

DESCRIPTION

TITLE: Method for dynamically allocating resources for radio communication in an interference situation

[0001] The invention falls within the field of radiofrequency telecommunications, on a network comprising base stations communicating with user equipments that may be dispersed over a territory. It focuses on the response to a situation involving frequency jamming of communication between a base station and certain user equipments present over the territory within which the base station and the user equipments are subject to interference. The network in question inevitably has limited resources, notably limited spectral resources, that is to say the base station does not have an infinite choice of frequencies on which to transmit in order to communicate to a particular user equipment, the spectral band being limited, and therefore has to make choices or even compromises in some circumstances. These choices or compromises are complicated by the presence of jamming, which, over part of a territory, makes it difficult to use a certain portion of the initially conceivable communication frequencies.

[0002] The communication networks that are used are mobile telephony cellular communication networks, such as 5G networks or networks developed based on 5G technologies, and also military radiofrequency communication networks based on base stations or a communication master, which may be a local ground master among other local ground masters, or possibly a single communication master, not necessarily on the ground.

[0003] The document "A study of 5G New radio and its vulnerability to jamming", FFI Norwegian Defence Research Establishment 22/00906, discloses various highly preliminary approaches for combating jamming. These approaches are the provision of additional power to user equipments, directional beamforming between the base station and a user equipment, the use of additional antennas for the user equipment, the use of massive MIMO technology (multiple input multiple output, with inter-antenna interference) in order to potentially detect and suppress interference, the changing of physical layer parameters such as for example increasing tolerance to high retransmission rates, or the user equipment switching to an available frequency band not subject to interference.

[0004] The various known anti-jamming solutions are thus at a preliminary stage and cannot be implemented simultaneously or in combination. The solution of a simple frequency fallback is implemented in a highly undifferentiated manner. Performance is impacted by the limitation of the utilized spectral band. The directional beamforming solution is sometimes insufficient, with the jamming being able to remain effective despite the directional beamforming.

[0005] In this context, the invention consists of a method for dynamically allocating resources for radio communication between a base station of a communication network and user equipments.

[0006] The method comprises, in response to detection of jamming between the base station and one or more user equipments, a step of assigning the user equipments to at least two classes of user equipments on the basis of at least one level of impact of the detected jamming on the communication between the respective user equipment and the base station.

[0007] Next, depending on the assignment, the method comprises

- for user equipments in at least one high jamming class, changing at least one frequency band or sub-band for communication thereof with the base station,
- for user equipments in at least one non-high jamming class, keeping the frequency bands and sub-bands for communication thereof with the base station essentially unchanged,
- and configuring beams from the base station to user equipments at least some of which are in the non-high jamming class.

[0008] Spectral resources are preserved as a result of this method: some users escape jamming as a result of the frequency change, and others escape the jamming as a result of the beamforming, and this achieves, overall, a high quality of service despite a moderate resource outlay, since only limited frequency changes are carried out.

[0009] If the beams were already to be formed at the time of detection of the jamming, the beams in the low jamming classes are maintained or even improved by taking into account the jamming and the reconfiguration of the spectral resources that is carried out in parallel.

[0010] And some users who are already spared from the jamming, or who may effectively be spared by improving the beams, according to the invention, keep the same frequency in order to preserve fallback frequencies available to users subjected to very high jamming levels, for which beamforming is not highly effective in terms of sparing them from the jamming.

[0011] If beams were not to be formed at the time of detection of the jamming, beams are created for users who are subjected to jamming without otherwise being in the high jamming class. And a frequency change is carried out for users subjected to the highest jamming levels, and according to the invention only for them, so as make optimum use of the spectral resources.

[0012] Thus, according to the invention, some users experiencing jamming without experiencing it as much as others benefit from a beam configuration and keep the frequency bands that were initially assigned to them, and other users, more impacted than the first users and selected on this basis so as to be in limited numbers, benefit from a new frequency band or frequency sub-band allocation. The limited number of users benefiting from a new frequency allocation makes it possible to manage the resource with limited available frequency ranges, without wasting it.

