Requirements for converged fixed and mobile networks

Executive Summary of the Deliverable

The main general COMBO target is the convergence of fixed and mobile networks, combining both to deliver an optimal and seamless Quality of Experience (QoE) for the end user; as well as to provide an optimized network infrastructure ensuring increased performance, reduced cost and power consumption. Under this general objective, WP2 performs the preliminary work on fixed, mobile and converged networks, to support the development of COMBO architectures.

The target of Task 2.4 is the specification of requirements and Key Performance Indicators (KPIs) for FMC networks. These requirements and KPIs will be used for the technical and economic assessment and comparison of the FMC architectures proposed in WP3. The present deliverable provides an initial complete set of requirements and KPIs as identified at the end of the first project year (month 12).

The analysis of requirements and KPIs for FMC networks is based on the previous activities of WP2, specifically included in the following deliverables:

- D2.1 provides the reference network, including the initial description of today's fixed and mobile networks describing the network segments, elements, location points, reference parameters and topology. This information is important to understand how current network are for the specification of the general requirements and KPIs.
- D2.1 also defines eight network use cases that describe the needs, which FMC networks shall fulfil. These network use cases are the base of the specific requirements and KPIs identified in D2.4.
- D2.2 provides the state of the art and the evolution of multiple fixed and mobile technologies. The description and limitations of current technologies and the expected enhancements according to the roadmap included in D2.2 have been used to specify challenging but attainable requirements and KPIs values.
- D2.3 has provided information regarding the fixed and mobile traffic to Task 2.4. That information is useful in order to know the current traffic distribution, the need to reduce traffic and to balance (using different networks) or to unify (using the same network) traffic in different environments. D2.3 also provides information related the traffic impact on FMC networks, for example on a

common aggregation network for fixed and mobile services, in order to evaluate if new requirements have to be added.

The methodology used in this task has followed the following steps including the main results on each section:

- The analysis and the specification of requirements, classified in two main groups:
  - Application level (throughput, network availability, delay, packet loss rate, etc.) and general requirements (enhanced QoS and QoE, reduced power consumption, multi-service network, compatibility with legacy networks and multi-operator network) have been included in the general requirements section.
  - Specific requirements for the use cases defined in D2.1. Mainly related to the following functionalities: data forwarding, OAM and management, mobility, security, automatic configuration, subscriber management and resilience. Other important aspects considered in the requirements are: deployment, business and performance.
- The identification of KPIs, with the intention to find a restricted set of agreed and quantifiable parameters to measure the performance of the different network aspects. Similar to the requirements, KPIs for general or common aspects (mainly related to QoS and QoE, techno-economic, power consumption and OAM topics), and use case specific KPIs have been identified (for example KPIs related to the service interruption time due to the handover, the backhaul capacity, the connection set-up time and synchronization accuracy).

Task 2.4 results are important for other activities in other work packages and it is planned to use these results in the following activities:

- For the definition and design of FMC architectures in WP3, as they are going to be based on the same reference network and use cases than Task 2.4. FMC requirements and KPIs will be considered to propose solutions that are able to fulfil them.
- For the studies regarding traffic performance monitoring and supervision in WP4. D2.4 provides KPIs to these studies in order to identify inside WP4 the parameters related to Quality of Service (QoS) performance monitoring and QoE and to define how and where to measure them.
- For the techno-economic assessment in WP5, for example taking into account the cost and energy consumption related requirements and KPIs.
- For the test-bed design and test procedures definition in WP6 during the lab and experimental practical work.

The requirements and KPIs developed by WP2, as a common framework for measurable and quantifiable assessment, will assure synchronization among all COMBO work packages, e.g. in their above listed activities.

It has been considered that during the COMBO project duration, some requirements and KPIs could be modified for several reasons (new or obsolete requirements or KPIs, increase the accuracy, changes in technology evolution, updates in network

use cases, etc.). For that reason a revision of this document will be done at the end of the second (month 24) and third project year (month 35). In that sense, it is planned to get feedback from other WPs results after this D2.4 version and to give feedback to them as well during the following two project years.

Table of Content

1 INTRODUCTION

Figure 1 shows the scope of the whole COMBO project. The work reported in the present deliverable covers the box “Requirements & KPI” of WP2. It identifies the requirements and Key Performance Indicators (KPIs) for the COMBO project that are going to be considered during the development of further activities inside other work packages: the FMC architecture design (WP3), performance monitoring evaluation (WP4), techno-economic assessment (WP5) and laboratory/experimental research activities (WP6).

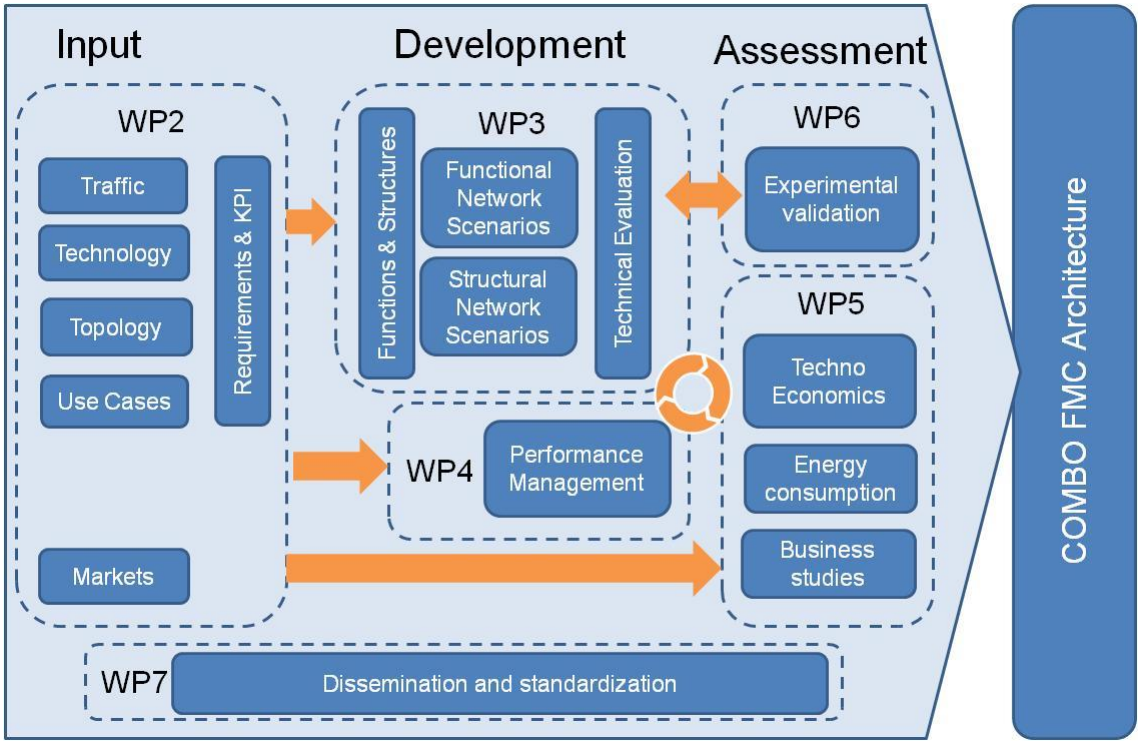

Figure 1: Work structure of COMBO project

The target of Task 2.4 is the specification of requirements and KPIs for FMC networks. The present deliverable provides an initial complete set of requirements and KPIs as identified at the end of the first project year (month 12). The methodology used in this task has followed the following steps:

- The analysis and the specification of requirements, classified in two main groups:
  - Application level and general requirements have been included in the general requirements section.
  - Specific requirements for the use cases defined in D2.1.
- The identification of KPIs, with the intention to find a restricted set of agreed and quantifiable parameters to measure the performance of the different network aspects. Similar to the requirements, KPIs for (1) general or common aspects, and (2) use case specific KPIs have been identified, which will be used by other work packages during their technical and economic assessment activity.

The document is structured in two main technical sections:

- Section 2 identifies and describes the requirements derived from the reference framework definition and FMC network use cases from Task 2.1, the defined fixed and mobile technologies and roadmaps from Task 2.2 and the traffic forecast from Task 2.3.
- Section 3 defines the KPIs for FMC networks that will be used in different work packages inside the COMBO project to perform the technical assessment, the comparison among different approaches and to select the best FMC solution.

Both sections provide respectively a classification of the related requirements and KPIs.

2 FMC NETWORK REQUIREMENTS

2.1 Introduction

This section specifies the fixed and mobile converged network requirements derived from the preliminary tasks developed in COMBO WP2:

- Task 2.1: Reference framework
- Task 2.2 Fixed and mobile network evolution
- Task 2.3 FMC traffic modelling

Currently, there are several Standard Development Organization (SDOs), such as European Telecommunications Standards Institute (ETSI), International Telecommunications Union (ITU), Internet Engineering Task Force (IETF), Institute of Electrical and Electronics Engineers (IEEE), etc., that specify reference architectures, protocols and requirements for fixed and mobile technologies and networks. However, SDOs create groups or are part of other consortiums, such as Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN), 3rd Generation Partnership Project (3GPP), Broadband Forum (BBF), Metro Ethernet Forum (MEF), etc., which are typically focused on either fixed or mobile environments. Therefore, a joint converged approach for both fixed and mobile networks is not usually considered.

The objective of this section is not to repeat current requirements and specifications from independent fixed and mobile network, but to provide a common point of view where both environments are considered inside a single FMC approach.

These requirements have been developed among COMBO partners; additionally we have tried to include the user point of view during this process as well, guaranteeing at least the same level of QoS and QoE than traditional fixed and mobile network or even improving it. For each use case a team including operators and industrial partners have participated in the requirement definition and academic partner have contributed in the review of all of them. Several cycles of definition, agreement and refinement have been followed to select those most oriented or relevant to FMC aspects.

This section is divided in two main groups:

a) General requirements addressing common areas of FMC networks and

b) Specific requirements addressing the needs to be fulfilled for particular FMC scenarios derived from the network use cases described in Task 2.1.

2.1.1 Conventions

All specifications covering different levels of requirements need to define some words to specify how requirements should be interpreted. The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [1]. A brief summary of the most common words is included below:

- MUST: this word, or the adjective “REQUIRED,” means that the definition is an absolute requirement of the specification.
- MUST NOT: this phrase means that the definition is an absolute prohibition of the specification.
- SHOULD: this word, or the adjective “RECOMMENDED,” means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications must be understood and carefully weighted before choosing a different course.
- MAY: this word, or the adjective “OPTIONAL,” means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

These words are always capitalized when used in their requirements sense.

2.2 General requirements

2.2.1 Application level requirements

This section introduces a set of reference applications that are typically found in fixed and mobile broadband networks. Some of them could be considered as traditional whereas other could be classified as emerging. A short definition and specific requirements of each reference application in terms of requested bitrate and Quality of Service (QoS) are provided.

2.2.1.1 Reference applications

For the purpose of this document the following list of reference applications is chosen:

- Legacy telephony:

  Legacy telephony transports voice information using narrow band signals over the traditional Public Switched Telephone Network (PSTN). Depending on the type of signals used, either analogue or digital, legacy telephony can be based on POTS (Plain Old Telephone Service) or ISDN (Integrated Services Digital Network), respectively.
- Voice over IP (VoIP)

  VoIP service delivers voice and multimedia contents over IP networks. For IP voice calls, the procedure is similar to traditional digital telephony but instead of being transmitted over a circuit-switched network, the digital information is packetized and transmitted as IP packets over a packet-switched network; moreover, signalling procedures do not rely only on legacy signalling protocols (SS7) but on specific IP based protocols such as SIP. Legacy telephony and VoIP can be considered as implementations of the same application using two different technologies; however the requirements can be different (e.g. in terms of bandwidth, bitrate, delay, etc.).
- Video conferencing

Another emerging high-bandwidth application is video conferencing. Today, web cameras are widely used for keeping in touch with friends and family with moderate quality and bandwidth requirements. However, video over instant messaging and video calling are experiencing high growth. Professional high quality video conferencing services (e.g. HD video conferencing) are becoming increasingly popular. Such applications require a high bidirectional service bandwidth. Especially, for the business user segment, a high growth of videoconferencing traffic is expected in coming years. Business users invest in high quality video conferencing systems in order to save travelling costs.

- Video services

  Consumer usage of bandwidth has increased significantly over the last few years and future multimedia services will continue to drive the bandwidth growth in telecommunications networks. The demand for video services (such as internet video to PC, internet video to TV, IPTV) is the key driver for this growth. The sum of all variants of video (TV, video on demand, internet, and peer-to-peer video broadcasting) will dominate the global consumer traffic with more than 90% by 2014 [2]. Increasing screen size and computing power (e.g. multi-core systems), as well as high and ultra-high definition video formats, boost this trend.

