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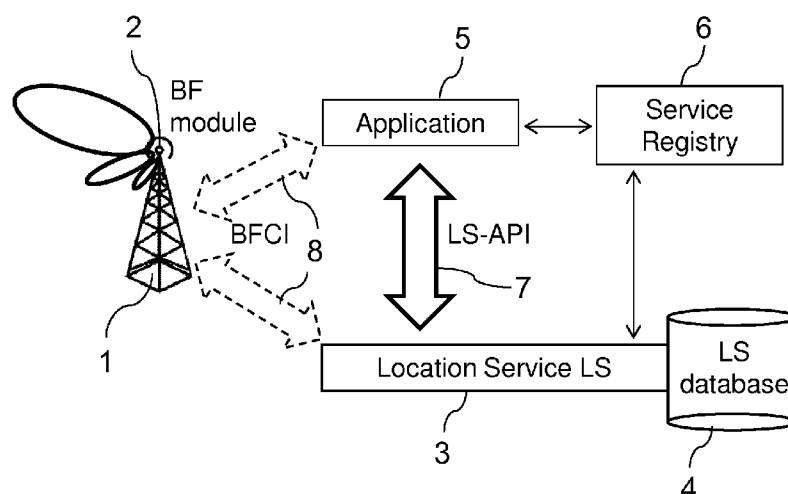


Fig. 1

(57) **Abstract:** The invention describes a device, a system and a method for providing location information within a mobile network with a mmWave communications deployment. Operator-owned, manufacturer's and third party's applications can access the proposed location service in order to retrieve and/or store user's terminal location information from and to the network. In particular, the proposed method allows the mobile network operator to compute the user's terminal location information (e.g., geolocation) by leveraging mmWave directional communications. Conversely, a mmWave access point's controller can use pre-computed location information of a mobile station to speed up the beamforming procedure and signal synchronization with such station. The invention specifies the system communication architecture, providing details on each component and their operations, as well as the data model involved in the communication between different interfaces across service platform, and the application that needs to use the geolocation information.





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LOCATION OF USER IN MMWAVE CELLULAR ENVIRONMENTS

The present invention relates to a method for providing location information within
5 a mobile network with beamforming characteristics, wherein said network
comprises at least one access point or base station that includes a beamforming
module. Furthermore, the present invention relates to a device and a system for
providing location information within a mobile network with beamforming
characteristics.

10 mmWave technologies (also known as mm-waves or millimeter-waves or
mmWaves) are gaining momentum in the emerging mobile network deployments
as the most promising communication medium for ultra-dense environments. Short
wavelength transmissions ensure a higher spectral efficiency, while minimizing the
15 path-loss impairment, thus enabling the ultra-capacity feature of mmWave
communications. However, high-frequency connections require directional
transmissions incurring in a number of design challenges. In particular, advanced
beamforming mechanism have been proposed and devised by following tracking
and tracing procedures. In particular, an incoming user interested in the available
20 ultra-capacity starts a so called 'engagement' procedure in order to connect with
the mmWave access point. The mmWave access point needs to identify the user's
terminal location for synchronization purposes, i.e. to hook the terminal's
synchronization signal and to initiate the handshake process. Once the user's
terminal is successfully connected to the mmWave access point, tracking and
25 tracing procedures allow obtaining the detailed position of the terminal and enable
terminal movements without incurring in connection loss.

Examples considering the mmWave specifics are provided by the IEEE 802.11ad
standard (cf. IEEE 802.11ad standard: "Enhancements for Very High Throughput
30 in the 60 GHz Band") and the WiGig standard (cf. Wireless Gigabit Alliance, Inc.,
"WiGig MAC and PHY Specification"), which aim to offer ultra-capacity facilities by
the means of 60 GHz band using single carrier and OFDM modulations and
exhibiting up to 6.7 Gbps (in case of 80211ad). In these standards, bidirectional
sequences of beamforming training frame transmission are devised in order to

sweep all spatial sectors and facilitate the necessary signaling. The protocol takes into account sector-level sweep, beam refinement protocol and beam tracking. When the beacon is sent, several sector sweep frames are transmitted as training signals in order to measure the quality of the received frames using a quasi-
5 omnidirectional beam-pattern. Based on the feedback, the sector with the highest channel gain is selected and used for the next transmissions. Once the transmitter and receiver are aligned, the beam refinement protocol starts iterative refinements of the beamforming configuration to face signal attenuations due to dynamic obstacles and/or channel impairments. For both protocols, special frames are
10 used to train the beamforming configurations.

While this basic protocol, already proposed and standardized, provides a good baseline, its usage and the interaction with the application layer, i.e. how the application layer can take advantage of user locations and beamforming
15 operations is still open. Methods that can enhance the discovery procedure, in terms of speed during the user discovery phase as well as the communication efficiency are desirable since they play a key-role in several user-related cellular operations. Unfortunately, there is no clear view on how to relate the beamforming discovery and the application and how they could be inter-connected to improve
20 the association process for particular applications. Conversely, applications may take advantage from using the antenna directivity to exploit the user mobility statistics for a particular area of interest.

In view of the above it is an objective of the present invention to improve and
25 further develop a method, a device and a system for providing location information within a mobile network with beamforming characteristics in such a way that the efficiency of a user terminal's discovery procedure is improved.

In accordance with the invention, the aforementioned objective is accomplished by
30 a method for providing location information within a mobile network with beamforming characteristics, wherein said network comprises at least one access point or base station that includes a beamforming module, the method comprising:

tracing and maintaining user terminals' location information in a location service entity deployed in said mobile network,

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providing location information of a user's terminal from said location service entity to the beamforming module of said at least one access point or base station in order to assist beamforming and association between said user's terminal and said at least one access point or base station, and

- 5 providing location information of a user's terminal from said at least one access point or base station to said location service entity in order to populate, update and/or refine a location information base of said location service entity.

10 Furthermore, the above objective is accomplished by a device for providing location information within a mobile network with beamforming characteristics, comprising:

 a location service entity including means for collecting user terminals' location information, and

- 15 a location service database connected with said location service entity for storing said user terminals' location information,

20 wherein said location service entity is configured to provide location information of a user's terminal to a beamforming module of at least one access point or base station of said mobile network in order to assist beamforming and association between said user's terminal and said at least one access point or base station, and

 wherein said location service entity is configured to receive location information of a user's terminal from said at least one access point or base station in order to populate, update and/or refine said location service database.

- 25 Still further, the above objective is accomplished by a system for providing location information within a mobile network with beamforming characteristics, comprising:

 at least one access point or base station including a beamforming module,

 a location service entity configured to trace and maintain user terminals' location information,

- 30 wherein said location service entity is configured to provide location information of a user's terminal to the beamforming module of said at least one access point or base station via a beamforming control interface in order to assist beamforming and association between said user's terminal and said at least one access point or base station, and

wherein said at least one access point or base station is configured to provide location information of a user's terminal to said location service entity (3) in order to populate, update and/or refine a location information base of said location service entity.

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According to the invention it has been recognized that in the existing prior art solutions the real limitation is represented by the strong relationship between the location service facilities (such as algorithms, database and application platform) and the antenna beamer, which needs to be guided on a real-time basis in order to discover a user terminal and to provide location information. Therefore, embodiments of the present invention perform a clear decoupling between the directional antenna beamer, i.e. the beamforming module, and applications aiming at finding a user terminal and storing the location information. In particular, embodiments enable decoupling the logic to control and configure a small cell deployment, e.g. mmWave-based, from the transceivers elements.

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In particular, embodiments of the present invention relate to a method, a device and a system that connect a mmWave-based small cell deployments to a location service (e.g., in MEC, Mobile Edge Computing, context, implemented by a Mobile edge platform and/or installed in a Mobile edge host) for LTE and emerging 5G networks, which is accessible by applications that can be owned by the network operator, provided by the system manufacturer and/or by a third party. The system leverages the location service enabling the application layer to feed the mmWave access point's beamforming module with relevant information about a user's terminal location in order to start a user terminal engagement phase, and, similarly, exploits the granularity offered by sophisticated beamforming techniques to refine the location estimation and make it available for future network association procedures. According to an embodiment the system enables i) the provisioning of location information (in a specific data model) from the location service in the network to an access point with beamforming capabilities in order to assist the beam steering and association between a user's terminal and the access point, and also ii) the provisioning of user location information (in a specific data model) from an access point to the location service in the network in order to populate/update/refine the information base of the location service.

