

Method for allocating radio resources in a wireless network, by learning

The invention relates to the field of wireless communication networks comprising a set of devices that communicate between one another and that
5 are organized into groups. The invention relates to a method for allocating radio resources, in particular radio resources taking the form of logic channels, in such a network. In other words, the invention relates to the management of the attribution of radio resources to various groups of the network, with a view to communication.

10 Below, the expression "logic channel" is understood to mean a set of frequency and/or time resources allocated to one or more terminals with a view to communication. A logic channel may be defined by a law defining frequency hops as a function of time. For example, a logic channel is defined by a preset frequency channel for each time interval, in a sequence
15 comprising a plurality of time intervals.

In a wireless network composed of devices that communicate with one another, the communications use radio resources, for example frequency resources or time resources or even resources defined by the power level of
20 the signals emitted to communicate.

For example, in a network organized into groups of devices, each group uses a set of radio resources, for example logic channels, to communicate.

If two groups use the same logic channels to communicate, they may
25 cause mutual jamming or interfere with each other depending on the distance that separates them. It is therefore necessary to take into account mutual interference between groups in order to optimally allocate radio resources to the groups of the network with an overall objective of maximizing the number of communication links that work with a sufficient link-quality level to
30 implement the services provided by the network.

To limit the influence of interference between groups of a given network, one existing solution consists in attributing orthogonal frequency channels to the various groups of the network. This solution is however
5 limited on account of the fact that the available spectral resource is itself most often limited.

Another solution consists in recycling channels spatially i.e. in attributing the same channels to groups that are sufficiently far apart - this requiring the positions of the groups to be known in advance, including in the
10 case of mobile networks. This allocation is then static and valid for the entire length of the mission. This solution has the limits of static allocation to moving objects. If the groups move closer during the mission, they are liable to cause mutual jamming.

It is therefore necessary to make recourse to dynamic solutions that
15 allow the best possible allocation of the channels over time to be achieved. This solution must also be distributed to the groups because it is difficult to imagine centralizing the calculation of this distribution for reasons of latency, of points of vulnerability and of overload of the signalling channels.

A method for allocating resources based on a mathematical algorithm
20 called "trial and error learning" (TEL) is also known. This method is described in scientific publication [1].

This method possesses good convergence properties and is implemented in a decentralized way within each group of the network. Each decision made by a group is based on a state diagram that only requires
25 local information including a metric of the perceived quality of the operation of the communication links within the group. The conditions of convergence of this algorithm however require the quality metric perceived by a group to be a deterministic value. In other words, for each configuration of the network, there must be one and only one quality value per group. However,
30 communication channels are subjected to various random effects (fading,

measurement noise, etc.) that introduce variations in the perceived quality value about its deterministic value. Under these conditions, the method proposed in [1] does not converge to a satisfactory operating point and the performance of the network is degraded.

5 One problem that the invention aims to solve is therefore that of improving the method proposed in [1] in order to achieve a convergence and a satisfactory performance even when the perceived quality metric is perturbed by random effects.

 Another problem to be solved is that of generalizing the method to
10 other trial and error learning algorithms, for example that described in the scientific publications [2] and [3].

 The invention allows the limitations of the solutions of the prior art to be solved by providing a method for allocating radio resources based on a
15 trial and error learning method implementing a state diagram, such as in particular described in references [1], [2] and [3]. The invention in particular consists in introducing a tolerance interval the limits of which are updated automatically in order to take into account the non-deterministic influence of perturbations of the propagation channels in a wireless network. The
20 tolerance interval is taken into account in the decisions made in the transitions of the state diagram. These transitions depend on the current value of the measured quality metric, which corresponds to the overall state of the communication links in a group of the network.

25 One subject of the invention is a method for allocating radio resources within a network of communicating devices organized into groups, the method comprising the following steps executed iteratively by at least one communicating device of each group:

- Selecting a new radio-resource allocation configuration a' to be
30 applied to the devices of the group, with a given selection probability,

or applying a reference allocation configuration $\bar{a}$, with a probability complementary to said selection probability,

- Measuring a metric u' of overall quality of the communication links between devices of the group,
- 5 - Comparing the measured quality metric u' with a reference quality metric $\bar{u}$, the comparison taking into account a tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric, the tolerance interval being defined by a low tolerance threshold δ_- and a high tolerance threshold δ_+ ,
- 10 - Depending on said comparison, making, within a state diagram having a preset number of states, a transition from a start state to an end state,
- Depending on the end state, updating or not the reference quality metric $\bar{u}$ with the measured quality metric u' and/or updating or not the
- 15 reference allocation configuration $\bar{a}$ with the new allocation configuration a' ,
- Depending on said transition and on said comparison, updating a memory containing at least one measured quality metrics so that the values contained in the memory remain stationary,
- 20 - Determining a lower limit and an upper limit of the distribution of the quality metrics so that a given percentage of values are comprised between the lower limit and the upper limit,
- Determining the high tolerance threshold δ_+ on the basis of the upper limit and the low tolerance threshold δ_- on the basis of the lower limit.
- 25 According to one particular aspect of the invention, the update of the memory comprises the following steps:
 - If a new radio-resource allocation configuration is selected,
 - If the reference quality metric is updated, resetting the memory with the measured quality metric,
 - 30 • Otherwise, not updating the memory,

- If the reference allocation configuration is applied,
 - If the measured quality metric is comprised in the tolerance interval, adding the measured quality metric to the memory,
 - Otherwise,
 - 5 ▪ If the reference quality metric is updated, resetting the memory with the measured quality metric,
 - Otherwise, not updating the memory.

According to one particular embodiment of the invention, the quality metric u' of a group is equal to the ratio between a number of communication
 10 links in a working state in the group and the total number of communication links in the group.

According to one particular embodiment of the invention, the radio resources are frequency resources.

According to one particular embodiment of the invention, the state
 15 diagram comprises a satisfactory state and an unsatisfactory state.

According to one particular embodiment of the invention, when the start state is the satisfactory state and a new radio-resource allocation configuration a' is selected:

- a transition is made to the satisfactory state with a transition
 20 probability dependent on the measured quality metric u' and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,
- a transition is made to the unsatisfactory state with a probability
 25 complementary to said transition probability.

According to one particular embodiment of the invention, when the start state is the satisfactory state and the reference radio-resource allocation configuration $\bar{a}$ is applied to the group:

- If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state,
- If the measured quality metric u' is not comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$:
 - a transition is made to the satisfactory state with a transition probability dependent on the measured quality metric u' and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' ,
 - a transition is made to the unsatisfactory state with a probability complementary to said transition probability.

