Future Integrated Mobile Communication Systems — An Outlook towards 6G

Christoph Fischer, Dennis Krummacker, Maximilian Berndt, and Hans D. Schotten

Abstract—**6G will come with a multitude of new features that will improve communication. These features will be strongly driven by Artificial Intelligence that is processing communication data and derive information. One feature that is already well discussed in the Research World is Joint Communication and Sensing. This says that along with the pure information transport the electromagnetic waves will be used to derive more information from the environment, which might be positioning information or perception of barriers. All these information will internally be used to then optimize the 6G Network with e.g., high precision beam forming or movement prediction for User Equipment. Be-side these internal optimizations, there will also be a multitude of external applications that can benefit from these information. By processing these information, external applications are capable of deriving further relevant information that can be used to integrate new management capabilities. This paper gives an outlook on the multitude of possibilities to exploit these information for various use cases, to make 6G not just another mobile communication standard but to enable an integration level for a communication technology that can be the unique selling point for 6G**

Index Terms—**Software defined networking, 6G mobile communication, industrial communication, heterogeneous networks, next generation networking.**

I. Introduction

With the finalization of 5G standardization, the whole re-search world is beginning to shift to the new generation of mobile communications, 6G. There are numerous interesting concepts and ideas for features that can or should be enabled by6G. Most of these concepts are communication centric, which deal with higher data rate, lower latency and high reliability. But there are also trends towards new action areas for the mobile communication.

The requirements for a future mobile communication technology are set by challenging technological domains, like industry, agriculture or autonomous driving. All these domains have a major requirement in common, which is the increase of aware-ness. The environment must be digitally perceived. This can be achieved by integrating vast number of sensors, which then have to be connected by a communication system. An approach currently discussed in 6G is to make 6G not just the technology of choice to enable connectivity to transfer those information but also use 6G radio access network as a sensor itself and producer of further sensing data. This being said the challenge of data management arises, since all these information have to be made available in order to derive further information or actions out of it. There is a need for a platform for those information, which can be intrinsically offered by 6G.

With 6G becoming the highest performing mobile communication system, an important aspect has to be considered. There will rarely be use cases that require all 6G enabled Key Performance Indicators (KPIs) to be maxed out concurrently but there will be networks that need to adapt over time to the user requirements. For that reason it is necessary to make6G not only the most performant but also the most flexible network. Using 5G as a starting point for developing 6G is therefore well suited since there are first steps accomplished on the way to a versatile architecture. 5G standardization has defined the first fully Service-Based Architecture (SBA) for mobile communications that enables a high grade of modularity.6G has to be taken one step further by enabling straightforward extensibility with proprietary modules that can have impact on the core functionalities. Hence, the hurdle for developing highly integrated functionalities has to be decreased, which only can be done if, for the scope of 6G, the underlying architecture is revised in its foundation.

To give a clear definition of what an integrated communication network means in the focus of this paper. An integrated communication network is a network that is serving the domain specific tasks that are imposed. This includes enabling connectivity, serving specific communication requirements and the provisioning and processing of relevant information and sensing data for a higher purpose to serve the operators, subscribers and third-party service providers. This paper gives an outlook on what integrated mobile communication systems are supposed to do in the future and furthermore gives more concrete ideas on how 6G might fill this gap. The remainder of the paper is structured as follows. In the beginning of the paper the section II analyzes 5G Mobile Communication in order to highlight the technological aspects that are relevant for this paper. Section III then gives an outlook on technological changes that are planned for 6G. The sections IV and V provide detailed information on the benefits that are currently under discussion in 6G and their usage for an integrated network. In Section VI a new architecture approach for 6G integrated networks is introduced and section VII gives

an outlook on the extendability of an integrated network. The last section, section VIII concludes the work of the paper

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and gives an outlook on the future work.

II. 5G, OLD AND NEW TECHNOLOGY

Discussions about 6G quickly lead to the assumption that 5Gis finished and running, which is not the case. While worldwide6G research is accelerating steadily, 5G research as well as standardization and product development is still ongoing. Due to this, it is important to consider 5G research, when talking about where 6G should go. This section is supposed to bring5G into the research context of this paper. In consequence the insights are used to build the foundation for 6G and derive further implications for 6G.

