

System and method for managing a wide-band radio network of the scheduled point-to-multipoint type with a time-intervalled frame structure for on-the-move applications in mesh networks

The present invention relates to a method for managing a radio communication mesh network and more specifically a method for managing point-to-multipoint communication frames according to the IEEE standard 802.16-2005-WiMax in a radio communication mesh network.

WiMAX, which stands for Worldwide Interoperability for Microwave Access, is a technology which allows access to wireless wide-band telecommunication networks. The abbreviation was formulated by the WiMAX Forum, a consortium formed by more than three hundred companies whose aim is to develop, supervise, promote and test the interoperability of systems based on the IEEE Standard 802.16.

In conventional systems, radio technologies structured in such a way as to be used in hierarchical networks of the point-to-multipoint type differ from radio technologies designed for use in parity networks of the mesh type. The first type of technology is related to mobile radio systems used in public cellular networks, while the second type is typically used in technological niches, also of large dimensions, such as sensor technology or security, military and police networks. This situation has resulted in and still results in discontinuous technological development and generally does not allow the solutions to be reutilised horizontally, i.e. independently of the network application to which they refer.

An object of the present invention is to propose a many-to-many parity communication technology based on a point-to-multipoint hierarchical network communication technology which is able to co-ordinate the participants in a mesh network, so that each participant is able to communicate, in the best possible conditions, with the other nodes participating in the network.

This and other objects are achieved by a method, the main features of which are defined in Claim 1.

Particular embodiments are the subject of the dependent claims.

The invention relates furthermore to a management system, a communication network and a network node as claimed.

The invention relates to wide-band radio transmission systems for mesh networks in mobility conditions of the participating nodes.

Briefly, the invention is based on the application of conventional functional roles of a point-to-multipoint network in a time division context with dynamic assignment of the roles of the communication nodes, namely the organisation of the communication time frame of a many-to-many parity network in a plurality of intervals or time units within each of which a point-to-multipoint hierarchical communication scheme is replicated.

The invention therefore provides a hierarchical communication scheme from one node to a multiplicity of other nodes for the purpose of providing many-to-many parity communications. In this way, the nodes participating in the network assume, based on a principle involving rotation of the functions, a "master" function of the hierarchical communication for the time intervals within which this role is pre-assigned.

The network is managed by adapting and modifying its mesh structure using operational parameters which are measured by the nodes themselves participating in the network. Examples of these parameters are the quality measurements on the radio channels and the dimensions of the load associated with each node participating in the network, in terms of Kb/s.

Further characteristics and advantages of the invention will become apparent from the detailed description which follows, provided purely by way of a non-limiting example, with reference to the accompanying drawings in which:

Figure 1 shows an example of partitioning of a communication frame according to the invention into four time units;

Figure 2 shows an example of partitioning of a frame of Figure 1 for three different network nodes operating as a base radio station;

Figure 3 shows a mesh network topology according to the invention, comprising four nodes and a "legacy" mobile terminal station; and

Figure 4 shows an example of frames for the network topology according to Figure 3.

The nodes according to the invention each consist of a base radio station part (BS) and a mobile terminal station part (MS). According to the method of the invention, the radio system operates through time periods (the blocks) in which the nodes assume the role either of base radio station or mobile terminal station.

A frame can be divided at the most into eight units, during which each node may:

- 1) assume, for a certain number N of blocks, the role of base radio station and for another number M of blocks, assume the role of mobile terminal station, in which N and M are each comprised within the range [1,7] and the sum of N and M is less than or equal to 7;
- 2) assume, for a number M of blocks, the role of mobile terminal station and never assume the role of base radio station, where M falls within the range [1,7].

The nodes which operate in mode 1) perform both the functions of operative base radio station and mobile terminal station and are designed to provide a communication of the one-to-many type. These nodes are called "multiple relay" nodes.

The nodes which operate in mode 2) perform only the function of operative mobile terminal station and are designed to operate in a mode called "MS mode". The mobile terminal station part of a "multiple relay" mode may become operative only when the base radio station part of the same node is not busy communicating.

It should be noted that the architecture divides up the time of a PMP frame according to the standard 802.16-2005 (duration 20 ms) at the most into eight blocks. Seven of these blocks can be used by the nodes to operate with time division and one is reserved for management procedures.

Within each block the base radio technology is a S-OFDMA derived technology, in accordance with the standard Wi-MAX 802.16-2005. The system according to the invention is composed of a physical level and a MAC level and is therefore conventionally related to the so-called level 2 switching structures used to form the network bridges or switches. This system is useful for providing level 2 radio switches from Ethernet via cable (IEEE 802.3 - extensions) to radio communication of the WiMAX point-to-multipoint type.

