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Monitoring parameters relation to QoS/QoE and KPIs

Executive Summary of the deliverable

Work Package 4 (WP4), Task 4.1 (T4.1) deals with the Quality of Service (QoS) and Performance Monitoring (PM) aspects of Fixed Mobile Converged (FMC) network architecture proposals, whereby mobile considers 2G, 3G, LTE and also as a wireless fixed access part Wi-Fi. Activities within the scope of T4.1 include a survey of existing QoS/PM tools and parameters, and the definition of these to support the requirements of an FMC network environment. Following the survey which was captured in Milestone 4.1 (M4.1) and covered tools across multiple layers and functions in addition to Quality of Experience (QoE) the goal is to begin the process of defining QoS/PM and QoE tools and parameters which support the FMC environment.

This deliverable is the first step in that process. It translates input from WP2 primarily, in the form of use cases, and where available KPIs; and provides a top-down analysis showing the relationship between QoS/PM and QoE tools and parameters arising from those use cases and KPIs.

Implementation options of use cases are explored in detail, and the QoS/PM and QoE tools and parameters are identified for each use case, and where possible, identification of common tools and parameters spanning multiple use cases is performed.

As well as addressing the scalability challenges that could be associated with converged networks, the impact of emerging network paradigms such as Cloud, SDN and NFV are also considered to identify the likely top level QoS/PM aspects which might arise in future.

This deliverable prepares for work to be undertaken in the subsequent and related deliverable D4.2 which refines the QoS/PM tools further under the scope of specific FMC architectures by which time a more fully defined list of KPIs and FMC architectures will be available from WP2 and WP3 respectively.

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1 Introduction

This document deals with the Quality of Service (QoS) and Performance Monitoring (PM) aspects of Fixed Mobile Converged (FMC) network architecture. Task T4.1 surveyed existing QoS/PM tools and parameters. The survey was captured in Milestone 4.1 (MS17), covering tools across multiple layers and functions in addition to Quality of Experience (QoE). A summary of that survey is captured in chapter 2 of this deliverable.

Chapter 3 translates input from WP2 Deliverable D2.1 [1], primarily in the form of use cases, providing a top-down analysis, showing the relationship between QoE and QoS/PM tools and parameters arising from the use cases. Chapter 3 also explores the impact scalability/complexity and emerging paradigms such as cloud computing, Software Defined Networking (SDN) and Network Function Virtualisation (NFV) on QoS/PM.

Chapter 4 takes preliminary input from early drafts of WP2 D2.4 [3] in the form of Key Performance Indicators (KPIs), and using the results from chapter 2 and 3 of this deliverable captures the relationship between KPIs, Use Cases and QoS/PM and QoE parameters. In cases where KPIs are not supported by obvious monitoring parameters, these are identified as gaps and proposed as topics to be addressed in future WP4 activities.

Chapter 5 briefly considers how to address gaps identified within the deliverable and looks ahead to the topics that need to be tackled in deliverable 4.2 of WP4 in order to propose a QoS/PM model that is tuned towards FMC based networks.

Chapter 6 summarises and concludes the deliverable pointing out the key messages arising from the activities and work undertaken.

2 QOS/PM survey documented in M4.1

This section revisits the main findings of the survey, which took place in reaching milestone MS17 "Survey of monitoring parameters and methods" achieved in month 6.

MS17 captured the existing QoS, QoE and PM parameters and methods, including the industry practice and current standards recommendations for both physical media and services. The survey made for MS17 classified the monitoring parameters and the corresponding methods and tools using different criteria:

- According to the physical medium or technology, in which optical fibre communications, copper (e.g., VDSL2 and G.fast), microwave radio links, Wi-Fi and Base-T (considering typical cables used in access networks).
- According to the protocol layer, with a deep focus on the OSI layers 2 and 3, including also 2.5 layer protocols such as MPLS.
- According to the type of service or function provided, such as mobile fronthaul, synchronization, energy consumption and protection, restoration resilience and availability features.

MS17 has been also useful to agree on the definition of different terminologies related to performance management and monitoring, such as active/passive monitoring and the relationship between QoS and QoE. The definition of passive and active monitoring is the following:

- Passive monitoring: non-intrusive tools that do not affect the supervised element/ path/service (e.g., available bitrate monitoring) or methods that do not manipulate packets but have visibility of packet headers and/or payload (e.g. packet counters).
- Active monitoring: intrusive tools that disrupt or impact the link or the service under supervision (e.g., loopback facility which affects a user or a service) or methods which can manipulate or add fields to packet headers or payloads for the monitoring of an element, service or path (e.g. timestamps, flags field, etc.).

The following tables provide a summary of this work containing the main methods and parameters: they represent multiple network layers and locations/functions in one place. Table 1 focuses on methods and parameters used in specific physical media and technologies, Table 2 makes a classification according to different protocol layers and finally Table 3 outlines the main tools and parameters for different services or functions.

Physical medium and technology	Passive methods	Passive parameters	Active methods	Active parameters
Optical fibre – xPON and point-to-point (1)	• Line monitoring • Optical performance monitoring • CD, PMD testers • Optical power meters • Transceiver diagnostic interface • OTDR out of band (w/ or w/o reflective filters, point-to-pint or point-to-multipoint, co-directional or contra-directional)	• LOS, BER, frame errors, loss of synchronization, FEC, OSNR • System load • PMD, CD • Transmitted/Received optical power • Transceiver parameters (temperature, supply voltage, bias current, Tx & Rx power) • Reflectometric traces (see active parameters)	• OTDR in band (w/ or w/o reflective filters, point-to-pint or point-to-multipoint, co-directional or contra-directional)	• Reflectometric traces (attenuation, reflection, end of fibre events, etc. including end-to-end loss, event loss, event reflection and attenuation slope)

Physical medium and technology	Passive methods	Passive parameters	Active methods	Active parameters
Copper – xDSL and G.fast (2)	• Status parameters monitoring • Performance parameters monitoring • Data gathering function (VDSL2) • Impulse noise monitoring • Active testing and diagnostics parameters monitoring	• SNR Margin, Max attainable data rate, Line attenuation (per band), Signal attenuation (per band) • Code Violations, ES, SES, FEC, Unavailability secs, Error-free bits (EFTR), Full initialization count, Re-synchs count • Time stamped events, e.g., End of showtime, Previous end of showtime • INP equivalent (INP required to prevent data errors), symbol interarrival time	• Retraining • DELT • SELT • MELT • Loop Qualification & Monitoring (LQ&M)	• Hlog, Hlin, SNR, QLN, FEXT coupling (XLIN) • Echo measurement (fault localisation) • Cable electrical parameters at DC or low frequency
Radio – uWave (3)	• Status monitoring • Performance monitoring over the link as a service	• Tx/ Rx frequency or radio channel • Available BW, Current BW • Available field polarization • Pmax, Pmin, Current Ptx • RSSI • Mmax, Mmin, Current Mtx and Mrx • Receiver EVM • Supply Current, demodulator unlocked alarm, clock, misaligned frames • Ethernet traffic (trx/refused, current link payload...) • Far-end Tx freq, BW, field polarization • Link Operating state, LOS, BER, EB, ES, SES, BBE, ESR, SESR, BBER, SEP, SEPI, unavailability rate, AR • MTBF, MTTR, MO, OI	• Performance prediction	• Diffraction fading, attenuation, multipath diffraction, frequency selective fading distortion, multipath propagation delay • Variation in the angle-of-arrival • Reduction of cross-polar discrimination (XPD)

Physical medium and technology	Passive methods	Passive parameters	Active methods	Active parameters
Radio – Wi-Fi (4)	• Status monitoring • Performance monitoring over the link as a service	SNR Channel usage ratio (for the same channel the AP operates in) • Adjacent AP detection (for the same channel the AP operates in)	Performance management • Diagnostics	Adjacent AP detection (all channels requires stopping the service or an additional radio) •
Service – Wi-Fi	• Status monitoring • Performance monitoring over the link as a service	Nominal bandwidth of the backhaul Service status Number of clients connected Client session time • Mean delay in the connection to the core	Performance management •	• Active backhaul quality measurement methods
Copper – BASE-T (Ethernet) (5)	• IEEE BASE-T Link Status tools • SNR margin from LDPC training operation • Physical counters	• Link status: Boolean check on link initiation and after re-establishment after a link down • PMA_RXSTATUS indication - used to indicate status of the receive link at the local phy. Implementation options, but Mean Square Error and symbol errors noted • SNR	• In maintenance windows, the link can be placed out of operation, and an electrical TDR function can be performed	• Distance to open • Crosstalk • Cable length

(1) See ITU-T G.984.2, ITU-T Recommendations L.40, L.44 and L.53, SFF-8472 specification, BBF WT-287, IEEE 802.3 Physical medium attachment/dependent

(2) See BBF TR-069, TR-188, TR-197, TR-198, TR-252, ITU-T Recommendations G.997.1, G.996.2, G.993.2 amd3, G.999.4amd2, G.997.1, G.998.4, IETF RFC4706, RFC5650, RFC6765.

(3) See ITU-R Recommendations P.530-14, F1.493, ITU-T Recommendations G.821, G.826, G.827, G.828, ETSI TR 101 534 V1.1.1, ETSI TS 136 322 V8.8.0

(4) See IEEE 802.11, BBF TR-069 and BBF TR-143.