According to one particular embodiment of the invention, when the start state is the unsatisfactory state, a new radio-resource allocation configuration a' is selected and:

- a transition is made to the satisfactory state with a transition probability dependent on the measured quality metric u' and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,
- a transition is made to the unsatisfactory state with a probability complementary to said transition probability.

According to one particular embodiment of the invention, the state diagram furthermore comprises at least one first transition state and one second transition state.

According to one particular embodiment of the invention, when the start state is the satisfactory state and a new radio-resource allocation configuration a' is selected:

- If the measured quality metric u' is lower than or equal to the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the satisfactory state without updating

either the reference quality metric $\bar{u}$ or the reference allocation configuration $\bar{a}$,

- If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ :

5 • a transition is made to the satisfactory state with a given transition probability and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,

10 • a transition is made to the satisfactory state with a probability complementary to said transition probability without updating either the reference quality metric $\bar{u}$ or the reference allocation configuration $\bar{a}$.

According to one particular embodiment of the invention, when the
15 start state is the satisfactory state and the reference radio-resource allocation configuration $\bar{a}$ is applied to the group:

- If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state without updating the
20 reference quality metric $\bar{u}$,
- If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the first transition state without updating the reference quality metric $\bar{u}$,
- 25 - If the measured quality metric u' is lower than the difference between the reference quality metric $\bar{u}$ and the low tolerance threshold δ_- , a transition is made to the second transition state without updating the reference quality metric $\bar{u}$.

According to one particular embodiment of the invention, when the start state is the first transition state, the reference radio-resource allocation configuration $\bar{a}$ is applied and:

- 5 - If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state without updating the reference quality metric $\bar{u}$,
- 10 - If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the satisfactory state and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' ,
- 15 - If the measured quality metric u' is lower than the difference between the reference quality metric $\bar{u}$ and the low tolerance threshold δ_- , a transition is made to the second transition state without updating the reference quality metric $\bar{u}$.

According to one particular embodiment of the invention, when the start state is the second transition state, the reference radio-resource allocation configuration $\bar{a}$ is applied and:

- 20 - If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state without updating the reference quality metric $\bar{u}$,
- 25 - If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the first transition state without updating the reference quality metric $\bar{u}$,
- 30 - If the measured quality metric u' is lower than the difference between the reference quality metric $\bar{u}$ and the low tolerance threshold δ_- , a transition is made to the unsatisfactory state without updating the reference quality metric $\bar{u}$.

According to one particular embodiment of the invention, when the start state is the unsatisfactory state, a new radio-resource allocation configuration a' is selected and:

- 5 - A transition is made to the satisfactory state with a given transition probability and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,
- 10 - A transition is made to the unsatisfactory state with a probability complementary to said transition probability without updating the reference quality metric $\bar{u}$ or the reference allocation configuration $\bar{a}$.

Another subject of the invention is a computer program including instructions for executing the method for allocating radio resources according to the invention, when the program is executed by a processor.

- 15 Another subject of the invention is a storage medium that is readable by a processor, on which is stored a program including instructions for executing the method for allocating radio resources according to the invention, when the program is executed by a processor.

20 Another subject of the invention is a communicating device able to communicate with a plurality of other communicating devices within a network organized into groups, the communicating device comprising means configured to implement the method for allocating radio resources according to the invention.

25 Other features and advantages of the present invention will become more clearly apparent on reading the following description with reference to the appended drawings, which show:

- Figures 1 to 4, four diagrams illustrating the implementation of a first method for allocating radio resources by trial and error learning according to the prior art,
- Figures 5 and 6, two diagrams illustrating the implementation of a second method for allocating radio resources by trial and error learning according to the prior art,
- Figures 7 to 10, the four diagrams of Figures 1 to 4 adapted to implement the method for allocating radio resources according to a first embodiment of the invention,
- Figures 11 and 12, the two diagrams of Figures 5 and 6 adapted to implement the method for allocating radio resources according to a second embodiment of the invention,
- Figure 13, a flowchart illustrating the main steps of implementation of the method for allocating radio resources according to the invention,
- Figure 14, a diagram of transitions between various states of a state machine illustrating the first step of implementation of the method for allocating radio resources according to the invention,
- Figure 15, a schematic illustrating a wireless network organized into groups of communicating devices, each group comprising at least one communicating device configured to execute the invention,
- Figure 16, a schematic illustrating a communicating device configured to execute the invention.

Firstly, a first method for allocating radio resources by trial and error learning according to the prior art is described with reference to Figures 1 to 4. This first method corresponds to the method described in reference document [1] and is referred to below as the TEL method, TEL being the acronym of “trial and error learning”. The principle of this method is the following. A network of mobile or fixed nodes that are able to communicate with one another via a wireless link is considered. The network of nodes is an ad-hoc network. The nodes are organized into groups of nodes. In each

group, a master node is in charge of executing the method for allocating radio resources so as to determine the radio resources that all of the nodes of the group must use to communicate at each time. The radio resources may be frequency resources or may comprise frequency and time resources
5 or even resources defined in terms of emitted signal power level. More generally, in the embodiments of the invention described below the radio resources are considered to be logic channels, as defined in the preamble of this text.

At each time, the master node receives information regarding the state
10 of the wireless communication links within the group. This information is, for example, received in the form of a metric of the overall quality of the state of the communication links. For example, the metric may be equal to the ratio of the number of communication links in a working state to the total number of communication links within the group.

15 A communication link in a working state is a communication link the signal-to-noise ratio and/or the signal-to-interference ratio of which is sufficiently high to allow a communication. Generally, the acceptable noise and/or interference level for a link to be in a working state may depend on the targeted quality of service and on the type of service that it is desired to
20 deliver over this link. At each time, the communication links of the network are perturbed by noise but also by interference generated by other nodes of the network, which communicate simultaneously with the same radio resources or nearby resources.

One objective of the method is to determine, at each time, the best
25 allocation of radio resources for each group in order to maximize the number of communication links in a working state in the entire network. In other words, the method aims to maximize the sum of the quality metrics over all of the groups that the network comprises.

At each time, the master node executes a set of actions that depend
30 on its state within a state diagram specific to the TEL method. According to this method, the state diagram comprises four states: a state called the

satisfactory state C, in which the node is when the resource allocation configuration is satisfactory, a state called the unsatisfactory state D, in which the node is when the resource allocation configuration is unsatisfactory, and two transition states H and W between the satisfactory state C and the
 5 unsatisfactory state D. The first transition state H is what is called an “optimistic” transition state. The second state transition state W is what is called a “vigilant” transition state.

