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(54) **Title:** NETWORK MANAGEMENT SYSTEM AND METHOD FOR A SHARED RADIO ACCESS NETWORK, RAN, INFRASTRUCTURE

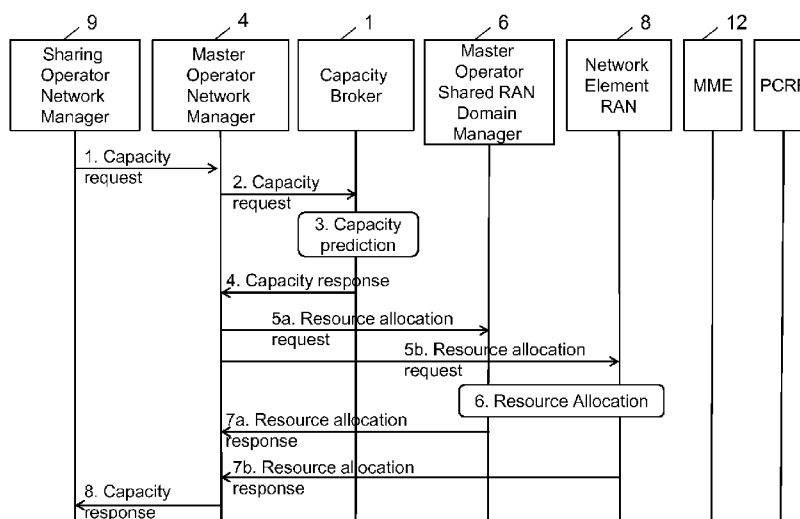


Fig. 3

(57) **Abstract:** A network management system for a shared Radio Access Network, RAN, infrastructure (3) provided by a mobile network operator, comprises a master operator network manager (4) of said mobile network operator for managing said shared RAN infrastructure (3), one or more tenants (2) configured to receive resource allocations from said master operator network manager (4), and a capacity or resource broker (1) that is configured to decide on said resource allocations to said one or more tenants (2), wherein said capacity or resource broker (6) resides inside the network of said mobile network operator. Furthermore, a corresponding method of performing network management for a shared RAN infrastructure (3) is disclosed.

NETWORK MANAGEMENT SYSTEM AND METHOD FOR A SHARED RADIO ACCESS NETWORK, RAN, INFRASTRUCTURE

The present invention generally relates to a network management system for a
5 shared Radio Access Network, RAN, infrastructure provided by a mobile network
operator.

Furthermore, the present invention relates to a method of performing network
management for a shared Radio Access Network, RAN, infrastructure provided by
10 a mobile network operator.

As mobile network operators are facing a tremendous traffic increase, not
corresponding to the associated revenue, they are in an urgent need to reduce
Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) costs.
15 Infrastructure sharing is a means to reduce network deployment and operation
costs provided that such an activity can reflect accurately mobile operator's
service demands. The first generation of network sharing solutions concentrated
on passive and active sharing based-on fixed, i.e. long term, contractual
agreements among mobile network operators and virtual mobile operators or third
20 parties, which are commonly referred to as tenants. Third Generation Partnership
Project (3GPP) has already specified two architectures for enabling network
sharing (for reference, see 3GPP TS 23.251, Network Sharing; Architecture and
Functional Description, Rel.12, Jun 2014). One referred to as Multi-Operator Core
Network (MOCN), where each operator is sharing base stations known as evolved
25 Node Bs (eNBs) in 3GPP terminology, connected to the core network elements of
each mobile network operator using a separate S1 interface. In the second one
named Gateway Core Network (GWCN) operators share additionally the Mobility
Management Entity (MME).

30 A method that defines how a mobile operator can identify a shared network
infrastructure, and selectively allow users to handover considering the scenarios of
offloading, coverage extension and virtual mobile operator is presented in
US 2013/0267229 A1, concentrating on the Radio Access Network (RAN). Such a
method is based on Public Land Mobile Network (PLMN) id or partner id, while

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handover mechanisms are specified considering both MOCN and GWCN architectures. A complementary method that identifies core network traffic related to different virtual operators ensuring isolation and provision of the appropriate Quality of Service (QoS) in the Evolved Packet Core (EPC) is introduced in
5 US 2013/0176975 A1.

However, these solutions are not meant to be dynamic, neither flexible considering short terms resource allocation request, i.e. in the scale of hours, minutes or even seconds. Recent solutions focus on more dynamic, on-demand mechanisms that
10 require no-human intervention, i.e. signaling-based, which can re-configure resources among different tenants within hours, a few minutes or even seconds. A set of such solutions introduce the network entity of capacity or resource broker, a centralized logical or physical entity that resides inside a mobile operator network or within a third party infrastructure and facilitates network sharing. In particular,
15 the capacity or resource broker is responsible for receiving service requests from virtual mobile network operators or application providers or third parties, assess such requests based-on the global network resource view and Service Level Agreements (SLAs), allocate network resources and network policies to accommodate the placed requests and support the related charging procedures.

20 The notion of capacity or resource broker is also introduced in 3GPP with a high level business use case presented in, which facilitates on-demand resource allocation in where a host RAN provider, i.e. infrastructure provider, can share via automated means an indicated portion of capacity for a particular time period with
25 a virtual mobile network operator (for reference, see 3GPP TR 22.852, Study on Radio Access Network (RAN) Sharing enhancements, Rel.13, Sep. 2014). Such a use case leaves open how the capacity or resource broker is integrated on the current 3GPP RAN architecture, considering the network interfaces needed and towards which Evolved Packet System (EPS) elements, while it also does not
30 detail the related operations.

In view of the above it is an objective of the present invention to improve and further develop a network management system for a shared Radio Access Network, RAN, infrastructure and a method of performing network management

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for a shared RAN infrastructure in such a way that multi-tenancy support is achieved that enables on-demand resource allocation towards different tenants in a dynamic fashion.

5 In accordance with the invention, the aforementioned objective is accomplished by a network management system for a shared Radio Access Network, RAN, infrastructure provided by a mobile network operator, comprising a master operator network manager of said mobile network operator for managing said shared RAN infrastructure, one or more tenants configured to receive resource
10 allocations from said master operator network manager, and a capacity or resource broker that is configured to decide on said resource allocations to said one or more tenants, wherein said capacity or resource broker resides inside the network of said mobile network operator.

15 Furthermore, the above objective is accomplished by a method of performing network management for a shared Radio Access Network, RAN, infrastructure provided by a mobile network operator, comprising:

managing said shared RAN infrastructure by means of a master operator network manager of said mobile network operator,
20 one or more tenants receiving resource allocations from said master operator network manager, and
deciding on said resource allocations to said one or more tenants by means of a capacity or resource broker that resides inside the network of said mobile network operator.

25 According to the invention it has been recognized that multi-tenancy support enabling an on-demand dynamic resource allocation towards different tenants including mobile virtual network operators (MVNOs) and third parties can be achieved by enhancing the existing 3GPP network management architecture by
30 placing a capacity or resource broker, i.e. an entity responsible for resource allocation inside a network of the mobile network master operator. Specifically, embodiments of the invention focus on integrating the capacity or resource broker in a current 3GPP Long Term Evolution (LTE) architecture as described in 3GPP TS 32.130 "Telecommunication management; Network Sharing; Concepts and

requirements”, Rel.12, Dec. 2014, where the master operator network manager, i.e. the network management entity of the operator that provides the network infrastructure, offers network sharing capabilities to mobile virtual network operators, referred to as sharing operators in 3GPP terminology, for certain regions of the radio access and core network considering both MOCN and GWCN scenarios. Consequently, embodiments of the present invention can be suitably applied in dynamic RAN sharing scenarios which are assumed to be widely employed in future mobile networks.

