Status of Next Generation (5G) Architecture Study in 3GPP SA2

August 2016
Adithyan Ilangovan, Waqar Zia, Eiko Seidel
NoMoR Research GmbH, Munich, Germany

Summary

The System and Service Aspects – Architecture group (SA2) of 3GPP has a dedicated study item for the study of the next generation networks. It is expected that this work will form the basis of the system architecture for the future 5G networks. Within SA2 group, regular meetings and discussions are held to discuss the progress of this study item. NoMoR Research follows these activities. This report presents a condensed summary of the earlier mentioned study item, including the latest updates from the most recent meeting held in Vienna, Austria from 11th – 14th July, 2016.

Introduction

The 3rd Generation Partnership Project (3GPP) is an organization that works on standardizing the telecommunication network technologies. Within 3GPP, the study for the next generation (NextGen) mobile networks[1] has officially begun with start of work on the Release-14 specifications[2]. 3GPP has released a tentative time-line for the completion of specifications for 5G networks [1] and this is shown in Fig. 1.

As it can be seen in Fig. 1, 3GPP has decided to submit the final 5G specifications by February, 2020 to the ITU-R to become part of the IMT-2020 access technologies. There are various groups within 3GPP working together to meet the above mentioned target. Among the different groups, SA2 group is in charge of developing the system architecture. The activities of SA2 group include identifying the main functions and entities of the telecommunication network, and further also deciding how these entities are linked to each other. This paper will focus on the 5G activities of the SA2 group.

In the above mentioned Release-14 specifications, the SA2 group has explicitly dedicated a study item for the architecture of NextGen mobile networks. This study item is titled as "*Study on Architecture for Next Generation system*" and a technical report of this study item is publicly available [2]. The technical report is currently updated with every SA2 meeting [3]. The most recent SA2 meeting was held at Vienna, Austria from 11th July – 14th July 2016. In this report, we summarize the study item "*Study on Architecture for Next Generation system*", including the significant developments from the recently held SA2 meeting.

[1] In this paper, the term 5G and next-gen shall be used interchangeably.

[2] Features for telecommunication networks are incrementally added in different stages known as *releases*.

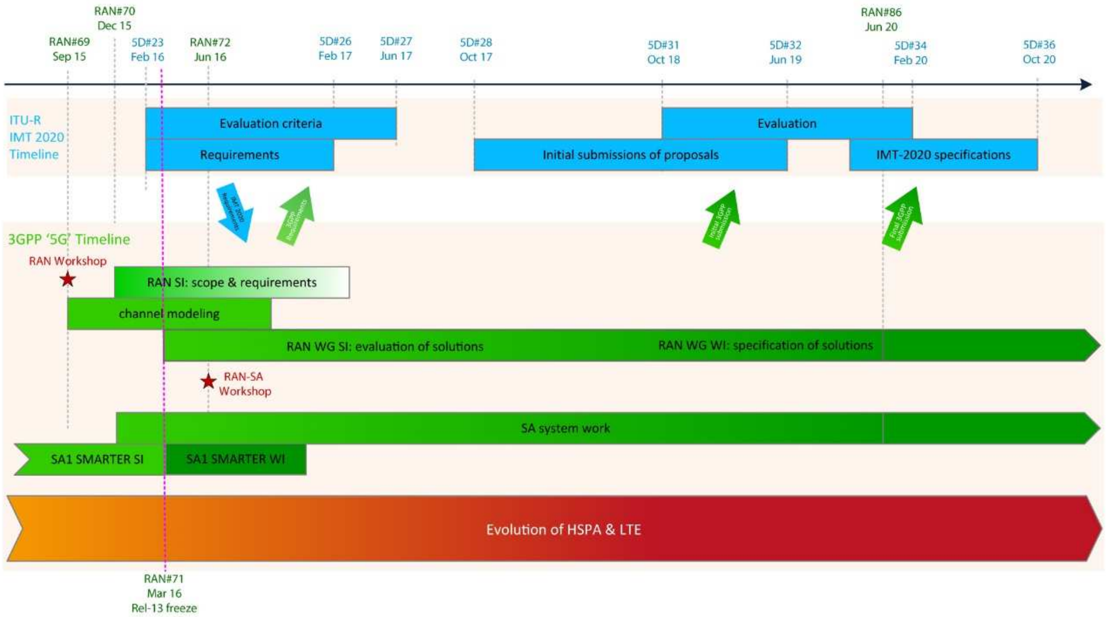


Figure 1 Timeline for 5G [1].

Overall plan

Study items within 3GPP, in general, have their own execution plan. First of all, it is important to understand the overall working plan for the *"Study on Architecture for Next Generation system".* This will provide us a high-level understanding of this particular study item. The work plan for this consists of two approaches that work simultaneously, namely:

1. Top-down approach
2. Bottom-up approach

Top-down approach

In the top-down approach, first of all a consolidated overall 5G architecture is proposed. The main focus of this consolidated architecture is to identify the different generic network functions[3] (NFs) and the related interfaces, within the architecture. Example of some of the identified generic NFs are:

- Mobility management control function
- Authentication function
- Policy control function

In this approach, the detailed functional aspects and behavior of how each NF behaves is not discussed. The goal is to provide a high-level modular reference architecture for the NextGen system. This idea is depicted in Fig. 2. As it can be seen from the figure, NFs that will become the functional building blocks of NextGen network are first identified and next the interfaces between NFs are assigned a name. To sum it up, in this approach only building blocks of the future 5G network are identified, not how each of the blocks behave. The different proposals for this approach will be later discussed in Section "Options for the overall architecture".

Bottom-up approach

[3] Network function is a processing function in a network, which has defined functional behaviour and defined interfaces.

