA level. Should the two Partnerships be implemented, operational approaches to generate common calls or common community collaboration will have to be developer. ECSEL is currently trialling a joint call with IMI, which though appears to be very complex within the current framework.

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1. Objective and Agenda

Given the upcoming definition of the next Multiannual Financial Framework, the workshop focused on the possible alignment and cooperation of two key Partnerships, the Smart Networks and Services (SNS) Partnership and the Key Digital Technologies (KDT) Partnership, what is the possible relationship between the two and what are the cooperation opportunities. Regarding new Smart Networks and Services, which is building on the 5G Public Private Partnership, the content of the research agenda is still under consideration and input from stakeholders is required.

8:30 – 9:00	**Registration**
9:00 – 9:25	**Welcome and EC Introduction on Smart Networks and Services Partnership** *Bernard Barani (European Commission), Werner Mohr (Networld2020/Smart Networks Task Force)*
9:25 – 9:50	**EC Introduction on Key Digital Technologies Partnership** *Bernard Barani (European Commission) and Yves Gigase (ECSEL)*
9:50 – 11:30	**European Strategy — Reviving Component and Device Value Chain for Future Networks** *Björn Ekelund (Ericsson), Colin Willcock (5G-IA)*
11:30 – 12:15	**Lunch + Coffee Break**
12:15 – 14:15	**Technology Deep Dive I — Energy Efficient Computing for Future Networks** **Part I: Advanced Processors for Edge Computing** **Part II:** A**dvanced Processor Platforms for Devices** *Jörg-Peter Elbers (ADVA), Chris Schläger (Amazon), Gerd Teepe (T3-Technologies), Carlo Reita (CEA-Leti)*
14:15 – 14:30	**Coffee Break**
14:30 – 15:40	**Technology Deep Dive II — Next Frontier for Future Networks: Hardware Security and Novel Devices** *Werner Haas (Cyberus), Michael Peeters (IMEC)*
15:40 – 16:45	**Technology Deep Dive III — Radio Technologies for Future Networks** *Hugo Tullberg (Ericsson), Stefan Schindler (Infineon)*
16:45 – 17:00	**Wrap up, way forward** *EC representative(s) and Networld2020*

2. EC and Private Side Introduction on Smart Networks and Services Partnership

Focus: next MFF, Partnership approach, main timing, stakeholder contributions needed, preparatory work on Smart Networks and Services, objectives and scope, envisaged main deliverables.

Speaker: Bernard Barani (European Commission)

From the public point of view, in the next years there is still a strong orientation on verticals to be expected since major industrial contributors to GDP have comparatively small investment in digital infrastructure today. With the ongoing digitalisation a large market and revenue potential can be envisaged. In this context, it needs to be determined if the 5G Vision KPI parameters will remain valid for current and future use cases. Likely, the basic set and approach will remain valid, but the values will be adapted and pushed to the limits.

Disruptions are to be expected from new technologies like artificial intelligence and Terahertz communications. Additionally, energy efficiency needs to be established as a key KPI and technology paradigms need to be balanced with society requirements, e.g., energy efficiency as convergence point between climate neutrality and cost reduction or edge cloud computing as opportunity for better user data control. Security is a second horizontal issue that needs to be tackled from an end to end perspective. Altogether, these requirements may lead to a significant change of network architecture. Overall a modified approach may be required: A Smart Networks and Services Partnership is under preparation, which

- Further pushes the limits of what is or may be Beyond 5G/6G
- masters the full value chain (Europe should have at least one alternative supply chain)
- enables new opportunities on devices and distributed computing, and leverages Europe's stronghold on connectivity
- leverages the capabilities and experience of Europe in terms of terminals, i.e., supports the strengths (Antennas, RF technologies etc.) and addresses the weaknesses (e.g., processors (esp. for NFV) etc.).

Thus, the Partnership requires a refreshed holistic picture. The timeline consists of an Impact Assessment for the different Partnership proposals (Commission internal) for 2019, such that decisions on supported Partnerships and finally the work programme can be finalized in 2020.

