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(54) **INTELLIGENT COMMUNICATION NODE OBJECT BEACON FRAMEWORK (ICBF) WITH TEMPORAL TRANSITION NETWORK PROTOCOL (TTNP) IN A MOBILE AD HOC NETWORK**

INTELLIGENTER KOMMUNIKATIONSKNOTENOBJEKT-BAKENRAHMEN (ICBF) MIT EINEM ZEITLICHENUEBERGANGSNETZWERKPROTOKOLL (TTNP) IN EINEM MOBIL-AD-HOC-NETZWERK

CADRE DE BALISE D'OBJET DE NOEUD DE COMMUNICATION INTELLIGENT (ICBF) A PROTOCOLE DE RESEAU DE TRANSITION TEMPORELLE (TTNP) DANS UN RESEAU AD HOC MOBILE

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Description

Background of the Invention

[0001] Wireless networks have experienced increased development in the past decade. One of the most rapidly developing areas is mobile ad hoc networks. Physically, a mobile ad hoc network includes a number of geographically-distributed, potentially mobile nodes wirelessly connected by one or more radio frequency channels. Compared with other type of networks, such as cellular networks or satellite networks, the most distinctive feature of mobile ad hoc networks is the lack of any fixed infrastructure. The network is formed of mobile nodes only, and a network is created on the fly as the nodes transmit to or receive from other nodes. The network does not in general depend on a particular node and dynamically adjusts as some nodes join or others leave the network.

[0002] In a hostile environment where a fixed communication infrastructure is unreliable or unavailable, such as in a battle field or in a natural disaster area struck by earthquake or hurricane, an ad hoc network can be quickly deployed and provide much needed communications. While the military is still a major driving force behind the development of these networks, ad hoc networks are quickly finding new applications in civilian or commercial areas. Ad hoc networks will allow people to exchange data in the field or in a class room without using any network structure except the one they create by simply turning on their computers or PDAs.

[0003] As wireless communication increasingly permeates everyday life, new applications for mobile ad hoc networks will continue to emerge and become an important part of the communication structure. Mobile ad hoc networks pose serious challenges to the designers. Due to the lack of a fixed infrastructure, nodes must self-organize and reconfigure as they move, join or leave the network. All nodes could potentially be functionally identical and there may not be any natural hierarchy or central controller in the network. Many network-controlling functions are distributed among the nodes. Nodes are often powered by batteries and have limited communication and computation capabilities. The bandwidth of the system is usually limited. The distance between two nodes often exceeds the radio transmission range, and a transmission has to be relayed by other nodes before reaching its destination. Consequently, a network has a multihop topology, and this topology changes as the nodes move around.

[0004] The Mobile Ad-Hoc Networks (MANET) working group of the Internet Engineering Task Force (IETF) has been actively evaluating and standardizing routing, including multicasting, protocols. Because the network topology changes arbitrarily as the nodes move, information is subject to becoming obsolete, and different nodes often have different views of the network, both in time (information may be outdated at some nodes but current at others) and in space (a node may only know the network topology in its neighborhood usually not far away from itself).

[0005] A routing protocol needs to adapt to frequent topology changes and with less accurate information. Because of these unique requirements, routing in these networks is very different from others. Gathering fresh information about the entire network is often costly and impractical. Many routing protocols are reactive (on-demand) protocols: they collect routing information only when necessary and to destinations they need routes to, and do not generally maintain unused routes after some period of time. This way the routing overhead is greatly reduced compared to pro-active protocols which maintain routes to all destinations at all times. It is important for a protocol to be adaptive. Ad Hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Temporally Ordered Routing Algorithm (TORA) are representative of on-demand routing protocols presented at the MANET working group.

[0006] Examples of other various routing protocols include Destination-Sequenced Distance Vector (DSDV) routing which is disclosed in U.S. Patent No. 5,412,654 to Perkins, and Zone Routing Protocol (ZRP) which is disclosed in U.S. Patent No. 6,304,556 to Haas. ZRP is a hybrid protocol using both proactive and reactive approaches based upon distance from a source node.

