IEEE P802.11
Wireless LANs

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| Industry and Other Views of 802.11 Access in 5G Networks |
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Abstract

This document contains a summary of various industry and other views of the roll of 802.11 (WLAN, Wi-Fi) in existing 3GPP Networks and next generation 5G networks. It is intended to be a working document that will eventually contain a summary of the key interface requirements and features that 802.11 networks/devices and 3GPP 5G networks should specify/agree to enable and enhance the capablities 5G networks.

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Many organizations and companies working toward making 5G a reality include WLAN/802.11/Wi-Fi (WLAN) as a radio access technology (RAT) in the 5G architecture. WLAN is included in several ways:

1. Integrated into a 3GPP micro/pico BS, as a RAT that is managed by the BS
2. As a co-located independent RAT that is trusted by the network operator
3. As an independent RAT that is trusted by the network operator
4. As an independent RAT that is not trusted by the network operator

**Some example statements follow:**Quoted from [1]:

“5G will include advanced support for carrier integrated Wi-Fi and other technologies in unlicensed spectrum. However it is also required that 5G coexist with third-party Wi-Fi services that have no carrier integration. Users may, in some cases, prefer third-party Wi-Fi services for reasons of cost, convenience, feelings of control, or to provide special access to local or enterprise services. The following use cases show some scenarios.”

Also quoted form [1]:

“We have shown various scenarios for how 5G technology can enhance coverage and capacity beyond that achieved by today's networks. Key aspects of this are:

• Intrinsic capabilities of 5G to tackle "difficult" environments particularly urban centers and the interior of high density buildings.

• Flexible use of available spectrum and access technologies including Wi-Fi, LTE-U, and other technology in unlicensed bands.

• Use of spectrum above 5GHz to provide high capacity, short range connections.

• Flexible models of network and coverage sharing including "neutral hosting" of in building services. “

Technical requirement taken for the Core Network, Seamless Mobility requirement from [7]:

“Shall support seamless mobility regardless of the cell types and RATs in the environment where the macro BS, small cell BS, personal cell, type 1/2 WLAN, and relay station are mixed and overlapped”

*Note that Type 1 WLAN is an AP connected to a BS, while a Type 2 WLAN is connected to the 5G GW*

Also note that there are multiple references that include WLAN assess in their proposed 5G network infrastructure. [2-6, 8].

**WLAN Network Requirements:**

These references [1-8] also provide or suggest requirements and performance goals for WLAN integration into 5G networks.

*<An agreed list of WLAN network requirements and areas that require agreement and mutual work in 802.11 and 3GPP SA be provided here.>*

**References:**

1. 5G REIMAGINED: A NORTH AMERICAN PERSPECTIVE (ISSUE 2), ATISI-000005.v00
2. IMT-2020 (5G) Summit – 5G Objective and Capability, Research Progress of IMT-2020 (5G) Promotion Group, Ms. CAO Shumin, 29 May, 2014, Beijing
3. 5G Technology: R&D in Korea, Yougnam Han, Steering committee Chair, 6G Forum Korea, 29 May 2014, Beijing
4. Adaptive and Software Defined 5G Air Interface, Dr. Peiying Zhu, Huawei Fellow, 28 May 2014, Beijing
5. Looking ahead to 5G, Ulrich Dropmann, Head of Industry Environment, Networks, Nokia, IMT-2020 (5G) Summit, Beijing 29 May 2014
6. 5G Concept, IMT-2020 (5G) Promotion Group, 11 February 2015
7. 5G Vision, Requirements, and Enabling Technologies (V.1.0), 5G Forum, March 2015
8. NGMN 5G White Paper, NGMN Alliance, 17 February 2015

### Appendix: Text/Graphics from referenced documents:

From ATISI [1]:

4.1.1 Third Party Wi-Fi Use Cases

5G will include advanced support for carrier integrated Wi-Fi and other technologies in unlicensed spectrum. However it is also required that 5G coexist with third-party Wi-Fi services that have no carrier integration. Users may, in some cases, prefer third-party Wi-Fi services for reasons of cost, convenience, feelings of control, or to provide special access to local or enterprise services. The following use cases show some scenarios. The following use cases rely on aspects/capabilities of WLAN:

4.1.1.1 Residential Home Network (Non-Integrated)

4.1.1.1.1 Story Highlights

Adam has a home Wi-Fi network which is not integrated with his mobile service provider. When Adam enters his home network area, his mobile automatically selects his home network for IP based services that are supported while maintaining a connection to the mobile network for value added services not provided on a non-integrated Wi-Fi network.

In this use case, services provided by the user's home Wi-Fi network are not billable by the mobile operator. Services provided by the mobile network while also connected to Wi-Fi are billable as normal.

4.1.1.1.2 Business Drivers & Deployment Scenario

Users will continue to want to make efficient use of their home network resources in the 5G timeframe. Independently deployed Wi-Fi networks should be supported, sometimes in preference to the mobile network.

However, not all 5G services may be available on simple Wi-Fi connections. Therefore in order to deliver the full range of services, both Wi-Fi and mobile connections should be simultaneously supported.