A. 5G Service Based Interface

One of the early decisions that were made in 5G standardization was to make 5G Core (5GC) a SBA, which means that functionalities of the 5GC were separated in Network Functions(NFs). Separating these functionalities in NFs made it necessary to think about unified interfaces, which led to the Service Based Interface (SBI). The SBI is a interface that works with RESTful API and by doing so standardizes the NFs interaction. Further-more the 3rd Generation Partnership Project (3GPP) set up a guideline for Service definition in the TS 29.501 [1], to assure compatibility with services of different vendors. In consequence there is a 5G System (5GS) architecture that enables an easy interaction internal and external with 5GC services, is scalable due to the use of isolated and stateless functions, and NFs are easily exchangeable. This leads to the possibility of integrating3rd party functions into the 5GC and paved the way for the Open Source community to produce new features for 5G.

B. G Non-public Networks (NPN)

For the sake of this research topic, 5G campus or also called private networks are of special interest. Several countries have decided to offer frequency resources for using 5G networks on demarcated private areas. With this decision, the first step to an integrated 5G mobile communication network was paved. The combination of the SBA and private networks was very promising for adapting 5G to personal preferences and make it a fully integrated communication technology. As of now there are several activities in this area and a lot of Open Source projects are currently ongoing but a simple way to use and adapt 5G to domain specific preferences is not given.

C. 5G Positioning and Localization

Providing integrated positioning features within a comprehensive mobile communication system promises great impact on various fields of applications and is seen as a key enabler for vertical industries, public safety and indoor navigation. Examples are assisted and autonomous driving as well as automatic train operation, asset tracking in automated production facilities or transportation of supplies in hospital environments, among many others. Although all of these applications share the necessity of retrieving positioning information, they nevertheless have distinct requirements, e.g., in terms of accuracy, precision and latency [2]. Generally, the minimum requirements on positioning features are described in [3] and differ largely, depending on the concrete use case. For instance, while the end-to-end latency required as a minimum are<30sec (e.g., emergency calls), the latency requirement on more strict, commercial applications is<1sec (e.g., control of Automated Guided Vehicles (AGVs)). Besides different requirements in positioning capabilities, these applications also differ in terms of the technologies that are suitable. For instance, while Global Navigation Satellite System (GNSS)-based positioning approaches are widely used in outdoor environments, they are hardly applicable within buildings or urban areas. Combinations of different positioning technologies are expected to provide the end user with enhanced capabilities in terms of precision, accuracy and availability. Localization and positioning features have already been introduced during the development and standardization of Long Term Evolution (LTE) (e.g. 3GPP Rel. 11: Uplink Time difference of Arrival (UTDOA) support for LTE; e.g. 3GPP Rel. 14: Indoor positioning enhancements). However, the main drivers for integrating these capabilities are inventions that have been coming with 3GPP Rel. 15 and the following. Examples are the potential integration for GNSS and Real Time Kinematics (RTK) systems, sidelinks and other features for native positioning in 5G networks.

