A Universal Access Gateway for Fixed and Mobile Network Integration

White Paper

April 2016

Executive Summary

Fixed–Mobile Convergence and Fixed–Mobile Network Integration are major research and development topics of the telecommunication industry. This area is the main scope of the COMBO (COnvergence of fixed and Mobile BrOadband access/aggregation networks) European Union FP7 ICT Project [1].

This white paper reflects some results of the research work carried out within the COMBO project which aims at pushing fixed–mobile network integration a step forward. This goal of progress is fulfilled by defining a new functional architecture for an integrated network.

The new functional architecture relies on a proposed network entity, called Universal Access Gateway which has the role of unifying user access to fixed and mobile networks.

The paper is structured as follows:

The first chapter, *Introduction and Rationale for Fixed and Mobile Network Integration,* presents the use cases for fixed–mobile network integration along with the related drivers and expected benefits.

In the second chapter introduces the *Universal Access Gateway,* and a target functional architecture for the control plane and data plane of the UAG is presented. Here we also discuss functional decomposition alternatives.

The third chapter, *UAG challenges,* gives an overview of the requirements, implementations options, deployment scenarios, enablers and challenges related to the UAG.

Finally, the fourth chapter, *Rationale and Motivation for standardization,* aims at identifying the missing pieces of the puzzle for making the UAG a standards-based network node.

The paper concludes that significant standardization work is required for the complete definition and specification of the functional architecture of an integrated network based on UAG concept. The data plane and control plane functions of the UAG need to be defined, as well as interfaces between UAG functional blocks, between UAGs and between UAGs and other network nodes. Standardization of the interfaces will ensure openness of the integrated network architecture and allows the different actors to access common infrastructure elements.

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Glossary

3GPP	3rd Generation Partnership Project
AAA	Authentication, Authorization and Accounting
BBF	BroadBand Forum
BBU	Base Band Unit
BNG	Broadband Network Gateway
CapEx	Capital Expenditures
CDN	Content Delivery Networks
CO	Central Office
CP	Control Plane
CPE	Customer Premises Equipment
DMM	Distributed Mobility Management
DP	Data Plane
EIR	Equipment Identity Register
EPC	Evolved Packet Core
ePDG	Evolved Packet Data Gateway
ETSI	European Telecommunications Standards Institute
FMC	Fixed–Mobile Convergence
FMNI	Fixed–Mobile Network Integration
HeNB GW	Home eNodeB Gateway
HAG	Hybrid Access Gateway
HSS	Home Subscriber Server
HLR	Home Local Register
ISG	Industry Specification Group
MASG	Mobile Aggregation Site Gateway
LTE	Long Term Evolution
MP-TCP	Multi Path – Transmission Control Protocol
MPE	Multipath Entity
OLT	Optical Line Terminal
NFV	Network Function Virtualisation

OCS	On-line Charging System
OFCS	Off-line Charging System
OTT	Over-The-Top
PCEF	Policy and Charging Enforcement Function
PCRF	Policy and Charging Rules Function
PDV	Packet Delay Variation
PGW	Packet Data Network Gateway
QoE	Quality of Experience
QoS	Quality of Service
OpEx	Operational Expenditures
SBI	Southbound Interface
SDN	Software Defined Networking
SGW	Serving Gateway
TWAG	Trusted Wireless Local Area Network Access Gateway
UAG	Universal Access Gateway
uAUT	universal Authentication
UDC	User Data Convergence
uDPM	Universal Data Path Management
UE	User Equipment
VNF	Virtual Network Function
UDR	User Data Repository
Wi-Fi AC	Wi-Fi Access Controller
Wi-Fi AP	Wi-Fi Access Point

1 Introduction and Rationale for Fixed and Mobile Network Integration

1.1 Drivers

Today's fixed, mobile and Wi-Fi networks have been developed independently of each other, and therefore network structure, equipment, the implementation of network functions and their distribution in the network are very different [2]. In addition, each network type is operated in a different way.

Fixed and mobile networks evolution is also focusing on their current specific constraints. Fixed networks are mainly constrained by resource usage, cost and energy efficiency; the main drivers are enhanced scalability, reliability, delay and reach. Mobile networks specifically face increasing data traffic, growing number of connected devices and diversification of services and equipment [3][4].

Fixed–mobile network integration (FMNI) proposes a more efficient network architecture and better customer service, concentrating on the main drivers:

- Bandwidth gain in the core and metro networks through mobile data traffic offloading: deployment of caches and data centres close to the end-users in order to ease traffic load on the backbone and metro networks.
- Optimised traffic control can help offloading traffic from congested areas: advanced interface selection assists the UE in automatically connecting to available networks and data path control functions help network operators implement an enhanced traffic control.
- Network resource sharing provides unified mechanisms to seamlessly serve fixed and mobile users at functional level, at the same time providing new bundled services to other network operators and content providers.
- Content distribution through Content Delivery Networks (CDN) caching schemes helps reducing the amount of traffic passing through the network backbone, and improves Quality of Service (QoS) and Quality of Experience (QoE) for the end users. A major benefit of FMNI is the sharing of caching and storage facilities among network types.
- The cost of infrastructure deployment and operation can be rationalised by providing a single common transport network, which supports greater flexibility in scaling resources up or down, and allows energy reduction as a result of network integration synergies.
- Additionally, over-the-top service providers and their customers can benefit from the new business opportunities of integrated networks, which are able to deliver consistent and rich QoS and extensive connectivity.

1.2 Uses cases

In this section we introduce a few use cases taking advantage of integrated fixed–mobile networks [5], focusing on network issues and considering the above drivers.

In an integrated network, mobile devices can use Wi-Fi in combination with mobile access. Advanced cooperation of access networks facilitates simultaneous attachment, seamless handover among technologies, and network assistance for interface selection and utilisation. As a result, 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. The networks provides assistance for selecting and using the most suitable interfaces depending of the current needs, resulting in increased data rates and seamless mobility.

A unified service delivery network allows designing an integrated caching system, which optimises content distribution, reduces traffic exchanges, latency and operational costs, at the same time improves QoS/QoE for end users.