[0007] These conventional routing protocols use a best effort approach in selecting a route from the source node to the destination node. Typically, the number of hops is the main criteria (metric) in such a best effort approach. In other words, the route with the least amount of hops is selected as the transmission route.

[0008] Existing communication node advertisement and communication node neighbor discovery approaches including those for ad hoc networks, only use network-condition-independent mechanisms such as constant transmit rate or random transmit rate "hello" messages from nodes to announce, or advertise, their presence. These transmitted announcements are called "beacons" and under conventional approaches, these beacons are not endowed with any degree of intelligence. Other nodes may detect these beacons and either form a network from scratch or add the newly-detected node to the existing network.

[0009] Document XP001071991 discloses a preemptive route maintenance and selection to ad hoc routing protocols by finding alternative paths when a link is in danger of breaking (but before the disconnection occurs). More specifically, when two nodes, A and B, are moving out of each other's range, source nodes of active paths that use the hop A to B are warned that a path break is likely to initiate route discovery early and switch to a more stable path potentially avoiding the path break. When a path break is not avoided, the path discovery latency is reduced. The signal strength is used as the preemptive trigger; other warning criteria such as location/velocity and congestion can also be used.

[0010] Document WO 01/73959 A1 discloses a system, apparatus, and method for conserving energy in a mobile station of an ad-hoc wireless data network. Information concerning motion of the mobile station is obtained, and a rate of motion is used to adjust network parameters such as a beaconing rate and a link change granularity. These parameters may be adjusted to reduce network overhead transmissions, and the power usage associated therewith, at appropriate times. In one embodiment, network-related transmissions, such as beacon signals and link state announcements, are reduced when the mobile station is moving quickly.

[0011] Document XP010562109 discloses a hybrid routing scheme that combines proactive route optimization to a reactive routing protocol, for reducing the average end-to-end delay in packet transmissions without exceeding the routing overhead. The disclosed scheme uses a pre-emptive route discovery to replace an existing route by a shorter route when the route has been used for a given interval of time. The optimum time for making the pre-emptive search is obtained by studying the statistical distributions of the link and route lifetimes. The preemptive search is restricted within a limited distance from the old route by using a query-localization method.

[0012] Document XP010538869 discloses a routing algorithm called Adaptive Distance Vector (ADV) for mobile, ad hoc networks (MANETs). ADV is a distance vector routing algorithm that exhibits some on-demand characteristics by varying the frequency and the size of the routing updates in response to the network load and mobility conditions. Document US6304556 B1 discloses two network communication protocols, one for routing and one for mobility management suited for use with ad-hoc networks. The routing protocol is a proactive-reactive hybrid routing protocol that limits the scope of the proactive procedure to the node's local neighborhood. The reactive procedure is limited during route discovery to queries of only those nodes located on the periphery of routing zones. The mobility management protocol relies on some network nodes assuming the mobility management function. Each network node is "associated" with one or more mobility management nodes. The mobility management nodes form a virtual network which is embedded within the actual ad-hoc network. Each mobility management node knows the location of all nodes within its zone, and communicates this information to any other mobility management node that requests it.

[0013] Document WO 01/92992 A2 discloses an apparatus for varying the rate at which the broadcast beacons are transmitted including at least one router. The router transmits beacons which contain various types of data, controls the rate at which the beacons are transmitted, and adaptively varies the rate at which the beacons are transmitted, in response to a variety of network conditions.