4.1.1.2 Enterprise Network (Non-Integrated)

4.1.1.2.1 Story Highlights

Bettina works in an office building with a Wi-Fi network which is not integrated with her mobile service provider. When Bettina enters her enterprise network area her tablet, which is 5G equipped, automatically selects her enterprise network for IP based services that are supported while maintaining a connection to the mobile network for value added services not provided on a non-integrated Wi-Fi network. Maintaining a connection to the enterprise network is important because some private enterprise services are only available to users connected over their enterprise network.

Bettina is able to access both service provider hosted services and enterprise hosted services while she is connected to both networks.

In this use case, services provided by the enterprise Wi-Fi network are not billable by the mobile operator. Services provided by the mobile network while also connected to Wi-Fi are billable as normal.

4.1.1.2.2 Business Drivers & Deployment Scenario

As with the residential home network case, independently deployed Enterprise networks should be supported.

4.1.3 International Roaming Use Cases

5G will provide users with global services based on the ability to roam and access local infrastructure in visited countries. The ability to balance user control and convenience associated with roaming is an important factor for users. Another important aspect is the consistency of services users experience when they are not in their home country.

4.1.3.1 Casual Consumer International Roaming

4.1.3.1.1 Story Highlights

Denise is taking a vacation abroad. While on vacation she wishes to continue to access social media sites and multimedia entertainment but wishes to manage roaming charges. Denise sets the preferences on her mobile to reflect this. While travelling her mobile only automatically connects to services which are compatible with her preferences. This may include connecting to services such as:

• Free public Wi-Fi services.

• Denise's operator's preferred roaming partner where usage is counted within Denise's normal monthly allowance.

In some locations Denise is unable to connect because there is no suitable provider available. Denise is happy to restrict her usage to manage roaming charges.

Sufficient information will need to be collected to bill Denise in this scenario. Information will also be required to support inter-operator billing. In addition to conventional inter-operator billing other payment scenarios are possible, for example payments could be automatically deducted from Denise's electronic wallet by the local providers.

4.1.3.1.2 Business Drivers & Deployment Scenario

Many mobile operators have preferred roaming partners, perhaps within the same group of companies. Users wishing to manage roaming charges should be steered towards these services.

Popular leisure destinations are often well provided with free Internet services both at tourist businesses (e.g., hotels and restaurants) and sometimes in public spaces as part of municipal initiatives. Users wishing to manage roaming charges will want to make the best use of these facilities when travelling.

4.1.3.2 Best Connectivity International Roaming

4.1.3.2.1 Story Highlights

Eric is a director of a large company. When travelling he wants to be constantly connected even if this incurs additional charges. Eric sets his preferences on his mobile to be "best connectivity" roaming. When travelling, his mobile automatically connects to any suitable connectivity service though it may prefer lower cost services where they are suitable and available. For example:

• While on a plane Eric's mobile will automatically connect to the in-flight Wi-Fi if his operator has a roaming agreement.

• While in a foreign country Eric's mobile will automatically connect to any roaming partner of his operator, though it will prefer roaming partners specified by his operator.

Sufficient information will need to be collected to bill Eric in this scenario. Information will also be required to support inter-operator billing. This scenario illustrates that 5G operators may provide services via a very wide range of third parties both at home and abroad. The need to manage these relationships in a simple, cost effective and secure manner will be an important feature of 5G.

4.1.3.2.2 Business Drivers & Deployment Scenario

For users demanding the best connectivity, continuous access to services even on buses, trains, and planes, this approach will become the expectation. Operators will make multiple roaming agreements to satisfy this demand. In some scenarios there may be a choice of partners to serve a user, depending on user preferences. Both technical and business aspects may feed in to the decision on which partner is used.

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4.3.6 Mobile Infotainment

4.3.6.1 Story Highlights

Video and audio streaming, video calls, social networking, and multimedia messaging are just some of the popular communications and entertainment applications used on today’s wireless networks. Additionally, new applications will emerge, such as real-time multi-user gaming, virtual/augmented reality, 3D multi-site telepresence, high-resolution (4K & 8K) video streaming, picture and video sharing, etc. These applications will require significant increases in data rate, capacity, and ultra-low communication latency that is not supported by today’s wireless networks. 5G will be the solution that enables the continued evolution of communications and entertainment applications.

4.3.6.2 Business Case

Cisco1and Ericsson2 predict that U.S. mobile data demand will grow by roughly a factor of 6 over the next five years to 2020. With the 3G and 4G enabled proliferation of smartphones and other mobile data devices, we have all come to expect Internet connectivity everywhere—at home, at work, in our automobiles, and wherever we go. The increasing adoption of mobile video and other data intensive applications is placing significant strain on today’s 3G and 4G networks. At event venues, stadiums, and other traffic hotspots with high concentrations of active wireless users, today’s networks can be severely congested leading to an unacceptable user experience. The voracious consumer appetite for anytime and anywhere information and entertainment will ensure that the exponential growth in mobile data demand will continue. How to support the rapid anticipated growth in mobile data traffic in densely populated areas will be an important driver of 5G requirements.