According to embodiments of the invention the capacity or resource broker may be designed as an entity that is responsible for resource, capacity, bandwidth and/or QoS allocations to different tenants and that may also be configured to facilitate admission control and Service Level Agreement (SLA) negotiations with MVNOs and/or service providers. The capacity or resource broker may be configured to receive, via the master operator network manager, service requests from the MVNOs or application providers or third parties, assess such requests based-on the global network resource view and Service Level Agreements (SLAs), allocate network resources and network policies to accommodate the placed requests and support the related charging procedures.

According to embodiments of the invention the capacity or resource broker may be placed at or may be implemented as part of the network management system of the infrastructure provider. Specifically, in case of a 3GPP network architecture, the capacity or resource broker may be placed at or may be implemented as part of the master operator network manager, i.e. the network management entity of the operator that provides the network infrastructure.

According to embodiments of the invention, a logical implementation of the capacity or resource broker may be realized, which may consist of a number of EPCs (Evolved Packet Cores) and network management entities. In this way, an introduction of the capacity or resource broker as a stand alone network entity requiring connectivity, i.e. a number of newly defined interfaces, towards the remaining of the 3GPP network, can be avoided. Specifically, according to embodiments of the invention the capacity or resource broker may be

implemented as a logically centralized network function that is composed by functions that reside on the master operator network manager, on the master operator shared RAN domain manager, on shared network elements of said shared RAN infrastructure, on the PCRF and/or on the MME.

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According to embodiments of the invention the master operator network manager may be implemented as an Integration Reference Point, IRP, manager that is configured to monitor and control shared network elements of the shared RAN infrastructure via an IRP agent that resides in the master operator shared RAN domain manager or network element managers of the shared network elements.

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According to embodiments of the invention the master operator network manager may be configured to enable sharing operator network managers of tenants, i.e. the network management system of a mobile virtual network operator, for instance, to monitor and control the respective allocated resources in isolation, for instance by introducing a PLMN id into the corresponding monitoring data.

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According to embodiments of the invention the capacity or resource broker may be configured to use (existing) network monitoring information that is collected at the master operator network manager for taking resource allocation decisions.

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According to embodiments of the invention the tenants may include mobile virtual network operators (MVNOs) comprising a sharing operator network manager that is configured to receive resource allocations from the master operator network manager. In this regard, it is noted that a Type 5 Interface between the master operator network manager and the sharing operator network manager, comprising enhancements that will be explained in detail below, can be used to provide resource and performance monitoring information towards MVNOs.

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According to embodiments of the invention the tenants may include third parties in a 3GPP architecture, i.e. service and/or application providers, like over-the-top content, OTT, application providers. In this regard it may be provided that a Service Capability Exposure Function (SCEF) that is placed in the network management system of the infrastructure provider, i.e. in case of 3GPP at the

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master operator network manager, is configured to use the capacity or resource broker for resource/capacity and/or SLA provisions/allocations/ to the application providers. By positioning the SCEF at the master operator network manager, the SCEF is not only exposing information for devices, e.g. MTC devices as in the case of OMA API, but can also use the capacity broker and the master operator network manager direct and indirect interfaces, i.e. Inf-N and Inf-B, to control SLAs and allocate resources.

According to embodiments of the invention the tenants may direct resource requests on-demand to the master operator network manager. These resource requests may be configured to contain at least one of an OTT application id, a service provider id, an OTT session id, a PLMN id, a specification of the requested resource allocation (e.g. resource blocks), the type of the request (e.g. periodic, on-demand), a time duration, resource type and/or QoS (e.g. radio bearer types). Additionally or alternatively, the resource requests may be configured to contain mobility related information (e.g. considering stationary users and average mobility speed, for instance with the grades low, medium and high), a mobility area and/or Tracking Area. Furthermore, the resource requests may be configured to additionally contain parameters for assisting traffic patterns predictability, e.g. keep alive messages in relation with particular applications, connection properties (high, medium, low throughput) and/or expected QoS considering the tolerance risk of resource starvation.

According to embodiments of the invention a set of different interface enhancements is introduced, considering the Inf-N, Inf-B, Type 5 interface and/or Application API in order to provide information regarding different tenants, the affected cells, type of requests, timing aspects and/or QoS, and to enable the interface to accommodate information contained in the respective resource requests. The embodiments regarding the different interfaces are as follows:

The existing 3GPP Int-N interface may be extended to accommodate information regarding the following but not exclusive list including the OTT application or OTT session id or service provider id or PLMN id, list of cells, and per cell or set of cells resource allocation (e.g. resource blocks) and type of request (periodic, on-

demand), resource type, time duration, QoS (e.g. radio and/or core network bearer types) and update information about offloading policies and mobility considering stationary users and average mobility speed (low, medium, high) as well as the mobility area or Tracking Area (TA). Additionally or alternatively, the existing 3GPP

5 Int-N interface may be configured to support resource and performance monitoring per OTT application or OTT session id or service provider id or PLMN-id or MVNO identifier either per eNB or aggregated considering a set of eNBs. To accomplish this, an OTT application provider or session identifier, the PLMN-id or some other related identifier may be introduced inside the monitoring packets related to a
10 particular MVNO.

The existing 3GPP Int-B interface may be extended to accommodate information regarding the following but not exclusive list including the OTT application id or service provider id or OTT session id or PLMN id, resource allocation (e.g.
15 resource blocks), type of request (periodic, on-demand), time duration, resource type and QoS (e.g. radio bearer types). According to embodiments, the existing 3GPP Int-B interface may also reflect mobility considering e.g. stationary users and average mobility speed (e.g. low, medium, high). Additionally or alternatively, the existing 3GPP Int-B interface may be configured to support resource and
20 performance monitoring per OTT application id or service provider id or OTT session id or PLMN-id or MVNO identifier. To accomplish this, the PLMN-id or some other related OTT application provider or session identifier may be introduced inside the monitoring packets related to a particular MVNO.

25 The existing 3GPP Type 5 interface may be extended to accommodate dynamic resource requests from MVNOs, which contain the following but not exclusive list of information including the PLMN id, list of cells (including potential cells due to user mobility profile), the resource allocation (e.g. resource blocks, throughput) and type of request (periodic, on-demand), resource type, time duration.
30 Additionally or alternatively, this interface may be configured to support resource and performance monitoring per PLMN-id or MVNO identifier, either per eNB or aggregated considering a set of eNBs. To accomplish this, the PLMD-id or some other related identifier may be introduced inside the monitoring packets related to

a particular MVNO and to distinct monitoring and performance information towards particular MVNOs.

The application API may be extended to accommodate on demand resource or
5 SLA provision considering the following but not exclusive list of information including the OTT id or OTT session id, list of cells (including potential cells due to user mobility profile), the resource allocation (e.g. resource blocks, throughput) and type of request (periodic, on-demand), resource type, time duration.

10 There are several ways how to design and further develop the teaching of the present invention in an advantageous way. To this end it is to be referred to the dependent patent claims on the one hand and to the following explanation of preferred embodiments of the invention by way of example, illustrated by the drawing on the other hand. In connection with the explanation of the preferred
15 embodiments of the invention by the aid of the drawing, generally preferred embodiments and further developments of the teaching will be explained. In the drawing

20 Fig. 1 is a schematic view illustrating a network management architecture accommodating a capacity broker in an MOCN scenario in accordance with an embodiment of the present invention,

25 Fig. 2 is a schematic view illustrating a network management architecture accommodating a capacity broker in a GWCN scenario in accordance with an embodiment of the present invention,

30 Fig. 3 is a flow diagram illustrating resource allocation and policy provision upon incoming resource requests from an MVNO in accordance with an embodiment of the present invention,

Fig. 4 is a flow diagram illustrating resource allocation and policy provision upon incoming resource requests from an OTT application server in accordance with an embodiment of the present invention, and

Fig. 5 is a schematic view illustrating a network management architecture accommodating a logical centralized version of the capacity broker in a MOCN scenario in accordance with an embodiment of the present invention.

