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Multiple Access Management Services  
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Abstract

A communication network includes an access network segment that delivers data to/from the users and an associated core network segment providing connectivity with the application servers. Multiconnectivity scenarios are common where an end-user device can simultaneously connect to multiple communication networks based on different technology implementations and network architectures like WiFi, LTE, DSL. A smart selection and combination of access and core network paths that can dynamically adapt to changing network conditions can improve quality of experience for a user in such a Multiconnectivity scenario and improve overall network utilization and efficiency. This document presents the problem statement and proposes solution principles. It specifies the requirements and reference architecture for a multi-access management services framework that can be used to flexibly select the best combination of access and core network paths for uplink and downlink, as well as the flexible usage of uplink and downlink, ensuring better network efficiency and enhanced application performance.

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## Table of Contents

1.	Conventions used in this document . . . . .	3
2.	Contributing Authors . . . . .	3
3.	Introduction . . . . .	3
4.	Terminology . . . . .	4
5.	Problem Statement . . . . .	5
6.	Solution Principles . . . . .	5
7.	Requirements . . . . .	6
7.1.	Access technology agnostic interworking . . . . .	6
7.2.	Support common transport deployments . . . . .	6
7.3.	Independent Access path selection for Uplink and Downlink . . . . .	6
7.4.	Core selection independent of uplink and downlink access . . . . .	6
7.5.	Adaptive network path selection . . . . .	7
7.6.	Multipath support and Aggregation of access link capacities . . . . .	7
7.7.	Scalable mechanism based on user plane interworking . . . . .	7
7.8.	Separate Control and Data plane functions . . . . .	7
7.9.	Lossless Path (Connection) Switching . . . . .	8
7.10.	Concatenation and Fragmentation to adapt to MTU differences . . . . .	8
7.11.	Configuring network middleboxes based on negotiated protocols . . . . .	8
7.12.	Policy based Optimal path selection . . . . .	8
7.13.	MAMS Control signaling . . . . .	8
7.14.	Service discovery and reachability . . . . .	9
8.	MAMS Reference Architecture . . . . .	9
9.	Solution Principles . . . . .	11

10. Implementation considerations . . . . .	13
11. Applicability to Mobile Edge Computing . . . . .	13
12. Security Considerations . . . . .	14
12.1. Data and Control plane security . . . . .	14
13. Contributors . . . . .	14
14. References . . . . .	14
14.1. Normative References . . . . .	14
14.2. Informative References . . . . .	15
Authors' Addresses . . . . .	15

## 1. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

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## 3. Introduction

Multi Access Management Services (MAMS) is a programmable framework that provides mechanisms for flexible selection of network paths in a multi-access communication environment, based on application needs, which can leverage network intelligence and policies to dynamically adapt to changing network/link conditions. The network path selection and configuration procedures use the user plane to exchange data between the functional elements in the network and the end-user device without any impact to the control plane signaling schemes of each individual access network. For example, in a multi-access network with LTE and WiFi technologies, existing LTE and existing WiFi signaling procedures will be used to setup the LTE and WiFi connections, respectively. The proposed MAMS framework offers the capabilities of smart selection and flexible combination of access paths and core network paths. It is a broad programmable framework providing functions beyond just sharing network policies, e.g. in comparison to ANDSF that provides policies/rules for assisting 3GPP devices to discover and select available access networks, that allows choosing and configuring user plane protocols and treatment depending on needs of the application.

The document presents the requirements, solution principles and functional architecture for the MAMS framework. MAMS mechanisms are not dependent on any specific network and transport protocols like TCP, UDP, GRE, MPTCP etc. It co-exists and complements the existing

protocols by providing a way to negotiate and configure the protocols based on client and network capabilities. Further it allows exchanges of network state information and leveraging network intelligence to optimize the performance of such protocols.

An important goal for MAMS is to ensure that there is minimal or no dependency on the actual access technologies of the participating links, beyond the fact that the MAMS functional elements can be placed in the user plane. This allows the scheme to be future proof, for addition of new access technologies and for independent technology evolution of the existing access and core networks.

#### 4. Terminology

"Client": The end-user device supporting connections with multiple access nodes, possibly over different access technologies.

"Multiconnectivity Client": A client with multiple network connections.

"Access network": The segment in the network that delivers user data packets to the client via an access link like WiFi airlink, LTE airlink, or DSL.

"Core": The functional element that anchors the client's IP address used for communication with applications via the network.

"User Plane Gateway": The functional element that can intercept and route user data packets.