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Hence, the interplay between an access point, e.g. a mmWave access point, and a location service, e.g. implemented in connection with a MEC system, can benefit both parties in terms of performance and information accuracy. Consequently, embodiments of the invention can speed up the association procedure of a terminal device in a small cell deployment. The only way to achieve similar results would be by adopting the trivial scanning methods proposed in 80211ad and WiGiG, which, however, takes more time and cannot facilitate communication with the application layer.

According to an embodiment of the present invention one or more applications may be enabled to interact with the location service via an interface of the location service entity. In this context it may be provided that the advanced features of beamforming are exposed to these (external) one or more applications, e.g. using a simple semantic based on geographical coordinates. Specifically, the applications may leverage the location service to feed the beamforming module of the access point or base station via the beamforming control interface with information about a user's terminal location.

According to an embodiment an application may retrieve from the location service, e.g. by sending a corresponding request, a location estimation for a user terminal (e.g., through regression solutions), possibly together with a corresponding error estimation. Based on the location estimation received from the location service entity, the application may instruct the beamforming module to perform a scan for the user terminal. Specifically, the received location estimation may feed a search algorithm in such a way that the received location estimation serves as the initial search position.

According to an embodiment the interaction between an application and the location service may be performed as a request/response communication or as a publish/subscribe communication. According to the request/response (or "pull") method, the application may issue the appropriate request message whenever its internal logic needs so, and retrieves the required information from the location service. In contrast, according to the publish/subscribe (or "push") method, the

application subscribes to a notification service, in order to receive the information indicated in the subscription whenever it is available from the location service. As will be appreciated by those skilled in the art, the location service entity's interface towards the application may allow a number of other ways to be exploited.

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According to an embodiment the provision of location information may be performed by using a predefined information and data model, which specifies the allowed logical interactions together with the required input parameters and with the returned output parameters. The predefined information and data model may
10 use a simple semantic based on geolocation (e.g., geographic coordinates) and/or contextual position (room, mall, aisle, etc.).

According to an embodiment of the invention the at least one access point or base station may be implemented as a mmWave access point, where the described
15 location service assisted mobile station engagement is to be particularly useful. However, the at least one access point or base station can also operate by using communications technologies that implement beamforming techniques different from the ones implemented by mmWave technology.

20 According to an embodiment of the invention the system may comprise a location service database that is connected with the location service entity that stores the user location information (geolocation) in the form specified by the implemented information and data model and that is configured to associate a user's location with a user identifier. The user identifier may be represented by a 3GPP identifier,
25 (e.g., IMSI, IMEI, etc.), or may be an alias used by the system to serve for identification purposes.

According to an embodiment the one or more applications may interact with the location service entity via a location service interface and with the beamforming
30 module either directly via a beamforming control interface or through the location service entity. The applications' interactions with the location service entity may serve the purpose of mediating the interactions between the location service entity and the at least one access point or base station. For instance, the applications may be configured to feed a beamforming module with information about a user's

terminal location. In this context it may be provided that an application is implemented as a tracking application in charge of assisting the beamforming module to properly steer the boresight towards a user terminal's location. Generally, the applications may include different kinds of applications, in particular
5 operator-owned, manufacturer's and third party's applications.

According to an embodiment the beamforming module comprises a beamforming control interface that terminates either at the location service entity or at any of the one or more applications.

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When multiple beamforming modules are installed in the system, they may all be connected to the same location service. However, since this increases the complexity of the location service, according to an embodiment it may be provided that each of the multiple beamforming modules connects to a dedicated location
15 service entity.

According to an embodiment of the invention the system may be configured in a MEC deployment. In this case the system may comprise a Mobile edge platform and a Mobile edge host, and the location service may be implemented as a Mobile
20 edge location service, and the one or more applications may be implemented as Mobile edge applications.

According to an embodiment of the device of the present invention the location service entity may comprise means for tracing user terminals' locations within the mobile network. Alternatively, the location service entity may be configured to
25 obtain user location information from an external source.

According to an embodiment of the device the location service entity may comprise an interface towards the beamforming module of the at least one access point or base station of the mobile network. This interface may be configured to
30 enable the location service entity to instruct the beamforming module to scan for a user terminal and to receive back results of the scan from the beamforming module.

According to an embodiment of the device the location service entity may comprise another interface that is configured to enable one or more applications to interact with the location service entity. In the context of this interaction the interface may be configured to enable the applications to use the location service entity to feed the beamforming module of the at least one access point or base station via a beamforming control interface with information about a user's terminal location.

According to an embodiment of the device the location service database may be configured to associate a user's location with a user's identifier.

According to an embodiment the device may comprise an MEC, Mobile Edge Computing, Mobile edge platform and Mobile edge host, wherein the location service entity is a Mobile edge location service provided by the Mobile edge platform or installed in the Mobile edge host. The applications that are enabled to enter act with the location service entity may be implemented as a Mobile edge application installed in the Mobile edge host.

According to a specific embodiment the present invention provides a method for facilitating and exposing the user's terminal position to operator-owned, manufacturer's and third party's applications by means of tracing and maintaining user location information and associated geolocation (e.g., geographic coordinates) and/or contextual position (room, mall, aisle, etc.) in a location service platform, comprising the steps of

- 1) Deploying a location service platform, with an interface to access it and exchange the user's terminal location information using the proposed information and data model;
- 2) Deploying beamforming-capable wireless access points, with an interface to control them and exchange the user's terminal location information using the proposed information and data model;
- 3) Deploying an application that may mediate the interaction between the location service and the wireless access point, through the corresponding interfaces.

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
5 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

- 10 Fig. 1 is a schematic view illustrating a system overview with functional entities and interfaces in accordance with embodiments of the present invention,
- 15 Fig. 2 is a schematic view illustrating a deployment scenario with the BF module being connected to the application in accordance with embodiments of the present invention,
- 20 Fig. 3 is a sequence diagram illustrating location service assisted station engagement in case the BF module is connected to an application in accordance with embodiments of the present invention,
- 25 Fig. 4 is a schematic view illustrating a deployment scenario with the BF module being connected to the location service in accordance with embodiments of the present invention,
- 30 Fig. 5 is a schematic view illustrating a deployment scenario with multiple BF modules, each being connected to a dedicated location service in accordance with embodiments of the present invention, and
- 30 Fig. 6 is a sequence diagram illustrating location service assisted station engagement in case the BF module is connected to the location service in accordance with embodiments of the present invention, and
- 30 Fig. 7 is a schematic view illustrating a deployment scenario in a mobile edge system in accordance with embodiments of the present invention.

Embodiments of the present invention, as described hereinafter in detail, relate to a device, a system and a method for providing location information within a mobile network with beamforming characteristics, in particular with a mmWave communications deployment. Operator-owned, manufacturer's and third party's applications can access the proposed location service in order to retrieve and/or store user's terminal location information from and to the network. In particular, the proposed method allows the mobile network operator to compute the user's terminal location information (e.g., geolocation) by leveraging mmWave directional communication properties. Conversely, a mmWave access point's controller can use pre-computed location information of a mobile station to speed up the beamforming procedure and signal synchronization with such station. Embodiments of the present invention specify the system communication architecture, providing details on each component and their operations, as well as the data model involved in the communication between different interfaces across service platform, and the application that needs to use the geolocation information.

Before returning to the detailed description of embodiments of the present invention, it is noted that, generally, in 3GPP networks the notion of user discovery with respect to a pre-subscribed service is specified by the Proximity-based Services (ProSe), for reference cf. 3GPP TS 23.303, Proximity-based Services (ProSe), Stage 2, Rel.13, March 2016. In ProSe the user subscribes to a particular service associated with a certain location, e.g., an advertising service of a certain brand, or a social application. Once the user's terminal is within the cell proximity of such a service, the network notifies the user to prepare for the service discovery process, which takes place by sending discovery broadcasts to identify the ProSe peer. Although, ProSe shares similarities with embodiments of the present invention with respect to the application/service discovery, the actual ProSe method is very different since it does not involve directional antennas neither need the geolocation of the user's terminal as in the case of mmWave communications.

Fig. 1 is a schematic view illustrating an embodiment of the present invention that relates to a communication method and architecture between a location service, a

mmWave-based small cells deployment and an application. Specifically, the system according to the illustrated embodiment comprises a mmWave access point or base station 1 being equipped with a beamforming (BF) module 2, a Location Service entity or platform 3, briefly denoted LS hereinafter, a Location Service DataBase (DB) 4, a location-aided application 5, a service registry 6, a
5 Location Service API (LS-API) 7 and a beamforming control interface (BFCI) 8.