a) 5G Positioning Approaches: One objective set for 5Gis the ability to provide position estimations with accuracy deviating less than one meter. However, depending on the specific use case there exist also applications that require even higher accuracy [2]. Hence, solutions exceeding the capabilities of CellID, which has been well established in mobile communication networks, have to be identified [4]. 5G New Radio (NR) comes with a set of different technologies that can be used to enable positioning by leveraging the capabilities of the mobile communication infrastructure itself. For the purpose of designing a comprehensive communication and positioning infrastructure within 5G NR, dedicated signals have been introduced of which some are briefly described here. For a detailed overview of the measurements in the 5G NR physical layer, see [5]. Originally introduced in evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (E-UTRA) and extended in 5G NR, pilot patterns dedicated to positioning purposes have been established by the 3GPP. On the one hand there is the Positioning Reference Signal (PRS), which is e.g., used for User Equipment (UE)-based Downlink Reference Signal Time Difference (DL RSTD) and Downlink Reference Signal Received Power (DL RSRP) measurements. On the other hand, there is the Sounding Reference Signal (SRS), which is e.g., used for Next Generation RAN (NG RAN)-based Uplink Relative Time of Arrival (UL RToA) and Uplink Reference Signal Received Power (UL RSRP) measurements. The Reference Signal Received Power (RSRP) approaches rely on measuring the power contributions of radio resource elements that carry RSRP and are configured accordingly. The Reference Signal Time Difference (RSTD) approaches, in contrast, rely on measured timely delays between reception of the respective signals received from multiple reference nodes. Itis worth mentioning that, especially considering higher carrier frequencies (Frequency Range 2 (FR2)), the approaches that are based on measurements in the delay domain are becoming more applicable. Furthermore, besides measuring delays or transmission/reception angles, positioning in 5G NR can also be based on a Received Signal Strength Indicator (RSSI). Here, not only signal strength measurements in the 5G NR are possible but also in Wi-fi networks [5]. Considerations to integrate Machine Learning (ML) systems here, e.g., for the purpose of fingerprinting within an unknown environment, are seen to be promising and have been subject to extensive research, e.g., for indoor positioning using wi-fi [6]. Additional considerable application areas for ML approaches can be seen in approximating the wireless channel, e.g., by using the method proposed by Jiang et al. in [7]. Moreover, procedures for measurements in the angular do-main (Angle of Departure (AoD) in the downlink, Angle of Arrival (AoA) in the uplink) have been established to leverage the capabilities of antenna arrays being more widely deployed in 5G NR cells. Note that all mentioned positioning procedures basically rely on the concepts of multi-lateration or multi-angulation. Thus, considering an exemplarily pure lateration approach, itis necessary to not only measure the distance of the UE towards the serving NG RAN, but rather to perform these measurements in a number of neighboring cells as well. Finally, communication via Sidelinks (Device-to-Device(D2D) communication) can for instance be used to detect the position of devices that are not or not currently able to connect to a NG RAN with the appropriate localization capabilities. For this reason, the Sidelink Received Signal Strength Indicator (SLRSSI) measurement capability of UEs has been established [5]. The use of Sidelinks might become especially important considering future mobility use cases, such as Vehicle-to-everything(V2X) and associated technologies, e.g., sensor sharing.

b) 5G Location Services (LCS): 5G Location Services (LCS) (formerly known as Location-Based Services (LBS)) are services that can be offered to different network participants in order to retrieve the location of a UE. Positioning of an UE can either happen in the uplink and/or in the downlink. In addition, positioning in a 5GS can also be realized independently of 3GPP Radio Access Technology (RAT), e.g., using wi-fi or GNSS. LCS requests can be invoked by LCS clients or Application Functions (AFs) (internal or external) or a control plane NF. Note that privacy features have also been considered here for the target UE (can be defined in LCS privacy profile) as well as the accessing NF. Finally, every incoming LCS request has a dedicated Quality-of-Service (QoS) indicator, which is characterized by the three QoS key attributed *accuracy, responsetime/latency and QoS class*. Note that the QoS classis either of type best effort (low requirements: send response anyway, even though accuracy requirement has not been met) or assured (strict requirements: instead of sending a response with unsatisfied requirements, return an error). Multiple types of location requests have been introduced. Generally, the three types of LCS requests are Network Induced Location Request (NI-LR) (initiated by serving Access and Mobility Management Function (AMF) upon request of regulatory agencies), Mobile Terminated Location Request (MT-LR) (initiated by LCS client - internal or external) and Mobile Originated Location Request (MO-LR) (initiated by UE). Additionally, it can be distinguished between immediate location requests (response reported immediately) as well as deferred location requests (response reported periodically, yet only supported for MT-LR). It is also worth mentioning here, that LCS requests do not necessarily have to refer to a single UE only, but instead can also request the location of a group of such. This can e.g.be applicable for centrally guided fleets of AGVs that may be operating in platooning mode [8]. In the following, selected network entities that are relevant for LCS services are presented briefly. For a comprehensive survey on LCS and components related to it in 3GPP Rel. 16, see [9]. The Gateway Mobile Location Center (GMLC) is an essential network component of any 5GS supporting LCS. Note that there may be multiple GMLCs per Public Land Mobile Network (PLMN). The GMLC exposes services to interact with internal as well as external LCS clients. Internal LCS clients can request LCS directly by accessing GMLC or via Network Exposure Function (NEF). External LCS clients can request LCS by accessing GMLC via Le reference point. Alternatively, external clients may use the Common API Framework (CAPIF) for this purpose. In order to assure compliance with the privacy policy of the UE and authorize the requesting LCS client, GMLC can access Unified Data Management (UDM). The NEF enables external and internal AFs to access location information by using a dedicated API. This can either happen by the NEF communicating with GMLC (via LCS request forwarding) or the serving AMF (via event exposure), depending on the required QoS. The Location Management Function (LMF) can be seen as the orchestrator (coordination and scheduling) of the resources responsible for location estimation. Besides estimating the final UE position, it can also use aggregated information to approximate the current UE velocity. Finally, the LMF can also be responsible for selecting suitable information sources for position estimation in order to comply with required QoS settings of the UE. The AMF handles functionality related to positioning of a target UE and covers all mentioned kinds of LCS request.