A single Customer Premises Equipment (CPE) can integrate fixed, mobile and Wi-Fi technologies. This universal access bundling for the residential gateway increases the bandwidth offered to the user, dynamically distributed among available access technologies.

Network sharing in integrated networks helps mobile-only operators entering the fixed market or vice versa, resulting in new cooperation possibilities. For example, in order to share the investment costs, a mobile-only operator may decide share the deployment costs of an LTE-Advanced network with a fixed-only operator which is interested in entering the mobile market. That will allow reducing the total cost, rollout time, time to market of new services, and optimise coverage and resource utilization.

1.3 Expected benefits

Clearly, any change in a communication network that requires investment must be justified by economic benefits that can compensate the investment costs. FMNI provides multiple levers to justify it.

FMNI enables a more efficient use of resources. In general, the more resources are shared, the more multiplexing gain is achieved – and this is exactly what FMNI brings by integrating resources in fixed, mobile and Wi-Fi networks. Higher resource utilization clearly leads to savings in terms of CapEx and OpEx.

More specifically, by offloading the mobile traffic to the Wi-Fi network, or even using both in a co-operative way, the mobile network can improve capacity. It can also facilitate an efficient distribution of traffic load among the available resources.

Energy efficiency reduces power consumption costs. Integrated networks can save energy by using the same resources for diverse types of access networks.

An integrated network leads to a simplified network management and savings in related costs, such as control, management, staff, education, provisioning, planning and inventory aspects. Fault management costs can be reduced by the increased availability due to redundant multi-access solutions.

Besides cost savings, improved network performance and service quality may lead to improved user experience. A more satisfactory service is an added value from the user's point of view. Automatic connection, configuration and authentication, load balancing among access networks and optimal location of the contents give the user the sense of comfort which comes from a fast and easy-to-use service. Users can enjoy increased coverage and capacity, having access to more services at a higher bandwidth, irrespective of the network which carries the data.

Shortened deployment time of services helps introducing new services to the market or extend the coverage of existing ones. A reduction in the time-to-market brought by integrated networks may result in higher revenues and increased market share for the operators. Finally, FMNI may bring changes to the whole business ecosystem – for instance, sharing of resources in a multi-operator environment may open a business case for new actors in the market.

2 The Universal Access Gateway

One approach to achieve the integration of fixed and mobile networks is to remove their differences, unifying network structure, equipment and network functions. A universal fixed and mobile access with a common gateway for both networks can be the key enabler towards FMNI.

The Universal Access Gateway (UAG) is a functional entity defined as the common subscriber IP edge for fixed, mobile and Wi-Fi. Among the reference locations illustrated in Figure 1, the UAG could be located at the current Central Offices (CO), but the preferred approaches, as explained in section 3, are at the main CO (special CO with higher aggregation level than standard COs and not connected directly to the network's core), or even higher in the network at core CO level. The possible implementations for the UAG will be addressed in more detail in section 3.

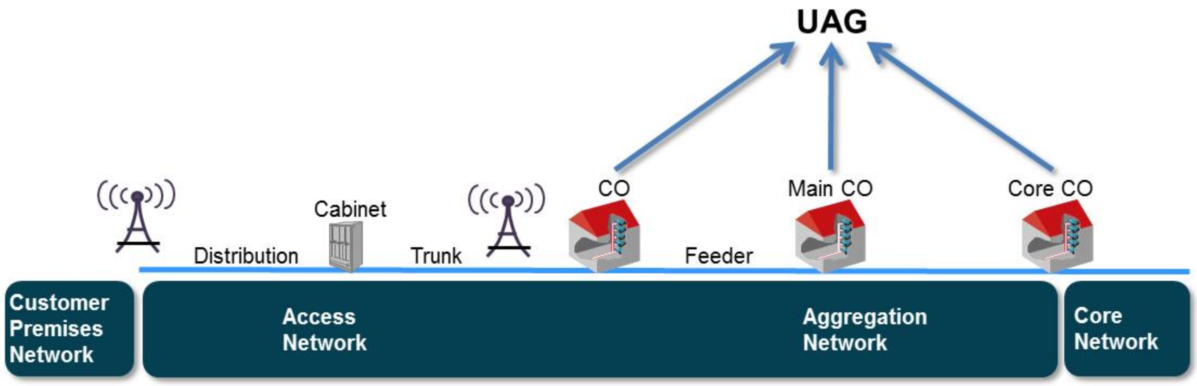

Figure 1 : Reference locations for Fixed and Mobile Network Integration

The UAG can encompass functions for mobile aggregation routers and data plane EPC gateways, Broadband Network Gateway (BNG) and security gateways. The Baseband Unit (BBU) for the radio processing units may also be part of it, depending on the location of the considered CO. The UAG can simplify the network by reducing the technology variety, improving latency and reliability at the same time.

The UAG also allows the separation of the control plane and the data plane (or *user plane* in 3GPP terminology, 3GPP TR 21.905). Regarding the control plane, network applications and service creation can be moved into the cloud (data centres) where SDN/NFV concepts could be applied. Mobile and fixed network functions (e.g. authentication, policing, charging, deep packet inspection, network address translation, etc.) can be abstracted, merged and implemented as common functions for both networks.

2.1 General functional description of UAG

As stated previously, the UAG is a functional entity defined as a common subscriber IP edge for fixed, mobile and Wi-Fi networks. This means that the data flows of a given user can be accessed individually within the UAG – they are not aggregated with the data flows of other users in a single tunnel; IP level data plane functions (such as filtering, scheduling, forwarding, etc.) can be applied within the UAG; finally, IP level control functions (such as users' IP session control) can potentially be hosted within the UAG.

Data and control functions may be implemented in separate functional entities, as UAG Data Plane (DP) and UAG Control Plane (CP), providing various benefits:

- scalability of planes can be managed independently of each other;
- deployment flexibility is enhanced by locating each plane at different topological or geographical places of the network;
- different implementations (e.g., CP in commodity servers and DP in specific hardware equipment) and providers (e.g., CP from a software vendor and DP from a network equipment manufacturer) can be considered;
- the implementation of innovative network control functions by developing new software for the UAG CP (typically by open source communities) is facilitated.