Speaker: Werner Mohr (Networld2020/Smart Networks Task Force)

From the private side, the Partnership is seen under the topic "Next Generation Internet" with strong links to other topics, e.g., Artificial Intelligence and Digital Technologies (i.e., device and component view). It is clear, that the system design cannot be carried out independently from the hardware capabilities, especially for wideband and terahertz systems and cooperation between the two communities is required. Besides research, also deployment aspects are considered to become part of the Partnership.

For the next step of research, a combination of the topics on digitalization, artificial intelligence and ubiquitous communications is foreseen. Driven by societal challenges such as sustainability and ubiquitous connection, future network shall become much more intelligent. The focus will be mainly placed on network architecture with additional elements on 5G evolution and terahertz communications. ICT services and platform economy represent a larger number of employees and part of GDP with comparable R&D investment than classical telecommunications. Thus, it is important to improve Europe's position in the cloud domain, the component and device domain, and in the platform economy domain. Central research topics here are data analytics (machine learning), distributed

computing and cybersecurity, which can be exploited only in combination with the right network architecture. Security is a key aspect due to the increasing involvement of networks and ICT in critical infrastructure use cases. Thus, the scope of the SNS Partnership needs to be extended compared to 5G PPP to

- IoT (where needed in the network)
- cloud service provision (today cloud control still outside of Europe)
- components and devices in the sense of available knowledge regarding hardware capabilities and its impact on system design, e.g., in cooperation with the ECSEL successor.

Many discussions are driven by digital autonomy, not in the sense of protectionism but alternative supply chains. Activities should be selected based on a value chain approach and the first concern of the Partnership should be 5G evolution, later activities can focus on exploring aspects of "6G". For the purpose of defining the Partnership, the way forward includes active discussion between network and device communities in the coming month in order to organise a successful cooperation.

3. EC Introduction on Key Digital Technologies Partnership

Focus: Partnership approach, main timing and stakeholder contributions needed regarding to components and devices for smart network.

Speaker: Bernard Barani (European Commission)

Considering the renewed interest on digital autonomy in Europe, it seems important to address the aspects of components for future connectivity platforms in the overall design of the next research programme. Therefore, a CSA has been designed to bring European players in microelectronics and telecommunications together, with the objective of developing a high-level strategic roadmap for Europe in this domain.

Speaker: Yves Gigase (ECSEL)

The KDT Partnership is currently defined as a successor of the ECSEL framework. There are significant activities within ECSEL on components for 5G and the importance of the European components sector on telecommunications should not be underestimated.

KDT and ECSEL are based on the Partnership of the European Commission, three industry associations and the participating states. Thus, synergies between commercial strategies and societal needs can be promoted and national and European strategies can be aligned. The overall strategy is defined by the industry associations and designed as a grid of key application areas (mobility, health, energy, digital industry and life) complemented by the essential capabilities required in these areas (systems and components, connectivity, security and reliability, computing and storage, manufacturing and materials). In addition, long term topics are defined. 5G fits in various places into this grid and its relevance for the European electronic components and systems industry is recognised. High priority topics comprise

- Efficient adaptive power management for 5G wireless networks
- Preparation of the 5G era in communications technology, and especially its manufacturing and engineering dimension
- Meeting future connectivity requirements leveraging heterogeneous technologies
- Enabling nearly lossless interoperability across protocols, encodings and semantics
- Ensuring Secure Connectivity and Interoperability.

The programme is overall industry oriented, such that most of the projects work topics have the potential to lead to products within the next couple of years. The projects involve companies from all

parts of the value chain as well as from outside the ECSEL framework. ECSEL is organised in clusters of projects and participants. The importance of cooperation has been recognised early-on, such that lighthouse initiatives on strategic topics have been started by bringing different industry associations together. This could be a model for cooperation with the 5G IA and potentially evolve to a framework for Partnership cooperation in Horizon Europe. Cooperation is essential for making 5G work. Besides ECSEL/KDT Partnerships, the Digital Europe programme offers a number of interesting topics for cooperation with the SNS Partnership. ECSEL/KDT Partnership has the same timeline as 5GPPP/SNS Partnership.