The MAC part of the overlying Mesh level (procedural management level of the mesh network) operates using a "scheduled PMP" principle based on the fact that, on a regular time basis, the assignment of each single unit by the controller node is redefined.

The system according to the invention, which may be basically defined as a scheduled system with time-intervalled frame structure, is based on the following assumptions:

- the communications permitted between the nodes, within each block, are in accordance with the PMP modes indicated in the standard 802.16-2005. Two-way communications base radio station-mobile terminal station are permitted (i.e. "multiple relay" to "multiple relay" and "multiple relay" to mobile terminal station) and neither communications between base radio stations nor communications between mobile terminal stations are permitted;
- each mobile terminal station is synchronized and communicates with only one base radio station, but may monitor the other base radio stations;
- the PMP frames must occur periodically and the frame period is fixed at 20 ms so as to ensure compatibility with the PMP standard.

Figure 1 shows an example of partitioning of a frame 10 into four blocks, and therefore suitable for a network which has at the most four orthogonal transmission channels. The units are indicated by 1, 2, 3, 4, respectively.

One or more blocks are assigned to each single base radio station of each node, as explained herebelow, and within each block each base radio station may communicate with

the mobile terminal stations associated with it, in PMP mode according to the standard 802.16-2005. The method according to the invention performs a time division of the radio resource between the base radio stations which occupy the orthogonal transmission channels.

In the blocks where the base radio station is not authorised to manage the radio channel, the node may in any case operate by means of the mobile terminal station; the base radio station interface in any case remains active at the MAC level but cannot access the transmitter/receiver or other physical level functions. A single antenna is in fact associated with each node and it is connected alternately to the base radio station part or to the mobile terminal station part.

During the time period where the mobile terminal station interface is operative, it is associated with the base radio station of another node of the network and will communicate in the manner stipulated by the standard WiMAX 802.16-2005.

In the example according to Figure 1, the blocks 1 and 2 are assigned to a first base radio station 100, where assignment is indicated by arrows 10a and 10b. The block 3 is assigned to a second base radio station 200, indicated by arrow 10c, and the block 4 is assigned to a third base radio station 300, indicated by arrow 10d.

Said base radio stations 100, 200 and 300 use the transmission channel, in "multiple relay" mode, for as long as the network considers it necessary. Assignment of the blocks involves coordination between the base radio stations, but ensures that there is no interference between communications of the latter with the mobile terminal stations associated with them.

The frame overstructure introduced in the present invention is obtained by suitably configuring the PMP standard frames, such that the base radio station of each "multiple relay" node shares a single time reference. The system envisages that the duration of a PMP frame is equal to the duration of N blocks, where in this example $N=4$, and that each base radio station 100, 200 or 300 of each "multiple relay" node transmits the signal at the

beginning of the blocks assigned to it.

The method according to the invention envisages that a base radio station in the units not assigned to it is switched to uplink mode and does not perform transmissions to the mobile terminal stations associated with it.

Figure 2 shows the three base radio stations 100, 200, 300 according to Figure 1 with which three frames 20, 30 and 40 are associated. In a similar manner to that shown in Figure 1, the blocks 1 and 2 of the first frame 20 are assigned to the first base radio station 100 (arrows 10e and 10f), the block 3 of the second frame 30 is assigned to the second base radio station 200 (arrow 10g) and the fourth block 4 of the third frame 40 is assigned to the third base radio station 300 (arrow 10h).

The frames 20, 30 and 40 of each base radio station 100, 200 and 300 will contain parts which cannot be used for communication by the respective base radio stations 100, 200 or 300. During these periods the base radio station will enter into an "idle" state. The part of each frame 20, 30 and 40 which is effectively at the disposal of each base radio station 100, 200 and 300 will therefore be only that defined by the blocks 1, 2, 3 and 4 assigned to it. Outside of these assigned blocks, each base radio station 100, 200, 300 must ensure that no transmissions are being performed (by itself and the associated mobile terminal stations).

The blocks 1, 2, 3 and 4 of each frame 20, 30 and 40 which can be used for communication contain both the downlink transmission part D and the uplink transmission part U, as explained below.

In Figure 2 the three frames 20, 30 and 40 are positioned on the basis of a single time reference, the origin O of which is fixed in the first block of the first frame 20. The frame 20 of the first base radio station 100 therefore begins in the unit 1, the frame 30 of the base radio station 200 begins in the block 3 and the frame 40 of the third base radio station 300 begins in the unit 4.