(5) See IEEE 802.3 Clauses 24.3.4.4, 40.2.8 and 55.4.2.5.7

Table 1: Monitoring parameters and methods: physical medium and technology specific

Protocol layer	Passive methods	Passive parameters	Active methods	Active parameters
Layer 2 (1)	• Remote Network Monitoring Information Base (RMON) IETF • Performance monitoring • Connectivity monitoring • Synthetic Loss Measurement • Probe monitoring • SLA monitoring	• RMON Etherstats (counters) • SMON Etherstats (counters) • Service availability, Frame loss, Frame misordering, Frame duplication, Frame transit delay, Frame lifetime, Undetected frame error rate, Maximum service data unit size supported, Frame priority, Throughput, Frame delay variation • MEF Technical Specification 10,2 • RFC1242 Benchmarking Terminology for Network Interconnection Devices	• ITU- Y.1731 SLA Monitoring • ITU-T Y.1564 Ethernet service activation test methodology • Benchmarking Methodology for Network Interconnect Devices (RFC 2544) • Connectivity fault management • Network and service testing • Network traffic management • Customer experience management • Trouble ticket management	• Frame Delay (latency) • Inter Frame Delay Variation • Frame Loss Ratio • Availability • CIR / EIR / Traffic policing parameters • MEF Technical Specification 10,2 • RFC1242 Benchmarking Terminology for Network Interconnection Devices
Layer 2.5 (2)	• Performance monitoring	• Loss and delay	• GAL (label 13) and G-ACh • Service delivery verification • Protection switching • Continuity check	• Loss and delay
Layer 3 (3)	• RMON • SMON • NetFlow • sFlow	• Packet loss ratio (one/two way) • Throughput • Delay (one/two way) • PDV • Inter Packet Gap (IPG) • Inter arrival Time • Packet rate • Burstiness, MTU • Availability parameters (Y.1540)	• ICMP echo • OWAMP, TWAMP • BFD (RFC 5880)	• Packet loss ratio (one/two way) • Throughput • RTT • Delay (one/two way) • PDV

(1) See IETF RFC 2819, RFC 4502, RFC 2613 and RFC 2544, IEEE 802.1D, 802.1Q-2011, ITU-T Recommendation Y.1564

(2) See ITU-T Recommendation Y.1731, IETF RFC 6669

(3) See BBF TR-143, TR-160, WT-304, IETF RFC 5357, RFC 6802, RFC 4149, RFC 5481, RFC 5880 etc. ITU-T Recommendations Y.1540 and Y.1543

Table 2: Monitoring parameters and methods: protocol layer specific

Service / Function	Passive methods	Passive parameters	Active methods	Active parameters
Service Level Monitoring (1)	• Dynamic following of the well-known ports • Analysis of statistical distributions • Traffic monitoring • RTFM • RMON MIB • IPPM • IPFIX • PSAMP	• Packet inter-arrival times • Packet length • PDP context lifetime • Control traffic decryption success rate	• Packet fingerprint analysis • ALTO • Traffic generators • Roaming testers • Fraud detection systems	• Malware presence • Attach/ detach rate • PDP context activation/ deactivation rate • Generated traffic upload/ download bandwidth
Synchronization (2)	• Measurement of network-related parameters • Relative measurements between redundant sync paths • Installation of a temporary measurement reference • Measurement against synthetic reference (local clock)	• Packet delay • Out of order packets • Packet drop statistics • Clock accuracy • Variance • Distance (number of hops) from master • Frequency offset • Missing clock cycles • Phase transients • Asymmetry in delay • Delay variations	• SSM/ESMC Traceability signalling	• Quality Level indication (note not absolute quality, more traceability to reference)
Energy Consumption (3)	• Energy consumption monitoring	• Power • Energy • Power interval • Voltage • Current • Duty Cycle • Power cycle		

Service / Function	Passive methods	Passive parameters	Active methods	Active parameters
Protection, Resilience, Restoration and Availability (4)	• Performance monitoring	• MTBF, MTTF, MTTR, MTBO, MTRS, etc. • Availability • Loss, recovery time, full restoration time, etc. • Severe Loss Block	• Failure characterization • TDR/monitoring trails	• Outage time • Failure occurrence
Intelligent Networks/Value Added Services (5)	• Performance monitoring	• Success/Rejects rates (per service key) • Session length (per service key) • Number portability KPIs • Charging KPIs • Ringtone services • Call back application service usage • USSD service usage • Location update success/reject rates • Service continuity success rates • Success/Reject rates of reaching VAS • Rates of using home short codes successfully/ unsuccessfully	• Regression testing when new services are introduced	• Identical to the passive parameters

(1) See IETF RFC 4594

(2) See ITU-T Recommendations G.810, G.8260, G.8273, MEF 22.1, MEF 23.1 and MEF 10.2

(3) See IEEE P802.3az

(4) See IETF RFC 2330, 3386, 3469, 4378, 3945, 4427, 4428, ITU-T Recommendations G.911, M60, M.3342, M.1301, P.10, X.641, Y.1540, Y.1541, Y.1542, Y.1561, Y.1562.

(5) See ETSI IN-CS1, IN-CS2, CAMEL (ETSI TS 123 078, 3GPP TS 29.078)

Table 3: Monitoring parameters and methods: by service/function

In this deliverable we used this survey of the state of the art to investigate how the different monitoring parameters and tools could support the FMC network use cases defined in WP2 and WP3. This work is also important for D4.2, where an efficient performance monitoring solution for FMC networks will be defined, because that solution will be based on a selection of existing performance monitoring solutions as well as new functionality developed within the project.

3 Monitoring parameters overview and use cases

In this chapter we are reviewing the use cases with focus on QoS/PM aspects, and looking at emerging paradigms and the impact of scalability and complexity on QoS/PM for FMC based networks.

3.1 Where in the Network is QoS/PM Placed and Why

Here we took the use cases from WP2 and for each of them perform top-down analysis on the various implementation options, and identify QoS/PM tools and parameters that might be used. The findings are summarised in a tabular format at the end of each section.

3.1.1 UC01 – FMC access for mobile devices

UC01 proposes an FMC network in which it will be possible to provide more capacity to end users using Wi-Fi networks in collaboration with mobile networks.

In this use case, mobile operators can increase their service coverage and capacity, offloading the mobile traffic into Wi-Fi networks in specific areas where high demand for mobile broadband and/or improved short-term capacity is needed. Mobile devices supporting Wi-Fi will offload mobile traffic automatically from the mobile network to the Wi-Fi network depending on the network status and on the operator's preferences using envisaged new functions.

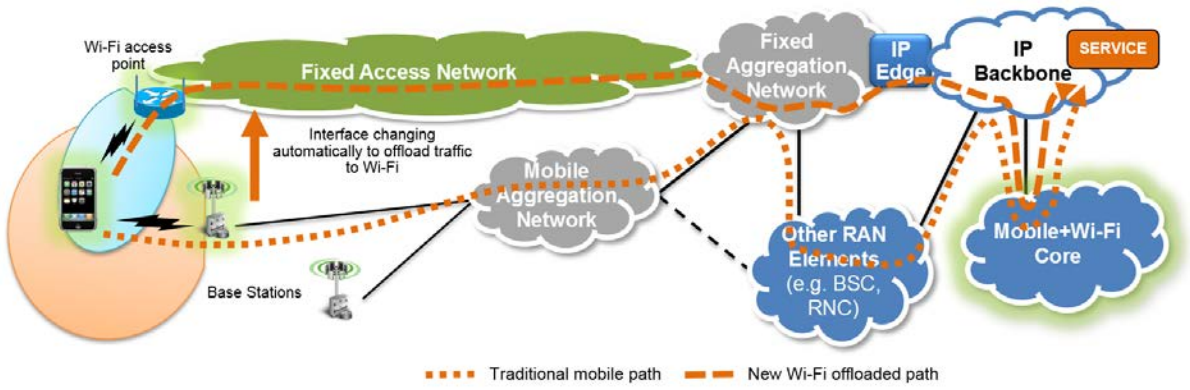

Figure 1: UC01 – FMC access for mobile devices using Wi-Fi offloading techniques

Figure 1 illustrates this use case, in which it can be seen that the mobile traffic (dotted line) is routed to the mobile core using a Wi-Fi network when the user is located in an area with Wi-Fi coverage (dashed line). The target traffic to be offloaded to Wi-Fi is data traffic, for example, web browsing, e-mail, video streaming, instant messaging, etc. Data services with specific needs of session continuity, such as VoIP or videoconferencing, will need an enhanced FMC access and core, as it is considered in UC02.

Additionally, Figure 1 highlights (with glowing green background) the main network elements that are important to QoS/PM for this use case: the UE (i.e., the mobile phone), the mobile and Wi-Fi access nodes and the mobile/Wi-Fi core network.

(Other elements are also important, such as the RNC or the backhaul network, but only the key elements are highlighted.)

Chapter 3.2 in D3.1 [4] analyses this use case and proposes some key aspects such as a common authentication, a seamless connectivity, the connection manager, the UE capabilities, etc. and some solutions to implement them, for example: IEEE 802.11u, EAP authentication, and ANDSF from 3GPP.

QoS/PM aspects of UC01 are summarised below.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Network discovery	• Where is Wi-Fi offloading available? • Is Wi-Fi offloading realised on UE or on network initiative? • What is the UE consumption due to network discovery activity?	• Channel monitoring, current location, radio environment information • UE monitoring and/or network monitoring • UE QoE and quick adaptation
Network selection	• Which is the most suitable access? • Which are the network conditions in terms of load, delay, throughput, etc.? • When to change from mobile to Wi-Fi? Or back? • For what services to change from mobile to Wi-Fi? • Which one is responsible of the selection: UE or the network? • How fast the switchover can be done? • How to avoid mobile to Wi-Fi to mobile again short cycles • Wi-Fi and cellular technologies have different QoS (e.g. different delays, jitter, etc.)	• Network conditions evaluation • PM selection and evaluation from different networks types and in different network elements • Policies evaluation based on current status • Selection of PM parameters to be forwarded to the UE agent in case they are needed for the selection decision • QoE and energy consumption impact in case the network selection is done in the UE or in the network • QoE impact due to a high number of network reconnections (e.g. switchover between Wi-Fi and mobile interfaces in cyclic way) • QoS/PM parameters threshold adaptation
Session continuity	• Can we avoid to break sessions not broken? • Can we avoid mobile to Wi-Fi to mobile short cycles? • Can we maintain a single level of QoS while Wi-Fi and cellular technologies have different QoS (e.g. different delays, jitter, etc.)? • Handovers: mobile-mobile, mobile-Wi-Fi, Wi-Fi to Wi-Fi	• Measurement of the number of broken sessions • Measurement of QoE under stressful conditions • QoS/PM parameters threshold adaptation
Charging	• Is there an impact on charging?	• Measure time on each network type

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Connection Manager	• How to collect network information? • Which intelligence will be located at the UE agents? • How to enforce policies?	• Specify and analyse methods used by the connection manager to retrieve measurements • Parameters measured on the UEs and forwarded to the sent to the connection manager • Based on the UE and/or the network

Table 4: UC01 QoS/PM aspects

3.1.2 UC02 – Enhanced FMC access for mobile devices

UC02 proposes an enhanced FMC network based on UC01, in which mobile devices are able to simultaneously use both Wi-Fi and mobile technologies to access to the operator's network and seamlessly move all or part of their traffic, even for the same application and session, from one access to another.

Figure 2 depicts this use case in which a UE with double attachment to both Wi-Fi and mobile networks can be seen. Additionally, a seamless handover between Wi-Fi APs as well as between Wi-Fi and mobile access technologies is shown. Finally, the network assistance for performing the access selection function is also presented and distributed between the mobile device agent and the network information and policies server.