"Network Connection manager"(NCM): A functional entity in the network that oversees distribution of data packets over the multiple available access and core network paths.

"Client Connection Manager" (CCM): A functional entity in the client that exchanges MAMS Signaling with the Network Connection Manager and configures the multiple network paths for transport of user data.

"Network Multi Access Data Proxy" (N-MADP): This functional entity in the network handles the user data traffic forwarding across multiple network paths. N-MADP is responsible for MAMS related user-plane functionalities in the network.

"Client Multi Access Data Proxy" (C-MADP): This functional entity in the client handles the user data traffic forwarding across multiple network paths. C-MADP is responsible for MAMS related user-plane functionalities in the client.

## 5. Problem Statement

Typically, an end-user device has access to multiple communication networks based on different technologies, say LTE, WiFi, DSL, MuLTEfire, for accessing application services. Different technologies exhibit benefits and limitations in different scenarios. For example, WiFi leverages the large spectrum available in unlicensed spectrum to deliver high capacities at low cost in uncongested scenarios with small user population, but can show significant degradation in application performance in congested scenarios with large user population. Another example is LTE network, the capacity of which is often constrained by high cost and limited availability of the licensed spectrum, but offers predictable service even in multi-user scenarios due to controlled scheduling and licensed spectrum usage.

Additionally, the use of a particular access network path is often coupled with the use of its associated core network. For example, in an enterprise that has deployed WiFi and LTE communications network, enterprise applications, like printers, Corporate Audio and Video conferencing, are accessible only via WiFi access connected to the enterprise hosted WiFi core, whereas the LTE access can be used to get LTE operator core anchored services including access to public Internet.

Application performance in different scenarios, therefore becomes dependent on the choice of the communication networks based on different technologies (e.g. WiFi and LTE) due to the tight coupling of the access and the core network paths. Therefore to achieve the best possible application performance in a wide range of possible scenarios, a framework is needed that allows the selection and flexible combination of access and core network paths for uplink and downlink data delivery.

For example, in uncongested scenarios, it would be beneficial to use WiFi access in both uplink and downlink for connecting to enterprise applications. Whereas in congested scenarios, where use of WiFi in uplink by multiple users can lead to degraded capacity and increased delays due to contention, it would be beneficial to use scheduled LTE as uplink combined with WiFi as downlink.

## 6. Solution Principles

This document proposes a Multiple Access Management Services(MAMS) framework for dynamic selection and flexible combination of access and core network paths as uplink and downlink for a device connected to multiple communication networks. The multiple communication networks interwork at the user plane. The selection of paths is

based on negotiation of capabilities (of device and network) and network link quality between the user plane functional elements at the end-user device/client (C-MADP) and the network (N-MADP). NCM has the intelligence to setup and offer the best network path based on device and network capabilities, application needs and knowledge of the network state.

The NCM communicates with the Client Connection Manager (CCM), a functional element in the device, for negotiation, sharing information on the network path conditions, and configuring usage of the network paths. The messages between the NCM and CCM are carried as user plane data over any of the available network paths between the NCM and CCM.

## 7. Requirements

The requirements set out in this section are for the definition of behavior of the MAMS mechanism and the related functional elements.

### 7.1. Access technology agnostic interworking

The access nodes can be of different technology types like LTE, WiFi etc. Since MAMS routes user plane data packets at the IP layer, which makes it agnostic to the type of underlying technology used at the access nodes.

### 7.2. Support common transport deployments

The network path selection and user data distribution should work transparently across transport deployments that include e2e IPsec, VPNs, and middleboxes like NATs and proxies.

### 7.3. Independent Access path selection for Uplink and Downlink

IP layer routing enables the client to transmit on uplink using one access and receive data on downlink using another access, allowing client and network connection manager to select the access paths for uplink and downlink independent of each other.

### 7.4. Core selection independent of uplink and downlink access

A client is able to flexibly select the Core, independent of the access paths used to reach the Core, depending on the application needs.

### 7.5. Adaptive network path selection

The MAMS functional elements have the ability to determine the quality of each of the network paths, e.g. access link delay and capacity. The network path quality information is fed into the logic for selection of combination of network paths to be used for transporting user data. The path selection algorithm can use network path quality information, in addition to other considerations like network policies, for optimizing network usage and enhancing QoE delivered to the user.

