

## METHOD FOR TRANSMISSION IN A 'CLUSTERED' NETWORK

The invention relates to a method of data transmission within a 'clustered' ad hoc wireless communication network, i.e. in which the transmitting/receiving nodes are distributed within multiple groups or clusters, each having a group or 'cluster' head.

One of the technical problems in ad hoc wireless communication networks is to enable a cluster head to communicate with other neighbouring cluster heads with the same number of radio resources regardless of the topology of the network. The known prior art techniques are based on establishing different paths of communication, according to the topology of the network, for enabling a cluster head to reach neighbouring cluster heads.

In a transmission network organized in clusters, each cluster operates on a different radio channel (frequency, code, etc.) and a common radio channel is used for the entire network for inter-cluster signalling. Each cluster has periodic guaranteed access to the common channel for broadcasting signalling or data to the other clusters. Intra-cluster communications are coordinated by the cluster head. Inter-cluster communications are, on the other hand, difficult to set up since they require coordination between the various cluster heads for sharing and access to the radio resources. As the inter-cluster heads are not always in direct sight of each other, i.e. with the possibility of reliably exchanging information directly without going through relay nodes, the signalling resource dedicated to these exchanges must be used effectively for enabling each cluster head to send its signalling messages to all the neighbouring cluster heads irrespective of the topology of the network.

One of the objectives of the present invention is to enable each cluster head to broadcast its inter-cluster signalling to all its neighbouring clusters, with a quantity of radio resources that does not depend on the topology of the network. Such access will reduce the need for inter-cluster

signalling and so make it possible to program this access more frequently over time thereby making signalling faster.

The invention relates to a method in which a signalling mechanism is used between groups or clusters, using the regular nodes of a cluster for  
 5 cooperatively relaying the signalling from cluster heads to other nodes or cluster heads.

In the rest of the description, 'regular node' refers to a node of a network provided with means of communication, and a 'cluster head' to a regular node further including a management module adapted to handle  
 10 regular nodes. The term 'intra' refers to the nodes in a group and the exchanges within this group. The term 'inter' refers to the exchanges between different groups. The expression 'node in the neighbourhood' or 'in radio range' refers to nodes that are located in radio range of a transmitting node, i.e. which can exchange information using communication channels  
 15 without going through relay nodes.

The following English abbreviations will be used:

- CH for referring to a communication channel, TX for transmission and RX for reception of signals,
- IRSCH: Inter-Cluster Relay Signalling Channel,
- 20 • RSCH: Relay Signalling Channel,
- CHSCH: Cluster Head Signalling Channel.

The invention relates to a method for broadcasting one or more signalling messages in a communication network comprising at least two clusters, a cluster including at least one cluster head adapted to handle  
 25 communications, multiple nodes provided with transmitting/receiving means characterized in that it comprises at least the following steps:

- at least one cluster head of a first cluster transmits a signalling message to a set of nodes located in its cluster, using a first dedicated radio resource,
- 30 • the nodes of the first cluster having received and decoded the signalling message relay this signalling message to one or more

nodes of the other clusters of the network that are in radio range using a distributed cooperative coherent transmission mechanism on a radio resource of a dedicated common channel,

- the relay node or nodes having received and decoded the signalling message transmit it to their cluster head using a distributed cooperative transmission method on a dedicated radio resource.

According to one variant embodiment a cluster head selects one or more relay nodes for reaching a set of neighbouring clusters and,

- if two selected relay nodes do not share an external neighbourhood then they transmit on the same radio resource without interfering with each other,
- if two selected nodes have a portion of their external neighbourhoods in common, then they use the same radio resource cooperatively for improving the quality of their transmission.

The method may use a common inter-cluster signalling channel including signalling corresponding to a time-slot used by a set of nodes belonging to a cluster for cooperatively relaying the signalling from their cluster head to the neighbouring clusters.

A communication channel dedicated to the cluster comprises a receiving slot, multiple slots  $RSCH_j$ , used by a set of nodes belonging to a cluster for cooperatively relaying the inter-cluster signalling received from the neighbouring clusters to their cluster head, a signalling slot  $CHSCH_j$  dedicated to the cluster heads.

The method may be implemented in a clustered ad hoc wireless communication network.

The invention also relates to a system of broadcasting signalling messages within a communication network comprising at least two clusters, a cluster comprising at least one cluster head adapted to handle communications, multiple nodes being provided with transmitting/receiving means, characterized in that:

- at least one cluster head of a first cluster comprises a module adapted to transmit a signalling message to a set of nodes located in its cluster, using a dedicated radio resource,
- the nodes of the first cluster are provided with means of receiving and decoding the signalling message and with means of relaying the signalling message to one or more nodes of the other clusters of the network that are in radio range using a distributed cooperative coherent transmission mechanism on a radio resource of a dedicated common channel,
- the node or nodes having received and decoded the signalling message transmit it to their cluster head using a distributed cooperative transmission method on a dedicated radio resource.

