

METHOD AND SYSTEM FOR MANAGING RADIO RESOURCES IN A MOBILE COMMUNICATION NETWORK

The invention concerns a method and a system for managing
5 radio resources in a heterogeneous mobile environment. The term
heterogeneous designates radio stations that can be different from one
another, either physically or in terms of telecommunication capacity or
performance, and the term mobile corresponds to a mobile station that
moves in a geographical area comprising the radio stations referred to
10 above, moving from one communication cell to another.

One of the problems faced in a network comprising heterogeneous
mobile radio stations is managing the radio resources enabling the latter
stations to access the radio medium for communications. The current known
solutions of the applicant consist, for example, in dynamic management of
15 the radio links in the vicinity of the mobile station in order to adapt to the
immediate environment and in order to meet a defined level of service. It is
possible to use for this cell changing procedures known as horizontal or
vertical handover or delay-tolerant networks (DTN).

It is also known to use a radio environment map REM, Radio
20 Environment Map or radio mapping, that makes it possible to improve the
choice of the radio link. The REM notably stores environmental data, such as
characteristics linked to geography, available services, spectrum regulation
information, the result of connections made during past experiments, the
levels of interference encountered during past experiments, in order to
25 determine for a mobile user concerned a local optimum in terms of channel
capacity, notably with the aim of having an opportunistic mobile user cohabit
with a primary user.

The prior art proposes different REM uses and techniques. For
each of the solutions on offer, the objective is to optimize the radio allocation
30 for a radio link in order to maximise the compliance with the quality of service

(QoS) constraints, with the possible pitfall of “over-allocating” the radio resource, no loosening of constraints being envisaged.

The document “Cognitive radio resource management exploiting heterogeneous primary users and a radio environment map” by A.Viziello et al - Wireless Netw. (2013) 19:1203-1216 describes a cognitive radio system associated with a REM storing information relating to a primary user in order to make possible or to optimise access to the radio spectrum for one or more opportunistic users. This system involves long time intervals that lead to non-optimum spectrum use.

The framework developed for the MIH/IEEE 802.21 standard for probing a radio environment and dynamic allocation in order to optimise vertical handovers employs radio link quality feedback to aid with the allocation decision, in order to effect dynamic management of radio resources. There is no a priori use of REM, in particular no prediction over a movement of a radio station is envisaged. Information on a link that is deteriorating is fed back whilst awaiting allocation to another link satisfying the required quality of service (QoS) constraint.

The 3GPP LTE/LTE-Advanced mobile communication standard, where LTE stands for “Long Term Evolution”, proposes optimisation of radio allocation in a vicinity: regular updating of a table characterizing the cells in the vicinity of a mobile user is effected in order to optimize the handovers. Here again, this is a question of dynamic management at a given time, with no subsequent use of the REM table created.

Despite the advantages of the prior art solutions, they nevertheless have certain disadvantages, for example:

- sub-optimality, either by feeding back to the mobile user information from probing the radio environment concerning them, or by the use of a REM relating to the environment of the primary users at their position, the allocation solution will be the optimum only for the mobile terminal, and not for a set of mobile stations or nodes in the vicinity; when what is required is to disseminate in the network connection

states beyond the vicinity, this is then costly in terms of signalling and subject to possible updating latency linked to transmission;

- the solution is causal, and on arriving at a position a mobile user is not able to anticipate the situation;
- 5 • the management of "short-term" links is deduced from the preceding point, which induces frequent handovers.

The prior art solutions do not address the following problems:

- the large amount of signalling in relation to an induced reduction of data rate and latency,
- 10 • in most terminals, the probing phase and the transmission phase are effected in a mutually exclusive manner, and so the probing phase or the phase of feeding back characteristics of the radio links is effected to the detriment to the transmission phase.

There is therefore a requirement for a method and a system
 15 making it possible to manage radio resources in order to provide a best possible level of service at the various nodes of a geographic area, taking into account the requirements of the various nodes and an allocation strategy varying in time. More specifically, the technical problem is notably to be able to reconfigure effectively and dynamically when a link is no longer able to
 20 provide the required service, but also to be able to anticipate the failure of links.