[0013] The following features are optional and advantageous:

- the change of at least one frequency band or sub-band may be carried out to at least one other band or sub-band identified by a power spectral density measurement and evaluated in a set of user equipments.
- the change of at least one frequency band or sub-band may comprise activating contiguous frequency blocks, notably bandwidth parts in the 5G standard, or else disjoint frequency blocks, or activating frequency blocks so as to aggregate a carrier. The activation may take place at the same time as deactivation of other frequency blocks.
- the beam configuration may additionally comprise modifying beams for a user equipment in a high jamming class after the change of at least one frequency band or sub-band for the communication of said user equipment with the base station, so as to maximize the gain for an uplink or for a downlink to said user equipment.
- the change of at least one frequency band or sub-band may comprise determining a jammed spectral band of a user equipment by analysing the blocks of physical resources allocated by the scheduling processor.

- the assignment to the classes may also be carried out taking into account the beamforming weights of beams formed prior to the detection of jamming between the user equipments and the base station.
- the assignment to the classes may also be carried out using location information or positioning techniques.
- with the network being a 4G or later cellular telephony network, the assignment to the classes may be carried out using information natively collected by the base station.
- the method may additionally comprise a beam configuration, by implementing a MIMO massive antenna function, comprising, in particular for user equipments in the high jamming class, coordinated scheduling of multiple spatially separate beams on the same time and frequency resources.
- the method may additionally comprise a beam configuration that, by implementing a MIMO massive antenna function, opens up beams directed towards users in a low jamming class more widely than towards users in a high jamming class.

[0014] The disclosure of the invention will be continued with reference to the figures, which are presented by way of illustration and in which

[0015] Figures 1 and 2 show jamming situations impacting certain user equipments over a territory covered by a base station.

[0016] Figure 3 shows the use of beamforming in such a situation.

[0017] Figure 4 shows the general process of the invention.

[0018] Figure 5 shows a first step of one embodiment of the invention.

[0019] Figure 6 shows a decision-making step at the end of the preliminary step.

[0020] Figure 7 shows the implementation of the central step of one embodiment of the invention.

[0021] Figure 8 shows one particular aspect of one embodiment of the invention.

[0022] Figure 1 shows, in the context of a cellular telephony network, a base station 10, on the ground or on a building resting on the ground and assumed to be fixed, transmitting in an area of coverage 20 with a frequency range F1. The orderly transmission of communications in a portion of the area of coverage 20 is hampered by a jammer 50, placed on the ground or on a building or vehicle resting on the

ground and assumed to be fixed, which transmits jamming waves in a jamming area 60 that intersects the area of coverage 20. The user equipments present in the area of coverage 20, which are intended to communicate on uplinks and downlinks with the base station 10, are located either outside the jamming area 60, and are classed as unaffected user equipments 25 because their uplink or downlink communication with the base station 10 is not affected by the jamming, or within the jamming area 60, and are then classed as jammed user equipments 65. The base station 10 shown in Figure 1, by way of illustration, transmits only over an angular sector around it, and is therefore present more at the periphery of the area of coverage 20. However, it may also be in the centre thereof, transmitting in all directions. In the same way, the jammer may be omnidirectional, although it often concentrates its power in a given direction.

[0023] Figure 2 shows a similar representation, the base station 10 this time being shown inside its area of coverage 20 - it transmits in all horizontal directions. Figure 2 moreover does not show any user equipment in the jamming area 60. On the other hand, the base station 10 is inside the jamming area 60, whereas it is not in Figure 1. Thus, ultimately, due to the presence of the base station 10 in the jamming area 60, all of the user equipments are jammed user equipments 65, although the jamming level may be variable, from low to high. Figure 2 also uses a directional symbol to show that the jamming is uplink jamming: the signals are transmitted by the jammer 50 into the field that the persons coordinating the jamming are seeking to impact.

[0024] Figure 3 shows the beamforming that is used in response to the detection by the network operators or the computer system thereof, or of the base station 10. Directional beams 90 are used to communicate between the base station 10 and each of the user equipments. These beams are superimposed over a small portion of their length and their width with the jamming area 60 (case in Figure 3, resulting from Figure 2), or some of them are not even superimposed at all therewith, if the base station 10 is not located within the jamming area 60 (case not shown that would result from Figure 1). These user equipments are classed as recovered user equipments 26 because, after the introduction of beamforming, they have a communication quality close to that of the unaffected user equipments 25. The beamforming, for each of them, has the consequence of achieving a higher gain, in the solid angle of the beam, which makes it possible to exceed the jamming power.

