

**A method and a mobile ad-hoc network for the effective
identification of neighbouring nodes**

The invention relates to a method for the effective
5 identification of neighbouring nodes in a mobile ad-hoc
network, accordingly a corresponding network.

In mobile networks without infrastructure - so-called ad-hoc
networks - the management, the monitoring and the control of
10 the data traffic is processed directly between the individual
network participants - the so-called network-nodes
respectively nodes.

In this context, one substantial function is the planning of
15 the route from the transmitting node to the receiving node,
the so-called routing. Accordingly, the routing between the
transmitting node and the receiving node can typically be
implemented via several intermediate nodes. For a multi-hop
routing of this kind, two classes of routing method have been
20 established in principle.

In the case of proactive routing, the direct neighbour nodes
of every individual node in an ad-hoc network are determined
in each case within a given time raster and stored in a
25 routing table which is notified to all nodes of an ad-hoc
network via selected nodes. By contrast, in the case of
reactive routing, the respective neighbour nodes of every
individual node in the transmission corridor between the
transmitting node and the receiving node are determined
30 uniquely in the case of a transmission request of a node
shortly before the transmission and communicated to the
individual nodes within the transmission corridor.

The data traffic for determining the neighbour nodes of every individual node and the data traffic for notifying the respective neighbourhood nodes of every individual node in the overall ad-hoc network requires transmission capacity which significantly minimises the transmission efficiency within the ad-hoc network. Conversely, because of the network nodes accessing and departing from the mobile ad-hoc network, a mobile ad-hoc network is typically highly variable and requires a continuous and rapid updating of the knowledge required for the proactive routing method regarding the nodes positioned in each case directly adjacent to every node of the ad-hoc network. For existing proactive routing methods, the topology of the ad-hoc network - that is, the knowledge regarding the distribution of the individual nodes in the ad-hoc network - is therefore determined within a time raster which represents a compromise between the degree of actuality of the topology of the ad-hoc network and the transmission efficiency within the ad-hoc network. Such a cyclical identification of a topology within an ad-hoc network is disclosed, for example, in WO 2011/154911 A1.

For a node which is disposed outside an ad-hoc network and which would accordingly seek to integrate as quickly as possible into an existing ad-hoc network or to establish a new ad-hoc network with another node also disposed outside an ad-hoc network, it is not feasible merely to announce its presence to potential neighbour nodes in a time raster extended on the basis of a compromise.

The object of the invention is therefore to provide a method for determining the topology of an ad-hoc network and an associated ad-hoc network in order to allow a node disposed

outside an ad-hoc network to integrate as quickly as possible into an ad-hoc network.

The object is achieved by a method according to the invention
5 for the effective identification of neighbouring nodes in a mobile ad-hoc network with the features of claim 1 and by an associated ad-hoc network according to the invention with the features of claim 13. Advantageous technical developments are specified in the respectively dependent claims.

10

Starting from a scenario in which every node displays its presence in the ad-hoc network through transmission of a message signalling a presence - typically a so-called "hello message" - within a given, constant time raster, which is
15 acknowledged with an acknowledgement message from every further node of the ad-hoc network which receives the message signalling a presence for the first time, according to the invention, a node which is disposed outside an ad-hoc network transmits the message signalling a presence in a varied time
20 raster.

The variation according to the invention of the time raster in which a node disposed outside an ad-hoc network transmits a message signalling a presence allows a notification of the
25 node disposed outside an ad-hoc network to potential neighbour nodes as quickly as possible and accordingly an integration of the node disposed outside an ad-hoc network into an ad-hoc network with at least one potential neighbour node as quickly as possible.

30

The node disposed outside an ad-hoc network, which moves to a position outside an ad-hoc network either by starting up, that is, for example, by switching on the operating voltage, at a

position outside an ad-hoc network or, if already started, which moves from a position inside an ad-hoc network to a position outside an ad-hoc network, will preferably initially select a comparatively longer time raster for the transmission of a message signalling a presence, in order promptly to receive for the first time and to acknowledge with an acknowledgement message - even before the transmission of its own message signalling a presence - a message signalling a presence transmitted from a potential neighbour node.