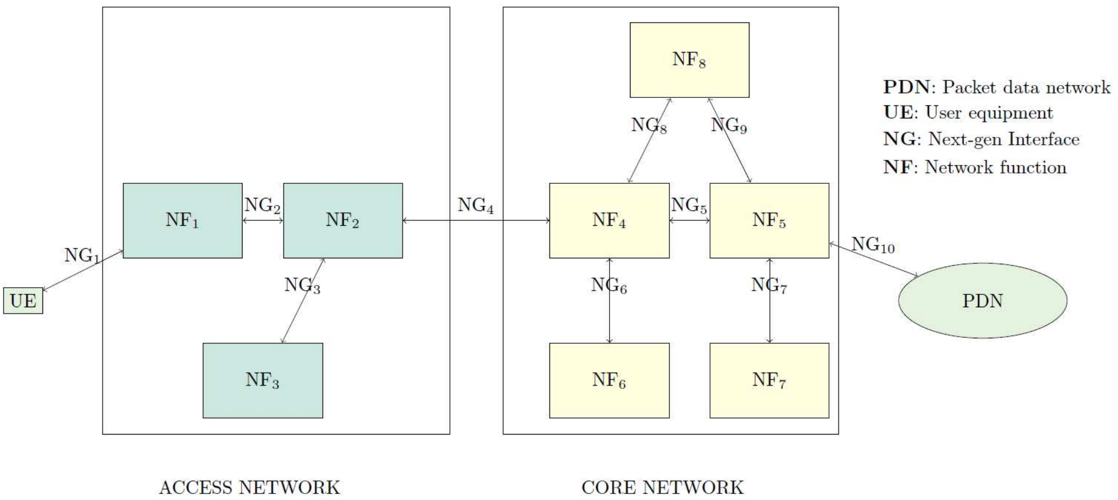


Figure 2: Top-down approach of identifying network functions and the next-gen interfaces. Only an overall high-level architecture is proposed in this method. Network functions (NF) will be the building blocks of the future networks.

This approach in contrast to the previous one, approaches the problem from bottom-up. Guided by the service requirements to be met by 5G network [4], this approach first identifies "Key issues"[4] for the future networks. For example, one of the key requirements is to meet diverse use cases (e.g. Internet of things, Enhanced broadband, critical communication) on top of the same 5G network. "Support of network slicing" (explained in later sections) has been identified as a "key issue"/solution for this particular requirement. Several such "key issues", that are meant to address different requirements are identified.

After identifying the key issues, detailed architectural solutions specific to each key issue are proposed. Typically, the architectural solutions for key issues, will contain NFs and interfaces that are only specific for it. Additionally, the functional aspects of each NF within the architecture is explained in detail. Also, the signaling flow between the different NFs is also discussed. This idea is depicted in Fig. 3. For example, an architecture for the "Support of network slicing" will have a NF in the Access network that is unique to it. This NF could have a "Network slice selection function" that decides which network slice to allocate depending upon the user requirement. It is important to note that the NFs proposed here need not necessarily be one of the NFs proposed earlier in Top-Down approach (see Fig. 2).

To sum it up, this approach identifies what "key issues" have to be solved in the NextGen network. Then, proposes architectural solutions that are specific to each key issue. The "key issue" and their solutions shall be further discussed in the later sections.

Combining Top-Down and Bottom-up

It is quite evident from the descriptions in earlier sections that the two approaches are very different. The Top-Down approach gives a bird's eye view of the architecture. Whereas, the

[4] The key issues could be thought of as innovative features that are introduced in 5G networks to meet the next-generation requirements.

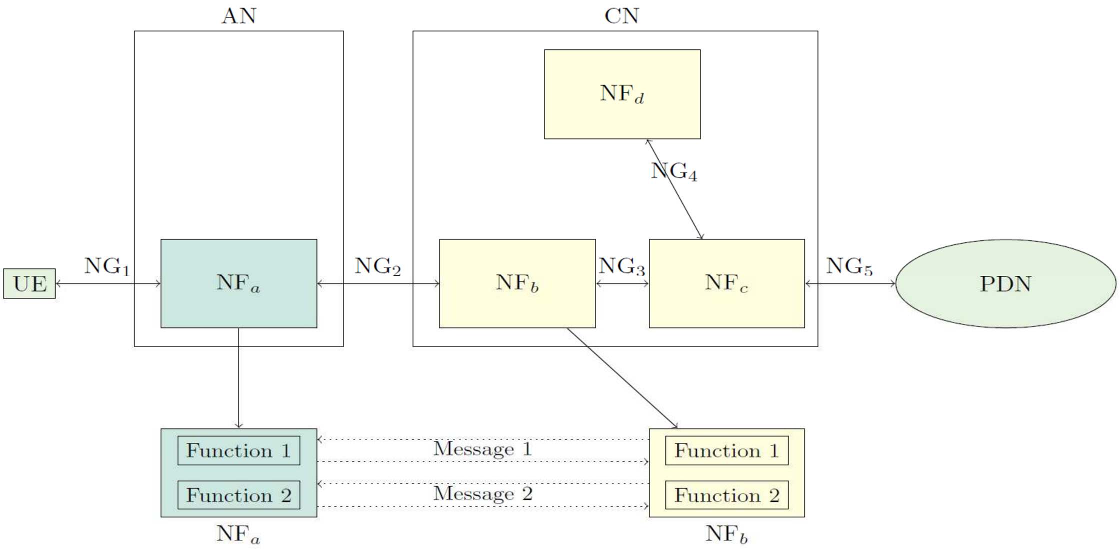


Figure 3: A depiction of bottom-up approach. An architectural solution specific to Key issue is defined. The functions of NF are explained. Also, signaling flow between NF is included.

Bottom-up approach provides the different nuts and bolts of the architecture.

The Bottom-up approach provides "architectural solutions to key issues with narrow scope to specific functional areas of the network". But, the problem with the bottom-up approach is that the different solutions (for the different key issues) are not put into the context of an overall architecture. Also, the other problem is that there could be important "aspects that span across the multiple key issues" [5] that have to be looked at. The top-down approach tackles these drawbacks. The top down approach creates a common network architecture that is capable of (later) integrating the different proposed solutions. There is an understanding within the SA2 group that the parallel progress on both the approaches enable a comprehensive next-gen system design [5].

Option for the overall architecture

Earlier in Section "Top-down approach", it was explained that the top-down approach defines an overall consolidated architecture. In the recent SA2 meeting, there were different options proposed for the overall architecture in the top-down approach. Four options to be precise, and two among these four received most of the interest.