Figure 2 depicts a high level functional view of the UAG showing the separation of control and data plane and its main interfaces:

- the control interface towards AAA services (authentication, policing, charging etc., as provided for instance by 3GPP-defined HLR/HSS, PCRF, OCS and OFCS functional entities through S6a, Gx, Gy, Gz, etc.),
- the control interface between the CP and DP,
- the network interfaces towards:
    - the access nodes, which may be connected either directly (e.g. when eNB-related BBU function is located in the same site) or through the aggregation network
    - the application services, terminating L4 connection, which may be also connected either directly (e.g., for local services such as CDN server) or through the core network (e.g., for internet services),
- the subscriber interfaces towards each subscriber equipment allowing the UAG to control the user traffic on a per-subscriber basis.

The network and subscriber interfaces mainly support user traffic, but also some control traffic with subscriber equipment and access nodes.

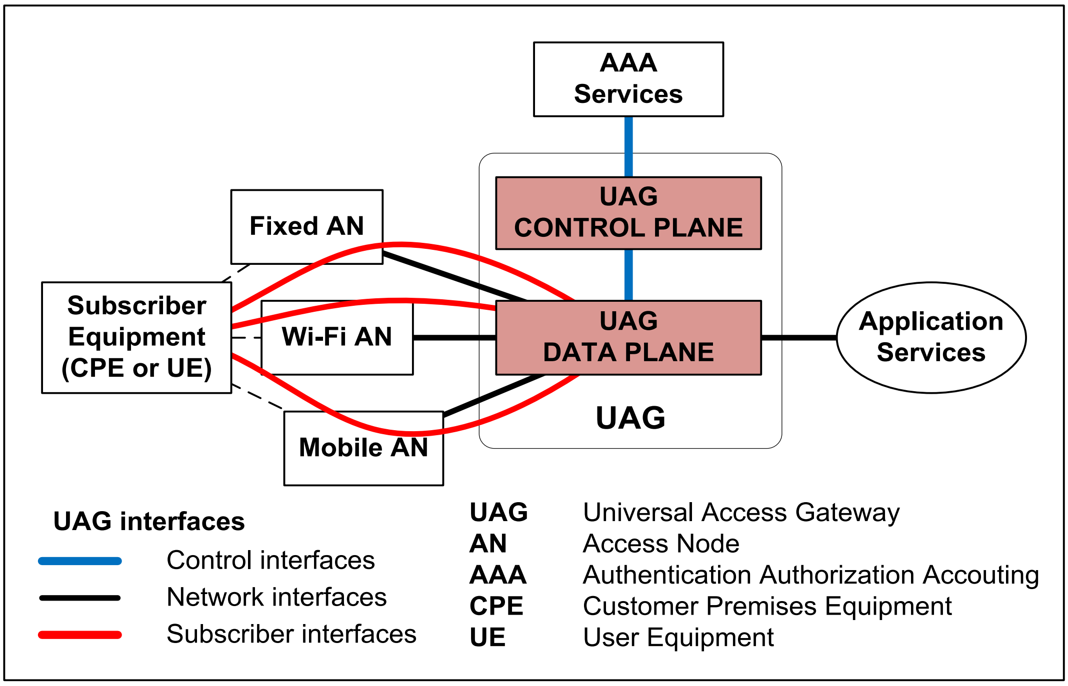

Figure 2: High level functional view of the Universal Access Gateway

Two main functional blocks are key for fixed–mobile network integration: Universal Authentication (uAUT) allowing user authentication independently from the access type used; and Universal Data Path Management (uDPM) ensuring highest quality delivery of any content to the UE taking into account all available paths through all available networks.

For providing a unified user authentication and session management, the UAG includes some parts of a larger functional block called uAUT which relies on improvements to the 3GPP's User Data Convergence concept (as defined in 3GPP TS 23.235): a single global Universal Data Repository (UDR) hosts and organizes user and subscriber data providing a unified view of users and subscriptions to the operator with the idea that a subscriber using any authorized network access type should be able to be seamlessly authenticated on the other network types.

Regarding interface selection and route control, the UAG functional block called uDPM provides the tools to map a given IP session on one or several data paths ensuring session continuity. It allows the operator to control the path that is used to route users' data. This entity is triggered by a session event which represents any singular event relative to the activity of a particular UE. When one of these triggers occurs, the uDPM decides the path or paths regarding the policies associated to the subscriber.

2.2 Control plane of the UAG

The control plane functions that could be implemented include a uAUT client, i.e. a AAA agent (proxy or client) facing the uAUT server, as a front-end of the AAA services in order to allow authenticating to multiple access networks on a single logical network. That uAUT server is the unique contact point of the UAG for all subscriber data and authentication related functions, whatever access type used. If the subscriber profiles are unified in a common database in the uAUT server, then the operator will be able to recognize a user behind any access type and thus will be able to provide them with convergent services, such as unified accounting, seamless authentication to service platforms (IPTV, VoD) and OTT partners, and access to the best of networks around the subscriber.

The UAG also implements control plane functions that realise Universal Data Path Management over the available access networks. This includes:

- Network part of a decision engine for data path management
- Network part of data path creation/destruction
- Path coordination and control

These uDPM functions are related to the current control functions included in the different network subscriber-oriented gateways, such as, BNG and EPC gateways.

The traffic split between multiple interfaces will need to be adapted in a flexible and fast way to changing parameters (e.g. throughput, latency, PDV, packet loss) of access networks.

The uDPM should allow the network operator to configure, control and prioritize traffic flows according to its preference (e.g. “cheapest pipe first” or “limitation of data rate to maximum upper limit”).

Moreover, the UAG can implement the Policy and Charging Enforcement Function (PCEF, as defined in 3GPP TS 23.203) which is responsible for providing controller functions in traffic handling, QoS at the UAG, and service data flow detection.

In order to improve the QoS of the content delivery service, a cache controller can interface with the UAG so that contents will be distributed optimally according thanks to the uDPM functional block.