The method according to the invention envisages that a base radio station switches from downlink D to uplink U before the end of the set of adjacent blocks in which it was transmitted. The first base radio station 100 has two adjacent blocks available, namely blocks 1 and 2 and may therefore decide to switch from downlink D to uplink U at the latest before the end of unit 2. The second base radio station 200 has only block 3 available and must therefore perform switching within this assigned interval. The third base radio station 300 also has only block 4 available and must therefore perform switching within this assigned interval.

As laid down in the Standard 802.16-2005 the position of the downlink D – uplink U boundary may change from frame to frame and is communicated by the base radio station in the downlink channels D.

For each base radio station 100, 200, 300 it is possible to define the blocks assigned to it and the blocks which must it leave free within each frame 20, 30 and 40. Considering a vector which contains N bits, it is possible to associate a “1” with the blocks 1, 2, 3 or 4 which the base radio station 100, 200 or 300 may use and a “0” with the blocks 1, 2, 3 or 4 in which the base radio station 100, 200 or 300 may not transmit. This vector is called “mask” associated with the frame 20, 30 or 40 and indicates to the base radio station 100, 200 or 300 where the frame 20, 30 or 40 begins and where the transmissions are permitted.

In the example according to Figure 2, the first base radio station will see a mask of the type [1100]; this mask indicates that the station 100 has the frame 20 which begins in the unit 1 and lasts for two blocks. The same mask indicates to the base radio station 100 that the blocks 3 and 4 must remain free. The second base radio station 200 and third base radio station 300 will have the following masks: [0010] and [0001]. As can be seen, the base radio stations 100, 200 and 300 must share a single time reference in order to operate with the masks, which indicates them where the first block of the frame 20, 30 or 40 begins, and to know the duration of this block.

The term “legacy” refers to standard terminals of the IEEE 802.16-2005-WiMAX which do not possess the base radio station part and which therefore operate exclusively as a

mobile terminal station. Consequently, the "legacy" terminals are always connected to a base radio station which organizes the transmissions performed by it so as not to disturb regular operation of the network.

Figure 3 shows four nodes 5, 6, 7 and 8 (three of which operate as "multiple relays" and one of which operates as a mobile terminal station) and a "legacy" mobile terminal station 9. The base radio station of the node 5 has associated the mobile terminal stations of the nodes 7 and 8, indicated by arrows 60 and 70, while the mobile terminal station of the node 5 is associated with the base radio station of the node 6, indicated by arrow 50. The base radio station of the node 7 is associated with the mobile terminal station of the node 6 and with the "legacy" terminal 9, indicated by arrows 80 and 90. The base radio station of the node 8 does not have assigned blocks and therefore cannot operate.

Figure 4 shows an example of frames for the network topology shown in Figure 3, representing an extension of that described with reference to Figure 2.

The base radio station of the node 5 has at her disposal the first two blocks 1 and 2, while the base radio stations of the nodes 6 and 7 have at their disposal the units 3 and 4. The base radio station of the node 8 does not have assigned blocks and is therefore in an OFF state, namely cannot access the transmission channel.

The frames of the base radio stations of the nodes 5, 6 and 7 are similar to those described with reference to Figure 2; the mobile terminal stations will be aligned with the frame emitted by the base radio station with which they are associated as above described.

Also in this case, the "idle" state indicates the blocks which cannot be used for communication by one or both the base radio and mobile terminal station interfaces of the node. However, it is necessary to emphasize that both the interfaces regard the "idle" blocks as part of their uplink subframe. Consequently, for both the interfaces, the uplink subframe U will extend from the end of the downlink subframe D to the beginning of the downlink subframe D of the next PMP frame irrespective as to whether or not the node can transmit/receive in this time period.

The base radio station of the node 7 has the "legacy" terminal 9 associated with it. Access to the network by this terminal is conceptually transparent: it receives the downlink messages D sent from the node 7 and the base radio station of said node 7 will authorise it to transmit its data in uplink mode U only within the units assigned to it and therefore without causing interference with the other nodes 5, 6 and 8. This can be obtained as a particular example of PMP standard operation and therefore does not result in any special design of the "legacy" terminal 9.

As already mentioned above, the PMP frame has a fixed length, while the position of the downlink D – uplink U boundary may be varied, both from one node to another and from one frame to another of the same node. The position of this boundary is determined in each case by the base radio station which manages the channel, and the associated mobile terminal stations are obliged to observe this position, as envisaged by the standard.