  - Broadcast TV/radio

    The overall broadcast TV service bandwidth will increase also due to the evolution from today's Standard Definition TV (SDTV) and upcoming High Definition (HDTV) towards 4k and Ultra HD (8k) and 3D formats. This is driven by the fact that the cost of flat-panel screens is continuing to drop, which allows residential and business users to expand their screen size. Additionally, a low latency for a fast channel hopping is important.

  - Video/audio/application on demand

    Today's service evolution shows that the trend goes for TV/Video services from linear transmission towards an individualized usage. Many people want to watch a TV program when it suits them (On-demand TV). In consequence, more and more video content is provided (controlled by network service providers). Furthermore, applications like internet video will also use advanced video formats (HD, 4k, Ultra HD and 3D) and therefore further drive the bandwidth requirements.

  - Video over-the-top

    Video over-the-top services are video services that can be used over a network but are not offered by the network operator. The video is transmitted on top of the services a customer already gets (typically an internet connection) and doesn't require any specific video service provided by the network operator.

- Peer-to-peer (P2P) video/audio/file exchange

  Today a major part of the consumer internet traffic is based on P2P file sharing that includes traffic from P2P systems such as BitTorrent, eDonkey, etc., as well

as traffic from web-based file sharing systems (including exchange of video files) [3]. P2P traffic is currently growing in volume, but declining as a percentage of overall IP traffic.

Predominance of traditional video distribution services (linear or on demand) would mean that residential traffic will remain asymmetric. However, this may change if content providers and distributors allow direct distribution for instance to offer live video streaming through P2P as practiced in China (PPLive).

Video-based P2P applications along with HD video conferencing would result in more symmetrical residential traffic. The business user segment requires typically more symmetrical services, e.g. LAN-to-LAN connection services, so that the evolution towards a converged access platform for residential and business applications drives the need for more symmetrical user service connections.

- Web browsing and downloading

  The primary purpose of web browsing is to bring information resources to the users, allowing them to view the information and navigate from one information point to another. Therefore, this service gives end-users access to internet with the capability to download different kinds of data (text, images, video, etc.) hosted in a web server using a web browser.

- E-mail

  This application refers to the exchange of messages and files between users using computers or terminals. Email servers accept, forward, deliver and store these messages so the end user only have to connect to the server for as long as it takes to send or receive the information.

- Instant messaging and chatting

  This application offers real time text transmission over internet. More advanced instant messaging systems also allow voice messaging, file sharing or video chat.

- Multiplayer gaming

  Today, the game content is locally stored on the user's PC so that gaming does not require a lot of access bandwidth. However, this situation is changing due to Gaming on Demand (GoD). GoD allows the streaming of gaming content to a terminal device in the form of a video/data stream similar to video on demand. In case that a significant amount of gaming activity moves online, the traffic increase could be extraordinary. Additionally, multiplayer gaming is very popular today, which drives to extremely high requirements on network latency.

- Cloud services

  A high growth can be foreseen for cloud services which offer a dynamic, virtualised IT and network infrastructure that can be used as a service by customers. Residential as well as business users will have access to a wide range of cloud services, available on demand over the internet provided by an increasingly large number of service providers (e.g. Amazon), IT and telecommunication providers. This will increase the number of services with high challenging requirements in terms of security, real time availability, traffic

symmetry and performance because the loss of business critical applications and systems or the loss of relevant business information such as client, order or invoice data may easily cause great economic damage.

- Social networking services

  One of the emerging trends in social networking is the real time distribution of content with broadcast characteristics, e.g. Twitter, and the content will evolve from today's mainly text-based to high-bandwidth demanding video streaming or photo sharing based services. In general, it will have impact on both fixed and mobile access, consumer and business segments. It is worth noting that mobile and location based social networking have become popular with the rising demand for smart phones. This trend drives the bandwidth growth considering the fact that mobile phones with 20 Megapixel cameras and HD video support are expected for the next years.

- Machine to Machine services (M2M)

  Machine-to-machine communications implies communication amongst machines without the interaction of human beings. M2M communications are increasingly used in applications such as tele-health, environmental monitoring, shipping and logistics, industrial automation, asset tracking, etc. Traffic generated by M2M applications may have a broad range of diverse requirements, for example smart meters and vending machines could have very flexible communication requirements (e.g. low bandwidth with bursty traffic); however, for applications such as security systems and health care, response times may be critical (e.g. high bandwidth with continuous data traffic).

- Digital Home services

  Telecommunication industry has evolved from telephony, internet and Triple Play services (telephony, internet access and video) towards Digital Home that combines Triple Play with lots of new consumer applications such as in-home streaming, home automation, and remote home security as well as additional services yet to come. The ever-increasing number of consumer devices, such as gaming consoles, digital picture frames, e-book readers, pico-projectors and TelePresence screens, also has a role in driving the need for higher access speeds.

2.2.1.2 Specific requirements and needs of reference applications

Services can be classified by their time dependency into real time and non-real time services. In real time applications, QoS is measured by metrics related to time, such as delay and Packet Delay Variation (PDV) and these type of services usually have more stringent QoS requirements than non-real time services. Services involving the interaction with, or between humans should provide an acceptable delay and PDV to make the service acceptable.

As such, regardless of the specific service, the quality level perceived from the end-user determines whether the service is acceptable. Outside of this limit, the user will become annoyed and will find the service unacceptable. To support these kind of services, they should be transmitted with a reliable bitrate, low PDV and loss rate [3].

On the other hand, applications that are considered as non-real time often generate best-effort traffic, not requiring any specific reliability in terms of QoS metrics. Web browsing, downloading and emailing are included amongst these applications, which are not very sensitive to timing constraints. This may not be the case for some business related non-real time applications.

R0_01. The following table provides the minimum bitrate that SHOULD be assured for the reference applications considering different environments: fixed, Wi-Fi and mobile networks. As far as bitrate is concerned, the minimum requirement is tightly related to the end device involved in the communication. Table 1 considers different devices, for example, residential devices (such as an IP phone, a TV set or a desktop PC) for the fixed environment, a portable device (such a laptop or a tablet) for the Wi-Fi environment or a mobile device (like a smartphone) for the mobile environment. Moreover, bitrate also depends on the codec used for the compression and transmission of audio and video services.

	Minimum bitrate up/down (bit/s)		
Representative Application	Fixed CPE	Wi-Fi device	Mobile UE
Legacy telephony	64 k (1)	N/A	12.2 k (AMR)
VoIP	10 k (1)	10 k	10 k (3)
Video conferencing	300 k (1) HD: 7-12 M	300 k HD: 2 M	300 k HD: 1 M
Broadcast TV/radio	MPEG2: SDTV<6 M HDTV<20 M (1) MPEG4: SDTV<3 M HDTV<10 M (1) HD3DTV: < 15 M 4kUHD <20 M (HEVC) 8kUHD < 100 M (HEVC)	SDTV : 2-5 M HDTV : 6-13 M	MPEG-1: 1.5 M MPEG-4: 500 k
Video/audio/application on demand	Same as broadcast TV/radio	Same than broadcast TV/radio	Same than broadcast TV/radio
Video over the top	360p 0.5 M (MPEG4) 720p 2-3 M (MPEG4) 1080p 3-6 M (MPEG4) Audio 192 k (AAC) Audio 64 k (MP3)	360p 0.5 M (MPEG4) 720p 2-3 M (MPEG4) 1080p 3-6 M (MPEG4) Audio 192 k (AAC)	240p 0.5 M (MPEG4) 720p 2 M (MPEG4) 1080p 3 M (MPEG4) Audio 64 k (MP3)

	Minimum bitrate up/down (bit/s)		
Representative Application	Fixed CPE	Wi-Fi device	Mobile UE
		Audio 64 k (MP3)	Audio 24 k (AAC)
Peer-2-peer video/audio/file exchange	N/A (1)	N/A	N/A
Web browsing and downloading	<<5 M/<<3 M (1), (2)	<<5 M/<<3 M	<<5 M/<<3 M
E-mail	<<1 M/<<500 k (1), (2)	<<500 k/< 100 k	<<500 k/< 100 k
Instant messaging and chatting	<<1 M/<<500 k (1), (2)	<<1 M/< 100 k	<<1 M/< 100 k
Multiplayer gaming	<<2 M/<<500 k (1), (2)	<<2 M/<<500 k	<<2 M/<<500 k
Cloud service	<<3 M/3 M	<<3 M/3 M	<100 k/100 k
Social networking	<<3 M/3 M	<<3 M/3 M	<<1 M/1 M
Machine to machine • smart meters • security systems	<10 k /50 k <1 M/10 M	<10 k /50 k <1 M/10 M	<10 k /50 k <10 k /50 k
Digital Home • content delivery • home automation	<50 M <200 k	<10 M <200 k	<1 M <200 k

(1) Source: IST-MUSE DA1.2 "Network Requirements for multi-service access", http://www.ist-muse.org/[5]

(2) These applications will select low values for the minimum bitrate to minimise cost. For example, web browsing could be possible with a minimum of 100 kb/s as the applications can adapt themselves to the existing network capacity.

(3) HD voice can require a higher bitrate. The minimum bitrate using AMD-WB codec is 6.6, 8.85 and 12.65 kb/s [6]

Table 1: Minimum bitrate for reference applications

R0_02. Table 2 provides some of the most important parameters that characterize the QoS requirements for the selected reference applications. All of them SHOULD be guaranteed:

Representative application	Network availability	Application set-up time	Connection set-up time	Delay (one-way)	PDV	Packet loss rate
Legacy telephony (1)	>99.99%	<2 s	<100 ms (time to get the tonality)	<100 ms	<20 ms	$<5 \times 10^{-2}$
VoIP (1)	>99%	<2 s	<300 ms	<200 ms	<20 ms	10^{-3}
Video conferencing (1)	>99%	<2 s	<300 ms	<200 ms	<10 ms	10^{-5}
Broadcast TV/radio (1)	>99.99%	<500 ms	<3 s	<400 ms	N/A	10^{-5} (MPEG2)
Video/audio/application on demand (1)	>99.99%	<500 ms	<3 s	<400 ms	N/A	10^{-5} (MPEG2)
Video over the top	>99%	<2 s	<3 s	N/A	N/A	N/A
Peer-2-peer video/audio/file exchange (1)	>99%	<1 s	<3 s	<200 ms	N/A	N/A
Web browsing and downloading (1)	>99%	<1 s	<3 s	N/A	N/A	N/A
E-mail (1)	>99%	<1 s	<3 s	N/A	N/A	N/A
Instant messaging and chatting (1)	>99%	<1 s	<3 s	N/A	N/A	N/A
Multiplayer gaming (1)	>99%	<1 s	<3 s	<50 ms	<1 ms	10^{-3}
Cloud services	>99%	<1 s	<3 s	N/A	N/A	N/A
Social networking	>99%	<1 s	<3 s	N/A	N/A	N/A
Machine to machine • smart meters • security systems	>99%	N/A	N/A	Depending on application		

Representative application	Network availability	Application set-up time	Connection set-up time	Delay (one-way)	PDV	Packet loss rate
Digital Home • content delivery • home automation	 >99% >99%	 <1 s <1 s	 <3 s <3 s	 < 250 ms N/A	 <100 ms N/A	 10^{-5} N/A

(1) Source: IST-MUSE D A1.2 "Network Requirements for multi-service access", http://www.ist-muse.org/[5]

Table 2: QoS requirements for reference applications

2.2.2 General network requirements

This section identifies general requirements for FMC networks that have been classified according to different aspects:

- End-users. End-users want to have access to a rich service portfolio of services and applications. Residential as well as business users expect the following basic features:
  - R0_03. The FMC network SHOULD have at least the same generic qualities of a current operated fixed and mobile network. Generic qualities include QoS/QoE, network performance, configuration, management, security, resiliency and integrity among resilience others.
  - R0_04. The FMC network MUST provide a transparent connectivity to the end users whatever the physical medium is being used.
- Migration path from fixed and mobile networks to an FMC network:
  - R0_05. The FMC network MUST support a migration path from the existing fixed and mobile network architectures without any prolonged service interruption.
  - R0_06. The FMC network SHOULD be capable of reusing existing fixed and mobile legacy network infrastructure as much as possible.
- Node consolidation:
  - R0_07. The FMC network SHOULD support node consolidation through a reduced number of access sites and elements compared to today's networks. This requirement is important for new network elements which combine fixed and mobile functionalities.
- Power consumption:
  - R0_08. The FMC network MUST be designed considering energy-efficient aspects whilst maintaining compatibility with the service requirements.
- Network flexibility and supervision:
  - R0_09. The FMC network SHOULD provide different services to different customer types using a common infrastructure.