### 7.6. Multipath support and Aggregation of access link capacities

MAMS supports distribution and aggregation of user data across multiple network paths at the IP layer. MAMS allows the client to leverage the combined capacity of the multiple network connections by enabling simultaneous transport of user data over multiple network paths. If required, packet re-ordering is done at the receiver, client (C-MADP) and/or the network (N-MADP), when user data packets are received out of order. MAMS allows flexibility to choose the flow steering and aggregation protocol based on capabilities supported by the client and the network data plane entities, C-MADP and N-MADP respectively. A MAMS multi-connection aggregation solution should support existing transport and network layer protocols like TCP, UDP, GRE. If flow aggregation functions are realized using existing protocols such as Multi-Path TCP (MPTCP) and SCTP, MAMS framework should allow use and configuration of these aggregation protocols.

### 7.7. Scalable mechanism based on user plane interworking

The mechanism is based on user plane interworking, requiring only that the MAMS functional elements (NCM and N-MADP) should be added in the user plane path between the client and the network. The interworking functionality is based on generically available routing and tunneling capabilities. This makes solution easy to deploy and scale when different networks are added and removed.

### 7.8. Separate Control and Data plane functions

The client negotiates with a network connection manager on the choice of access for both uplink and downlink, as well as the Core. The network connection manager configures the actual user plane data distribution function. This allows common control protocol to be used with multiple and potentially different user plane (e.g. tunneling) protocols, thus maintaining a clear separation between the control and data plane functions. This makes the MAMS framework

scalable and extensible, e.g. by being amenable to SDN based architecture and implementations.

#### 7.9. Lossless Path (Connection) Switching

When switching data traffic from one path (connection) to another, packets may be lost or delivered out-of-order, which will have negative impacts on the performance of higher layer protocols, e.g. TCP. MAMS should provide necessary mechanisms to ensure in-order delivery at the receiver, as well as support retransmissions at the transmitter during path switching.

#### 7.10. Concatenation and Fragmentation to adapt to MTU differences

MAMS should support heterogeneous access networks, which may have different MTU sizes. Moreover, tunneling protocols also have a big impact on the MTU size. Hence, MAMS should support concatenation such that multiple IP packets may be encapsulated into a single packet to improve efficiency. MAMS should also support fragmentation such that a single IP packet may be fragmented and encapsulated into multiple ones to avoid IP fragmentation.

#### 7.11. Configuring network middleboxes based on negotiated protocols

MAMS enables identification of the optimal parameters that may be used for configuring the middle-boxes, like binding expiry times and supported MTUs, for efficient operation of the user plane protocols, depending on the data plane related parameters negotiated between the client and the network, e.g. Configuring longer binding expiry time in NATs when UDP transport is used in contrast to the scenario where TCP is configured at the transport layer.

#### 7.12. Policy based Optimal path selection

MAMS framework should support consideration of policies at the client, in addition to guidance from the network in determination of network paths selected for different application services.

#### 7.13. MAMS Control signaling

MAMS control signaling is carried over the user plane and is transparent to the transport protocols. MAMS should support delivery of control signaling over the existing Internet protocols, e.g. TCP or UDP.



7.14. Service discovery and reachability

MAMS offers the flexibility for the functional entity NCM to be collocated with any of the network elements and reachable via any of the available user plane paths. MAMS framework allows the flexibility for the CCM to choose one of the available NCMs and exchange control plane signaling over any of the available user plane paths. The choice of NCM can be based on considerations like, but not limited to, quality of link through which the NCM is reachable, Client preference, or pre-configuration etc.