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The focus of the embodiments of the invention described hereinafter is on integrating a capacity or resource broker in a 3GPP architecture where the broker resides inside the network of the mobile network operator responsible of allocating resources to virtual operators. In contrast to prior art solution, these embodiments strictly follow the 3GPP network management architecture described in 3GPP TS 32.130 "Telecommunication management; Network Sharing; Concepts and requirements", Rel.12, Dec. 2014. Furthermore, these embodiments do not require the introduction of new interfaces, but specific extensions to existing ones to support multi-tenancy using the already existing 3GPP network management architecture. In addition, the embodiments consider interfaces extensions that facilitate Over-The-Top (OTT) Application providers and services to acquire network resources from the capacity broker, building on the top of the Service Capability Exposure Function (SCEF) described in 3GPP TR 23.708 "Architecture enhancements for service capability exposure", Rel.13, Dec. 2014, providing extensions on the Application Programming Interface (API) considered in 3GPP, e.g. on the existing interfaces defined at OMA/GSMA, as will be described in detail below.

Fig. 1 is a schematic view illustrating a network management architecture accommodating a capacity or resource broker 1 in an MOCN (Multiple Operator Core Network) scenario in accordance with a first embodiment of the present invention. The capacity or resource broker 1 is integrated in the network management architecture to facilitate network sharing among multiple tenants 2 in a mobile network or, more specifically, in a shared RAN 3. While the present invention can be applied in connection with various network management architectures, in the illustrated embodiment the focus is on the 3GPP Long Term Evolution (LTE), considering the network management architecture described in 3GPP TS 32.130, "Telecommunication management; Network Sharing; Concepts

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and requirements”, Rel.12, Dec. 2014, which is incorporated herein by way of reference.

According to this architecture the master operator network manager 4, i.e. the
5 network management entity of the operator that provides the infrastructure of the
mobile network 3, offers network sharing capabilities for certain regions of the
radio access network to different tenants 2 including mobile virtual network
operators 5, referred to as sharing operators in 3GPP terminology, and to third
parties. In the 3GPP network management architecture for enabling network
10 sharing the master operator network manager 4 is defined as the *Integration
Reference Point* (IRP) manager that monitors and controls the shared network
elements via the IRP agent, which either resides in the master operator shared
RAN domain manager 6 or in a network element manager 7 of a shared eNB 8.
The master operator network manager 4 in turn enables the sharing operator
15 network manager 9, i.e. the network management system of the mobile virtual
network operator 5, to monitor and control the corresponding allocated resources.

As shown in Fig. 1, in accordance with an embodiment of the invention the
capacity or resource broker 1 is placed at or is a part of the master operator
20 network manager 4 to facilitate admission control and Service Level Agreement
(SLA) negotiation with MVNOs 5 and third parties, e.g. with application servers 10
of OTT providers. The capacity or resource broker 1 can use the existing network
monitoring information that is collected at the master operator network manager 4
in order to take a decision on resource allocation. Further, the capacity or resource
25 broker 1 can use the existing interfaces, amended as described below to control
and allocate resources accordingly.

In addition, the provision of resources and SLA for OTT application providers 10
can be achieved by positioning the Service Capability Exposure Function (SCEF)
30 11 at the master operator network manager 4. In this way the SCEF 11 is not only
exposing information for devices, e.g. MTC devices, as in the case of OMA API,
but can also use the capacity or resource broker's 1 and the master operator
network manager's 4 direct and indirect interfaces, i.e. Inf-N and Inf-B, to control
SLAs and allocate resources.

Fig. 2 is a schematic view illustrating a network management architecture accommodating a capacity or resource broker in a GWCN (Gateway Core Network) scenario in accordance with an embodiment of the present invention. In Fig. 2, which is similar to Fig. 1, like reference numerals denote like components as in Fig. 1. In contrast to the MOCN scenario illustrated in Fig. 1, the Mobility Management Entity (MME) 12 is additionally involved in the GWCN scenario and shared between tenants 2.

10 In the illustrated embodiment, both in the MOCN scenario and in the GWCN scenario, resource requests placed by a MVNO 5 or an OTT/service provider 10, are designed to contain the respective OTT application id, the service provider id, the OTT session id and/or PLMN id. Moreover, the resource requests may contain information on resource allocations (e.g. in form of specifying certain resource
15 blocks), on the type of the resource request (e.g. whether it is periodic or on-demand), on the time duration (for which the resources shall be allocated), on the resource type and/or on the required/desired QoS (e.g. by specifying radio bearer types). In addition, it may be provided that the resource requests also reflect mobility, i.e. considering whether stationary users are concerned or, in case of
20 moving users, considering an average mobility speed (e.g. low, medium, high), and/or considering a mobility area or Tracking Area. Still further, the resource requests may contain additional parameters for assisting traffic patterns predictability, e.g. keep alive messages in relation with particular applications, information on connection properties (e.g. high, medium, low throughput) as well
25 as information on expected QoS considering the tolerance risk of resource starvation. It should be noted that any combination of the above mentioned information items may be included in a resource request. Furthermore, as will be easily appreciated by those skilled in the art, it should be noted the above list is not exclusive and that alternative or additional information items, which are not
30 explicitly mentioned above, may be contained within the resource requests.

Generally, a resource request may be performed when a MVNO 5 needs more resources, capacity and/or QoS for a particular service or in relation with an event or occasion, where the amount of network usage is expected to be high, or simply

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in case of congestion, or for specific type of users or applications that require a premium service. Furthermore, a resource request can also be placed by OTT and service providers 10 on a per application basis, i.e. when a user requests a particular application, e.g. high definition television streaming, or on a per token basis, i.e. when a user signals that he/she needs more resources, or per subscription profile.

The embodiments of the invention described above take advantage of the standardized interfaces, wherein enhancements per interface may be implemented basically in order to comply with the resource requests as described above. Specifically, these enhancements may be implemented as follows:

Type 1 interface Inf-B: The interface Inf-B 13 is the interface between the master operator-shared RAN domain manager 6 and the eNBs 8. According to embodiments of the invention this interface 13 is extended to accommodate information regarding the respective OTT application id and/or service provider id and/or OTT session id and/or PLMN id. Moreover, the interface Inf-B 13 may be extended to accommodate information on resource allocations (e.g. resource blocks), on the type of request (e.g., periodic, on-demand), on the time duration, the resource type and QoS (e.g. radio bearer types). In addition, the interface Inf-B 13 enhancement may also reflect user mobility and aggregate or group user mobility, considering e.g. stationary users and average mobility speed (e.g. low, medium, high). In addition, the interface Inf-B 13 may be adapted to support resource and performance monitoring per OTT application id or service provider id or OTT session id or PLMN id or MVNO 5 identifier. To accomplish this, the PLMN id or some other related OTT application provider identifier or session identifier may be introduced inside the monitoring packets related to a particular MVNO 5. Again, it should be noted that any combination of the above mentioned enhancements may be implemented by Inf-B 13. Furthermore, as will be easily appreciated by those skilled in the art, it should be noted the above list is not exclusive and that alternative or additional enhancements, which are not explicitly mentioned above, may be implemented.

