Title: ALLOCATION AND DISTRIBUTION OF NETWORK RESOURCES ACCORDING TO THE RESOURCE STATUS OF THE NETWORK UNITS

Abstract: The present invention relates to a method and arrangement, e.g. in a communication network, for allocation and distribution of appropriately defined network resources. A network provider provides network resources, e.g. in form of a number of standardised communication channels, to a network operator. The allocation and distribution of said resources amongst the network units is performed by means of the inventive method including the steps of determining a resource status of subordinated network units, indicating said status to a superior network unit, and equalising resource excesses and deficits between subordinated units.
Allocation and distribution of network resources according to the resource status of the network units

FIELD OF THE INVENTION

The present invention relates to a system of interconnected units, e.g., a communication network, and in particular to a method and an arrangement for allocation and distribution of appropriately defined system resources in order to optimise said system in accordance with a suitable criterion.

BACKGROUND OF THE INVENTION

Traditional communication systems have often been designed to support certain types of communication services between two end terminals. This has resulted in a plurality of networks that are each dedicated for certain types of services, e.g., narrow-banded networks for transmission of speech and/or data or broad-band networks for transmission of video. Instead, modern communication systems are developed, inter alia, with focus on the support of various kinds of services. This implies for a network operator the need to allocate the total network resources in a most efficient way, i.e. to support a large number of network subscribers with the desired service and an acceptable quality of service. One should also bear in mind that the resource need is a changing quantity both with respect to time and place. Resource handling relates thus to the handling of services, features and other logical related resources, e.g. capacity, in a communication network.

Resources can be defined according to several aspects: When regarding a network structure consisting of a plurality of interconnected network units, resources constitute a share of the functionality of said network units that a network operator in fact can use in order to serve the network
subscribers. The available resources result thus from the access that a network provider has granted to the network operator by means of access licence agreement. Regarding a multiple access radio communication systems, e.g. a CDMA-based communication system or a GSM-system, resources constitute also of the characteristic feature that is used in order to distinguish the communication channels to and from the various subscribers. Such distinguishing features could be, e.g., a unique code sequence in a CDMA-based communication system or a frequency band in a GSM-system. Said resources can be illustrated by means of, e.g., standardised communication channels with certain characteristics that are allocated to the system of a network operator.

With regard to network transmissions, critical resources can also be defined as, e.g., the allocated bandwidth and the time for which said bandwidth is allocated. Both parameters depend mainly on the type of communication and the requested service that is performed between two network clients. The bandwidth demand, for instance, is higher for a communication connection that is used for a video application compared to a connection that is applied for speech transmission. Another influence on the resource need of a network unit results from the time that is actually used for data exchange via a communication connection, e.g. a permanent connection or packet-based connection. Finally, the resource need will also depend on the fact whether certain service guarantees must be taken into account or whether the service is performed on a best-effort basis.

In a communication network, e.g. a nation-wide network, the network operator will operate the network preferably from one location. The operator’s access to the system is defined by some form of a general subscription agreement while the degree to which extend the network operator is allowed to
use said system will be regulated by means of a licence agreement.

According to the state of the art, mainly two types of resource allocation schemes are in use: When using a fixed allocation scheme, the network operator has to decide in advance on the requirements per area. Apparently, this static decision does not take into account possible changes of the resource need such that the allocated resources are probably not optimised to the actual need. Another solution is to handle the resources from a central resource pool. This means that each time the operator accesses the system, a request for resources has to be sent to said pool. However, this concept implies certain drawbacks mainly due to increasing response times, i.e. requested resources are possibly not available in time. Other drawbacks may relate to, e.g., an increased sensitivity to faults due to the central positioning of the pool such that a fault in the central pool will impact the whole communication system.

**SUMMARY OF THE INVENTION**

With regard to the allocation of system resources, e.g., for system installation or expansion or due to varying resource need in an existing system, it has been observed to be a problem to control on the one hand the total resource need centrally while handling, on the other hand, the allocation and distribution of said resources as decentrally as possible.

It is a principal object of the present invention to achieve a method and an arrangement that facilitates system maintenance for a system operator.
It is thus an object of the present invention to achieve a method and an arrangement that allows a central supervision of the total resource need of the system.

It is another object of the present invention to achieve a method and an arrangement that supports a decentralised allocation and distribution of said resources on a "per need"-basis to the various system units without any further involvement of the system operator.

It is still another object of the present invention to provide a method and an arrangement that allows an increased flexibility in system maintenance on basis of, e.g., system and/or subscriber parameters that have an impact on the actual resource need of a network unit.

It is yet another object of the present invention to provide a method and an arrangement that facilitates resource allocation in case of a system expansion.

It is another principal object of the present invention to achieve an arrangement and a method that allows a system provider to install a system structure comprising standardised system units that are easily adaptable to the specific needs of a system operator.

It is thus an object of the present invention to achieve a method and an arrangement that facilitates for a system provider the activation/deactivation of system resources.