2.3 Data plane of the UAG

So far, identified data plane functions within a UAG include “Session Mapping Execution”:

- In the downstream as there are multiple data paths that link the user to the UAG, each session is mapped to one or more of these paths. The data plane of the UAG performs the forwarding of IP packets over the appropriate data path;
- In the upstream, the UAG may include a Multipath Entity (MPE) as multiple paths from the user are merged; the MPE could be implemented as an MP-TCP proxy, for instance;
- In case of mobility, the UAG could implement data buffering and redirection in order to ensure smooth handover.

It may also be necessary to implement data plane level monitoring functions in the UAG in order to help supervising the characteristics of the different data paths between user and the UAG, proper resource allocation and interact with the uDPM functional block.

2.4 UAG deployment models

Two deployment models must be considered for the UAG: the standalone model where no interface is specified between CP and DP and the split model, which relies on an explicit interface defined between CP and DP. In the standalone model, both CP and DP functions have to be located in the same equipment, whereas in the split model, CP and DP functions can be implemented in different equipment.

The UAG DP being the topological IP edge node, it is located at the border of the access/aggregation and IP network in both models. The split model allows for a centralised implementation of the UAG control plane functions, while keeping the data plane distributed.

The following Figure 3 shows both the standalone and split models.

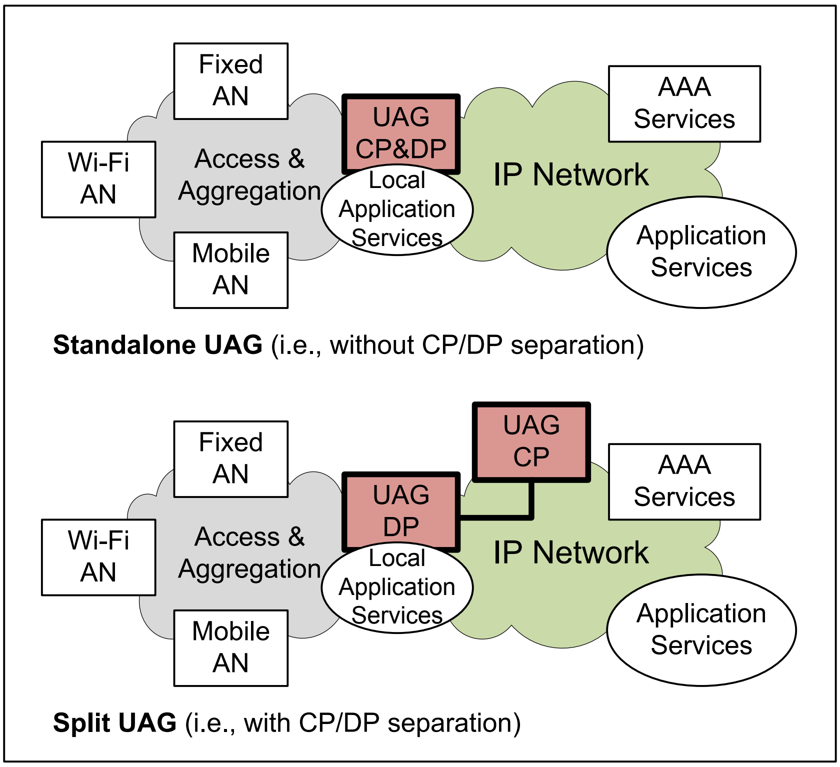

Figure 3: UAG deployment models

3 UAG challenges

3.1 Requirements

As a result of the previous chapter, the UAG should support all the required functions to enable IP traffic control and processing on a per user-basis: attachment (authentication, addressing…), data path management (forwarding, tunneling, multi-path connections, mobility…), policy enforcement (QoS, legal interception, routing, filtering…), data path monitoring (for data path selection, optimal content delivery…).

Those functions should thus be provided by the aforementioned uDPM and uAUT functional blocks, and by additional functions such as PCEF, so that the UAG constitutes a complete and optimal converged IP edge.

In order to manage the migration from the currently specified 3GPP and BBF functional entities, the UAG must include subscriber-related functions of the entities controlling subscriber IP sessions:

- BNG (BBF TR-101, TR-146, TR-178 and TR-291)
- Wi-Fi in Multi-service Broadband Networks (BBF WT-321)
- Hybrid Access Gateway (HAG, BBF WT-348)
- Packet Data Network Gateway (PGW, 3GPP TS 23.401 and TS 23.402)

Since the UAG interfaces with different access nodes, it should also incorporate the following 3GPP-specified entities, which manage subscriber contexts (but not necessarily at the IP layer):

- Serving GW (SGW, 3GPP TS 23.401)
- Mobility Management Entity (MME, 3GPP TS 23.401)
- Evolved Packet Data Gateway (ePDG, 3GPP TS 23.402)
- Trusted WLAN Gateway (TWAG, 3GPP TS 23.402)

Consequently, the UAG also needs to interface the following entities (which are part of the AAA services as described in section 2):

- BBF AAA server and PDP
- 3GPP HSS, PCRF, OCS, OFCS, AAA server and other UDR Front Ends

Some functions should remain out of the scope of the UAG as a functional entity. These include aggregation functions that may be necessary for backhauling fixed and mobile traffic (such as Wi-Fi AC, MASG, HeNB GW and Security GW), as well as different access functions (e.g. OLT, eNB, Wi-Fi AP). However, those functions may be collocated with the UAG in the same node.

3.2 Implementation options

3.2.1 Incremental implementation

A first possible approach for the UAG implementation is the integration of the current BBF and 3GPP functional entities into a single node, so that the UAG can be regarded as a kind of structural fixed–mobile converged subscriber IP edge.

Thus, the UAG integrates CP and DP functions, and a uAUT-related AAA agent (proxy or client) is also included to provide a unified interface towards the AAA services as depicted on Figure 4. That implementation option could be a first step for the UAG achievement, with even so a functionally-converged AAA interface through the uAUT functional block.