Type 2 interface Inf-N: The interface Inf-N 14 is the interface between the master operator network manager 4 and the master operator-shared RAN domain manager 6 or network element manager 7 at the eNB 8. According to embodiments of the invention the Inf-N interface 14 may be extended to
5 accommodate information regarding the OTT application or OTT session id or service provider id or PLMN id. Moreover, interface Inf-N 14 may be extended to accommodate information on the respective cells that are affected by a resource request (e.g. in form of a list of cells) and/or per cell or per a set of cells the resource allocation (e.g. resource blocks) and type of request (periodic, on-
10 demand), resource type, time duration, QoS (e.g. radio and/or core network bearer types) and/or update information about offloading policies. In addition, the interface Inf-N 14 enhancement may also reflect user mobility and aggregate or group user mobility per cell or set of cells, considering e.g. stationary users and average mobility speed (e.g. low, medium, high) as well as the mobility area or
15 Tracking Area (TA). Furthermore, this interface 14 may be configured to support resource and performance monitoring per OTT application or OTT session id or service provider id or PLMN-id or MVNO 5 identifier, either per each individual eNB 8 or aggregated considering a set of eNBs 8. To accomplish this, the OTT application provider or session identifier PLMN-id or some other related identifier
20 may be introduced inside the monitoring packets related to a particular MVNO 5. Again, it should be noted that any combination of the above mentioned enhancements may be implemented for interface Inf-N 14. Furthermore, as will be easily appreciated by those skilled in the art, it should be noted the above list is not exclusive and that alternative or additional enhancements, which are not
25 explicitly mentioned above, may be implemented.

Type 5 interface: The Type 5 interface 15 is the interface between the master operator network manager 4 and the sharing operator network manager 9 of an MVNO 5. This interface is typically used to provide roaming services across a
30 number of PLMNs. In the network sharing scenario it is used for providing resource and performance monitoring information towards MVNOs 5 assuming a static resource allocation per MVNO 5. Currently, this interface is established typically upon an agreement between mobile operators. According to embodiments of the present invention this interface 15 is extended as described

below to accommodate dynamic resource requests from MVNOs 5. For instance, such dynamic resource requests may contain the following but not exclusive list of information including the PLMN id, list of cells (including potential cells due to user mobility profile), the resource allocation (e.g. resource blocks, throughput) and type of request (periodic, on-demand), resource type, time duration. In addition, this interface 15 may be configured to support resource and performance monitoring per PLMN-id or MVNO 5, identifier either per eNB 8 or aggregated considering a set of eNBs 8. To accomplish this, the PLMN-id or some other related identifier may be introduced inside the monitoring packets related to a particular MVNO 5 and to distinct monitoring and performance information towards particular MVNOs 5. Again, it should be noted that any combination of the above mentioned enhancements may be implemented for Type 5 interface 15. Furthermore, as will be easily appreciated by those skilled in the art, it should be noted the above list is not exclusive and that alternative or additional enhancements, which are not explicitly mentioned above, may be implemented.

Application API: The Application API 16 is the interface between an application server 10 and the SCEF 11. The specifics of this interface are currently open under discussion in 3GPP (see, for reference 3GPP TR 23.708, "Architecture enhancements for service capability exposure", Rel.13, Dec. 2014), which is also willing to adopt APIs from other standardization bodies, e.g. OMA for MTC and GSMA Open API for OTT Application providers. This interface 16 provides access and control to OTT application providers focusing on device management. According to embodiments of the present invention this interface 16 is extended to accommodate on demand resource or SLA provisions, considering the following but not exclusive list of information including the OTT id or OTT session id, list of cells (including potential cells due to user mobility profiles), the resource allocation (e.g. resource blocks, throughput) and type of request (periodic, on-demand), resource type, time duration. Again, it should be noted that any combination of the above mentioned enhancements may be implemented for the Application API 16. Furthermore, as will be easily appreciated by those skilled in the art, it should be noted the above list is not exclusive and that alternative or additional enhancements, which are not explicitly mentioned above, may be implemented.

Existing 3GPP mechanisms provide monitoring information among network manager entities, which were typically used within the same operator. Hence, all monitoring information is shared among network management systems. This simple approach is currently followed in network sharing scenarios assuming that all participating MVNOs share the entire set of resources following a resource pooling paradigm. Although the option of propagating monitoring and performance information per MVNO only with respect to the isolated resources allocated is considered in 3GPP management study (for reference, see 3GPP TS 32.130, "Telecommunication management; Network Sharing; Concepts and requirements", Rel.12, Dec. 2014), the current mechanisms cannot support it, requiring extension to the management architecture included in 3GPP TS 32.301, "Telecommunication management; Principles and high level requirements", Rel. 12, Sep. 2014. Monitoring applies mostly in the case of MVNO and not so much about OTT application providers, unless OTTs application providers possess an OAM system that needs to regulate or policy the allocated resource.

According to the embodiments of the present invention enhancements are introduced to support monitoring per MVNO's or OTT application provider's utilized portion of resources or resource slice, with the monitoring information being distributed only to the corresponding operator or OTT application provider. This can be achieved by introducing a PLMN id or a MVNO identifier or a service id or OTT id or OTT session id, either on each measurement report or on an aggregate measurement report propagated from a network management element 7 residing at an eNB 8 and/or from the master operator shared RAN domain manager 6 towards the master operator network manager 4. Alternatively, this can be provided by a User Equipment (UE) directly indicating the PLMN id or a MVNO identifier or a service id or OTT id or OTT session id. The master operator network manager 4 can divide such data and then propagate towards the corresponding MVNO or OTT application provider. MVNOs and OTT application providers can then monitor and control the resources that correspond to their share via the sharing operator network manager 9, i.e. the management entity of participating operators, which can receive network management information, e.g. performance, alarms.

According to one embodiment the capacity or resource broker 1 is a physically centralized function being located at the master operator network manager 4. This functional location comes along with the benefit of using the conventional monitoring network information, e.g. UL/DL load, performance measurements, energy saving, alarms, etc. to provide intelligence for multi-tenancy support, and of using the network planning information, e.g. topology, network design, etc. from the Operations Support Systems/Business Support Systems (OSS/BSS). Consequently, in this embodiment the capacity or resource broker 1 can introduce a finer control on a triggering mechanism related to multi-tenancy support at the master operator network manager 4 to retrieve performance and traffic load information from selected RAN regions on-demand at critical instances. The notion of 'critical' can be defined with respect to a selected RAN regions, which can be realized by a significant change on load or performance, e.g. a significant increase of traffic load, high load variations, frequency of receiving request for a particular area, the handover ratio towards or within a particular RAN region, high variability reports of the radio conditions, etc.

Fig. 3 illustrates a call flow in an infrastructure as shown in Figs. 1 or 2 that describes the steps for allocating resources, capacity and policies in accordance with an embodiment of the present invention, once a new capacity or resource request from an MVNO 5 is received at the master operator network manager 4, as shown in step 1. The master operator network manager 4 forwards the capacity or resource request to the capacity or resource broker 1 in step 2, which checks the sharing configuration and allocates capacity or resource if that is possible in step 3, returning back to the master operator network manager 4 the required resource allocation or virtual slice. In addition, the capacity or resource broker 1 may also return back to the master operator network manager 4 certain specifics regarding the allocated resources, for instance with respect to the starting time and duration, the probability/confidence degree of resource utilization and/or the SLAs including data offloading towards specific eNBs 8 and the corresponding policies for the core network in step 4. Once this information is available, the master operator network manager 4 forwards this information via the Inf-N 14 towards the master operator shared RAN domain manager 6 or to network elements 8 of the shared RAN 3 in step 5a and step 5b, respectively, which

allocate the corresponding resources in step 6 and provide back a resource allocation response in step 7a and step 7b, respectively.