1 Cisco Visual Networking Index (VNI), May 2015: < http://www.cisco.com/c/en/us/solutions/collateral/service-provider/ip-ngn-ip-next-generation-network/white\_paper\_c11-481360.html >.

2 Ericsson Mobility Report, June 2015: < http://www.ericsson.com/res/docs/2015/ericsson-mobility-report-june-2015.pdf >.

4.3.6.3 Deployment Model

More access nodes, improved spectral efficiency, and more spectrum must be leveraged in tandem to satisfy the rapidly growing demand for bandwidth. Improved utilization of current frequency bands <6GHz and new technologies such as higher order MIMO, advanced carrier aggregation, closer integration of Cellular and Wi-Fi, NSLO, CoMP, and direct device to device communication will be implemented in future versions of 4G. But to meet demand, 5G will need to deliver even more effective use of licensed and unlicensed spectrum, ultra dense network deployments using ever higher frequency spectrum, and efficient allocation of wireless resources based on application and context. 5G will also expand on the techniques developed in 4G for new network architectures, secure protocols, smart antennas, and much more.

4.3.8 IoT Device Focused Services

4.3.8.1 Story Highlights

There is a great deal of interest and early work around enabling smart, connected devices and the creation of an Internet of Things (IoT). This use case is about enabling growth through the following:

1. Reducing the cost of connectivity of Smart Devices to support massive deployments.

2. Enabling carrier networks to provide connectivity for both cellular and non-cellular IoT devices.

3. Enabling the efficient use of spectrum for peer to peer devices.

This use case builds upon the ideas proposed in the “Lo/no Mobility” and “Local Offloaded Broadband” use cases to provide greatly improved cost, lower complexity, and improved efficiency for IoT applications.

4.3. 8.2 Business Drivers

• Accelerate uptake by enabling a more efficient ecosystem.

• Expand the addressable IoT market for carriers.

• Enable efficient P2P solutions.

4.3. 8.3 Deployment Model

• Dedicated spectrum to support a more efficient ecosystem could be realized through a nationwide IoT Spectrum Block (along with appropriate service profiles).

• Expanding the addressable market through simpler protocols would be deployed by essentially allowing non-cellular devices to be integrated into a carrier’s network trivially and automatically, with minimal to no effort. This could be at the device level or through interfaces to the devices cloud applications (an implementation plan has not been defined yet). As such, this might require some enablement of device ID sharing between IoT device providers and carriers. For example, ZigBee devices ideally would be plug and play into a carrier core network via Wi-Fi to a carrier’s router, or ZigBee devices known to their own cloud application could be interfaced via Internet into the carrier’s network trivially.

• P2P communications using dynamically managed spectrum would be deployed with increments to existing D2D protocols that would enable the allocation and then release of spectrum in real-time for short bursts of data transfer.

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4.5.1 Local Offloaded Broadband (Roaming Alternative)

4.5.1.1 Story Highlights

The scenario here is to create a class of services that do not require connection-maintaining mobility and can deal with being offloaded to the Internet at the RAN level. This approach has the potential to significantly lower the cost of a high percentage of mobile broadband traffic while simultaneously improving latency and user experience. If this class of service were made available at a substantially lower cost, it is likely that many of today’s mobility applications would be revised to take advantage of this service profile.

4.5.1.2 Business Drivers

• 70% of users are not mobile, and IoT growth will likely increase the level of non-mobile users.

• Non-licensed competitors will likely focus on this segment of the market for expansion.

• Enables limited mobility solutions like Wi-Fi to be used to reduce costs and increase bandwidth.

• May ease initial use of millimeter wavelength spectrum to enhance coverage and bandwidth.

• End-user ability to absorb increased costs for increased levels of mobile broadband consumption is limited.

• Competitive and regulator pressure to create flat-rate roaming scenarios.

• Service profile well suited for flat-rate and zero rated billing models.

• Enables or simplifies a broad range of emerging MVNO and flat-rate roaming scenarios (see related use cases).

4.5.1.3 Deployment Model

• Locally administered core functions (e.g., connection, IP address assignment, RAN QoS, perhaps limited mobility).

• Usage/billing data is the only item that is transferred to centralized “administrative mobile core”. The end user’s device could be used as a source for usage data.

• This service profile should be independent of RAN type and spectrum selection but can take advantage of many existing unlicensed RAN architectures including Wi-Fi and others.

• User device and associated applications will negotiate for QoE and other service parameters such as session persistence, constant IP addresses, etc. with network.

• Compatible with licensed spectrum assisted models being discussed today (e.g., LTE-U).