10 Since a common ad-hoc network between two nodes is realised from the time at which the two nodes have made themselves known to one another, the acknowledgement of a message signalling a presence received from a neighbour node through transmission of an acknowledgement message represents the fastest possibility for a node disposed outside an ad-hoc network to integrate itself into an existing ad-hoc network or to establish a new ad-hoc network, because, in this case, only the transmission of an acknowledgement message is required.

20 With the progress of time, during which the probability for the reception of a message signalling a presence transmitted from a potential neighbour node decreases, the node disposed outside an ad-hoc network will preferably reduce the time raster within which it transmits a message signalling a presence in order to make itself known to a potential neighbour node as promptly as possible, to come into contact with it and accordingly to integrate itself into an existing ad-hoc network with the potential neighbour node or to establish a new ad-hoc network with a potential neighbour node.

The reduction of the time raster is preferably continued until the time raster reaches a previously specified minimal value. This minimal-value time raster is retained by the node disposed outside an ad-hoc network until it is integrated in the ad-hoc network.

In order additionally to accelerate the integration of a node disposed outside an ad-hoc network into an existing ad-hoc network or the establishment of a new ad-hoc network between two nodes disposed outside an ad-hoc network, every message signalling a presence received by a node is preferably acknowledged as quickly as possible with an acknowledgement message.

In a first preferred variant of the invention, the acknowledgement with an acknowledgement message is implemented immediately after the reception of a message signalling a presence. In a second preferred variant of the invention, the acknowledgement with an acknowledgement message is slightly delayed by a statistical delay time associated with the respective node in order to prevent a simultaneous acknowledgement of the message signalling a presence by several nodes receiving this message signalling a presence and accordingly a blockage in the ad-hoc network.

The time of the reception of an acknowledgement message in the node which has transmitted the message signalling a presence to be acknowledged preferably represents the time of the start of an ad-hoc network between the node transmitting a message signalling a presence and the node acknowledging the message signalling a presence with an acknowledgement message and additional nodes which are already operating an existing ad-hoc network with one of the two nodes.

A node which acknowledges a received message signalling a presence with an acknowledgement message therefore knows that it will shortly be integrated in an ad-hoc network, and, like
5 every other node which belongs to an ad-hoc network, will therefore transmit its messages signalling a presence within a previously specified, constant time raster, preferably from the time of the transmission of an acknowledgement message. In an equivalent manner, provided it does not already belong to
10 an ad-hoc network, a node which receives an acknowledgement message and therefore knows that it now belongs to an ad-hoc network will therefore, like every other node which belongs to an ad-hoc network, preferably transmit its messages signalling a presence within a previously specified, constant time raster
15 from the time of the reception of an acknowledgement message.

If a node which transmits a message signalling its presence and is knowingly disposed in an ad-hoc network at this time, does not receive a message signalling a presence from another
20 node of the ad-hoc network within a previously specified time interval, then it is knowingly disposed outside an ad-hoc network.

While the formation of an ad-hoc network between at least two
25 nodes is activated with the reception of the acknowledgement message of one of the two nodes by the respectively other of the two nodes, a secured, bi-directional transmission between these two nodes - that is, the presence of a secured, symmetrical transmission between the two nodes - is preferably
30 only given if both nodes know that their transmitted message has been correctly received by the respectively other node. This is preferably only the case if one of the two nodes receives a further acknowledgement message which the

respectively other node transmits upon receiving the acknowledgement message transmitted by one of the two nodes.

By preference, the method according to the invention for the effective identification of neighbouring nodes in a mobile ad-hoc network is used in the preliminary stages of a proactive routing method - routing method - which operates with the so-called Optimised Link State Routing (OLSR) protocol - Optimised Link State Routing protocol.