4. European Strategy — Reviving Component and Device Value Chain for Future Networks

Focus: During the past 10 years, European industry has gradually lost its position in the areas of components and devices for networks. With ever-growing global competition as well as the increasing possibility of global supply chain disruption, it is strategically important for Europe to revive and rebuild a complete component and device value chain. This session will focus on reflecting these issues at a strategic level for contributing to both the Smart Networks and Services Partnership and Key Digital Technologies Partnership.

Speaker: Björn Ekelund (Ericsson)

In order to maintain its macro-economic independence, Europe needs a strong electronics research. Especially the increased scope of application in 5G will impose additional challenges on components and result in a broad innovation platform for society. Connecting things will be a large step-up compared to places and people, for which 4G is not a solution since it does not scale. Thus, 5G and Electronics will be a central part of all industries in the future. Already today, the top five goods exported from Europe either contain electronics or rely heavily on them in their manufacturing, such that research into wireless networks and devices is vital for Europe. Furthermore, "moving up the value chain" is not an option: Materials and manufacturing on the bottom as well as platform economy and end-user services and equipment are dominated by non-European players. With increasing integration in semiconductor technology on the bottom and increasing software and device development activities on the top of the value chain, Europe's slice is vanishing and the value is lost, if this development is not counteracted.

Speaker: Colin Willcock (5G-IA)

The 5G IA represents the private side of the 5G PPP and aims to be the voice of the European 5G eco-system, including industry, SMEs and research institutes. The 5G research in the 5G PPP was organised in three phases: definition of 5G and its basic concepts, involving the vertical industries, and creation of platforms that enable innovation on top of 5G across Europe. The second phase is essential for 5G to build up to its potential and still an ongoing process. Active cooperation is required in order to convince the verticals to trust and invest in 5G.

5G is standardised especially for eMBB. However, not all elements are available yet like URLLC and mMTC, which are important for verticals. This is coming soon. 5G is now being deployed. The new Partnership will look at 5G evolution. That means further improvements and adding new features. This will enable the use cases that will deliver the significant added value in large industry areas by using 5G, which is foreseen to be in the order of 60.000 Million Euro. Furthermore, the added value of 5G for society can/should be exploited commercially, such that other concepts of investment than purely commercial structures need to be considered. Eventually, these future communications networks are essential to the industry and society of the future and will be a critical infrastructure – from a safety as well as from a competitive point of view.

On top of these ongoing activities, an end-to-end story is required. The Smart Network and Services Partnership needs to be tied in with the overall ecosystem: Cloud, artificial intelligence, IoT, devices, Big Data etc., especially with the focus on digital autonomy. Ideally, within the Partnership strong areas can be leveraged to increase competence in areas, that are now Europe's weaknesses. Besides devices and competitive advantages, digital autonomy is also about values like user protection. Thus, the next programme needs to be manifold. It has to

- deliver the promise of 5G
- ensure that new developments are born in Europe with European values
- leverage existing strength to create markets in other areas.

Panel Discussion Morning Session: Bernard Barani, Werner Mohr, Björn Ekelund, Colin Willcock

Regarding the role of photonics in ECSEL/KDT Partnership, there is some research on VCSELs and LEDs, however, photonics ICs have their own programme. Clearly, programmes will be required to work closer together since their boundaries become blurry, in this case due to the increasing integration of optics and electronics. This is also true for research on network architecture (fixed and wireless) versus system components. With all the aspects going into 5G and beyond, it is critical that the scope of the SNS Partnership does not become too broad, otherwise the programme will achieve nothing. On the other hand, a holistic network and service vision is needed. Key building blocks need to be defined, where Europe actually can compete and it needs to be clear, which research topics will have practical relevance. Unfortunately, in the past European component industry hasn't been very active in the area of communications/5G. Ideally, with a more concerted approach, Europe can move faster in 6G in the interest of improving IP and digital autonomy.