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4.5.2 Flexible MVNO & Carrier Partnering Models

4.5.2.1 Story Highlights

There is a great deal of interest in business models which enable more efficient use of infrastructure, spectrum, and other resources which make up wireless infrastructure. There is also considerable interest in cooperative business models involving carriers, content providers, and MVNOs. This use case addresses these opportunities via a variety of breakthrough approaches to billing and customer care coupled with a flexible and lighter weight approach to infrastructure sharing, control, and management. The use case includes the need to accommodate alternative billing models for “flat-rate”, “zero-rated”, mutual “all you can eat”, and standard billing models as well as a customer experience management and “care” platform which unifies provider owned content and networks along with shared wireless infrastructure. This use case could be applied to video, voice, broadband data, or IoT wireless services. Many of the customer, service, and business scenarios enabled by this use case will also make use of our Local Offloaded Broadband, Low/No Mobility Services, and Network Resource Sharing Use Cases.

4.5.2.2 Business Drivers

• Vertical market segments such as content providers and IoT applications service providers would be able to focus on their customers and service experiences without having to address the complexity of building and managing complex wireless infrastructures.

• Carriers will be able to share each other’s infrastructure as well as access to 3rd party networks (e.g., Wi-Fi in buildings) in a way that provides a seamless end-user experience to their customers.

• Content providers are looking for mechanisms to utilize wireless infrastructure to deliver their content and services in a manner which can guarantee a high-quality user experience. At the same time, these providers often wish to maintain a primary, one-stop customer care and billing relationship with their customers.

• Wireline-centric and other fixed broadband and unlicensed wireless providers are looking to create a seamless MVNO-style relationship with wireless operators to provide wireless and mobile extensions to their service sets.

• Significant improvements in end-user experience are possible using the “SmartPipe” services and seamless sharing of 3rd party networks that would be enabled by this use case.

• A much higher level of dynamic sharing of wireless infrastructure and spectrum would be enabled which in turn would significantly lower costs while simultaneously improving the utilization of precious resources such as wireless spectrum.

• The potential to deliver a much improved end-user experience for content (e.g., entertainment video) and other services would be enabled by this use case.

4.5.2.3 Deployment Model

• An MVNO, content provider, or a service provider engaged in network sharing would realize a highly integrated service delivery capability via a light weight platform providing customer care, experience management, and billing services. This platform would interoperate with a partner network that would provide access and possibly mobile core capabilities. Such a lightweight billing and customer care platform might be realized via a cloud/NFV-based architecture. This approach would enable a content provider, a carrier engaged in network sharing, or an MVNO to deliver wireless services without building a conventional packet core or RAN network to cover some or any of their service footprint.

• An operator should be able to provide mobile service by building any combination of the required elements – billing/customer care virtual core, packet core, and RAN – and sharing the rest via appropriate business relationships with other operators.

• The virtual billing/end-user care component should be architected to be “light weight” and cloud based to facilitate integration with content service platforms which already exist on the Internet (e.g., Netflix®, Hulu™.)

• There will need to be some changes in existing service models to accommodate some of the flexible roaming arrangements outlined above (e.g., carriers hosting roaming would not be required to apply home network services).

• Interfaces between the virtual core and the packet core/RAN should enable a variety of service profiles and billing models to be applied to realize a “SmartPipe” capability for content and other performance sensitive services.

• As in other use cases, the network should decouple the service profile from the specifics of RAN type and spectrum chosen to deliver a service.

• The business models outlined here would be realized using a combination of licensed, unlicensed, and license assisted access methods which meet the requirements of the associated service profiles.

• This use case could be greatly facilitated by user device-driven billing models which are secure and reliable. This area needs to be explored in more detail.

• This use case would likely be utilized in conjunction with our Local Offloaded Broadband, Low/No Mobility, and Network Resource Sharing Use Cases to efficiently realize a range of content and other services.

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• A much higher level of dynamic sharing of wireless infrastructure and spectrum would be enabled which in turn would significantly lower costs while simultaneously improving the utilization of precious resources such as wireless spectrum.

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• There will need to be some changes in existing service models to accommodate some of the flexible roaming arrangements outlined above (e.g., carriers hosting roaming would not be required to apply home network services).

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• As in other use cases, the network should decouple the service profile from the specifics of RAN type and spectrum chosen to deliver a service.

• The business models outlined here would be realized using a combination of licensed, unlicensed, and license assisted access methods which meet the requirements of the associated service profiles.

• This use case could be greatly facilitated by user device-driven billing models which are secure and reliable. This area needs to be explored in more detail.

• This use case would likely be utilized in conjunction with our Local Offloaded Broadband, Low/No Mobility, and Network Resource Sharing Use Cases to efficiently realize a range of content and other services.

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4.6.4 Device-Centric Approaches to QoE Use Cases

4.6.4.1 Story Highlights

The breakthrough in this feature is if a user were to start to select a certain application, the network would be advised and may move the user to a more appropriate RF channel or cell. For example, say a user is currently on a macro cell and starts to select a streaming video service. Before that service is even launched, the UE could advise the network that it is going to need a certain QoE. The network could then handover the UE to a small cell site or add a carrier that can provide the needed data bandwidth to the user. In this way the service is launched on the best available part of the network. The network is not overburdened providing service in the least appropriate RF channel or cell site.

4.6.4.2 Business Drivers

Improved customer satisfaction.