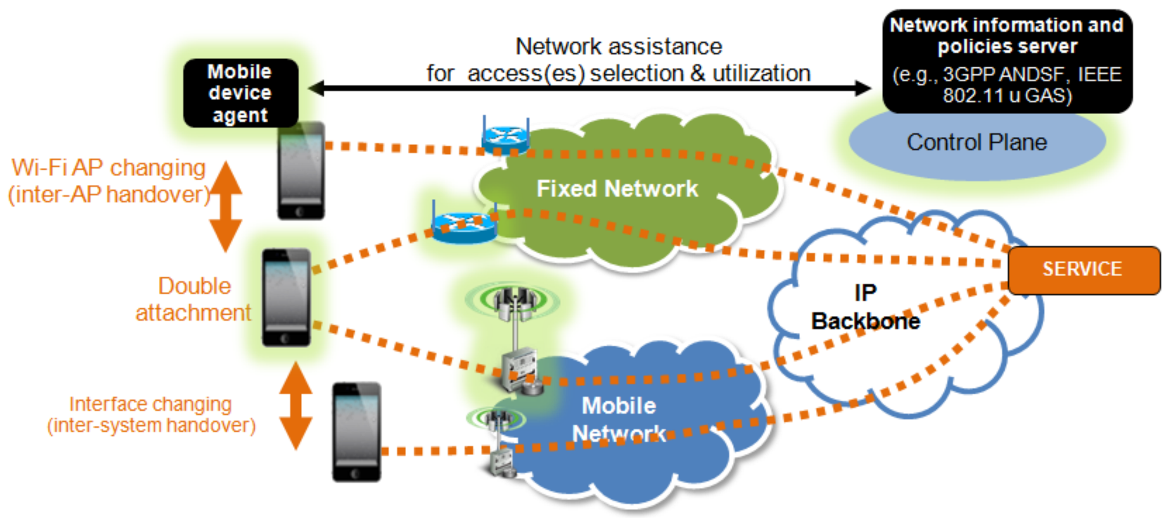

Figure 2: UC02 – Enhanced FMC access for mobile devices using Wi-Fi offloading techniques

Additionally, Figure 2 highlights the main network elements that are important to QoS/PM for this use case: the User Equipment, the mobile and Wi-Fi access nodes (i.e., the Wi-Fi access points and the base stations) and the network element in charge of the network assistance.

As commented in the previous section, chapter 3.2 in D3.1 [4] identifies the seamless handover and double attachment as the key aspects for UC02. It also introduces a mobility manager entity in the network and multipath TCP or other approaches to resolve mobility and dual-attachment aspects, respectively. Where to locate the control entity in the network is an open issue and will be investigated in WP3.

All QoS/PM aspects considered for UC01 also apply to UC02; additionally Table 5 includes all specific QoS/PM to UC02:

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Network discovery	• What role does the UE has in the assistance to the network discovery?	• Parameters transmitted to the UE for the network discovery process (e.g. visited network parameters and thresholds) and how frequently must be forwarded to the UE
Network selection	• What interfaces can be used? • When is it possible to use Wi-Fi and mobile? • How to assure the QoS for different services using multiple physical interfaces?	• Dual Wi-Fi and mobile periodic monitoring to know the network availability • Identify the UE as smart phone or tablet etc. (coding etc.) • Network current status, the specific needs of QoS of each service, user preferences and current policies are needed to be checked as the service could be assigned to a single interface or both, even in a dynamic way • QoS/PM at service level will be needed
Session continuity	• Intra-AP handover, inter system handover relationship with QoS/PM • How to know what the general QoS is when dual attachment is used?	• QoS/PM for multiple interfaces will be needed • QoS/PM values will be needed to be aggregated to know the current QoS at service level
Connection and mobility manager	• How to transfer a session between two access nodes? • UE agent will need to monitor all interfaces	• QoS/PM parameters can be shared among access points or the information can be centralised • Stricter mobile and Wi-Fi monitoring of performance parameters to assure QoS and perform the appropriate switching

Table 5: UC02 QoS/PM aspects

3.1.3 UC03 – Converged CDN for unified service delivery

Content Delivery Networks (CDNs) have been widely deployed to provide efficient content delivery services. UC03 refers to CDN deployment in a converged scenario, which can enable a unified service delivery. In such a scenario, a rising trend for content delivery is to push the contents towards the end users, adding caching capabilities to the edge nodes, as well as to the STB of the residential networks or to strategic nodes of the aggregation and access networks. By distributing *caching nodes* through customer premises, the aggregation and/or access segments of the network, operators can achieve cost savings by offloading core network traffic (e.g., inter-domain traffic is reduced) and QoE is improved by e.g. by lower delays. Note that, caching can also apply to the Home / Small Office / Corporate network segments, but it is out of the scope of UC03. Different parameters and tools, as described in the table, can be used for Performance Monitoring, according to the different solutions in terms of number of caching nodes and their position in the aggregation and/or access network.

Note that the position of caches plays an important role in relation to the number and typology of users, who can potentially be served by the converged CDN: determining the position of caches in the network strongly depends on the characterization of local traffic. Cache placement must take into account statistical models. This can guarantee the usefulness of content replication in a specific position of the network. In Figure 3 different cache elements can be found distributed across the FMC network. However, their location, as well as the NG-PoP introduction, are chosen as a reference only. The final architecture of the solution must still be defined.

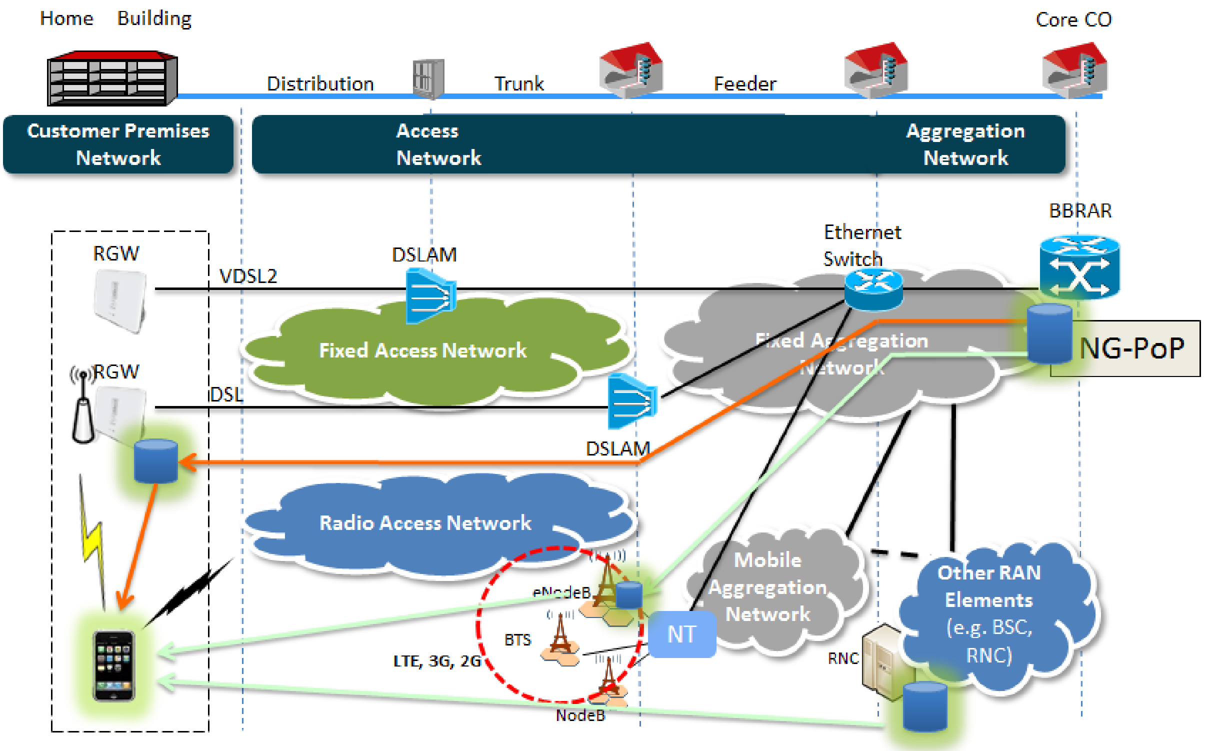

Figure 3: UC03 – Converged CDN for unified service delivery

QoS/PM aspects of Use Case 03, with a specific emphasis regarding FM convergence, are summarised in the following table.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Caching frequently accessed contents	• Where to place caches? How close are caches to the end users? • Can the caches be shared among the fixed and the mobile network? • Will the cache need to store multiple copies of the same content? (E.g., for different screen resolutions?) • How beneficial can be convergence in terms of cache sharing? • How much cache will be needed? • Can cache improve the quality (E.g., less loss, fewer bottlenecks?) • Do lower delays improve performance of on-demand media streaming and vertical handover?	• Measure Average latency (user waiting time), i.e. delay between content request and beginning of content reception • Measure Average content download time, i.e. total time to retrieve content object • Monitor core traffic and of inter-domain traffic evolution to assess whether caching allows to lower their respective amounts • Measure the hit ratio in various caches
Caching of specific services/ applications	• To what kind of services/applications does caching apply?	• Is it necessary to implement Deep packet inspection in order to identify relevant applications? • perform delay measurements per application type • Specific service request block
Caching strategies	• What type of caching strategy can apply for which applications (Proactive vs. reactive caching) • What type of Cache replacement policy should be implemented. • How can copyright be ensured? • What type of reaction to copyright violations can be implemented? • What caching technology should be implemented? Collaborating caching? Dedicated data servers? Distributed/P2P CDN? • Does FMC has an impact on caching strategies?	• Monitor Content-related parameters: - Cache hit ratio - Cache utility - Cache ageing time • Monitor Network-based parameters: - Availability of bandwidth from the source to the cache and from the cache to the end-user – the latter being more critical. • Monitor Average latency • Monitor Average content download time

Table 6: UC03 QoS/PM aspects

3.1.4 UC04 – Reuse of infrastructure for indoor small cell deployment

When considering deployment of small cells, one must also plan for the backhaul connectivity for these small cells. The backhaul connections can be either wired (based on copper or fibre) or wireless.