Without loss of generality, other state diagrams are envisageable, in particular state diagrams that comprise only two states C, D or that comprise
 10 more than two transition states.

Figures 1 to 4 illustrate the state diagram of the TEL method and the actions executed by the master node depending on its start state and depending on the value of the received quality metric.

15 According to the notations used in Figures 1 to 4, the quality metric measured at each new time is denoted u' , the reference quality metric stored in memory by the master node is denoted $\bar{u}$, the new resource allocation configuration applied to the group is denoted a' , and the reference resource allocation configuration applied at the preceding time and stored in memory
 20 by the master node is denoted $\bar{a}$. A resource allocation configuration corresponds to a logic channel allocated to the group with a view to communication. The quality metrics have a value that increases with the overall level of operation of the communication links within a group. In other words, the lower the value of the quality metric, the more degraded the state
 25 of the links within the group. In contrast, the higher the value of the quality metric, the more satisfactory the state of the links within the group. Advantageously, the quality metric may be normed so as to ensure its value is comprised in the interval $[0; 1]$.

30 Figure 1 illustrates the possible transitions from the satisfactory state C. From the state C, the master node will either randomly select a new

resource allocation configuration a' different from the reference resource allocation configuration $\bar{a}$, with a preset probability ϵ , or preserve the reference resource allocation configuration $a' = \bar{a}$ with the complementary probability $1 - \epsilon$.

5 The probability ϵ may be constant or variable in order to decrease convergence time. Advantageously, the value of the probability ϵ is set in the interval $[0; 1]$ to a value close to 0, for example $10^{-1}, 10^{-2}, 10^{-3}$. Preferably, the value of the probability ϵ is set to a value that is not too close to 1 in order to not make the system unstable.

10 In the first case ($a' \neq \bar{a}$), the new measured quality metric u' is compared to the reference quality metric.

 If $u' > \bar{u}$, the master node accepts the new configuration a' and the new quality metric u' as references with a preset probability q . The final state remains the satisfactory state C. With the complementary probability $1-q$, the
 15 reference configuration and the reference metric are not modified. The probability q is for example calculated via the following relationships:
 $q = \epsilon^{G(u' - \bar{u})}$ with $G(x) = -\gamma_1 x + \gamma_2$. The constants γ_1 and γ_2 are chosen so that for any value x belonging to the interval $[0, 1]$, $0 \leq G(x) < \frac{1}{2}$. If in contrast, $u' \leq \bar{u}$, then the master node remains in the satisfactory state C and does not
 20 modify the reference values $(\bar{a}, \bar{u})$.

 In the second case ($a' = \bar{a}$), the new measured quality metric u' is also compared to the reference quality metric.

 If $u' > \bar{u}$, the master node makes a transition to the first transition state H and does not modify its reference values $(\bar{a}, \bar{u})$.

25 If $u' < \bar{u}$, the master node makes a transition to the second transition state W and does not modify its reference values $(\bar{a}, \bar{u})$.

 If $u' = \bar{u}$, the master node remains in the satisfactory state C and does not modify its reference values $(\bar{a}, \bar{u})$.

Figure 2 describes the possible transitions from the first so-called “optimistic” transition state H. In the state H, the master node preserves the reference allocation configuration $a' = \bar{a}$ and compares the new measured quality metric u' to the reference quality metric.

5 If $u' > \bar{u}$, the master mode makes a transition to the satisfactory state C and modifies its reference quality metric with the new measured metric: $\bar{u} = u'$.

 If $u' < \bar{u}$, the master node makes a transition to the second transition state W and does not modify its reference values $(\bar{a}, \bar{u})$.

10 If $u' = \bar{u}$, the master node makes a transition to the satisfactory state C and does not modify its reference values $(\bar{a}, \bar{u})$.

Figure 3 illustrates the possible transitions from the second so-called “vigilant” transition state W. In the state W, the master node preserves the reference allocation configuration $a' = \bar{a}$ and compares the new measured quality metric u' to the reference quality metric.

 If $u' > \bar{u}$, the master node makes a transition to the first so-called “optimistic” transition state H.

20 If $u' < \bar{u}$, the master node makes a transition to the unsatisfactory state D.

 If $u' = \bar{u}$, the master node makes a transition to the satisfactory state C.

 The reference values are never updated starting from the second transition state W.

25 Figure 4 describes the possible transitions from the unsatisfactory state D. In the state D, the master node selects a new allocation configuration a' randomly among all the possible configurations, including the reference configuration $\bar{a}$.

 The master node makes a transition to the satisfactory state C with a
30 preset probability p and remains in the unsatisfactory state D with the

complementary probability $1-p$. During the transition to the satisfactory state C, the reference values are updated $(\bar{a}, \bar{u}) = (a', u')$.

The probability p is for example defined by the following relationships:
 $p = \epsilon^{F(u)}$ where $F(x) = -\phi_1 x + \phi_2$, and the constants ϕ_1 and ϕ_2 are chosen
 5 such that for any value of x comprised in the interval $[0,1]$, $0 \leq F(x) < \frac{1}{2K}$. K is
 equal to the number of groups in the network.

Figures 5 and 6 illustrate the transitions in a state diagram comprising
 two states C and D, for implementation of a second method for allocating
 10 radio resources according to the prior art. This second method is described in
 references [2] and [3].

A common point between this second method and the first method
 described with reference to Figures 1 to 4 is the use of a state diagram to
 model the actions implemented by the master node of a group each time it
 15 receives a new quality metric u' . In this second method, the state diagram
 only comprises two states, a satisfactory state C and an unsatisfactory state
 D.

Figure 5 illustrates the possible transitions starting from the
 20 satisfactory state C

In the state C, the master node will either randomly select a new
 resource allocation configuration $a' \neq \bar{a}$ different from the reference resource
 allocation configuration $\bar{a}$, with a preset probability ϵ^c , or preserve the
 reference resource allocation configuration $a' = \bar{a}$ with the complementary
 25 probability $1 - \epsilon^c$. c is an integer strictly higher than the number K of groups
 in the network.

In the first case ($a' \neq \bar{a}$), the master node makes a transition to the
 unsatisfactory state D with a probability $1 - \epsilon^{1-u'}$. With the complementary
 probability $\epsilon^{1-u'}$, the master node remains in the satisfactory state C and

updates the reference allocation configuration and the reference metric $(\bar{a}, \bar{u}) = (a', u')$.