The BF module 2 is a logic component built in the mmWave access point 1; hence, the terms “BF module” and “mmWave access point” are sometimes used
10 interchangeably hereinafter. In particular, the BF module 2 is in charge of beaming a particular geographical position associated with a user’s terminal. Furthermore, the BF module 2 is in charge of getting the geographical position of a particular user’s terminal already connected to the mmWave access point 1. Once a user (who is not yet connected to the mmWave access point 1) is discovered, the
15 association procedure starts. The BF module 2 might need the user ID information, which may be retrieved from an external entity, by making use of conventional mechanisms. Since it is assumed that a skilled person is sufficiently familiar with such mechanisms for retrieving user ID information from external entities, a detailed description of this aspect is omitted here.

20 The LS 3 is in charge of storing and retrieving user location information (geolocation) to and from the Location Service DataBase (LS-DB) 4. It also offers an API, LS-API 7, to the application 5 in order to enable the application 5 to interact with the LS 3. According to some embodiments, the LS-API 7 may be
25 used to communicate with the mmWave BF module 2 too.

The LS-DB 4 is configured to store the user location information (geolocation) in a particular form, which may be specified by a particular data model explained in more detail below. The LS-DB 4 is directly connected with the Location Service LS
30 3. The database’s 4 primary scope is to associate a user’s location with a user’s identifier, which can be represented by a 3GPP identifier, (e.g., IMSI, IMEI, etc.), or by an alias used by the system to serve for identification purposes and provided by an (external) entity, which is out of the scope of the present invention.

According to the illustrated embodiment the (location-aided) application 5, which may include, but not limited to, operator-owned, manufacturer's and third party's applications, can leverage the location service 3 through the corresponding API 7 to perform and/or enhance their operations. For instance, a special purpose application may implement a discovery algorithm that leverages the BF module's capabilities to get a user's geolocation within the small cells network. Such an application includes a direct or indirect interaction with the BF module 2 to perform advanced beamforming operations. For instance, it could include an advanced procedure to speed-up the user's terminal discovery operations during the association procedure, as will be explained in detail below in connection with Figs. 3 and 6.

The service registry 6 provides information about the available services (e.g., location service) to the applications 5 that are authenticated for the first time, in order to enable the applications 5 to use such services. Applications 5 may interrogate it to discovery available services. As will be easily appreciated by those skilled in the art, beyond the authentication of applications 5 and the provision of information about available services, the service registry 6 may implement additional features, which are, however, out of the scope of the present invention.

The Location Service API (LS-API) 7 is the interface that enables applications 5 to interact with the Location Service 3. The data model and parameters included in the API will be described in detail below.

Finally, the beamforming control interface (BFCI) 8 is the interface terminated at the mmWave BF module 2 that enables communication either with the Location Service 3 or directly with an application 5.

The system according to the embodiment of Fig. 1 can be suitably used in a twofold, quasi bidirectional way: on the one hand it can be used to provide a user terminal's location information from the location service 3 to the mmWave access point 1, either directly or through a dedicated application 5, in order to create an association between the terminal and the access point 1. On the other hand, it can be used to provide the user terminal's location information from the mmWave

access point 1 to the location service 3, either directly or through a dedicated application 5, in order to populate/update/refine the location service's 3 information base.

- 5 As already mentioned above, an application 5 may interact with the Location Service 3 through the LS-API 7, which may be configured to allow a number of different non-exclusive ways to be exploited. These ways may include, but not limited to, that the LS-API 7 implements a request/response or "pull" method, where the application 5 issues the appropriate request message whenever its
- 10 internal logic needs so, and retrieves the required information from the LS 3. Alternatively or additionally, the LS-API 7 may implement a publish/subscribe or "push" method, where the application 5 subscribes to a notification service, in order to receive the information indicated in the subscription whenever it is available from the LS 3.

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- Considering both communication patterns as described above (i.e. the "pull" and the "push" method), a specific information and data model may be implemented for the LS-API 7. For instance, according to an embodiment of the present invention the following logical interactions issued by an application 5 towards the Location
- 20 Service 3 to store or retrieve user terminal's location information may be implemented, as shown in Table 1:

Table 1: Logical Interactions in the LS-API 7

Logical interaction	Input parameters	Returned parameters
getPosition	Location type User ID type + User ID Subscription type Mobility type Tenant ID Time interval	Location type Location info Timestamp User ID type User ID
getIdentity	Location type Area range type Area range Time interval	User ID type User ID Timestamp Subscription type Mobility type Tenant ID
putPosition	Location type Location info User ID type User ID Timestamp Subscription type Mobility type Tenant ID	STATUS code (Success/Failure/Info)
connectivityRequest	User ID	void

- 5 The logical interaction 'getPosition' lends itself to be used in multiple ways: it can be used to request the position of individual user(s) indicated by their user ID, and/or to request the position of a group of users indicated by, e.g., their subscription type, mobility type, tenant ID, etc. The request may include a time interval to get the information multiple times within this time interval.
- 10 The interaction 'getIdentity' may be used to collect the User-ID(s) or group type of the user(s) in the area specified by the respective request. The request may include a time interval to get the information multiple times within the interval.
- 15 The interaction 'putPosition' may be used to provide a new or update an existing entry in the Location service DataBase 4.

Finally, the interaction 'connectivityRequest' may be used to trigger the association procedure with a mobile station. It can be sent only by the LS 3 to an application 5.

5 The table below shows a data model and a resource type according to an embodiment of the present invention that may be used in the logical interactions of the LS-API 7.

Table 2: Information elements in the LS-API

Element / sub-element		Type	Description
Location type		String	It indicates how the location info is provided, among the location types specified below
Localization source		Numeric/string	It indicates which localization mechanism has been used to provide the location information
Location info	Absolute coordinates ^(γ)	Longitude: a°,b'c"; Latitude: d°,e'f"; Altitude: [m]	Longitude in degrees, primes and seconds Latitude in degrees, primes and seconds Altitude in meters above sea level
	Relative coordinates + Reference point ^(μ)	Cartesian (x,y,z) or polar (r, φ, θ) coordinates	Cartesian or polar coordinate system from a reference point
		Longitude: a°,b'c"; Latitude: d°,e'f"; altitude: [m]	Longitude in degrees, primes and seconds Latitude in degrees, primes and seconds Altitude in meters above sea level
	Error estimation ^(γ,μ)	Numeric [m]	It indicates the position estimation within a certain confidentiality interval
	Cell (or sector) ID ^(ζ)	String/numeric	Cell (or sector) Identifier based on operator's policy
	Contextual ^(ξ)	String	Position based on context defined by the operator (e.g., room, hall, aisle, etc.)
Area range type		String	It indicates how the area range is provided, among the range types specified below
Area range	Circular range ^(γ)	Coordinates of center + radius	Coordinates can be absolute or relative
	Rectangular range ^(μ)	Coordinates of opposite vertices	Coordinates can be absolute or relative
	Polygon ^(ζ)	Coordinates of vertices	Coordinates can be absolute or relative
User ID type		String	it indicates how the user ID is provided,
User ID	Subscriber ID (IMSI, TMSI, etc.) ^(γ)	Numeric	Identification of mobile subscribers as per 3GPP TS 23.003

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	Mobile station ID (IMEI, IMEISV)^(γ)	Numeric	Defined by 3GPP TS 23.003
	User alias^(μ)	String / numeric	Identification mechanism within the system based on operator's policy
	IP address^(ν)	Numeric	IPv4 or IPv6 address (IETF RFC 791 and RFC 2460)
Timestamp		Numeric	Time of day based on the time method configured by the operator
Time interval		Start and stop time	Starting and ending time of the interval
Subscription type		String	Describes the service the user has subscribed to
Mobility type		String/ numeric	Defines the mobility characteristics (static, low, high, etc) according to operator's policy
Tenant ID		String/numeric	Identifies the tenant the user belongs to, as per the policy defined by the operator for the tenants served by the system (if any)
NOTES: Parameters in bold are mandatory in the embodiment. However, some of them are mutually exclusive: when the same symbol (γ, μ, ν, ζ, ξ) is applied, those parameters can be specified together.			