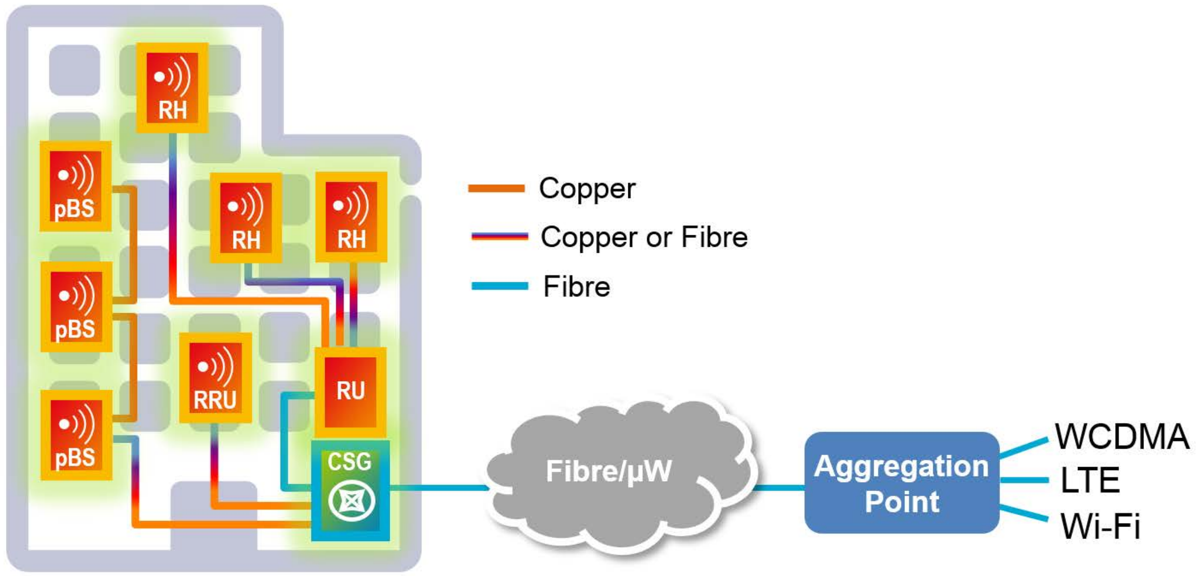

Figure 4: UC04 – Indoor small cells reusing existing fixed copper/fibre infrastructure

Considering indoor small cell deployment, residential and business buildings often have existing fixed/wired copper and/or fibre infrastructure that can be reused to provide backhaul connectivity. Thus, as illustrated in Figure 4, this use case highlights the opportunities to reuse that infrastructure in order to reduce costs and deployment time for cost-sensitive small cells.

As illustrated in the figure, the small cells can be either pico Base Stations (pBSs) with Base Band Units (BBUs) or Remote Radio Units (RRUs) with centralised BBUs; in the latter case, CPRI is an implementation option (this will be handled in further detail in upcoming deliverables). In residential buildings, the pBS is located in the RGW to apply mobile coverage in the home network. The backhaul will be dominated by the available fixed access technology, like VDSL2, G.fast, base-T or PON. In many aspects, the physical backhaul connection will determine the level of complexity in the mobile cell versus a centralized node.

The performance monitoring and QoS aspects of this use case are summarised in the table below.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Media and connection impact on QoS	• What is the QoS impact on services used by mobile subscribers when different types of media (copper, fibre, or wireless) and different types of connections (backhaul or fronthaul) are used? • What is the minimum achievable bit rate, delay and delay variation? • How to achieve a consistent level of synchronisation over the different types of connections?	• Measure the average bit rate, delay and delay variation in the different media and types of connections. • Measure the average packet delay & delay variation in the different types of connections.
Service delivery	• How stable will the mobile connection be?	• For sensitive services monitoring of transmission errors, packet loss and delay variations.
Traffic load adaptation	• How to adapt active cells to the required traffic load? • What is the quality of the backhaul to the central station?	• Available data rate and delay on the line • Obtain Details on the transmission channel, by e.g. TDR for copper.

Table 7: UC04 QoS/PM aspects

3.1.5 UC05 – Effective wireless backhaul deployment for outdoor small cells

In order to provide increased capacity and improved coverage, operators are considering deploying small cells as a complement to existing macrocells. These small cell deployments need, of course, backhaul connectivity. The backhaul connections can be either wired or wireless. Wired connections are not always available for outdoor deployments so a wireless connection is sometimes the only option. The small cells may be served by Line of Sight (LOS) wireless backhaul connections, but small cells deployed at street level in outdoor urban environments cannot always count on LOS between the small cell and the hub, which may be co-located with a macro base station (see Figure 5) or a fixed distribution point. The link endpoints may very well be obstructed by, for example, trees, street curves and/or building corners. This is where a non-LOS (NLOS) solution gives operators a solution with yet greater flexibility to deploy the small cells as they see fit, i.e., where there is a need for more capacity and coverage without worrying about the backhaul connection. Thus, the focus of this use case is quick and easy NLOS backhaul deployment for outdoor small cells.

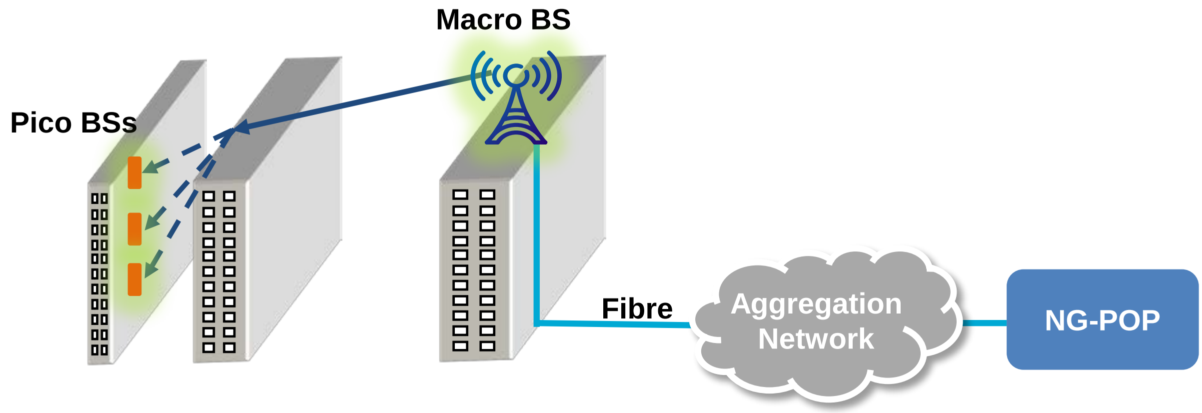

Figure 5: UC05 – NLOS wireless backhaul for outdoor small cells

The performance monitoring and QoS aspects of this use case is summarised in the table below.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Link availability	• How are links affected by weather conditions such as heavy rain? • How are links affected by interference? • How are links affected by multipath propagation, e.g. reflections in the environment?	• Monitor link availability, taking into account that Availability requirements are often more relaxed for small cell backhaul solutions (99-99.99 %)
Performance measurement		• Measure throughput, power, delay, jitter, and packet loss between pico BS and macro BS • Sharing link quality information between macro and small BS (e.g., via the X2 interface in LTE)

Table 8: UC05 QoS/PM aspects

3.1.6 UC06 – Common fixed and mobile access termination in hybrid connectivity for FMI customer services

In UC06, the point of convergence between fixed and mobile access is located in the RGW in combination with a hybrid connection gateway (HCG). The RGW is thus called a converged residential gateway (CRGW). The objective is to dynamically manage and fulfil the user service demands.

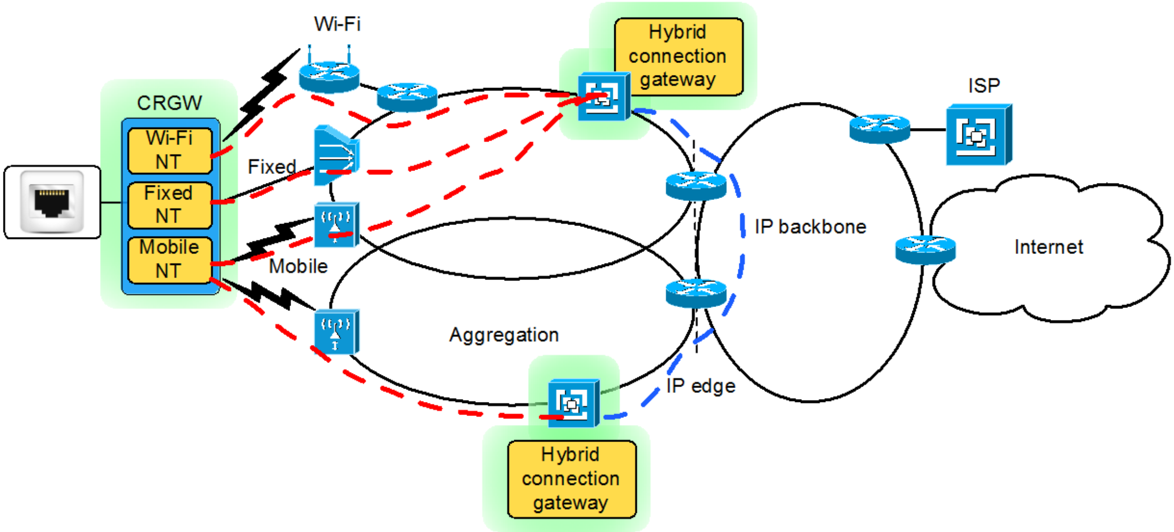

Figure 6: UC06 – Common fixed and mobile access termination in hybrid connectivity for FMI customer services

All traffic to and from the RGW is tunnelled over three main routes: the fixed access, a nearby Wi-Fi AP and the mobile network, according to a specified prioritisation, see Figure 6. The tunnelling (red dashed lines in the figure) can be obtained by e.g. MPLS, IP over IP or multipath TCP. The HCG acts as the tunnel termination point in the network for all three paths. On the other side of the tunnelling, the RGW orders the packets in the flows. The fixed network will often be preferred path as it is generally more stable. In the case of residential customers, using Wi-Fi access means that neighbours share a portion of their access capacity to even out individual traffic peaks – which are assumed to be only lightly correlated. The HCG should also coordinate the handover between networks on the outside as users enter or leave the local network. For a converged aggregation network, the natural position of the HCG is in the aggregation region. If, on the other hand, the access links are connected to different aggregation networks the HCG can either be moved higher up in the network or individual HCGs be interconnected by tunnelling (blue dashed lines in the figures).

From performance management perspective, the connectivity and QoS parameters for the three tunnelling paths need to be monitored. The preferred packet routes are then decided by the HCG according to SLA or connectivity demands. More specifically the parameters needed are listed in the following table.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Connectivity demands	• What type of services and what is the requirement? • What are the available connectivity from the different paths?	• For each tunnel path, monitor - Configured capacity - Available capacity - Delay/delay variation - Packet loss
Resilience	• What is required in relation to the SLAs?	• Monitor the availability of Each alternative tunnel
Packet ordering in tunnel termination points	• What are the delay differences and delay variations in the paths?	• For each tunnel path - Delay (two-way) - Delay variation

Table 9: UC06 QoS/PM aspects

3.1.7 UC07 – Support for large traffic variations between public, residential, and business areas

This use case, UC07, relates to network infrastructure convergence by sharing the resources of the aggregation network for mobile, residential and business users. Focus is on the need to handle large variations in traffic demand at different times of the day and week.