The first one was proposed by a consortium of network operators: *Cisco Systems, ATT, Sprint, Allot Communications*. Their proposed overall architecture is depicted in Fig. 4. For detailed description of this overall architecture, refer to [6]. During the recent meeting, it was agreed that this current proposal does not satisfactorily address the case of roaming. It is fair to expect that in the future meetings; this proposal will be updated to better accommodate the roaming cases.

The other proposal came from a team of mobile vendors: *Nokia, Ericsson, Samsung, Intel, LG Electronics, Alcatel-Lucent Shanghai Bell (also Verizon)*. Their approach is shown in Fig. 5. For detailed description of this architecture, refer to [7]. Unlike the previous proposal, this approach did include support for roaming. There was feedback to improve certain aspects and this can be expected to be reflected in the next meeting cycles.

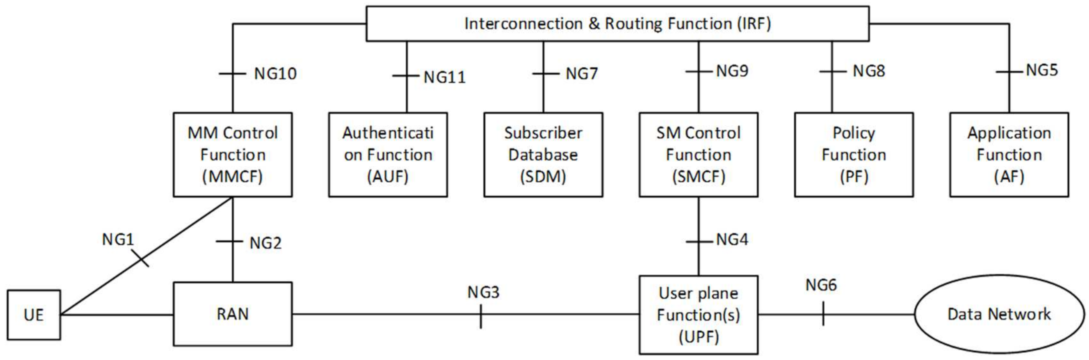


Figure 4: Overall architecture option as proposed by network operators [6].

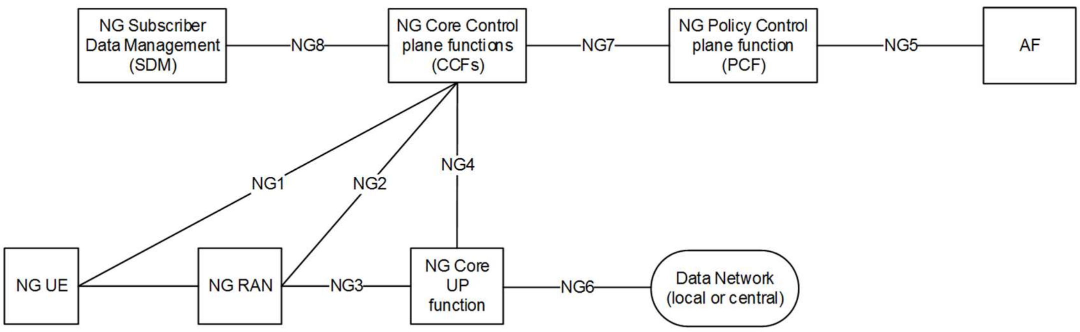


Figure 5: Overall architecture option as proposed by mobile vendors [7].

Key issues and their guidelines

Earlier in Section "Bottom-up approach", it was explained in brief how the bottom-up approach works. Here, we will discuss in detail about this approach. To reiterate, guided by the requirements and the assumptions laid out by the other groups, the bottom-up approach identifies "key issues" that have to be solved for the architecture design. Further, it also proposes solutions for "key issues". This idea is depicted in Fig. 6. To know more about the architectural requirements and assumptions, refer to [2]. In the following, we will explain about the "key issues" and their solutions.

<u>Key issues</u>

In total, there are 21 "key issues" identified for now. The key issues, along with a brief description[5] for each, are listed out in the following:

1. *Support of network slicing*

   Network slicing is envisioned as one of the key capabilities that will enable flexibility in 5G networks. Essentially, network slicing allows multiple logical networks to be created on top of a

[5] These brief descriptions come from the original source document [2]. Reader is asked to refer to the original document for further detailed descriptions.

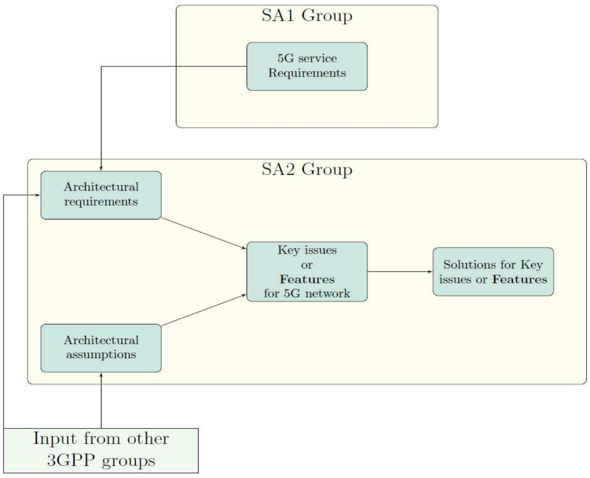


Figure 6: Working approach for the identifying key issues and defining their solutions.

common shared physical infrastructure. These different logical networks enable operators to provide networks on an as-a-service basis and meet the wide range of use cases. For example, on top of the same shared physical infrastructure, three network slices can be created:

- Slice 1: Smartphones
- Slice 2: Autonomous driving
- Slice 3: Massive IoT

These three slices would be configured with entirely different parameters that are attuned for their specific use case. In general, the greater flexibility brought about by network slicing will help to address the cost, efficiency, and flexibility requirements imposed by future services.

2. *QoS framework*

This key issue studies the overall QoS framework for the system architecture. The QoS framework ideally should enable the operator to provide QoS for the wide range of use cases that is expected to be fulfilled by the NextGen architecture.

3. *Mobility frame work*

This key issue will look into solutions for a mobility management framework that enables the operator to provide mobility support which, if needed, includes session continuity for all types of devices that connect to NextGen core via 3GPP accesses and/or non-3GPP accesses.