- R0_10. The FMC network MUST provide suitable performance monitoring, fault management and diagnosis solutions for fault detection and localization for the different network segments.
- Network sharing: A multi-operator network in which the network equipment can be shared is a priority for FMC networks. Requirements for network sharing are specified in section 2.3.8.

2.3 Specific network use cases requirements

The following sections specify the requirements relative to the different use cases identified in D2.1 [8].

2.3.1 Requirements for UC1 - Unified FMC access for mobile devices

This section includes the requirements that must be met by the different elements that are part of an FMC solution able to offer unified mobile and Wi-Fi services in a seamless and transparent way to the end user with the target of using the most effective connectivity solution in cost and throughput, at any time. Additionally, mobile devices are able to simultaneously use both Wi-Fi and mobile accesses and seamlessly move all or part of their traffic from one access to another. Network assistance allows for selecting and using the most suitable access network(s) according to application needs. Thus, the Wi-Fi and mobile access networks should complement each other in order to provide the customers with a higher global data rates, better latency time and the seamless mobility.

Use case 1 is described in detail in the section 3.4.1 of D2.1 [8]. The next figure depicts the general network model for this use case:

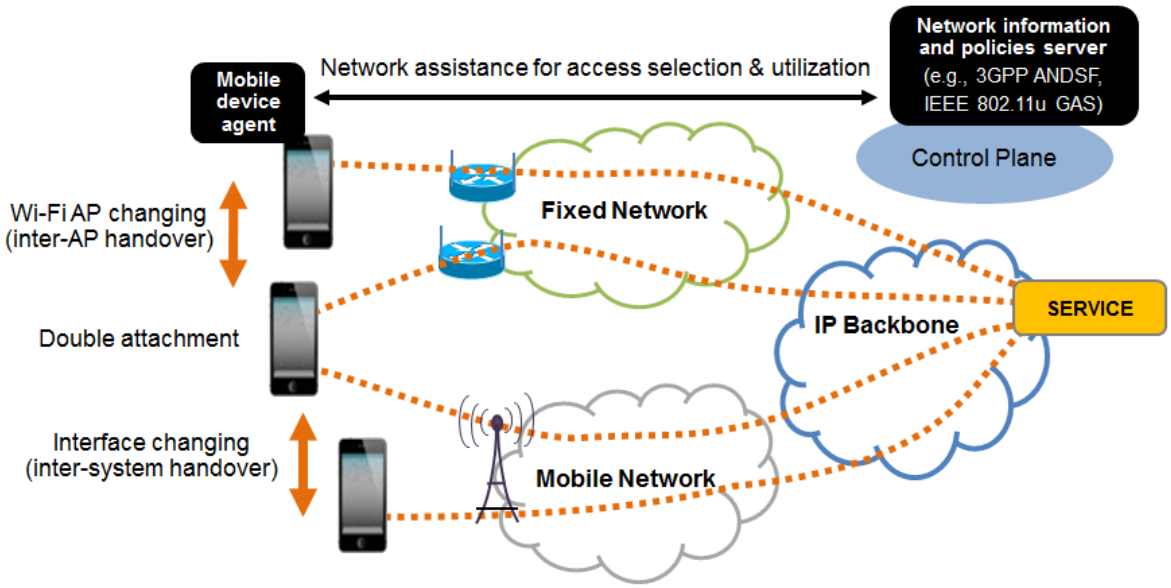

Figure 2: General network model for UC1

2.3.1.1 Wi-Fi access requirements

Carrier Wi-Fi SHOULD be used (the requirements of which can be found below):

- R1_01. Advanced radio techniques to improve the performance, such as beam forming, MIMO, spatial multiplexing, 40 MHz channels, frame aggregation, client load balancing and block acknowledgment.
- R1_02. Self-Organizing Network (SON) techniques to assure the QoS: interference detection and mitigation, band steering[1], air time fairness[2], traffic classification and prioritization.
- R1_03. Security implementations to have the same level of security as in mobile networks: wireless authentication (e.g.802.1x, EAP-SIM, EAP-AKA, EAP-TLS and EAP-TTLS), encryption (e.g. WPA and WPA2) and wireless intrusion detection.
- R1_04. Be able to work with different backhaul technologies, such as: Ethernet, Digital Subscriber Line (DSL), Fibre (GPON or point-to-point fibre), Hybrid Fibre-Coaxial (HFC) and mesh (using also Wi-Fi).

2.3.1.2 FMC network requirements

- R1_05. The FMC network MUST optimize the network resources to share them among the different local Wi-Fi networks, reducing the cost per AP and the maintenance and supervision costs, e.g. installing the centralized Access Controllers in the Central Offices (CO).
- R1_06. The FMC network MUST provide appropriate packed delay and PDV values for different applications requirements. The FMC network MUST at least have the same level of QoE than a non FMC network.
- R1_07. The FMC network MUST be able to keep track of mobile devices' sessions and traffic transmitted/received through 3GPP and Wi-Fi systems for charging and/or lawful interception purposes.
- R1_08. The FMC network MUST be able to accept a mobile device to simultaneously connect through Wi-Fi and through the mobile network.
- R1_09. IP session continuity: the FMC network MUST be able to minimize the packet loss and interruption time when the mobile device performs a handover, either between two Wi-Fi APs or between Wi-Fi and mobile networks.
- R1_10. Traffic and load balancing: when mobile devices simultaneously connect to the Wi-Fi and mobile networks, it MAY be possible to move only a part of the traffic from one interface to another.

[1] Band steering is the act of an AP steering clients from the 2.4 GHz band to the 5 GHz band in order to increase throughput by reducing contention for the busy 2.4 GHz band resources.

[2] Air time fairness means to allow faster clients to have more airtime than slower clients.

- R1_11. Access selection: The FMC network MUST be able to dynamically provide the mobile device with the relevant information to enable it to select the most suitable access network according to the network conditions and the user subscription.

2.3.1.3 Terminal requirements

- R1_12. The mobile device MUST include Wi-Fi connectivity using at least 802.11n (5 GHz SHOULD be preferred). Other future Wi-Fi technology evolutions (e.g. 802.11ac) SHOULD also be used when available.
- R1_13. The mobile device MUST be compliant with Wi-Fi security mechanisms (WPA2, WPA2 keys distribution/configuration over the air, WPS, etc. can be part of the FMC solution and required in the terminal).
- R1_14. The mobile device MUST be compliant with authentication mechanisms (EAP-SIM, EAP-AKA, EAP-TLS, EAP-TTLS, etc. can be part of the FMC solution and required in the terminal). The User Equipment (UE) SHOULD use the existing 3GPP credentials for authentication purposes (based on SIM cards).
- R1_15. The mobile device SHOULD be able to receive and process information from the network to be used during the discovery and selection of the operator's managed Wi-Fi networks.
- R1_16. The mobile device MUST allow a standalone way of operation based on static policies provisioned on it.
- R1_17. The mobile device MUST allow an automatic discovery, selection and registration in a Wi-Fi network without the user's interaction, as it is done on a mobile. This process MAY be based upon different criteria, such as, user preferences, operator policies and network optimisation rules.
- R1_18. Dual attachment: the mobile device MUST be able to simultaneously connect to the Wi-Fi and mobile network and to balance the traffic over the two interfaces according to different criteria (e.g. application ID, network quintuplet[3]…).
- R1_19. The mobile device MUST be able to perform inter-access mobility without noticeable impact on upper application layers, maximizing QoE (i.e. when the network interface is changing in the case of a handover between Wi-Fi and mobile networks).

2.3.2 Requirements for UC2 - Converged content caching for unified service delivery

In this use case a content caching solution provides services to the users of a FMC network. As stated in the section 3.4.2 of D2.1 [8], video traffic is expected to be the main network driver in the years to come. Therefore, FMC networks must provide a way of being able to cope with future traffic demands by optimising CDN and caching

[3] Network quintuplet: IP source and destination addresses, protocol number, TCP/UDP source and destination ports.

related functions within the FMC network as proposed in the general network model for this use case (see next figure). The current section describes the main requirements to achieve it.

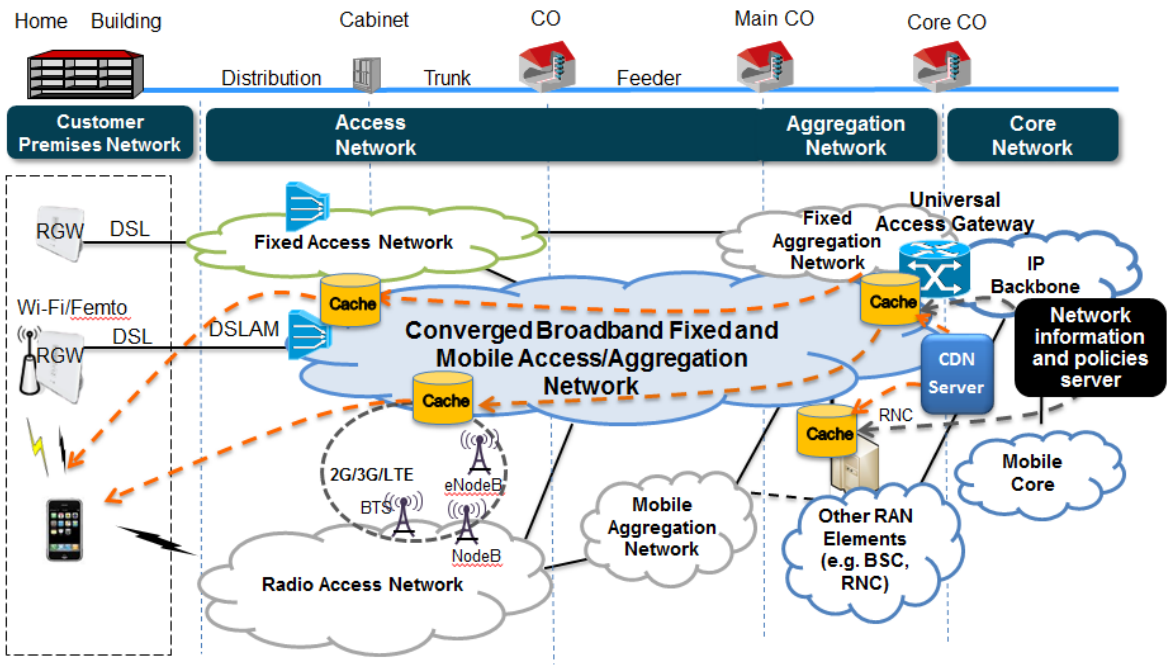

Figure 3: General network model for UC2

2.3.2.1 FMC network requirements

- R2_01. The content caching solution MUST be comprised of different caching elements placed along the network that are able to cooperate among them. Concretely, their presence is required in the UAG and in other network elements as shown in Figure 3.
- R2_02. Depending on the deployment area, caching elements MAY be placed in the access network elements (such as DSLAMs and eNodeBs), in order to be able to serve content as near as possible from the user.
- R2_03. The content caching solution MUST interact with the mechanism defined in UC1, where the network can decide to change the access of a mobile device, which affects ongoing sessions with the content caching solution.
- R2_04. The FMC network SHOULD ensure that handovers do not affect content streaming sessions from the FMC's content caching solution.
- R2_05. The caching elements MUST be managed by the FMC network. That is, the FMC network will take into account the location of the cache and its size, the network status and the clients' demands in order to store contents in each of them, so that the resources of the FMC network, as a whole, can be used more efficiently.

2.3.2.2 Wi-Fi access serving requirements

- R2_06. The devices (such as residential gateways), providing Wi-Fi access to subscribers MUST be able to differentiate the physical interface currently used in order to apply different constraints to users connected through cable of through Wi-Fi.
- R2_07. Rate control or quality supervisions MAY be used in the case of Wi-Fi in order to ensure the distribution of the available bandwidth in the Wi-Fi air interface.

2.3.3 Requirements for UC3 - Reuse of infrastructure for small cell deployments

In order to provide better coverage and capacity, especially to indoor end-users, operators are looking to deploy indoor small cells as well as outdoor small cells as a complement to existing macro cells. To facilitate wide deployment of small cells, the deployment costs need to be reduced. Therefore, it is important that small cells can reuse existing infrastructure wherever possible, even if the conditions for residential and business buildings are different. While small cell coverage for office buildings can often make use of an existing infrastructure of category 5, 6, 7 cables (or even optical), the case is different for residential buildings. Here, the infrastructure often consists of category 3 telephony cables, where the cross talk, both external and internal, is the main source of disturbance.