D. 5G URLLC

A 5G feature that is strongly driven by industry and autonomous driving is low latency communication, called 5G Ultra Reliable Low Latency Communication (URLLC). In its essence, it is basically a combination of a precise time synchronization and a scheduling algorithm that enable a deterministic, low latency and reliable communication. By introducing this, 5Ghas paved the way for closed loop applications. For integrated networks, this feature brings a new dimension since it enables a communication domain that is dominated by wired technologies
until today. Since this feature is an essential part of 5G 3GPPreleases 16 and later, there are no products available yet.

III. 6G FEATURES

This section is supposed to give an overview of the currently discussed topics for 6G. Since this is an active research area, it is not yet known what of those features will be included in 6G. 6Gmobile communication will again pioneer towards higher frequencies and due to this opens up new possibilities. With higher frequencies, the physics change since there is less diffraction of the electromagnetic waves and consequently stronger shadowing effects. Additionally, the electromagnetic waves will have a higher path loss which results in lower cell coverage or higher needed transmit power. This higher path loss generally results in a smaller number of multipath components that are detectable and a dominating Line of Sight (LoS) component, which can be beneficial for e.g., positioning purposes. A benefit of these high transmission frequencies is the available high bandwidth and the resulting data rates that come along with increasing bandwidth and reduced latency due to shorter block lengths. It is important to distinguish between Sub 6GHz (5G Frequency Range 1) and mmwave communication (5G Frequency Range 2), since there are important differences - while, in Sub6, only the angle domain is resolvable accurately (considering antenna arrays), mmwave communication also enables accurate resolution in the delay domain. This high resolution in delay domain can not only enable the use to filter multipath components out but rather use this additional information (s.c. virtual anchors) to enhance positioning accuracy It could also be feasible to assume that, especially considering indoor environments that usually have a lower delay spread, a high resolution in the delay domain is crucial to resolve multipath components. This is due to the ability to differentiate closely spaced replicas of the signal produced by nearby reflecting surfaces. Interfering replicas do not affect the ranging estimation in case their relative delay is higher than the inverse of the bandwidth. This would be in case of 30GHz correspond to 1cm [10]. These physical properties come along with new challenges and new possibilities as the current research shows. A feature that is known from 5G as 5G Side Link Communication is also a research topic in 6G. Due to the limited cell coverage, 6G networks will need solutions to maintain a seamless connectivity. Therefore, 6G is supposed to get rid of the classical cellular network approach, called Beyond Cellular. The idea is that the coverage of the 6G network is organic and provides coverage to the needs of the environment. A network cell in this approach can be partially increased or decreased by exploiting high precision beamforming or 6G User Equipments (UEs), which are able to forward connectivity to UEs that are currently out of coverage. The forwarding can be achieved by enabling UEs to set up their own Ad-Hoc networks, also known in 5G under 5G Sidelink. In 6G this idea is taken further to the point of the complete absence of dedicated 6G core servers, by distributing the core services on various UEs and enable complete 6G networks without stationary backhaul equipment.