4. *Session management*

The session management is responsible for the setup of the IP or non-IP traffic connectivity for the UE, as well as managing the user plane for that connectivity. Scenarios and mechanism on connectionless traffic transmission, which may not require the session to be established, will also be investigated in this key issue.

5. *Enabling selection of efficient user plane paths*

This issue will look into the aspects of identifying efficient user plane paths in the NextGen networks.

6. *Support for session and service continuity*

The purpose of this key issue is to study aspects such as:

- The types of sessions to be considered in the context of session continuity;
- The level of session continuity to be supported depending on e.g. the type of service such as broadband, group communications, mission critical communications, etc.;

7. *Network function granularity and interaction*

   As already described, future networks network systems will consist of multiple physical and/or virtual network functions that may be deployed in the operator's network, and they should support diverse service requirements. To achieve such a scenario, we would have to carefully study the function granularity. The solution for the functional granularity should cover:
   - Criteria to determine the right level of granularity of next generation network functions
   - The level of inter-dependency between network functions
   - Need for independent scalability of individual network functions

8. *Next generation core and access – functional division and interface*

   This issue shall analyze in detail the functionality for the Next Generation Core and for the interface between the access networks and the Next Generation Core to support the LTE radio access network, the new, expected 5G radio access network, and also for non-3GPP networks.

9. *3GPP architecture impacts to support network capability exposure*

   As discussed earlier, the next generation system is expected to accommodate various services, such as massive IoT, critical communications, and enhanced mobile broadband. Requirements from the network for each of the service categories have been defined (and will be updated). To allow the 3rd party/UE to access information regarding services provided by the network (e.g. connectivity information, QoS, mobility, etc.), the next generation system should provide suitable access/exchange of network/connectivity information (e.g. via APIs) to the 3rd party/UE. This key issue looks into such aspects.

10. *Policy framework*

    Simply put, policy framework is a service-based framework that is used for flow-based online policy control, and also for online/offline charging. Most of the aspects are expected to be similar to LTE/EPC. An evolution of the earlier policy framework is expected.

11. *Charging*

    Mobile System Architecture cannot be considered complete without having appropriate charging support. While the charging requirements in Next Generation System are expected to be similar in nature to LTE/EPC, depending upon the Next Gen System Architecture how, where and when charging data gets collected and communicated can be different. This key issue will look into the architectural aspects of collection of charging data.

12. *Authentication framework*

    The authentication function is responsible for the authentication of the identity (e.g. user identity) that is presented to the network, when a UE requests to receive service(s) from the next generation network.

13. *Broadcast/Multicast Capabilities*

    This key issue will address the need and possible solutions to support capabilities, such as provided by eMBMS in LTE/EPC networks. It will specifically investigate how to architecturally support one-to-many and one-to-all communications involving 5G capabilities specified by RAN. There is also discussion on including support for features related to mission-critical applications via multicast.

14. *Support for Off-Network Communication*

    This key issue is to define support for off-network communication capabilities for in-coverage and out-of-coverage devices

15. *NextGen core support for IMS*

    This key issue will study the system requirements and the solutions required in order to enable the next generation system to support IMS. The IP Multimedia Subsystem (IMS) is an architectural framework for delivering internet protocol (IP) multimedia to mobile users.

16. *3GPP system aspects to support the connectivity of remote UEs via relay UEs*

    This key issue, among other things, will study about:

    - Definition of a relay UE in the NextGen framework.
    - The effects of a relay UE on the mobility framework as well as session management and session continuity.
    - Which functions are further required/enhanced comparing to Rel-13 relay UE functionality.
    - If there is need for selection criteria based on operator policy between the direct connectivity to the network and the connectivity via a relay UE to provide efficient service.

17. *3GPP architecture impacts to support network discovery and selection*

    "In order to enable integration of various 3GPP accesses and non-3GPP accesses and to cater for the architectural requirements and assumptions for the NextGen system, the introduction of a network discovery and selection mechanism will provide operators with a solution to flexibly control UE to select various accesses according to operator policy" [2].

18. *Interworking and Migration*

    This key issue focuses on migration and interworking scenarios.

19. *Architecture impacts when using virtual environments*

    The NextGen system is expected to support deployments in virtualized environments. This key issue will determine the need for and architecture impacts due to load rebalancing and load migration in the context of:

    - scaling of a network function instance, and
    - dynamic addition or removal of a network function instance.

20. *Traffic Steering, Switching and Splitting between 3GPP and non-3GPP Accesses*

    For UEs that can be simultaneously connected to both 3GPP access and non-3GPP access, the NextGen system should be able to take advantage of these multiple accesses in a way that improves the user experience, optimizes the traffic distribution across various accesses, enables the provision of new high-data-rate services, etc. This key issue will look into such aspects.

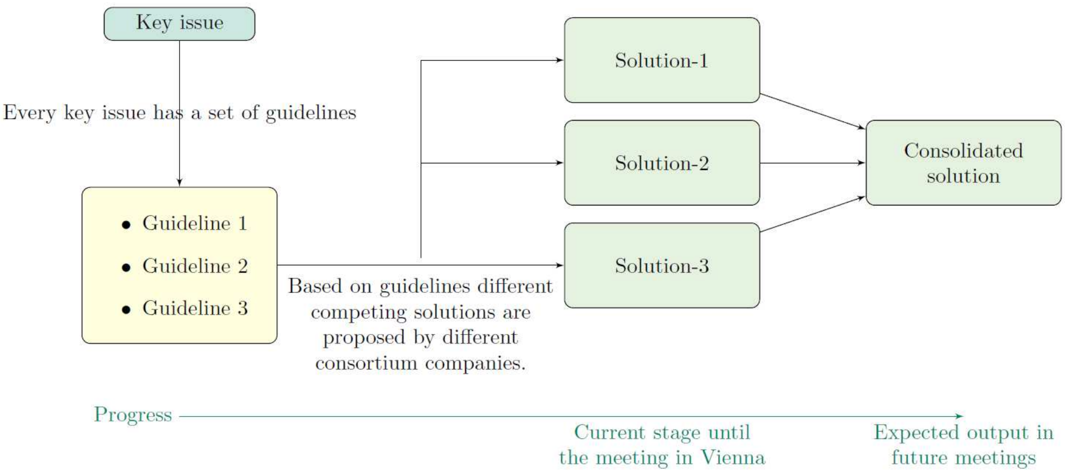


Figure 7: Approach of arriving at a consolidated solution for each Key issue.