The common channel is, for example, a common inter-cluster signalling channel including signalling corresponding to a time-slot used by a set of nodes belonging to a cluster for relaying the signalling from their cluster head to the neighbouring clusters.

A channel dedicated to a cluster comprises, for example, a receiving slot, multiple signalling relay slots  $RSCH_j$ , used by a set of nodes belonging to a certain cluster for cooperatively relaying the inter-cluster signalling received from the neighbouring clusters to their cluster head, and a signalling slot  $CHSCH_j$  dedicated to the cluster heads.

Other features and advantages of the present invention will become better apparent upon reading the following description given by way of illustration but in no way restrictively in the accompanying figures which represent:

- Figure 1, an example of a network composed of multiple clusters each having a cluster head, and
- Figure 2 and Figure 3, two examples of the steps implemented by the method.

The ad hoc network in which the invention is implemented is organized into groups or clusters, each cluster operating on a different radio

channel (frequency, code, etc.). A common radio channel is used for the entire network for inter-cluster signalling. Each cluster has periodic guaranteed access to the common channel for broadcasting signalling or data to the other clusters. The method is based notably on exploiting the spatial diversity of the network and on the concept of the cooperative relaying for enabling each cluster head to select and use one or more relay nodes in its group to reach one or more sets of neighbouring clusters.

Figure 1 schematically depicts an example of a transmission network including multiple clusters  $10_i$ , each cluster  $10_i$  including multiple nodes  $11_{ik}$  each provided with a module for transmitting/receiving 12, 13, a module 14 suitable for cooperative transmission, a cluster head  $24_j$ , including a module for transmitting/receiving 25, 26, a module for decoding signalling messages 29, a module for managing 27 the communications of the set of nodes present in the cluster whereof it is the head, and a module suitable for cooperative transmission 28.

Each of the clusters operates, for example, on a different radio channel, frequency  $F_c$ , code  $M_c$  and has periodic access to a common signalling channel CS.

In Figure 1, the arrows I, II, III correspond to three stages of the method according to the invention which will be explained below in relation to Figures 2 and 3. Transmissions take place on dedicated radio resources without prior requests.

In a first stage, a cluster head  $24_1$  will broadcast the signalling message to be transmitted to the cluster heads  $24_j$  located in the other clusters of the communication network to the regular nodes  $11_{1k}$  present in its cluster  $10_1$ . The broadcasting takes place, for example, on a dedicated radio resource, time, frequency, code. The regular nodes  $11_{1k}$  of this cluster  $10_1$  listen to this radio resource  $CH_1$ . The regular nodes  $11_{1k}$  are relay nodes which will enable the transfer of the signalling message M from the cluster head to the cluster heads  $24_j$  located in the other clusters  $10_j$  of the network.

The cluster head  $24_1$  identifies or selects the relay nodes for reaching the set of neighbouring clusters, according to a method known to the person skilled in the art. A cluster head has at its disposal a database giving the configuration of the communication network.

5           If two selected relay nodes  $11_{12}$ ,  $11_{11}$ , do not share an external neighbourhood, i.e. neighbouring nodes not belonging to the same group, i.e. neighbours outside their group/cluster, then they may transmit on the same radio resource, which corresponds to spatial diversity.

10           If two selected relay nodes  $11_{12}$ ,  $11_{13}$  have a portion of their external neighbourhoods in common then the concept of cooperative relaying enables them both to have the same radio resource allocated to them and to make the radio link to their common neighbourhoods more robust to transmission errors.

15           At the end of the first stage I, the relay nodes  $11_{11}$ ,  $11_{12}$ ,  $11_{13}$ , of the source cluster  $10_1$  have at their disposal the information or the message to be transmitted to the various cluster heads  $24_j$ .

20           In a second stage II, the regular nodes of the source cluster  $10_1$  which have received the signalling message M, will relay the message M intended for the neighbouring cluster heads  $24_j$ , using the cooperative transmission mechanism, to their external neighbourhoods belonging to a different cluster ( $10_2$ ,  $10_3$  and  $10_4$ ). Relaying the message M is done using a technique of cooperative coherent transmission of the message. This transmission is, for example, performed, on the communication channel CS common to all the clusters, on a radio resource dedicated to the cluster  $10_1$  to which the head  $24_1$  transmitting the message M belongs. All the nodes  $11_{jk}$  of a cluster  $24_j$  listen to the radio resources dedicated to relaying the other clusters. At the conclusion of this second stage II, certain relay nodes  $11_{23}$ ,  $11_{41}$ ,  $11_{42}$ ,  $11_{31}$  of the clusters  $24_j$  have received the message M to be transmitted to their respective cluster heads.