It is another object of the present invention to delegate responsibility for system maintenance and expansion from the system provider to the system operator.

Briefly, these and other objects of the present invention are accomplished by the method and the arrangement according to the present invention, which are applicable in systems that are designed as hierarchical and layered structures of units that are interconnected in such a way that each unit
provides one connection to an assigned superior unit on a hierarchically higher level, which functions as the controlling unit of said unit, and can provide connections to one or more dedicated subordinated units on a hierarchically lower level, which represent the controlled units of said unit. This logical structure is then applied in, e.g., a communication system in order to allocate and distribute necessary resources, e.g. in form of standardised communication channels.

The method according to the present invention implies for each system unit the steps of determining the actual resource status and indicating said status to the superior unit on the next higher hierarchical level. The superior unit is responsible for equalising between indicated resource excesses and deficits of said subordinated units. The arrangement according to the present invention comprises correspondingly means for determining a resource status from indicated resource statuses of its subordinated units, means for indicating and weighting said status, and means for equalising between indicated resource deficits and excesses of said subordinated units.

As a first advantage, the present invention provides a method and arrangement with an increased flexibility in allocating system resources granting access to the system facilities on a "per need"-basis.

It is another advantage of the present invention that the decentralised resource allocation provides a faster and more reliable system that is less affected with faults.

It is yet another advantage of the present invention that a system can be installed using standardised system units.

Other objects, advantages and novel features of the invention will become apparent from the following detailed
description of the invention when considered in conjunction with the accompanying drawings and claims.

**BRIEF DESCRIPTION OF THE DRAWINGS**

5 For a better understanding, reference is made to the following drawings and preferred embodiments of the invention.

Figure 1 shows a system structure within which the method according to the present invention can be applied.

10 Figure 2 shows a flowchart of the various steps that are performed in the method according to the present invention.

Figure 3 shows a more detailed flowchart for one of the method steps according to figure 2.

Figure 4 shows a diagram of signals that are applied for transfer and allocation of resources.

15 Figure 5 shows an arrangement in a unit of a system according to figure 1 that performs the method steps according to figures 2 and 3.

Figure 6 shows a first embodiment of the method and arrangement according to the present invention in, e.g., a nation-wide communication system.

20 Figure 7 shows a second embodiment of the method and arrangement according to the present invention in, e.g., a part of a cellular radio communication system.

**DETAILED DESCRIPTION**

Figures 1-4 describe the principles of the present invention in broad terms. Figure 1 shows a logical system
structure within which the inventive method, as presented in the flowcharts of figures 2 and 3, can be applied. Figure 4 shows the necessary signalling flow between system units when said method is applied.

5 Principally, the method according to the present invention can be applied in any kind of hierarchical system 10 as presented in figure 1. Such a system 10 is designed as a plurality of interconnected units 11,121-123,131-135 with well-defined functionalities that interact with each other. However, one should bear in mind that figure 1 only describes the logical aspects of a system structure with regard to the distribution and allocation of system resources whereas the system can be structurised in another way with respect to communication aspects, e.g. information exchange or signalling. Said figure shows only those units that perform the method according to the present invention while other units are omitted. The logical system structure 10 comprises in total (L+1) hierarchical levels that are distinguished by help of a level index value (L-j); j=L...0 such that j=L denotes the uppermost level and j=0 denotes the lowest level. Each of said hierarchical levels (L-j) contains a number I(j) of system units that are distinguishable by help of unique identifier sequences IDj(i); i=1...I(j) that are assigned to the units. Thus, a unit in such a hierarchical system can be identified as U[j,i]. In particular, said system units are arranged such that a unit U[j,i], e.g. 122, on a first level (L-j) can be connected to a number of subordinated units U[j-1,i**], e.g. 132-134, on a lower hierarchical level. i** denotes the set of index values that distinguishes the identifier sequences IDj-1(i**) of these subordinated units on the lower level, i.e. i**={i-1,i,i+1} for the unit U[j,i] 122 in the present example. Preferably, as shown in figure 1, the lower level is the level (L-j+1) directly below said first level. Correspondingly, said unit U[j,i] has also a
connection to a superior unit \( U[j+1,i^*] \), e.g. 11, on a higher hierarchical level, which preferably is the level directly above said first level. \( i^* \) denotes the index value that distinguishes the identifier sequence \( ID_{j+1}(i^*) \) of said superior unit on the higher level, i.e. \( i^*=i \) the unit \( U[j,i] \) 122 in the present example. The lowest hierarchical level contains units 131-135 without dedicated children and the highest level denotes the root unit 11 in such a hierarchical system. Within the scope of the present invention said units interact with each other by means of two commands: The transfer request indication command 14 indicates resource status information of a system unit to its superior unit. The transfer allocation command 15 allocates resources of a superior unit to one of its subordinated units.