As illustrated in Figure 4, the small cells can be of different types: pico Base Stations (pBSs) with integrated BBUs that are deployed indoors and outdoors, Remote Radio Units (RRUs) with BBUs centralized in the network, or Radio Heads (RHs) connected to a Radio Unit (RU). An indoor small cell gateway provides baseband functionality for the RRUs and aggregates the traffic from all small cells in the building. In residential buildings, the pBS is located in the RGW to provide mobile coverage in the home network.

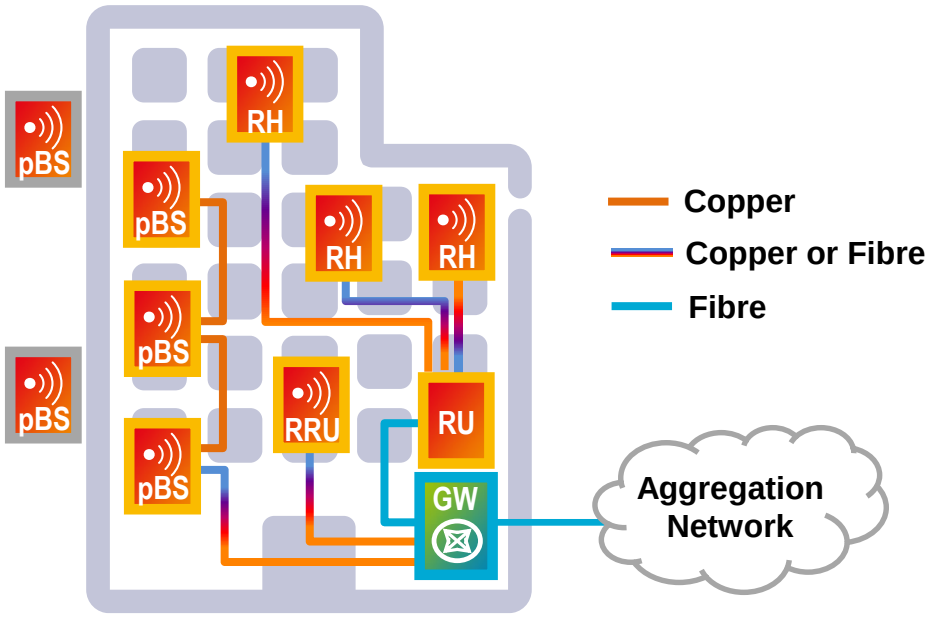

Figure 4: Illustration of reusing existing infrastructure for small cell deployments

In addition to the requirements specified in this section we would like to refer to the study in [10], which specifies small cell backhaul requirements in the following categories: *Backhaul Architecture*, *Coverage and Connectivity*, *Capacity Provisioning*, *QoS Support*, *Synchronisation*, *Availability and Resiliency*, *Physical Design / Hardware Architecture*, *Security*, and *Operational, Management, Traffic Engineering*.

2.3.3.1 Infrastructure requirements

- R3_01. Fixed copper infrastructure already deployed for legacy telephony MAY be used to provide connectivity from the Cell Site Gateway (CSG) to the small cells. New copper technologies, such as G.fast, can be used to provide the expected capacity demands.
- R3_02. Small cell deployments reusing a building's fixed infrastructure SHOULD be able to co-exist with other broadband deployments.
- R3_03. The fixed infrastructure MUST support synchronization of small cells.
- R3_04. Mechanisms that enable fixed infrastructure sharing between different network operators SHOULD be provided.

2.3.3.2 Small Cell Node requirements

- R3_05. Interference mitigation SHOULD be supported, so that the baseband parts of a small cell and the cell or cells it is to be coordinated with (macro, other small cell) shall be collocated or connected via very low latency links (preferably well below 1 ms, worst case in the order of tens of ms for slower RRM).
- R03_06. Multi-RAT solutions SHOULD be supported.
- R3_07. The small cell SHOULD support Wi-Fi.

- R3_08. Multi-operator mechanisms SHOULD be supported simultaneously over the same small cell.
- R3_09. Operations, Administration and Maintenance (OAM) SHOULD be supported to manage the indoor network of small cells.
- R3_10. SON SHOULD be supported to enable simple installation and network auto-configuration.

2.3.4 Requirements for UC4 - Universal access bundling for residential gateway

The scope of this section is to describe high-level requirements for the hybrid connectivity for FMC customer services required to implement and operate a bundling of DSL access and mobile/wireless access.

The target is to provide the user with dynamic optimum bandwidth and efficient resource via available fixed, cellular mobile and Wi-Fi technologies. Such access bundling is achieved by using several transmission channels simultaneously (e.g. fixed xDSL, Wi-Fi hotspot and cellular radio) (see Figure 5). An additional element is required in the network, called Hybrid Connection Gateway, which is in charge of redirecting/collecting IP flows to and from multiple paths for a given end-user.

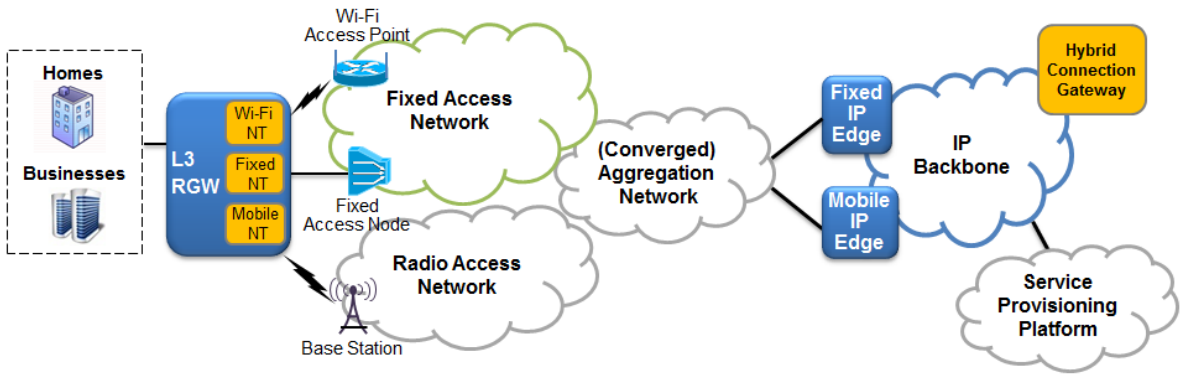

Figure 5: General network model for UC4

One prerequisite for this use case is the ability of the Customer Gateway (CGW), e.g. Residential Gateway (RGW), to connect on the physical layer in parallel both fixed and mobile networks. In addition most CGWs today have Wi-Fi routing functionality. Another general precondition within the network is that the Hybrid Connection Gateway (HCG) needs IP connectivity.

Since this use case aims at maximising the customer connection speed from the technical point of view the CGW as well as the HCG SHOULD optimize the distribution of the temporally variable connectivity request either in upstream (CGW) or in downstream (HCG) direction.

The following points address some further more specific requirements (RECOMMENDED by default):

- Usability requirements from Customer's perspective:
  - R4_01. The solution MUST work without any configuration by the end user known as "zero configure secure plug & play".
  - R4_02. Credential requests MUST be minimized to configure and to run the Hybrid Access solution, either fixed or mobile credentials only, or an FMC operator universal subscriber identity have to be supported. The universal subscriber identity means one unique authentication credential for the end user.
- Functional requirements:
  - R4_03. The solution SHOULD allow the implementation of policy based load balancing.
  - R4_04. L3-GW: The solution MUST support to set up and maintain multiple IP connectivity states and routes for transparency between the Customer Gateway and the Hybrid Connection Gateway.
  - R4_05. The solution SHOULD provide idle interfaces to be set to sleep or off-mode to save energy.
  - R4_06. The solution MUST support an automated reset or switch off of "Hybrid Access" software in case of unexpected state.
- Performance requirements:
  - R4_07. DSL and wireless access channels MUST be automatically combined.
  - R4_08. The traffic split between DSL and wireless access channels MUST be adapted in a flexible and fast way to changing parameters (e.g. throughput, latency, PDV, packet loss) of access media, in particular radio access (e.g. by measurement of access channel characteristics).
  - R4_09. The combined bandwidth MUST be higher than the best performing single physical connectivity (either fixed or mobile access).
  - R4_10. The solution MUST support the service related requirements on delay and PDV degradations (refer to Table 2).
  - R4_11. The solution MUST support an overhead of less or equal to 10% for the "bonding" mechanism.
  - R4_12. The solution MUST support possibilities for network operator to configure, control and prioritize traffic flows over DSL access channel and mobile access channel (e.g. "cheapest pipe first" or limitation of data rate to maximum upper limit).
- Service-and application related requirements:
  - R4_13. The solution MUST enable possibilities of the network operator to differentiate between different application categories and their QoS requirements and to adapt the routing mechanisms (applications or application categories may be for example identified by IP address or port address of source or destination).
  - R4_14. The data transmission MUST in general be transparent above the IP layer, but dedicated handling possibilities for dedicated services or service categories MUST be possible, e.g.

- Routing of VoIP only over DSL.
- No IPTV if DSL is not sufficient.

– R4_15. The solution MUST support a possibility for “break out” use cases where traffic of some applications is not distributed by the bonding mechanism, i.e. it uses only one default interface and is transported by using usual IP mechanisms (e.g. to ensure reachability of service control platform for VoIP).

2.3.5 Requirements for UC5 - Support for large traffic variations between public, residential and business areas

This section specifies the requirements to be met in order to support dynamic handling of network resources related to mobile, residential and business services (both IP and CPRI/OBSAI based). This assumes a convergent and common infrastructure able to interoperate with any backhaul and front-haul network element (NE) or, in general, with any fixed/mobile access.

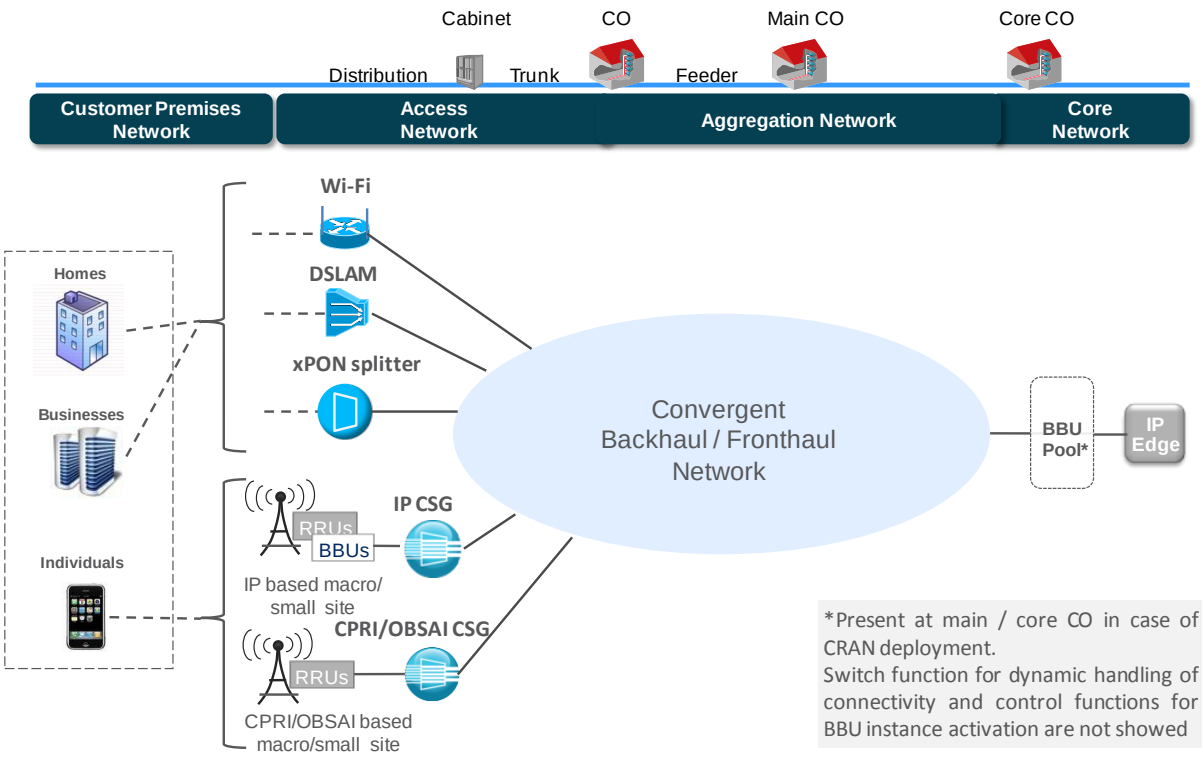

Figure 6: Network reference for UC5

2.3.5.1 Interoperability with fixed/mobile network elements

- R5_01. The convergent infrastructure MUST, interoperate seamlessly with any fixed/mobile NEs, allowing for the effective transport of:

a. IP services, related to conventional mobile applications (e.g. IP-cell site gateway), fixed applications (e.g. DSLAM, ONT/ONU) and Wi-Fi hot-spots;

b. TDM services, related to upcoming "CRAN model" (i.e. CPRI/OBSAI-cell site gateway).