An already well discussed topic in 5G, positioning, is also a research topic on the 6G agenda. The high bandwidth enables a high time resolution, as shown with the Equation 1. It shows the autocorellation of the chirp signal, a signal that is often used for radar applications.

$$\langle s_{\tilde{c}}, s_{\tilde{c}} \rangle(t) = A^2 T \Lambda\left(\frac{t}{T}\right) sinc\left[\Delta f t \Lambda\left(\frac{t}{T}\right)\right] e^{2\pi i f_0 t} \quad (1)$$

Here, Δf stands for the bandwidth of the signal. It can be seen that increasing Δf also increases the factor for the argument of the *sinc* function and thus causes a narrower main lobe of the autocorrelation function. By doing so a higher time resolution of the signal is possible. This fact can be translated to position resolution for time measurements in positioning signals as Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Round Trip Time (RTT) or the granularity for differentiating echoes in radar systems. This example leads to the second important facet that was already mentioned, the usage of 6G as a radar sensor. In6G, radar is discussed in connection with Joint Communication and Sensing (JCAS), a concept where signals should be used as both, information carrier and radar echo-signal. This radar is supposed to have a high resolution due to the previously mentioned physical relation. In consequence it is supposed to enable a precise perception of the surrounding. By using the same signal for radar and communication purposes, a high up-date rate of the perception can be achieved and therefore should be useful for challenging use cases like safety in autonomous driving scenarios.

For the scope of communication, the following features are current points of interest in 6G research [11]:

- ubiquitous Mobile Broad-Band (uMBB)
- Ultra-reliable Low-latency Broadband Communication (ULBC)
- Massive Ultra-Reliable Low-Latency Communication (mULC)

To give more context to these features, the authors of [11] introduced a possible capability list for 6G, as shown in a condensed version in Table I.

TABLE I: POSSIBLE 6G CAPABILITIES ACCORDING TO BIN HAN ET AL[11]

Major Factors	6G	5G
Peak Data Rate	>100G/s	20G/s
Delay	<1ms	ms Level
Reliability	>99,999%	99,9%
Position Accuracy	Centimeter Level	Meter Level

These values are relevant for the following section since they give a first insight on what 6G might provide in terms of Key performance indicators. Furthermore, it can be seen that 6G peak KPIs are planned to be increased with the factor ten or more. The5G research already showed that these peaks proclaimed for 5Gare only reachable in a perfect environment and with settings that are optimized for one specific KPI benchmark. Hence, it can be assumed that—similarly to 5G— the 6G KPI predictions are peaks that will most likely not be achievable concurrently in real world use cases.

IV. RELEVANT INFORMATION CONSUMABLE BY 6G

First of all, it is important to mention that the list of information that this section will arise does not claim to be complete but should provide an understanding of the importance of these information for applications. In order to get a better under-standing, the relevant parameters will be distributed into two categories, where the first is communication meta information and the second parameter set will be summed up under sensing information.

A. Communication Meta Information

To differentiate a bit further, this set of information is already available inside a communication system and the efforts to provide that data to a third party are only caching and forwarding these information.

Relevant information in this category are the Signal to Noise Ratio (SNR) and the communication channel utilization since it helps an application to predict the communication behavior in the near future. The next steps that can follow are adaption mechanisms as e.g., increasing cycle times for an autonomous vehicle by decreasing speed and thus loosen the time restrictions for the control loop. By doing so, less channel load will be added and there is a higher probability that the application will endure a temporary channel deterioration without the need for switching into a failure mode.

Another important information explicitly relevant in time critical domains is the time synchronization, enabling the access to a common time base. For real time communication, this is a well known aspect and there are already, a lot of mechanisms to ensure synchronization in communication networks. Also5G has covered this within the standardization of URLLC. For applications that are using this network, the synchronized time is just as important, since it helps to ensure the correct processing of synchronized operational sequences.

To conclude, another information that can be provided is the power status information for battery driven UEs. For a scenario, where a centralized controller needs to manage multiple autonomous vehicles, this information is needed and since it is available, at least in previous generations of mobile communication, an additional exchange of the same information can be spared.

B. Sensing Information

This subsection gives an overview of the information that can be derived by the communication network with the necessity of an active sensing process to generate the information. An important aspect here is the positioning information that can be measured by the 6G network. In a mobility scenario this information is very important and even if there are restrictions with the coverage, the information can still be used to interpolate with other positioning information and thereby achieve higher precision or higher update rates, which can be useful in critical traffic scenarios as big parking lots or traffic lights.