Since the ECSEL framework is organised bottom up and due to the large investments required in this area, industry and research go where the profit is. There has been the attempt to steer activities top down via special topics. However, when European technologies become available as, e.g., FDSOI, European industry needs to start using it (the biggest market for FDSOI is currently in US/China). Eventually, all relevant parts of the network need to be covered and there is a need to streamline content of and cooperation between the programmes and initiatives. There is an inherent difficulty to define the Partnerships without knowing how their cooperation could be organised. Nevertheless, openness will be part of evaluation of the Partnerships. The main take away from ECSEL lighthouse initiatives is that bringing together the industry associations is essential, not only on the working but especially on the decision level. Additionally, an intermediate level of confidentiality is defined for the lighthouses: not confidential to the project, but not available for everyone. Cooperation between Partnerships will add another level of complexity from a legal point of view, such that it must be where it makes sense. With a content first approach, Europe should have a clear vision about enabling technologies. Eventually, digital autonomy is a long term undertaking and requires a large investment and coordinated players. Therefore, a realistic goal is essential, however, Europe should start to believe in its capabilities to achieve this.

5. Technology Deep Dive I — Energy Efficient Computing for Future Networks

Focus: Energy consumption of future networks must be sustainable. This will be extremely challenging to achieve within the coming age of network virtualization and network/device intelligence. Meanwhile, despite of its leadership position in the area of network infrastructure, European industry has so far developed very limited competence, know-hows and skills on the key computing components that will empower "brains" of future networks, e.g., (micro-)processors. In this context, it is of high interest and high priority of Europe to build such critical components yet

missing competence. This lies at the very core of achieving European strategic autonomy in the domain of future networks.

In this session, the focus will be then placed on discussing key enabling technology building blocks, the related software technologies and the required ecosystems for supporting energy efficient computing at the both infrastructure and device sides. Considering the fact that the required hardware and software technologies as well as their connections to legacy technologies differ largely at the infrastructure side and at the device side, this session will be divided into two parts:

Part I: Advanced Processors for Edge Computing

Part II: Advanced Processor Platforms for Devices

Speaker: Jörg-Peter Elbers (ADVA)

The continuous innovation on the hardware level has been a key factor for the success of today's networks, which shows the importance of network, system, and component research going hand-in-hand. Smart future networks will consist of various technologies working together in order to deliver the required quality of experience to the user. In order to make these networks sustainable, energy efficiency has to become a key design aspect. As can be seen from ICT energy consumption forecasts, especially in the network and data centres, energy consumption is expected to rise dramatically. It is unlikely that this can be counteracted by microprocessor scaling since despite the scaling the performance is observed to saturate. Therefore, more parallelisation and solutions beyond the general-purpose processor have to be found and task specific computing is required. In any case, an increasing amount of communications is required and more communications will move from electronic to optical media as throughputs get higher.

Technology challenges from an optical point of view are

- Novel System-in-Package/System-on-Chip approaches (multiple technologies, heterogeneous materials)
- Advanced (optical) transceiver chipsets and related digital signal processors
- Optical-wireless integration (analog/digital) towards "optical radios"
- New processing nodes for edge applications (AI inference, video pre-processing, …)
- HW-based security functions

Speaker: Chris Schläger (Amazon)

Amazon Web Services (AWS) is driven by a customer centric approach and consists of three important areas:

- Storage (defined by throughput, latency, and redundancy)
- Compute power (including processors in all flavours (CPUs, General Purpose Processors, AI-chips etc.) and memory)
- Networking (again with the KPIs throughput and especially latency)

In order to enable latency critical applications, AWS provides additionally points of presence at the network edge beyond the regional data centres (called AWS Outpost), which provide fast connections to the core. Thus, although not technically an edge cloud, these outposts can enable edge applications. For a viable business model, a full-service solution is required, including cloud management and especially including the possibility of online maintenance by separating customer and hardware via virtualization. However, as a pure service provider without access to the hardware, it is difficult to guarantee a certain Quality of Service or Experience. When service provider virtualises storage, networking and compute the CPU becomes the central element of its architecture. CPU determines the performance, reliability and security posture of the overall cloud infrastructure. The level of control of the CPU and Operating System design becomes the differentiating factor vs. its competitors.