Exemplary embodiments of the method according to the invention for the effective identification of neighbouring nodes in a mobile ad-hoc network and of the associated ad-hoc network according to the invention are explained in detail in the following with reference to the drawings by way of example. The figures of the drawings show:

Fig. 1 an exemplary time diagram of the messages signalling a presence and associated acknowledgement messages;

Fig. 2A a regional diagram of a first scenario of an ad-hoc network with nodes disposed inside and outside the ad-hoc network;

Fig. 2B a regional diagram of a second scenario of an ad-hoc network with nodes disposed inside and outside the ad-hoc network;

Fig. 2C a regional diagram of a third scenario of an ad-hoc network with nodes disposed inside the ad-hoc network;

Fig. 2D a regional diagram of a fourth scenario of an ad-hoc network with nodes disposed inside and outside the ad-hoc network and

5 Fig. 3 a flow chart of an exemplary embodiment of the method according to the invention for the effective identification of neighbouring nodes in a mobile ad-hoc network.

10 In the following, an exemplary embodiment of the method according to the invention for the effective identification of neighbouring nodes in a mobile ad-hoc network represented by the flow chart in Fig. 3 and the associated exemplary embodiment of the ad-hoc network according to the invention
15 will be explained in detail in the scenarios represented in Figures 2A to 2D.

In the first method step S10 of the method according to the invention, a network node, for example, a mobile-radio device
20 or cellular-radio device, - referred to by way of abbreviation in the following as a node - starts to operate, for example, in that the user of a device representing a node switches on the operating voltage and the device runs through the conventional initialisation routines. After the completion of
25 this start-up, the node is typically still not integrated in an ad-hoc network.

Alongside a node which implements a new start-up, a node which was still integrated in an ad-hoc network shortly before and
30 has left the ad-hoc network through a regional change of its position relative to the transmission range of the ad-hoc network, can, in an equivalent manner, also find itself in the situation of no longer being integrated in an ad-hoc network

and accordingly of seeking participation in an ad-hoc network as quickly as possible.

For this purpose, in the next method step S20, the node
 5 disposed outside an ad-hoc network transmits a message signalling its presence which is typically a "hello message" ("hello message") and is supposed to indicate the presence of the node in the region to the potential neighbour nodes present in the region. Such a message signalling a presence
 10 typically contains only information about the identity of the node - typically identification number of the node - and the transmission time of the message signalling its presence at a local time of the node, which is preferably referenced to a reference-time source - for example, the Global Position
 15 System (GPS) time.

The time raster ΔT_2 in which the node disposed outside an ad-hoc network transmits its messages signalling its presence 1 is comparatively high, as shown in Fig. 1, at the beginning of
 20 the search for an ad-hoc network and, also as shown in Fig. 1, is reduced successively. This guarantees that, at the beginning of its search for an ad-hoc network, before it transmits its first message signalling its presence 1, the node has a sufficiently long time at its disposal to receive
 25 correctly a message signalling a presence 1 transmitted by a potential neighbour node. In fact, a correct reception of a message signalling a presence 1 transmitted from a potential neighbour node is not possible for a node in parallel with the transmission of a message signalling a presence 1, because
 30 parallel transmission and reception is not possible in simplex traffic.

The relatively higher prioritisation of the reception of a message signalling a presence 1 transmitted from a potential neighbour node by comparison with the transmission of a message signalling a presence 1 allows the node disposed
5 outside an ad-hoc network to integrate itself as quickly as possible into an existing ad-hoc network with a neighbour node or to establish an ad-hoc network with a neighbour node as quickly as possible, since the integration of the ad-hoc network-seeking node is completed with the reception by the
10 node which transmitted the message signalling a presence 1 of an acknowledgement message 2 to the received message signalling a presence 1 transmitted by the node.

In the next method step S30, the node seeking an ad-hoc
15 network attempts to identify the reception of an acknowledgement message 2 of the potential neighbour node, which the potential neighbour node radiates to the node by way of acknowledgement upon the reception of the message signalling a presence 1. If the node identifies the reception
20 of such an acknowledgement message 2, it then recognises that it is positioned within the transmission range of the potential neighbour node. With the occurrence of this condition, the node seeking an ad-hoc network with the potential neighbour node respectively with additional nodes
25 which are already disposed in an ad-hoc network with potential neighbour nodes, is disposed in a common ad-hoc network. Furthermore, at this time, the seeking node recognises that a secured bi-directional transmission is present between itself and the potential neighbour node, because, on the one hand, a
30 potential neighbour node has securely received a message transmitted by itself, and, on the other hand, it has itself securely received a message transmitted from the potential neighbour node.