The efficiency of such a system 10 could be characterised by means of its system capacity, which denotes, e.g., the amount of dedicated system actions that the system can perform. This capacity depends mainly on resources that are allocated to the system in order to perform such actions. In particular, both the total amount of allocated resources and the allocation of such resources to the various units will have an impact on the total system capacity.

As explained in the examples that are presented later on, the hierarchical system 10 as described above could be, e.g., a nation-wide telecommunication system or a certain area that is part of such a telecommunication system. For these examples, a possible measurement of the system capacity could be the maximum number of user equipments that can be served with a sufficient quality of service and system units could be identified, e.g., as radio base stations or radio network controllers. Licence agreements can be based, e.g., on the number of available communication channels. Generally, resources could therefore be defined by means of communication channels.
that are characterised by means of certain parameters, e.g. the channel bandwidth, channel delay time, or packet loss. For multiple access communication systems, e.g. a CDMA-based or GSM-system, yet another important parameter is the characteristic that distinguishes the various communication channels in such a system, e.g. unique code sequences or bearer frequencies. This will be explained in greater detail in figures 6 and 7.

The method according to the present invention as presented in figure 2 is applied for resource distribution in a hierarchical system 10 as illustrated, e.g., in figure 1. Said method is performed at periodical times $T=T_0$, block 21, for all system units $U[j,i]$, i.e. within the range $j=0..L$ and $i=1..I(j)$. It starts on the lowest level ($j=0$), block 21, comprising a range $i=1..I(0)$ of units and is then repeated on the higher levels ($j=1..L$) for the corresponding ranges $i=1..I(j)$ of units.

In a first step, a unit $U[j,i]$ must determine its actual resource status, block 23. Said resource status includes information about the resources of the unit itself and information about the resource status that is indicated from possible subordinated units $U[j-1,i**]$ that are connected to said unit $U[j,i]$ in its function as a superior unit. Each of said subordinated units contributes with either a deficit or an excess of resources such that the total resource status $R_{tot}$ of the superior unit can be determined by means of the sum of resources of the superior unit itself and of its subordinated units:

$$R_{tot}\{U[j,i]\} = R\{U[j,i]\} + \sum_{i**} R_{tot}\{U[j-1,i**]\}$$

Apparently, the reported resource status of the subordinated units includes in its terms also the resource status of units on an even lower level that are connected as subordinated units directly or indirectly to the actual
subordinated units U[j-1,i**]. The resource status of a unit can be below zero indicating, e.g., a need for more resources or above zero indicating, e.g., that the unit allocates more resources than necessary. R(U[j,i])=0 indicates that the unit neither need to allocate additional resources nor has an excess of resources.

In a next step, block 25 and block 28, the unit U[j,i] indicates the determined total resource status to a unit on a hierarchically higher level. If said unit is a subordinated unit of a superior unit on a higher level in the hierarchical system, block 24 Yes, i.e. the unit is another system unit on a hierarchical level (L-j-1) with j<L, the resource status is indicated to this superior unit U[j+1,i*]. The indicated resource status will then be applied by the superior unit U[j+1,i*] to determine its total resource status as correspondingly described for U[j,i]. If the unit for which the total resource status has been determined is the unit on the uppermost level j=L, block 24 No, said resource status can be indicated to a supervising external unit, block 28. The resource status that is indicated by said unit on the uppermost level j=L is of certain interest because it contains information representing the total excess or deficit of resources in the entire system. This information can be applied by an external supervising unit, e.g., a network operator, in order to initiate further actions. In case of an indicated deficit of resources this could imply, e.g., to allocate additional resources to the system. However, it is notwithstanding possible that a network operator can retrieve the resource status from an arbitrary unit in the hierarchical system in order to get the resource status of certain parts of the system.

The following step of equalising indicated resources, block 26, builds on the presumption that resources are transferable preferably between arbitrary system units but
at least between a narrow group of system units. As mentioned above, a unit U[j,i] calculates in its function as a superior unit its total resource status by help of the indicated resource statuses of its subordinated units U[j-1,i**] and reports this status to its superior unit U[j+1,i*]. However, said total resource status gives no indications about the distribution of these resources amongst the subordinated units. When supposing a superior unit indicating, e.g., a total resource status zero, it is one possibility that each of its subordinated units has reported a resource status value zero. However, the other possibility is that some of the subordinated units have an excess of resources while others have a corresponding deficit of resources. Because these differences are not visible for a unit on a higher hierarchical level, it is the responsibility of the superior unit U[j,i] to initiate appropriate measures in order to equalise resource deficits and excesses between its subordinated units U[j-1,i**], block 26, such that, e.g., a deficit of resources in one of said subordinated units is, at least partly, compensated by an excess of resources in another subordinated unit.

The steps of indicating the resource status to the superior unit, block 25, and equalising of reported resources amongst the subordinated units, block 26, will be described in more detail in figure 3 and in connection with the signalling diagram in figure 4.