Furthermore, the entire system needs to be designed with energy efficiency in mind. AWS currently uses load balancing, i.e., optimization between units instead within units since experience shows that today's hardware is more efficient under full load. Overall optimization for energy efficiency is tricky.

Speaker: Gerd Teepe (T3-Technologies)

The semiconductor market has been growing since the 1980s and there is no indication that this development will stop and its importance for other markets keeps increasing. Current semi-conductor growth factors include AI, IoT, Smart cities, digital health, and smart transport. Therefore, European industry and decision makers need to acknowledge the strategic value of building up and maintaining expertise in this area within Europe. A successful example is Infineon's leadership in power semiconductors and other areas need to follow, e.g., transport and automotive.

There is the need to focus on design in order to bridge the gap between technology and application. Future systems and applications might increasingly rely on the design of task specific hardware, for instance, AI chips in autonomous driving units from Tesla or Audi. These systems will contain the relevant IP and thus the competitive advantage and may be simply not available for European industry or with sufficient numbers if not designed in Europe. Overall,

- design bridges the gap between product and technology
- general purpose devices are vanishing – If you don't design a device, you don't get it.
- Sovereignty means choice of value chain in production, design, tooling, materials, and packaging
- "Open Source" is starting to become an alternative

Speakers: Carlo Reita (CEA-Leti)

Although components represent a smaller market share in terms of revenue, they are critical for controlling the entire system. This is increasingly important since network distributed computing needs specialised hardware and processing at all network levels so that for energy efficiency and privacy reasons only the necessary information is transmitted not the full data. For this type of applications, FDSOI is a key technology for achieving the energy efficiency and the performance required. It exhibits good properties for mixed signal design and is expected to scale well below 10nm. Thus, with investment in this European technology, emerging applications like AI and 5G can benefit. It has to be avoided that European know-how and development is brought to the market elsewhere as has happened for the 3D packaging technology that was pioneered here. However, the situation in which Europe has lost its position in advanced digital design and fabrication is not irreversible. The important competences are still present and new applications evolution (like 5G and 6G) open up new opportunities. It is worrying that in the current 5GPPP, most phase 3 demonstrators rely on components-off-the-shelf or dedicated products from the US and Asia, because they are lower cost, need less resources and are less risky. While initially attractive this does not position Europe for the future markets and, hence, have no added value. Dedicated activities are needed to support innovative component and demonstrator design in Europe, if necessary by creating incentives for start-ups and small companies and R&D accessible platform to implement them.

Panel Discussion: Jörg-Peter Elbers, Chris Schläger, Gerd Teepe, Carlo Reita

For investment in technology, there are several options: foundries (representing the most expensive part of the process), design (which can be comparatively cheap if there is volume, i.e., a market), and focusing on the already existing strengths. There is no need to go all-in for the latest and most expensive technology. The number of CMOS tape-outs decreases with at the most advanced technology node due to the increasing design cost, which leaves enough time to build up know-how in slightly larger technologies with comparable performance. Success requires that the European industry pools its resources to achieve profitable volumes domestically.

Furthermore, it is essential that European technology is used to build up European systems by the industry. Currently, it often seems cheaper to buy components-off-the-shelf, however, these will probably not fulfil requirements of the future and increase the dependence on other areas choices. Europe needs a strategy to make research results available for a reasonable price and effort also for small and medium-sized companies. Here, market fragmentation and risk aversiveness of European industry is again a problem, which needs to be overcome, e.g., by resource pooling or by combining the strength of the existing industry in an appropriate way. This could also be encouraged by cooperation between the research Partnerships to encourage joint activities of companies along the full supply chain.

As a general strategy, for dedicated hardware a certain market size is required. Thus, solutions in silicon should address problem classes and provide for customer specific adaptation needs to be realised in software. This importance of software has to reflect also in ECSEL/KDT Partnership. At the moment, software research activities carried out in ECSEL are mainly related to embedded software design. With novel compute concepts like the edge cloud, consisting of sensor fusion, decision making and decision communication, the notion of computers and software will change and the integration of components and software needs to be intensified.