If the seeking node identifies the reception of an acknowledgement message 2 radiated from a potential neighbour node to a message signalling a presence 1 radiated from the seeking node, the seeking node is consequently disposed in an ad-hoc network, and the method according to the invention is continued with the method step S80 presented in greater detail below.

10 Otherwise, in the next method step S40, the node seeking an ad-hoc network attempts to identify the reception of a message signalling a presence 1 radiated from a potential neighbour node. For the case that the seeking node identifies the reception of a message signalling a presence 1 radiated from the potential neighbour node, the seeking node is positioned
15 in the transmission range of a potential neighbour node and is accordingly capable of forming a common ad-hoc network with this potential neighbour node and additional nodes which already form an ad-hoc network with this potential neighbour
20 node. Accordingly, it will acknowledge the received message signalling a presence 1 of the potential neighbour node with an acknowledgement message 2.

The foreseeable time of the reception by the potential
25 neighbour node of the acknowledgement message 2 radiated from the seeking node represents for the seeking node the start of a common ad-hoc network between the seeking node and the potential neighbour node and additional nodes linked to the potential neighbour node within an already existing ad-hoc
30 network.

In order to realise the time of the start of a common ad-hoc network as soon as possible, in a first variant of the

invention, the seeking node will transmit the acknowledgement message 2 immediately after reception of the message signalling a presence 1 of the potential neighbour node. In a second variant of the invention, the seeking node will also
 5 radiate the acknowledgement message 2 as close in time as possible in order to realise the time of the start of the common ad-hoc network as soon as possible. However, in this second variant of the invention, the acknowledgement message 2 is delayed by a slight delay time ΔT_2 associated with the
 10 respective node relative to the reception time of the message signalling a presence 1 of the potential neighbour node, in order to prevent a simultaneous acknowledgement of this received message signalling a presence 1 by other nodes in the transmission range of the potential neighbour node and thereby
 15 a blockage ad-hoc network.

The node foreseeably disposed in an ad-hoc network will consequently continue with method step S80 presented in greater detail below delayed by the transmission time of the
 20 acknowledgement message 2 and a statistical delay time possibly used in the second variant of the invention.

If no reception of a message signalling a presence 1 radiated from a potential neighbour node is identified by a node
 25 seeking an ad-hoc network, in the next method step S50, further messages signalling a presence 1 are radiated in an increasingly smaller time raster ΔT_2 as shown in Fig. 1. The reduction of the time raster is meaningful, since, with increasing time in which the node seeking an ad-hoc network
 30 has received no message signalling a presence, the probability for the reception of a message signalling a presence 1 transmitted from a potential neighbour node decreases. The minimisation of the time raster for the transmission of a

message signalling a presence 1 is continued until an appropriate, previously specified minimal-value time raster ΔT_3 has been reached. As will be explained in detail below, this minimal-value time raster ΔT_3 is retained until the
 5 seeking node is integrated in an ad-hoc network.

After the transmission of a further message signalling a presence 1, the seeking node will attempt, in the next method step S60 by analogy with method step S30, to identify the
 10 reception of an acknowledgement message 2 radiated from a potential neighbour node to a message signalling a presence 1 radiated by the seeking node. If the seeking node does not identify a reception of an acknowledgement message 2, in the next method step S70 by analogy with method step S40, it will
 15 attempt to identify the reception of a message signalling a presence 1 radiated from a potential neighbour node. For the case that the seeking node does not identify the reception of a message signalling a presence 1 radiated from a potential neighbour node, it will, according to method step S50, radiate
 20 a further message signalling a presence 1 in a further reduced time raster or in a minimal-value time raster.