30           In a third stage III, all the nodes of one or more neighbouring clusters of the cluster  $10_1$  which have correctly decoded the message M

originating from the transmitting cluster  $10_1$  relay this message  $M$  using a coherent transmission message protocol to their cluster head  $24_2$ ,  $24_3$ ,  $24_4$  (e.g. in Figure 1), according to a cooperative transmission mechanism and stages known to the person skilled in the art. For this, they use a dedicated  
 5 radio resource which is listened to by the cluster head.

Figures 2 and 3 schematically depict the implementation of the three stages previously described.

Figure 2 depicts the common inter-cluster signalling channel  $CS$ , the channel  $CH_1$  dedicated to cluster  $10_1$ , the channel  $CH_2$  dedicated to  
 10 cluster  $10_2$ , the channel  $CH_3$  dedicated to cluster  $10_3$ , and the channel  $CH_4$  dedicated to cluster  $10_4$ .

The common inter-cluster signalling channel includes an inter-cluster signalling  $IRSCH$ , 30, for cooperatively relaying between clusters, corresponding to a time-slot used by a set of nodes belonging to a certain  
 15 cluster for relaying the signalling from their cluster head to the neighbouring clusters.

The first channel  $CH_1$  dedicated to cluster  $10_1$  comprises a receiving  $RX_1$  slot  $31_1$ , multiple slots  $RSCH_1$ ,  $32_1$ , used by a set of nodes belonging to a certain cluster for cooperatively relaying the inter-cluster  
 20 signalling received from the neighbouring clusters to their cluster head, and a signalling slot  $CHSCH_1$  dedicated to the cluster heads.

This configuration is found for the channels dedicated to the other clusters.

The second channel  $CH_2$  dedicated to cluster  $10_2$  comprises a  
 25 receiving  $RX_1$  slot  $31_2$ , multiple slots  $RSCH_2$ ,  $32_2$ , used by a set of nodes belonging to a certain cluster for cooperatively relaying the inter-cluster signalling received from the neighbouring clusters to their cluster head, and a signalling slot  $CHSCH_2$  dedicated to the cluster heads.

The third channel  $CH_3$  dedicated to the third cluster  $10_3$  comprises  
 30 a receiving  $RX_1$  slot  $31_3$ , multiple slots  $RSCH_3$ ,  $32_3$ , used by a set of nodes belonging to a certain cluster for cooperatively relaying the inter-cluster

signalling received from the neighbouring clusters to their cluster head, and a signalling slot  $\text{CHSCH}_3$  dedicated to the cluster heads.

The fourth channel  $\text{CH}_4$  dedicated to the fourth cluster  $10_4$  comprises a receiving  $\text{RX}_1$  slot  $31_4$ , multiple slots  $\text{RSCH}_4$ ,  $32_4$ , used by a set  
 5 of nodes belonging to a certain cluster for cooperatively relaying the inter-cluster signalling received from the neighbouring clusters to their cluster head, and a signalling slot  $\text{CHSCH}_4$  dedicated to the cluster heads.

Figure 3 schematically depicts the three stages of the method according to the invention, stage I, stage II and stage III.

10 First, the cluster head  $24_1$  of the first cluster or source cluster  $10_1$  sends a signalling message  $M$  intended for the various neighbouring cluster heads to the nodes of its cluster (the neighbouring clusters contain nodes in the neighbourhood of the nodes in its cluster). This transmission takes place on a dedicated radio resource that all the regular nodes of the cluster must  
 15 listen to, signalling slot  $\text{CHSCH}_1$ .

The regular nodes  $11_{1k}$  of the first cluster  $10_1$  having received the message  $M$ , relay the signalling message from their cluster head  $24_1$  to the neighbouring clusters  $10_j$ ,  $\text{IRSCH}$  slot, stage II, and to the regular nodes  $11_{jk}$  of other clusters  $10_j$  using a dedicated radio resource ( $\text{IRSCH}$  slot on the  
 20 common channel  $\text{CS}$ ) to the cluster to which the cluster head  $24_1$  transmitting the message belongs. This relaying is done using a cooperative coherent transmission of the message. All the nodes of a cluster must listen to the radio resources dedicated to relaying the other clusters.

The regular nodes  $11_{jk}$  of the neighbouring clusters  $10_j$  of the first  
 25 source cluster  $10_1$  which have received and correctly decoded a signalling message  $M$  originating from the source cluster  $10_1$  will relay it using a cooperative coherent transmission of this message, stage III, to their cluster head  $24_j$  using a dedicated radio resource that the cluster head must listen to,  $\text{RSCH}$  slots.