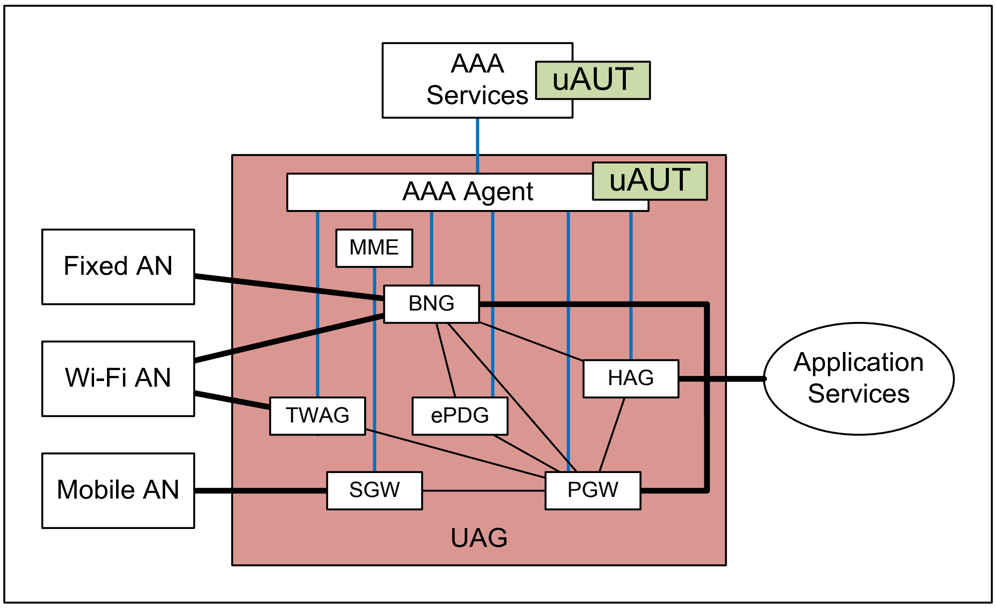

Figure 4: UAG as a structurally converged IP edge (incremental implementation)

3.2.2 Disruptive implementation

A second approach would be the merging of the fixed and mobile subscriber IP edge functions into common generic FMNI functions, possibly also with common interfaces and protocols, whatever the type of access (wired and/or wireless) and user (fixed and/or mobile). By implementing those FMNI functions, the UAG can be considered a true functionally converged subscriber IP edge entity.

As depicted in Figure 5, the uDPM and uAUT functional blocks can be fully integrated and the separation of data and control planes is also considered: as depicted in Figure 5, the UAG CP is in charge of the user session control, while the UAG DP performs user traffic processing.

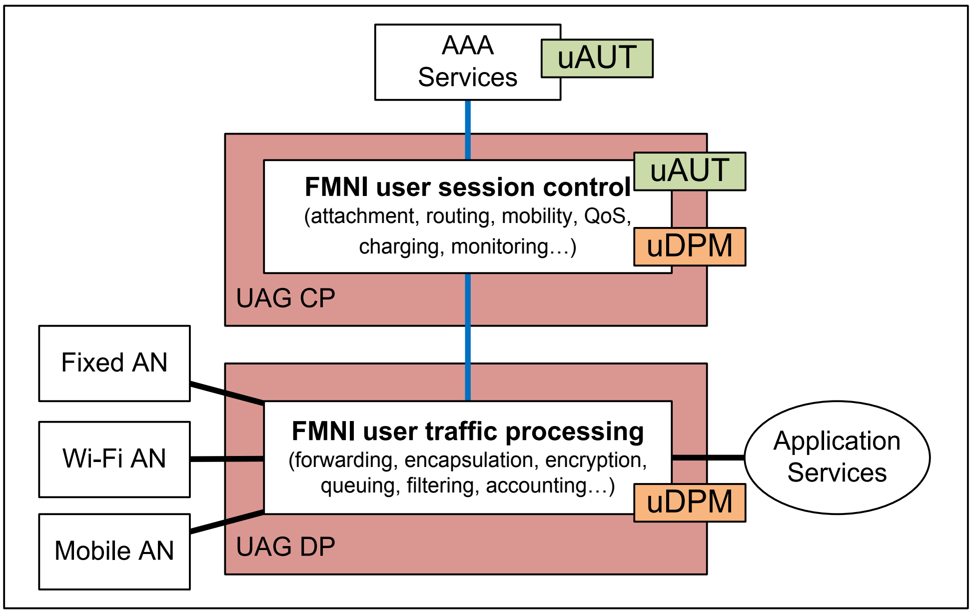

Figure 5: UAG as a functionally converged IP edge (disruptive implementation)

3.2.3 Intermediate implementation

The third approach for the UAG implementation is based on the first incremental approach, with separation of the data and control planes. Thus, the DP of the fixed and mobile entities can be functionally unified for processing user traffic in an integrated way, while the CP remains functionally separated, but structurally unified, physically located in the same network node.

Figure 6 represents this implementation with a AAA agent included in the UAG CP (as for the incremental option) and the "Session Mapping Execution" part of the uDPM which could also be implemented in the UAG DP. A DP controller is then required in the UAG CP for unifying the control of the UAG DP.