8. MAMS Reference Architecture

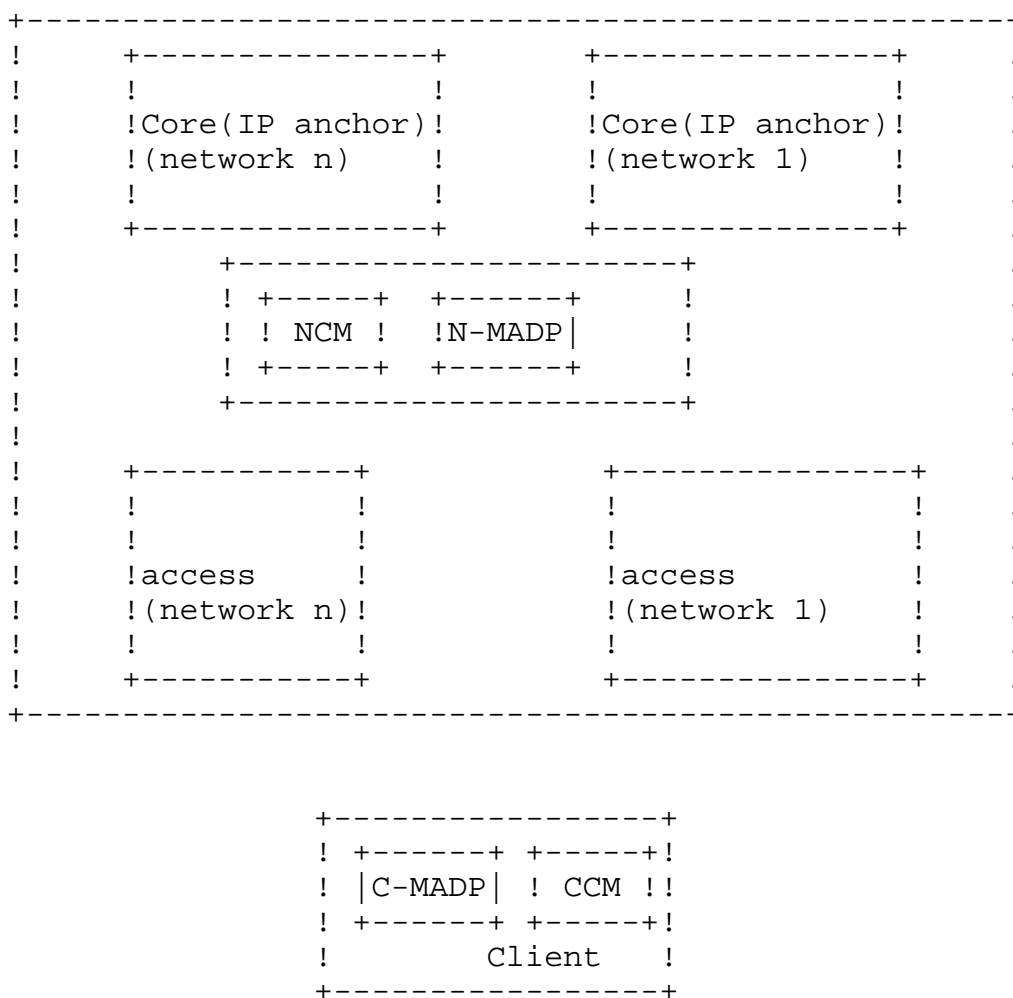


Figure 1: MAMS Reference Architecture

Figure 1 illustrates MAMS architecture for the scenario of a client served by multiple (n) networks. The NCM and N-MADP, functional

elements, are introduced for supporting MAMS mechanisms. The architecture is extendable to combine any number of networks, as well as any choice of participating network types (e.g. LTE, WLAN, MuLTEfire, DSL) and deployment architectures (e.g. with user plane gateway function at the access edge).

The N-MADP entity, at the network, handles the user data traffic forwarding across multiple network paths, as well as other user-plane functionalities, e.g. encapsulation, fragmentation, concatenation, reordering, retransmission, etc. N-MADP is the distribution node for uplink and downlink data delivery with visibility of packets at the IP layer. There can be multiple N-MADP entities in the network, e.g. to load balance across clients. A single client can also be served by multiple N-MADP instances, e.g. to address different user plane requirements of multiple applications running on the client. Identification and distribution rules for different user data traffic types at the N-MADP are configured by the NCM. The NCM configures the data delivery paths, access links, and user plane protocols to be used by N-MADP for downlink user data traffic. The CCM configures the data delivery paths, access links, and user plane protocols to be used by C-MADP for uplink user data traffic based on the signaling exchanged with NCM. In the UL, NCM allows selection of the core network path to be used by N-MADP to route uplink user data.

The scheduling and load balancing algorithm at the N-MADP is configured by the NCM, based on static and/or dynamic network policies like assigning access and core paths for specific user data traffic type, data volume based percentage distribution, and link availability and feedback information from exchange of MAMS signaling with the CCM at the Client.

At the client, the Client Connection Manager (CCM) manages the multiple network connections. CCM is responsible for exchange of MAMS signaling messages with the NCM for supporting functions like UL and DL user network path configuration for transporting user data packets, link probing and reporting to support adaptive network path selection by NCM. In the downlink, for the user data received by the client, it configures C-MADP such that application data packet received over any of the accesses to reach the appropriate application on the client. In the uplink, for the data transmitted by the client, it configures the C-MADP to determine the best access links to be used for uplink data based on a combination of local policy and network policy delivered by the NCM. The C-MADP entity handles all MAMS-specific user-plane functionalities at the client, e.g. encapsulation, fragmentation, concatenation, reordering, retransmissions, etc. C-MADP is configured by CCM based on signaling exchange with NCM and local policies at the client.