During business hours and during the working days of the week, demand for example on mobile networks may be geographically concentrated around industrial zones or large cities, while mobile networks in rural areas may be less loaded. However, in the evening, or during weekends, when workforce and commuters return home, the demand on mobile network resources changes and the residential/rural areas become more congested while the resources in the business zones become less loaded. One key implication of this use case is that some RRUs will be put into sleep mode. In a geographic region where RRUs can be placed into a sleep mode, at least one RRU will need to remain online so that new users can be detected, and to allow the flexible restoration of service and the graceful bring up of RRUs from sleep mode.

In addition to structural convergence, in order to transport the mix of traffic including mobile and fixed line as well as supporting a centralized RAN model, some protocol convergence is also a possibility. Thus the impact of transporting IP based services from fixed line users across a fronthaul/CPRI based topology or vice versa, will need to be considered from a QoS/PM perspective.

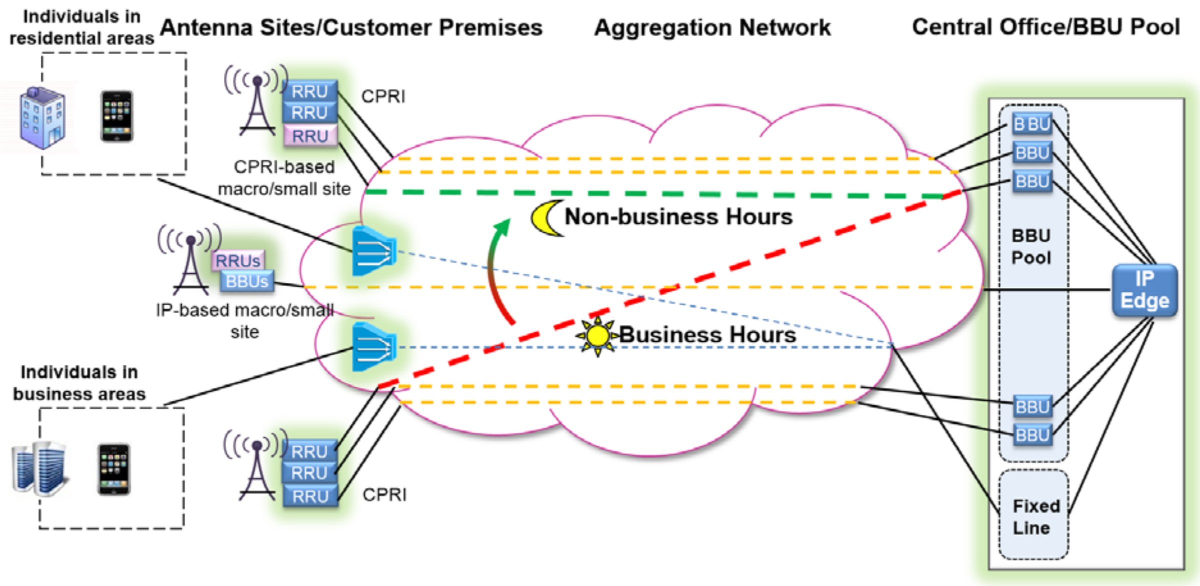

Figure 7: UC07 – Support for large traffic variations between public, residential, and business areas

Additionally, due to the selective switch-off in areas with temporarily decreased traffic, the power consumption is decreased; however, the QoS and availability will likely deteriorate. Therefore, QoS/PM should cater for monitoring the anticipated impact. The QoS/PM aspects of this use case are summarised below.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Identify which cells to put into sleep mode	• From an OpEx saving point of view, is it preferable to put into sleep mode high power macro BSs with large coverage or low power pico BSs with small coverage? Or should a selected combination of pico and macro BSs be put into sleep mode?	• Measure the traffic volume that needs to be supported and choose which nodes to put into sleep mode, for optimal OpEx savings while maintaining the requested QoS.
Dynamic allocation of resources	• Does it mean turning on/off e.g. specific radio access nodes?	• Measure time to bring back resources online?
Virtualization	• BBUs • How fast switchover / reconfiguration can be done?	• Monitor VM resources in BBU Pool – warnings when certain percentage of BBUs in use? • Measure and report on switchover times

Monitoring	• Requested load/bandwidth • Number of users • Time of the day/week/month • Energy • Manual reconfiguration • Automatic Reconfiguration • Delay across aggregation/switch devices • Delay variation introduced per device	• Which control channels to monitor and how - S1? • Time based statistics and binning • Power monitoring at base-stations, power at aggregation switches, power at server rooms etc. • Time taken to switch • Time taken to detect reason to switch, then time to switch? • Delay/latency monitoring • Delay variation
Protocol Convergence	• L2/L3 over CPRI/Fronthaul • CPRI/Fronthaul over L2/3 or alternative	• How to measure QoS and identify faults? Monitor CPRI? • BER of either service not impacted • Impact on delay profile of CPRI traffic • Delay, jitter and frequency accuracy performances compatible with 3GPP protocols constraints (e.g. HARQ_LTE).
Port operating modes	• Interface utilisation at edge and at aggregation nodes • Range from 1-10Gbit/s at edge • Range from 10-40 – perhaps 100Gbit/s for large CPRI example	• Monitor % utilisation of interfaces • Monitor number of active interfaces vs. sleep interfaces and report.

Table 10: UC07 QoS/PM aspects

3.1.8 UC08 – Universal Access Gateway (UAG) for fixed and mobile aggregation network

The motivation for this Use Case of a Universal Access Gateway (UAG) is to simplify the access and aggregation networks, reduce the potential for technology variety, and thus achieve an improved utilization of infrastructure and systems.

The network scenario is characterized by partly merging the access and aggregation networks, using for example TDM/TDMA technology for mass-market access such as a typical FTTH deployment and over the same network enable backhaul (e.g. DSLAM, Mobile) and future WDM overlay services for fronthaul (or other very demanding services beyond 1Gb/s). NGPON2 as considered by FSAN could be an option for the transport layer.

Furthermore, certain functionality of the mobile packet core can be moved into the UAG. In this sense the UAG could potentially include SGW and PGW as well as fixed, mobile and Wi-Fi IP edge functionalities or co-ordination instances from the mobile core as described in UC02, UC03 and UC06.

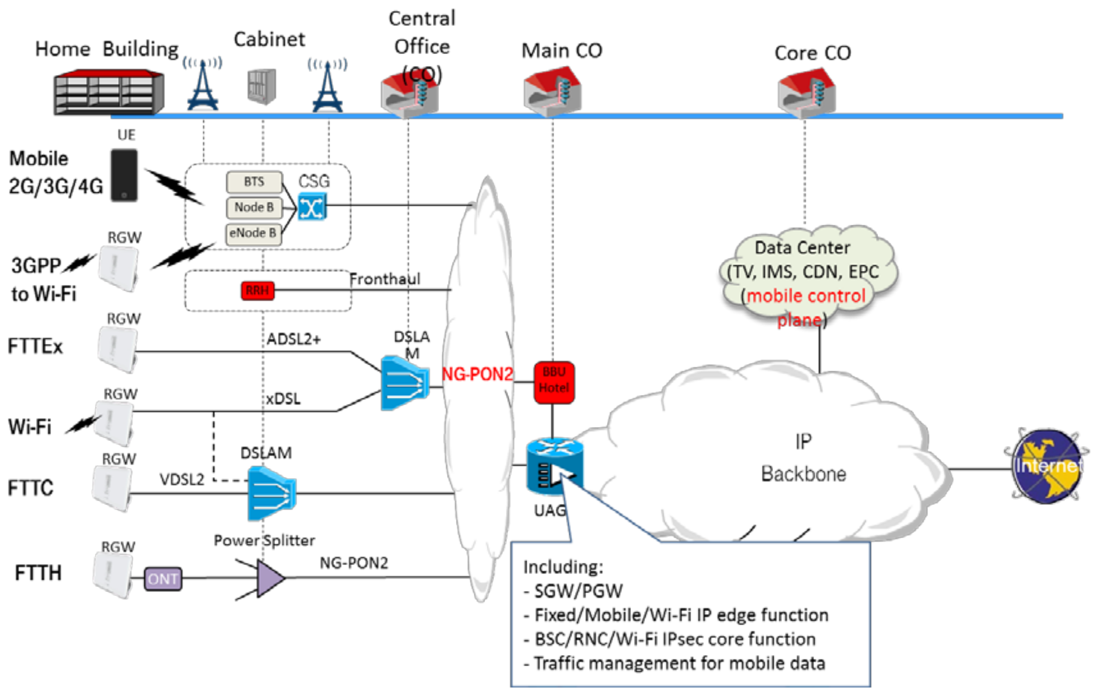

Figure 8: UC08 – Universal Access Gateway (UAG) for fixed and mobile aggregation network

The principle architecture should support COMP and BBU hoteling concepts. Additionally, the UAG could comprise further elements such as the BBU hotel for example. The home plus UAG will cover the range of typical access and aggregation network sizes. As already shown in WP2 [2], the mobile traffic expected at such a UAG location is just a fraction of the fixed network traffic at the same location. Thus one could expect that a fixed network BNG is capable of serving both the mobile and fixed network.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Monitoring	• L2/L3 characteristics	• Throughput, delay, packet delay variation, packet loss
Reach	• Can we reach the distance specified?	• Optical power budget
Traffic mix	• What is the proportion of the mobile vs. fixed line traffic	• Deep packet inspection

Table 11: UC08 QoS/PM aspects

3.1.9 UC09 – Convergent access and aggregation technology supporting fixed and mobile broadband services

UC09 aims at specifying a converged access and aggregation network based on a single universal technology (see Figure 9). It should be able to support all different services aimed for residential, business and mobile backhauling.