The radar information as already mentioned can be used for environment perception purposes. Accordingly, autonomous driving is most likely the most relevant use case. In high density areas, it is also possible to merge differently perceived 3D Point Clouds in order to get a more detailed 3D map of the environment. This can be used to get more detailed information such as movement prediction for pedestrians, that are currently out of the the view range. In an industrial environment, it can be assumed, that 6G can be used as a high precision positioning system for a limited area, in which critical processes are realized. This might be an area, where humans collaborate with mobile robots. Furthermore, it is necessary that there is still a backup technology, that serves a seamless position information also between high precision areas. Technologies that are feasible for these purposes are e.g., Ultra-wideband (UWB) positioning, Supersonic positioning, GNSS, differential GNSS or 5G positioning as this technology might serve a better coverage. Important here to mention is the seamless data flow of the positioning information. Therefore, it is very important to integrate the sensing information derived from mobile communication systems into a higher-level position management system.

C. Relevant Information Consumable by 6G

The information mentioned in the preceding section and additional information that might be available need to be investigated for deriving control and management decisions for the 6G network itself. This section is supposed to highlight novel beyond state of the art approaches.

An aspect that can be envisioned here is to use the position information in order to focus the communication beam. The techniques that are performed in 5G for this purpose are based on pilot signals in order to distinguish the reachability of a UE for different beams. In 5G this procedure has another important reason because beams experience diffraction and reflection and due to this, it is not trivial to derive the correct beam by having only position information. Since these physical peculiarities change with higher frequencies it can be assumed that the position information is sufficient to determine the correct beam direction. Furthermore, a frequent position update can be used to derive movement predictions and as a result can be used to determine the best beam for subsequent transmissions. This aspect can be handled by only processing the information derived by the 6G network. In a network where positioning is assumed to be necessary, it is highly probable that more positioning technologies are used in order to have a seamless position information. By forwarding this position information to the 6G network, it can be used to predict the access of a UE to the cell and therefore prepare mechanisms that accelerate the communication establishment like the determination of the correct beam. Furthermore, the beyond cellular aspect has to rely on positioning information that are derived outside of the 6G network since the purpose is to connect exactly these UEs that are currently not covered by a base station. Hence it is important for connecting not only UEs that are leaving the current coverage but also UEs that are accessing potential coverage zones.

Combined with a certain environmental know how, as it can be assumed in an intralogistics use case, these information lead to a network estimation since the amount of UEs can be anticipated for the near future, if you leave UEs that are switched on or come back out of standby out of consideration These inchoate information of future network clients can still be used to approximate a potential network load by using context information of the use case. Having this information, it can be used to optimize the network behavior since bottlenecks can be predicted and countered with offloading mechanisms or change of the network capacity, like increasing the bandwidth.

V. Information Exchange Concept

The previous sections were focusing on features that need to be changed for the development of 6G. This section rather aims on how to change todays mobile communication in order to reach these challenging goals. A key for an easily integratable and adaptable communication system will be the ease of use for creating additional functionality and accessibility of information, to make it a fully integrated communication system. As already stated, 5G has already paved the way in the right direction, with implementing the SBA and SBI. These concepts will also be transferred and reused in this concept.

With a new approach, this can be taken one step further by using an abstraction of the inter service communication. The idea is to create a context aware communication management system to setup connection between the services, as it was introduced by the authors of [12].

In a first step, a new service is introduced to the architecture, the Interconnection Framework (IcoF) that is the central instance for handling connectivity details for the NFs, external applications and sensing information. The IcoF has a list of all 6G services and their addresses and gets updated by new incoming services. Furthermore, will this knowledge base be extended with entries for the available sensing data from the 6G system itself and external sensors. These entries are not supposed to have the actual updated sensing data but the address of the sensing soft- or hardware and a context of the data. This connectivity information will then be extended with an individual topic identifier.

Each service can subscribe or publish to a topic with the restriction that for publishing, the service has to be the owner of the topic or has to be authorized to do so. For this purpose, the implementation of a central authorization function is necessary. By subscribing to a topic, which might be called "AMF-API-address", the subscriber will be updated with the current address of the AMF API. In case that for example the AMF changes the server, or a new AMF is deployed, the connected services can be redirected to the new address. A distribution of these information is also handled by the Context Management (CoMa). The IcoF will then replace the function of the Network Repository Function (NRF), which is responsible in the 5G SBA for providing these connection information and further context information. The NRF is already doing subscription-based updates for clients and accordingly is already handling some of the previously mentioned tasks. The reason to switch to an publish subscribe mode via a dedicated IcoF is the increasing core dynamics and information flow of 6G systems as stated in section III.