A user plane tunnel, e.g. IPsec, may be needed for transporting user data packets between the N-MADP at the network and the C-MADP at the client. The user plane tunnel is needed to ensure security and routability of the user plane packets between the N-MADP and the C-MADP. The most common implementation of the user plane tunnel is the IPsec. C-MADP receives the configuration from CCM indicates, to C-MADP, the access network interfaces over which the IPsec tunnel needs to be established, and for each of the indicated interfaces, the parameters (e.g. N-MADP IPsec endpoint IP address reachable via the indicated access network interface) for setting up the IPsec tunnel. C-MADP sets up the IPsec tunnel with the N-MADP via each of the indicated access network interfaces, using appropriate signaling, say IKEv2 and parameters provided by the CCM. In deployments where N-MADP and the client are connected via a secure and direct IP path, user plane tunnel may not be needed. Note that the method for transporting user data packets between the N-MADP and the C-MADP should be general, based on the existing protocols, and consider minimizing overhead.

## 9. Solution Principles

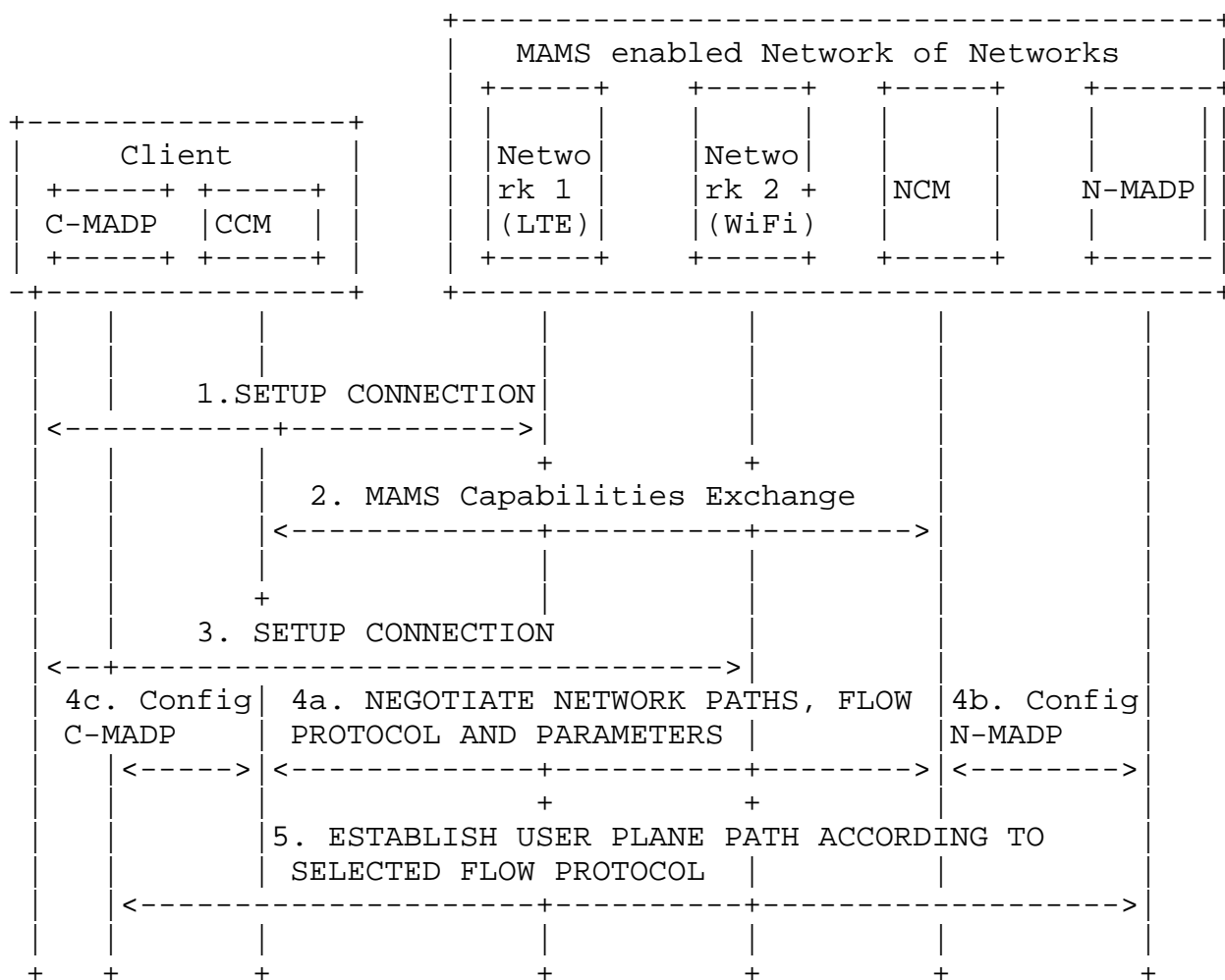


Figure 2: MAMS call flow

Figure 2 illustrates the MAMS signaling mechanism for negotiation of network paths and flow protocols between the client and the network. In this example scenario, the client is connected to two networks (say LTE and WiFi).

1. UE connects to network 1 and gets an IP address assigned by network 1.
2. CCM communicates with NCM functional element via the network 1 connection and exchanges capabilities and parameters for MAMS operation. Note: The NCM credentials (e.g. NCM IP Address) can be made known to the UE by pre-provisioning.
3. Client sets up connection with network 2 and gets an IP address assigned by network 2.
4. CCM and NCM negotiate capabilities and parameters for establishment of network paths, which are then used to configure

user plane functions N-MADP at the network and C-MADP at the client.

4a. CCM and NCM negotiate network paths, flow routing and aggregation protocols, and related parameters.

4b. NCM communicates with the N-MADP to exchange and configure flow aggregation protocols, policies and parameters in alignment with those negotiated with the CCM.

4c. CCM communicates with the C-MADP to exchange and configure flow aggregation protocols, policies and parameters in alignment with those negotiated with the NCM.

5. C-MADP and N-MADP establish the user plane paths, e.g. using IKE [RFC7296] signaling, based on the negotiated flow aggregation protocols and parameters specified by NCM.

