Service Based Architecture Study

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CONTENTS

1. INTRODUCTION

1.1. Goal of the Paper

This Paper will talk about on the principles of Service Based Architectures by comparing it to its enabler technologies. It will provide a general overview why to use SBA as in what are the advantages and limitations of this Architecture style and focus on the growing need of reliable dynamic products. Especially focusing SBA in the 5G-Core.

1.2. Technologys Surveyed

Service Based architecture (SBA) is a style of software design where services are provided to the other components by application components, through a communication protocol over a network. The basic principles of service Based architecture are independent of vendors, products and technologies. A service is a discrete unit of functionality that can be accessed remotely

The concept of distributed services, which form a modular system, is well known from SOA- and Microservices.

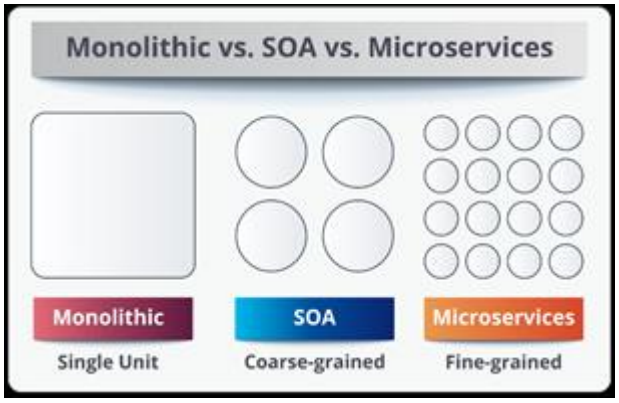
Service Based Architectures are usually mentioned in context of the 5G Core Network.

1.3. Taxonomie

The idea of constructing software as an orchestration of services is not new. At the end of the 1990s, triggered by increasingly complex IT systems and the invention of Web services, which were originally controlled by Microsoft and became publicly relevant in the year 2000, many new concepts emerged under which SOA prevailed at the application level. (Josuttis, 2009)

This resulted in a paradigm shift: from a centrally managed, "container"-like structure (also called Monolithic) to a freer collection of independent and more flexible services. In practice, this has led to a new combination of departmental and project-oriented organizational structures.

The principle of "microservices", however, emerged much later and can be seen as a further development of SOA: SOA uses services to integrate various applications. These services are combined by orchestration or choreography, allowing portals to provide a common user interface (UI) for all services. Microservices, on the other hand, structure an application through services. Each microservice can contain a user interface and implement business processes such as those found in SOA in orchestration.



(Samarpit, 2019)

The other subject that should not be forgotten when considering the 5G Core Network is the 4G Evolved Packet Core. To be investigated is: How does the architecture of the new core network differ from its predecessors? What are the reasons for these intended modifications? And does SBA, which, as already mentioned, was originally only designed for the development of applications, lead to process optimization in mobile network management?

1.4. Motivation

New generation 5G architecture is unique in many ways. Normally 3GPP followed the same model of development for 2G, 3G and 4G, where we have seen different reference point core architectures, but in the 5G Core Network everything is intended to be based on Service Based Interfaces and APIs. (Mitra, 2018)

Using Service Based Architecture as an architectural style promises scalable resource management, cost and availability to be optimized.

2. SBA IN CONTEXT OF 5G CORE NETWORK

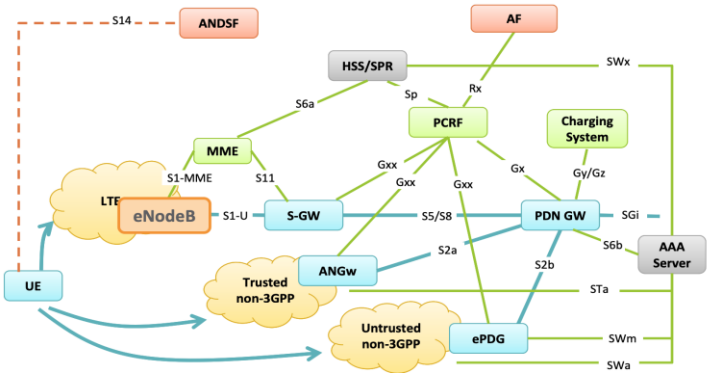
In this part, the essential technologies and ideas that are brought together in the 5G-CN are briefly described and analysed with regard to their advantages and problems: Which problems remain and which will be eradicated by the merge? Will there may even be new problems?