In the second case ($a' = \bar{a}$), the master node compares the new measured quality metric u' to the reference quality metric. If the two metrics are equal to each other, the master node remains in the satisfactory state C. If the two metrics have different values, the master node makes a transition to the unsatisfactory state D with a probability $1 - \epsilon^{1-u'}$. With the complementary probability $\epsilon^{1-u'}$, the master node remains in the satisfactory state C and updates the reference allocation configuration and the reference metric $(\bar{a}, \bar{u}) = (a', u')$.

Figure 6 illustrates the possible transitions from the unsatisfactory state D. In the state D, the master node selects a new allocation configuration a' randomly among all the possible configurations, including the reference configuration $\bar{a}$.

The master node makes a transition to the satisfactory state C with a probability $\epsilon^{1-u'}$ and remains in the unsatisfactory state D with the complementary probability $1 - \epsilon^{1-u'}$. During the transition to the satisfactory state C, the reference values are updated $(\bar{a}, \bar{u}) = (a', u')$.

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The two methods for allocating radio resources, by trial and error learning, according to the prior art, introduced above, have the common drawback of being able to operate correctly only if the quality metric is a deterministic value. In other words, these methods assume that if the same resource allocation configuration is applied to a group of the network at two different times, the measured quality metric will be identical at the two different times.

However, this assumption is invalid in the context of a real network of nodes in which the wireless communication links are subjected to perturbations that are inherent to the used transmission channels and that are variable over time. Specifically, the transmission channels are subjected

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to various random effects such as fading, whether frequency selective fading or not, measurement noise and other forms of perturbations that are variable over time. These effects cause the perceived quality value to vary about its deterministic value. Under these conditions, the methods described above no longer converge to a satisfactory operating point and the performance of the network is degraded thereby.

The invention aims to remedy these problems by introducing tolerance thresholds into the steps of comparing the measured quality metric u' with the reference quality metric.

Figures 7 to 10 show the four diagrams of Figures 1 to 4 adapted to implement the method for allocating radio resources according to a first embodiment of the invention. This embodiment corresponds to an improvement of the method described in the reference document [1] and presented in Figures 1 to 4.

Figures 7 to 10 again show the various transitions between states of the state diagram such as already presented in Figures 1 to 4.

The transitions are modified by introducing a high tolerance threshold δ_+ and a low tolerance threshold δ_- for the comparison between the measured quality metric u' and the reference quality metric. In other words, the transitions and actions undertaken when $u' > \bar{u}$ are now undertaken when $u' > \bar{u} + \delta_+$. Likewise, the test $u' < \bar{u}$ is replaced by $u' < \bar{u} - \delta_-$. Lastly, the test $u' = \bar{u}$ is replaced by $u' \in [\bar{u} - \delta_-, \bar{u} + \delta_+]$.

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In the same way, Figures 11 and 12 show the two diagrams of Figures 5 and 6 adapted to implement the method for allocating radio resources according to a second embodiment of the invention. This second embodiment corresponds to an improvement of the method described in documents [2] and [3] and presented in Figures 5 and 6.

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Figure 13 shows a simplified flowchart of the main steps of implementation of the method for allocating radio resources according to any one of the embodiments, the method being executed continuously by a master node of each group of the network.

5 In a first step 100, the master node selects the radio-resource allocation configuration a' to be applied, whether this be a new configuration, or the reference configuration.

 In a second step 101, the master node receives a new measured quality metric value u' .

10 In a third step 102, a comparison is carried out between the new metric u' and the reference metric. For certain transitions however, step 102 is omitted. This is in particular the case for transitions from the unsatisfactory state D.

 In a fourth step 103, the master node makes a transition in the state
15 diagram, depending on the result of the comparison. This transition may be different depending on the embodiment of the invention. In two particular embodiments of the invention, the transitions are according to those illustrated in Figures 7 to 10 and 11 to 12, respectively. However, the particular examples of states diagrams described in these two embodiments
20 may be generalized to any state diagram comprising at least two states, as will be explained below. The actions prior to the transitions comprise at least one comparison between the measured quality metric u' and the reference quality metric, this comparison taking into account the tolerance thresholds (δ_-, δ_+) .

25 Depending on the transition made and the end state, the so-called reference radio-resource allocation configuration is updated with the new allocation configuration selected in step 100 or not. The value of the reference quality metric $\bar{u}$ is also updated.

30 In a fifth step 104, a memory n containing some of the quality metrics measured in the past is updated depending on the transition made and the end state.

In a sixth step 105, the tolerance thresholds (δ_- , δ_+) are recalculated on the basis of the memory n so as to be updated for the following iteration of the method.

5 Figure 14 schematically shows a portion of a state diagram used to implement the first four steps 100-103 of the method, in a general context.

In a start state X_i , the master node either performs a new resource allocation 201 with a given probability p , or it preserves the reference resource allocation configuration 202 used beforehand, with a
10 complementary probability $1-p$.

Next, a comparison 210 is carried out between the measured quality metric u' and the reference quality metric. Depending on the result of the comparison, a transition 220 is made to an end state $X_{j1}, X_{j2}, \dots, X_{jk}$ with a given transition probability. If the transition probability is different from 1, two
15 transitions to two different end states are possible. In the contrary case, a single transition is possible.

Depending on the transition made, the reference quality metric and/or the reference resource allocation configuration are/is updated 230 or not.

Steps 210, 220 and 230 are carried out identically after step 202 and
20 after step 201. Figure 14 does not show all the possible transitions as it is given by way of illustration so as to explain the general operation of the transitions.

The general state diagram presented in Figure 14 is a generalization of the two particular embodiments of the invention illustrated in Figures 7-10
25 and 11-12, respectively. The number of transitions and states may be different from that shown in Figure 14. In the most general case, the number of states is at least equal to two.

The fifth step 104 of the method according to the invention is now
30 described in more detail. This fifth step consists in updating a memory n containing some of the quality metrics measured in the past. The update of

the memory comprises three different possible actions A1, A2, A3 depending on the transitions of the state diagram. In Figures 7 to 12, for each transition, the reference of the action to be implemented to update the memory n has been indicated below the final state.

5 At each time t , a new quality metric x_t is measured. The state of the memory n at the time t is denoted n_t . The state of the memory n at the time $t+1$ is denoted n_{t+1} .

A first possible action A1 consists in not modifying the memory at the time $t+1$ with respect to the time t : $n_{t+1} = n_t$.