In the remainder of the description, the expressions "mobile terminal", "mobile station", and "mobile user" will be used interchangeably to designate the same mobile terminal of a communication network. The
 25 expression "target QoS" designates a quality of service expressed by a communication request sent by a mobile user.

The method in accordance with the invention notably relies on the use of a mechanism conjointly with the use of an experiment REM database storing the radio environment data in accordance with space, time, and
 30 frequency dimensions (3D radio map) in order to manage in a global manner

for a zone the opportunistic access to the available radio links, determining an optimum for a set of users.

The invention concerns a method for the management of radio resources in a communication network R comprising at least one central database REM_C containing information relating to the scheduling of the communication network R at a given time, and one or more mobile stations comprising a database containing information on a radio environment of the mobile station, characterized in that it comprises at least the following steps:

- transmitting a communication request R_q sent by a mobile station to a REM analysis algorithm module and also to a REM_{ri} database of the mobile station,
- analyse using the analysis algorithm the communication parameters contained in the request R_q taking account of the required quality of service (QoS) and of parameters characterizing a radio situation at a given time delivered by the REM_{ri},
- determining if a latency constraint exists in the request R_q,
 - if no latency constraint exists, then transmitting the request R_q to a time-delay step before it is analysed again by the REM analysis module,
 - if a latency constraint exists, deciding on the radio link to use and initiating the communication, and transmitting data and returning a report containing information on events that occurred during the communication.

In accordance with one embodiment, the analysis algorithm comprises the following three phases:

- calculating the available QoS value,
- calculating the probability that the target QoS is supported by the QoS that can be allocated to a link,
- verifying for each frequency/channel of the coverage area of a mobile station the probability that the target QoS constraint will be complied with, and choosing the link to be allocated as a function of that probability value.

The probabilities may be calculated considering a parameter QI characterizing the radio link and by executing the following steps:

- adopting a Gaussian distribution hypothesis,

- the target parameter QI being known in the request Rq, the parameter QI_{LIEN} available on the link being calculated and, with μ_i and σ_i respectively being the mean value and the standard deviation associated with each radio link i , determining the probability that the parameter $QI_{QOS-CIBLE}$ is less than the parameter QI_{LIEN} that can be allocated to a radio link i :

$P_r(QI_{QOS-CIBLE} \leq QI_{LIEN})$ with:

$$P_r(QI_{QOS-CIBLE} \leq QI_{LIEN}) = 1 - \text{erf}\left(\frac{QI_{QOS-CIBLE} - \mu_i}{\sigma_i}\right) \quad \text{where erf is the error function mathematical function,}$$

- knowing the available links and the probabilities for each of those links, applying a cost function and determining the link to be used to satisfy a quality of service of a request Rq.

There may be used as a parameter characterizing a radio link the target data rate $D_{QOS-CIBLE}$ for the required QoS parameter and the calculated available data rate D_{LIEN} on the link.

For the execution of the method there may be used as a quality of service parameter to be complied with any parameter characterizing the quality of service such as the error rate, the bandwidth, the authorised latency.

The method may also comprise the execution of a background task executed on a mobile station outside the step of sending data in order to probe the radio environment of a mobile station, choosing frequency values stored in the REMri and over a widened area comprising the cell containing the mobile station and adjacent cells in order to determine the data of the REMri of the mobile station.

In accordance with a variant embodiment, on reception of priority event information, the analysis algorithm interrupts the current communication and allocates the radio link to the priority communication.

In accordance with another variant, on reception of an event modifying the radio environment during a communication or while establishing a communication link, the information is sent to the analysis algorithm and a modification is sent in return to adapt to the new situation.