2.1. Enabler for the Paradigm SBA in 5G

2.1.1. 4G Evolved Packet Core

The Evolved Packet Core (EPC) is a framework for providing converged voice and data on a 4G Long-Term Evolution (LTE) network. It is composed of different components which are connected via a point-to-point integration.

The specific task of the components is not important for this paper the basic functionality is however similar to the 5g core network. (Rouse, 2011)



(Magedanz & Corici, 2019)

In system integration, by point-to-point architecture we usually mean direct connection between applications. The calling application has to know the parameters to pass and the exact address of the application it invokes. All this information is usually configured or even hard-coded.

The applications can be located on the same computer or in data centers on different continents. This lead to a very static, jet efficient design since it does not require any intermediary software in order to provide address translation.

The static characteristics of this architecture became a problem in recent years since there is a growing need for flexibility in terms of address translation and data format flexibility. Since the location of applications or even the applications itself can change constantly with remote or third party services.

In practice a lot of configurations were not designed to be done remotely but rather on the host device itself. (Noriskin, Olechko, & Dovgal, 2014)

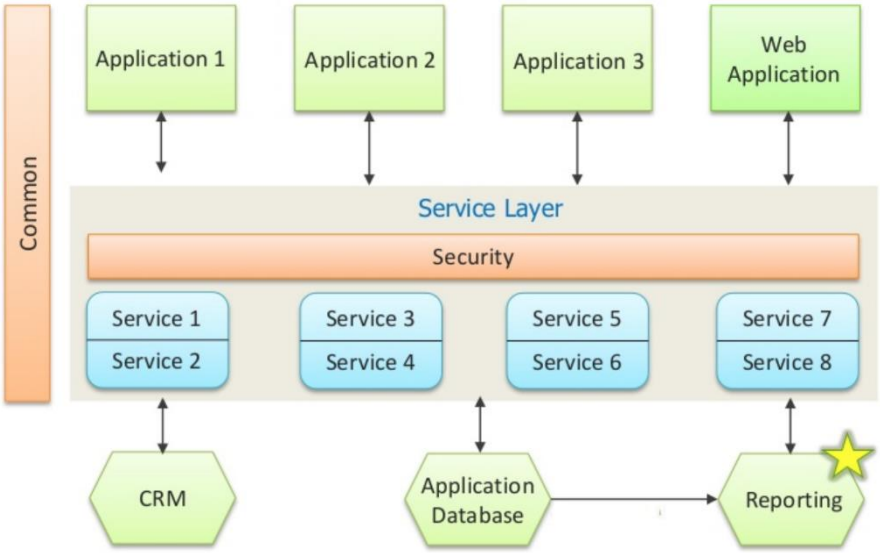
2.1.2. Service Oriented Architecture

Short Overview

A service-oriented architecture (SOA) is an architectural pattern in computer software design in which application components provide services to other components via a communications protocol, typically over a network. The principles of service-orientation are independent of any product, vendor or technology. SOA makes it easier for software components over various networks to work with each other.

Web services which are built as per the SOA architecture tend to make them more independent. The web services themselves can exchange data with each other and because of the underlying principles on which they are created, they don't need any sort of human interaction and also don't need any code modifications. It ensures that the web services on a network can interact with each other seamlessly.

This flexibility and loose coupling is a fundamentally different approach to connecting different system components compared to point to point architectures.



(Edureka!, 2015)

Opportunities through SOA

Service Reusability: services can be reused in multiple applications independent of their interactions with other services.

Easy/More reliable Maintainability: A service oriented architecture can be easily updated or maintained without having to worry about other services. Large, complex

applications can thus be managed easily. Small, independent services are easier to test and debug as compared to massive chunks of code.

Location Independence: The services are usually published to a directory where consumers can look them up. This approach allows a service to change its location at any time.

Improved Scalability and Availability: Multiple instances of a single service can run on different servers at the same time. This increases the scalability and availability of the service.

Improved Software Quality: Since services can be reused, there is no scope for redundant functionality. This helps reduce errors due to inconsistent data, and thereby improves the quality of code.

Platform Independence: SOA facilitates the development of a complex product by integrating different products from different vendors independent of the platform and technology.

Obstacles of SOA

Increased Overhead: Due to the distributed structure, many messages are required for interaction between the services. For an error-resistant architecture, a complete validation of each input parameter is necessary. This results in an increased workload and, finally, an increased response time. It is difficult to maintain high performance, so SOA cannot be used to implement a real-time application.