10 A second possible action A2 consist in refreshing the memory with the new quality metric received at the time $t+1$ and in forgetting the old values contained in the memory at the time t : $n_{t+1} = x_{t+1}$.

A third possible action A3 consists in adding to the memory the new quality metric received at the time $t+1$ and in preserving the old values in
15 memory: $n_{t+1} = [n_t, x_{t+1}]$.

Generally, step 104 of the method according to the invention consists in updating the memory n using one of the three actions A1, A2, A3. The memory is updated after a transition of the state diagram in step 103. This
20 update is carried out in the following way, in three steps.

Step 1)

- If a new resource allocation 201 is applied, step 3) is passed to directly
- If the reference resource allocation 202 is applied, step 2) is
25 passed to directly

Step 2)

- If the measured quality metric u' is close to the reference quality metric, in other words if u' belongs to the interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$, then the memory is updated using the action A3,
30
- Otherwise, step 3) is passed to directly

Step 3) if the reference values are updated $(\bar{a}, \bar{u})$, then the memory is updated using the action A2, otherwise the memory is updated using the action A1.

5 The update of the memory n in step 104 of the method according to the invention allows the content of the memory n to be limited to observations that may be considered to be stationary. The calculation of the tolerance thresholds δ_-, δ_+ is the result of an estimation (explained in more detail below). Thus, it is possible to carry out an unbiased estimation of these
10 thresholds when the values contained in the memory n are stationary. For example, when an update of the reference values $(\bar{a}, \bar{u})$ is carried out, subsequently received quality-metric measurements cannot be considered to be stationary with respect to the measurements received beforehand and contained in the memory n . Specifically, the change in reference values is a
15 result of a change in the state of the system from the point of view of the group. This is why, in this case, the memory n is refreshed.

The implementation in step 105 of calculating the tolerance thresholds from the memory n will now be described.

20

The tolerance thresholds δ_-, δ_+ are determined so that the quality-metric values saved in the memory n are for the most part comprised in the interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference value $\bar{u}$ of the quality metric. Thus, in the step of comparing the new measured metric u' with the reference
25 metric $\bar{u}$, a tolerance interval about the value $\bar{u}$ is introduced in order to avoid the undesired fluctuations in the algorithm that random effects affecting the transmission channel would otherwise cause.

When the reference value $\bar{u}$ has been set for a group, there are values
30 δ_+^* and δ_-^* such that, if the state of the system remains stationary, then the interval $[\bar{u} - \delta_-^*, \bar{u} + \delta_+^*]$ contains a certain percentage $(1 - R_1) \times 100$ of the

values of the metric u . One objective of the step 103 is to make the tolerance thresholds δ_+ and δ_- tend to the values δ_+^* and δ_-^* when the size of the memory n increases. If the tolerance thresholds δ_+ and δ_- are smaller than the values δ_+^* and δ_-^* then the system may become unstable. Therefore, the
 5 tolerance thresholds δ_+ and δ_- must converge from values higher than the values δ_+^* and δ_-^* , respectively.

Step 105 firstly consists in determining, by virtue of the memory n , a lower limit, denoted L , and a higher limit, denoted U , of the distribution of the values of the metrics u , such that, with an overall risk lower than R_2 , R_1
 10 percent of the values of u are contained below the limit U and above the limit L .

With these limits, the thresholds may be calculated directly in the following way: $\delta_+ = \max(0, U - \bar{u})$ and $\delta_- = \max(0, \bar{u} - L)$, where $\max()$ is a function that returns the maximum of the two operands. The $\max()$ function is
 15 used to ensure that the two thresholds are indeed always higher than or equal to 0.

When $\bar{u} \in [L, U]$, $\delta_+ + \delta_- = L + U$, always. However, $\bar{u}$ may depart from this interval $[L, U]$, for example when the noise level is too high or after the state of the system is modified. In this case, there is an update of the
 20 thresholds according to which the equality $\delta_+ + \delta_- = L + U$ is no longer verified and $\delta_+ + \delta_- > L + U$ is obtained. It follows that one of the two thresholds is necessarily zero and, to regain the equality $\delta_+ + \delta_- = L + U$, the nonzero threshold is then forced to decrease. For example, imagine that following an update, $\delta_- = 0$, then in this case, it will be required that $\delta_+ = L +$
 25 U . This procedure will necessarily decrease the tolerance interval about $\bar{u}$, which is not recommended. The consequence of this is to cause the group to change reference value in the subsequent iterations of the algorithm.

When the memory n contains few values, the tolerance thresholds
 30 must have a high value that is such that the group is relatively insensitive to the variations in the value of the quality metric. This first of all allows

tolerance-threshold values higher than the values δ_+^* and δ_-^* to be obtained, in order to make the thresholds converge from higher values. This in addition allows the system to be stabilised so that the values received by each group remain stationary. Considering the risks R_1 and R_2 in the estimators, the
 5 obtained limits will naturally be very high when the memory is of small size.

One possible embodiment of step 103 is now described in detail.

The tolerance thresholds are calculated from the memory n and from
 10 the reference value $\bar{u}$ at the current time t . The way in which the tolerance thresholds are calculated may depend on the information contained in the measured quality metric. We present here one embodiment in which the quality metric is calculated from operating values of each link i of the group. A link i is considered to be in a working state if the received value l_i is equal
 15 to 1 and is considered to be inoperable if l_i is equal to 0. Because of random effects present in the system, this operating value is a random variable. More precisely, this variable follows a Bernoulli law of parameter p_i for each link i . With a probability p_i the link works ($l_i = 1$), otherwise it does not work ($l_i = 0$). In this example, the measured quality metric is defined by

$$u = \frac{1}{N_1} \sum_i l_i$$

20 N_1 is the number of communication links in a group.

As the value of the quality metric u is a sum of independent random variables, it is possible to obtain its distribution by performing a convolution of the distributions of the laws of each link i , which depend on their probability p_i . On the basis of the exact distribution of u , it is possible to directly calculate
 25 the value of the ideal limits, which are denoted L^* and U^* . Let us assume that the exact values of the probabilities p_i are known for each link i . In this case, it is possible to calculate the exact distribution, denoted pdf, of the variable u . In other words, for $k \in [1, N_1]$, $\text{pdf}\left(\frac{k}{N_1}\right)$, is the probability k that links are in a

working state. In the following reasoning, $P(k) = \sum_{i=1}^k \text{pdf}\left(\frac{i}{N_l}\right)$ is the probability that k links are in a working state. The value of k such that the probability that k links are in a working state is lower than $\frac{R_1}{2}$ is sought. L^* represents this value. The formal calculation is carried out in the following way

$$L^* = \operatorname{argmax} \left\{ k \mid P(k) \leq \frac{R_1}{2} \right\}.$$

In other words, the value of L^* is the highest value of k such that the probability of obtaining k links that are in a working state is lower than $\frac{R_1}{2}$.