As already mentioned above, the BF Module 2 terminates the Beamforming control interface BFCI 8, which may be used by an application 5 to configure the beamforming mechanism. The BFCI 8 may be designed to support a request/response (client/server) communication model, started by an application 5. An information and data model for BFCI 8 the in accordance with an embodiment of the present invention may implement the logical interactions/remote calls illustrated in the following table:

Table 3: Logical interaction in the BFCI

Logical interaction	Input parameters	Returned parameters	Description
Sent to the BF module			
setBeam	Beam power Beam width Beam direction angle (θ) Beam height angle (ϕ)	STATUS code (Success/Failure/Info)	Used to configure the beamforming parameters
isConnected	User ID	Boolean	Used to assess if a user's terminal is associated with the access point
Sent by the BF module			
isConnected	User ID Beam power Beam width Beam direction angle (θ) Beam height angle (ϕ)	Void	Used to convey the beamforming parameters for a user's terminal that gets connected
connectionLost	User ID Beam power Beam width Beam direction angle (θ) Beam height angle (ϕ)	Void	Used to convey the beamforming parameter for a user's terminal that gets disconnected
connectivityRequest	User ID	void	Used to trigger the association procedure with a user's terminal

- 5 The table below shows a data model and resource type used in the logical interactions of the BFCI 8 in accordance with an embodiment of the present invention.

Table 4: Information elements in the BFCI

Element / sub-element		Type	Description
Beam power		Numeric	It indicates the transmitting power used by the mmWave access point
Beam width		Numeric	Angular width of main radiating lobe
Beam azimuth angle		Numeric	Angle of the main radiating lobe's axis on the horizontal plane
Beam tilt angle		Numeric	Angle of the main radiating lobe's axis on the vertical plane
User ID	Subscriber ID (IMSI, TMSI, etc.) ^(y)	Numeric	Identification of mobile subscribers as per 3GPP TS 23.003
	Mobile station ID (IMEI, IMEISV) ^(y)	Numeric	Defined by 3GPP TS 23.003
	User alias ^(μ)	String / numeric	Identification mechanism within the system based on operator's policy
	IP address ^(v)	Numeric	IPv4 or IPv6 address (IETF RFC 791 and RFC 2460)
NOTES:			
Parameters in bold are mandatory. However, some of them are mutually exclusive: when the same symbol (y, μ, v) is applied, those parameters can be specified together.			

- 5 The system described above in connection with Fig. 1 can be modified and deployed following different embodiment options, depending on the endpoints of the Beamforming control interface (BFCI). Whereas one endpoint is always terminated at the Beamforming module, the other can be terminated either at i) the application (connected to the location service through the LS-API), or at ii) the location service.

Fig. 2, where like reference numbers denote like elements as in Fig. 1, illustrates an embodiment where the BF module 2 is connected to a (controller) application 5. In other words, in this configuration, the application 5 has a direct connection with the BF module 2, which allows the application 5 to read and write location

information from and to the location database 4, and then operate the BF module 2 accordingly.

5 Generally, this configuration allows to install multiple BF modules 2 and to connect them to a single application 5. Alternatively, each of the multiple BF modules 2 may be connected to a dedicated application 5.

10 In any case, the illustrated embodiment enables location service assisted mobile station engagement, as will be described hereinafter in connection with Fig. 3. While the embodiment of Fig. 3 specifically relates to mmWave technology, it will be easily appreciated by those skilled in the art that the described location service assisted mobile station engagement can be performed in connection with communications technologies that implement beamforming techniques different from the ones implemented by mmWave technology.

15 In mmWave communications, only those mobile stations (namely UEs, according to the 3GPP terminology) that fall within the LoS (Line of Sight) region of a transmitter can benefit from the highly effective communications. (Potentially, the mmWave transceivers could exploit the first reflected beam as well; still the directivity of the transceivers would play a paramount role.) However, the highly directional antennas reduce the LoS area to a narrow beam in the radiating direction. It is therefore important for a transmitter to “engage” a mobile station before starting the data transmission to and from it. Therefore, a transmitter should acquire the target station in its radiating main lobe to ensure a successful data transmission. There are already different algorithms that enable a transmitter to search for a terminal in the surrounding area by modifying the radiation pattern until the target station is engaged. According to embodiments of the present invention such an operation is supported in two different ways, which are i) decoupling of the logic of the searching algorithm from the transmitter beamforming module, and ii) usage of the location service to get a first estimation of the user’s terminal location (e.g., through regression solutions), used to feed the algorithm initialization.

Fig. 3 is a sequence diagram illustrating location service assisted station engagement in accordance with embodiments of the present invention, applied in the deployment scenario of Fig. 2, i.e. in case the BF module 2 is connected to an application 5. As will be easily appreciated by those skilled in the art, some of the steps described below may be executed in a different sequence or may even be omitted, where applicable.

As shown in Fig. 3, in a first step the network 9 (i.e. an appropriate component within the network that holds the respective information, e.g. MME, Mobility Management Entity) informs the system that a new user is coming under the mmWave BF module's 2 coverage and looking for the directional synchronization signal. The mmWave BF module 2 shall start the discovery procedure. In step 1a, the network 9 sends the trigger to the mmWave BF module 2 and, in step 1b, the mmWave BF module 2 forwards the trigger to the application 5 to start the discovery procedure, with the mobile station ID of the incoming user (hereinafter denoted userID). Alternatively to steps 1a and 1b, the network 9 may send the connection request trigger to the application 5, as shown in step 1c.

Next, shown as step 2 in Fig. 3, the application 5 calls the Location Service 3 to get a location estimation for userID, if available. In step 3, the Location Service 3 replies with the location estimation and the error estimation. These parameters feed the initialization of a searching algorithm. If the user joins the network for the first time, no previous location information are retrieved from the Location Service 3. In this case, the searching algorithm may be initialized with default location values that may be either predefined or may be determined from case to case.

As shown in step 4, the application 5 issues a command to set the transmitter, i.e. the BF module 2, on the initial search position in order to beam the user. The BF module 2 performs a first scan accordingly and sends back the results of this scan to the application 5 in step 5.

If the first scan was not successful, i.e. if the user could not be engaged, the method, based on the search algorithm, proceeds by identifying a new searching area, which is communicated to the BF module 2, as shown in step 6. The

application 5 receives the results of the search task in step 7. If the target station is still not engaged, the sequence is repeated from step 6.

Finally, the desired target terminal will be engaged and the data transmission can start. The final location computed by the algorithm is sent back to the Location Service 3, as shown in step 8, to keep track of the updated user location. In case of discovery failure, however, no position information are stored or updated and the process aborts. This could happen, for instance, if the user is placed behind an obstacle and cannot be reached by the synchronization signal.

As shown in step 9, it may be provided that the Location Service 3 acknowledges the location update.

Turning now to Fig. 4, this figure illustrates an embodiment of the present invention where the BF module 2 is connected to the Location Service, LS, 3 so that an application 5 communicates with the BF module 2 through the LS 3. The corresponding communication flow for location service assisted station engagement in such configuration is described below in connection with Fig. 6.

It should be noted that when multiple BF modules 2 are installed in the system, they can all be connected to one and the same LS 3 shown in Fig. 4, even though the different BF modules 2 may belong to different vendors. However, this will increase the complexity of the LS 3, which shall be able to aggregate consistently the information and dispatch the communications appropriately with different BF modules 2.

In view of the above, an alternative configuration may be implemented in which each BF module $2_1, \dots, 2_n$ connects to a dedicated Location Service 3, resulting in different Location Service entities $3_1, \dots, 3_n$, as depicted in Fig. 5. This increases the complexity of the application 5 though, which has to contact each Location Service 3_i separately and discover through the Service Registry 6 which is the BF module $2_1, \dots, 2_n$ connected.

Fig. 6 illustrates an embodiment of the present invention related to a location service assisted station engagement in case the BF module 2 is connected to the location service 3, as shown in Fig. 4. When the system is deployed as per the configuration described here in connection with the embodiment of Fig. 6, the communication flow undergoes major changes compared to the previously described embodiments, as will be described hereinafter in detail. It should be noted that the application entity 5 could be envisaged as a tracking application in charge of assisting the BF module to properly steer the boresight towards the user location. Further, as will be easily appreciated by those skilled in the art, some of the steps described below may be executed in a different sequence or may even be omitted, where applicable.

In a first step, the network 9 (i.e. an appropriate component within the network that holds the respective information, e.g. MME, Mobility Management Entity) informs the system that a new user is coming under the BF module's 2 coverage and looking for the directional synchronization signal. The mmWave BF module 2 shall start the discovery procedure.