Complex Service Management: The service needs to ensure that messages have been delivered in a timely manner. But as services keep exchanging messages to perform tasks, the number of these messages can go into millions even for a single application. This poses a big challenge to manage such a huge population of services.

High Investment Cost: Implementation of SOA requires a large upfront investment by means of technology, development, and human resource. (Takale, 2018)

2.1.3. Microservices

Microservices - also known as the microservice architecture - is an architectural style that structures an application as a collection of services that are

I. Highly maintainable and testable

II. Loosely coupled

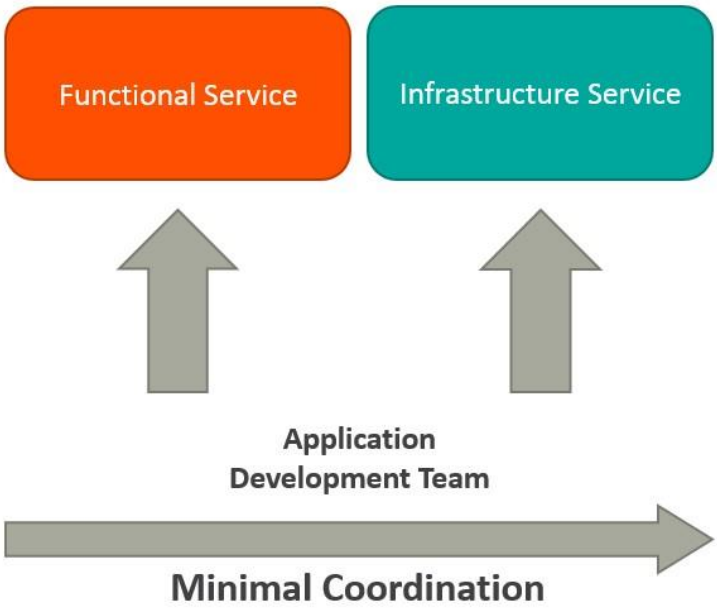
III. Independently deployable

IV. Organized around business capabilities.

The microservice architecture enables the continuous delivery/deployment of large, complex applications. It also enables an organization to evolve its technology stack.

Microservices Architecture (MSA) and Service-Oriented Architecture (SOA) both rely on services as the main component. But they vary greatly in terms of service characteristics.

MSAs have limited service taxonomy. The architecture consists of two service types as depicted below.



(Watts, 2017)

Functional services support specific business operations. The services are accessed externally and they are usually not shared with any other service. As in SOA, infrastructure services implement tasks such as auditing, security, and logging. The services are not exposed to the outside world and they are available internally. (Watts, 2017)

In conclusion, microservices represent an increasingly popular style of application architecture. From a DevOps standpoint, they are a mixed blessing due to the relative ease and reduced liability of deploying individual components coupled with the increased complexity of managing a larger number of components that grow and change on varying schedules. (Hubbell, 2018)

Key Differences Between SOA and MSA

Microservices are very **agile and allow Fast Development** since they allow to iterate on a very small, focused piece of functionality quickly and to see results. (JAX, 2016)

Testing: Microservices in isolation is quite easy because there isn't a lot of functionality in a single microservice however testing the whole system requires a consumer-driven contract model, it's the consumer's responsibility to provide a suite of tests that specify what types of interactions are needed and in which format. Your service would then agree to this contract and ensure that it's not broken. (Richardson, 2018)

In order to satisfy scalability and availability requirements we must run multiple instances of the application on multiple machines, and in microservice case: small, independent services are easier to scale.

Microservices have Medium performance because of the increased Overhead in the service to service communication caused by the validation of the input parameters the response time and machine load is increased and so it is not suitable for real-time applications.