4.6.4.3 Deployment Model

Instead of a meaningless signal strength meter the device can display what the network is capable of handling. For example, ‘HDVideo-Streaming’ as an icon when there is unrestricted capacity available. This would work in concert with network analytics.

When less capability is available on the network the device may only display an icon indicating ‘VOICE’ or ‘TEXT’ services.

If a user begins to select a service for which the network does not have adequate resources, prior to the resources being requested the UE could be told to possibly select Wi-Fi if it is available or that it will experience a degraded experience.

If the network cannot handle UL requests of large files such as photos, the device should indicate to the user that uploads are suspended until the network regains capacity. This will reduce user frustration when users think that a file has been uploaded but are unable to find it and resend it again, which uses up even scarcer network resources.

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6.1 AR and VR Network Performance Requirements

Augmented Reality (AR) and Virtual Reality (VR) are going to be important applications in the 5G timeframe. This document assesses the 5G radio and system performance requirements needed to deliver these AR and VR services.

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6.1.2 Impact of User-Experienced Data Rate

The user-experienced data rate is a measure of the data rate that the 5G radio interface can deliver to a single user under reasonable operating conditions. This should be distinguished from the peak data rate which is only attainable under ideal conditions.

Some AR and VR services will have large amounts of content pre-loaded on to the UE and stored locally so that only the rendering of this content has to take place in real-time. In some cases, it may be possible to pre-load content over very high-speed WLANs or near-field radio interfaces. This type of interface can sustain a very high user data rate over a short range. In other cases, content may be slowly pre-loaded (e.g., during off-peak periods) to make use of spare radio interface capacity. These types of approach can help reduce congestion on the normal, wide-area, 5G radio.

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8 Conclusions/Recommendations

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8.2 Coverage & Capacity

Users’ growing reliance on mobile connectivity continues to present technical and economic challenges for the provision of adequate coverage and capacity. Increasing utilization of virtual reality and augmented reality services are examples of changes in user behavior that can generate significantly greater performance demands on the network. We have shown various scenarios for how 5G technology can enhance coverage and capacity beyond that achieved by today's networks. Key aspects of this are:

• Intrinsic capabilities of 5G to tackle "difficult" environments particularly urban centers and the interior of high density buildings.

• Flexible use of available spectrum and access technologies including Wi-Fi, LTE-U, and other technology in unlicensed bands.

• Use of spectrum above 5GHz to provide high capacity, short range connections.

• Flexible models of network and coverage sharing including "neutral hosting" of in building services.

We recognize that sustaining excellent coverage and capacity is not a static event but a continuous process. It must be possible to efficiently reconfigure 5G systems to account for special events including planned events such as sports games and unplanned events such as natural disasters.

For smart devices, coverage requirements include international mobility ("roaming") and support for services in moving environments such as cars, planes, and mass transit. 5G should improve the user and operational experience in these areas.

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From Reasearch Progress of IMT2020 (5G) Promotion Group [2]:



02\_5G Summit\_Beijing [3] –



Example of Core Network Architecture:



Adaptive and Software Defined 5G air Interface [4]



Looking ahead to 5G [5]



5G Concept [6]



5G Forum White Paper on: 5G Vision, Requirements, and Enabling Technologies (V.1.0) [7]

* 1. Core Network Requirements

Core Network Requirement is investigated in three aspects.

* + - Bottom‐Up Requirement is driven by the lower layer (L1~L2) function. The diverse features of the 5G radio access require the core network to be more radio independent.
		- Top‐Down Requirement is driven by the higher layer (application layer) function. To support variety of 5G mobile services such as M2M and IoT, the core network should be more flexible.
		- Enhancement Requirement is driven by the evolution path of the core network. The scope includes overcoming fundamental limitation of legacy network, preventing future potential problems such as traffic explosion, and following the evolution mega trend.

Table 3.1 Core Network Requirements

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| --- | --- | --- |
|  | Brief Description | Technical Requirements for 5G Core Network |
| B1 | Seamless mobility | Shall support seamless mobility regardless of the cell types and RATs in the environment where the macro BS, small cell BS, personal cell, type 1/2 WLAN,and relay station are mixed and overlapped |
| B2 | Multiple RAT interworking | Shall have architecture to support ‘Flow over Multi‐RAT’ to provide the high volume service with low cost and guarantee the service continuity in spite of the bandwidth deficiency in a wireless access |
| T1 | Wired/wirelessterminal switching | Shall support terminal and/or session mobility to provide fast handover betweenwireless and wired terminals |
| T2 | Networkon‐demand | Shall be able to build the network based on the QoS/QoE, charging, and servicecharacteristics |
| T3 | Context aware bestconnection | Shall utilize the various context information (device context, user context,environment context, network context) to provide always best connection/service |
| T4 | Single ID formultiple access | Shall recognize a mobile terminal as a single entity regardless of its accessnetwork |
| T5 | Fine grainedlocation tracking | Shall have function to trace the mobile terminal location in a fine granularity inorder to provide advanced location based service |
| E1 | Distributedarchitecture | Shall support the distributed network architecture to accommodate anticipated1000 times of traffic |
| E2 | Inter GW mobility | Shall guarantee the service continuity when the change of anchoring GW occursfrequently in the distributed architecture |
| E3 | Flexible reconfigure& upgrade | Shall provide virtualization environment and support to reconfigure and upgradethe core network at low cost without changing the physical network infrastructure |