If the node seeking an ad-hoc network has either identified the reception of an acknowledgement message 2 radiated from a
 25 potential neighbour node or the reception of a message signalling a presence 1 radiated from a potential neighbour node and is therefore disposed in a common ad-hoc network with the potential neighbour node and further nodes which already form an ad-hoc network with the potential neighbour node, in
 30 the next method step S80, as shown in Fig. 1, the seeking node will, like all other nodes disposed in an ad-hoc network, continuously radiate a message signalling a presence 1 within a previously specified, constant time raster ΔT_1 .

The node now disposed in an ad-hoc network will attempt, in the subsequent method step S90, to identify the reception of a message signalling a presence 1 radiated by further nodes, in each case associated with the ad-hoc network. If no further message signalling a presence of a node associated with the ad-hoc network is received by the node now disposed within an ad-hoc network within a previously specified time interval ΔT_4 since the last reception time of a message signalling a presence of a further node of the ad-hoc network, the node will then recognise that it is no longer disposed within an ad-hoc network.

In this case, the node now disposed outside an ad-hoc network will radiate a message signalling a presence 1, according to method step S20, within a time raster ΔT_2 minimising itself, as shown in Fig. 1, in the fastest possible search for a new ad-hoc network.

If the node receives a further message signalling a presence of this node, it is still disposed within the ad-hoc network. A departure of the node disposed in an ad-hoc network from the ad-hoc network is possible only within the framework of the concluding method step S100, if the node shuts down its operation, for example, in that the user of the device corresponding to the node switches off the operating voltage of the device and, within the framework of shut-down routines, then adopts a switched-off operating mode.

If the operation of the node in the final method step S100 is not shut down, the node disposed in an ad-hoc network transmits a further message according to method step S80 signalling a presence 1 in the constant time raster ΔT_1 .

At this point, it should be noted that not only the node disposed outside an ad-hoc network and therefore seeking an ad-hoc network, but all nodes - also those already disposed
5 within an ad-hoc network - acknowledge a received message signalling a presence 1 through an acknowledgement message 2 in an accelerated manner, that is, therefore, according to the first variant of the invention, immediately after the reception of the message signalling a presence 1, or delayed
10 by a statistical delay time ΔT_s assigned to the respective node relative to the reception time of the message signalling a presence 1.

Furthermore, as is evident from Fig. 1, it should be stated
15 that, at the reception time of the acknowledgement message 2, the node 1 knows that its associated, transmitted message signalling a presence 1 has been securely received by the node 2, and accordingly, node 2 is securely disposed within the transmission range of node 1 and, at the same time, with the
20 secure reception of the acknowledgement message 2 from node 2, that it is securely disposed within the transmission range of node 2.

Node 2 recognises a secure transmission between node 1 and 2
25 only at the reception time of a further acknowledgement message 3 of node 1 to the reception of the acknowledgement message 2 from node 2. Only from this time, does a secure, symmetrical transmission link exist between node 1 and node 2.

30 Figures 2A to 2D show various scenarios of a changing ad-hoc network.

In Fig. 2A, a node disposed outside the transmission range of another node or of an already existing ad-hoc network - empty circle - is seeking an ad-hoc network and moves towards a group of three nodes - filled circles (see arrow), which are disposed within the transmission range relative to one another and accordingly within a common ad-hoc network.

In Fig. 2B, the seeking node is already disposed in the transmission range of the ad-hoc network comprising three nodes but is not yet integrated into the ad-hoc network, since the message exchange (transmission of the message signalling a presence and an acknowledgement message) between the seeking node and at least one of the three nodes integrated in the ad-hoc network has not yet concluded.

In Fig. 2C, the message exchange has been completed and the seeking node is integrated in the ad-hoc network.

The scenario in Fig. 2D represents the case that the original seeking node has moved out of the ad-hoc network again, since the three nodes originally disposed in the ad-hoc network have jointly removed themselves regionally from the original seeking node (see arrow), and the original seeking node is therefore positioned outside the transmission range relative to all three nodes of the ad-hoc network.

The invention is not restricted to the embodiment illustrated and the variants presented. In particular, all possible combinations of all features claimed in the claims, of all features disclosed in the description and of all features illustrated in the figures of the drawings are also covered by the invention. In particular, the features of the dependent

method claims can also be realised in combination with the independent network claim.