5 The invention also concerns a system for the management of radio resources in a communication network R comprising at least one central database REM_C containing information relating to the scheduling of the network at a given time, and one or more mobile stations comprising a database REM_{ri} containing information on a radio environment of the mobile
10 station, characterized in that a mobile station is equipped with a REM analysis algorithm module adapted to receive a communication request R_q sent at least by the mobile station and data specific to the radio environment of said mobile station, a decision module supplying the authorization to initiate a communication and the communication links to be used or the
15 transmission of the request R_q to a time-delay module as a function of a latency parameter contained in the request R_q , a module sending data once the communication is established, a module establishing a communication report in liaison with the database of the mobile station.

20 The analysis module is adapted to execute the following steps, for example:

calculating the available QoS value,
calculating the probability that the target QoS is supported by the QoS that can be allocated to a link,
verifying for each frequency/channel of the coverage area of a mobile station
25 the probability that the target QoS constraint will be complied with, and choosing the link to be allocated as a function of that probability value.

For example, the analysis module is adapted to calculate probability values considering as a quality of service parameter the data rate parameter and to execute the following steps:

30 - adopting a Gaussian distribution hypothesis,

- the parameter $Ql_{QOS-CIBLE}$ characterizing the radio link being known in the request Rq , the Ql parameter Ql_{LIEN} characterizing the link being calculated and, with μ_i and σ_i respectively being the mean value and the standard deviation associated with each radio link i ,

- 5 - determining the probability that the target parameter $Ql_{QOS-CIBLE}$ is less than the available parameter Ql_{LIEN} that can be allocated to a radio link i :

$P_r(Ql_{QOS-CIBLE} \leq Ql_{LIEN})$ with:

$$Pr(Ql_{QOS-CIBLE} \leq Ql_{LIEN}) = 1 - \text{erf}\left(\frac{Ql_{QOS-CIBLE} - \mu_i}{\sigma_i}\right) \text{ where erf is the error}$$

function mathematical function, and in that

- 10 - the decision module is adapted to determine the link to be used to satisfy a quality of service of a request Rq taking into account the available links and the probabilities for each of those links.

Other features and advantages of the present invention will become more apparent on reading the following description given by way of nonlimiting illustration, with the appended figures, in which:

- 15
- Figure 1 shows an example of a mobile network,
 - Figure 2A and Figure 2B are two diagrams representing modules and steps executed by the method in accordance with the invention,
 - Figure 3 is an illustration for a mobile carrier,
 - 20 • Figure 4 is a diagram of the distribution of the available data rate for a coverage area,
 - Figure 5A, 5B is a numerical example of link distribution,
 - Figure 6 shows an example of the use of the method, and
 - Figures 7A, 7B, 7C and 7D show an example of the execution of the
- 25 steps of the method.

Figure 1 shows an example of a mobile network comprising a plurality of nodes or mobile stations $10i$, a plurality of wireless communication links $11i,j$ connecting the mobile stations to one another, and a server 12 holding a central REM (REMc) database in communication with the mobile stations. Each mobile station $10i$ comprises a module $13i$ for communicating

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with the other mobile stations via wireless links, a processor 14i for executing the steps of the method in accordance with the invention and a simplified REMri for the management of exchanges with the other nodes.

Figures 2A and 2B are diagrams of modules that will be implemented at the level of mobile terminals forming part of a communication network. The REMri in the case of a mobile terminal could be a simplified image of a central REM situated at the level of a central server to which the mobile terminals are connected by radio links, for example.

Figure 2A is a diagram representing a background task executed permanently during a mission. It comprises a step 1 of probing the state of the radio environment, i.e. determining the radio links that are busy or free, for example on all of the frequencies scheduled for a mission or an application, followed by a step 4 of comparing the measurements effected by a mobile terminal and the elements from the onboard radio database REMri, the simplified version of the central REM (REMc) situated on the server, not shown for simplicity, in order to update and to adjust the content of that REM.

The expression "simplified REM" means for example that a REMri will be generated from the central REM, choosing a geographical area for a mobile terminal that is restricted compared to the geographical area associated with the central REM. The restriction could also be effected by choosing a frequency range or a time zone narrower than that of the central REM and better suited to a given mobile terminal.

Figure 2B is a diagram of an example of modules and steps that will be implemented by the method in accordance with the invention at the level of each mobile station 10i sending a communication request Rq.