In order to perform correct allocation of the channels in the network and to manage changes in topology it is necessary for the nodes to co-operate in order to establish mutual visibility. For this purpose, it is possible to use both the base radio station and the mobile radio station and, if necessary, also the information which the mobile terminal stations associated with the base radio stations (when operative) are able to collect.

A node in "MS mode" is able to detect to which base radio stations have been assigned a block for the transmission and communicate this to the base radio station with which it is associated. A "multiple relay" node, when it has the base radio station active, cannot perform measurement operations because its mobile terminal part does not have access to the physical layer. This "multiple relay" node may, however, ask the associated mobile terminal stations to perform measurements in order to detect the base radio stations which are operating on other channels (i.d. on other blocks) and which are visible in them. This measurement operation will obviously start at the end of the time block assigned for communication to the base radio station of the "multiple relay" node.

A "multiple relay" node operating in base radio station mode manages to detect only the

mobile terminals which communicate their presence in the registration or pre-registration channels. Therefore, in general, the nodes which do not have an active base radio station cannot be detected without introducing sophisticated multiple registration functions in the base radio stations. In any case, the base radio stations which are switched off cannot detect each other.

This limitation poses problems both in the network extension procedures and in mobility management. In order to allow, however, exploration of the surroundings and/or the recovery of nodes which move away from the network, the eighth management block above-mentioned is reserved for carrying out measurements of the non-operative base radio stations.

The rules governing assignment of the "master" role to the nodes participating in parity communication depend on many factors including, for example, the content of the communication and the relative position of the nodes in the territory. This latter aspect influences the capacity of a node to communicate effectively with the other nodes, but also its potential ability to contribute towards the successful outcome of communication performed by the other nodes, repeating the information received to the destination node. In so doing it is possible to obtain effective parity among the participating nodes by means of intelligent rotation of the "master" role.

The decision as to assignment of one or more blocks to a node is responsibility of a controller node which effects the assignment based on a decisional algorithm supplied by measurements distributed to it and conveyed via the known mechanism of "network flooding" of the switching control protocols.

So that the network may be truly parity in nature, the participants must also co-operate in the carrying out of certain network control functions, for example exploring the surroundings in order to detect the presence of other nodes able to form part of the network or recover the nodes which, for operative reasons, tend to move away from the central core of the network. Finally, the parity network operates in a "democratic" manner in the sense that it is available to separate into various sub-networks as well as to aggregate and merge

with it new sub-networks which are situated in the vicinity of the central core of the parity network. Both separation and aggregation are performed while respecting the principle of continuity of the communications.

Clearly, the principle of the invention remaining the same, the embodiments and the details of production can be varied considerably from what has been described and illustrated purely by way of a non-limiting example, without thereby departing from the scope of the invention as defined in the accompanying claims.

CLAIMS

1. Method for managing communication frames for a telecommunication mesh network, comprising at least one transmission channel, the method being characterized in that it comprises the steps of:

- providing at least one plurality of communication nodes each having a base radio station and a mobile terminal station;
- subdividing at least one predetermined communication frame into time periods of predetermined duration;
- assigning to said base radio stations respective time periods in which the base radio stations are able to be operative;
- each base radio station accessing the transmission channel only for the duration of the time period associated with it.

2. Method for managing frames according to Claim 2, also comprising the operation of associating with said base radio stations respective mobile terminal stations of different nodes.

3. Method for managing frames according to Claim 1 or 2, in which each base radio station accesses the transmission channel only when the mobile terminal station of the same node is not busy communicating.

4. Method for managing frames according to any one of the preceding claims, in which each base radio station is able to remain active at the MAC level when the mobile terminal station of the same node is busy communicating.

5. Method for managing frames according to any one of Claims 2 to 4, in which each base radio station is designed to interrogate the respective mobile terminal stations associated with it in order to perform measurements on the transmission channel.

6. Method for managing frames according to any one of the preceding claims, in which at least one of said time periods is used to perform management operations.

7. Method for managing frames according to any one of the preceding claims, in which at least one of said plurality of nodes is arranged to function exclusively as a mobile terminal station.
8. Management method according to any one of preceding claims, in which at least one of said time periods contains a boundary able to subdivide said time period into a first part arranged to perform a downlink transmission and a second part arranged to perform an uplink transmission.
9. Method for managing frames according to any one of the preceding claims, in which said base radio stations are able to communicate with standard "legacy" terminals.
10. Management system arranged to implement the method as claimed in any one of Claims 1 to 9.
11. Communications network arranged to operate in accordance with the method as claimed in any one of Claims 1 to 9.
12. Network node comprising a base radio station and a mobile terminal station designed to operate according to the method as claimed in any one of Claims 1 to 9.