The method steps as described above are repeated for all units within the range i=1...I(j) on the level (L-j), block 27. Yes, by means of incrementing the index value i of the identifier sequences on said level, block 271. When said method steps have been performed for said units, i.e. i=I(j), block 27 No, said steps are performed on the next higher hierarchical level by means of incrementing the level index j, block 272, and resetting the index value i, block 22. After the resource status has been indicated, e.g., to
an external unit by the system unit on the uppermost level, block 28, the timer index value \( n \) is incremented, block 29, which indicates that the method is repeated at a subsequent time \( T_{n+1} \).

5 Figure 3 shows in greater detail the method steps that are performed in order to equalise excesses and deficits between subordinated units of a unit \( U[j,i] \). Said steps can be performed only if some of the subordinated units have reported a deficit of resources while other subordinated units have reported an excess of resources, block 261 Yes and block 263 Yes. If, however, none of the subordinated units have indicated an excess of resources, block 261 No, this can imply that all subordinated units are in a resource equilibrium or all indicating a resource deficit such that the superior unit only need to indicate that deficit but cannot perform any equalisation measures before it will have received the necessary resources. The exceeding resources of the subordinated units can be allocated to the superior unit, block 262, in order to be available for a unit on a higher hierarchical level or in order to be allocated to subordinated units that indicate a resource deficit, block 264. However, if none of the subordinated units has indicated a resource deficit, block 263 No, no equalisation measures need to be performed. For subordinated units that indicate a resource deficit, block 263 Yes, there are several alternatives to perform a resource equalisation: The preferred alternative is to distribute the exceeding resources subsequently to the subordinated unit that has the largest resource deficit at the moment, block 264. By this means resources are quickly distributed to those units that probably have the largest traffic density at the moment. Another alternative would be to distribute said exceeding resources subsequently to the subordinated unit that momentarily has the lowest resource deficit. By this means the total number of units with sufficient resources could be
maximised. However, it is notwithstanding possible to apply any other ranking criterion for determining an order within which exceeding resources are allocated.

Figure 4 shows the signalling flow between system units that is performed by a unit $U[j,i]$ 42 in connection with a transfer of resources that is performed by means of the above described steps of indicating the resource status to the superior unit $U[j+1,i^*]$ 41 on a higher level and equalising the reported resources amongst the subordinated units $U[j-1,i^{**}]$ 43 on a lower level. Said transfer of resources is performed by help of two commands: Subordinated units 43 report their excess or deficit of resources by means of a transfer request indication 44 to their respective superior unit 42. From this the unit 42 can determine its total resource status, which is reported to the superior unit 41 on the next higher level, by means of another transfer request indication 45. The step of resource equalisation as described above is performed if some of the subordinated units 43 have reported a deficit of resources while other subordinated units 43 have reported an excess of resources. By using a transfer allocation command 46, it is possible for the superior unit 42 to transfer exceeding resources from one subordinated unit to another subordinated unit that has indicated a deficit of resources. Apparently, a unit 42 must only be aware of the distribution of resource excesses and deficits amongst its direct subordinated units 43. However, units 41 on a higher level need no information about that distribution but only about the total resource excess or deficit of the unit 42. When the unit on the highest level $j=L$ receives resource status information indicating a deficit or excess of resources in its subordinated units, this information represents the excess or deficit of resources of the entire system and can be used, e.g., by an operator for further actions. The transfer request indication 45 that has been sent to the superior
unit 41 on a higher hierarchical level will result in the allocation of the required additional resources in connection with a transfer allocation command 47 from said superior unit 41. When the method steps according to the present invention then are performed at a subsequent time $T_{n+1}$, the superior unit 42 can, by means of recurring transfer allocation commands 46, transfer the required amount of resources to those of its subordinated units that have indicated the corresponding resource deficit during the preceding time interval $T_n$.

If the total resource status of a unit 42 indicates a deficit of resources while some of the subordinated units 43 nevertheless indicate an excess of resources, said equalisation measures can be performed according to several strategies: A first strategy, as described above, is to distribute exceeding resources that are already available for the superior unit 42 at once by means of said transfer allocation commands 46 while the remaining resources are distributed when said superior unit 42 has received these resources from its superior unit 41. Another conceivable strategy could be that a superior unit 42 keeps the already available resources until it has received the remaining resources from its superior unit 41 and then distributing the resources to the appropriate subordinated units 43. This implies, with regard to figure 4, that the superior unit 42 waits for the transfer allocation command 47 from its superior unit 41 before performing the transfer allocation commands 46 towards its subordinated units 43.

From this two advantages of the invention become apparent: The excess or deficit of resources in the system can be detected centrally by the system operator. As explained above, this information can be retrieved from the uppermost unit of the hierarchical system. The operator does not need any detailed knowledge which units in fact have, e.g., a deficit of resources. Instead, it is enough to provide the
necessary resources to the uppermost unit such that said
deficit can be equalised. By means of the method according
to the present invention, in particular by means of the
equalisation of resources amongst subordinated units as
described above, these resources will be automatically
distributed to those units that have reported the deficit of
resources.