Regarding the other limit U^* , symmetrical reasoning may be applied (to the right of the distribution). The number of links k such that the probability that more than k links are in a working state is lower than $\frac{R_1}{2}$ is sought. The probability complementary to $P(k)$ gives

$$1 - P(k) = \sum_{i=k+1}^{N_l} \text{pdf}\left(\frac{i}{N_l}\right)$$

The probability $1-P(k)$ represents the probability that $k+1$ links or more are in a working state (see the starting index of the sum). Therefore, this underestimates the probability that at most k links are in a working state and may lead to instability in the algorithm. To solve this drawback, the value $1 - P(k - 1)$ is simply used, and the formula for calculating the limit U^* becomes $U^* = \operatorname{argmin} \left\{ k \mid 1 - P(k - 1) \leq \frac{R_1}{2} \right\}$.

In other words, the value of U^* is the minimum value of k such that the probability that at most k links are in a working state, $1 - P(k - 1)$, is lower than $\frac{R_1}{2}$.

Next, the ideal tolerance thresholds are obtained using the relationships $\delta_+^* = U^* - \bar{u}$ and $\delta_-^* = \bar{u} - L^*$. By calculating the tolerance thresholds in this

way, $(1 - R_1) \times 100$ % of the values of u are comprised in the interval $[\bar{u} - \delta_-^*, \bar{u} + \delta_+^*]$ with a probability equal to 1.

One problem is that to obtain the tolerance threshold values (δ_-^*, δ_+^*) , it is necessary to know the parameters p_i of each link i . To calculate these parameters, the memory n is used, which is of finite size; therefore, it is only possible to access estimated values $\hat{p}_i$ of p_i . As a result, it is not possible to calculate L^* and U^* directly and therefore it is not possible to obtain the tolerance values (δ_-^*, δ_+^*) . Only intermediate values L and U are accessible by calculation and allow only the intermediate tolerance thresholds (δ_-, δ_+) to be obtained. To do this, the proposed method is based on an estimation of a confidence interval about the parameters p_i . It is possible with the memory n , to construct a confidence interval, denoted $C_i = [p_i^-, p_i^+]$, about p_i such that p_i belongs to the interval C_i $(1 - R_2) \times 100$ percent of the time.

How this interval is used to calculate the estimated limits of L^* and U^* , which are denoted L and U , will be explained below, after the presentation of the calculation of this interval.

Let $x^i = (x_1^i, \dots, x_M^i)$ be M measurements of the values of the state of a link l_i ; we know that the variable $y_M^i = \sum_k x_k^i$ respects a binomial law and therefore that:

$$p(y_M^i = k | p_i) = \binom{M}{k} (p_i)^k (1 - p_i)^{M-k}$$

Next, a Bayesian approach is used to find the *a priori* law governing the values of p_i . Using the above formula, it may be deduced that the *a priori* law governing p_i is proportional to $(p_i)^k (1 - p_i)^{M-k}$. To obtain a law, it is ensured that this formula is equal to 1 when it is integrated over the support of p_i $([0, 1])$. This gives:

$$p(p_i | y_M^i = k) = \frac{(M+1)!}{k! (M-k)!} (p_i)^k (1 - p_i)^{M-k}$$

This formula is the integrand of the incomplete beta function denoted $B_{\text{int}}(p_i, k + 1, M - k + 1)$. The interval C_i may be directly deduce therefrom with the desired confidence $(1 - R_2)$ in the following way

$$p_i^- = \arg \left\{ p \mid \int_0^p B_{\text{int}}(x, k + 1, M - k + 1) dx = \frac{R_2}{2} \right\}$$

and

$$p_i^+ = \arg \left\{ p \mid \int_p^1 B_{\text{int}}(x, k + 1, M - k + 1) dx = \frac{R_2}{2} \right\}$$

5

Next, it will be explained how to obtain the values of U and L with these approximations of the values of the parameters p_i , i.e. solely with the interval C_i about p_i .

Let three random Bernoulli variables X_1, X_2 and X_3 of parameters $p_i^- < p_i < p_i^+$, respectively, be considered. By definition, the probability that X_1 is lower than X_2 is higher than the inverse, and likewise the probability that X_2 is lower than X_3 is higher than the inverse. Now, let three utility values Z_1, Z_2 and Z_3 be calculated such that, the parameters p_i^- are used for Z_1 , the parameters p_i are used for Z_2 and lastly the parameters p_i^+ are used for Z_3 . It is possible to reiterate the above reasoning with the variables X_j , namely, for example, that the probability that Z_1 is lower than Z_2 is higher than the inverse. If the distributions of Z_1, Z_2 and Z_3 are denoted pdf_- , pdf and pdf_+ then, for example, it is known with a confidence $1 - \frac{R_2}{2}$ that

$$\forall k \in [1, N_l], P_-(k) \geq P(k)$$

where according to pdf_- the probability that at least k links are working is

$$P_-(k) = \sum_{i=1}^k pdf_- \left(\frac{k}{N_l} \right)$$

20 and that

$$\forall k \in [1, N_l], 1 - P(k - 1) \leq 1 - P_+(k - 1)$$

where according to pdf_+ the probability that at most k links are working is

$$1 - P_+(k-1) = \sum_{i=k}^{N_1} \text{pdf}_+ \left(\frac{k}{N_1} \right).$$

More precisely, $P_-(k)$ represents an overestimation, with a confidence, $1 - \frac{R_2}{2}$ of the probability of there being at least k links that are in a working state. Likewise, $1 - P_+(k-1)$ represents an overestimation, with a confidence $1 - \frac{R_2}{2}$, of there being more than k links that are in a working state. It will be
 5 noted that the user has access only to the probabilities P_+ and P_- and not to the probability P . In other words, it is not possible to directly calculate L^* and U^* . However, it is possible to adapt the formulae used to calculate L^* and U^* to the available information, P_- and P_+ , in order to obtain L and U . The adapted formulae are:

$$L = \operatorname{argmax} \left\{ k \mid P_-(k) \leq \frac{R_1}{2} \right\}$$

$$U = \operatorname{argmin} \left\{ k \mid 1 - P_+(k-1) \leq \frac{R_1}{2} \right\}$$

10 L is the maximum value of k such that the overestimation of probability (with a risk of underestimation lower than $\frac{R_2}{2}$) $P_-(k)$ of $P(k)$ is lower than $\frac{R_1}{2}$.