- R5_02. Depending on the specific application, the convergent infrastructure SHOULD interoperate with fixed/mobile NE's for what relates:

  a. OAM functions for Fault Management and Performance Management,

  b. Resilience means,

  c. Management and control protocols means for Configuration Management, Fault Management and Performance Management.

  d. Synchronization means.

- R5_03. The functional interoperability addressed at R5_03 MUST occur at the layer handled by the specific fixed/mobile NE, for the interested service: then L1 and/or L2 and/or L3.

- R5_04. The convergent infrastructure MUST interoperate with any fixed/mobile NEs at physical layer. This implies the capability to match different topologies, including point-to-point, tree-PON and ring with dedicated items (see, optical power splitter, optical filters, etc.)[4]. This includes, also, the capability to match optical interfaces performances, in terms of:

  – Span r*each* – *U*p to 40 km, in case of signal termination at the edge node; up to 80 km, in case of no termination performed at edge node.

  – Operative rate - 1 to 10 Gb/s.

  – Operative wavelength - depending on the deployment scenario, non-coloured, coloured (e.g. CWDM, DWDM, TWDM-PON and GPON/XGPON).

  – Operation mode (single/dual fibres), usually single mode fibre; dual mode where required.

  o Tunable/Colourless function, where required.

2.3.5.2 Internal networking requirements

- R5_05. Appropriate means for allowing the dynamic allocation over time of connectivity resources, across the network, MUST be implemented. This includes appropriate combination of control plane protocols and management plane applications.

- R5_06. Networking technologies MUST provide appropriate flexibility and scalability, depending on the specific network application needs. This implies providing the appropriate granularity of connections at the most appropriate layer

[4]The integration of these optical items into a unique fixed/mobile equipment or their hosting into a co-located box is implementation dependent.

(see L1 optical/digital and L2 packet); so as, the capability to dynamically control this connectivity.

- The convergent network MUST support:
  - R5_07. Adaptation of L1/L2/L3 clients to/from fixed/mobile NEs towardsL1/L2 server technologies (e.g. MPLS-TP, Ethernet, ODUk).
  - R5_08. Means for multiplexing signals in order to optimize communication resource usage according to the layer/technology implemented (L1/L2 on wavelengths, packets, TDM circuits).
  - R5_09 Consistently with R5_7 and R5_9, appropriate means for Fault Management, Performance Management, Resilience, Configuration Management and Synchronization.
- R5_10. The interfaces to be used within the convergent network are expected to be compatible with application scenarios, they SHOULD, consequently, match the following performances:
  - Span reach - 20 km to 60 km.
  - Operative rate - 10 Gb/s to 40 Gb/s. (1 Gb/s as lowest rate or 100 Gb/s as highest rate, where required).
  - Operative wavelength - DWDM grid, 100, 50 or 25 GHz fixed channel spacing or flexible channel spacing (*N*x 12.5, 25, 50 GHz) .
  - Operation mode (single/dual fibres), usually dual mode fibres; single mode where required.
  - Tunable/colourless function, where required.

2.3.6 Requirements for UC6 - Convergence of fixed, mobile and Wi-Fi gateway functionalities

The scope of this chapter is to describe the high-level requirements of the Universal Access Gateway (UAG) also known as next generation Point of Presence (NG-POP). The UAG is a key element of the use case 6 “Convergence of fixed, mobile and Wi-Fi gateway functionalities”.

The major requirement for an operator facing tremendous bandwidth increase is to reduce the production costs. Thanks to the UAG concept, it will be possible to reduce the amount and plurality of network equipment for Capital Expenditures (CapEx) and Operational Expenditures (OpEx) saving and increased reliability.

The UAG concept allows new functionalities to enable new customer service features as for instance media streams optimised for different customer terminals (e.g. transcoding) and better QoS by delivering media content via cache node functionally as well, just to name some.

The UAG combines fixed line intelligence and mobile baseband and data plane processing and enables as such the integrated IP service creation point. It may also

include Wi-Fi hotspot controller functionality and cover all the functions of a Wi-Fi IP edge.

The gateway functionality for both fixed and mobile services allows users traffic routing flexibility, e.g. towards local content, core IP network, content delivery optimization (CDN), internet peering points, etc.

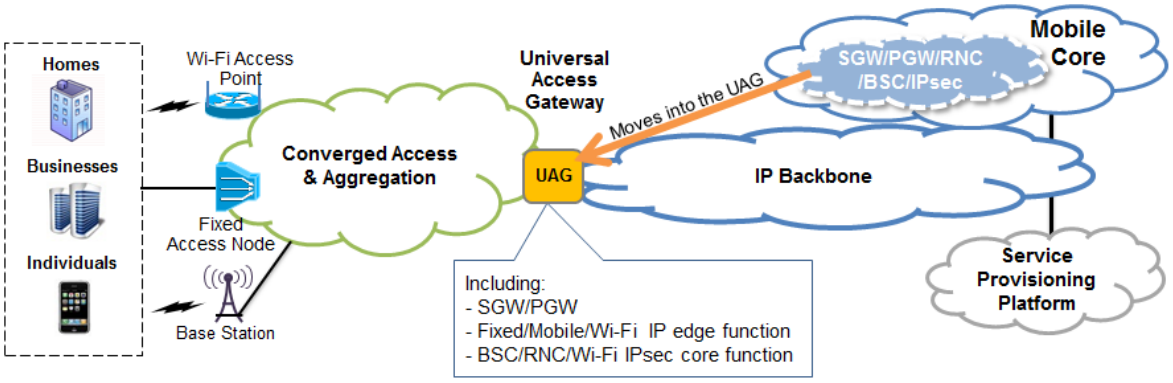

Figure 7: General network model for UC6

The UAG concept could be extended with the option to introduce backwards compatibility regarding 2G / 3G network elements or functions for example Base Station Controller (BSC) and Radio Network Controller (RNC) functionalities. Such network elements are described in COMBO D2.1 (sections 2.1) and COMBO D2.2 (chapter 3).

This concept is driven by:

- Availability of intelligent systems and high performing devices for integrated operation of fixed and mobile access functionalities.
- Availability of high capacity and reliability access networks to transport the high data volume with required QoS (e.g. low delay and PDV).

2.3.6.1 Mobile network related requirements

- R6_01.The UAG solution MUST support S-GW and P-GW functions.
- R6_02. The UAG MAY provide the Mobility Management Entity (MME) functions. However, the other Evolved Packet Core (EPC) control entities (e.g. HSS, AAA, PCRF and ANDSF) MAY be considered to stay more central.
- R6_03. The UAG MAY support legacy RNC, BSC functions and Femto-GW functions.
- R6_04. The UAG SHOULD support the ePDG for untrusted access to mobile IP core.
- R6_05. The UAG MAY provide BBU functions for mobile fronthauling.

2.3.6.2 Wi-Fi network related requirements

- R6_06. The UAG MUST provide Wi-Fi IP Edge functions and support the Trusted WLAN Access Gateway (TWAG) mode (as in 3GPP TS 23.402 specifications, for P-GW anchoring).
- R6_07. The UAG MAY provide Wi-Fi AP controller functions.

2.3.6.3 Fixed network and backhaul related requirements

- R6_08. The UAG MUST provide Broadband Network Gateway (BNG) functions including per-user and per-session L2-L4 traffic policy enforcement (QoS, interception, routing, filtering, monitoring, etc.).
- R6_09. The UAG MAY provide OLT and DSLAM functions. In this case the UAG provides optical interfaces for FTTH/B/C/dp access networks as well a copper lines broadband access.
- R6_10. The UAG SHOULD provide Mobile Aggregation Site Gateway (MASG) functions.
- R6_11. The UAG SHOULD provide the Security GW function for untrusted backhaul networks (e.g. Wi-Fi AP, Femto AP or eNodeB located in unsecured places).

2.3.6.4 Common requirements

- R6_12. The UAG MUST include all requirements for Hybrid Connection Gateway (HCG) implementation (as defined for UC4 in 2.3.4).
- R6_13. The UAG solution MAY support a resource management of heterogeneous access technologies, ready for cooperation and convergence (e.g. Wi-Fi/4G).

2.3.7 Requirements for UC7 - Converged access and aggregation technology supporting fixed and mobile broadband services

This section describes the requirements on an FMC access architecture that is based on a common optical infrastructure (structural convergence) for all types of services: fixed, mobile and Wi-Fi.

The use case 7 is described in detail in D2.1 chapter 3 [8]. Figure 8 illustrates the new access-aggregation network able to provide all kinds of services for all types of customers (e.g. residential, business, backhaul, etc.).

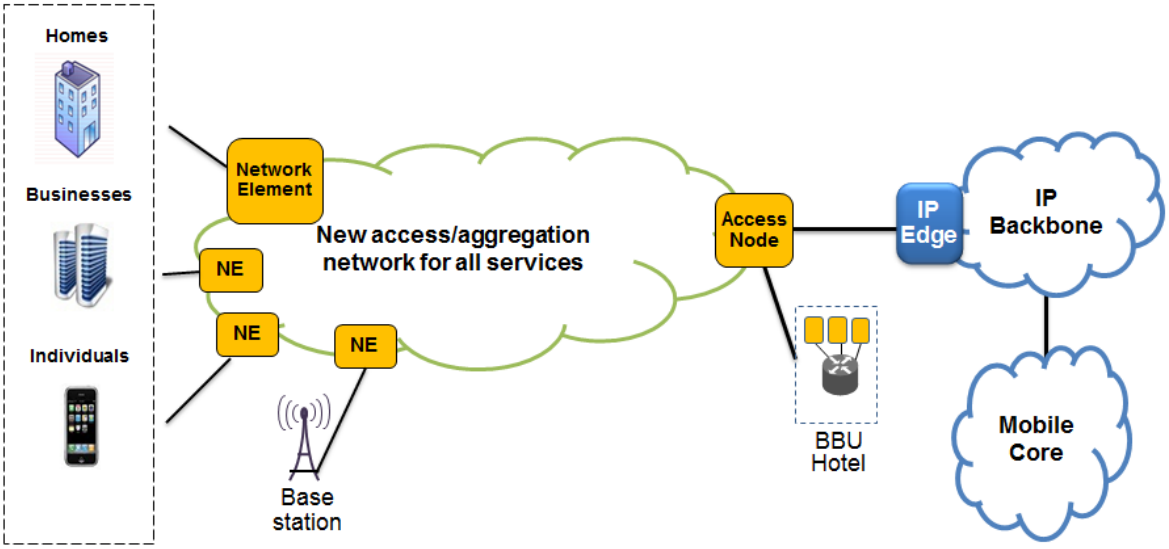

Figure 8: Access-aggregation network proposed by UC7

2.3.7.1 General network requirements (derived from FSAN and ITU- T)

The following section summarizes the general network requirements addressing an optical infrastructure based on Passive Optical Network (PON).

- R7_01. The FMC network MUST support the recommendations originated by FSAN and ITU-T within the NG-PON2 framework (including ITU-T Recommendation G.989.1: 40-Gigabit-capable passive optical networks - NG-PON2). However, for the implementation of this use case, the deployment of technologies not included in NG-PON2 recommendations is not prevented, provided that the requirements hereafter listed are satisfied.
- R7_02. Synchronization: Future FMC network MUST support frequency synchronization and phase/time synchronization:
  - Frequency accuracy +/- 5 ppb.
  - Phase synchronization with maximum time error < ± 500 ns[5].
- R7_03. Fault management: IT-supported optical diagnosis and measurement solutions for FTTH, Fixed & Mobile backhaul and fronthaul MUST be supported.

2.3.7.2 Fronthaul and backhaul requirements

- Fronthaul requirements:

[5] Phase/time synchronization requirements regarding LTE-A CoMP joint processing with ISD 780 m:

- Max +/- 500 ns deviation from UTC (in the air interface).
- Max +/-400 ns deviation from UTC at the eNB NNI.