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3.1.1. Bottom‐up Requirements

3.1.1.1. (B1) Seamless Mobility

5G core network shall support seamless mobility regardless of the cell types and RATs in the environment where the macro BS, small cell BS, personal cell, Type 1 WLAN, Type 2 WLAN1), and relay station are mixed and overlapped. Current mobile core network is mainly designed for macro cell. Thus, seamless HO is supported only between macro cells. The seamless HO between WLAN and macro cell and HO between relay stations are not supported. Since the future mobile core network will support various wireless access in the common platform, the seamless HO among different types should be supported.

3.1.1.2. (B2) Multiple RAT interworking

5G core network shall have architecture to support ‘Flow over Multi‐RAT’ to provide the high volume service in low cost and guarantee the service continuity in spite of the bandwidth deficiency in a wireless access. Currently, the multi‐RAT related technology is used for offloadingpurpose, and consideration on service continuity and QoS support is not being made.

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3.1.4 5G Core Network Architecture

Figure 3.1 5G Core Network Architecture (Example)

The example of the architecture is depicted in Figure 3.1. The key points of the core network architecture can be summarized as follows.

* + - * 5G core network covers both wire‐line and wireless accesses
			* Control plane is separated from the data plane and implemented in a virtualized environment
			* Fully distributed network architecture with single level of hierarchy
			* GW to GW interface to support seamless mobility between 5G‐GW
			* Traffic of the same flow can be delivered over multiple RAT
			* BS co‐located content cache and GW co‐located content/service cache to support low latency service
			1. Architecture Overview

In the 5G network, the performance of wireline service and wireless service will not be different significantly. The service will move freely between wireless access and wireline access, and 5G core network covers both wire‐line and wireless accesses. The wired terminals can be HDTV, PC, and home WiFi AP. These terminals will be connected to 5G‐GW to support seamless mobility between wired and wireless terminals.

The wireless access is connected to either macro BS or 5G‐GW. The macro BS, small cell BS, and Type 2 WLAN are connected to 5G GW. Relay station and Type 1 WLAN are connected to macro BS. Direct connection between small cell and macro BS is not assumed in the figure, but it may be possible. Wireless access connected to the macro BS can be more tightly controlled and possibly provide faster HO to/from the macro BS. Note that we assume two types of WLAN access. Type 1 and Type 2 WLANs are connected to the macro BS and 5G‐GW, respectively. Control plane is separated from the data plane and implemented in virtualized environment. By separating the two functions, more diverse applications and services can be delivered without changing the physical network infrastructure.

* + - 1. Data Plane

In the data plane, seamless mobility is controlled either by macro BS and 5G‐GW. Mobility between relay station and Type 1 WLAN under the same macro BS is locally controlled by the macro BS. Mobility among macro BS, small cell BS, Type 2 WLAN, wired access is controlled by either 5G‐ GW or macro BS. Base station regardless of macro BS or small cell is responsible for L1/L2 based forwarding and 5G‐GW is responsible for L3 based forwarding. Traffic of the same flow can be delivered over the multiple RATs. Multi‐flow can be supported at the peer level, GW level, and BS level. Similar concepts of multi‐flow in peer level and multi‐flow in GW level are MAPCON and IFOM respectively. In order to support load balancing and inter‐GW seamless handover, 5G‐GW to 5G‐GW interface may be required. Main purpose of the inter GW interface is to provide seamless mobility between 5G‐GW and to enable UE to receive/transmit multiple sessions or one session through multiple 5G‐GWs.

* + - 1. Control Plane

Control plane of the 5G core network is expected to be implemented in the virtualized environment. Logical GW in the virtualized environment contains the control plane function of the GW. The logical GW controls multiple GW data‐plane switches. It is expected to have two new functional blocks in the 5G control plane. First one is Radio Resource Information block. It is required to provide the capability to select the best possible radio access among all available wireless accesses. The typical function of the block includes monitoring the radio resources of multiple RATs, Macro‐Relay topology based on channel condition, and etc. Second one is the geometrical location information block. It is required to trace the precise UE location and to identify the best available radio access in the UE location.

Following table explains how we reflect the requirement in the proposed network architecture.