The flexibility of the method according to the present
invention could be increased with regard to two aspects:

According to a first aspect, resource equalisation presumes,
as already mentioned above, that resources are transferable
preferably between arbitrary system units. However, with
regard to real systems, it becomes apparent that resources,
e.g. communication channels, can have varying
characteristics depending on the unit to which said
resources are allocated. For instance, a communication
channel in a GSM-system, which is characterised by its
carrier frequency, can have, e.g., an insufficiently high
interference level when transferred from one cell to a
neighbour cell. It is also possible that said communication
channel is not suitable for the type of service for which it
shall be applied in the neighbour cell, e.g. with respect to
path loss or delay. Therefore, it is a conceivable
modification of the method and arrangement according to the
present invention that the system units contain appropriate
means not only to determine the number of exceeding
resources that shall be indicated to the superior unit but
also to determine the characteristics of said resources in
order to decide which of said exceeding resources may be
transferred. Correspondingly, a unit must not only indicate
a resource deficit but also the characteristics of the
required resources. It is then the responsibility of the
superior unit to equalise between matching resource excesses
and deficits of its subordinated units.
Another aspect to increase the flexibility of the method according to the present invention relates to the equalisation of exceeding resources: In certain situations it would be beneficial for a unit to keep at least some of the exceeding resources. Said method equalises exceeding resources always at first amongst those other units that have the same superior unit and then successively amongst those units that have a common superior unit on a higher level. However, it might be beneficial to be able to select the units that shall receive exceeding resources in the first place and the order in which said resources are distributed amongst these units. In addition to this, sometimes it would be beneficial for a unit to keep at least some of the exceeding resources. Therefore, it is one conceivable modification to apply a weighting factor $\omega_{j,i}$ to the resource status information that a subordinated unit $U[j,i]$ reports to its superior unit by help of the transfer request indication. Said weighting factor could be defined, e.g., for a range $[0,1]$. With regard to an excess of resources, $\omega_{j,i}=0$ indicates that such resources must not be allocated to other units while $\omega_{j,i}=1$ indicates that all exceeding resources can be allocated to other units. Correspondingly, $\omega_{j,i}<1$ may indicate that a unit requires less additional resources than indicated by the determined resource deficit, e.g. with regard to other units having an even greater need. Other values within this range indicate that only a part of, e.g., the exceeding resources may be distributed to other units. A value $\omega_{j,i}=0.25$, e.g., implies that a unit with an excess of four resources provides only one resource for allocation to other units.

Thus, when applying said weighting factors $\omega_{j,i}$ the total resource amount of a superior unit $U[j,i]$ can be calculated as
\[ R_{\text{tot}} \{U[j,i]\} = \omega_{jj} \cdot R[U[j,i]] + \sum_{l=1}^{n} \omega_{j-l,j*} \cdot R_{\text{tot}} \{U[j-l,i**]\} \]

For a resource status that is only applicable as an integer value this formula must be modified such that the total resource status of a unit is calculated by always applying the next lower integer value:

\[ R_{\text{tot}} \{U[j,i]\} = \lfloor \omega_{jj} \cdot R[U[j,i]] + \sum_{l=1}^{n} \omega_{j-l,j*} \cdot R_{\text{tot}} \{U[j-l,i**]\} \rfloor \]

For the sake of clarity, the method according to the present invention will now be explained by help of an example that is applied in a system as presented in figure 1: Supposing a unit U[2,i+1] 134 has reported an excess of two allocated resources while another unit U[2,i-2] 131 has reported a deficit of three resources. All other units in the system are supposed to have neither an excess nor a deficit of resources. Said units will report their excess or deficit of resources to their respective superior units, i.e. U[1,i] 122 and U[1,i-1] 121, which in their part as subordinated units will report this status to their common superior unit U[0,i] 11. In this example, the resource excess of U[2,i+1] 134 is reported upwards to U[0,i] 11 because no other subordinated unit of U[1,i] 122 indicated a deficit of resources. Correspondingly, the resource deficit of U[2,i-1] 132 cannot be equalised by its superior unit U[1,i-1] 121. U[0,i] 11 is thus the superior unit on the lowest possible hierarchical level of both a subordinated unit U[2,i+1] 134 that has an excess of resources and a subordinated unit U[2,i-2] 131 that has a deficit of resources. Therefore, it is this superior unit 11 that can start the appropriate equalisation measures as described above in order to transfer the exceeding resources from U[2,i+1] 134 to U[2,i-2] 131. However, in this example the receiving unit 131 needs more resources than the delivering unit 134 can provide. This deficit can be monitored by the operator, here
by means of resource information that is reported from 
U[0,i] 11. Then, the operator can, e.g., allocate an 
additional resource to the system which will automatically 
be transferred to U[2,i-2] 131 via the intermediate superior 
units that indicate a deficit of resources, i.e. U[1,i-1] 
121.