21. *Minimal connectivity within extreme rural deployments*

    This key issue will address the need and possible solutions to support minimal services in the context of extreme rural deployments, where territories are very large or resources are limited, e.g., limited electricity provided by alternative energy sources as there is no electricity grid, unreliable and costly backhaul, etc.

Guidelines

After identifying the key issues for the NextGen architecture, the technical report provides "a set of guidelines" for each key issues. The idea behind the guideline is that they define what aspects should the solution for each "key issue" consider. To better elucidate this, we consider an example in the following. One "key issue"/feature that has been identified as essential for future 5G network is the "Support of network slicing". The study item defines the following points to be studied carefully for this specific "key issue":

- How to achieve isolation/separation between network slice instances and which levels and types of isolation/separation will be required;
- How and what type of resource and network function sharing can be used between network slice instances;
- How to enable a UE to simultaneously obtain services from one or more specific network slice instances of one operator;
- How to support Network Slicing Roaming scenarios.

These points are used as guidelines to develop solutions for the key issue: "Support of network slicing". Similar to the earlier shown example, every "key issue" has a set of base guidelines (or points) to follow. For the complete list of guidelines for each "key issue" refer to the technical report [2].

Architectural solutions for key issue

Based on the above mentioned guidelines, architectural solutions are proposed for each key issue. Until the last meeting in Vienna, architectural solutions are still being contributed by different consortium companies. Work is still

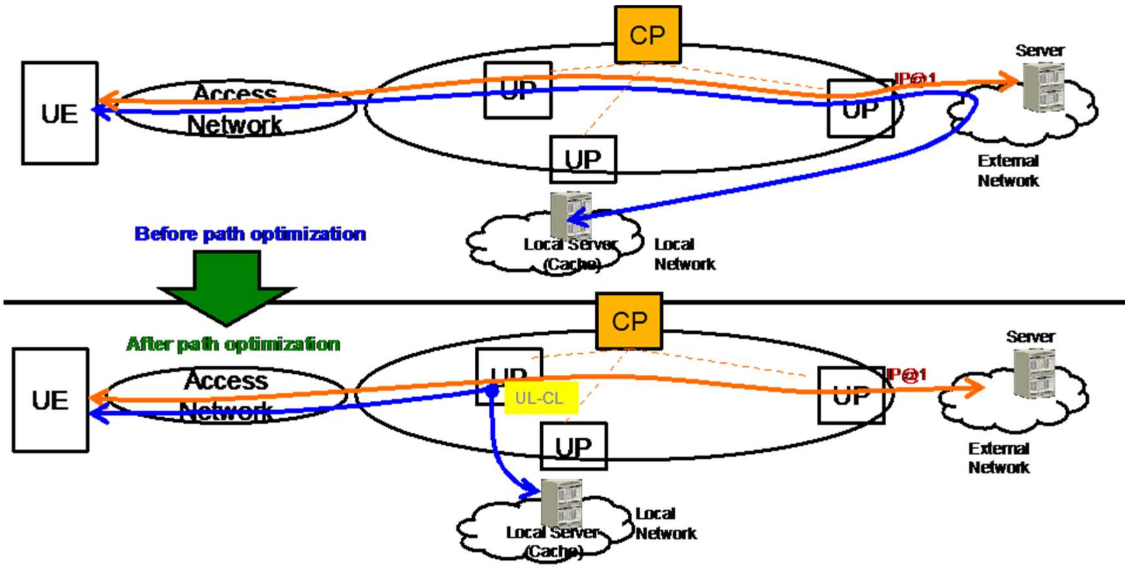


Figure 8: Depiction of offloading data to local cache using the concept of dedicated bearers [18].

in progress. Hence, there are multiple architectural solutions proposed for a single "key issue". In general, these different architectural solutions could be either competing or could cover different aspects of the same issue.

For example, for the key issue "Support of network slicing", 4 solutions are proposed until now:

- Network slicing without slicing the radio
- Network slicing selection
- Support of multiple connections to multiple network slices
- Network slicing architecture for Network Slice Instance Selection

In this specific example, Solution 2 and 4 offer alternative architectural strategies on how to select the network slice instance. Whereas, solution 1 and 3 cover different architectural aspects of this key issue.

Also, certain "key issues" (among the 21) do not have any architectural solutions for now. This is mainly due to lack of contribution from companies towards certain key issues. Contributions are expected in future meetings.

To conclude, there are multiple architectural solutions proposed for a single issue. These different solutions will be carefully compared, consolidated and refined later during the course of the next meetings. This idea of deriving solution is solution is depicted in Fig. 7.

As mentioned earlier, there are different solutions for each key issue. For the recently held Vienna meeting, the title of all the different solutions, along with the contributing companies, could be found in [8]. Summarizing the large number of solutions is out of scope of this paper. Instead, in the following, we list out some of the interesting solutions and provide references to them. Interested readers can follow the references for further details.