U is the minimum value of k such that the overestimation of the probability (with a risk of underestimation lower than $\frac{R_2}{2}$) $1 - P_+(k-1)$ of $1 - P(k-1)$ that at most k links are working is lower than $\frac{R_1}{2}$.

15 Thus, it may be stated that, with a confidence equal to $(1 - R_2) \times 100\%$, $L \leq L^*$ and $U \geq U^*$. Therefore, the set defined by $[L, U]$ covers at least $(1 - R_1) \times 100\%$ of the values of u with at most the considered risk R_2 .

R_1 represents the portion of the quality-metric values that it is desired
 20 to take into account. R_2 represents the risk of making a mistake in the choice of the tolerance thresholds. The calculated thresholds δ^+ and δ^- are estimators because the limits L and U are themselves estimators. Therefore, there is a risk that that they will be wrong, and R_2 represents this risk. For

example, when the average of a random variable (i.e. the sum of the received values divided by the total number of values) is calculated, there is a risk that the estimator will be above (or below) the statistical average. It is important that this risk is controlled in order to prevent the thresholds from
 5 being too low, which would lead to a general instability in the system because the group would then react to noise, thinking that it represented modifications to the state of the system.

The values of R_1 and R_2 are chosen depending on the parameters of the system.

10 For example, in order to cover a good portion of the possible values of u while remaining sensitive to the changes of possible actions in the network, R_1 may be chosen such that $1 - R_1 > 0.95$.

15 The value of R_2 is, for its part, dependent on the estimation used in the calculation of the thresholds. For example, in the example described above, R_2 may be chosen such that $1 - R_2 \approx 0.6$. The value $1 - R_2$ may be considered the confidence in the estimator used. If $1 - R_2$ is very low, it means that there is a high confidence in the ability of the estimator to find the
 20 sought-after parameter; in contrast, if $1 - R_2$ is very high then the estimation is very circumspect with respect to the received values. It is then necessary to wait many samples before the thresholds converge.

The invention may be implemented in the form of a computer program
 25 including instructions for the execution thereof. The computer program may be recorded on a storage medium that is readable by a processor. The invention may be completely or partially executed by a master node of a group of nodes that communicate within a network. One node corresponds to one device comprising means for communicating with other neighbouring
 30 nodes, for example by way of a radiocommunication link.

The reference to a computer program that, when it is executed, performs any one of the functions described above, must not be understood to solely mean a program application that is executed on a single host computer. On the contrary, the expressions “computer program” and
5 “software package” are used here in a general sense to make reference to any type of computer code (for example a software application, firmware, micro code, or any other form of computer instruction) that may be used to program one or more processors to implement aspects of the techniques described here. The computing resources or means may in particular be
10 distributed (Cloud computing), optionally through peer-to-peer technologies. The software code may be executed by any suitable processor (for example a microprocessor) or processor core or a set of processors, whether they be provided in a single computational device or distributed between a plurality of computational devices (for example such as generally accessible in the
15 environment of the device). The executable code of each program allowing the programmable device to implement the process according to the invention, may be stored, for example, on a hard disk or in read-only memory. Generally, the one or more programs will possibly be loaded into one of the storage means of the device before being executed. The central
20 unit may control and direct the execution of the instructions or sections of software code of the one or more programs according to the invention, which instructions are stored on its hard disk or in its read-only memory or indeed in other of the aforementioned storage elements.

25 Alternatively, the invention may also be implemented by means of a processor that may be a generic processor, a specific processor, an application-specific integrated circuit (ASIC) or a field-programmable gate array (FPGA). Each node of the meshed network and the external equipment associated with the root node may use, to implement the invention, one or
30 more dedicated electronic circuits or a general-use circuit. The technique of the invention may be carried out by a reprogrammable computing machine (a

processor or a microcontroller for example) that executes a program comprising a sequence of instructions, or by a dedicated computing machine (for example a set of logic gates such as an FPGA or an ASIC, or any other hardware module).

5

The invention applies to any meshed network comprising a plurality of nodes that are mobile or fixed communicating devices, which may be located, for example, in vehicles, smart phones or any type of terminal.

10 Figure 15 schematically shows an ad-hoc network comprising a plurality of communicating terminals that are organized into groups. In each group G, at least one terminal N_M plays the role of master node and is configured to implement the method according to the invention with the aim of allocating communication resources, for example frequency resources, to
15 all of the terminals N_M, N_1, N_2, N_3, N_4 of the group G

To this end, as illustrated in Figure 16, the terminal N_M comprises the equipment necessary to implement the invention. It in particular comprises a device MES for measuring, receiving or calculating a metric of the quality of the communication links between terminals of the group. For
20 example, the quality metric may be calculated from information transmitted by each terminal of the group G to the master terminal N_M. This information may comprise measurements of the signal-to-noise ratio on the communication links.

The terminal N_M also comprises a computer CALC or any other
25 equivalent device for executing the invention and a piece of equipment ALLOC for allocating radio resources, which receives, at each time, the resource allocation configuration determined by the computer, and communicates it to an entity outside of the network in charge of controlling resource allocation, or communicates it directly to the nodes of the group G
30 so that they may use the authorized resources, depending on the determined configuration, to communicate with one another.

References

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CLAIMS

1. Method for allocating radio resources within a network of communicating devices (N_1,N_2,N_3,N_4,N_M) organized into groups (G), the method comprising the following steps executed iteratively by at least one communicating device (N_M) of each group (G):
 - Selecting (100) a new radio-resource allocation configuration a' to be applied to the devices of the group, with a given selection probability, or applying a reference allocation configuration $\bar{a}$, with a probability complementary to said selection probability,
 - Measuring (101) a metric u' of overall quality of the communication links between devices of the group (G),
 - Comparing (102) the measured quality metric u' with a reference quality metric $\bar{u}$, the comparison taking into account a tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric, the tolerance interval being defined by a low tolerance threshold δ_- and a high tolerance threshold δ_+ ,
 - Depending on said comparison, making (103), within a state diagram having a preset number of states, a transition from a start state to an end state,
 - Depending on the end state, updating or not the reference quality metric $\bar{u}$ with the measured quality metric u' and/or updating or not the reference allocation configuration $\bar{a}$ with the new allocation configuration a' ,
 - Depending on said transition and on said comparison, updating (104) a memory containing at least one measured quality metric so that the values contained in the memory remain stationary,
 - Determining a lower limit and an upper limit of the distribution of the quality metrics so that a given percentage of values are comprised between the lower limit and the upper limit,