When the master-operator network manager 4 receives the resource allocation response from the RAN, i.e. either from the master operator shared RAN domain manager 6 or from a network element 8 of the shared RAN 3, it then replies to the requesting sharing operator network manager 9 in step 8. If the request was successful, the master-operator network manager 4 may indicate within its capacity or resource response the time duration and/or regularity of the resource allocation, the probability/confidence degree of resource utilization and/or, as the case may be depending on the specific configuration, any similar information items related to the resource allocation. If, following step 4, the master operator network manager 4 receives a negative capacity or resource response from the capacity or resource broker 1, it can immediately skip all remaining configuration steps and get to step 8 immediately, creating a capacity or resource response that suggests, e.g., an SLA modification, a reduction of the required time duration, a change of the starting time, and/or a reduction of the number of cells that are available for accommodating the request. Based-on such a feedback the sharing operator network manager 9 can then issue a new modified request, or it can simply terminate the capacity request process towards that particular infrastructure provider. In addition, the Inf-N 14 can coordinate the decisions of the capacity or resource broker 1 with the PCRF (Policy and Charging Rules Function, not shown in Figs. 1 and 2) in order to enforce policies in the EPS regarding particular OTT applications or services or resource allocations towards MVNOs 5.

As mentioned earlier, in order to facilitate on-demand resource provision for OTT application and service providers, according to embodiments of the invention the Service Capability Exposure Function (SCEF) 11 may be integrated within the master operator network manager 4. This service capability exposure function 4 can provide authentication, authorization and discovery means to external entities, whilst it can take, once integrated within the master-operator network manager 4, advantage of the capacity or resource broker's 1 global network view, which can be used for resource abstraction.

Fig. 4 shows a call flow according to an alternative embodiment of the invention. Specifically, Fig. 4 illustrates the steps for allocating capacity or resource, once a new capacity or resource request from an OTT application or service provider 10 is received at the SCEF11, as shown in step 1. The SCEF11, as shown in step 2, provides the corresponding authentication and authorization procedures. Once this process is successful, the capacity or resource request is forwarded through the master operator network manager 4 to the capacity or resource broker 1 in step 3 and step 4, respectively. The capacity or resource broker 1, in step 5, checks the sharing configuration and allocates capacity if that is possible, returning back to the master operator network manager 4, in step 6, the required resource allocation or virtual slice and, depending on the specific configuration, specifics regarding, e.g., the starting time and duration, probability/confidence degree of resource utilization and the SLAs and the corresponding policies for the core network. The master operator network manager 4 then forwards via the Inf-N 14 such configurations towards the corresponding master operator shared RAN domain manager 6 or network element RAN 8 in step 7a and step 7b, respectively, which allocate the corresponding resources in step 8 and provide back a resource allocation response in step 9a and step 9b, respectively.

The master operator network manager 4 finally contacts the OTT application provider 10 via the SCEF 11, indicating in the capacity or resource response, in case the request was successful, its time duration and/or regularity, the probability/confidence degree of resource utilization, etc. in step 10 and step 11. If, following step 4, the master operator network manager 4 receives a negative capacity or resource response from the capacity or resource broker 1, it can immediately skip all remaining configuration steps and get to step 10 and step 11, creating a capacity or resource response that can suggest, e.g., an SLA modification or reduction of the required time duration or starting time or reduce the number of cells that are available for accommodating the request. Based-on such a feedback the OTT application provider 10 can then issue a new modified request or can simply terminate the capacity or resource request process towards that particular infrastructure provider. When the master-operator network manager 4 receives the resource allocation response from the RAN, i.e. either from the master operator shared RAN domain manager 6 or from a network element 8 of

the shared RAN 3, it can then use the Inf-N 14 to coordinate the decisions of the capacity broker 1 with the PCRF (not shown in Figs. 1 and 2) in order to enforce policies in the EPS regarding particular OTT applications.

5 Fig. 5 illustrates an embodiment of the present invention where the network management architecture accommodates a logical centralized version of the capacity or resource broker 1. While the illustrated embodiment considers a MOCN scenario, it should be noted that an implementation of a logically centralized capacity broker 1 is also possible in connection with different
10 scenarios, in particular in connection with GWCN scenarios. Generally, the capacity or resource broker 1 can be a logically centralized network function that is composed by functions that reside on the master operator network manager 4, e.g. monitoring for creating the global network view and/or executing the capacity forecasting/allocation algorithm, etc., on the master operator shared RAN domain
15 manager 6 and/or on a master operator shared eNB network element manager 7, e.g. creating a local network view to be combined with local network views of other network elements for composing a global one and/or executing a capacity forecasting/allocation algorithm, etc., on the PCRF (not shown in Fig. 5), e.g. facilitating a dynamic policing, and, for the GWCN case, on the MME (Mobility
20 Management Entity, not shown in Fig. 5), e.g. enabling a dynamic handover policy. The OSS/BSS can still provide the network planning/topology and facilitate manual changes and updates. An overview of a simple logical global capacity or resource broker architecture, in where the capacity or resource broker 1 is composed by the master operator network manager 4, a set of master operator shared RAN domain
25 managers 6 and network element managers 7 is shown in Fig. 5.

In this case, once a capacity or resource request is received at the master operator network manager 4, it is forwarded towards the corresponding master operator-shared RAN domain manager 6 or network element managers 7 that in
30 turn retrieve the required information to create the global view from selected other master operator shared RAN domain managers 6 or other network element managers 7.

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To accomplish this, according to these embodiments information exchange/transfer enhancements on the type 4 interface Inf P2P 17 are introduced, including, but not limited, the exchange of OTT application or OTT session id or service provider id or PLMN id, list of cells (if the information exchange is between master operator shared RAN domain managers 6) or per cell (if the information exchange involves network element managers 7), the resource allocation (e.g. resource blocks and/or throughput) and/or the type of request (e.g., periodic, on-demand), the resource type, the time duration, QoS (e.g. radio bearer types) and update information about offloading policies. In addition, the type 4 interface Inf P2P 17 exchange/transfer enhancements may also reflect mobility per cell or set of cells considering stationary users and an average mobility speed of the users (e.g., with the grading low, medium, high).

In these embodiments the master operator network manager 4 can forward the capacity or resource request towards the PCRFs (not shown in Fig. 5), and then these elements can coordinate with the corresponding master operator shared RAN domain manager 6 or network element managers 7 via the master operator network manager 4 through the Inf-N interface 14.

Many modifications and other embodiments of the invention set forth herein will come to mind the one skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing description and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Reference numbers

	1	resource/capacity broker
	2	tenant
5	3	mobile network / shared RAN
	4	master operator network manager
	5	mobile virtual network operator, MVNO
	6	master operator shared RAN domain manager
	7	network element manager
10	8	shared eNB
	9	sharing operator network manager
	10	application server of OTT provider
	11	Service Capability Exposure Function, SCEF
	12	Mobility Management Entity, MME
15	13	interface Inf-B
	14	interface Inf-N
	15	Type 5 interface
	16	Application API
20	17	Type 4 interface Inf P2P

Claims

1. Network management system for a shared Radio Access Network, RAN, infrastructure (3) provided by a mobile network operator, comprising:
 - 5 a master operator network manager (4) of said mobile network operator for managing said shared RAN infrastructure (3),
one or more tenants (2) configured to receive resource allocations from said master operator network manager (4), and
a capacity or resource broker (1) that is configured to decide on said
10 resource allocations to said one or more tenants (2), wherein said capacity or resource broker (6) resides inside the network of said mobile network operator.
2. System according to claim 1, wherein said capacity or resource broker (1) is placed at or is implemented as part of said master operator network manager (4).
- 15 3. System according to claim 1 or 2, wherein said capacity or resource broker (1) is implemented as a logically centralized network function that is composed by functions that reside on said master operator network manager (4), on the master operator shared RAN domain manager (6), on shared network elements (8) of said
20 shared RAN infrastructure (3), on the PCRF and/or on the MME (12).
4. System according to any of claims 1 to 3, wherein said master operator network manager (4) employs an Integration Reference Point, IRP, manager that is configured to monitor and control shared network elements (8) of said shared
25 RAN infrastructure (3) via an IRP agent that resides in the master operator shared RAN domain manager (6) or network element managers (7) of said shared network elements (8).
5. System according to any of claims 1 to 4, wherein said master operator
30 network manager (4) is configured to enable sharing operator network managers (9) of said tenants (2) to monitor and control the respective allocated resources.
6. System according to any of claims 1 to 5, wherein said capacity or resource broker (1) is configured to use network monitoring information that is collected at

the master operator network manager (4) for taking resource allocation decisions satisfying SLA.