In addition, some location based services may require a max. deviation time less than ± 200 ns

- R7_04. At least 8 fronthaul links per ODN SHOULD be supported. A minimum of 4 fronthaul links MUST be supported in case fronthaul links are needed in an ODN.
- R7_05. A symmetric bit rate MUST be supported for fronthaul applications.
- R7_06. Maximum BER 10^{-12} MUST be guaranteed.
- R7_07. The full set of CPRI and OBSAI data rates MUST be supported:
  - CPRI1 = 614.4 Mb/s.
  - OBSAI1 = 768 Mb/s.
  - CPRI2 = 1228.8 Mb/s.
  - OBSAI2 = 1536 Mb/s.
  - CPRI3 = 2457.6 Mb/s.
  - CPRI4 & OBSAI3 = 3072.0 Mb/s.
  - CPRI5 = 4915.2 Mb/s.
  - CPRI6 & OBSAI4= 6144.0 Mb/s.
  - CPRI7 = 9830.4 Mb/s.
  - CPRI8 = 10137.6 Mb/s.
- R7_08. Frequency accuracy +/- 2 ppb MUST be guaranteed.
- R7_09. Time/phase synchronization MUST follows existing CPRI and OBSAI requirements.
- R7_10. PDV MUST follow CPRI requirements (v6.0 – 2013-08-30).
- R7_11. Round Trip Time (RTT) latency between RRH and BBU MUST be as maximum 400 µs including the delays of the fibre links and the FMC network equipment between BBU to RRH and excluding the processing time of BBU and RRH.
- R7_12. Protection schemes and optical infrastructure monitoring SHOULD be supported. The FMC network SHOULD support a Wavelength level protection. In the case one transceiver fails, ONUs can be tuned to another Channel Pair within the same FMC network.

• Backhaul requirements:
  - R7_13. Following backhaul applications MUST be supported:
    - Mobile macro cell backhauling (2G, 3G and 4G).
    - Mobile small cell backhauling.
    - DSLAM/MSAN backhauling.
    - Wi-Fi backhauling.
  - R7_14. The backhaul peak data rate MUST support at least 10 Gb/s.

- R7_15. LTE Latency MUST be guaranteed:
  - S1- delay < 10 - 50 ms[6].
  - X2 - delay for handover < 30 ms.
  - X2 - delay for RRM advanced functionalities such as CoMP, eICIC, etc. < 1 ms.

2.3.8 Requirements for UC8 - Network sharing

This section describes a multi-operator environment where competing operators can cooperate and share their network resources, such as antenna sites, radio resources, and backhaul connectivity, in order to use the resources more efficiently and obtain additional savings in an FMC architecture. Figure 9 illustrates several operators saving costs by sharing one converged access and aggregation network. The physical infrastructure can be used to share residential as well as mobile backhaul and fronthaul traffic. More information about this use case can be found in D2.1 [8].

This section describes the requirements on an FMC network shared among different network operators. In this section, we use the following terminology:

- A wholesale provider is an access network operator that offers a service provider a preliminary service product (wholesale) on the basis of a standardised interface.
- A wholesale customer is a service provider (that may as well be a network operator) that offers a service to its end users.

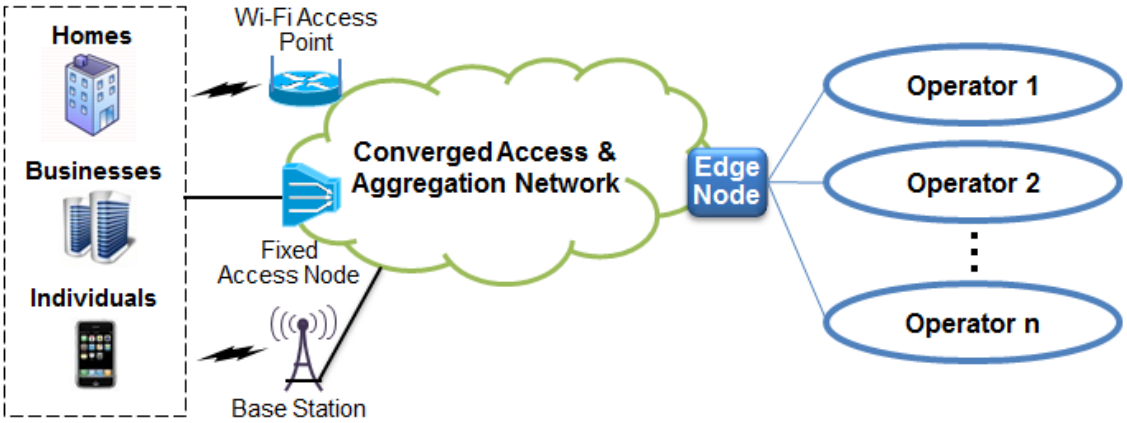

Figure 9: Converged access & aggregation with multi-operator approach

The requirements in this section are divided in three parts:

[6]From 3GPP TS23.203. It assumes 20 ms average transport delay, 10ms between eNB and near EPC and 50ms between eNB and far EPC.

i. General FMC requirements are requirements that can be put on any FMC network, i.e., even on FMC networks that are not shared. For this reason, these requirements start with, e.g. “The FMC network MUST/SHOULD…”.

ii. General network sharing requirements are requirements that can be put on an already shared FMC network. For this reason, these requirements start with, e.g. “The shared FMC network MUST/SHOULD …”.

iii. Bit Stream Access (BSA) requirements are requirements that are specific to a BSA scenario.

2.3.8.1 General FMC Requirements

- R8_01. The FMC network MUST allow sharing of all or parts of its resources among several operators; these operators can offer only fixed, only mobile services or both types of services at the same time.
- R8_02. The FMC network MUST allow reducing costs by sharing the cost of the whole network among the wholesale customers using it.
- R8_03. The FMC network MUST be flexible enough to implement and validate different Service Level Agreement (SLA) schemes suitable for multiple wholesale customers.

2.3.8.2 General Network Sharing Requirements

- R8_04. The shared FMC network MUST support observation of fixed and mobile traffic, PM and QoS per wholesale customer. Monitoring of RAN resource usage SHOULD be also included.
- R8_05. The shared FMC network SHOULD support access to fixed and mobile network resources on different layers including appropriate interfaces in order to access these network resources:
  - Layer 0: e.g. sharing of sites, ducts, and routes.
  - Layer 1: e.g. sharing of fibre, wavelengths, and frequencies.
  - Layer 2: e.g. sharing of Layer 2 connectivity (Layer 2 BSA).
  - Layer 3: e.g. sharing of Layer 3 connectivity (Layer 3 BSA).
- R8_06. The shared FMC network SHOULD ensure Configuration Management (CM) data consistency and non-discriminatory checks between sharing wholesale customers’ OSS systems.
- R8_07. The shared FMC network MUST implement security mechanisms to avoid attacks between the different networks of the sharing wholesale customers
- R8_08. The shared FMC network MUST be scalable and possible performance problems in a wholesale customer (e.g. due to a high number of user simultaneously) MUST not affect the QoS and QoE of other wholesale customers.

2.3.8.3 BSA Requirements

- R8_09. The FMC network MUST support a generic BSA solution that is independent of the access technology.
- R8_10. The BSA SHOULD be supported on different layers (e.g. Layer 2 and Layer 3) with well-defined handover interfaces. L2/L3 BSA is the first notion to allow production across a multitude of access architectures and systems.
- R8_11. The FMC network MUST support a BSA solution for the following customer groups (not specific to FMC).:
  - Residential.
  - Small Office, Home Office (SoHo).
  - Small Medium Business.
  - Large Business (including mobile backhaul and fronthaul for other mobile operators).
- R8_12. The FMC network SHOULD support multiple BSA services per access line, e.g. BSA services from different wholesale providers.
- R8_13. BSA handover interfaces SHOULD be provided at different network segments. BSA handover interfaces MUST be provided at least at the Main CO and the Core CO location (see Chapter 2 in D2.1 [8]).
- R8_14. The BSA solution MUST support the following security functions:
  - Rate Limit PPPoE Control.
  - Rate Limit Layer 2 Broadcast.
  - MAC Anti-Spoofing.
  - Dynamic ARP Inspection.
  - Anti-IPv4 Spoofing.
  - Rate Limit DHCP.
  - Rate Limit ARP.
  - Rate Limit IGMP (in the case of multicast support).
  - Dynamic "IPv6 neighbour solicitation/advertisement" inspection.
  - DHCPv6 snooping.
  - Neighbour Unreachability Detection (NUD) filtering.
  - Router Advertisement (RA) filtering.
  - Duplicate Address Detection (DAD) snooping and filtering.
  - Anti-IPv6-Spoofing.
  - Rate Limit DHCPv6.
  - Rate Limit ICMP Neighbour Discovery (ND).

3 FMC KEY PERFORMANCE INDICATORS

3.1 Introduction

KPIs are agreed and quantifiable (that is, measurable) indicators used to measure or evaluate the performance of a process, parameter, achievement of a target, etc. KPIs are typically used to reflect an organization's goals where KPIs are the key indicators to its success.

KPIs will differ depending on the organization (a big company, a university or a non-profit organization will typically have different KPIs) or on the type of subject to evaluate. FMC networks will have a different set of KPIs from those of independent fixed and mobile networks, although it will be possible to find the same KPIs for several networks and even the same KPI name with a different definition depending on the specific context.

The number of KPIs is often limited to keep everyone's attention focused on achieving the goals. However, when defining KPIs for FMC networks, the target is to perform the technical assessment and comparison among different solutions, so different KPIs will be needed to consider techno-economical aspects.

The following sections identify KPIs with the intention to find a restricted set of agreed and quantifiable parameters to measure the performance of the different network aspects. Similar to the requirements, some KPIs are proposes for general or common aspects and some KPIs are proposed for the different use cases. These KPIs will be used by other work packages during their technical and economic assessment activities, for example:

- WP3: for the technical assessment and comparison among FMC architectures.
- WP4: for the FMC network performance monitoring.
- WP5: for the techno-economic assessment.
- WP6: for the lab tests procedures preparation and validation.

3.2 General KPIs for FMC

This section covers generic KPIs to be used in FMC networks. As these KPIs apply to both non FMC and FMC networks, they can be used to compare an FMC network to a non FMC network, or to compare different implementations of FMC networks.

It is possible that many of these KPIs could take identical values when comparing potential FMC solutions or when comparing an FMC solution to an independent fixed and mobile network. However, depending on the solutions to be compared, it is expected that some KPIs will take different values, thus allowing be able to detect key parameters with different performances.

The following list contains the most important KPIs found considering all network use cases in addition to their specific KPIs:

- QoS and QoE:
  - Throughput: average sustained user bit rate that can be transmitted and received over a long time in a communication link at layer 2 per access point. The minimum value per session and application type can be found in Table 1.
  - Delay: time it takes for a packet of data to be carried by the network from the origin to the destination. The maximum value per application type can be found in Table 2.
  - PDV: variance in the delay of received packets across the time (see Table 2).
  - IP packet loss rate: number of lost IP packets divided by the number of packets sent (see Table 2).
  - Application set-up time: network time between the user application request and the response (see Table 2).
  - Application Mean Opinion Score (MOS ITU-T recommendation P.800, from 1 or bad to 5 or excellent with a minimum threshold for acceptable quality of 3.5) for voice, audio/video (e.g. using Video Quality Metric tools) and for channel zapping (less than 500 ms for a MOS value of 3.5).
- Techno-economic KPIs used for the comparison of different FMC alternatives and non-FMC traditional solutions or only among FMC alternatives. CapEx, OpEx and deployment time are the most important techno-economic KPIs. When applicable, absolute values can be assessed (e.g. when there is not an alternative scenario to be compared to) as well as relative values; below some relative targets for these KPIs are proposed when a reference solution exists:
  - CapEx and OpEx. A relative reduction ratio will be used for both CapEx and OpEx: <10% poor; 10-20% fair; 20-40% good; >40 excellent. A minimum of a 20-40% reduction is needed to be acceptable.
  - Network deployment time. A relative reduction ratio will be used: <10% poor; 10-20% fair; 20-40% good; >40 excellent. A minimum of 20-40% reduction is needed to be acceptable.
- Power consumption is the KPI to assess the energy efficiency aspects of FMC solutions. As techno-economic KPIs, the power consumption could be measured as an absolute value to check the performance of a single solution or it can be measured compared to other alternatives. Below some relative targets for these KPIs are proposed when a reference solution exists:
  - Power consumption considering the whole solution, the maximum number of users supported and per transmitted/received bit. A relative ratio will be used for the power consumption reduction: <10% poor; 10-20% fair; 20-40% good; >40 excellent. A minimum of a 20-40% reduction (not needed all simultaneously) is needed to be acceptable.
- OAM:
  - Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR). These values are different for each network element, so FMC approaches will need to show an improvement. Target is as low as possible or near 0. Network availability can be derived from them (availability is equal to [MTBF / [MTBF +

MTTR]]*100). End to end availability can be derived from all network elements which composes the final solution according to their serial or parallel contribution to the total network availability. Availability target is as high as possible or near 100 percent.

3.3 Network use cases KPIs for FMC

This section identifies KPIs for the use cases. For each use case, FMC features have been identified with their corresponding requirements. Each KPI is related to the assessment of the fulfilment of these requirements.