In the following sections, first we will discuss the solution for "Network slicing". Next, a solution for "QoS framework" will be briefly discussed. Third, the solutions for "Efficient user plane paths" will be presented. Finally, we will look at a specific solution for "Interworking and migration". This final solution was particularly interesting and it

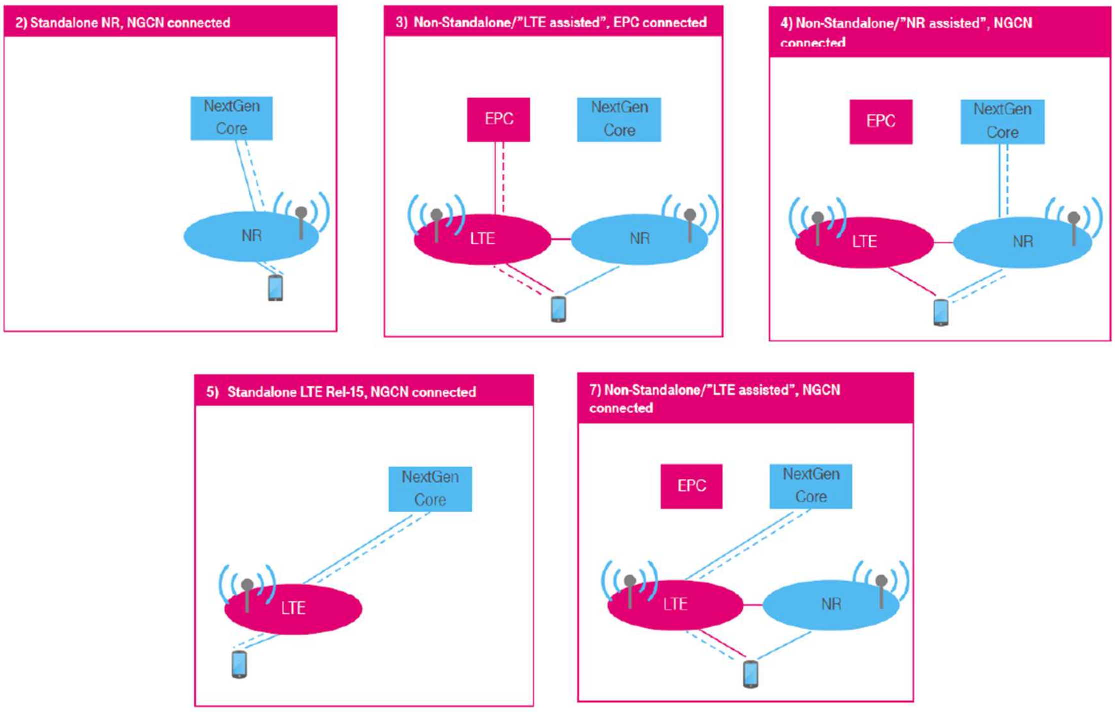


Figure 9: Deployment perspective for future 5G networks [20].

proposed a way-forward on how to smoothly move from the current LTE-network to 5G including support for backwards compatibility.

<u>Solutions for "Network slicing"</u>

1. *How to decide which network slice to select?*

   There were solutions that were dedicated to discuss about which slice within the network should the UE be connected to [9, 10, 11, 12, 13]. Particularly interesting was a solution proposed by a consortium of major mobile vendors [13]. This solution proposed the concept of Multi-Dimensional Descriptor (MDD) together with other miscellaneous information to support the Network Slicing Selection over the NextGen system. This solution generated a lot of discussion in the latest Vienna meeting.

2. *How to be connected to multiple network slices at once?*

   There might be multiple applications running in a single UE and there might be a need for this UE to be connected to multiple network slices at once. There were solutions proposed that discussed on how can multiple connections to multiple network slices be achieved [14,15].

There were few other solutions that cannot be categorized in either of the above categories. Refer to [8] for further details.

<u>Solution for "QoS framework"</u>

A solution proposed by Qualcomm "introduces a granular traffic differentiation via a mechanism to enable differentiated QoS treatment of encrypted multimedia traffic (e.g. video streaming)" [16]. This solution mainly seems solve to the problem of traffic differentiation for HTTP based video streaming.

Other new solutions proposed for the QoS framework in the Vienna meeting can be found in [16, 17].

Solution for "Efficient user plane paths"

Related to this key issue, there was a new solution proposed for "user plane optimization based on use of dedicated bearers" [18]. The main idea is that some of the traffic can be better served from an operator's local network that is geographically closer to the UE's location. "This can be the situation for the case of content delivery networks, where the content that the user is interested in is cached in a local network which is closer to the UE's location and hence can save operator's core network resources and also reduce the latency in providing traffic to the user" [18]. This idea is depicted in Fig. 8. Essentially, a functionality is deployed in the user-plane of the UE's traffic. By inspecting the traffic, this functionality enables the offloading of traffic destined to local operator's network. The functionality provides features such as packet routing, packet forwarding, traffic offloading to a local network as well as charging. Refer to [18] for further details.

An another interesting solution regarding the efficient user plane paths can be found in [19].

Solution for "Interworking and migration"

In general, there were many solutions proposed or updated for this specific key issue in the Vienna meeting [20, 21, 22]. The document proposed by AT&T [20] generated the most discussion and this is summarized in the following.

It has been agreed that the Options shown in Fig. 9 will considered as initial deployment options for Release-14 (note the option numbers in Fig. 9, they shall be referenced later). Further, it was discussed on how to move things forwards. Especially, what are the key migration paths, migration principles and roaming scenarios to consider. Appropriate text has been extracted from [20] and presented here.

The report states that Option 2 / Option 4 (see Fig. 9) will be the target architecture for the NextGen network. But it further argues that for the "majority of the operators it may involve one or more intermediate steps in some cases over a longer period of time". It is also to be noted that the goals of target architecture (e.g. fulfilling service level or architectural requirements) will not be sacrificed in order to fit a specific intermediate step. This target architecture along with intermediate steps is termed as "key migration paths" or migration scenario. The document recommends the following migration scenarios to be worked on in Release 14:

- [now] -> [intermediate steps] -> [Target architecture]

a. LTE/EPC -> Option 7 -> Option 2/ Option 4
b. LTE/EPC -> Option 3 -> Option 2/ Option 4
c. LTE/EPC -> Option 3 -> Option 7 -> Option 2 / Option 4
d. LTE/EPC -> Option 2 / Option 4

The document also recommends the following "Key migration principles" to be considered for the above mentioned migration paths:

- "A standalone deployment of NextGen System without interworking is the goal after migration. NextGen Core's requirements therefore shall not be compromised to improve inter-working."
- "eLTE in option 7 (see Fig. 9) provides direct connectivity to the NextGen core. Upgrade of LTE to eLTE should therefore be considered not only from option 7 solution perspective but also as a migration strategy."

Further, UE's forward compatibility is also ensured to be part of this work while keeping in mind UE complexity and agreed migration paths and roaming scenarios.