Claims

1. A method for the effective identification of neighbouring nodes in a mobile ad-hoc network, wherein each node
5 transmits within a given time raster ($\Delta T_1, \Delta T_2, \Delta T_3$) a message signalling its presence (1) which is acknowledged through the transmission of an acknowledgement message (2) by at least one node which receives the message signalling the presence (1) for the first time,
10 **characterised in that**
the time raster ($\Delta T_2, \Delta T_3$) in which the message signalling a presence (1) is transmitted is varied by a node which is disposed outside an ad-hoc network.
- 15 2. The method according to claim 1,
characterised in that
the time raster (ΔT_2) in which the message signalling its presence (1) is transmitted from a node disposed outside an ad-hoc network directly after a start-up of the node
20 disposed outside an ad-hoc network, is adjusted to a comparatively high value, which is successively reduced until a previously determined minimal-value time raster (ΔT_3) is reached.
- 25 3. The method according to claim 1 or 2,
characterised in that,
directly after it has identified that it is now disposed outside an ad-hoc network, a node transmits the message signalling its presence (1) in a time raster (ΔT_2) with a
30 comparatively high value, which is successively reduced until a previously determined minimal-value time raster (ΔT_2) is reached.

4. The method according to any one of claims 1 to 3,
characterised in that
the acknowledgement message (2) is transmitted directly
5 after the reception of the message signalling the presence
(1).

5. The method according to claim 4,
characterised in that
10 the acknowledgement message (2) is transmitted immediately
after the reception of the message signalling a presence
(1).

6. The method according to claim 4,
15 **characterised in that**
the acknowledgement message (2) is transmitted after the
reception of the message signalling a presence (1) with
the addition of a statistical delay time (ΔT_s) associated
in each case with the respective node.

20 7. The method according to any one of claims 1 to 6,
characterised in that
a node disposed outside an ad-hoc network transmits a
message signalling a presence (1) within a previously
25 specified, constant time raster (ΔT_1) from the time of the
reception of the acknowledgement message (2).

8. The message according to any one of claims 1 to 6,
characterised in that
30 a node disposed outside an ad-hoc network transmits a
message signalling a presence (1) within a previously
specified, constant time raster (ΔT_1) from the time of the
reception of a message signalling a presence (1) of

another node, which it acknowledges with an acknowledgement signal (2).

9. The method according to any one of claims 1 to 8,

5 **characterised in that**

a node is integrated in an ad-hoc network with at least one further node as soon as one of the two nodes receives the acknowledgement message (2) to its transmitted message signalling a presence (1) from the respectively other
10 node.

10. The method according to any one of claims 1 to 9,

characterised in that

a node is disposed within an ad-hoc network so long as it receives a further message signalling a presence (1) of a
15 node of the ad-hoc network within a previously specified time interval (ΔT_4) since the last reception time of a message signalling a presence (1) of a node of the ad-hoc network.

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11. The method according to any one of claims 1 to 10,

characterised in that

a secured and/or encrypted symmetrical data transmission between at least two nodes disposed within an ad-hoc
25 network is implemented as soon as one of the two nodes receives a further acknowledgement message (3) to its transmitted acknowledgement message from the respectively other node.

- 30 12. The method according to any one of claims 1 to 11,

characterised in that

the identification of neighbouring nodes in a mobile ad-hoc network precedes a routing-planning, preferably a

routing-planning according to the Optimised-Link-State-Routing protocol.

13. A mobile ad-hoc network with at least one node disposed
5 inside or outside the mobile ad-hoc network and
transmitting a message signalling its presence (1) within
a given time raster ($\Delta T_1, \Delta T_2, \Delta T_3$) and at least one node
disposed inside or outside the mobile ad-hoc network
receiving the message signalling the presence (1) for the
10 first time and acknowledging the latter through
transmission of an acknowledgement message (2),
characterised in that
the time raster ($\Delta T_2, \Delta T_3$) for the transmission of the
message signalling a presence (1) is varied in the case of
15 a node disposed outside the ad-hoc network.