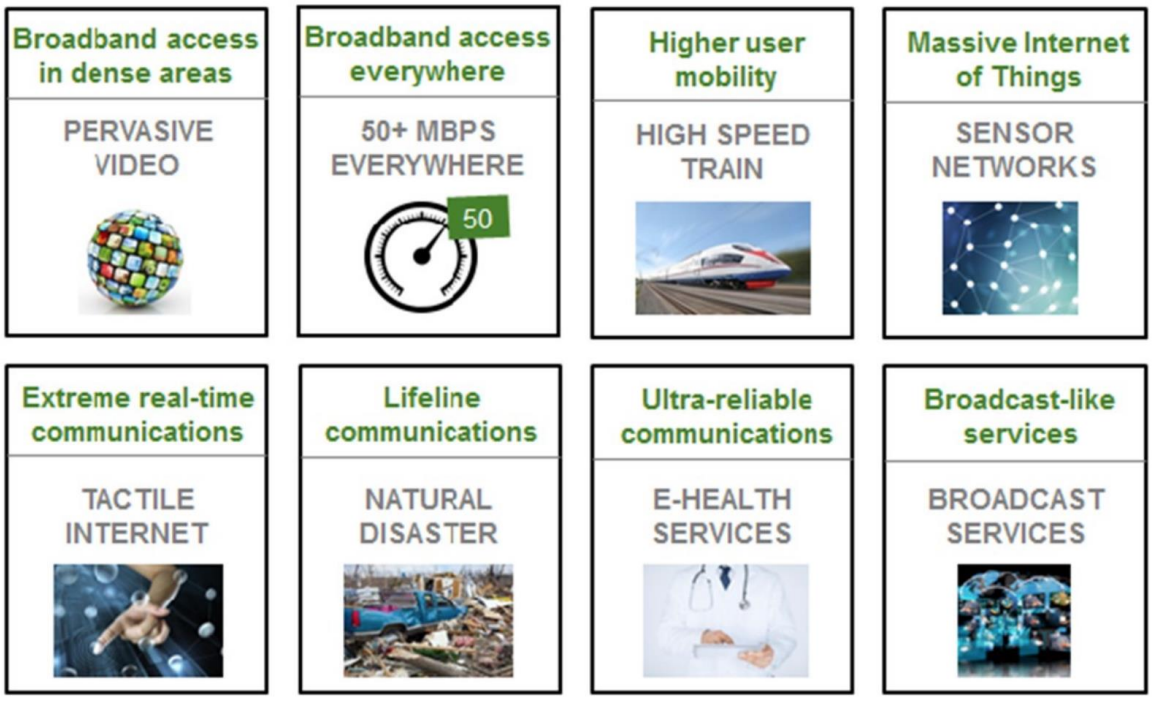
Architecture / Criterion	µ-service architecture
Agility	High
Deployment	High
Testability	High
Scalability	High
Performance	Medium
Simplicity	Medium

(Bessem, 2018)

Since the system consists of many independent microservices, it can be hard to comprehend depending on how many different microservices are connected to each other. However, the microservices themselves are simple to understand for lack of its requirements. (Bessem, 2018)

2.2. Future Goals of Mobile Networks

There is nothing fundamentally wrong with the current mobile network architecture and therefore it will not be immediately replaced by the 5G network, but there is much room for improvement to accommodate more capabilities.



(Magedanz & Corici, 2019)

NGMN defined the need for several use case families with very different needs towards the network in terms of latency, bandwidth and connectivity.

Comparing for example massive Internet of Things with the need for data rates of only 1-100 kbps and latencies up to several hours to extreme real-time communications with intended data rates of 50 Mbps and delay of less than 1 ms.

To accommodate these different application requirements the 5G network has to be very agile compared to the monolithic point-to-point driven 4G EPC.

The use case families serve as an input for stipulating requirements and defining the building blocks of the 5G architecture. The use cases are not meant to be exhaustive, but rather as a tool to ensure that the level of flexibility required in 5G is well captured.

In The 4G EPC there was no way to make individual changes to the networking in order to make it more suitable for specific tasks. In future networks this flexibility is needed. (Wang & Sun, 2018)

2.3. 5G Core Network

Short Overview

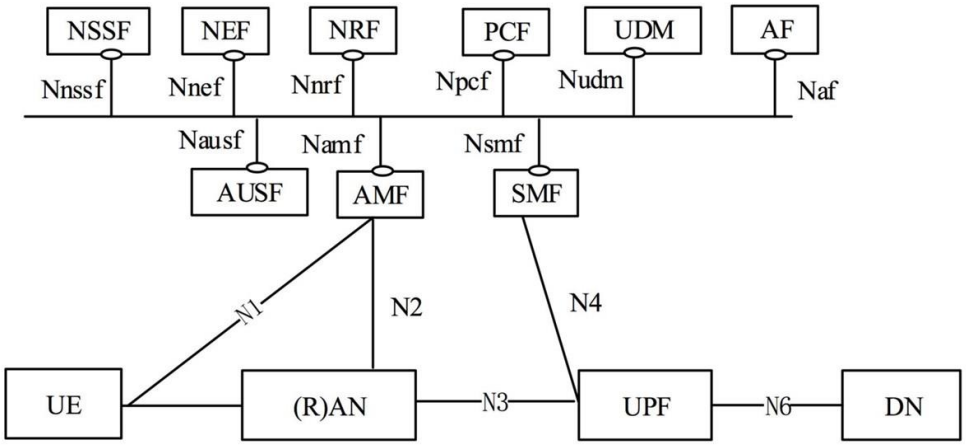
To support the diversity of use cases and requirements, the system design should move away from the 4G monolithic design optimized for mobile broadband. In this regard, a rethink of models [...] is needed. (Wang & Sun, 2018)