This higher gain is obtained in transmission mode (downlink) and in reception mode (uplink). The beamforming also has the effect of developing interference rejection or attenuation (null steering or zero forcing) in the direction of the jammer 50 which, with respect to the base station 10, is in a direction that does not coincide with any of the formed beams.

[0025] Figure 4 shows the general process of the invention. A step E1 of partitioning the user equipments is performed, and this is then followed by a step E2 of defining a configuration strategy for the base station, including the spatial configuration and the frequency configuration, and then by a step E3 of implementing the strategy, and finally a step E4 of allocating the antenna elements. A step E5 following step E4 is indicated to show the return to step E1, because the process is a continuous uninterrupted loop process.

[0026] Figure 5 shows the initial step of the invention, by way of which, in response to detection E0 of suspected jamming for a user equipment, for example by identifying a low signal-to-interference-plus-noise ratio (SINR) on the x-axis in view of a reference signal received power (RSPR) value on the y-axis, the user equipments present over the area of coverage 20 (Figures 1 or 2) are classified into multiple categories. This is step E1 of partitioning the user equipments. This classification may be carried out before the beamforming, or after this, taking into account information measured or obtained once the beams have been formed.

[0027] There may be three categories, or clusters, if these are established before the beamforming, in which case the categories low jamming, medium jamming and high jamming are involved.

[0028] They may also be in two categories, notably if they are established after the beamforming: the category of user equipments with persistent jamming after the beamforming and the category of user equipments that do not require any additional measure beyond the beamforming.

[0029] From the time when one or more user equipments are classified into a medium or strong jamming category (classification with 3 categories), or persistent jamming (classification with two categories), a strategy of combating jamming according to the invention, that is to say through frequency modification, is implemented. Figure 5 however focuses on the formation of the categories.

[0030] To establish these categories, an approach is taken of partitioning all of the user equipments known to the base station 10 as being present within its area of coverage 20, using an artificial intelligence process such as machine learning, which may be a support vector machine (SVM), a K-nearest neighbour (KNN) method, a k-means partitioning, or a decision tree forest method.

[0031] The decision-making process is carried out on the basis of the data that are obtained initially, namely the spectral and spatial characteristics associated with each user equipment and the observed jamming levels.

[0032] Each jammed user equipment is, for partitioning purposes, characterized spectrally and also spatially.

[0033] The spectral characterization is carried out by identifying the spectral bands and sub-bands impacted by the jammer. For this purpose, the method step that is implemented is:

- obtaining and reading the blocks of physical resources allocated by the scheduler in charge of the base station in order to ascertain the jammed spectral band.

[0034] With regard to the spatial characterization, this is carried out with location information if such information is available, or via beam directivity if beamforming has been applied. Doppler-based positioning techniques, uplink time difference of arrival (UTDOA) analysis, IA, etc. are utilized. If beamforming has been undertaken, the amplification factors (weights) of the beamforming or the beam identifiers are spatial location indicators utilized for spatial characterization.

[0035] Figure 5 shows a machine learning-based implementation, carried out by comparing signal-to-interference-plus-noise ratio (SINR) data on the x-axis (logarithmic scale) and reference signal received power (RSRP) data on the y-axis (logarithmic scale) at the times t and $t-1$. The algorithm determines a boundary, a hyperplane, which is here a line, between

- the user equipments considered to be unaffected 100 (SINR, therefore x-axis higher for an RSRP, therefore y-axis proportionately lower)
- and those considered to be jammed 110 (SINR lower for a proportionally higher RSRP).

[0036] The partitioning may be carried out by generally using input data from measurements natively collected in 4G or 5G or later cellular telephony, such as

channel quality information (CQI, Channel Quality Indicator), the number of retransmissions related to the #NACK Not-Acknowledged and the modulation and coding scheme (MCS).