Specifically, in step 1a, the network 9 sends the trigger to the mmWave BF module 2. In step 1b, the mmWave BF module 2 forwards the trigger to the location service 3 to start the discovery procedure with the mobile station ID – userID – of the incoming user. In step 1c, the request is forwarded by the location service 3 to the application 5. Alternatively to steps 1a, 1b and 1c, the network 9 may send the connection request trigger to the application 5, as shown in step 1d of Fig. 6.

As shown in step 2, the application 5 calls the Location Service 3 to get an location estimation for the userID, if available.

As shown in step 3, the Location Service 3 replies with a location estimation and an error estimation. These parameters feed the initialization of a searching algorithm. If the user joins the network for the first time, no previous location information are retrieved from the Location Service 3. In this case, the searching algorithm may be initialized with default location values that may be either predefined or may be determined from case to case.

As shown in step 4, the application 5 sends a start beamforming request to the Location Service 3, including the initial search position (denoted 'area range' in Fig. 6) obtained by the initial application of the searching algorithm together with the user ID.

As shown in step 5, the Location Service 3 translates the command into primitives for the BF module 2 to steer the transmitter beam. In step 6 the BF module 2 (or, to be more specific, the antenna controller of BF module 2) sends back the output information from the first scan, and in step 7 the output information are forwarded to the application 5.

As shown in step 8, based on the search algorithm, a new searching area is identified and communicated to the Location Service 3. The antenna controller/BF module 2 obtains the new search area to scan from the Location Service 3 (step 9). In step 10 the search results are sent to the Location Service 3, and in step 11 the application 5 receives the results of the search tasks. If the target station is not yet engaged, the sequence is repeated from step 9.

As shown in step 12, the desired target terminal is engaged and the data transmission can start. The final location computed by the algorithm is sent back to the Location Service 3 to keep track of the updated user location. In case of discovery failure, no position information are stored or updated and the process aborts. This could happen, e.g., if the user is placed behind an obstacle and cannot be reached by the synchronization signal. Finally, as shown in step 13, the Location Service 3 may acknowledge the location update request.

Turning now to Fig. 7, this figure illustrates a system configuration in an MEC (Mobile Edge Computing) deployment in accordance with an embodiment of the invention. Generally, the MEC technology (as described in ETSI GS MEC 003 V1.1.1 (2016-03): "Mobile Edge Computing (MEC); Framework and Reference Architecture", which is incorporated herein by way of reference) enables third party's application to be installed in the operator's premises, such as the Radio Access Network, and to benefit from dedicated services offered by the mobile

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edge platform (as shown/described in sections 5 and 7.1.2 of the document cited above). One of such services is the mobile edge location service (as described in section 8.3 of the above document), accessible through a dedicated API.

5 In this context, it is noted that the mobile edge computing (MEC) concept can bring intelligence and enhance the operations at the edge of a mobile network. Specifically, MEC provides the facilities (provided by the Mobile edge platform installed in a Mobile edge host) bringing computational power and storage at the edge to enable applications to run in the networks' edge, in proximity to the users,
10 and exploits its privileged location to provide additional services to applications, e.g., user location, radio analytics, etc.

The system proposed in the present invention finds a natural application in an MEC deployment. By referring to the MEC architecture as disclosed in the above
15 document, the configuration illustrated in Fig. 7 can be described as follows, wherein like numerals denote like corresponding elements as in the previously described embodiments:

In the MEC deployment illustrated in Fig. 7, the location service 3 (and the LS
20 database 4) as described in the embodiments above is embodied by the Mobile edge Location Service 3, as described in ETSI GS MEC 013 V0.0.1 (2016-03): "Mobile Edge Computing (MEC); Location Service API" – work in progress, which is incorporated herein by way of reference. Similarly, the LS API becomes the Mobile edge Location Service API 7.

25 The location service 3 is offered by the Mobile edge platform 10 and discovered by applications 5 through the Service Registry 6, included in the platform 10 itself. Here, it should be noted that a mobile edge service, like the Location Service 3, can be offered as well by an application external to the platform 10. Still, such
30 service would be exposed through the platform's 10 service registry 6 and offered through the location service API 7, thus without affecting the described operations.

The controller application would be installed in the mobile edge host 11 as a mobile edge application 5. The mobile edge host 11 is the logical container of the

platform 10 and of the mobile edge application 5. The BF module 2 would be external to the Mobile edge host 11, as shown in Fig. 7.

5 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
10 specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. Method for providing location information within a mobile network with beamforming characteristics, wherein said network comprises at least one access point (1) or base station that includes a beamforming module (2), the method comprising:
- 5 tracing and maintaining user terminals' location information in a location service entity (3) deployed in said mobile network,
- providing location information of a user's terminal from said location service entity (3) to the beamforming module (2) of said at least one access point (1) or base station in order to assist beamforming and association between said user's terminal and said at least one access point (1) or base station, and
- 10 providing location information of a user's terminal from said at least one access point (1) or base station to said location service entity (3) in order to populate, update and/or refine a location information base of said location service entity (3).
- 15
2. Method according to claim 1, further comprising:
- enabling one or more applications (5) to interact with said location service entity (3) via an interface (7) of said location service entity (3),
- 20 wherein said one or more applications (5) leverage said location service entity (3) to feed the beamforming module (2) of said at least one access point (1) or base station via a beamforming control interface (8) with information about a user's terminal location.
- 25
3. Method according to claim 1 or 2, wherein an application (5) retrieves a location estimation for a user terminal from said location service entity (3) and instructs said beamforming module (2) to scan for said user terminal based on a search algorithm that is fed with said location estimation as the initial search position.
- 30
4. Method according to claim 2 or 3, wherein the interaction between said one or more applications (5) and said location service (3) is performed as a request/response communication or as a publish/subscribe communication.

5. Method according to any of claims 1 to 4, wherein the provision of location information is performed by using a predefined information and data model.

5 6. Device for providing location information within a mobile network with beamforming characteristics, the device comprising

a location service entity (3) including means for collecting user terminals' location information, and

a location service database (4) connected with said location service entity

10 (3) for storing said user terminals' location information,

wherein said location service entity (3) is configured to provide location information of a user's terminal to a beamforming module (2) of at least one access point (1) or base station of said mobile network in order to assist beamforming and association between said user's terminal and said at least one
15 access point (1) or base station, and

wherein said location service entity (3) is configured to receive location information of a user's terminal from said at least one access point (1) or base station in order to populate, update and/or refine said location service database (4).

20

7. Device according to claim 6, wherein said location service entity (3) comprises means for tracing user terminals' locations within said mobile network.

8. Device according to claim 6 or 7, wherein said location service entity (3)
25 comprises an interface towards the beamforming module (2) of said at least one access point (1) or base station of said mobile network, said interface being configured to enable said location service entity (3) to instruct said beamforming module (2) to scan for a user terminal and to receive results of the scan from said beamforming module (2).

30

9. Device according to any of claims 6 to 8, wherein said location service entity (3) comprises an interface that is configured to enable one or more applications (5) to interact with said location service entity (3) and to leverage said location service entity (3) to feed the beamforming module (2) of said at least one

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access point (1) or base station via a beamforming control interface (8) with information about a user's terminal location.

10. Device according to any of claims 6 to 9, wherein said location service
5 database (4) is configured to associate a user's location with a user's identifier.

11. Device according to any of claims 6 to 10, comprising an MEC, Mobile Edge
Computing, Mobile edge platform and Mobile edge host, wherein said location
service entity (3) is a Mobile edge location service provided by the Mobile edge
10 platform or installed in the Mobile edge host, and/or wherein said application (5) is
a Mobile edge application installed in the Mobile edge host.

12. System for providing location information within a mobile network with
beamforming characteristics, in particular for executing a method according to any
15 of claims 1 to 5, comprising:

at least one access point (1) or base station including a beamforming
module (2),

a location service entity (3) configured to trace and maintain user terminals'
location information,

20 wherein said location service entity (3) is configured to provide location
information of a user's terminal to the beamforming module (2) of said at least one
access point (1) or base station via a beamforming control interface in order to
assist beamforming and association between said user's terminal and said at least
one access point (1) or base station, and

25 wherein said at least one access point (1) or base station is configured to
provide location information of a user's terminal to said location service entity (3) in
order to populate, update and/or refine a location information base of said location
service entity (3).

30 13. System according to claim 12, further comprising one or more applications
(5) that are enabled to interact with said location service entity (3) via a location
service interface (7) and with said beamforming module (2) either directly via a
beamforming control interface or through said location service entity (3), wherein
said one or more applications (5) may be configured to mediate the interactions

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between said location service entity (3) and said at least one access point (1) or base station.