Figure 5 illustrates the various components that are 
necessary for a unit 50 in a hierarchical system as 
described above to perform the inventive method as presented 
in figures 2 and 3. The system unit 50 receives by means of 
dedicated connections 56 information regarding the resource 
status of its subordinated units. From this information and 
its own resources the unit can by help of appropriate means 
determine its total resource status and via indication 
means 51 indicate said status to its superior unit. Said 
indication means 51 are also responsible for an optional 
weighting of the determined resource excess or deficit. In 
order to perform the above described equalisation measures 
the unit must keep track on those subordinated units that 
have indicated an excess of resources, e.g. by means of a 
first register 52, and those subordinated units that have 
indicated a deficit of resources, e.g. by means of a second 
register 53. Then, the equalising means 55 can allocate the 
exceeding resources from units in said first register 52 to 
units in said second register 53 by using appropriate 
ranking and selecting criterions. Said equalising means 55 
could preferably also contain appropriate means to determine 
resource parameters that support to decide which of said 
exceeding resources may be transferred or, correspondingly, 
to determine resource parameters in case of a resource 
deficit in order to equalise between matching resource 
excesses and deficits amongst the subordinated units. Said 
allocated resources are provided to the subordinated units 
by means of dedicated connections 57.
The following figures 6 and 7 illustrate examples of systems and system resources that are an object of the method and arrangement according to the present invention: In figure 6 the above described logical system structure is applied in a nation-wide CDMA-based communication network. Said network comprises a network operator centre (NOC) 61, which is the central supervising unit of this network, and corresponds to the unit on the uppermost level in the hierarchical system as presented in figure 1. A number of mobile switching centres (MSC) 62a-62c representing the next level structure are connected to said network operation centre 61. Each of said mobile switching centres 62a-62c controls a large geographical area that is covered by radio base stations 64a-64c. A plurality of neighboured radio base stations are connected to a radio network controller (RNC) 63a-63b that is responsible for a variety of maintenance functions for said radio base stations and, e.g., for handling of communication connections to and from the network clients. In terms of the hierarchical system structure according to figure 1, the radio base stations 64a-64c and the radio network controllers 63a-63b are represented by the units on the two lowest levels. The radio base stations 64a-64c are located mainly with focus on, e.g., environmental aspects or the expected traffic density in a certain area. This allows a variety of alternatives for the placement of radio base stations: The radio base stations 64a can be directly connected to the radio network controller 63a. Another example is to place the radio base stations 64b in a cascade-like form, e.g. in order to support clients along a highway. It is yet another possibility to connect several radio base stations 64c by means of a concentrator 65 which by this means provides a common connection to a radio network controller 63b.

The network provider can by help of access licences determine to which degree a network operator can use the
facilities of the above described units in an installed network structure. This is advantageous in view of two aspects: The network operator has an increased flexibility to individually adapt the network conditions. Examples for said flexibility are the speed of network expansion or, to a certain extent, the ability to react on changes of the network traffic distribution regarding, e.g., the number of network subscribers or the number and kind of requested services. Said flexibility implies also a cost-optimised network because the network operator only pays for the use of network functionalities that he actually has subscribed to use. The network provider, on the other hand, can install standardised network units and easily dedicate the appropriate access licences, e.g. in case of a network expansion, by means of activating more of the already available functionalities in the network units. The access to said functionality is thus controlled and permitted by the network provider on request of the network operator, which is more efficient than operator-individual solutions.

A licence agreement between network provider and network operator can also include the definition of a tolerance range that allows the network operator to access more than the licenced resources during a certain time period.

Said access licences for usage of a share of the network unit facilities are mainly determined by the number of network subscribers, i.e. by a number of standardised communication channels, but also by the service that these subscribers request from the network, i.e. the number of such standardised communication channels that are necessary in order to perform the requested service. A standardised communication channel could be, e.g., a 64kbit/s-speech channel complying with certain channel characteristics regarding, e.g., path loss and delay. Thus, an agreement on the usage of a share of the facilities of a communication network between a network provider and a network operator
will preferably base on the number of such standardised communication channels that the network provider provides to the network operator. Therefore, in the following said standardised communication channels will constitute the system resources. Resource parameters, i.e. said channel characteristics, will have an influence on whether or not and to which extent these resources are transferable between arbitrary system units. Resource allocation and distribution in such a system will now be illustrated by help of the example as presented in figure 6: Supposing a network operator intends to start operating a new installed communication network. For this purpose, a network provider installs in a starting phase only a minor system comprising, e.g., a network operation centre 61, one mobile switching centre 62a, and one radio network controller 63a with a number of radio base stations 64a that are appropriately connected to said radio network controller 63a. However, in view of the preliminary expected amount of communication traffic that must be handled by said network, the network operator only needs to use a minor part of the facilities of said installed network units; although, said units are capable to handle larger amounts of traffic. The network operator thus buys only an appropriate number of resources, i.e. said standardised communication channels, from the network provider.