3.3.1 KPIs for UC1 – Unified FMC access for mobile devices

The following list describes the KPIs related to the network use case 01:

- Dual attachment performance, comparing two scenarios: mobile access only and a mobile and Wi-Fi access simultaneously used:
  - Throughput average: the throughput increment should be at least the double (when mobile and Wi-Fi interfaces are simultaneously used compared to when it is only used the mobile link) at channel level (capacity shared among all users) and at user level to be interesting for the operator and for the users.
  - Delay and PDV: the simultaneous use of mobile and Wi-Fi interfaces must not increase the maximum delay and PDV, so the standard values per application type apply.
- Mobility:
  - Handover interruption time: interruption time during a handover from mobile to Wi-Fi and from Wi-Fi to mobile. Target is 0 seconds or no interruption time.

3.3.2 KPIs for UC2 - Converged content caching for unified service delivery

The following list describes the KPIs related to the network use case 2:

- Performance compared to other solutions which do not follow this approach:
  - Data volume reduction in the core and aggregation networks. A relative ratio will be used: <5% poor; 5-10% fair; 10-20% good; >20 excellent. A minimum of a 10-20% reduction is needed to be acceptable.
  - Content latency reduction for the application set-up time or channel switching delay for video service. A relative ratio will be used: <5% poor; 5-10% fair; 10-20% good; >20 excellent. A minimum of a 10-20% is needed to be acceptable.
- Mobility:
  - Handover interruption time: interruption time during a handover from mobile to Wi-Fi and from Wi-Fi to mobile while successfully keeping a streaming session. Target is 0 seconds or no interruption time.

3.3.3 KPIs for UC3 - Reuse of infrastructure for small cell deployments

The following list describes the KPIs related to the network use case 3:

- Techno-economic: CapEx, OpEx and deployment time per installation site for a given coverage/capacity (see general KPIs in section 3.2).
- Small cell backhaul link capacity in Mbit/s. The reference value is 100 Mb/s.

3.3.4 KPIs for UC4 - Universal access bundling for residential gateway

This section lists the KPIs related to the use case 4:

- Performance:
  - Hybrid access line set-up time: The additional time needed to establish the complete hybrid access line for different transmission channel combinations. The reference value is the maximum set-up time among all access lines: <5% excellent; 5-10% good; 10-20% fair; >20 poor. A maximum of a 5-10% additional time considering the slowest connection is needed to be acceptable:
    - fixed xDSL, Wi-Fi hotspot and cellular radio
    - fixed xDSL and cellular radio
    - fixed xDSL and Wi-Fi hotspot
    - Wi-Fi hotspot and cellular radio
  - Availability of the Hybrid access line for different transmission channel combinations:
    - fixed xDSL, Wi-Fi hotspot and cellular radio
    - fixed xDSL and cellular radio
    - fixed xDSL and Wi-Fi hotspot
    - Wi-Fi hotspot and cellular radio
- Scalability:
  - HCG channel number: The number of simultaneous transmission channels supported by one HCG element. The reference value is 50.000 (minimum value proposed in D2.1 for the number of subscribers per BRAS network element).
- Techno-economic:
  - CapEx savings of the Hybrid access line compared to a Next Generation Access (NGA) deployment providing the same performance (see general KPIs in section 3.2).

3.3.5 KPIs for UC5 - Support for large traffic variations between public, residential and business services

The following list describes the KPIs related to the network use case 5:

- Performance compared to other solutions which don't follow this approach:
  - Reduction on the BBUs number. The reference value is the number of BBUs without a BBU hostelling approach. A relative ratio will be used: <5% poor; 5-10% fair; 10-20% good; >20 excellent. A minimum of a 10-20% reduction is needed to be acceptable
- OAM:

- Time to re-configure the network resources, e.g., reconfiguring transport services from one RRU to another, upon a change request, i.e., time from when the trigger event occurs until the new RRU is fully activated and ready to serve subscribers. A relative ratio will be used based on the current re-configuration time in distributed RAN: <10% poor; 10-20% fair; 20-40% good; >40 excellent. A minimum time reduction of 20-40% is needed to be acceptable.

3.3.6 KPIs for UC6 - Convergence of fixed, mobile and Wi-Fi gateway functionalities

The following list describes the KPIs related to the network use case 6:

- Techno-economic:
  - CapEx and OpEx savings of UAG solution compared to the state of the art deployment with dedicated stand-alone equipment for fixed, mobile and Wi-Fi network (see general KPIs in section 3.2).

3.3.7 KPIs for UC7 - Converged access and aggregation technology supporting fixed and mobile broadband services

The following list describes the KPIs related to the network use case 7:

- Performance:
  - Passive reach: minimum reach between OLT and ONU without the use of reach extender (40 km is the minimum reach required for all applications except fronthaul and 10 km is the minimum reach between RRH and BBU for fronthaul).
  - Peak rate: up- and downstream peak rate for residential user applications (minimum 1 Gb/s for FTTH or FTTB is required) and up- and downstream peak rate for business and back-/fronthaul applications (minimum 10 Gb/s is required).
  - Frequency accuracy: minimum accuracy for frequency synchronisation. A minimum accuracy of +/- 2 ppb is required.
  - Latency:
    - Generic latency: maximum latency between OLT and ONT for all applications except fronthaul and mobile LTE backhaul with advanced RRM (CoMP). A maximum latency of 10 ms is required.
    - Fronthaul RTT latency: maximum RTT latency between RRH and BBU for fronthaul applications. A maximum RTT latency of 400 µs is required.
    - LTE Latency: maximum latency to be considered for mobile backhaul:
      - S1 - delay < 10 - 50 ms.
      - X2 - delay for handover < 30 ms.
      - X2 - delay for RRM advanced functionalities such as CoMP, eICIC, etc. < 1 ms.

- Time error: phase synchronization with maximum time error. A maximum value less than ± 500 ns is required.
- Maximum BER: maximum BER between OLT and ONU. A maximum BER less than 10^{-12} is required.

3.3.8 KPIs for UC8 - Network sharing

The following list describes the KPIs related to the network use case 8:

- Techno-economic: CapEx and OpEx savings for the shared network compared to separate networks (see general KPIs in section 3.2). In line with the total cost divided among the number of operators using the network (assuming an equivalent use of the network).
- Ratio of network resources (mainly network capacity) that can be shared per network segment (access and aggregation) including fixed, mobile and fixed-mobile converged network elements. Target is 100%.
- Number of wholesale customers that can share a network node fulfilling requirements on QoS and security. Scalability of the solution regarding the number of wholesale customers including only fixed and only mobile operators. Minimum is 3 to avoid the market dominance by two operators.
- Number of network layers that can be shared: layer 0, 1, 2 and 3. Typical values are from 1 (the minimum) to 4 (the maximum), see R8_05 for more details.

4 CONCLUSIONS

This report identifies and classifies the preliminary sets of requirements and KPIs for FMC networks, which will be used by other work packages throughout the work of COMBO:

- a proposed FMC architecture supports a use case if it fulfils the all the related (general and use case specific) requirement defined in this document.
- when COMBO focuses on finding "optimal" scenarios, the KPIs described in this document will be used to compare competing solutions.

Two main types of requirements have been specified: those from a general FMC point of view and those corresponding to the uses cases defined in D2.1.

The main key findings and results regarding the requirements are:

- The FMC network must support the same type of applications used in today's network with at least the same level of QoS and QoE, this document provides a general reference for the main QoS and QoE parameters (throughput, network availability, delay, packet delay variation, packet loss rate, etc.) included in Table 1 (page 13) and Table 2 (page 15).
- FMC networks must enhance the end user QoE (e.g. providing a transparent connectivity, increasing the throughput, reducing the application's delay, using the most appropriate network interface considering the network conditions, etc.).
- Other general and important requirements for a FMC network are: enhanced QoS, reduced power consumption, multi-service network, compatibility with legacy networks and multi-operator network.
- Particular FMC requirements have been set for the use cases. Most of them are related to the following functionalities: data forwarding, OAM and management, mobility, security, automatic configuration, subscriber management and resilience. Other important aspects considered in the requirements are: deployment, business and performance.

General and specific KPIs for the uses cases have been also identified:

- The most important general KPIs are those related to QoS and QoE (such as the throughput, delay, PDV, packet loss and MOS), techno-economic (e.g. CapEx and OpEx), power consumption and OAM (such as MTBF).
- Some of the most relevant KPIs specific for the use cases are those related to the service interruption time due to the handover, the backhaul capacity, the connection set-up time and the synchronization accuracy.

These requirements and KPIs will serve as the basis for the comparison and the technical assessment of the different approaches of FMC architectures that are being developed in WP3. They will thus allow selecting the most FMC compliant solution.

As the present deliverable shows, requirements and KPIs will be key factors for the technical assessment of the FMC architecture work in WP3. This work will be the reference for additional studies during the second and third years of COMBO project from different points of view inside WP4, WP5 and WP6. Additionally, this document

provides the requirements and the related KPIs for their specific area of work: performance monitoring (for WP4), techno-economic assessment (for WP5) and functional development & experimental research (for WP6).

Although a major review of this deliverable is not expected, a periodic review will be performed including the delivery at the end of the second (month 24) and third project year (month 35) based on the feedback from the work on WP3 regarding the FMC architecture, WP4 about the performance monitoring, WP5 dealing with the techno-economic assessment and WP6 including the experimental part of COMBO.

5 REFERENCES

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A NETWORK USE CASE REQUIREMENTS TABLES

This section contains a summary of the requirements in a table format. Each requirement is identified with its reference number and provides information regarding the network elements and the functional groups it is related. These tables will help WP3 to initially assess the impact of FMC requirements on the functional groups specified in D3.1.

NOTE: Non-functional requirements are identified in the functional group column by the letters NF (Non Functional) and the type of requirement that it is, e.g. power consumption, deployment, performance, etc.

A.1. General Requirements

Requirement	Network segment	Network element/CPE	Functional Group
R0_01	FMC network	All could be affected	NF. Performance
R0_02	FMC network	All could be affected	NF. Performance
R0_03	FMC network	All could be affected	All groups are affected
R0_04	FMC network	Mainly CPE and UE, but networks elements too	Forwarding
R0_05	FMC network	All could be affected	NF. Deployment
R0_06	Access network	UE, CPE, access nodes	NF. Deployment
R0_07	Access, aggregation network s	Access and aggregation nodes	NF. Deployment
R0_08	FMC network	All could be affected	NF. Power consumption
R0_09	FMC network	All could be affected	NF. Flexibility
R0_10	FMC network	All could be affected	OAM & Management

Table 3: Summary of general requirements

A.2. Network use case requirements

A.2.1 Requirements for UC01 – Unified FMC access for mobile devices

Requirement	Network segment	Network element/CPE	Functional Group
R1_01	Wi-Fi network	AP	Forwarding
R1_02	Wi-Fi network	AP	Automatic configuration and management, Policy and Charging
R1_03	Wi-Fi network	UE, AP	Security
R1_04	Wi-Fi network	AP	Forwarding
R1_05	Wi-Fi network	AC	NF Deployment
R1_06	FMC network	Wi-Fi, Mobile and backhaul elements	Policy and Charging, OAM & Management
R1_07	FMC network	FMC core	Subscriber data and session management , Policy and Charging
R1_08	FMC network	FMC Core	Subscriber data and session management
R1_09	FMC network	FMC Core	Mobility
R1_10	Customer FMC network	UE FMC Core	Forwarding, Policy and charging
R1_11	FMC network	FMC Core	Subscriber data and session management, Mobility
R1_12	Customer	UE	Forwarding
R1_13	Customer	UE	Security
R1_14	Customer	UE	Security
R1_15	Customer	UE	Automatic configuration and management, Subscriber data and session management, Mobility
R1_16	Customer	UE	Automatic configuration and

Requirement	Network segment	Network element/CPE	Functional Group
			management, Policy and Charging
R1_17	Customer	UE	Automatic configuration and management, Policy and Charging
R1_18	Customer	UE	Subscriber data and session management, Policy and charging
R1_19	Customer	UE	Mobility

Table 4: Summary of UC1 requirements

A.2.2 Requirements for UC2 - Converged content caching for unified service delivery

Requirement	Network segment	Network element/CPE	Functional Group
R2_01	FMC network	UE	Automatic configuration and management, Subscriber data and session management, Mobility, OAM & Management
R2_02	FMC network	FMC Access	NF. Deployment
R2_03	FMC network	FMC Core	Automatic configuration and management, Subscriber data and session management, Policy and Charging
R2_04	FMC network	UE, FMC Core	Mobility
R2_05	FMC network	UAG, DSLAM, eNodeB	Automatic configuration and management. Subscriber data and session management
R2_06	Wi-Fi network and fixed access	AP, RGW	OAM & Management, Policy and Charging
R2_07	Wi-Fi network	AP	OAM & Management,