14. System according to claim 13, wherein an application (5) is implemented as
5 a tracking application in charge of assisting said beamforming module (2) to properly steer the boresight towards a user terminal's location.

15. System according to any of claims 12 to 14, comprising multiple
beamforming modules (2), wherein each of said multiple beamforming modules (2)
10 connects to a dedicated location service entity (3).

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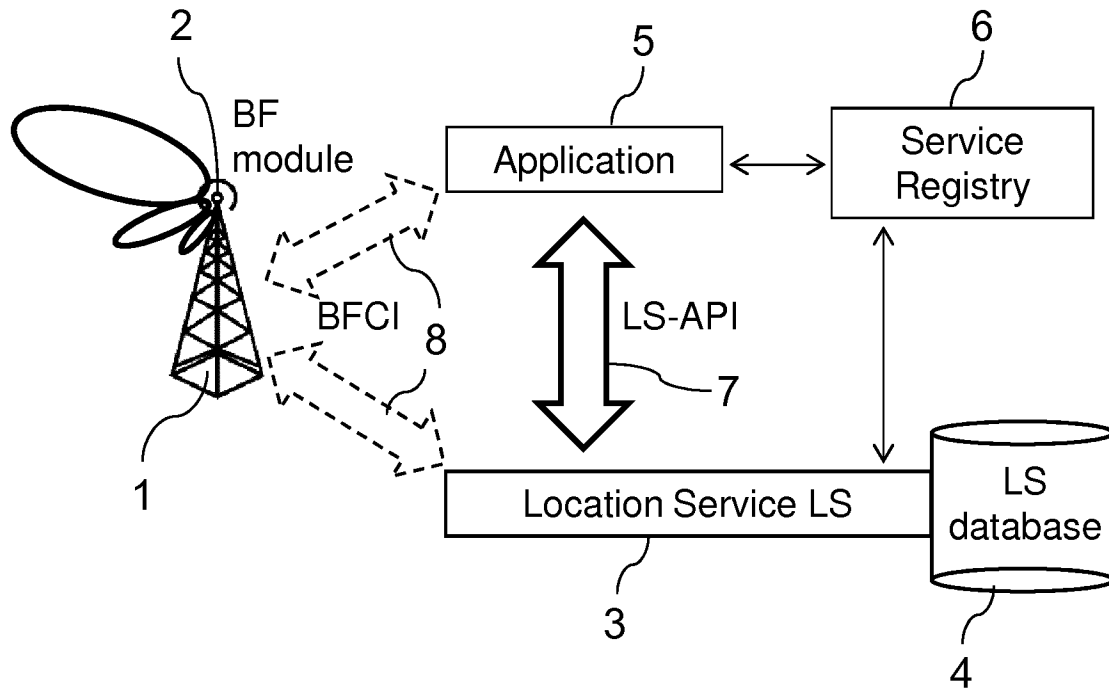


Fig. 1

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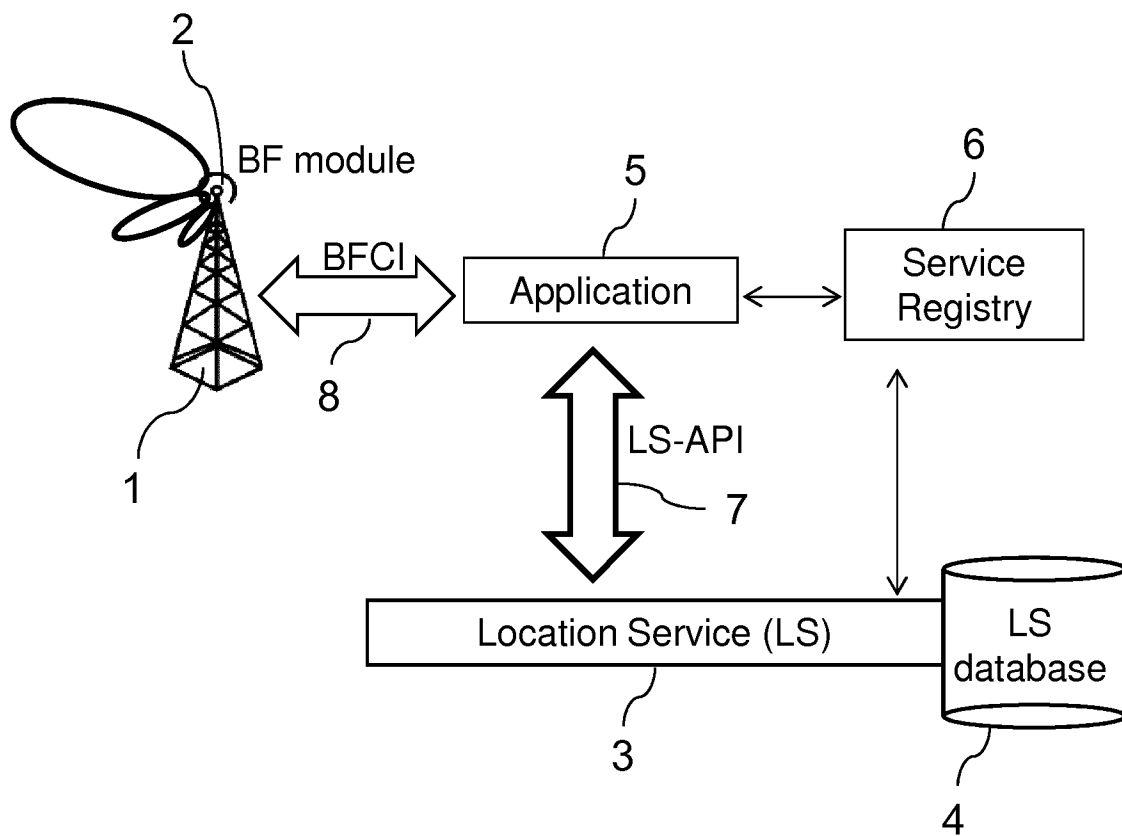


Fig. 2

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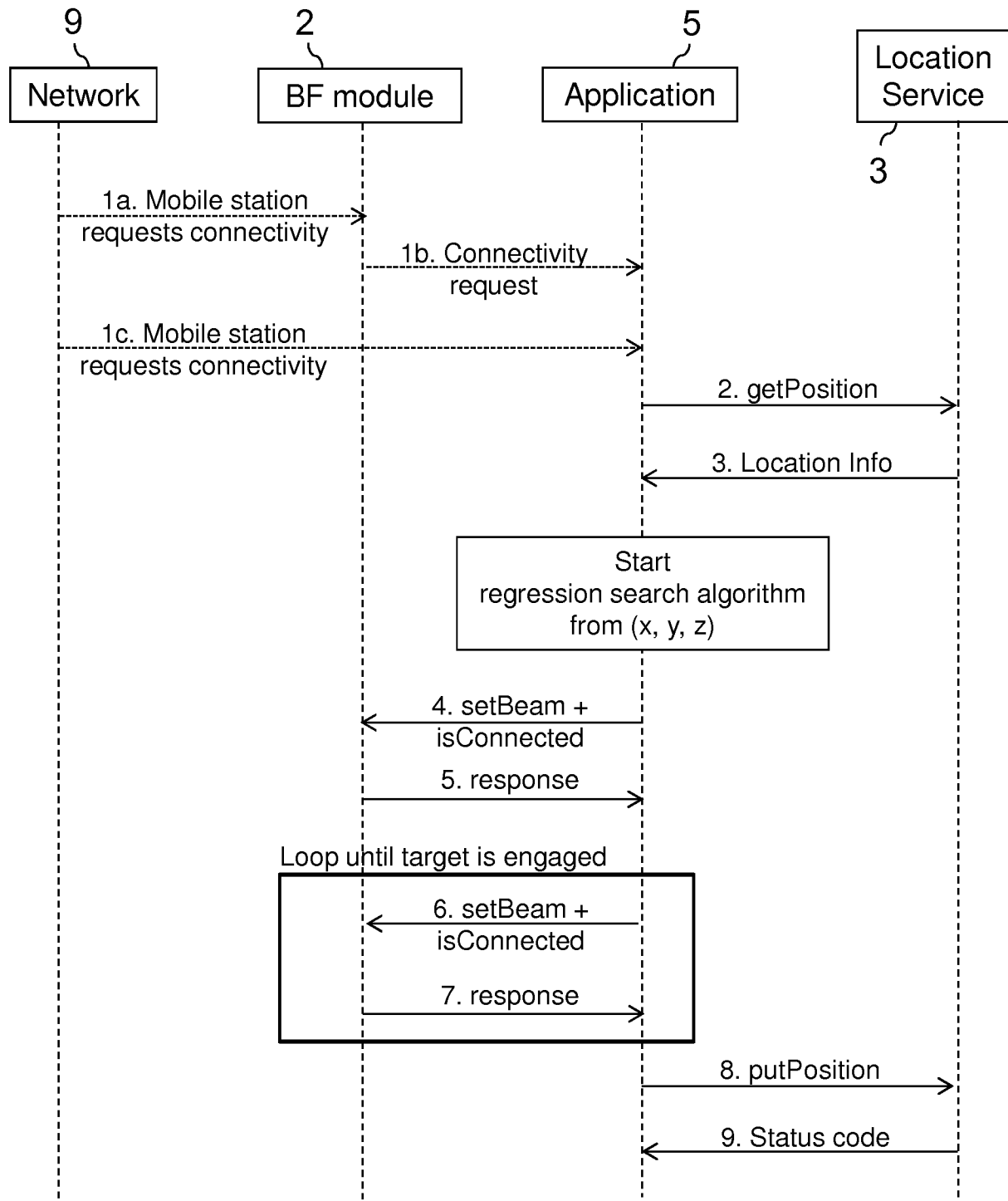