6. Technology Deep Dive II — Next Frontier for Future Networks: Hardware Security and Novel Devices

Focus: Security of future networks will be the foundation of its success. Associated with its increasing impact on economy and society, the future network is expected to face more frequent and more sophisticated cyber-attack and security breaches. This session will focus on identifying a) major security challenges on the hardware side of networks, including both infrastructure and devices, as well as, b) the required R&I areas for secured network, with respect to a hardware security approach and a joint hardware-software security approach. In addition, new devices that enable novel human-machine/machine-machine/AI-AI networks will emerge, which will potentially impose currently unknown yet very stringent requirements to the network infrastructure. Therefore, this session will also discuss and envision some emerging new devices and applications that future network/infrastructure will support as well as a perspective on new challenges imposed on network design. The associated value chain and ecosystem will also be analysed.

Speaker: Werner Haas (Cyberus)

The current communications infrastructure is based on several layers from application over software-defined radio, virtualization and virtual machines down to operating systems, firmware, microcode and silicon. All lower levels from silicon to microcode possess significant vulnerabilities as exposed in the past years by Operation Soft Cell (Operating System), LoJax (Firmware), Checkm8 (Microcode), and Meltdown and Spectre (Silicon). Side channel attacks continue to be a considerable risk for any communications and computing infrastructure. Especially silicon as the foundation of any communications infrastructure must not possess vulnerabilities and it is vital for the networks of the future to build on secured hardware and (micro)processors. Especially a separation between user domain and operating systems as in the RISC-V instruction set architecture is important from a security point of view.

Speaker: Michael Peeters (IMEC)

It is crucial to continue the research in and beyond 5G, especially since the promised disruptive capabilities of 5G for vertical applications and industries are not yet a reality. These applications cannot be realised only via softwarisation and virtualization but they require a solid stack from materials up to applications.

From an application point of view, the biggest push from industry will likely remain human-centric broadband-services. Regarding the other promises of 5G, the field of "4.0"-applications remains, which emphasises the necessity of edge computing or edge AI and, thus, requires a large step-up in energy efficiency. Especially for edge AI, everything is a bottleneck: memory, compute power, communications bandwidth, and battery life. All these areas provide research opportunities for Europe to catch up.

Other applications will not directly be monetizable. This includes body machine interfaces, autonomous intelligence, and biological IO. In order to realise these future technologies, device research has to find solutions for

- Communications at higher frequencies (potentially beyond CMOS)
- Increasing complexity of networks and environment

Device research, e.g., on THz devices or III-V/CMOS integration needs to start now, and European industry is very well positioned in this area. Overall, smart networks are built on smarter devices (components, modules, subsystems).

Panel Discussion: Werner Haas, Michael Peeters

It is still an open topic, how to protect objects in computers. Currently, all protection is on the naming layer and advances in computer architecture are required to differentiate data, e.g., regarding its criticality, in order to develop mechanisms to protect the data itself. It is urgent to realise for industry and decision makers that such advanced protection mechanisms and security in general has to become a commercial requirement in order to implement the use cases of the future in a reliable manner. Security made in Europe further opens up a potential to differentiate. An open processor platform with assessable hardware specification is here a possible way. There will always be a trade-off between shared resources and security and given the expected heterogeneity of future networks, the possibility of insecure devices needs to be incorporated in the network design. These challenges require system level security concepts addressing the entire stack.

In order to deal with the expected heterogeneity of future networks, the evolution of software-defined radio is a promising approach. Despite the variety of applications, data rate and frequency requirements largely overlap. Thus, by focusing on the commonalities in these applications mass-market devices, modules or subsystems can be fabricated at reasonable cost. For manufacturing subsystems operating at high frequencies, appropriate integration and packaging technologies are required in order to avoid large losses in electrical interconnects.

Using biological processes for power generation yet remains on long-term roadmaps.