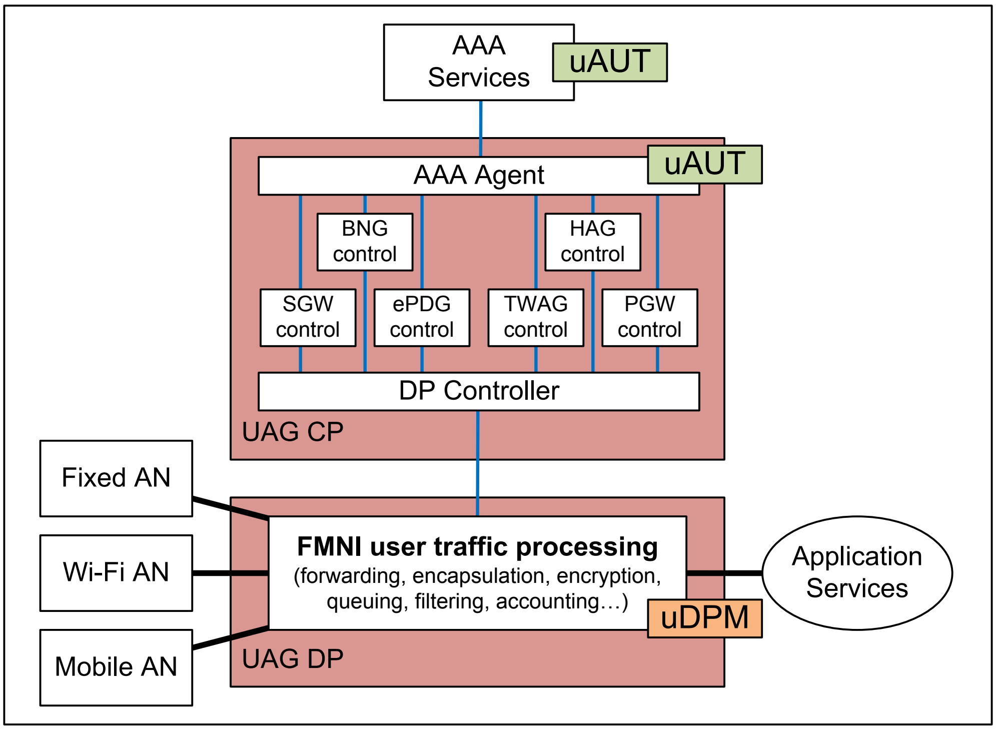

Figure 6: UAG as an IP edge with structurally-converged control plane and functionally-converged data plane (intermediate implementation)

3.3 Deployment scenarios

Regarding deployment scenarios of a UAG, different placement options could be rationalized. For a user accessing services through the mobile network, the UAG hosts functions of both SGW and PGW; for a user accessing services through the fixed network, the UAG hosts the functions related to the BNG. If the UAGs are located at the main CO (and even more at the CO), this also implies increasing the number of locations where it is located. As the functions associated with BNG, SGW and PGW are complex, increasing the number of locations where those functions are located will potentially increases the cost of the network, and adds complexity to its deployment. On the other hand, due to reduced latency and improved scalability potential, the equipment itself supporting these functions could be simpler.

Deploying UAGs instead of separated IP edges for each network type allows the network to control all user sessions, taking advantage of the resources available within each access network. This simplifies the connexion of subscriber equipment with multiple interfaces (e.g. smartphones, home gateways with both DSL and cellular interface). Moreover, it allows sharing service level resources (such as storage facilities, content distribution servers, game logics, M2M gateways) among users, irrespective of their access network.

Figure 7 and Figure 8 illustrate different deployment scenarios for the UAG, with two different DP distribution levels (at main CO or at core CO). It indicates the possible separation of CP and DP, allowing the network operator to locate and scale each plane independently.

It should be noticed that the main CO (and even more the CO) as DP location implies to extend the IP network, so that an IP aggregation network CO for the user traffic must be considered between the main CO and the core CO.