With this idea in mind, 3GPP decided to basically restructure the 4G EPC during the standardization process of the 5G Core Network according to the principles of Service Oriented Architecture and Microservices.

Control plane functionality and common data repositories of a 5G network are delivered by way of a set of interconnected Network Functions (NFs), each with authorization to access each other's services. Assuming the role of either service consumer or service producer, Network Functions are self-contained, independent and reusable. (Dredge, What is the 5G Service-Based Architecture (SBA)?, 2019)

The communication, according to the 3GPP, is carried out via the so-called Service Based Interface (SBI) which connects all the control-plane functions. This Bus like connection enables each service to be directly connected to any other service if required. In the initial release each Network Function service exposes its functionality through a Service Based Interface , which employs a well-defined RESTful APIs using HTTP/2 over TCP. (Brown, 2017)

The decision to use RESTful APIs was made since the functional exposure functionality (which allows external developers to change the networks behaviour as they need it) also use RESTful APIs to communicate with the Network Exposure Function, thus allowing a harmonized and holistic technological approach of the complete 5G system. (Mayer, 2018)



(Arkko, 2017)

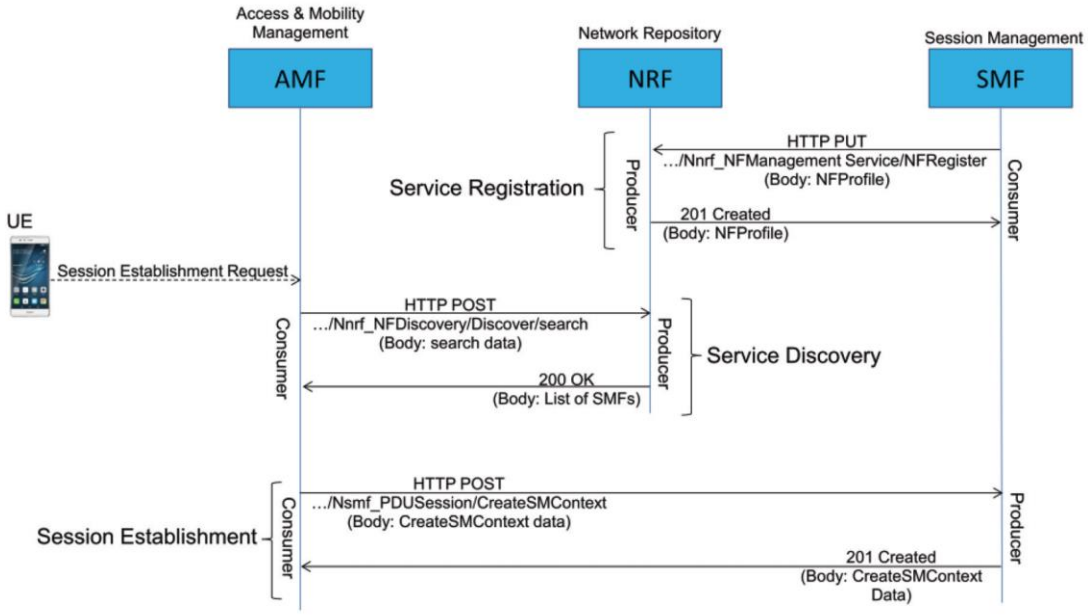
Some key principles and concepts from the current standardisation 23.501 of 3GPP (3GPP, 2019) in context of SBA are to:

- Separate the User Plane (UP) functions from the CP functions, allowing independent scalability, evolution and flexible deployments e.g. centralized location or distributed (remote) location.
- Modularize the function design, e.g. to enable flexible and efficient network slicing.
- Wherever applicable, define procedures (i.e. the set of interactions between network functions) as services, so that their re-use is possible.
- Enable each Network Function and its Network Function Services to interact with other NF and its Network Function Services directly or indirectly via a Service Communication Proxy if required. The architecture does not preclude the use of another intermediate function to help route Control Plane messages (e.g. like a DRA).
- Minimize dependencies between the Access Network (AN) and the Core Network (CN). The architecture is defined with a converged core network with a common AN - CN interface which integrates different Access Types e.g. 3GPP access and non-3GPP access.
- Support a unified authentication framework.
- Support "stateless" NFs, where the "compute" resource is decoupled from the "storage" resource.
- Support roaming with both Home routed traffic as well as Local breakout traffic in the visited PLMN.

How SBA uses the Service Based Interface

To illustrate the principles above the following is an example in order to show how a typical procedure in the 5G core is carried out.

It explains how a User Entity (UE) is introduced to a Session Management Function.



(Mayer, 2018)

The Network Repository (NRF) is a key component in the dynamically organised SBA as it allows services to make themselves available if they are available.

There are multiple Network Repositories in the 5G core, they know each other and work similar to Domain Name System. (EventHelix, 2018)

The 5G **Session Management Function (SMF)** is a fundamental element of the 5G Service-Based Architecture (SBA). The SMF is primarily responsible for interacting with the decoupled Data Plane, creating updating and removing Protocol Data Unit sessions and managing the session context with the Control Plane. (Dredge, What is the 5G Session Management Function (SMF), 2019)

There are several SMF in the system. The right one is chosen based on the user's needs and use case.

Access Management Function (AMF), which serves as the single-entry point for a user equipment (UE) for all its communication.

There are several AMF in the system. Depending on the position and network slice the user entity will be assigned to one of them.

The discovery process can be divided in three steps:

1. Service Registration: As soon as the SMF comes to live in the system the SMF registers the services it provides with the NRF.
2. Service Discovery: the AMF queries the NRF for a suitable SMF and in return receives the address of the SMF which has registered before (step 1).
3. Session Establishment: the requested session is established via the SBI by the AMF via the SMF.

Opportunities through Service Based Architecture

First of all, let's take a quick look again at the problems with 4G:

(I) very static (jet efficient) design

(II) growing need for flexibility in terms of use cases, address translation and data format flexibility.

(III) Difficulties with updates/maintenance/integration of new functions

(IV) Location-bound nature of administrative functions

Will these issues be solved in 5G by the features of SOA/Microservices?

Are there further advantages of SBA?

Improved Scalability and Availability

Tens of billions of smart devices will use their embedded communication capabilities and integrated sensors to act on their local environment and use remote triggers based on intelligent logic. (El Hattachi & Erfanian, 2015)

In order to keep a system as high performing as possible but at the same time as lucrative as possible (electricity costs, maintenance costs,...), the effort must always be adapted to the demand. Since it is assumed that the number of UEs will increase significantly in the future, a scalable structure is indispensable.

"Service Based architectures are definitely easier to scale than monolith but get kind of a medium [position] in this particular range because we have in service based approaches split up the application into multiple pieces so we have different applications and in this particular case we can scale each portion of this application much easier than we can with a monolith. [...] However the Microservices Architecture definitely wins this particular characteristic. because we have such fine-grained services, we have the opportunity to do even more fine-grained scalability within each of the services." (Richards, 2015)

Location/ Platform Independence

By connecting the different services over the SBI it does not matter were a virtualized service is hosted or by whom it is provided as long as it is able to connect to the 5G core Network. (Krishna & Vyakaranam, 2018)

Easy Maintainability

Easy maintainability is achieved through a fine-granulated separation of services. This allows individual services to be upgraded with minimal impact to other services.

For example, in case there is an issue in one of the network repository functions it can be solved and deployed while other working network repository functions are still in operation. There will be no downtime of the network since componence can be swapped out without a retouch of the whole system. (Bessem, 2018)

Open Extensibility

For extensibility the same applies as for maintainability so new features can be easily and continuously deployed. Together with some management and control functions (i.e. authentication, authorization, accounting) external users such as 3rd parties can get access to the information about a 5G network through a specific service without complicated protocol conversion. This achieves better integration and a reduced time-to-market.