[0037] The partitioning may be based on spectral data (spectral clustering) or involve hierarchical clustering.

[0038] The partitioning that is used leads to clustering of the user equipments, which, in each group, have a strong spectral and spatial similarity and a strong similarity in terms of jamming class.

[0039] Figure 6 shows step E2 of defining the configuration strategy for the base station.

[0040] The table shows 3 clusters, C1 to C3, which are or are not subjected (Y/N) to beamforming B between the base station and the user equipments of the cluster because they are in the category of high jamming or medium jamming (Y) or low jamming (N). Those of the clusters that are subjected to such beamforming are or are not subjected (Y/N), in addition and according to the invention, to a frequency fallback R, if they are in the category of high jamming. Those that are subjected to such a frequency fallback, because they are in the category of high jamming, or persistent jamming, have their initial frequency band F_i replaced by a final band F_f , different from F_i . This may be identical for all of the user equipments undergoing a frequency fallback, and is denoted F_2 .

[0041] Thus, for the user equipments of the cluster C1, neither beamforming nor frequency fallback take place. For the equipments of the cluster C2, beamforming takes place but not frequency fallback, and for the equipments of the clusters C3, C4 and C5, beamforming and frequency fallback to final bands specific for each user take place.

[0042] The method for identifying a fallback frequency band or sub-band for the user equipments identified as having high jamming or persistent jamming may be based on a frequency scan or an artificial intelligence-based learning method, with prediction of the fallback band based on a power spectral density measurement at the scale of all of the user equipments of the cluster for which a frequency fallback is coordinated (the cluster C3).

[0043] Figure 7 shows the implementation of the strategy for combating jamming, defined in Figure 6. This is step E3 of implementing the strategy, in a simplified case with two clusters, a first cluster 100 and a second cluster 110, formed according to step E1 around a base station 10 communicating with user equipments 25 and targeted by a jammer 50 that creates a jamming area 60.

[0044] The beams 90 are formed for all of the user equipments - one beam per user equipment, and the direction and the aperture of the beam are optimized - be these in the cluster 100 or the cluster 110, because the cluster 100 has been evaluated as having low jamming, and the cluster 110 as having strong jamming.

[0045] And, at the same time or shortly thereafter, the frequency band associated with the user equipments 25 of the cluster 110 is modified, in this case changing from the frequency band F1 to the frequency band F2. On the other hand, the user equipments 25 of the cluster 100 all communicate with the base station 10 on the frequency band F1, in the same way as before the implementation of the process of combating the jamming.

[0046] The following three technical means may be implemented individually or in combination.

[0047] 1) The bandwidth parts (BWPs, in 5G cellular communication) are activated on the fallback band, through RRC (radio resource control) signalling.

[0048] 2) The scheduling controller (scheduler) in charge of the base station is notified to restrict certain blocks of physical resources that have been identified as jammed.

[0049] 3) A carrier wave is aggregated by activating the frequency bands selected for the fallback and allocated to one and the same user.

[0050] Next, the beamforming parameters, namely the direction of the beams and their aperture or the pointing angle, are optimized so as to maximize the gain in transmission mode and in reception mode by beams directed towards the area of the user equipment in question in order to counter the jammer. This optimization is carried out using artificial intelligence, for example through Bayesian optimization.

[0051] In addition, interference from the jammer is rejected by sending zeros in the direction thereof from the base station.

[0052] In one exemplary implementation, 400 user equipments are distributed around 3 base stations each comprising three sectors with pointing directions to be configured. An omnidirectional jammer is present: some users are dissatisfied with the quality of the communication, but others are satisfied. Initially, 52.5% of the users are satisfied, and then the orientations of the three antenna sectors are configured, and 73.5% of the users are satisfied. Next, the principles of the invention are adopted, and first of all a beam reconfiguration is carried out for each of the three sectors of the antenna, and 85% of the users are satisfied, and finally, the frequency fallback is carried out, and 92.5% of the users are satisfied.

[0053] Figure 8 shows step E4 of allocating the antenna elements of the relay antenna 10 confronted with the jammer 50, creating a jamming area 60.