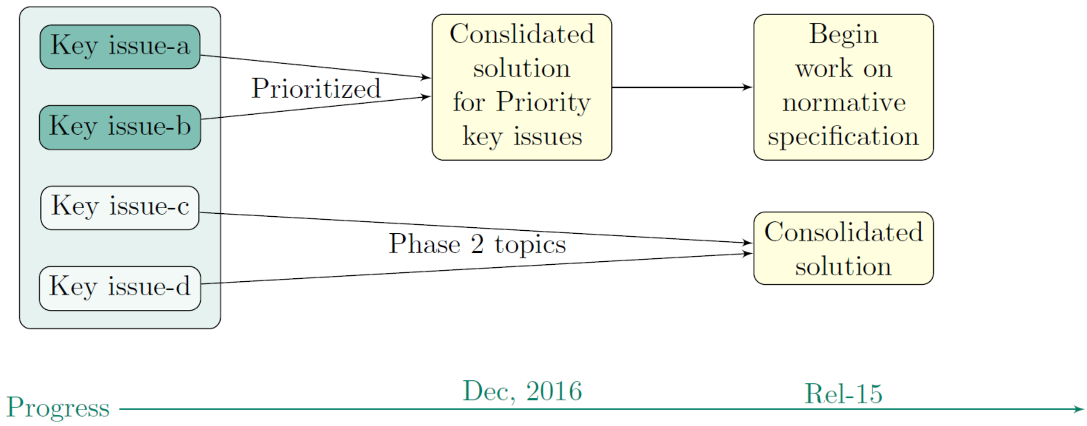


Figure 9: Future plan of the NextGen study item.

Time frame for the study item

The development of a completely new system architecture including a new core network is a significant and complex standardization effort. The completion of this task is expected to take multiple 3GPP releases. But that being said, there is an understanding within the SA2 group on how to meet various deadlines for anticipated technology trials and deployment. The overall plan is split in two stages:

1. "An early availability of basic system for trials and limited deployments that fulfils the goals and expectations set about for Next Generation of System including the Core Network."
2. "Building of a complete and feature rich system using the basic system defined in step 1 as a foundation thereby ensuring backwards compatibility within Next Gen Ecosystem."

Keeping the above guidelines in mind, in the recently held Vienna meeting it was agreed that "some prioritization is essential to focus on the NextGen work on essential building blocks for the foundation architecture" [23]. The idea is to address important key issues in Phase 1/Rel-14 and push the other key issues to Phase 2. Consolidated solutions for Phase-1 key issues is expected to be available by December, 2016. In the meeting, discussion was held on what "key issues should be completed during the Rel-14 study to result in Rel-15 normative specification." [23]. The priority as decided in the meeting is shown in Tab. 1. The whole work plan is depicted pictorially in Fig. 10.

Table 1 : Priority of key issues.

Key issue		Priority
		Phase 1 or 2 (Rel. 14 or 15)
1.	Support of network slicing	Phase 1
2.	QoS framework	Phase 1
3.	MM framework	Phase 1
4.	SM framework	Phase 1
5.	Enabling (re)selection of efficient user plane path	Phase 1
6.	Support for Session and Service continuity	Phase 1
7.	NF granularity and interaction between NFs	Phase 1
8.	NG Core and Access - functional	Phase 1

	split	
9.	3GPP arch impacts to support Network capability exposure	Phase 2
10.	Policy framework	Phase 1
11.	Charging	Phase 1
12.	Security	Phase 1
13.	Broadcast/Multicast Capabilities	Phase 2
14.	Support for Off-Network Communication	Phase 2
15.	NG Core support for IMS	Phase 1
16.	3GPP system to support remote UEs	Phase 2
17.	3GPP arch Impact to support discovery	Unclear/Still in discussion
18.	Interworking and Migration	Phase 1
19.	Virtual environments	Phase 1
20.	Traffic steering and others	Phase 2
21.	Minimal connectivity	Phase 2

Conclusions

In this paper, we presented a condensed summary of "*Study on Architecture for Next Generation system"* study item of the SA2 group. This study item will be basis for the next generation telecommunication networks. The aspects of this study item such as:

- Timeline
- Overall plan
- Features being considered
- Preliminary solutions for the features

were briefly summarized. Extensive references are also provided in this paper for the benefit of interested readers.

References

[1] Dino Flore, Tentative 3GPP timeline for 5G, http://www.3gpp.org/news-events/3gpp-news/1674-timeline_5g [Online; posted March 17, 2015].

[2] 3GPP, "Study on Architecture for Next Generation System", TR 23.799, version-0.5.0, June 2016.

[3] List of all the SA2 meetings, "3GPP meetings for group S2", http://www.3gpp.org/dynareport/Meetings-S2.htm?Itemid=441 [Online; posted July, 2016].

[4]"SA1 completes its study into 5G requirements", http://www.3gpp.org/news-events/3gpp-news/1786-5g_reqs_sa1 [Online; posted June, 2016].

[5] 3GPP, "Proposal on NextGen Architecture Top-Down Approach", TDoc S2-163708, Meeting S2-116, Vienna, July 2016.

[6] 3GPP, "Consolidated overall CN architecture option", TDoc S2-163265, Meeting S2-116, Vienna, July 2016.

[7] 3GPP, "Next Generation Network Architecture", TDoc S2-163529, Meeting S2-116, Vienna, July 2016.

[8] 3GPP, List of all the TDoc for the S2-116 meeting, ftp://ftp.3gpp.org/tsg_sa/WG2_Arch/TSGS2_116_Vienna/TdocsByAgenda.htm [Online; posted July, 2016].

[9] 3GPP, "Selection of a network slice instance", TDoc S2-163338, Meeting S2-116, Vienna, July 2016.

[10] 3GPP, "Network slicing selection solution based on Slice ID.", TDoc S2-163344, Meeting S2-116, Vienna, July 2016.

[11] 3GPP, "Service triggered Network slice selection procedure.", TDoc S2-163344, Meeting S2-116, Vienna, July 2016.

[12] 3GPP, "Network slice selection based on Usage class.", TDoc S2-163399, Meeting S2-116, Vienna, July 2016.

[13] 3GPP, "Network slice.", TDoc S2-163507, Meeting S2-116, Vienna, July 2016.