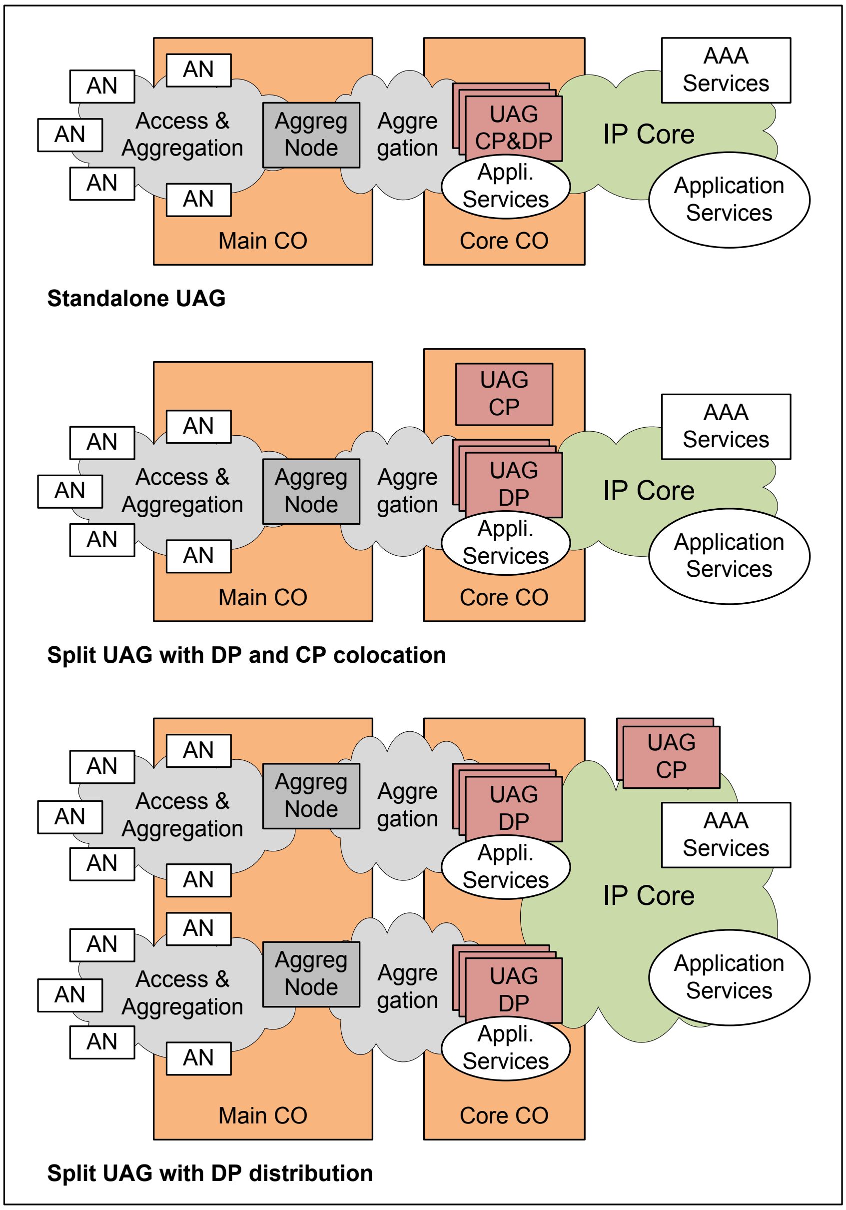

Figure 7: UAG deployment scenarios with UAG DP at core CO

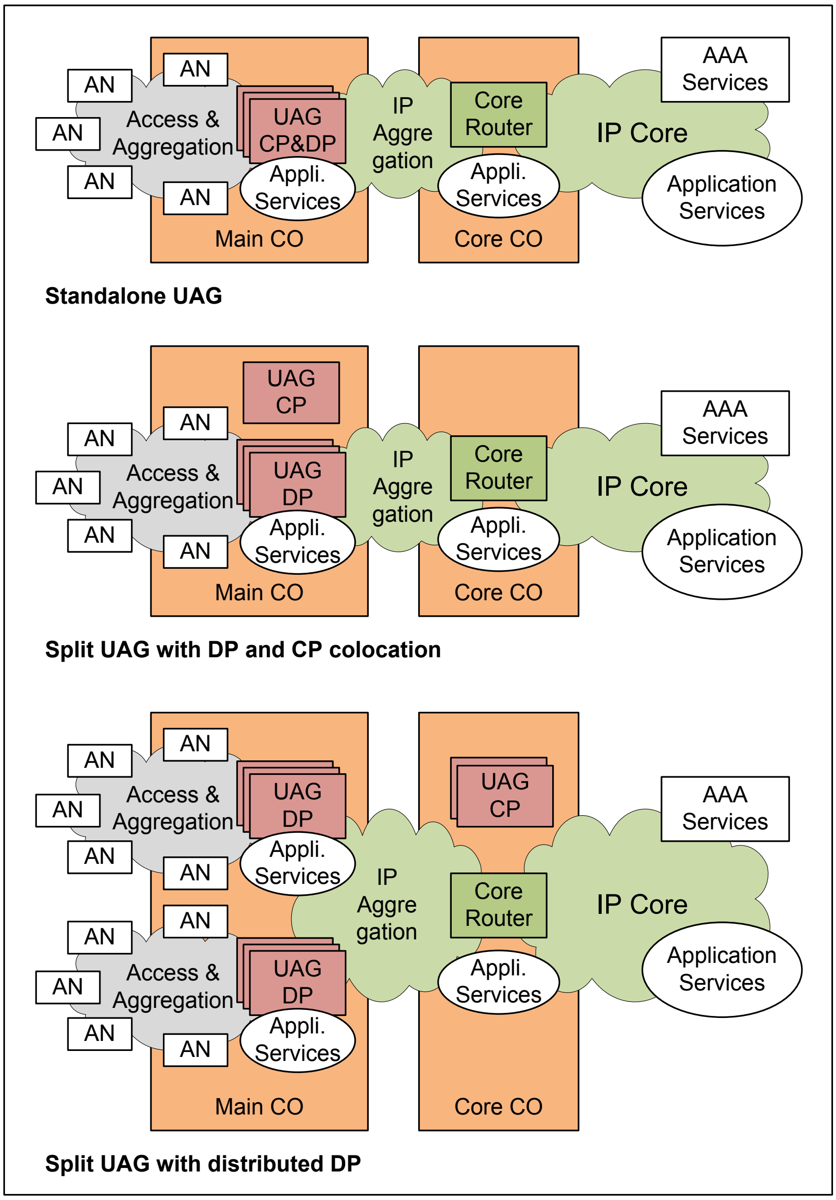

Figure 8: UAG deployment scenarios with UAG DP at main CO

3.4 Enablers

Software defined networking is an important enabler, because it allows for the separation of data and control planes (e.g., through using OpenFlow), making it possible to consider the disruptive and intermediate implementations of the UAG as described earlier.

The ETSI network function virtualization specifications are also relevant, particularly for the UAG CP entity, since they enable hosting related functions on commodity servers.

The effort on the IP anchor distribution – currently provided by the IETF DMM working group (IETF RFC 7333) – should also be useful for addressing the questions raised by the distributed variant of the UAG DP.

Fixed–mobile convergence specifications deriving from the common work done by 3GPP and BBF must also be considered – particularly BBF TR300 and 3GPP

TS 23.203 Annex P –, because they specify the same control interfaces for both fixed and mobile access towards the AAA services for policing and charging functions (namely Gx, Gy and Gz).

3.5 Challenges

3.5.1 Implementation-related challenges

The level of **DP/CP separation** needs to be addressed, since a piece of control plane must remain in the UAG DP entity (at least, to manage the interface with the UAG CP, and for the latency sensitive control functions). The objective is to keep a minimum amount of control functions in the UAG DP entity.

The direct consequence of that separation is that the DP/CP interface (a.k.a. southbound interface, SBI, in the SDN paradigm) must also provide the abilities to control all the data plane functions (e.g. for tunnelling or encryption control).

The application of **NFV technology** may raise scalability and latency issues that must be addressed (e.g. by considering software and hardware acceleration techniques). This firstly regards the UAG DP virtualization, but also the UAG CP, depending on the control function needs.

3.5.2 Deployment-related challenges

The UAG DP distribution at the main CO implies **mobile IP edge distribution**, so that the architecture needs to allow such distributed mobility anchoring, and thus include inter-UAG interfaces at the control and/or data planes.

The UAG DP distribution also implies the **extension of the IP network** to the main CO – the current edge reaches to the Core CO only. Such an extension (which may be considered as an IP aggregation network) can strongly impact routing management, and thus require reviewing the IP architecture.

4 Rationale and Motivation for standardization

4.1 Rationale for standardization

The exponential increase of mobile traffic leading to the requirements defined for 5G makes Fixed–Mobile Network Integration an essential step in order to reach the required traffic capacity. This integration, mainly through the UAG concept defined above, allows providing common network infrastructure, functions and services at an optimal cost to all actors involved like fixed and mobile network operators, virtual operators and content providers.