30 The method according to the invention notably enables a cluster head to broadcast its inter-cluster signalling to its neighbouring clusters, with

a quantity of radio resources that does not depend on the topology of the network. Such access reduces the need for inter-cluster signalling and so makes it possible to program this access more frequently over time. The size and the number of radio resources that reach the entire neighbourhood of a  
5 cluster are independent of the topology of the network. The method allows a gain in the signalling size by having a true broadcast channel for point-to-multipoint signalling and possible multiplexing of point-to point signalling.

## CLAIMS

- 1 – Method for broadcasting one or more signalling messages in a communication network comprising at least two clusters ( $10_1$ ,  $10_2$ ), a cluster comprising at least one cluster head ( $24_1$ ,  $24_2$ ) adapted to handle communications, and multiple nodes ( $11_{1k}$ ,  $11_{2k}$ ) provided with transmitting/receiving means (12, 13), characterized in that it comprises at least the following steps:
- 10       • at least one cluster head ( $24_1$ ) of a first cluster ( $10_1$ ) transmits a signalling message M to a set of nodes ( $11_{1k}$ ) located in its cluster ( $10_1$ ), using a dedicated radio resource  $CH_1$ ,
  - the nodes ( $11_{1k}$ ) of the first cluster ( $10_1$ ) having received and decoded the signalling message M relay this signalling message M to one or more nodes ( $11_{jk}$ ) belonging to other clusters of the network that are in radio range using a distributed cooperative coherent transmission mechanism on a radio resource of a dedicated common channel CS,
  - 15       • the relay node or nodes ( $11_{jk}$ ) having received and decoded the signalling message M transmit it to their cluster head ( $24_j$ ) using a distributed cooperative transmission method on a dedicated radio resource  $CH_j$ .
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- 2 – Method according to Claim 1, characterized in that a cluster head selects one or more relay nodes for reaching a set of neighbouring clusters, and
- 25       • if two selected relay nodes do not share an external neighbourhood then they transmit on the same radio resource without interfering with each other,
  - if two selected nodes have a portion of their external neighbourhoods in common, then they use the same radio resource cooperatively for improving the quality of their transmission.
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3 – Method according to one of Claims 1 or 2, characterized in that it uses a common inter-cluster signalling channel including signalling corresponding to a time-slot used by a set of nodes belonging to a cluster for cooperatively relaying the signalling from their cluster head to the neighbouring clusters.

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4 – Method according to one of Claims 1 to 3, characterized in that a channel  $CH_j$  dedicated to the cluster  $(10_j)$  comprises a receiving  $RX_j$  slot  $(31_j)$ , multiple slots  $RSCH_j$ ,  $(32_j)$ , used by a set of nodes belonging to a cluster for cooperatively relaying the inter-cluster signalling received from the neighbouring clusters to their cluster head, and a signalling slot  $CHSCH_j$  dedicated to the cluster heads.

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5 – Use of the method according to one of Claims 1 to 4 in a clustered ad hoc wireless communication network.

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6 – System for broadcasting one or more signalling messages within a communication network comprising at least two clusters  $(10_1, 10_2)$ , a cluster comprising at least one cluster head  $(24_1, 24_2)$  adapted to handle communications, and multiple nodes  $(11_{1k}, 11_{2k})$  provided with transmitting/receiving means  $(12, 13)$ , characterized in that:

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- at least one cluster head  $(24_1)$  of a first cluster  $(10_1)$  comprises a module adapted to transmit a signalling message  $M$  to a set of nodes  $(11_{1k})$  located in its cluster  $(10_1)$ , using a dedicated radio resource  $CH_1$ ,
- the nodes  $(11_{1k})$  of the first cluster  $(10_1)$  are provided with means of receiving and decoding the signalling message  $M$  and with means of relaying the signalling message  $M$  to one or more nodes  $(11_{jk})$  of the other clusters of the network that are in radio range using a distributed cooperative coherent transmission mechanism, on a radio resource of a dedicated common channel  $CS$ ,

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- the node or nodes (11<sub>jk</sub>) having received and decoded the signalling message M transmit it to their cluster head (24<sub>j</sub>) using a distributed cooperative transmission method on a dedicated radio resource CH<sub>j</sub>.

- 5     7 – System according to Claim 6, characterized in that the common channel is a common inter-cluster signalling channel including signalling corresponding to a time-slot used by a set of nodes belonging to a cluster for relaying the signalling from their cluster head to the neighbouring clusters.
- 10    8 – System according to one of Claims 6 or 7, characterized in that a channel CH<sub>j</sub> dedicated to a cluster (10<sub>j</sub>) comprises a receiving RX<sub>j</sub> slot (31<sub>j</sub>), multiple slots RSCH<sub>j</sub>, (32<sub>j</sub>), used by a set of nodes belonging to a certain cluster for relaying the inter-cluster signalling received from the neighbouring clusters to their cluster head, and a signalling slot CHSCH<sub>j</sub> dedicated to the cluster
- 15    heads.