- Determining (105) the high tolerance threshold δ_+ on the basis of the upper limit and the low tolerance threshold δ_- on the basis of the lower limit.
- 5 2. Method for allocating radio resources according to Claim 1, wherein the update (104) of the memory comprises the following steps:
- If a new radio-resource allocation configuration is selected,
 - If the reference quality metric is updated, resetting the memory with the measured quality metric (A2),
 - 10 • Otherwise, not updating the memory (A1),
 - If the reference allocation configuration is applied,
 - If the measured quality metric is comprised in the tolerance interval, adding the measured quality metric to the memory (A3),
 - 15 • Otherwise,
 - If the reference quality metric is updated, resetting the memory with the measured quality metric (A2),
 - Otherwise, not updating the memory (A1).
- 20 3. Method for allocating radio resources according to one of the preceding claims, wherein the quality metric u' of a group is equal to the ratio between a number of communication links in a working state in the group and the total number of communication links in the group.
- 25 4. Method for allocating radio resources according to one of the preceding claims, wherein the radio resources are frequency resources.
- 30 5. Method for allocating radio resources according to one of the preceding claims, wherein the state diagram comprises a satisfactory state (C) and an unsatisfactory state (D).

6. Method for allocating radio resources according to Claim 5, wherein, when the start state is the satisfactory state (C) and a new radio-resource allocation configuration a' is selected:
- a transition is made to the satisfactory state (C) with a transition probability dependent on the measured quality metric u' and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,
 - a transition is made to the unsatisfactory state (D) with a probability complementary to said transition probability.
7. Method for allocating radio resources according to either of Claims 5 and 6, wherein, when the start state is the satisfactory state (C) and the reference radio-resource allocation configuration $\bar{a}$ is applied to the group:
- If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state (C),
 - If the measured quality metric u' is not comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$:
 - a transition is made to the satisfactory state (C) with a transition probability dependent on the measured quality metric u' and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' ,
 - a transition is made to the unsatisfactory state (D) with a probability complementary to said transition probability.
8. Method for allocating radio resources according to one of Claims 5 to 7, wherein, when the start state is the unsatisfactory state (D), a new radio-resource allocation configuration a' is selected and:
- a transition is made to the satisfactory state (C) with a transition probability dependent on the measured quality metric u' and the

reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,

- a transition is made to the unsatisfactory state (D) with a probability complementary to said transition probability.

9. Method for allocating radio resources according to Claim 5, wherein the state diagram furthermore comprises at least one first transition state (H) and one second transition state (W).

10. Method for allocating radio resources according to Claim 9, wherein, when the start state is the satisfactory state (C) and a new radio-resource allocation configuration a' is selected:

- If the measured quality metric u' is lower than or equal to the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the satisfactory state (C) without updating either the reference quality metric $\bar{u}$ or the reference allocation configuration $\bar{a}$,
- If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ :
 - a transition is made to the satisfactory state (C) with a given transition probability and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,
 - a transition is made to the satisfactory state (C) with a probability complementary to said transition probability without updating either the reference quality metric $\bar{u}$ or the reference allocation configuration $\bar{a}$.

11. Method for allocating radio resources according to either of Claims 9 and 10, wherein, when the start state is the satisfactory state (C) and the reference radio-resource allocation configuration $\bar{a}$ is applied to the group:
- If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state (C) without updating the reference quality metric $\bar{u}$,
 - If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the first transition state (H) without updating the reference quality metric $\bar{u}$,
 - If the measured quality metric u' is lower than the difference between the reference quality metric $\bar{u}$ and the low tolerance threshold δ_- , a transition is made to the second transition state (W) without updating the reference quality metric $\bar{u}$.
12. Method for allocating radio resources according to one of Claims 9 to 11, wherein, when the start state is the first transition state (H), the reference radio-resource allocation configuration $\bar{a}$ is applied and:
- If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state (C) without updating the reference quality metric $\bar{u}$,
 - If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the satisfactory state (C) and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' ,
 - If the measured quality metric u' is lower than the difference between the reference quality metric $\bar{u}$ and the low tolerance threshold δ_- , a transition is made to the second transition state (W) without updating the reference quality metric $\bar{u}$.

13. Method for allocating radio resources according to one of Claims 9 to 12, wherein, when the start state is the second transition state (W), the reference radio-resource allocation configuration $\bar{a}$ is applied and:

- 5 - If the measured quality metric u' is comprised in the tolerance interval $[\bar{u} - \delta_-, \bar{u} + \delta_+]$ about the reference quality metric $\bar{u}$, a transition is made to the satisfactory state (C) without updating the reference quality metric $\bar{u}$,
- 10 - If the measured quality metric u' is higher than the sum of the reference quality metric $\bar{u}$ and of the high tolerance threshold δ_+ , a transition is made to the first transition state (H) without updating the reference quality metric $\bar{u}$,
- 15 - If the measured quality metric u' is lower than the difference between the reference quality metric $\bar{u}$ and the low tolerance threshold δ_- , a transition is made to the unsatisfactory state (D) without updating the reference quality metric $\bar{u}$.

14. Method for allocating radio resources according to one of Claims 9 to 13, wherein, when the start state is the unsatisfactory state (D), a new radio-resource allocation configuration a' is selected and:

- 20 - A transition is made to the satisfactory state (C) with a given transition probability and the reference quality metric $\bar{u}$ is updated with the measured quality metric u' and the reference allocation configuration $\bar{a}$ is updated with the new allocation configuration a' ,
- 25 - A transition is made to the unsatisfactory state (D) with a probability complementary to said transition probability without updating the reference quality metric $\bar{u}$ or the reference allocation configuration $\bar{a}$.

15. Computer program including instructions for executing the method for allocating radio resources according to any one of the preceding claims, when the program is executed by a processor.
- 5 16. Storage medium that is readable by a processor, on which is stored a program including instructions for executing the method for allocating radio resources according to any one of Claims 1 to 14, when the program is executed by a processor.
- 10 17. Communicating device (N_M) able to communicate with a plurality of other communicating devices (N_1, N_2, N_3, N_4) within a network organized into groups (G), the communicating device comprising means configured to implement the method for allocating radio resources according to any one of Claims 1 to 14.