Table 3.3 Architectural Consideration for Requirements

|  |  |  |
| --- | --- | --- |
|  | Requirements | Architectural Consideration |
| T1 | Wired and wireless terminal switching | Integrate the wired terminal into the same control domain as the wireless terminal.Same 5G‐GW controls both wired terminal and wireless terminal. |
| T2 | Network on‐demand | Using the network virtualization control capability, network function can be provided in the virtualized control domain |
| T3 | Context diversity | Addition of new context can be flexibly achieved by adding new context or by exchanging related information with the servers in the virtualization environment |
| T4 | Single ID for one mobile UE | Handling the multiple types of radio access in the same 5G‐GW No distinction for each access network in the control plane |
| T5 | Fine grained location tracking | To trace the fine grained user’s location and select the best possible access network, two new functions are added |
| B1 | Seamless mobility | Macro BS level, 5G‐GW level, inter 5G‐GW mobility is supported |
| B2 | Multiple RAT interworking | Architecture allows multiple level of multi‐flow implementationE.g., peer level (e.g. MAPCON), 5G‐GW level (e.g. IFOM), and BS level |
| E1 | Distributed architecture | Two levels of core network hierarchy (S‐GW and P‐GW) are reduced to one level5G‐GW is located closely to the user side at the same position as the macro BS |
| E2 | Inter GW mobility | GW‐to‐GW interface is defined to support seamless mobility between GWs |
| E3 | Flexible reconfiguration& upgrade | Realization of network is done in the control domain in virtualization environment |

3.2 Wireless Network Requirements

Table 3.4 summarizes the wireless network requirements and the detailed descriptions are as follows.

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Requirement | Brief Definition | Value |
| R1 | Cell spectralefficiency | The aggregate throughput of all users divided by the channel bandwidth divided by the number of cells | DL: 10 bps/Hz/cellUL: 5 bps/Hz/cell |
| R2 | Peak data rate | The maximum theoretically achievable data rate which can be assigned to a single mobile station assuming error‐free conditions when all the available radio resources are utilized for the corresponding link | DL: 50 GbpsUL: 25 Gbps |
| R3 | Cell edge userdata rate | 5% point of the cumulative distribution function (CDF) of the user data rate | DL: 1 GbpsUL: 0.5 Gbps |
| R4 | Latency | Control plane latency: typically measured as transition time from different connection modes, e.g. from idle to active state. User plane latency: the one‐way transit time between an SDU packet being available at the IP layer in the user terminal/base station and the availability of this packet (PDU) at IP layer in the base station/user terminal. | Control plane: 50 ms User plane: 1 ms |
| R5 | Mobility | A mobility class is supported if the traffic channel link can be maintained when the user is moving at the maximum speed in that mobility class. | 500 km/h |
| R6 | Handoverinterruption time | The time duration during which a user terminal cannot exchange user plane packets with any base station. | 10 ms |
| R7 | Areal capacity | In order to accommodate the explosive increase of future mobile data traffic, 5G RAN should be able to scale‐up system capacity by adding more cells in a target area. | [TBD] |
| R8 | Energy efficiency | 5G radio access technology design should aim for higher energy efficiency against increased device/network energy consumption required on 5G wireless communications. | [TBD] |
| R9 | Connectivity | Connectivity in 5G is simply not limited to mobile devices. Instead, every single unit mounting a modem function will connect together for any reasons of safety, communication, cozy life, and so on. | [1000 times] |
| R10 | Positioning | Positioning technology with high resolution is inevitable in establishing an UE centric and UE experiencing services in anytime and anywhere. | [a few cm] |

Table 3.4 Summary of Wireless Network Requirements

NGMN 5G White Paper V1.0 [8]

* 1. **Enhanced Services**

In the 5G environment, services will be developed using a rich set of network and value enabling capabilities as outlined in Chapter 3. Enhanced services will be characterized by a high level of security,

experience and features.

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* + - **Connectivity Transparency**

Connectivity transparency is a key requirement for delivering consistent experience in a highly heterogeneous environment.

5G may involve a combination of radio access technologies (RATs). In addition, given that 3GPP LTE / LTE-Advanced is likely to further evolve within the 5G era, both new RATs and the LTE RAT may be accessible to 5G user terminals.

It is expected that a terminal may be connected to several RATs (including both new RATs and LTE) at a given instant, potentially via carrier aggregation, or by layer 2 (or higher) bandwidth aggregation mechanisms. This combination of RATs may involve also non-3GPP RATs, e.g., IEEE 802.11ax (High Efficiency Wi-Fi).

Each RAT will naturally be deployed from several radio access points; potentially comprising of both high transmit-power (macro type) and low transmit-power (e.g., micro, pico, femto) access points.

The connectivity transparency refers to the following requirements:

* + - * The user application should be always connected to the RAT or combination of RATs and/or access point (or other user equipment in case of D2D) or combination of access points providing the best user experience without any user intervention (context-awareness);
			* Further, the requirement above should be achieved in a seamless way from a user perspective.

By defining the service interruption time as the time during which the user is not able to receive any user plane data, including inter-system authentication time, this requires:

* + - * + Inter-RAT mobility service interruption time, including between 3GPP and non-3GPP RATs, shall be possible to be unnoticeable by the user (possibly depending on the user subscription).
				+ Intra-RAT mobility service interruption time shall be possible to be unnoticeable by the user (possibly depending on the user subscription).
				+ Seamless inter-system authentication, including between 3GPP and non-3GPP RATs.
			* From the network perspective, the network shall be able to control the access points (or other user equipment in case of D2D) and RATs the user device will connect to, based on operator preferences and user’s subscription;
			* In addition, 5G should provide new and more efficient connection management functionalities without the need to use legacy connection functions (e.g., Access Network Discovery and Selection Function - ANDSF).