Fig. 3

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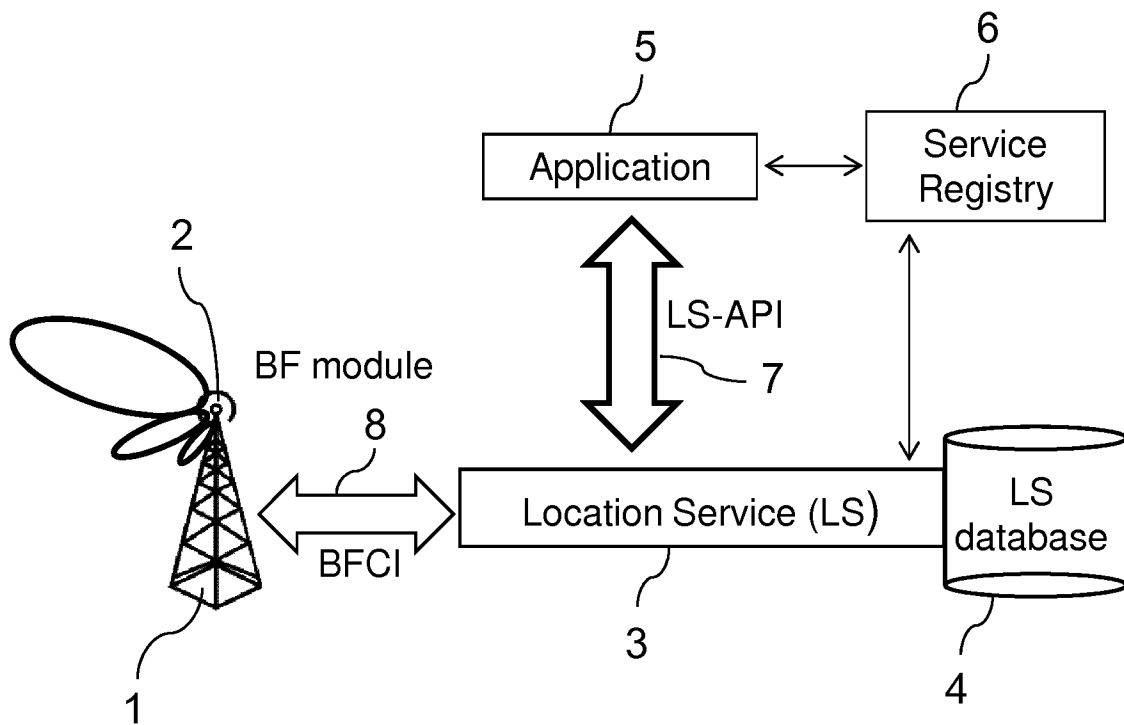


Fig. 4

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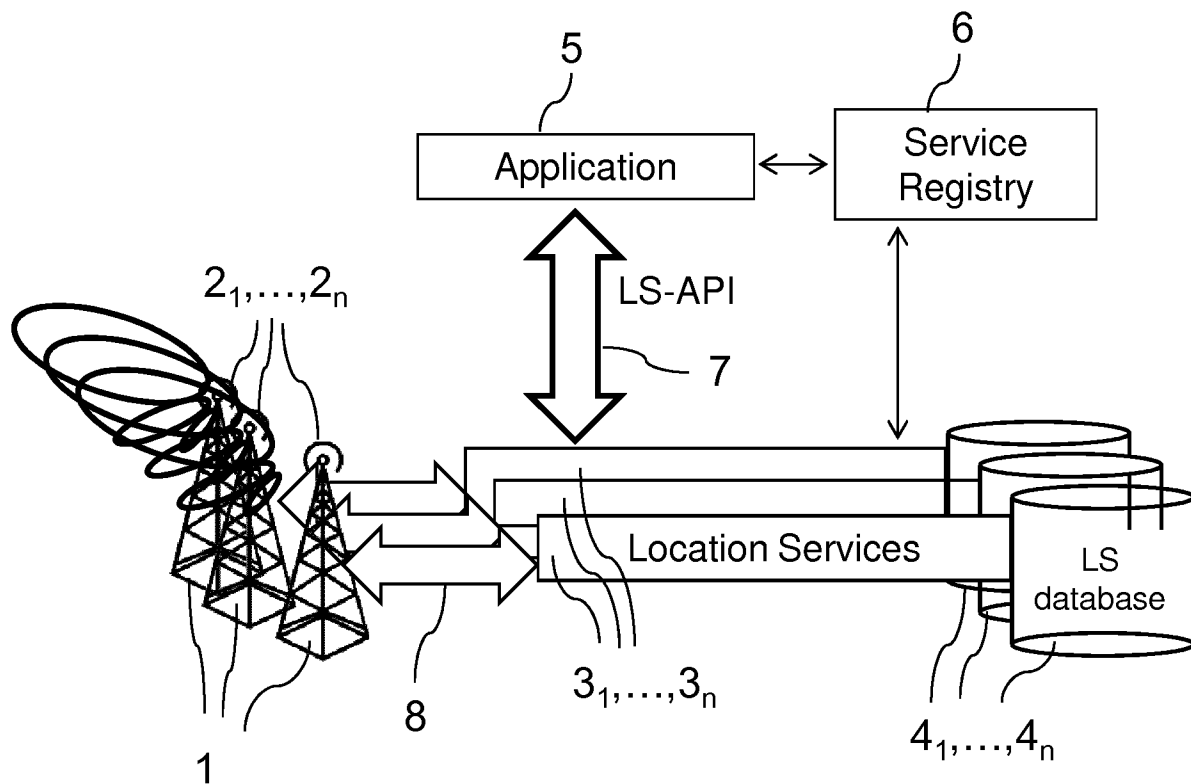