A communication request Rq sent by a mobile station 10i includes quality of service (QoS) parameters to be complied with, including in particular data rate and latency parameters. The request is sent by the application level 20 of a mobile terminal, for example. The request Rq is transmitted to a REM analysis algorithm module 21 and also to a REMri base 22. The REMri base 22 will send to the REM analysis module 21 a set of

parameters responding to the request Rq. The REM analysis module 21 effects an analysis of the radio situation at the time of sending the request Rq, taking account of data produced by the REM and quality of service (QoS) constraints imposed in the request Rq and representative of a given application. The analysis module will also take account of the latency parameter included in the request. The result of the analysis is transmitted to a decision module 23 that contains link allocation strategy rules or link allocation decision rules.

If the communication request Rq is able to tolerate a time-delay Δt before the communication is established, for example according to the value of the latency parameter indicated in the request, then the packets 29 to be transmitted are sent to a storage module 24 pending the availability of a link that is more favourable for the quality of service (QoS) constraints, in order to initiate the communication. When the time-delay has elapsed, the request Rq is examined again, with the new transmission parameters: parameters transmitted by the REMri updated after the time-delay to take account of the updated radio conditions and the quality of service (QoS) constraints, since the latency possibility is reduced. If the request Rq can again tolerate a time-delay, this step is repeated; if not, there follows a processing step corresponding to a "no delay tolerance" transmission state described hereinafter.

If the request Rq cannot tolerate a delay in establishing the communication, then the decision module 23 allocates a communication link to the mobile terminal 25. The mobile terminals in the vicinity having listening capacities in accordance with the invention will take account of the state of the link (link busy and not available) for their own allocation strategy. With the link established, the communication can take place 26 unless an emergency event 30 interrupts it. The radio link is maintained until the end of the communication 27. At the end of the communication 27, the method will feed back to the REM database 28 a report CR including significant information that has appeared during communications established, for example link

quality data, information on the location of a mobile station, indexes of a major modification of the radio environment, a break in service, statistical information on connectivities, in order to improve the data stored in the REM by rendering its content closer to the real functioning of the system. The
5 central REM is updated at the end of mission, at the time of the mobile station returning to an "anchor point"; this updating is effected via a local radio link, for example.

If an event that modifies the radio environment occurs during a communication or when establishing a communication link 31, for example a
10 radio link dropping out, a situation of information of the vicinity of the mobile terminals of the network greatly modified, the impossibility of complying with the QoS with the available radio link, then the method will transmit this radio environment modification information to the analysis algorithm, which will take account of it and in return proceed to a modification of its analysis; this
15 new analysis will be transmitted to the decision module 23 that will consequently make a decision appropriate to the new situation, either to delay 24 or to establish a link 25; the link established may be the same as before but with different parameters.

If a priority event occurs during a communication, then the
20 analysis algorithm will interrupt 30 the communication in progress or establishing the communication.

The method includes an a posteriori analysis step, executed at the level of the analysis module 28, for quantifying the match between the radio link allocated at a given time and the quality of service (QoS) constraint, in
25 accordance with a principle known to the person skilled in the art, using statistical analyses and filtering of connection events. The module 28 placed between the end of communication and the local REM will effect the update, the statistical analysis and the filtering of events. The statistics will employ statistical analysis principles known to the person skilled in the art.

There will now be described in more detail an example of tasks, requests and modules forming part of the method in accordance with the invention and their functionality.

Background Task

- 5 A background task is executed in each of the mobile stations of the communication network and corresponds to an advanced probing of the radio environment effected outside the sending phase:
 - the probing will be limited to a set of frequency values F /channels CH deemed of interest (information coming from the REM of the mobile station),
10 in order to accelerate the probing,
 - the information supplied not being limited to an availability of the radio links (free/not free), but complementary link quality characteristics are accessible (quantitative information usually characterizing a radio link, such as the data rate or the bandwidth, the authorized latency, the error rates).
- 15 This probing will be effected over a widened coverage area corresponding to the cell in which a radio station is located, but also in adjoining cells, with a priori scheduling of the cells changes known as handovers or HO, and the occupancy of the radio resource over {frequency/channel; channel capacities or MCS} pairs. The probing obviously has a lower priority than the
20 communication.