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**5G Interfacing Options**

Three interfacing options for the access technologies, as depicted in [Figure 10](#bookmark1), provide potential migration paths towards 5G. It is assumed here that the 5G RAT family comprises multiple RATs optimized for different use case categories and/ or spectrum. In [Figure 10,](#bookmark1) the 5G RAT family comprises a new RAT (e.g., optimized to provide high data rates and capacity in higher frequency bands, ultra-low latency or ultra-high reliability, among others) and an evolved LTE RAT (e.g., after a certain 3GPP Release, to provide coverage and support for other use case categories such as low-end machine communications). Nevertheless, the discussion in this section also applies to the alternative case of a new unified RAT supporting all scenarios.

In the first interfacing option, all access-agnostic components supporting the 5G RAT family are provided through EPC [3](#bookmark3) . This option may require evolution of EPC to enable 5G access-agnostic functions to be provided. With this option, there is minimal impact to legacy RAN. Nevertheless, the three interfacing options for the access technologies, as depicted in [Figure 10](#bookmark1), provide potential migration paths towards 5G. It is assumed here that the 5G RAT family comprises multiple RATs optimized for different use case categories and/ or spectrum. In [Figure 10,](#bookmark1) the 5G RAT family comprises a new RAT (e.g., optimized to provide high data rates and capacity in higher frequency bands, ultra-low latency or ultra-high reliability, among others) and an evolved LTE RAT (e.g., after a certain 3GPP Release, to provide coverage and support for other use case categories such as low-end machine communications). Nevertheless, the discussion in this section also applies to the alternative case of a new unified RAT supporting all scenarios.

**Figure 10: Access-technology interfacing options**[**2**](#bookmark2)

In the first interfacing option, all access-agnostic components supporting the 5G RAT family are provided through EPC [3](#bookmark3) . This option may require evolution of EPC to enable 5G access-agnostic functions to be provided. With this option, there is minimal impact to legacy RAN. Nevertheless, the degrees of freedom to evolve the EPC in a manner that efficiently provides 5GFs to support the diversity of use cases may be limited. Thus, legacy paradigms may be applied to all use cases, which may be inefficient and expensive.

In the second option, the 5G access-agnostic functions are provided both through an evolution of EPC and a new design denoted “5G NW functions”. But the new design only supports the new RAT and 4G evolution is supported by the EPC. The advantage is that it allows the benefits of new technologies such as virtualization to be realized while at the same time minimizing the impact to legacy RAN. However, the drawback is that the benefits of the new design can only be realized in areas where there is new RAT coverage. Furthermore, due to limited coverage of the new RAT, interworking interfaces may be needed between the new design for 5GFs and EPC to support mobility between the new RAT and 4G evolution. Providing mobility support through such interfaces may incur significant signalling burden.

In the final option, all components of the 5G RAT family are supported by the new 5GFs design. Other RATs (e.g., Wi-Fi) and the fixed network may also be supported through the new 5GFs design. This option also allows for support of the 4G evolution through the EPC to provide backward compatibility for devices that cannot utilize the new design (e.g., devices that only support LTE before a certain 3GPP Release). Similar to Option 2, this option allows the benefits of new technologies to be fully realized. In addition, it overcomes the mobility issues associated with Option 2. This is because mobility between the new RAT and 4G evolution can be handled by the 5GFs without the need for any interworking. In addition, this option provides a sound migration path, since all RATs (4G evolution as well as evolution of local-area access technologies) can immediately benefit from the 5GFs, even in areas without new RAT coverage.

Nevertheless, Option 3 also introduces new challenges. For instance, it requires the 4G RAN to be upgraded to support both connection through the EPC and the new 5GFs design. Some interfaces may also be needed during the migration phase for basic limited interworking until all 4G base stations have been upgraded to support the new 5GFs design. The same is true for the fixed network and other RATs which will connect to the new 5GFs design. Nevertheless, supporting multiple-connectivity at the device side should reduce the legacy interworking requirements on the network side, and allow design of 5GFs without legacy constraint. For these reasons Option 3 is currently considered by NGMN as the preferred option. In order to facilitate migration toward 5G, NGMN recommends that LTE/ LTE-Advanced and Wi- Fi, as well as their evolution, are to be supported by the new 5GFs design. Thus, the access-agnostic network functions should accommodate any new RATs, as well as LTE/ LTE-Advanced, Wi-Fi, and their evolution.

Regardless of the architecture option pursued, harmonizing different identity and authentication paradigms in cellular networks, (wireless) local access networks, and fixed networks will be essential to enable convergence of different access types, and also to facilitate the realization of different business models. The architecture must also facilitate further convergence of fixed and mobile networks in a manner that efficiently addresses the needs and requirements originating from regulators (e.g. requirements to support MVNOs and MNP for different parts of the converged network).

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