By providing access to the core network partners would be enabled to implement propositions. This will allow faster development and launch of these partner services at the benefit of all. (Bessem, 2018)

higher flexibility, programmability, automation and significant cost/energy reduction

The network is composed of modularized services reflecting the network capabilities and provides support to key 5G features such as network slicing.

A service can be easily invoked by other services (with appropriate authorization), enabling each service to be reused as much as possible.

5G core platform will be more programmable and allow many different functions to be built, configured, connected and deployed at needed scale. Each functionality shall be able to upgrade according to new requirements and scale-out according to system capability, without affecting other functionalities. (Bessem, 2018)

Obstacles of Service Based Architecture

Complex Service Management/Delay

This issue of real-time communication was critical in the research by Moreland Jr (2014), which reported on the US military's use of real-time communication for combat warships. Moreland highlighted the need for more research about the efficiency and challenges of real-time communication for SOA.

Since SOA is the more explored predecessor of SBA and a lot of future network use cases should have quite similar technical demands as combat warships the latency problems caused by the overhead typically caused by service oriented or based networks it will be an obstacle that has to be overcome. (Knutsson & Glennow, 2015)

This problem could be reduced by introducing a more efficient network protocol. Under discussion is QUIC, an experimental transport layer network protocol initially developed by Google that improves the performance of connection-oriented web applications currently using TCP. Due to its importance, it is also called "HTTP/3", inspired by IETF in October 2018. (Grüner, 2018)

High Investment Cost

The implementation of SOA requires a large upfront investment by means of technology, development and human resource.

SOA requires significant up-front investments, and in return, promises a vast array of benefits. Unfortunately, in contrast to the costs of the investment, monetary benefits associated with SOA are more difficult to measure. For one reason, benefits such as increased agility or improved flexibility are elusive in nature, making it harder to define metrics for their calculation. (Ilk, Goes, & Zhao, 2010)

Security Concerns

New cloud/virtualization technologies such as software-defined networking (SDN) and network functions virtualization (NFV) are thriving in anticipation of 5G networks, but they too come with new security concerns. Because of their open, flexible, programmable nature, SDN and NFV open up a new avenue of security threats. For example, a network element of an SDN such as the management interfaces could be used to attack the SDN controller or management system and bring down the system.

"A major paradigm shift in 5G is the move away from "signalling" interfaces and protocols (SS7, Diameter) towards a modern "Service Based Architecture" (SBA). Core network functions in SBA will offer REST APIs (with information elements in JSON objects), both internally and externally. Network architects hope to reap benefits like

efficiency, scalability, modularity, and flexibility from using modern web techniques – but ***security experts fear that this also brings new weaknesses, while existing inter-operator issues remain unsolved."*** (Schröder, 2018)

Stefan Schröder *primary delegate of Deutsche Telekom in the 3GPP security group SA3 for fifteen years (has been working on security standards for UMTS, LTE, IMS, Femtocells, 5G, and others) and more…*

3. CONCLUSION

It is always difficult to predict whether the benefits and performance requirements will be met by systems under development.

The expected increased development expenditure and the high costs to be expected as a result of it shouldn't be a limiting factor in the context of important infrastructure systems.

Especially since these increased upfront expenditure will be harmonized by minimizing the network load cost as well as data centre resources cost by finding the optimal placement of the data centres. (Basta, et al.)

Not being able to fully test a flexible system will always be an obstacle that won't be overcome completely. However automated testing should keep the necessarily workload manageable.

Time will show whether the overhead in the communication data leads to handlebar problems in the network, we assume that this problem is solvable. since the means of communication is interchangeable so an nonperformant solution can be swapped out.

The security architecture of all systems, in particular of fundamental infrastructure Projects, has to be anchored in the principles of development from the beginning.

According to our sources (3GPP, 2019) (Schröder, 2018) (Knutsson & Glennow, 2015) there are a lot of problems to be solved as soon as possible.

Security should also be regulated by politics since it is mostly not immediately in the financial interest of provider's to care about security.

As a result of the possibilities to virtualize the system and to keep the different services interchangeable in functionality and location, there are the advantages of a fast and flexible development, a scalable resource management, the feasibility of a cost and availability optimization and the open extensibility.

Even if the predictions about the required performance of the system are accurate, new use cases (due to new inventions, ...) may occur in the medium term and the system requirements may change significantly. Therefore, a flexible structure is very important.

This leads us to the conclusion that a 5G Core Network structured as a Service Based Architecture will provide a sustainable basis for the mobile internet of tomorrow.

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