A gradual system expansion could, in a first aspect, imply to connect additional radio base stations to the radio network controller 63a either in order to cover a larger geographical area or in order to be able to increase the number of supported subscribers within a given area. Another reason for a system expansion could be to offer an increased variety of services that are available in the network: Real-time based communication services, for instance, that require a high bandwidth, e.g. video communication connections, will lead to an increase of, e.g., the
necessary data rate or uplink and downlink power need, which implies raised demands for the network units. In the present example, a system expansion causes a higher system load for the system units which in its turn will require additional resources in form of said communication channels in order to serve the increasing number of subscribers and/or in order to be able to perform the more complex services.

A system expansion in another aspect could imply to extend the communication network in order to cover a new larger region. This probably requires new installations of network units, e.g. an additional radio network controller or even an additional mobile switching centre 62b, because the new network structure must be installed for all units on a lower hierarchical level, i.e. radio network controllers 63b and radio base stations 64b-64c that are directly or indirectly connected to the new mobile switching centre 62b. Also this will require additional network resources that are provided to the network operator in form of additional communication channels that are allocated by the network provider on request of the network operator.

In order to handle, e.g., an increasing number of subscribers or more complex service requests the radio base stations 64a and accordingly the radio network controller 63a need additional communication channels, i.e. resources that permit the usage of currently unused facilities in these units. By means of the inventive method, namely the steps of determining and indicating the resource status of the various system units, this resource deficit will be indicated to units on a logically higher level and eventually noticed by the network operator. It is then the responsibility of the network operator to request from the network provider additional resources for units of the communication system. The distribution of said resources, i.e. which units are allowed to use which share of the additionally available functionalities, is automatically
handled by the inventive method, namely by the step of equalising indicated resource excesses and deficits, without any further involvement of the network operator or the network provider.

5 The communication network according to figure 6 refers to a cellular radio communication network, in particular a CDMA-based communication network. However, it is notwithstanding possible to apply the inventive method for resource allocation, i.e. allocation of access licences, to other kinds of networks of any size. Conceivable communication networks could be, e.g., other kinds of radio networks or fixed communication networks. Additionally, it would also be possible to apply the method according to the present invention in a network without dedicated hierarchical structure, e.g. the Internet.

10 In figure 7 the hierarchical system structure according to figure 1 is applied in a part of a cellular multiple access radio communication network 70, e.g. a CDMA-based communication system or a GSM-system, comprising a centralised controller unit 71 that controls a number of neighboured cells each of which equipped with a radio base station 72a-72f. Apparently, for a multiple access communication system the resources, i.e. the number of available communication channels, that can be allocated to the system units depend mainly on the approach for sharing the commonly used communication medium amongst a plurality of subscribers. These approaches base on the principle to provide each single subscriber with a communication connection having a certain characteristic that makes this connection distinguishable from other connections sharing simultaneously the same communication medium: A frequency division multiple access (FDMA) communication system distinguishes the communication connections by distinct frequency bands while connections in a time division multiple access (TDMA) system can be distinguished by
distinct time slots that are provided to the connection at periodically times. Finally, in a code division multiple access (CDMA) communication system a distinction of different communication connections of the shared communication medium is made by applying a plurality of unique code sequences to the user signals. For these scenarios, the method and arrangement according to the present invention can be used in order to facilitate the distribution and allocation of said resources, e.g., with respect to the number of subscribers or the traffic distribution in the cells.

Thus, when regarding the communication network 70 as a CDMA-based communication system, system resources depend on the unique code sequences that need to be allocated to, e.g., the radio network controller 71 that covers a number of neighboured cells each of which comprising a radio base station 72a-72f. Common types of code sequences that are applied for the uplink and downlink radio channels are, e.g., so called pseudo-noise (pn) sequences, which are generated by help of feedback shift registers and appropriate starting sequences, or other kinds of suitable orthogonal codes, e.g., Walsh-codes or Gold-codes. With respect to the method and arrangement according to the present invention, the radio network controller 71 represents a system unit on a first hierarchical level while the radio base stations represent the system units on a lower level.

A GSM-system on the other hand bases principally on a mixed frequency division and time division multiple access technique such that the spectrum is subdivided into a number of distinct frequency bands by help of frequency division and each of said bands is subdivided into time slots that form a number of communication channels. Apparently, the total available frequency spectrum of the GSM-system can be used within a limited area that is covered by a number of
neighbouring cells. However, a frequency band that is used in one of said cells must not be re-used within a certain minimum distance from said cell. Instead of this static relationship between said frequency bands and the cells it would be desirable to assign the frequency bands more flexibly amongst the neighbouring cells of the above-mentioned area. This is possible by means of the method and arrangement according to the present invention when applying appropriate measures in order to keep said minimum distance for re-using frequency bands in a cell. Thus, when regarding the communication network 70 as a GSM-system, system resources depend on the share of frequency bands that are allocated amongst a group of neighbouring cells.