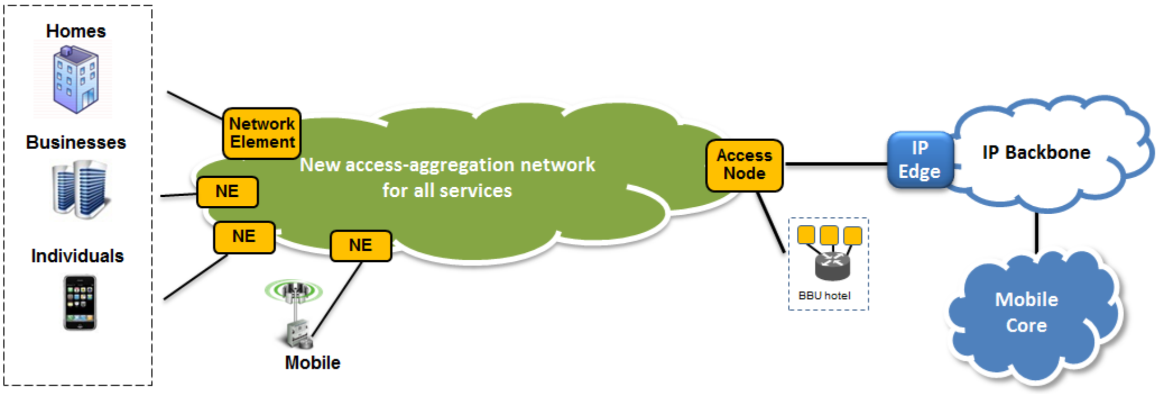

Figure 9: UC09 – Converged access and aggregation network.

To have the same network technology requires that it is possible to handle high data rates with a low delay and low delay variation. This points in the direction of an all-optical infrastructure. The high demands of this structure mean, for a general roll out, that it is some years in the future. In 2017 it is expected that 80-90% of all consumer traffic consist of video and other streaming media [5]. Hence, to ensure the quality of both IPTV and OTT delivery, parameters on all layers related to QoE must be monitored regularly. IPTV and OTT demand high QoS mainly downstream. Even so, upstream QoS requirements are important for other services, such as cloud access or backup, and should not be neglected. Another demanding service on such networks is the mobile fronthaul. Here, data rate, delay and delay variation are crucial for CPRI, which demands both a very high data rate of minimum 614 Mb/s per line in each direction and a low round trip delay. There are also specific requirements for the X2 interface in the mobile network for handling mobile device handover between eNodeBs.

Typical parameters that should be monitored for this use case are given in the following table.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Support of Video services	• What parameters are relevant for QoE for IPTV, OTT, video conference and VoD services?	• To ensure the QoE according to SLA • Monitor end to end path for e.g. data rate, delay variation and packet loss is needed for all services • Monitor latency for real time video services.
Services based on IP best-effort transport	• What parameters are relevant in addition to the ones for downstream delivery?	• Similar monitoring needs as for video services but other requirements and also for upstream.
Support of LTE	• What are the requirements for CPRI, OBSAI and X2?	• To transmit the radio signals digitally it is required to have good knowledge of data rate, delay and delay variation. Further, the X2 protocol has requirements on the round trip delay.

Table 12: UC09 QoS/PM aspects

3.1.10 UC10 – Network sharing

UC10 proposes a multi-operator environment where competing operators can cooperate and share their network resources, such as antenna sites, radio resources, backhaul connectivity, etc., in order to use the resources more efficiently and obtain additional savings in an FMC network scenario. This can be considered analogous to code sharing

flights in the aviation business, where sharing a single plane full of passengers is beneficial to operating two planes of two companies on the same route, both with few passengers. When a network failure arises, it should be possible to guarantee a premium service to one or more operators, depending on the subscribed SLA from the Wholesale Network Company as a provider.

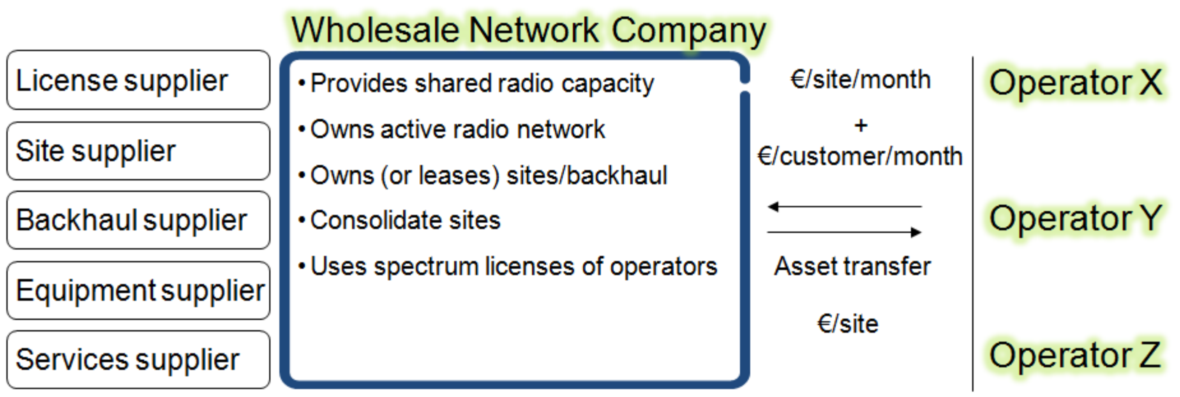

Figure 10: UC10 – Illustration of network sharing using a third-party network company

Figure 10 illustrates how different operators can, for example, share a single network deployed by a third-party network company. It highlights the physical network provider as one of the main actors where QoS/PM needs to be considered. The physical network provider will also be a key actor for the physical performance monitoring. Operators also have the possibility to supervise the shared network resources by themselves, but at Layer 2 or higher. Chapter 3.2 in D3.1 [4] identifies some possible solutions for network sharing, such as network virtualization and SDN mechanisms.

The performance monitoring and QoS aspects of UC10 are summarised in the table below.

Use Case Consideration	Implications / Questions arising	QoS/PM Impact
Monitoring	• Fair use of the low level monitoring information • Visibility of PM data • Sensitive PM data • Efficient PM • Typical PM parameters and areas to monitor in a shared resource	• Only PM information related to the specific shared resource will be available to operators • Each operator shall see only its own PM data. The network resource operator could see all operators' PM data • Sensitive shared PM data will need to be handled with confidentiality • The wholesale company is the one to monitor the use of the network resources such that each operator gets resources according to its SLA. Each operator can in turn monitor that the resources it is getting are in line with its SLA. • Throughput, delay, jitter, packet loss, availability, reliability, usage. Parameters will depend on the specific resource to monitor.

Table 13: UC10 QoS/PM aspects

3.2 Scalability and Complexity: Centralisation/Decentralisation of QoS/PM

The monitoring tasks in some of the above described use cases are initiated individually, but in most situations monitoring should be performed regularly. Furthermore, the location of the monitoring equipment or measurement points differs for the individual parameters. In the case of more centralised monitoring, the complexity of the task grows with the number of monitored nodes.

3.2.1 Performance monitoring by SNMP

In a network many of the monitored parameters can be read remotely over a private management network using SNMP (Simple Network Management Protocol), which is a protocol for remote management of network elements. Currently the protocol is in its third version (SNMPv3) that is described by RFC 3411–RFC 3418 and also known as also known as STD 62 [11]. This protocol makes it possible for the network provider to centralise the monitoring of the network entities and to collect the data at a central node.

SNMP itself does not define which information (which variables) a managed system should offer. Rather, SNMP uses an extensible design, where the available information is defined by MIBs (Management Information Bases), a virtual database used for managing the entities in a communications network. The MIB describes the structure of the management data of a device subsystem by using a hierarchical namespace containing OID (Object Identifiers) where each identifies a variable that can be read or set via SNMP. Carrier grade hardware usually offers SNMP as one of the available options to manage the deployed network elements. An application would be in charge of managing the different elements of the network by connecting to them through SNMP and performing different operations.

3.2.2 Scalability and complexity

Measurement of QoS and QoE parameters has always been a challenge, but the introduction of new use cases and emergence of FMC architectures are likely to compound this problem. Regular measurement of performance parameters may not be scalable for large networks. For most networks, capacity is not the problem since inband control data requires low bandwidth. Since reading and delivering a parameter (e.g. by SNMP) requires a small amount of network resources, there is a limit on the number of parameters that can be read from any single node. Therefore, large networks, e.g. metro or even national networks, cannot have a completely centralised monitoring. Instead, the monitoring system must collect local data for restricted parts of the network, using distributed monitoring nodes or agents. The data can then be collected in a centralised database.

There is also a difference in the complexity of the monitoring equipment. For many parameters read from physical layer (e.g. available capacity or error rates), the data is stored in remote equipment as MIB data, e.g. counters. Reading these requires only an SNMP/Get bulk call to the monitoring equipment. This can also apply for higher layers' passive parameters. In general, passively monitored parameters require little computational effort. There are, however, more demanding monitoring methods, such as deep packet inspection, which may be considered as necessary for implementing caching in CDN or energy aware networks. These can be even more complicated when a stream or a flow carries encrypted data. Active monitoring such as TDR or ICMP echo also increases the complexity of the system. The main consideration with such methods is normally that they might affect real traffic on the links. In some cases, like TDR, the end equipment must interrupt the normal traffic streams during the measurements.

3.2.3 Centralisation/decentralisation

Depending on the purpose of monitoring, data can also be stored in decentralised nodes. In large networks it may be useful to decentralize the management and evaluation tools in order simplify analysis of specific parts of the network. Then, in order to get an overview of the complete network, a centralised management node can collect pre-processed, higher-level data from the decentralised nodes.

In an FMC scenario the natural monitoring points in the network are shifted, as governed by the modified network architecture. In the next section the question of function virtualisation and software defined networking is discussed in more detail.

3.3 Impact of emerging paradigms, such as Cloud Computing, SDN and NFV on QoS/PM

This section explores the impact of new technologies in relation to QoS/PM. The analysis performed earlier and the survey from Milestone 4.1 is useful for looking at existing use tools/parameters, but new concepts such as cloud computing, software defined networking, and network function virtualization may cause some new requirements or changes to the current best practice.

These emerging paradigms' impact on convergence is considered in WP3 Deliverable 3.1. Likewise, within WP4 they should be explored with emphasis on the implications of QoS/PM.

3.3.1 Cloud Computing

Cloud services can be categorized into specific use cases, including services such as Infrastructure as a Service (Iaas), Platform as a Service (PaaS) and Software as a Service (SaaS). In these cases users run their software applications or business packages on remote servers and store their data in a data centres, which are likely to support multiple different customers/users using the same infrastructure. Instead of the users running their platforms and applications locally, they use a thin client to access and modify their data using cloud services. For a more in-depth discussion on the actual impact of cloud services please see D3.1 [4]. For the purposes of the present deliverable, we can consider the characteristics of cloud services more generally.

The standardization of cloud services by groups such as NIST (in the USA) [6] and ITU [7] all address elasticity. Cloud services are assumed to be used in an on-demand model, where a path to the service is provisioned or scaled up when needed, and scaled back down or taken down when the service is no longer needed.