7. System according to any of claims 1 to 6, wherein said one or more tenants (2) are configured to direct resource requests on-demand to said master operator network manager (4), and wherein said one or more tenants (2) include a mobile virtual network operator (5) comprising a sharing operator network manager (9) that is configured to receive resource allocations from said master operator network manager on demand (4).

8. System according to any of claims 1 to 7, wherein said one or more tenants (2) include application providers (10), like over-the-top content, OTT, application providers.

9. System according to any of claims 1 to 8, wherein a Service Capability Exposure Function (11) that is placed at said master operator network manager (4) is configured to use said capacity or resource broker (1) for capacity and/or SLA allocations to said application providers (10).

10. System according to claim 9, wherein said resource requests contain at least one of an OTT application id, a service provider id, an OTT session id, a PLMN id, a specification of the requested resources, the type of the request, and a time duration.

11. System according to claim 9 or 10, wherein said resource requests contain mobility related information, parameters for assisting traffic patterns predictability, and/or connection properties.

12. System according to any of claims 1 to 11, wherein the existing 3GPP Int-N interface (14) between said master operator network manager (4) and the master operator shared RAN domain managers (6), the existing 3GPP Int-B interface (13) between the master operator shared RAN domain managers (6) and network elements (8) of said shared RAN infrastructure (3), and/or the existing 3GPP Type 5 interface (15) between said master operator network manager (4) and sharing

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operator network managers (9) of said tenants (2) are extended to accommodate information contained in said resource requests.

13. System according to any of claims 1 to 12, wherein said Int-N interface (14) between said master operator network manager (4) and the master operator shared RAN domain managers (6) and/or said Int-B interface (13) between the master operator shared RAN domain managers (6) and network elements (8) of said shared RAN infrastructure (3) and/or said Type 5 interface (15) between said master operator network manager (4) and sharing operator network managers (9) of said tenants (2) are configured to accommodate information regarding the OTT application, the OTT session id, the service provider id, the PLMN id, information on the respective cells that are affected by a resource request, information on the resource allocation, on the type of request, resource type, time duration, QoS and/or update information about offloading policies.

14. System according to any of claims 1 to 13, wherein an application API (16) between an application provider (10) and a Service Capability Exposure Function (11) at said master operator network manager (4) is configured to accommodate information regarding the OTT id, the OTT session id, the list of cells, information on the resource allocation, on the type of request, on the resource type, and/or on the time duration.

15. Method of performing network management for a shared Radio Access Network, RAN, infrastructure (3) provided by a mobile network operator, comprising:

managing said shared RAN infrastructure (3) by means of a master operator network manager (4) of said mobile network operator,

one or more tenants (2) receiving resource allocations from said master operator network manager (4), and

deciding on said resource allocations to said one or more tenants (2) by means of a capacity or resource broker (1) that resides inside the network of said mobile network operator.