Communication Request

- The objective of the REM + QoS analysis is to provide for each accessible radio link Li,j in a given coverage area an evaluation of the probability that the target QoS indicated at the level of a sending request Rq is supported by the
25 QoS that can be allocated to the link. To this end, the analysis algorithm executed in the analysis module 21 is divided into three phases described in detail in the following description:

- Phase 1. Calculation of the available QoS parameter, based on the radio information supplied by the REM as a function of the geographical position of
30 the mobile station, and by application of the applicable schemes (MCS) for the frequencies/channels concerned,

Phase 2. Calculation of probabilities in order for the target QoS to be supported by the available QoS,

Phase 3. Verification that the QoS constraints will be satisfied.

The final decision on the choice of the link will be made precisely in the "link decision" module and will correspond to the application of a strategy or rules linked to system operation considerations such as financial cost, use of its own resources, handling different priority levels.

For the analysis of the QoS, a parameter P_{QoS} will be used quantifying the QoS concerned:

- $P_{QoS-CIBLE}$ will designate the target value required by the application for the QoS parameter, indicated in the request R_q ,
- P_{LIEN} corresponds to the value that a radio link is able to provide for this QoS parameter. This value is supplied by the REM which reflects what the environment is able to offer.

For a better understanding of this algorithm, an example will be used illustrated by Figures 3 and 4 and considering the available data rate and the target data rate as a parameter characterizing a radio link.

Consider a mobile carrier 41, situated in a coverage area ZC1, in which three frequencies/channels MCS1, MCS2 and MCS3 are accessible, each with a different capacity. MCS1 and MCS2 are immediately available, with different characteristics, whereas for MCS3 Δt is a necessary time-delay before establishing the communication and transmitting data.

The QoS parameter used by way of nonlimiting example corresponds to the data rate D to be transmitted, with the following definitions:

Target data rate: $D_{QoS-CIBLE}$,

Possible data rate on the link: D_{LIEN} .

Calculation of the available QoS parameter

The REM will supply information linked both to the quality of the radio link and to statistics on the use effected on this link (history of use). The objective is notably to determine the available data rate portion for use on this link, in order to initiate the communication and the transmission of data. Returning to

the illustrative example using the data rate (Figure 4), there are identified in the maximum accessible data rate:

- the portion D_a of the data rate in use (allocated to other users): this value is obtained by listening (on orthogonal frequencies of TDMA type, for example) and/or by prediction,
- the reserved portion D_r of the data rate (security part, typical for pre-emptive requests),
- the available portion D_u of the data rate.

The available data rate therefore corresponds to the difference between the total data rate and a margin:

- the total data rate D_t : the maximum value that may be expected, given the characteristics of the radio link concerned; this value is obtained by prediction,
- the margin D_m : this is the sum of the reserved data rate D_r and the data rate D_a in use. This is a random variable depending on the predictable usage and a variable stub allocated to possible usage in the case of a priority indication. This margin value comes from the REM and is refined by a learning process using information from the REM updated as the method is executed.

Calculation of Probabilities

The parameter P_{LIEN} linked to the quality of service (QoS) and available on the radio link concerned makes it possible to introduce a probabilistic representation of the data. Assuming a Gaussian distribution, it is possible to calculate the probability that the target QoS parameter required by the application is supported by the parameter that can be allocated to the link given by the REM.

To illustrate this calculation, we return to the example of the data rate:

- the target data rate $D_{QOS-CIBLE}$ for the required QoS parameter is known,
- the data rate D_{LIEN} on the link is calculated,
- the mean value and the standard deviation associated with each radio link i are respectively denoted μ_i and σ_i .