Such paths to the service may need to support dynamic bandwidth provisioning, adaptive quality of service SLAs and different levels of performance monitoring. This differs from existing services such as VPNs, which also rely on elasticity being provided by the network operator. Dimensioning is currently performed thanks to efficient traffic monitoring, and equivalent bandwidth schemes.

The implications of Cloud Computing therefore on QoS/PM could include in the first instance:

1. The need of a newer definition for QoS/PM suitable for elastic services, whose requirements can change over time. An inelastic definition of the SLA would result in underprovisioning or overprovisioning, which are unsuitable or inefficient.
2. The impact of IaaS, PaaS and SaaS on the end user service performance. In particular, security is affected, because the user data shares the same infrastructure with other users. Application response latency is also affected, because the application is running remotely.

3.3.2 SDN

Software Defined Networking (SDN) is currently under discussion in several standardisation bodies and a precise definition is still missing, because of different opinions within industry. In simple terms, one could say that SDN relates to splitting the control plane from the data plane, and implementing part of the control plane outside of the equipment in charge of the data plane.

Several of SDN aspects are relevant for the COMBO project. First of all, the definition of a “southbound” API relying on the OpenFlow protocol [8], which allows the forwarding infrastructure to be controlled by an external intelligence source. The forwarding databases and look-up tables in switches and routers can in theory be de-layered and controlled by the OpenFlow Controller and modified to configure specific paths for different flow types.

Another notable characteristic of SDN is the ability of partitioning the network infra-structure into slices that can be used different customers or groups of users. The following are a few issues with SDN that are relevant to COMBO.

1. The need for new APIs for instantiating SDN-controlled QoS/PM tools and for monitoring SDN controlled nodes.
2. The need for a new QoS/PM model that deals with network slicing. In particular, for defining which resources would be shared among slices and which should be instantiated per-slice. Note that this aspect is also related to the cloud service discussion about elastic SLA support.
3. If SDN enabled networks rely on a centralised controller, then the performance of the channel, the access and the response of the controller will affect the entire network – it is highly likely that the channels to the controller will be a key performance indicator within the network being monitored. WP4 is collaborating with WP2 and WP3 for feeding requirements back in order to formulate the KPIs and network scenarios.

3.3.3 NFV

Network Function Virtualisation – just like Cloud Computing – is a hot topic in industry debate and discussions. It is driven primarily by the operator community, which wishes to implement network functions on generic servers and not on specific equipment, as is generally the case in telecom networks. The generic servers could also be implemented in data centers. NFV is expected to help in reducing cost, complexity, energy consumption and OpEx, and to promote better interoperability. The ETSI standards organisation currently has an active NFV group comprising operators and vendors [10].

The characteristics of NFV can be summarised as:

1. Virtualisation eliminates dependency between a network function and its hardware. NFV takes functions from existing devices in the network, realizes them in software, and then migrates them to be hosted in alternative (centralised) locations.

2. Discrete Virtual Network Functions such as the list below are likely to be implemented in virtual machines that are hosted in data centre servers: Network Address Translation, Authentication, IPSec, Firewalls and Cache facilities.
3. Some functions are no longer performed in the place where they once were – functions become mobile.

Moreover, some functions within the network will not be virtualised, because they are either hardware-bound or needs to be optimised for performance:

1. Media and/or rate conversion of physical interfaces
   a. Optical to electrical and/or single mode to multi-mode etc.
   b. 1Gbit/s interfaces into higher speed such as 10Gbit/s
2. Aggregation of lower ports into higher ports – could still remain in hardware
3. Specific modulation schemes that rely on physical signals rather than DSP routines
4. Synchronization i.e. oscillators and critical timing devices
5. Hardware-bound performance monitoring tools related to these areas can be virtualised only to some extent, since they are tightly linked to the physical media or the physical instance.

From an analysis of how NFV might affect the QoS/PM model, two points emerge:

1. the concept that QoS/PM can be virtualised itself and
2. how to measure the QoS/PM of a virtualised system
   a. measurement of the host servers
   b. measurement of the virtual servers.

As far as QoS/PM virtualisation is concerned, there may be a need for specific QoS/PM based Virtual Networking Functions that are implemented in VMs. Otherwise, all VMs supporting the functions mentioned above will need to contain an element of QoS/PM – both models may be present. Depending on the implementation model and the way VMs are chained together, they may have differing levels of visibility of the whole service, path or network – i.e., their view of the world might be limited.

As for measuring QoS/PM of a virtualised system, NFV requirements include mechanisms to support QoS metrics and ensure that these metrics are met for the service level agreement [10]. If the NFV migrates network functions to a centralised location, then it is likely that those centralised locations become the critical place which need to be monitored for QoS/PM. This may allow simplification of devices that remain physically present, and perhaps put more emphasis in these locations on passive rather than active monitoring.

VMs need to be turned on, managed, and they become something to be monitored since they directly affect the QoS and QoE. These tasks include:

- Monitor how fast VMs are spun up and brought online

- Manage the detection of failed VMs and dynamic instantiation or relocation of replacements. (Current implementations of large data centers are already designed this way.)
- Measure the latency impact of implementing function in VMs
- Monitor VM resources: server capacity and current resource levels; support warning thresholds etc.

It will be interesting to monitor VM resources and the impact on the environment such as energy consumption per VM or to at least understand the contribution of a pool of VMs. It will be necessary to somehow monitor the environment and correlate that with the VM resources used.

4 Mapping from KPIs to QoS/PM and QoE

So far we considered the QoS/PM aspects of current networks and functions, use cases from WP2, scalability, complexity and the impact of emerging technologies. We now aim to consider further input from WP2 in the form of key performance indicators for FMC networks; this input is part of D2.4 [3].

The aim of this section is to identify relationships between KPIs and use cases, and to eventually map and identify the likely QoS/PM tools and/or methods that will be needed to meet the KPIs. When preparing this table, we started from section 2 of this document. The table below captures these relationships and where needed highlights potential gaps in the toolsets currently available.

KPI	Measurement point	Use Case relationship	QoS/PM Tool/Method
Network availability	Access point	01, 02, 03, 05, 06, 07	1) Layer 1 a) Optical: LOS, BER, PMD, CD, OTDR, SNR b) Copper: SNR, Monitor Code violations c) Radio – uWave/Wi-Fi: SNR, Available BW, Modulation index where applicable d) BASE-T Electrical: Link status, PMA RXSTATUS indication SNR e) General – loopback testing 2) Protocol Layers are device dependant a) General Loopback capability at different layers b) Frame Error rate
Terminal equipment availability	Terminal Equipment	07	3) Physical layer loopbacks on devices can be used to check physical layer availability 4) Device forwarding capability/correct configuration a) Layer 2: IEEE 802.1ag – CFM, ITU-T Y.1731 b) Layer 2.5: BFD c) Layer 3: BFD, ICMP Echo Request (ping)

KPI	Measurement point	Use Case relationship	QoS/PM Tool/Method
Device set-up time	Terminal Equipment		***Gap candidate*** *– How to monitor device set-up time, in a standard, well defined way* Could this be based on Intelligent Networks/Value Added Services – Success/Reject times etc. – (See table 3)
Service set-up time	Access point	02, 06	5) Intelligent Networks/Value Added Services (See table 3) ***Gap candidate*** *– Useful to explore Service set-up time Methods in future activity*
Connection set-up time	Access point	02, 06	6) Intelligent Networks/Value Added Services (See table 3) ***Gap candidate*** *– Useful to explore Connection set-up time Methods in future activity*
Transmission rate/bandwidth	Terminal Equipment, network probe	01, 02, 03, 04, 05, 06, 07, 08	7) Physical layer – port rate reporting a) Measured Bit rate 8) Packet/Forwarding a) Y.1731 throughput testing, Y.1564 stepped bandwidth tests b) RFC 2544 c) Traffic Management – Policing/Shaping profiles vs. measured d) RMON, SMON at Layer 2 and 3 using packet counters and derived frame rates etc.
Delay	Terminal Equipment	01, 02, 03, 04, 05, 06, 07, 08	9) Protocol Layers a) Layer 2 – ITU-T Y.1731 b) Layer 3 - TWAMP 10) QoE Related a) Mapping from QoS to QoE or do we need other QoE tools
Jitter	Terminal Equipment	01, 02, 03, 04, 05, 06, 08	11) Physical layer monitoring a) Jitter monitoring is likely a gap at least in real-time physical signal integrity b) Do we really need it? 12) Packet Jitter – Packet Delay Variation a) ITU-T Y.1731 b) PDV Estimation using IEEE 1588

KPI	Measurement point	Use Case relationship	QoS/PM Tool/Method
Bit error rate	Terminal Equipment	01, 02, 03, 04, 05, 06, 07	13) Physical layer methods a) See table 1 14) Protocol layer methods a) Use RMON and Packet metrics to derive BER from Frame Error Rate
Packet loss rate	Terminal Equipment	01, 02, 03, 04, 05, 06	15) RMON, SMON, ITU-T Y.1731
Connection loss rate	Terminal Equipment	01, 02, 03, 04, 05, 06	16) For typical connections this may be a ***gap candidate*** a) Or can this be monitored i.e. by a BRAS/BNG – counting the number of lost PPPoE/DHCP sessions – either way not captured in Section 2, so could be a gap
Service availability	Terminal Equipment	01, 02, 03, 04, 05, 06, 07, 08	17) Monitor protection switching events and response times (see table 3) 18) Monitoring of parameters such as MTBF, MTTF, MTTR etc.