Fig. 5

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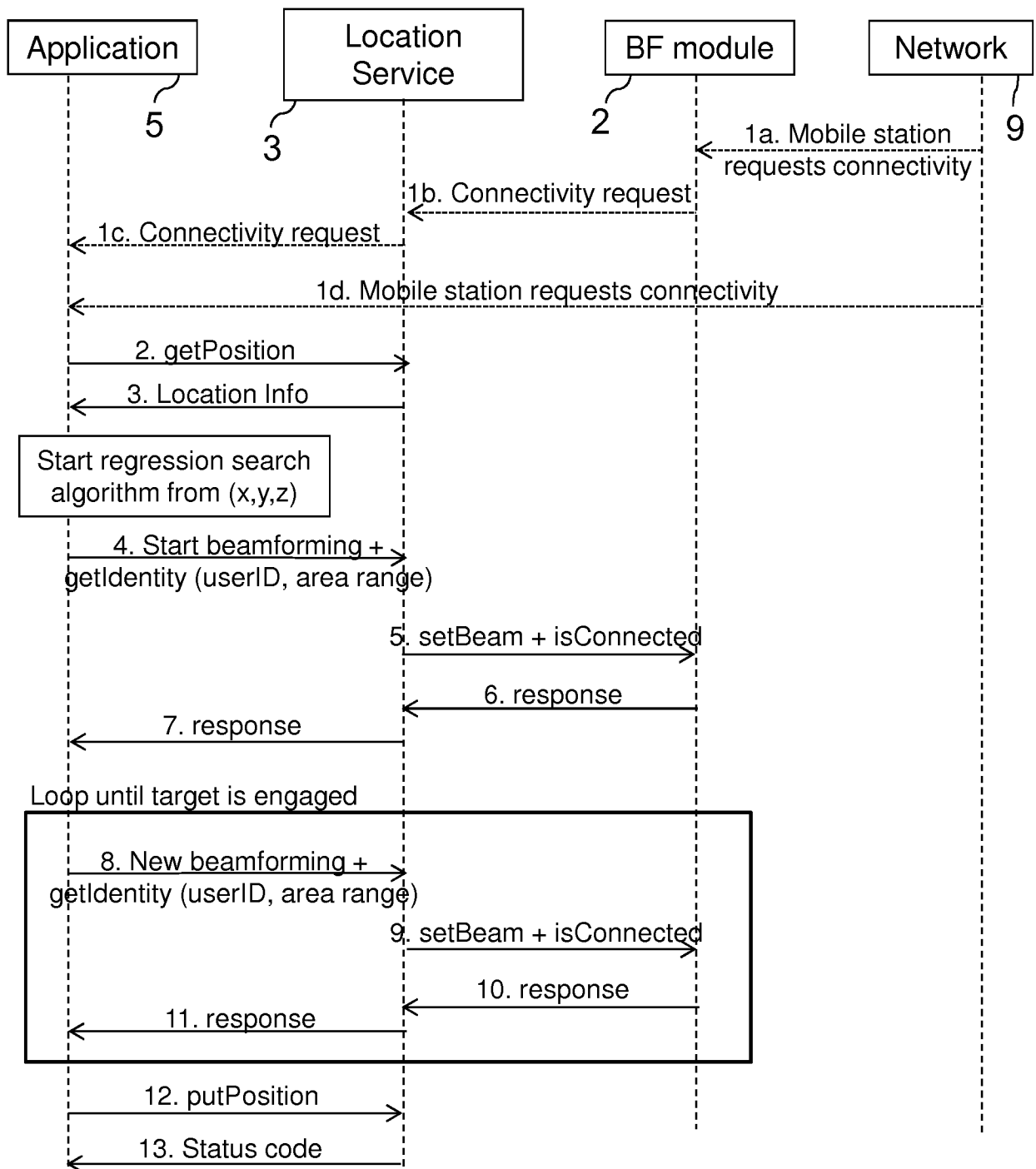


Fig. 6

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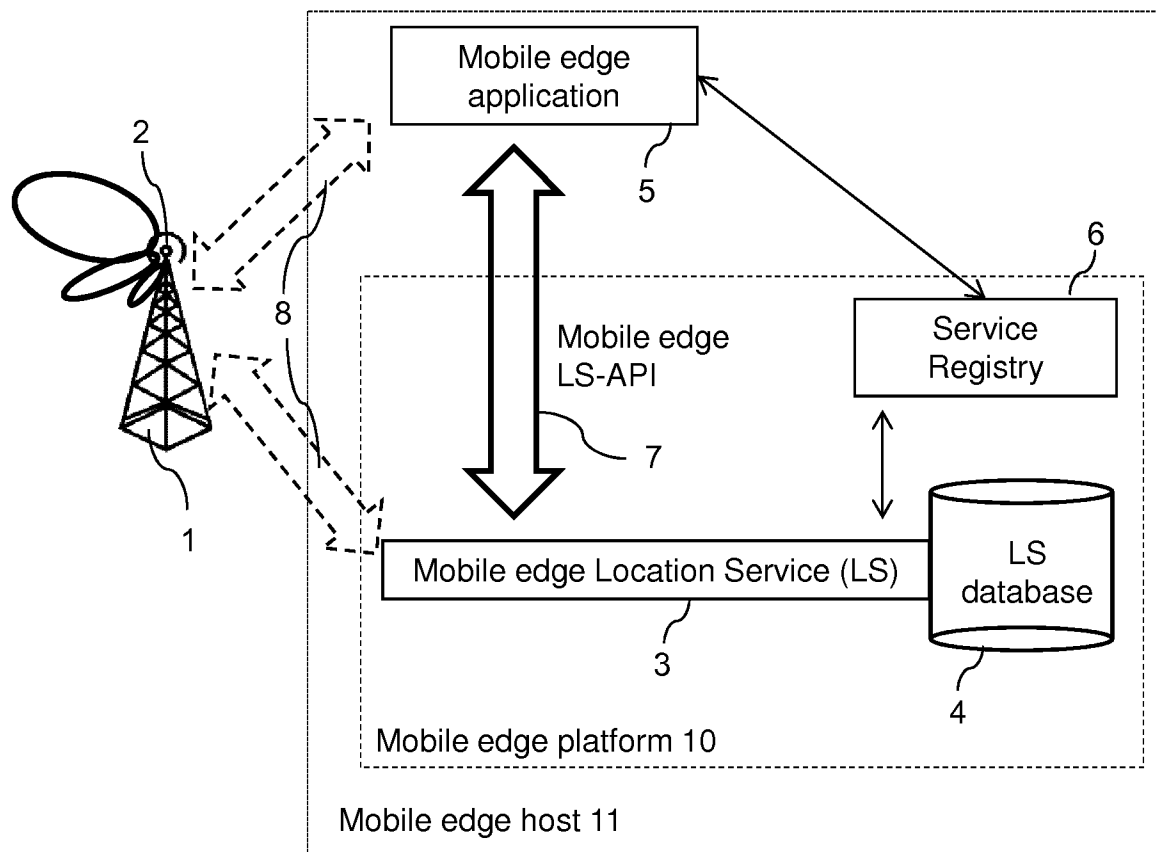


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/069289

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W64/00
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, COMPENDEX, INSPEC, IBM-TDB, 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	Antonio Capone ET AL: "Context Information for Fast Cell Discovery in mm-wave 5G Networks", 9 January 2015 (2015-01-09), XP055369130, Retrieved from the Internet: URL:https://arxiv.org/pdf/1501.02223.pdf [retrieved on 2017-05-03] page 2, left-hand column, paragraph 1 Section IV, paragraph 1 page 3, left-hand column, paragraph 2 - paragraph 3 figures 1, 3 ----- -/-	1-15



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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

3 May 2017

Date of mailing of the international search report

12/05/2017

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/069289

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DI TARANTO ROCCO ET AL: "Location-Aware Communications for 5G Networks: How location information can improve scalability, latency, and robustness of 5G", IEEE SIGNAL PROCESSING MAGAZINE, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 31, no. 6, 1 November 2014 (2014-11-01), pages 102-112, XP011561532, ISSN: 1053-5888, DOI: 10.1109/MSP.2014.2332611 [retrieved on 2014-10-15] "Achieving location awareness"; page 110	1-15
A	----- ZHU XIAOYI ET AL: "Spatial Reuse for Location-Aided Multi-User Beamforming in 60 GHz WPAN Systems", 2013 IEEE 77TH VEHICULAR TECHNOLOGY CONFERENCE (VTC SPRING), IEEE, 2 June 2013 (2013-06-02), pages 1-5, XP032547958, ISSN: 1550-2252, DOI: 10.1109/VTCSPRING.2013.6692764 [retrieved on 2013-12-22] Section IV.A. figure 3	1-15
A	----- CONGZHENG HAN ET AL: "Location-Aided Multi-User Beamforming for 60 GHz WPAN Systems", 2012 IEEE 75TH VEHICULAR TECHNOLOGY CONFERENCE (VTC SPRING 2012) : YOKOHAMA, JAPAN, 6 - 9 MAY 2012, IEEE, PISCATAWAY, NJ, 6 May 2012 (2012-05-06), pages 1-5, XP032202395, DOI: 10.1109/VETECS.2012.6239978 ISBN: 978-1-4673-0989-9 Section IV.A ----- -/--	1-15

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/069289

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GARCIA NIL ET AL: "Location-aided mm-wave channel estimation for vehicular communication", 2016 IEEE 17TH INTERNATIONAL WORKSHOP ON SIGNAL PROCESSING ADVANCES IN WIRELESS COMMUNICATIONS (SPAWC), IEEE, 3 July 2016 (2016-07-03), pages 1-5, XP032940098, DOI: 10.1109/SPAWC.2016.7536855 [retrieved on 2016-08-09] page 1, left-hand column, last paragraph Section II, last paragraph page 2, left-hand column, line 4 - line 22 page 2, left-hand column, last paragraph page 4, right-hand column, paragraph 1 -----	1-15