It is therefore possible to determine the probability that the target data rate will be less than the data rate that can be allocated to the link:

$\Pr(D_{QOS-CIBLE} \leq D_{LIEN})$:

$$\Pr(D_{QOS-CIBLE} \leq D_{LIEN}) = 1 - \text{erf}\left(\frac{D_{QOS-CIBLE} - \mu_i}{\sigma_i}\right) \quad \text{where erf is the}$$

5 mathematical function known as the "error function".

More generally, considering a parameter QI characterizing the radio link instead of the "data rate" parameter, there is obtained the relation:

$\Pr(Q_{QOS-CIBLE} \leq Q_{LIEN})$,

$$\Pr(Q_{QOS-CIBLE} \leq Q_{LIEN}) = 1 - \text{erf}\left(\frac{Q_{QOS-CIBLE} - \mu_i}{\sigma_i}\right)$$

10 with QI being the target parameter and Q_{LIEN} the parameter available on the radio link.

The probability value found is compared for example to a threshold value P_{seuil} to decide the radio link to allocate. This decision is part of the chosen link allocation strategy: it is possible to choose a strategy made up of
15 simplistic rules with comparison to a threshold, or progressive implementation of more and more elaborate rules.

This principal may be illustrated by the following numerical example represented in Figures 5A, 5B. The two radio links LR_1 , LR_2 are considered with respective estimated data rates of 1 Mbps and 800 kbps. After the
20 calculation of probabilities, it is found that the radio link LR_2 is more suitable for transmitting the communication with a QoS of 600 kbps. This step makes it possible to supply to the next step of analysis of compliance with the QoS constraints quantitative data for aiding the decision. It is therefore possible for each frequency/channel of the coverage area to determine the probability of
25 complying with the QoS constraint.

Are the QoS constraints satisfied?

Continuing with the example using the data rate as the QoS parameter, at this stage links are available as well as probabilities of the QoS being complied with on each of those links.

The idea is therefore to apply a cost function in the broad sense, involving criteria of choice linked to the strategy to be applied:

- financial aspect with the actual cost, typically the example of the cost of a satellite link,
- 5 - use of resources aspect (preservation or not of own resources),
- priority management aspect, which can vary from one configuration to another.

A few examples are given in the table below, with the parameters considered being the data rate and the links with characteristic MCS1, MCS2 and MCS3:

	Description	Probabilities	Choice	Comments
①	D _{QOS-CIBLE} on MCS1, MCS2 and MCS3 with latency of t1, t2 and $\Delta t + t3$ (delay awaiting visibility from MCS3).	MCS1 $\rightarrow$ 100% MCS2 $\rightarrow$ 95% MCS3 $\rightarrow$ 100%	MCS1	The data rate may be complied with, with no waiting time; the choice is to send as fast as possible.
②	D _{QOS-CIBLE} on MCS1, MCS2 and MCS3 with latency of t1, t2 and $\Delta t + t3$ (delay awaiting visibility from MCS3).	MCS1 $\rightarrow$ 80% MCS2 $\rightarrow$ 80% MCS3 $\rightarrow$ 100%	MCS3	Compatible constraints and preserve radio resource in MCS1 and MCS2.
③	Same configuration as ① but with simplified link quality on MCS1 and no tolerance of delay.	MCS1 $\rightarrow$ 50% MCS2 $\rightarrow$ 95% MCS3 $\rightarrow$ 100%	MCS2	Compatible data rate and latency constraints.

④	Same configuration as ① but with simplified link quality on MCS1 and a cost penalty on MCS2.	MCS1 → 50% MCS2 → 95% MCS3 → 95%	MCS3	Application of strategy rules.
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The link allocation decision will be taken by the "link decision" module, applying the strategy rules decided on at the start of mission.

5 Figure 6 shows an example of the progress of a mission considering two platforms A and B in a radio environment consisting of three links (LOS1, LOS2 and LOS3), the coverages of which are of different kinds (size, geographical positions). Each platform A, B has an onboard version REM_A , REM_B of the central REM (REM_C) (reduction of the REM to the
10 geographical area envisaged for the movement).

Figures 7A, 7B, 7C and 7D illustrate two possible link allocation scenarios.