Table 14: Mapping of KPIs, to Use Cases and QoS/PM Tools

In most cases, QoS methods and parameters are readily available to support the use cases and the KPIs. The key tools which are likely to be needed are shown in the table above. However, there are some cases where the KPIs and use cases do not easily relate to a given QoS tool or the parameters associated with those tools. In addition, during the preparation of this deliverable, the emerging technology analysis has highlighted some possible KPIs that could apply in future in relation to cloud, SDN and NFV. Such cases are identified as gaps and explored in further depth below:

1. Set-up time of Devices, Services and Connections
    a. In the QoS tools survey considered in section 2, no tool seems to be relevant for monitoring these particular KPIs
    b. Perhaps the most relevant set of QoS/PM tools may be related to those tools identified in relation to Intelligent networks and value added services in section 2, table 3
    c. Perhaps these set-up times are more akin to connections involving mobile devices and therefore perhaps some methods may be explored from the 3GPP suite of specifications – and brought into the FMC tool set for such monitoring in FMC networks
2. Connection Loss Rate
    a. This KPI may be something that a BRAS or BNG typically supports by default – however no such tools was identified in the survey we performed or during

the analysis of use cases from WP2. We assume that the mechanisms for monitoring lost connections may be done in implementation specific ways – therefore some common and agreed methods need to be identified.

b. 3GPP specifications are good candidates to identify the suitable tools to support this – since such a KPI seems to be related to mobile connection loss rate

3. KPIs Possibly emerging from WP4 that could be fed back to WP2
   a. Cloud Services
      i. If the service is elastic, can the QoS/PM support scale up and down in sympathy with the service – is there a view that the KPIs might themselves be elastic
      ii. KPIs relating to security aspects i.e. number of failed authentication attempts or similar should be considered
      iii. Application Layer delay/latency – more QoE associated than network or packet associated perhaps delay KPI needs to be further refined or split into categories
   b. SDN
      i. KPIs may be needed which are associated with availability, performance and bandwidth capabilities of centralised network controllers
   c. NFV - Virtual Machine related KPIs covering:
      i. Resource pools and % utilisation
      ii. Time to bring new VMs online
      iii. Time to migrate VMs between locations
      iv. Environmental monitoring – in correlation with the performance of the virtual machines

The gaps identified in this section need to be addressed in future work, and communication between WP4 and WP2 should be considered in order to ensure that KPIs finally produced by WP2 take the input above into account.

5 KPIs and FMC architecture impact

The previous section develops the information extracted from the Use Case analysis and explores how QoS/PM tools and parameters relate to, and support the monitoring of KPIs anticipated within the network. Several gaps were identified which need to be considered in more detail in future activities.

The next stage in Task 4.1 is to analyse the architectures that emerge from WP3 and the KPIs from WP2. The aim is to prepare a QoS/PM model and guidance for the FMC network topologies and functions that the COMBO project proposes. D4.2 “Performance monitoring for FMC networks” planned for M18 will address this.

D4.2 is therefore expected to explore the challenges and benefits associated with the QoS/PM model for FMC networks, and to discuss the changes or developments beyond state of the art – which are needed to make the QoS/PM model proposed a suitable proposition, tackling the gaps identified in the preparation of this deliverable. D4.2 is anticipated to explore an initial information model or MIB for QoS/PM aspects of FMC networks.

6 Summary and conclusions

The activities performed during the preparation of this deliverable has allowed considerable collaboration between WP2 and WP4. The use cases from WP2 were explored in-depth with focus on QoS/PM aspects using the information provided by the internal milestone MS17 research, which is summarised within the deliverable and provided a state of the art view of QoS/PM tools and parameters across multiple layers and functions.

The use case analysis highlighted a number of tools which are common across the use cases, and was used to create a list of the most important QoS/PM tools. In parallel activities, an analysis of emerging technologies and consideration of scalability and complexity added to the list of QoS/PM tools and parameters which are anticipated to be needed for FMC networks.

The KPIs generated in WP2 were cross-checked against the QoS/PM methods and parameters, so that we can start to gain confidence that a QoS/PM model can be proposed which supports the final FMC topologies and functions that the COMBO project develops.

Finally, the objectives of Deliverable 4.2 were considered in more detail, and the remaining objectives of Task 4.1 were further defined. Deliverable 4.1 highlights the following key points:

1. Use Cases developed by WP2 all generated specific QoS/PM tools and parameters. In order to support them, for each use case multiple tools and parameters are needed. The deliverable provides a list of these and shows how they relate to KPIs generated by WP2.
2. Some monitoring aspects were not accurately considered during the state of the art review in M4.1, but are needed to support use cases from WP2, and therefore need to be further researched in preparation of D4.2 – specifically how to monitor fronthaul networks and how to provide SLA monitoring of CPRI topologies
3. An important aspect of QoS/PM for FMC networks relates to the adoption of SDN and NFV. These are potentially disrupting technologies, which could cause major differences in how functions and networks are monitored.

7 References

[1] COMBO deliverable D2.1: “Framework reference for fixed and mobile convergence”, V1.0, September 2013.

[2] COMBO deliverable D2.2: “Roadmaps for independent fixed and mobile network evolution”, V1.0, September 2013.

[3] COMBO deliverable D2.4: “Requirements for converged fixed and mobile networks”, V1.0, December 2013.

[4] COMBO deliverable D3.1: “Analysis of key functions, equipment and infrastructures of FMC networks”, V1.0, November 2013.

[5] “Cisco Visual Networking Index: Global Mobile Data Traffic Forecast 2012–2017”, Cisco Systems. http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf

[6] Final Version of NIST Cloud Computing Definition Published, NIST Tech Beat: October 25, 2011 http://www.nist.gov/itl/csd/cloud-102511.cfm

[7] Cloud Computing Standards: Overview and ITU-T positioning, ITU Workshop on “Cloud Computing”, Tunis, Tunisia, 18-19 June 2012, Dr Jamil CHAWKI, http://www.itu.int/dms_pub/itu-t/oth/06/5B/T065B00001C0043PDFE.pdf

[8] Software-Defined Networking: The New Norm for Networks, ONF White Paper April 13, 2012; https://www.opennetworking.org/images/stories/downloads/sdn-resources/white-papers/wp-sdn-newnorm.pdf

[9] Network Functions Virtualisation (NFV), Network Operator Perspectives on Industry Progress, October 2013, http://portal.etsi.org/NFV/NFV_White_Paper2.pdf

[10] ETSI GS NFV 004, Network Function Virtualisation, Virtualisation Requirements, October 2013

[11] “STD 62: SNMPv3 (RFC 3411 to RFC 3418)”, IETF, 2002.

8 Glossary

Acronym / Abbreviations	Brief description
2G	2nd Generation (mobile service)
3G	3rd Generation (mobile service)
ANDSF	Access Network Discovery and Selection Function
BBU	Base Band Unit
BER	Bit Error Rate
BFD	Bidirectional Forwarding Detection
BS	Base Station
BSC	Base Station Controller
CD	Chromatic Dispersion
COMBO	COnvergence of fixed and Mobile BrOadband
CPRI	Common Public Radio Interface
DELT	Double Ended Line Test
EAP	Extensible Authentication Protocol
EFTR	Error-Free Throughput
EFS	Error-Free Seconds
eNB	Evolved Node B (base station)
ES	Errored Seconds
ESMC	Ethernet Synchronization Message Channel
FEC	Forward Error Correction
FEXT	Far End Crosstalk
FMC	Fixed Mobile Convergence (Converged)
GPRS	General Packet Radio Service
G-ACh	Generic Associated Channel

Acronym / Abbreviations	Brief description
GAL	Generic Associated Channel Label
Hlin	Linear channel characteristic function
Hlog	Logarithmic channel characteristic function
IaaS	Infrastructure as a Service
ICMP	Internet Control Message Protocol
IEEE1588	Institute of Electrical and Electronic Engineers 1588 (Precision Time Protocol)
IP	Internet Protocol
IPG	Inter Packet Gap
ITU-T	International Telecommunications Union- Telecommunication Standardisation Sector
KPI	Key Performance Indicator
LTE	Long Term Evolution (3GPP standard)
LOS	Loss Of Signal
MELT	Metallic Line Test
MIB	Management Information Base
MME	Mobile Management Entity
MPLS-TP	Multi-Protocol Label Switching – Transport Profile
MTBF	Mean Time Between Failures
MTBO	Mean Time Between Outages
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
NFV	Network Function Virtualisation
NGPON2	Next Generation Passive Optical Network 2
OBSAI	Open Base Station Architecture Initiative

Acronym / Abbreviations	Brief description
OTDR	Optical Time-Domain Reflectometer
OSNR	Optical Signal-To-Noise Ratio
OWAMP	One Way Active Measurement Protocol
PaaS	Platform as a Service
PDN	Packet Data Network
PDP	Packet Data Protocol
PDV	Packet Delay Variation
P-GW	Packet Data Network Gateway
PHY	Physical Layer Device (interface component)
PIANO+	European Commission Framework 7 Program – PIANO+
PM	Performance Monitoring
PMD	Polarization Mode Dispersion
QLN	Quiet Line Noise
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RGW	Radio Gateway
RGW	Residential Gateway
RNC	Radio Network Controller
RMON	Remote Network Monitoring
RRH	Remote Radio Head
RRU	Remote Radio Unit
RTT	Round-Trip Time
RU	Radio Unit

Acronym / Abbreviations	Brief description
SaaS	Software as a Service
SDN	Software Defined Networking
SELT	e Ended Line Test
SES	Severely Errored Seconds
S-GW	Serving Gateway
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SNR	Signal-to-Noise Ratio
SMON	Switch Monitoring
SR	Symbol Rate
SSM	Synchronization Status Message
TDR	Time-Domain Reflectometer
TWAMP	Two Way Active Measurement Protocol
STB	Set-top box
UE	User Equipment
USSD	Unstructured Supplementary Service Data
VAS	Value Added Service
VoD	Video on Demand
VoIP	Voice over Internet Protocol
WDM-PON	Wave Division Multiplexing-Passive Optical Network
Wi-Fi	Wireless Local Area Network – Commercial name
Xlin	Linear Crosstalk Coupling

9 List of Tables

10 List of Figures

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11.3 Document History

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1	2013.10.03 13:18	Document added to EMDESK	Peter Olaszi
2	2013.10.17 09:41	Added some of the notes of the Barcelona / Castelldefels brainstorming session	Peter Olaszi
3	2013.10.17 13:04	Minor formatting	Peter Olaszi
4	2013.10.23	Minor formatting	Peter Olaszi
5	2013.10.28	Copied over Peter Olaszi's brainstorming notes	Peter Olaszi
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7	2013.10.29	Copied over Peter Turnbull's brainstorming notes	Peter Olaszi
8	2013.10.30	Categories of KPIs moved into Section 4. Minor editing made during the telco.	Peter Olaszi
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10	2013.11.01 14:03	Updated UC06	Stefan Höst
11	2013.11.04 09:12	Updated Section 2	Jose Gijón
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15	2013.11.11 17:32	Added content to UC01, UC02	Jose Gijón
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17	2013.11.12 15:39	A new version of UC06	Dirk Breuer, Xavier Lagrange Stefan Höst, Dirk von Hugo
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59	2013.12.12 12:41	Updated UC01 figure Updated Section 2 tables Implemented outstanding review comments	Jose Gijón, Jens Andersson, Peter Olaszi
60	2013.12.12 14:28	Updated UC03	Lander Alonso
61	2013.12.12 17:59	Addressed outstanding review comments	Peter Olaszi, Jens Andersson, Stefan Höst, Ali Hamidian, Anthony Magee, Lander Alonso, Joseph De Biasio, Annie Gravey
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