Apparently, the method and arrangement according to the present invention could advantageously be applied in order to flexibly react, e.g., on changes in the number of subscribers in a cell. One possible scenario could relate to more or less regular changes in communication traffic with respect to the time of day: Certain cells cover, e.g., a working area that has a high traffic density at normal working hours while there is only little traffic at other times when the traffic instead increases, e.g., in typical housing estates. Another scenario could relate to certain peaks in communication traffic, e.g. due to a special event that may cause a high traffic density within a limited area, e.g. a single cell, but only for a limited time whereafter the traffic density rapidly decreases. It is the responsibility of a unit 71 on a higher hierarchical level, i.e. the radio network controller for a CDMA-based communication system or the mobile switching centre for a GSM-system, to cope with such fluctuations or peaks of the resource need of units on a lower hierarchical level, i.e. the radio base stations, in order to allocate and distribute the necessary resources, i.e. a range of appropriate code sequences or frequency bands, to the cell.
With regard to the first scenario, said unit on a higher hierarchical level will, e.g., in the evening detect and indicate an increasing deficit of resources in cells that cover a housing estate area. At the same time an increasing excess of resources is indicated from cells that cover a working area. This imbalance can at least in parts be equalised by means of the method and arrangement according to the present invention by means of transferring the exceeding resources to areas that indicate a deficit of resources. A more general increase of the communication traffic will be detected by the network operator that can allocate additional resources, e.g. another range of code sequences, to the network whereafter these resources are distributed to those units, i.e. radio base stations, that have reported a deficit of resources.
1. Method for allocation and distribution of system resources that is performed in each unit of a system structure (10) comprising a plurality of said units (11, 121-123, 131-135) that are interconnected in such a way that each unit provides one connection to an assigned superior unit and can provide connections to one or more dedicated subordinated units, characterised by determining (23) a resource status from indicated resource statuses of the dedicated subordinated units, indicating (25, 28) said determined resource status to the assigned superior unit, equalising (26) indicated resource deficits and resource excesses by means of transferring (262) resources from those of said dedicated subordinated units that have indicated a resource excess and allocating (264) resources to those of said dedicated subordinated units that have indicated a resource deficit.

2. Method according to claim 1, characterised by indicating a determined resource status along with resource parameters, equalising indicated resource deficits and resource excesses having matching resource parameters.

3. Method according to claim 1 or 2, characterised by
weighting the indicated resource status with an appropriate
weighting factor $\omega$.

4. Method according to one of claims 1 - 3,
characterised by

allocating exceeding resources to dedicated subordinated
units in an order that is determined by an appropriate
ranking criterion.

5. Method according to claim 4,
characterised by

allocating (264) said exceeding resources to those dedicated
subordinated units that indicate the largest resource
deficit.

6. Method according to one of claims 1 - 5 in which the
system constitutes a communication system applying
communication channels with appropriate properties as the
system resources.

7. Method according to claim 6 wherein the communication
channels are speech channels.

8. Arrangement for allocation and distribution of system
resources in each unit of a system structure (10) comprising
a plurality of said units (11,121-123,131-135) that are
interconnected in such a way that each unit provides one
connection to an assigned superior unit and can provide
connections to one or more dedicated subordinated units,
characterised in

means (54) for determining a resource status from indicated
resource statuses of the dedicated subordinated units,
means (51) for indicating and weighting said determined resource status to the assigned superior unit,

means (55) for equalising indicated resource deficits and resource excesses by means of transferring (262) resources from those of said dedicated subordinated units that have indicated a resource excess and allocating (264) resources to those of said dedicated subordinated units that have indicated a resource deficit.

9. Arrangement according to claim 8,

characterised in

first register means (52) for storing information about dedicated subordinated units indicating a resource excess and information about resource parameters,

second register means (53) for storing information about dedicated subordinated units indicating a resource deficit and information about resource parameters,

said first and second register means being connected to said means (55) for equalisation.

10. Arrangement according to claim 9,

characterised in

means (55) for equalising indicated resource deficits and resource excesses having matching resource parameters.

11. A communication system comprising a plurality of system units and applying as system resources a plurality of communication channels with appropriate properties,

characterised in
two or more of said system units comprising the arrangement according to one of claims 8 - 10 and performing at regular times the method steps according to one of claims 1 - 7.

12. The communication system according to claim 11 being a multiple access cellular radio communication system.
T = T_n, j = 0

i = 1

determine resource status for U[j,i]

j < L ?

indicate status to external unit

indicate status to superior unit

equalise resources between subordinated units

i < I(j) ?

i = i + 1

j = j + 1

n = n + 1

Fig. 2
3/7

A

261

some subordinated units indicate resource excess?

No

262

transfer exceeding resources to superior unit

Yes

263

some subordinated units indicate resource deficit?

No

264

allocate resources to subordinated unit with largest resource deficit

Yes

265

exceeding resources left?

Yes

No

B

Fig. 3
INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01631

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04Q 7/38
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04Q, H04B

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

SE, DK, FI, NO classes as above

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search: 18 October 2001

Date of mailing of the international search report: 19-10-2001

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