In Figure 7A, the QoS criteria of platforms A and B may be satisfied using the link LOS1. Platform B sees its link allocated, whereas for
15 platform A the link with LOS1 is scheduled.

In Figure 7B, the movements of platforms A and B continue. Platform A goes from the area covered by LOS1 to that covered by LOS2 and platform B leaves that area.

In Figure 7C, during the situation analysis, it is realised in relation
20 to LOS1 that the QoS requirements of platform B will be very demanding. On the other hand, for its communication, platform A can tolerate a delay through storing the packets to be transmitted. In this case, link allocation for platform A to LOS3 is delayed but is already scheduled.

In Figure 7D, the movements of platforms A and B continue, with
25 for each of them links allocated to different radio points in order to optimize the QoS constraints.

The method in accordance with the invention is generic, even though the use of the REM and the context analysis for link management rely on radio data in turn linked to the physical layers of the standards concerned, the method making it possible to provide the best service not depending only on intrinsic characteristics of the link; it uses prediction and learning. It makes it possible to allocate the radio links to a plurality of mobile stations by proposing a configuration that will optimise overall service.

The method is based on learning the radio environment, which is particularly suitable for deployment and use in a defined zone, a theatre of operations, an airport, a coastal region.

Moreover, this method extends radio link management in time:

- before moving in a predefined area: scheduling of the mission is effected in order to simplify the probing and to use an a priori knowledge of the temporal history of the REM;
- during the movement of a mobile station, radio allocation is effected dynamically, enabling the mobile station to anticipate events (links KO, number of important nodes in an area, etc.) or where appropriate to limit the impact of unexpected events;
- after the movement, feeding of significant data back to the central REM makes it possible on the one hand to confirm or to correct the radio coverage information and on the other hand also to store a metric quantifying the quality of the allocation choice, for use on the movement that is to come.

CLAIMS

1 – Method for the management of radio resources in a communication network R comprising at least one central database REM_C containing information relating to the scheduling of the communication network R at a given time, and one or more mobile stations (10i) comprising a database (REM_{ri} , 22i) containing information on a radio environment of the mobile station, characterized in that it comprises at least the following steps:

- transmitting a communication request R_q sent by a mobile station (10i) to a REM analysis algorithm module (21) and also to a REM_{ri} database (22) of the mobile station, said communication request R_q comprising characteristics relating to the constraint of a required quality of service,
- the analysis algorithm analysing the communication parameters contained in the request R_q taking account of the required quality of service (QoS) and of parameters characterizing a radio situation in a coverage area and at a given time sent by the REM_{ri} ,
- determining if a latency constraint exists in the request R_q ,
 - if the communication request R_q can tolerate a time-delay Δt before establishing the communication, transmitting the request R_q to a time-delay step (24) before it is analysed again by the REM analysis module (21),
 - if the request R_q cannot tolerate a time-delay Δt before establishing the communication, then allocating a communication link to a mobile terminal (25) and initiating the communication (26), and transmitting data and returning a report containing information on events that occurred during the communication.

2 – Method according to Claim 1 characterized in that the analysis algorithm comprises the following three phases:

- calculating the available QoS value,
- calculating the probability that the target QoS is supported by the QoS that can be allocated to a link,

- verifying for each frequency/channel of the coverage area of a mobile station the probability that the target QoS constraint will be complied with, and choosing the link to be allocated as a function of that probability value.

5 3 – Method according to Claim 2, characterized in that the calculation of the probabilities considering a parameter QI characterizing the radio link comprises the following steps:

- adopting a Gaussian distribution hypothesis,

- the target parameter QI being known in the request Rq, the parameter Q_{LIEN} available on the link being calculated and with μ_i and σ_i respectively
10 corresponding to the mean value and to the standard deviation associated with each radio link i , determining the probability that the parameter $Q_{QOS-CIBLE}$ is less than the parameter Q_{LIEN} that can be allocated to a radio link i :

$P_r(Q_{QOS-CIBLE} \leq Q_{LIEN})$ with:

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$$Pr(Q_{QOS-CIBLE} \leq Q_{LIEN}) = 1 - \text{erf}\left(\frac{Q_{QOS-CIBLE} - \mu_i}{\sigma_i}\right)$$
 where erf is the error function mathematical function,

- knowing the available links and the probabilities for each of those links, applying a cost function and determining the link to be used to satisfy a quality of service of a request Rq.