A full openness of Fixed–Mobile Network Integration would require that –

- All data and control plane functions (including the UAG) and the interfaces between these functions, are defined and standardised. These should also include inter-UAG interfaces for enabling distributed mobility management.
- Interfaces between infrastructure elements are standardised so that anyone can have access to common infrastructure elements.

These functions include common authentication, caching, QoS, mobility, resilience, security, OAM and sharing of infrastructure equipment (e.g. BBUs and OLTs).

Fixed–Mobile Network Integration involves several activities for standardisation:

- Defining the requirements, corresponding use cases and scenarios brought by FMNI.
- Defining architectures – both at the infrastructure and functional level – that fulfil these requirements.
- Defining interfaces and protocols (i) between the integrated fixed–mobile network and content/service providers and operators, and (ii) between different infrastructure entities and network functions; on this last aspect, different issues, which will most probably involve standardisation, can be developed below.

At the network functional level, the following points are to be addressed:

- QoS: how to coordinate fixed and mobile networks to provide QoS in an optimal way, involving an interface towards service/content providers, and also coordinated mechanisms to handle session management between fixed and mobile data paths.
- Content delivery: how to offer an interface to content/service providers, and to enable caching at different network locations, taking benefit of the SDN/NFV concept, specifying what protocols/semantics to use.
- Authentication, Authorization and Accounting (AAA): standardisation of a single logical Universal Data Repository (UDR), protocols and its communication requests to other AAA systems.
- Layer 2 interface: very tight coupling between Wi-Fi and mobile 5G will most probably require definitions of protocols and interfaces at the MAC layer level.

At the infrastructure level, the UAG implementation allows infrastructure elements like BBU and OLT to be shared among operators. Therefore, the architecture, interfaces and protocol need to be standardised for these elements.

More generally, additional network functions (such as security or radio resources) can be added to the UAG as required.

4.2 Relation to standards developing organizations and industry initiatives

At the time this white paper is being published the following bodies have been identified:

- EP E2NA/TC NTECH works on end-to-end network and service architecture;
- ETSI ISG NFV defines the requirements and architecture for the virtualization of network functions;
- ETSI ISG MEC is working on mobile edge computing;
- 3GPP covers cellular telecommunication network technologies, including radio access, the core/transport network and service capabilities. The work includes provisioning and management of the network and its services;
- The Broadband Forum (BBF) developed some activities regarding fixed–mobile convergence in the past and continues working on related topics in collaboration with 3GPP, particularly on architectures for fixed–mobile convergence, interworking and policy management.

Other organizations and groups related to the topics investigated are:

- IETF and IRTF on caching and AAA issues;
- FSAN on optical transport issues.

4.3 Call for active participation

As detailed in Chapter 1 of this white paper, fixed–mobile network integration is an evolution, driven by multiple factors:

- technology evolutions in infrastructure elements and generalisation of NFV, which makes networks flexible and scalable;
- requirements to optimise cost and energy consumption in order to satisfy seamless mobility and increasing demand for bandwidth;
- necessity of network operators to enable smooth transition to multi-operator scenarios, and to provide rich QoS and service security to other stakeholders like content and over-the-top service providers.

This white paper presents possible architectures to enable this integration between fixed and mobile networks, being an integral part of the 5G vision. The architecture, functional blocks and interfaces if an integrated network must be fully defined to achieve seamless interoperability among network nodes produced by various vendors, and to maintain multi-operator support of the network. Other actors like over-the-top service and content providers must be able to access the functions of this integrated architecture.

The authors propose that this standardization work can be part of the current and future standardization activities inside the different SDOs (mainly ETSI, BBF and 3GPP) dealing with next generation networks.

The players in the value chain (vendors, operators, OTT service and content providers, application providers, …) are invited to actively participate to develop the ideas around Fixed–Mobile Network Integration. The participants are also invited to support the specification dissemination activity; particularly, the development of proof of concepts is encouraged.

5 Conclusion

Today's fixed, mobile and Wi-Fi networks have been developed independently of each other and therefore the network structure, equipment, implementation of network functions and their distribution in the network are very different.

This paper, endorsed by the COMBO European project, proposes Fixed–Mobile Network Integration as an ultimate step of fixed–mobile convergence at network level. True integration of fixed and mobile networks will enable more cost-efficient and energy-efficient use of network resources through distribution of traffic loads among available access networks. Integrated networks also offer simpler network management, increased availability of resources, improved user experience, and enable new business cases in multi-operator environments.

The Universal Access Gateway is proposed as a key enabler for integration of fixed and mobile networks. The UAG is a functional entity defined as the common subscriber IP edge for fixed, mobile and Wi-Fi. It has the role of unifying access to fixed and mobile networks. Data flows of a given user can be individually managed within the UAG. The proposed functional definition of UAG separates data plane and control plane, so can be managed and scaled independently. The UAG could thus be deployed as a standalone network node integrating the data and control plane, or as multiple entities where data plane and control plane functions are physically separated across a well-specified interface. The UAG has to include essential functions for FMNI, including universal data path management and a proxy or client to a universal authentication server, allowing authentication through multiple access networks on a single logical network.

Whereas an incremental implementation of UAG could be realised by aggregating already defined functional entities (such as BNG, SGW, PGW, Wi-Fi BNG) into one entity, a disruptive implementation with re-defined and optimised interfaces would allow a true functional convergence. Such a disruptive UAG implementation comprises a generic data plane implementing user traffic processing and a control plane implementing session control. In different deployment scenarios the UAGs are either distributed in main Central Offices (typically at the frontier between access and aggregation networks) or centralised in core Central Offices (at the frontier between aggregation and core networks). Depending on the chosen implementation and deployment scenario, the UAG realisations will rely on enablers such as SDN, NFV, and DMM. We addressed various issues, including virtualisation of UAG functions, mobile IP edge distribution, inter-UAG interfaces and latency and IP network extension in case of distributed UAG deployment.

Significant standardisation work is required for a complete specification of the functional architecture of integrated networks based on the UAG concept. The UAG data plane and control plane functions need to be defined, as well as the interfaces between UAG functional entities, between UAGs and between UAGs and other network nodes. Standardisation of the interfaces will allow openness of the integrated architecture and access to common infrastructure elements by any player.

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