7. Technology Deep Dive III — Radio Technologies for Future Networks

Focus: Capacity of future networks is expected to be perceived as infinite by its users. From the radio access point of view, this requires further development of efficient, flexible and agile spectrum usage techniques/mechanisms as well as efficient exploitation of mmWave and THz frequencies, both of which must be supported by enabling radio technologies (including RF, baseband and I/O designs and integration) and potentially optic technology. In addition, the use of mmWave and THz frequencies will pave the way to integrate sensing and imaging into the service portfolios of future network. This session will identify major technology building blocks for enabling commercially viable and energy efficient radio implementations that support seemly infinite capacity at both infrastructure and device sides.

Speaker: Hugo Tullberg (Ericsson)

When defining 5G in the research community, the well-known use cases of enhanced massive broadband (eMBB), ultra-reliable low-latency communications (uRLLC) and massive machine type communications (mMTC) were intended as the corner stones of a linear combination of requirements on data rate, latency and number of devices, that allow to represents any use case within the network. These have fallen apart into three separate use cases during the ongoing developments and need to be brought back together for a holistic approach on designing future communications networks. Additionally, besides KPIs for the traditional network design, a shift towards key value indicators is happening such as sustainability, intelligence, and trust, which have to be translated into technical aspects of the network. Challenges comprise

- The joint design of the radio interface and the network
- Higher frequencies and spectrum flexibility, component and system design for THz frequencies
- Flexible network topologies
- Device co-operation
- Components for massive IoT
- Cellular as a sensor
- Machine learning and artificial intelligence, especially under sustainability considerations
- Service based architecture

Thereby, the task of research is to explore the space of opportunities and not all results need to translate into products.

Speaker: Stefan Schindler (Infineon)

Major future growth factors comprise energy efficiency, mobility, security, IoT & big data. In order to cope with the increased data volume expected, technology advances in mmWave-communications are required. For mmWave-devices, considerable enabling cost are required to increase the maximum frequency of oscillation (fmax) of transistors at high frequencies. Challenges are

- higher integration
- higher output power
- higher efficiency
- lower cost in production

Making mmWave communications a reality requires close cooperation between industry and academia. Especially under energy efficiency considerations, a large amount of research on new technologies is required.

Panel Discussion: Hugo Tullberg, Stefan Schindler

Regarding flexible network topologies, there is always a trade-off between a less flexible, more efficient dedicated hardware solution and overprovisioning on general purpose hardware. If a zero-energy radio as a concept for reducing the power consumption of all layers of the network shall become a reality, purely software driven solutions will not deliver. Especially since with the developments in AI and ML, the compute power can be expected to exceed the radiated power.

The energy efficiency of mobile equipment keeps dropping during the generations due to the increased requirements on the hardware by the applied modulation and coding schemes. In the interest of sustainability, waveform design for communications in the EHF band needs to follow hardware capabilities.

Single-chip solutions from baseband to radio-frequency are still inefficient due to limitations in integrating the power amplifiers. Currently, the separation between baseband and radiofrequency part is the most efficient solution. For future research, a below 28nm BiCMOS technology with a sufficiently high fmax could provide a solution when production costs are reasonable. Another opportunity could be 28nm FD-SOI technology, if the limited output power can be counteracted by antenna-array size at very high frequencies. Eventually, the technology choice is also use case driven and hetero-integration of technologies is a key topic.

There is an issue remaining regarding the scalability of network equipment for smaller/on-premise networks. Unfortunately, existing EU initiatives target high-performance computing more than small-scale solutions.

8. Wrap up, way forward

Speakers: Bernard Barani, Werner Mohr

Regarding the joint design of hardware and network capabilities for future connectivity platforms, the European commission has set up measures that now have to be followed up on by industry and academia. This includes especially the CSA to shape Strategic Innovation and Research Agenda of Horizon Europe. It is a promising development that the overall resonance in industry and academia recognizing the importance of joint and efficient network and component design has increased since the start of 5G PPP.

Naturally, Networld2020 has focused activities so far on networking topics. Clearly, system design and implementation cannot be dealt with independently. Thus, a successful revision of the research agenda requires additional expertise on components and devices within Networld2020.

The revision will start with a workshop in November 2019 and the next version of the agenda is estimated to be available around April 2020.