Requirement	Network segment	Network element/CPE	Functional Group
			Policy and Charging

Table 5: Summary of UC2 requirements

A.2.3 Requirements for UC3 - Reuse of infrastructure for small cell deployments

Requirement	Network segment	Network element/CPE	Functional Group
R3_01	Fronthaul/backhaul Network	Small cell, CSG	NF. Deployment
R3_02	Fronthaul/backhaul Network	Small cell	NF. Deployment
R3_03	Fronthaul/backhaul Network	Small cell	Synchronisation
R3_04	Fronthaul/backhaul Network	Small cell, CSG	NF. Business
R3_05	Access Network	Small cell, CSG	OAM & Management, Automatic configuration and management
R3_06	Access Network	Small cell, CSG	NF. Business
R3_07	Customer Premises Network	Small cell, CSG	NF. Business
R3_08	Access Network	Small cell, CSG	NF. Deployment
R3_09	Access Network	Small cell, CSG	OAM & Management
R3_10	Access Network	Small cell, CSG	OAM & Management, Automatic configuration and management

Table 6: Summary of UC3 requirements

A.2.4 Requirements for UC4 - Universal access bundling for residential gateway

Requirement	Network segment	Network element/CPE	Functional Group
R4_01	Customer Premises Network	Customer Gateway (CGW)	Automatic configuration and

Requirement	Network segment	Network element/CPE	Functional Group
			Management
R4_02	Customer Premises Network	Customer Gateway (CGW)	Subscriber data and session management
R4_03	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Resilience, Policy and Charging
R4_04	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Forwarding, Automatic configuration and management
R4_05	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	OAM & Management, Automatic configuration and Management
R4_06	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	OAM & Management
R4_07	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Automatic configuration and Management
R4_08	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Forwarding, Subscriber data and session management
R4_09	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	OAM & Management
R4_10	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Forwarding, Policy and Charging
R4_11	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Forwarding, OAM & Management
R4_12	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Policy and Charging, Automatic configuration and Management
R4_13	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Forwarding, Traffic analysis
R4_14	FMC Network	Hybrid Connection Gateway (HCG) and	Forwarding

Requirement	Network segment	Network element/CPE	Functional Group
		Customer Gateway (CGW)	
R4_15	FMC Network	Hybrid Connection Gateway (HCG) and Customer Gateway (CGW)	Forwarding

Table 7: Summary of UC4 requirements

A.2.5 Requirements for UC5 - Support for large traffic variations between public, residential and business areas

Requirement	Network segment	Network element/CPE	Functional Group
R5_01	FMC network	Aggregation node	NF. Deployment
R5_02	FMC network	Aggregation node	OAM & Management Resilience Synchronization
R5_03	FMC network	Aggregation node	OAM & Management Resilience Synchronization
R5_04	FMC network	Aggregation node	NF. Deployment, Performance
R5_05	FMC network	Aggregation node	Automatic configuration and management, OAM & Management
R5_06	FMC network	Aggregation node	NF. Deployment
R5_07	FMC network	Aggregation node	Forwarding
R5_08	FMC network	Aggregation node	Forwarding
R5_09	FMC network	Aggregation node	OAM & Management, Resilience, Synchronizaton
R5_10	FMC network	Aggregation node	NF. Deployment, Performance

Table 8: Summary of UC5 requirements

A.2.6 Requirements for UC6 - Convergence of fixed, mobile and Wi-Fi gateway functionalities

Requirement	Network segment	Network element/CPE	Functional Group
R6_01	Mobile core network	Universal Access Gateway	Forwarding, Subscriber data and session management, Legal interception and data retention, Policy and charging, Mobility
R6_02	Mobile core network	Universal Access Gateway	Subscriber data and session management, Mobility
R6_04	Mobile access network	Universal Access Gateway	Forwarding, Automatic configuration and Management, Mobility
R6_05	Mobile core network	Universal Access Gateway	Forwarding, Subscriber data and session management
R6_06	Mobile access network	Universal Access Gateway	Forwarding, Automatic configuration and Management
R6_07	Wi-Fi access network	Universal Access Gateway	Forwarding, Automatic configuration and Management, OAM & Management
R6_08	Fixed core network	Universal Access Gateway	Forwarding, Subscriber data and session management, Legal interception and data retention, Policy and charging
R6_09	Fixed access network	Universal Access Gateway	Forwarding

Requirement	Network segment	Network element/CPE	Functional Group
R6_10	Mobile backhaul network	Universal Access Gateway	Forwarding
R6_11	Mobile/Wi-Fi backhaul network	Universal Access Gateway	Forwarding, Security
R6_12	Fixed core network	Universal Access Gateway	Forwarding, Security, OAM & Management
R6_13	Mobile/Wi-Fi access network	Universal Access Gateway	Automatic configuration and Management

Table 9: Summary of UC6 requirements

A.2.7 Requirements for UC7 - Converged access and aggregation technology supporting fixed and mobile broadband services

Requirement	Network segment	Network element/CPE	Functional Group
R7_01	FMC network	Access node, ONU, Reach extender	NF. Performance OAM & Management NF. Compatibility NF. Deployment NF. Migration etc.
R7_02	FMC network	Access node, ONU	Synchronization
R7_03	FMC network	Access node, ONU	Resilience, OAM & Management
R7_04	FMC network	Access node	NF. Performance
R7_05	FMC network	Access node	NF. Performance
R7_06	FMC network	Access node, ONU	NF. Performance
R7_07	FMC network	Access node, ONU	NF. Performance
R7_08	FMC network	Access node, ONU	NF. Performance
R7_09	FMC network	Access node, ONU	Synchronization
R7_10	FMC network	Access node, ONU	NF. Performance
R7_11	FMC network	Access node, ONU	NF. Performance

Requirement	Network segment	Network element/CPE	Functional Group
R7_12	FMC network	Access node, ONU	Resilience
R7_13	FMC network	Access node, ONU	Forwarding
R7_14	FMC network	Access node, ONU	NF. Performance
R7_15	FMC network	Access node, ONU	NF. Performance

Table 10: Summary of UC7 requirements

A.2.8 Requirements for UC8- Network sharing

Requirement	Network segment	Network element/CPE	Functional Group
R8_01	FMC access, aggregation and core	All network elements	All
R8_02	FMC access, aggregation and core	All could be affected	NF. Economic
R8_03	FMC access, aggregation and core	All network elements	Policy and Charging, Subscriber data and session management, Mobility
R8_04	FMC access, aggregation and core	All network elements	OAM & Management
R8_05	FMC access, aggregation and core	All network elements	Automatic configuration and management , OAM & Management, Policy and Charging
R8_06	FMC access, aggregation and core	All network elements	Automatic configuration and management , OAM & Management
R8_07	FMC access, aggregation and core	All network elements	Security
R8_08	FMC access and aggregation	All network elements	NF. Performance
R8_09	FMC aggregation and core	Access nodes, indirect access point	Forwarding, Policy and Charging
R8_10	FMC aggregation and core	Access nodes, indirect access point, IP edge	Forwarding, Policy and Charging

Requirement	Network segment	Network element/CPE	Functional Group
R8_11	FMC aggregation and core	Access nodes, indirect access point, IP edge	Automatic configuration and management , OAM & Management, Policy and Charging
R8_12	FMC access and, aggregation and core	Access nodes	Forwarding, Automatic configuration and management, Policy and Charging
R8_13	FMC aggregation and core	Access nodes, indirect access point, IP edge	NF-. Deployment
R8_14	FMC aggregation and core	Access nodes, indirect access point, IP edge	Forwarding, Security

Table 11: Summary of UC8 requirements

6 Glossary

Acronym / Abbreviations	Brief description
2G	2nd Generation (mobile service)
3G	3rd Generation (mobile service)
3GPP	3rd Generation Partnership Project
4G	4th Generation (mobile service)
AAA	Authentication, Authorization and Accounting
ANDSF	Access Network Discovery and Selection Function
AP	Access Point
ARP	Address Resolution Protocol
BBF	Broadband Forum
BBU	Base Band Unit
BSA	Bit Stream Access
BSC	Base Station Controller
C-RAN	Centralized, Co-operative, Cloud or Clean RAN
CapEx	Capital Expenditure
CGW	Customer Gateway
CM	Configuration Management
CO	Central Office
COMBO	COnvergence of fixed and Mobile BrOadband access/aggregation
CoMP	Coordinated MultiPoint
CoS	Class of Service
CPE	Customer Premises Equipment
CPRI	Common Public Radio Interface
CSG	Cell Site Gateway
CWDM	Coarse Wavelength Division Multiplexing
DHCP	Dynamic Host Configuration Protocol
DHCPv6	Dynamic Host Configuration Protocol version 6
DS	Downstream
DSL	Digital Subscriber Line
DWDM	Dense Wavelength Division Multiplexing
EAP-AKA	Extensible Authentication Protocol - Authentication and Key Agreement
EAP-SIM	Extensible Authentication Protocol - Subscriber Identity Module
EAP-TLS	Extensible Authentication Protocol - Transport Layer Security
EAP-TTLS	Extensible Authentication Protocol - Tunnelled Transport Layer Security
eICIC	Enhanced Inter-Cell Interference Coordination
EPC	Evolved Packet Core

Acronym / Abbreviations	Brief description
ETSI	European Telecommunications Standards Institute
FM	Fault Management
FMC	Fixed Mobile Convergence
FSAN	Full Service Access Network
FTTB	Fibre To The Building or Fibre To The Basement
FTTC	Fibre To The Cabinet or Fibre To The Curb
FTTdp	Fibre To The distribution point
FTTH	Fibre To The Home
GEM	GPON Encapsulation Method
GoD	Gaming on Demand
GPON	Gigabit-capable Passive Optical Network
GW	Gateway
HCG	Hybrid Connection Gateway
HD	High Definition (multimedia/TV)
HDTV	High Definition Television
HFC	Hybrid Fibre Coax
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPsec	Internet Protocol Security
IPTV	Internet Protocol Television
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IT	Information Technology
ITU	International Telecommunication Union
ITU-T	International Telecommunications Union- Telecommunication
KPI	Key Performance Indicator
LAN	Local Area Network
LTE	Long Term Evolution
M2M	Machine to Machine
MAC	Media Access Control
MME	Mobility Management Entity
MPLS-TP	Multi-Protocol Label Switching - Transport Profile
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
MUSE	European Commission Framework 6 Program – MUSE
ND	Neighbour Discovery

Acronym / Abbreviations	Brief description
NE	Network Element
NGA	Next Generation Access
OAM	Operations, Administration and Maintenance
OBSAI	Open Base Station Architecture Initiative
ODN	Optical Distribution Network
ODU	Optical channel Data Unit
ONU	Optical Network Unit
OpEx	Operational Expenditure
P-GW	Packet Data Network Gateway
P2P	Peer to Peer
pBS	pico Base Station
PC	Personal Computer
PDV	Packet Delay Variation
PM	Performance Monitoring
PON	Passive Optical Network
POTS	Plain Old Telephone Service
QoE	Quality of Experience
QoS	Quality of Service
RA	Router Advertisement
RAN	Radio Access Network
RF	Radio Frequency
RGW	Residential Gateway
RNC	Radio Network Controller
RRH	Remote Radio Head
RRU	Remote Radio Unit
RTT	Round Trip Time
SDO	Standard Development Organization
SDTV	Standard TV
SLA	Service Level Agreement
SoHo	Small Office – Home Office
SON	Self-Organizing Network
TDM	Time Division Multiplexing
TR	Technical Report
TWAG	Trusted WLAN Access Gateway
TWDM-PON	Time and wavelength division multiplexed PON
UAG	Universal Access Gateway
UC	Use case

Acronym / Abbreviations	Brief description
UE	User Equipment
US	Upstream
VLAN	Virtual Local Area Network
VoIP	Voice over Internet Protocol
WDM	Wavelength Division Multiplexing
Wi-Fi	IEEE 802.11 Wireless Local Area Network
WP	Work Package
WPA	Wi-Fi Protected Access
xDSL	Digital Subscriber Line technologies
XG-PON	10 Gigabit Passive Optical Network
xPON	Passive Optical Network technologies

7 List of Tables

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10 Further information

Grant Agreement number: 317762

Project acronym: COMBO

Project title: COnvergence of fixed and Mobile BrOadband access/aggregation networks

Funding Scheme: Collaborative Project – Integrated Project

Date of latest version of the Deliverable 2.4: 20-06-2014

Delivery Date: **Month 24**

Leader of the deliverable: TID

File Name: COMBO_D2.4_WP4_20June2014_TID_V2.0.docx

Version: V2.0

Authorisation code: PU = *Public*

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