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4 – Method according to Claim 3 characterized in that there is used as a parameter characterizing a radio link the target data rate $D_{QOS-CIBLE}$ for the required QoS parameter and the calculated available data rate D_{LIEN} on the link.

25 5 – Method according to Claim 1 characterized in that there are used as quality of service parameters to be complied with any parameter characterizing the quality of service such as the error rate, the bandwidth, the authorised latency.

6 – Method according to any one of Claims 1 to 5 characterized in that it also
30 comprises the execution of a background task executed on a mobile station (10i) outside the step of sending data in order to probe the radio environment of a mobile station, choosing frequency values stored in the REMri and over a

widened area comprising the cell containing the mobile station and adjacent cells in order to determine the data of the REM_{ri} of the mobile station (10i).

7 – Method according to any one of Claims 1 to 6 characterized in that on
5 reception of priority event information, the analysis algorithm interrupts the current communication and allocates the radio link to the priority communication.

8 – Method according to any one of Claims 1 to 6 characterized in that on
10 reception of an event modifying the radio environment during a communication or while establishing a communication link, the information is sent to the analysis algorithm and a modification is sent in return to adapt to the new situation.

15 9 – System for the management of radio resources in a communication network R comprising at least one central database REM_C containing information relating to the scheduling of the communication network R at a given time, and one or more mobile stations (10i) comprising a database (REM_{ri}, 22i) containing
20 information on a radio environment of the mobile station, characterized in that a mobile station (10i) is equipped with a REM analysis algorithm module (21) configured to analyse the communication parameters contained in a communication request R_q and with regard to the required quality of service (QoS) and parameters characterizing a radio situation in a given coverage area and at a given instant, a decision module (23) supplying the authorization to
25 initiate a communication and the communication links to be used or the transmission of the request R_q to a time-delay module as a function of a latency parameter contained in the request R_q, a module sending data once the communication is established, a module establishing a communication report in liaison with the database (22i) of the mobile station.

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10 – System according to Claim 9 characterized in that the analysis module (21) is adapted to execute the following steps:

- calculating the available QoS value,
 - calculating the probability that the target QoS is supported by the QoS that can be allocated to a link,
 - verifying for each frequency/channel of the coverage area of a mobile station
- 5 the probability that the target QoS constraint will be complied with, and choosing the link to be allocated as a function of that probability value.

11 – System according to Claim 10 characterized in that the analysis module is adapted to calculate probability values considering as a quality of service

10 parameter the data rate parameter and to execute the following steps:

- adopting a Gaussian distribution hypothesis,
 - the parameter $Ql_{QOS-CIBLE}$ characterizing the radio link being known in the request Rq , the Ql parameter available on the link Ql_{LIEN} being calculated and, with μ_i and σ_i respectively being the mean value and the standard deviation
- 15 associated with each radio link i ,
- determining the probability that the target parameter $Ql_{QOS-CIBLE}$ is less than the available parameter Ql_{LIEN} that can be allocated to a radio link i :

$P_r (Ql_{QOS-CIBLE} \leq Ql_{LIEN})$ with:

$$Pr(Ql_{QOS-CIBLE} \leq Ql_{LIEN}) = 1 - \text{erf}\left(\frac{Ql_{QOS-CIBLE} - \mu_i}{\sigma_i}\right) \text{ where erf is the error}$$

- 20 function mathematical function,
- the decision module is adapted to determine the link to be used to satisfy a quality of service of a request Rq taking into account the available links and the probabilities for each of those links.

25 12 – System according to Claim 11, characterized in that the parameter characterizing a radio link is the target data rate $D_{QOS-CIBLE}$ for the required QoS parameter and the calculated available data rate D_{LIEN} on the link.