[0054] The user equipments in the clusters with low jamming are served primarily by a small number of antenna elements, represented by the panel 410, which, due to their small number, generate continuous coverage over a wide area 91 (seen from the base station, this is a wide angle or a wide solid angle), thereby making it possible to maintain communication with a large number of user equipments with few antenna resources, in this case a small number of antenna elements. This is the case even if the user equipments in question are relatively dispersed in the field, the main thing being that they are impacted little by the jamming.

[0055] Strongly jammed user equipments are served, on the other hand, by directional beams 92, each dedicated to a limited number of user equipments grouped in a narrow area (seen from the base station, this is a narrow angle or a narrow solid angle), and requiring a high number of antenna elements, represented by the panel 420, for generation thereof. The gain is higher due to the beamforming, thereby making it possible to overcome the jamming.

[0056] The scheduling processor also chooses, from among the user equipments and the associated beams to be served, those for which it is able to carry out joint resource allocation (co-scheduling: coordinated scheduling), this being able to improve spectral efficiency.

[0057] Thus, a multi-beam allocation (Multi User-MIMO technology) is performed, and it is then possible to release frequencies that may be reused for other purposes.

[0058] The invention is applicable to 4G or later cellular-technology communication networks, but also to tactical military communication networks.

CLAIMS

1. Method for dynamically allocating resources for radio communication between a base station (10) of a communication network and user equipments (25), the method comprising, in response to detection (E0) of jamming between the base station (10) and one or more user equipments (25), a step of assigning (E1) the user equipments (25) to at least two classes of user equipments on the basis of at least one level of impact of the detected jamming on the communication between the respective user equipment and the base station, and then, depending on the assignment, for user equipments in at least one high jamming class, changing (E3a) at least one frequency band or sub-band for communication thereof with the base station, for user equipments in at least one non-high jamming class, keeping (E3b) the frequency bands and sub-bands for communication thereof with the base station essentially unchanged, and configuring (E3c) beams from the base station (10) to user equipments (25) at least some of which are in the non-high jamming class.
2. Resource allocation method according to Claim 1, characterized in that the change (E3a) of at least one frequency band or sub-band is carried out to at least one other band or sub-band identified by a power spectral density measurement and evaluated in a set of user equipments.
3. Resource allocation method according to Claim 1 or Claim 2, characterized in that the change (E3a) of at least one frequency band or sub-band comprises activating contiguous frequency blocks or activating frequency blocks so as to aggregate a carrier, other frequency blocks possibly being deactivated.
4. Resource allocation method according to one of Claims 1 to 3, characterized in that the beam configuration (E3c) additionally comprises modifying beams for a user equipment in a high jamming class after the change (E3a) of at least one frequency band or sub-band for the communication of said user equipment with the base station, so as to maximize the gain for an uplink or for a downlink to said user equipment.
5. Resource allocation method according to one of Claims 1 to 4, characterized in that the change (E3a) of at least one frequency band or sub-band comprises determining a jammed spectral band of a user equipment by

analysing the blocks of physical resources allocated by the scheduling processor.

6. Resource allocation method according to one of Claims 1 to 5, characterized in that the assignment (E1) to the classes is additionally carried out taking into account the beamforming weights of beams formed prior to the detection (E0) of jamming between the user equipments and the base station.
7. Resource allocation method according to one of Claims 1 to 6, characterized in that the assignment (E1) to the classes is additionally carried out using location information or positioning techniques.
8. Resource allocation method according to one of Claims 1 to 7, characterized in that, with the network being a 4G or later cellular telephony network, the assignment (E1) to the classes is carried out using information natively collected by the base station.
9. Resource allocation method according to one of Claims 1 to 8, characterized in that the method additionally comprises a beam configuration (E4), by implementing a MIMO massive antenna function, comprising, for user equipments in the high jamming class, coordinated scheduling of multiple spatially separate beams on the same time and frequency resources.
10. Resource allocation method according to one of Claims 1 to 9, characterized in that the method additionally comprises a beam configuration (E4) that, by implementing a MIMO massive antenna function, opens up beams directed towards users in a low jamming class more widely than towards users in a high jamming class.