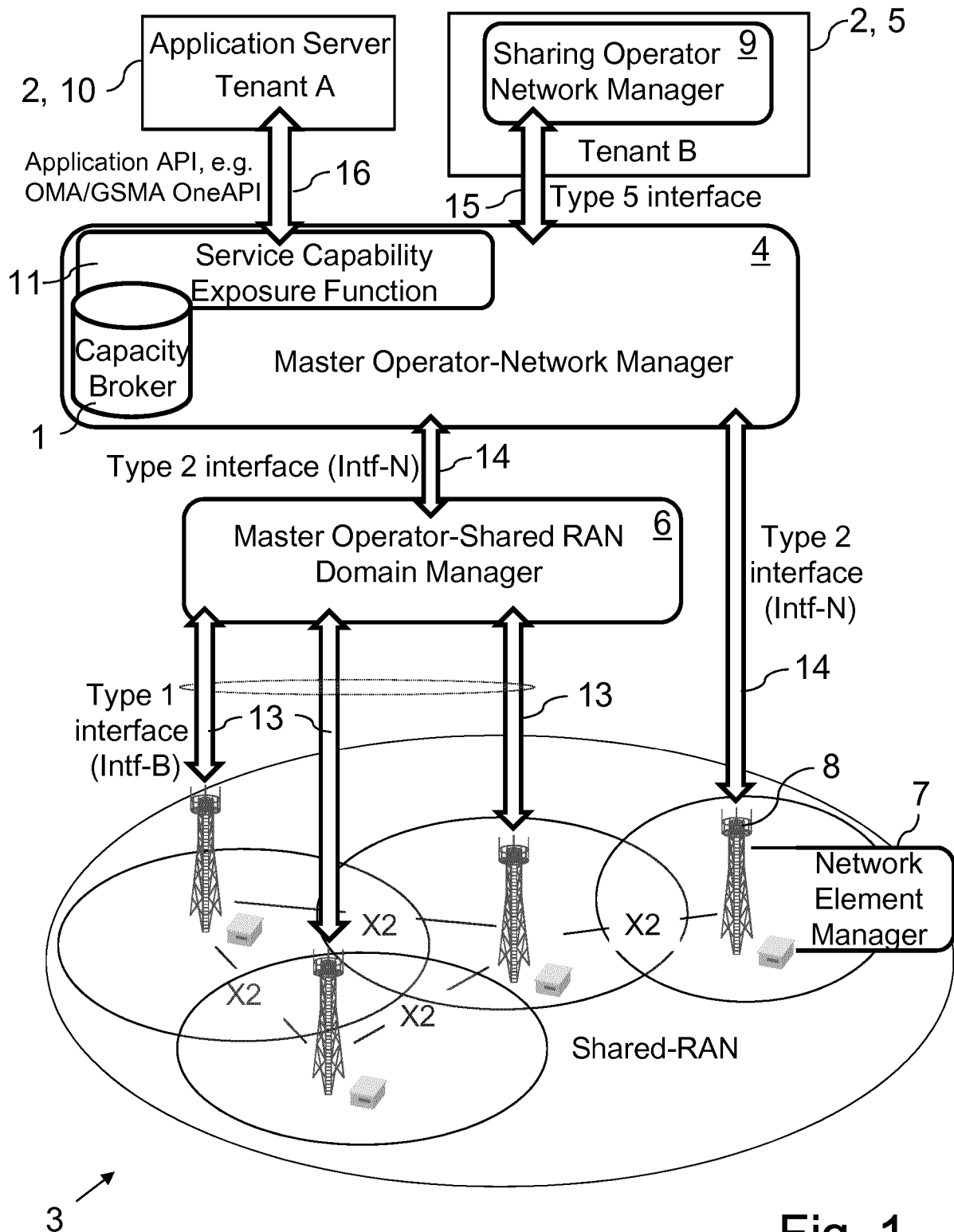


Fig. 1

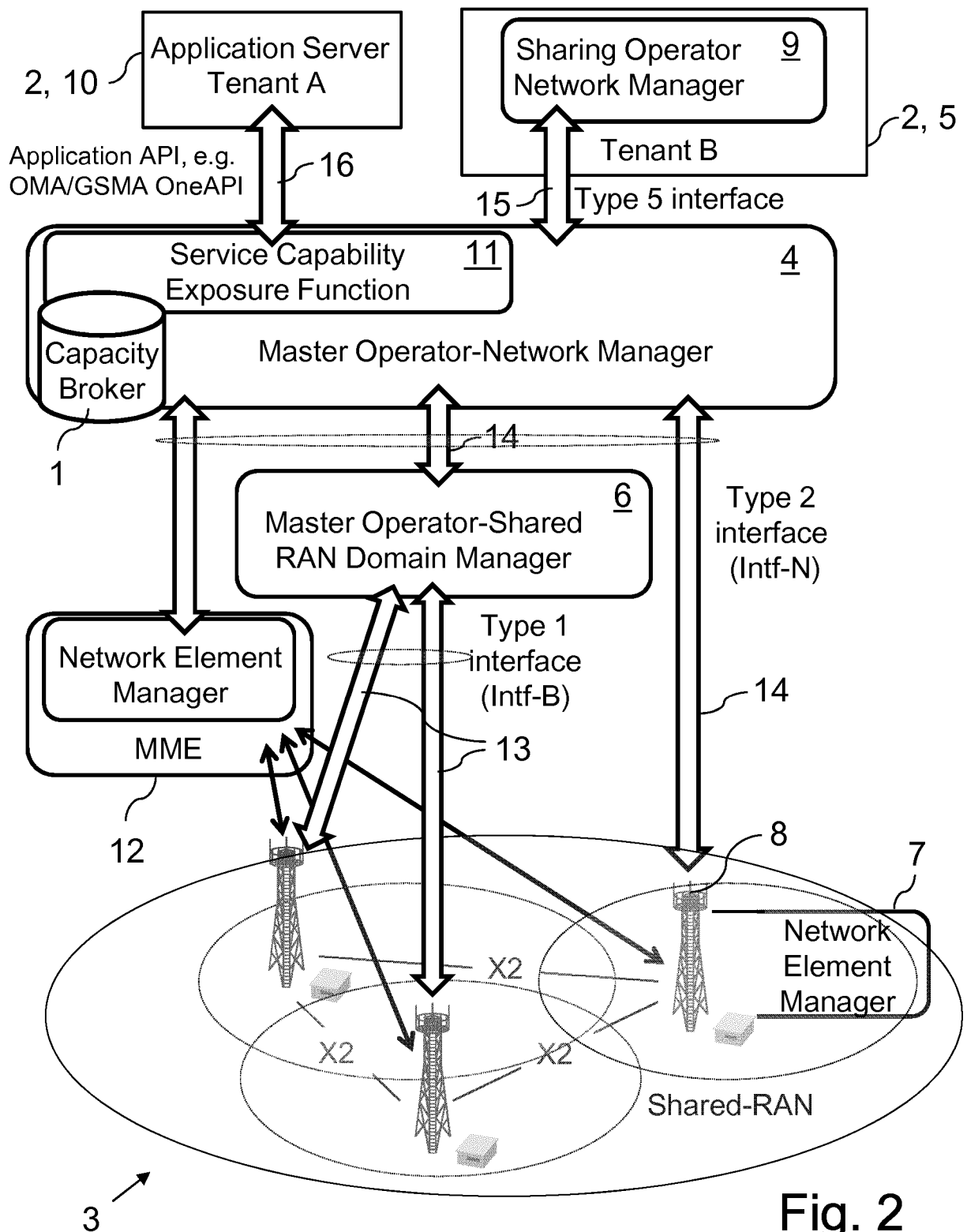


Fig. 2

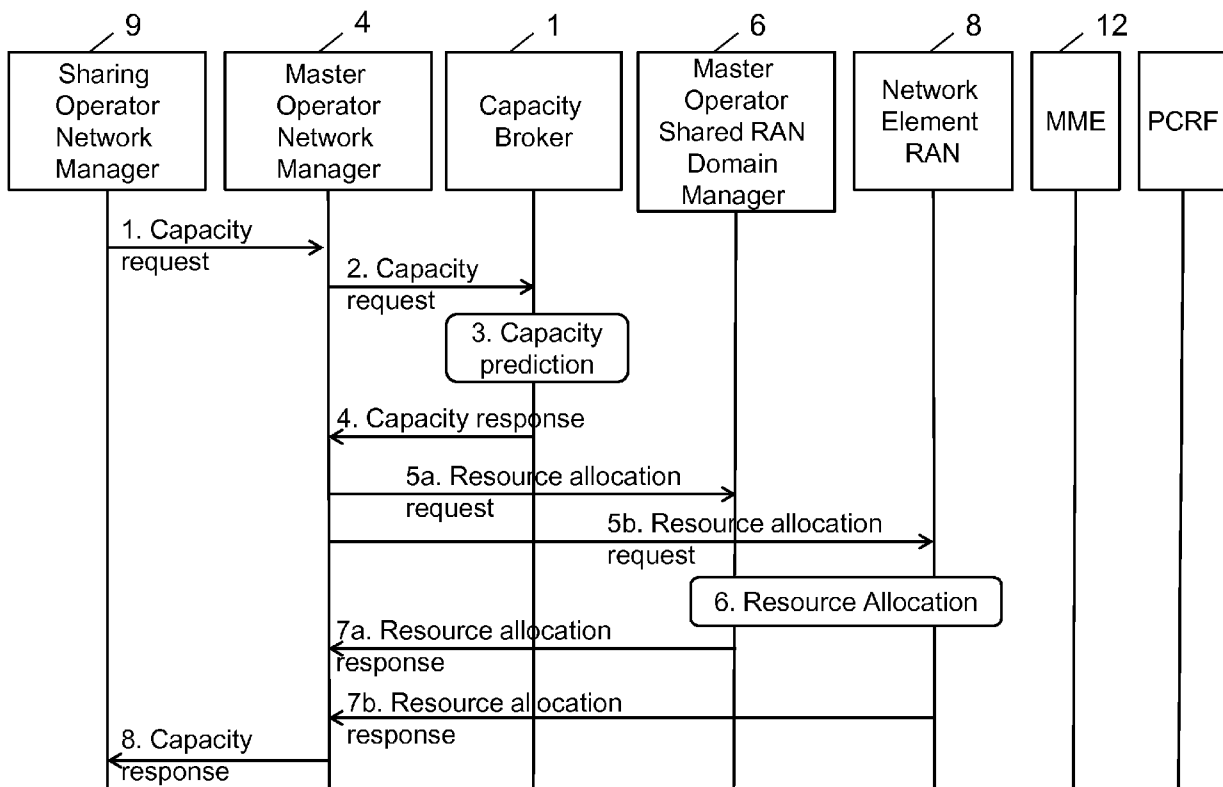
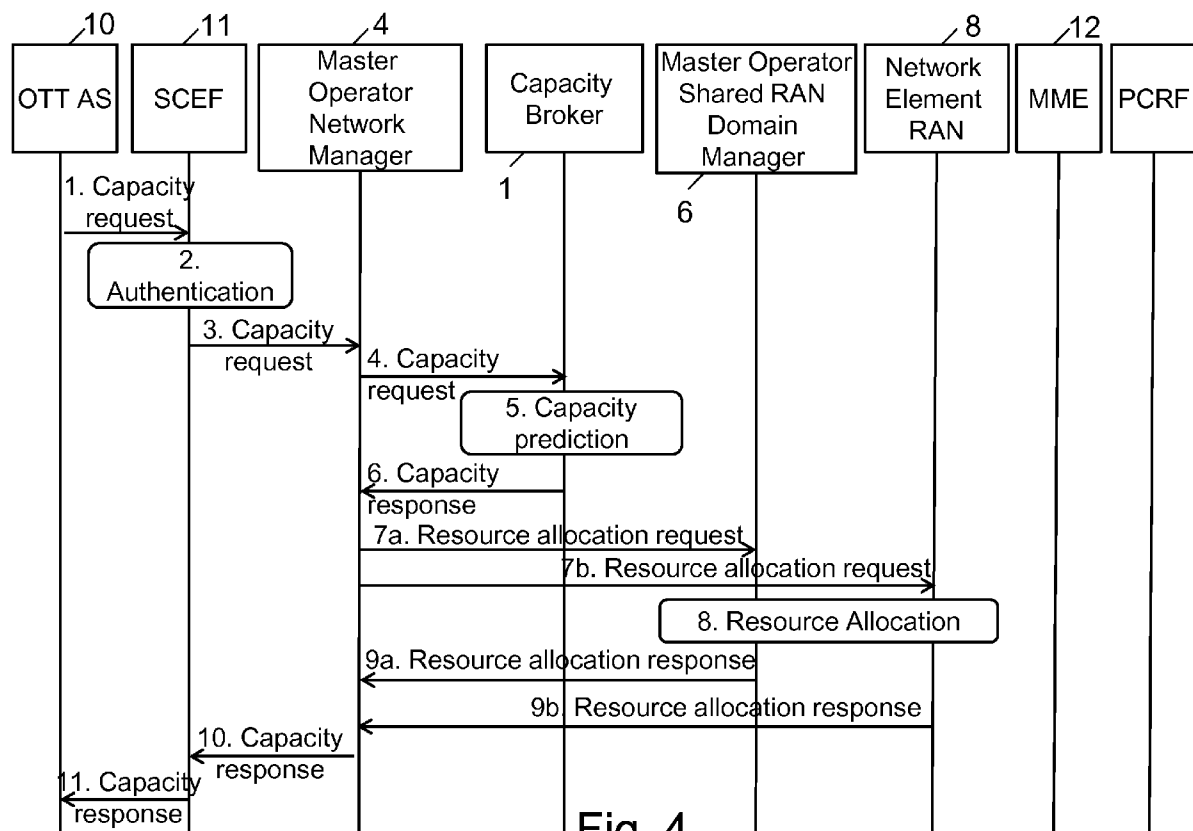