CCM and NCM can further exchange messages containing access link measurements for link maintenance by the NCM. NCM evaluates the link conditions in the UL and DL across LTE and WiFi, based on link measurements reported by CCM and/or link probing techniques and determines the UL and DL user data distribution policy. NCM and CCM also negotiate application level policies for categorizing applications, e.g. based on DSCP, Destination IP address, and determining which of the available network paths, needs to be used for transporting data of that category of applications. NCM configures N-MADP and CCM configures C-MADP based on the negotiated application policies. CCM may apply local application policies, in addition to the application policy conveyed by the NCM.

## 10. Implementation considerations

MAMS builds on commonly available functions available on terminal devices that can be delivered as a software update over the popular end-user device operating systems, enabling rapid deployment and addressing the large deployed device base.

## 11. Applicability to Mobile Edge Computing

Mobile edge computing (MEC) is an access-edge cloud platform being standardized at ETSI, whose initial focus was to improve quality of experience by leveraging intelligence at cellular (e.g. 3GPP technologies like LTE) access edge, and the scope is now being extended to support access technologies beyond 3GPP. This applicability of the framework described in this document to the MEC

platform has been evaluated and tested in different network configurations.

The NCM and N-MADP are hosted on the MEC cloud server that is located in the user plane path at the edge of multi-technology access networks, and in a particular large venue use case at the edge of LTE and Wi-Fi access networks. The NCM and CCM negotiate the network path combinations based on application needs and the necessary user plane protocols to manage the multiple paths. The network conditions reported by the CCM to the NCM is used in addition to Radio Analytics application residing at the MEC to configure the uplink and downlink access paths according to changing radio and congestion conditions.

The aim of these enhancements is to improve the end-user's quality of experience by leveraging the best network path based on application needs and network conditions, and building on the advantages of significantly reduced latency and the dynamic and real-time exposure of radio network information available at the MEC.

## 12. Security Considerations

This section details the security considerations for the MAMS framework.

### 12.1. Data and Control plane security

Signaling messages and the user data in MAMS framework rely on the security of the underlying network transport paths. When this cannot be assumed, network connection manager configures use of protocols, like IPsec [RFC4301] [RFC3948], for securing user data and MAMS signaling messages.

## 13. Contributors

This protocol is the outcome of work by many engineers, not just the authors of this document. In alphabetical order, the contributors to the project are: Barbara Orlandi, Bongho Kim, David Lopez-Perez, Doru Calin, Jonathan Ling, Krishna Pramod A., Lohith Nayak, Michael Scharf.

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