[14] 3GPP, "Support of multiple connection to multiple network slices.", TDoc S2-163707, Meeting S2-116, Vienna, July 2016.

[15] 3GPP, "Support access to multiple independent network slices.", TDoc S2-163400, Meeting S2-116, Vienna, July 2016.

[16] 3GPP, "QoS packet differentiation.", TDoc S2-163388, Meeting S2-116, Vienna, July 2016.

[17] 3GPP, "Application based UL traffic differentiation.", TDoc S2-163262, Meeting S2-116, Vienna, July 2016.

[18] 3GPP, "Dedicated bearers based user plane optimization.", TDoc S2-163491, Meeting S2-116, Vienna, July 2016.

[19] 3GPP, "Application aware UP selection.", TDoc S2-163600, Meeting S2-116, Vienna, July 2016.

[20] 3GPP, "Migration and interworking aspects.", TDoc S2-163348, Meeting S2-116, Vienna, July 2016.

[21] 3GPP, "Solution for interworking and migration 1.", TDoc S2-163391, Meeting S2-116, Vienna, July 2016.

[22] 3GPP, "Solution for interworking and migration 2.", TDoc S2-163481, Meeting S2-116, Vienna, July 2016.

[23] 3GPP, "Phase 1 priority features.", TDoc S2-163537, Meeting S2-116, Vienna, July 2016.

3GPP Simulation Services

Nomor Research has developed a comprehensive simulation environment supporting various standards such as LTE, LTE-A, LTE-A Pro and 5G and offers related services to support research, development and standardisation. Different simulator approaches include link level, system level, protocol simulators as well as a SON simulator.

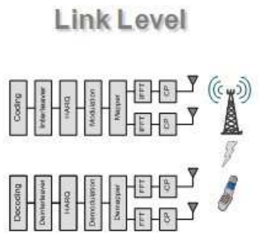
Features of the dynamic multi-cell, multi-user system level simulator include:

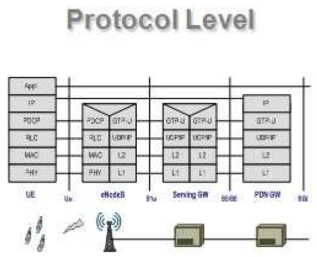
- macro-cell and HetNet deployments (pico-, femto-cell, relay nodes)
- various feature groups e.g. eMBMS for LTE-Broadcast, D2D for LTE V2X, SC-PTM for Public Safety
- flexible base station and user configurations and drop models
- different transmitter and receiver chains incl. MIMO, ZF, MMSE
- channel modelling with slow/fast fading, pathloss, full user mobility
- intra- and intercell interference modelling for OFDMA, SC-FDMA and WCDMA
- 2D and 3D antenna pattern and multi-antenna beam forming
- extensive metrics and KPIs: capacity, throughput, spectral efficiency, user QoS etc

The simulators can be used on project basis or in customized simulation campaigns. The performance of the system level simulator has been calibrated to simulation results obtained in standardisation.

Research on advanced algorithms include, but are not limited to:

- LTE-B, LTE-V2X, LTE Public Safety link budget and performance analysis
- various aspects of scheduling and resource allocation algorithms considering channel and buffer status, QoS etc.
- inter-cell interference coordination, avoidance and cancellation
- single user-, multi-user MIMO with open and closed loop feedback
- cooperative multi-point transmission and reception
- functions for self-organising and self-optimizing networks (e.g. load balancing, mobility optimization, tilt optimisation, range extension, power saving etc.)





If you are interested in our services please contact us at info@nomor.de or visit us at http://www.nomor-research.com/simulation

Standardisation Service

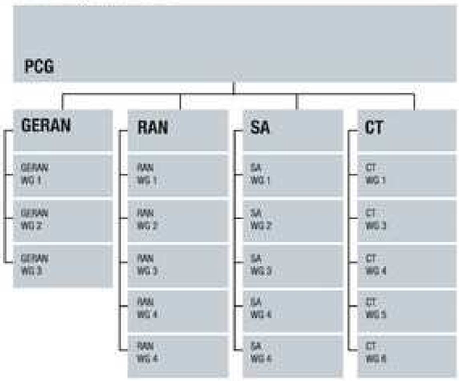
Standardisation is often essential to drive technology, to get knowledge about market trends, customer or competitors and basically to lay ground for future business with the required knowledge for implementation. Real impact in standardisation will be time and cost intensive since it requires years of attendance with excellent contributions, working across various groups and contacts to the decision makers, and is thus mostly limited to the key player. Right not 5G standardisation starts as a huge standardisation effort.

Nomor Research's standardisation services provide you the resources and the knowledge needed to understand and influence standardisation from the beginning. Sharing the resources between partners and projects maximized your impact and presence while limiting your cost.

3GPP RANx, 3GPP SAx, ETSI, DVB, IETF, ITU, ISO/MPEG, and DASH-IF, we can support you in manifold tasks on short notice as well as in long lasting projects.

Contact us at standard@nomor.de or visit http://www.nomor.de/lte-standardisation

3GPP Working Group Structure



Consulting can include, but is not limited to:

- Regular standardisation updates,
- In-depth information on technical areas,
- Release overview, analysis, feature roadmaps and complexity analysis,
- Contribute and influence standards activities,
- Represent your company at standardization,
- Analyze the feasibility of concepts for standardization,
- Evaluation of own and other contributions,
- Answer questions concerning certain standards.

Technology Training

NoMoR provides you professional training held by distinguished expert in mobile communication industry and in standards.

Standard Courses:

- LTE Technology and Signalling/Protocols
- Advanced LTE MIMO Technologies
- LTE-Advanced and LTE-Advanced Pro
- Overview Release 10, 11, 12, 13 and 14
- Future LTE based Public Safety Systems
- NEW: 5G New Radio and Core Network

As development cycles are getting shorter and new technologies are emerging frequently in a rapidly changing market, your teams need to act quickly once strategic decisions have been taken. Professional training tailored to your specific needs and any level of background will get your team up-to-date and will save you money, since your staff can focus on the task to be done.

Contact us at training@nomor.de or visit http://www.nomor.de/training