An architectural transition from 5G to 6G and the adaption of the IcoF is shown in Fig. 1 and 2.

On the one hand will the new IcoF also replace the NEF, which is responsible for making core functions externally available. This can be done since the IcoF will also come along with security features that enable authentication & authorization and different access levels to distinguish core functions and external functions as visualized in figure 2 with the color transition in the IcoF. On the other hand, the IcoF is also handling the sensing information provided and consumed by 6G. By doing so, the IcoF is the platform that is needed to enable interaction of core and external services and at the same time is capable of delivering the relevant information for the services. Needless to say, that in this case the whole SBI can also be tunneled over the IcoF.

The architecture is now enabled to simplify the implementation of new functionalities and the acquisition of information. Needed information can be consumed or distributed by subscribing or publishing to relevant topics.

The GMLC as it is used in NPNs will be replaced by a Positioning Sensor Fusion Platform (PSFP). The platform differs from the GMLC in its ability to integrate dedicated positioning solutions. Where the GMLC can only provide information supported by 5G, the PSFP will also be able to integrate other solutions such as UWB or ultrasonic systems that might be integrated in an e.g., industrial plant and merge their data.

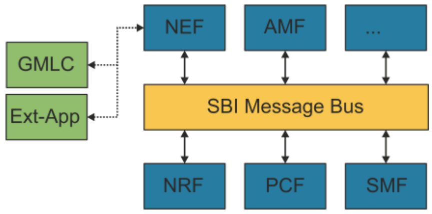

Fig. 1. 5G Service based architecture

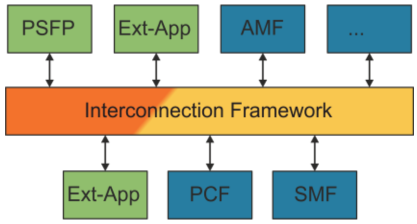

Fig. 2. 6G Future Architecture for integrated networks.

VI. Extendibility with Other Communication Technologies

Using the context manager to connect all the 6G services and external services leads to the next concept that will be introduced in this section. Concepts already well known to mobile communication is the Offloading. It enables a crowded communication cell to exploit another communication technology for distributing the work load. In mobile communications, this was done and standardized with Wi-Fi. There are reasons why this gets more complicated in 6G. First of all, 6G will have to handle time critical traffic, offloading this to Wi-Fi will destroy all reliability for time restrictions, since Wi-Fi has only unlicensed spectrum. Even though this is another research topic and Wi-Fi is planned to enable time critical traffic in the future this is not the focus of this section. The point is that an offloading mechanism has to be context sensitive and a 6G system should not be able to decide which traffic to offload. This leads to the concept of a centralized traffic scheduler that manages various communication technologies. In this concept, there is no hierarchy between the communication systems as it is with the previously mentioned Offloading concept. All available communication technologies will build up on the same IcoF. By doing so, they will be able to share functions like authentication and authorization functions and due to this have the same trustzone. In consequence, a fast change of the communication technology for the clients is enabled. For time critical traffic, there will be a central scheduler that is aware of communication technology restrictions as well as traffic requirements. That combination enables a context sensitive distinction of communication technologies for traffic and assures time critical traffic to get transmitted reliably.

VII. Conclusion and Future Work

This paper has shown the necessity for integrated communication networks for critical environments like industry, autonomous driving or agriculture. A leading idea was to show the gap between what was already achieved by established communication technologies and what can be achieved by future communication technologies like 6G. The concept described from section VI on shows one possible way to go for enabling 6G to be an integrated network.
There are lots of advantages that are coming along with adapting to this concept. Further research will use this concept to exploit the awareness of the positioning information to make a predictive scheduling for information in the pipeline or adding redundancy by using several communication channels in parallel.

Conflict of Interest

The authors declare no conflict of interest.

Author Contribution

Christoph Fischer, conceptualization, aggregation, 6G research, writing draft. Dennis Krummacker, conceptualization, Software concept and implementation focus. Maximilian Berndt, conceptualization, Focus on 5G aspects. Hans D. Schotten, research/ relevance alignment, review, collaboration in design. All authors had approved the final version.

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