Fig. 3



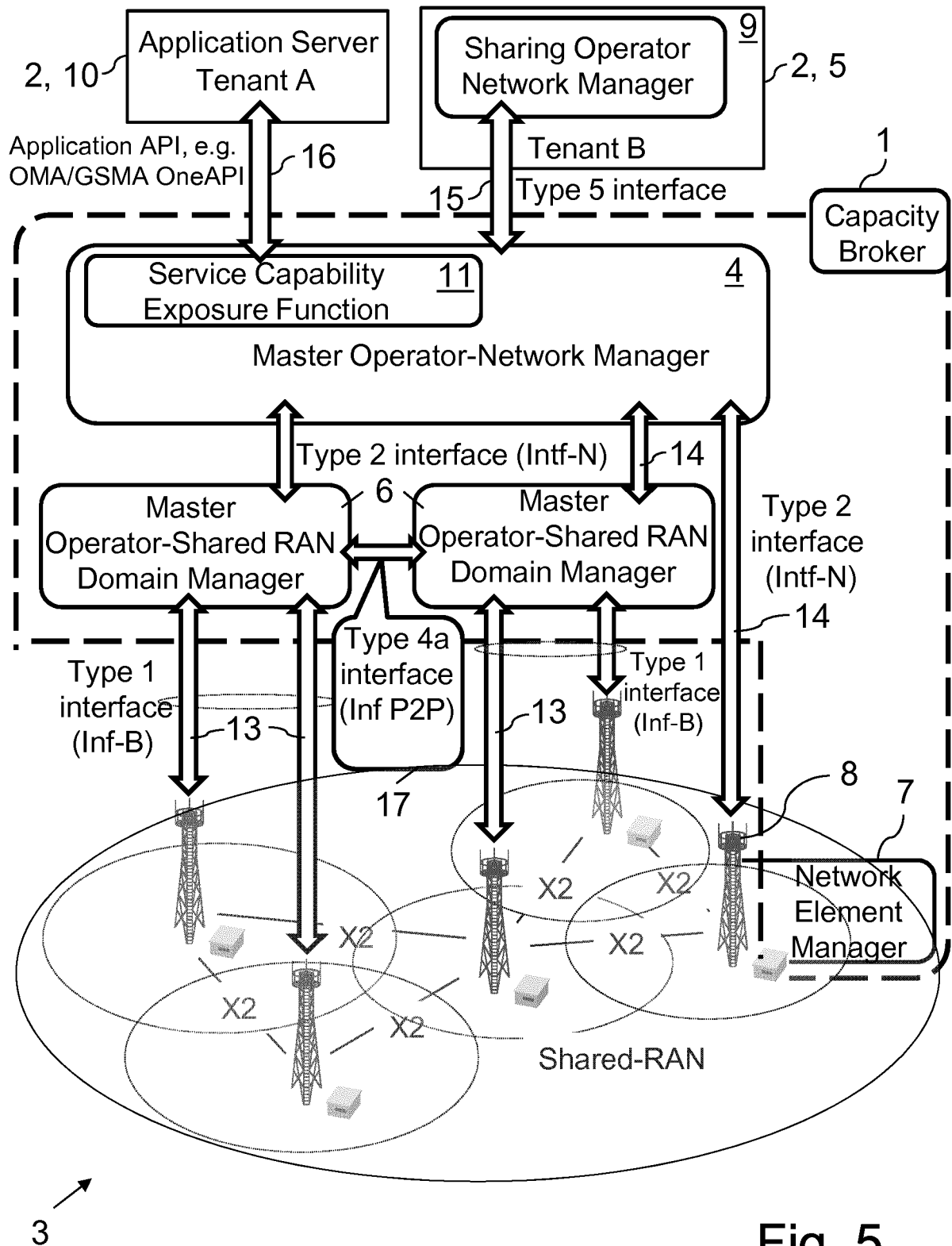


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/063018

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W28/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/303114 A1 (AHMAD SAAD [CA] ET AL) 14 November 2013 (2013-11-14)	1-3,5, 7-15
Y	paragraphs [0083] - [0088], [0122] - [0125], [0150] - [0155]; figures 9, 10, 11	4,6
X	----- US 2015/003413 A1 (MCKIBBEN BERNARD [US] ET AL) 1 January 2015 (2015-01-01)	1,2,7,15
A	paragraphs [0028], [0035] - [0039]; figure 5	3-6,8-14
Y	----- US 2012/026961 A1 (PITTMANN FRANK [DE] ET AL) 2 February 2012 (2012-02-02)	4
A	paragraphs [0082], [0083]; figure 3	1-3,5-15
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 February 2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/063018

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014/060424 A2 (NEC EUROPE LTD [DE]) 24 April 2014 (2014-04-24)	6
A	page 4, lines 1-12; figure 2 page 4, line 29 - page 5, line 32 page 12, line 23 - page 13, line 8 -----	1-5,7-15
A	WO 2015/070909 A1 (NOKIA SOLUTIONS AND NETWORKS MAN INTERNAT GMBH [DE]) 21 May 2015 (2015-05-21) page 4, lines 6-24 page 5, lines 1-19 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/063018

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