[0014] Document XP010511730 discloses a distributed dynamic routing (DDR) algorithm constructing a forest from a network topology, where each tree of the constructed forest forms a zone. The network is partitioned into a set of non-overlapping dynamic zones. Each zone contains mobile nodes. Then, each node calculates its zone ID independently. Each zone is connected

Summary of the Invention

[0015] In view of the foregoing background, it is therefore an object of the present invention to provide the "Intelligent Communication Node Object Beacon Framework" (ICBF), for intelligent, adaptive advertisement by any communications node

[0016] via the nodes that are not in the same tree but they are in the direct transmission range of each other. So, the whole network can be seen as a set of connected zones. The size of zones increases and decreases dynamically depending on some network features such as node density, rate of network connection/disconnection, node mobility and transmission power. object of its presence along with the management and control of route discovery and associated processes via temporal transitioning processes and events in a mobile ad hoc network.

[0017] This and other objects, features, and advantages in accordance with the present invention are provided by a method for managing and controlling the discovery and maintenance of routes in a mobile ad hoc network, the method comprising the features of claim 1. A route is a set of wireless communication links and mobile nodes from a source to a destination.

[0018] The method preferably includes switching back to the first one of the proactive and reactive route discovery processes when predicted route stability reaches a second transition parameter, and the first and second transition parameters preferably specify time-dependent conditions. Varying the beacon signal may comprise varying at least one of transmission rate, transmission frequency and transmission pattern. Also, the transmission rate of the beacon signal should not exceed a rate threshold based upon available bandwidth.

[0019] The node/group condition may include node/group movement, and varying the beacon signal may comprise increasing the transmission rate based upon increased node/group movement and decreasing the transmission rate based upon decreased node/group movement. Node/group movement comprises at least one of node/group velocity, node/group acceleration and node/group movement pattern of the corresponding mobile node or group of mobile nodes. Node/group condition information is based upon node mobility, link failure, link creation, node/group stability and link quality, and storing node/group condition information may comprise creating and updating a time-dependent route stability profile. Furthermore, storing node/group condition information may also include creating and updating a time-dependent route segment stability profile. A segment is a set of links and nodes which define a reusable entity in one or more routes.

[0020] A mobile ad hoc network according to the present invention includes a plurality of mobile nodes, and a plurality of wireless communication links connecting the mobile nodes together. Each mobile node include a communications device to wirelessly communicate with other nodes of the plurality of nodes via the wireless communication links, and a controller to route communications via the communications device. The controller has a condition determining unit to determine a condition of the mobile node or group of nodes, and a beacon signal generator to generate and transmit beacon signals. The beacon signal generator varies the beacon signals based upon the determined condition of the mobile node/group.

[0021] Route tables define routes in the network. A route is a set of wireless communication links and mobile nodes from a source to a destination. The controller also includes a route discovery module to discover routes and update the route tables with one of a plurality of route discovery processes, a condition module to receive beacon signals and store node/group condition information, a route stability predictor to predict route stability over time based upon the node/group condition information, and a route discovery process selector to select between the plurality of route discovery processes based upon the predicted route stability.

Brief Description of the Drawing

[0022]

FIG. 1 is a schematic diagram of a mobile ad hoc network in accordance with the present invention.

FIG. 2 is a flowchart illustrating the steps of a method for managing and controlling the discovery and maintenance of routes in accordance with the present invention.

FIG. 3 is a schematic diagram illustrating a router of a node in accordance with the network of the present invention.

FIG. 4 is a schematic diagram illustrating the details of the controller of the router in FIG. 3.

Detailed Description of the Preferred Embodiment

[0023] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. Like numbers refer to like elements throughout, and prime notation is used to indicate similar elements in alternative embodiments.

[0024] As will be appreciated by those skilled in the art, portions of the present invention may be embodied as a method, data processing system, or computer program product. Accordingly, these portions of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment, or an embodiment combining software and hardware aspects. Furthermore, portions of the present invention may be a computer program product on a computer-usable storage medium having computer readable program code on the medium. Any suitable computer readable medium may be utilized including, but not limited to, static and dynamic storage devices, hard disks, optical storage devices, and magnetic storage devices.

[0025] The present invention is described below with reference to flowchart illustrations of methods, systems, and computer program products according to an embodiment of the invention. It will be understood that blocks of the illustrations, and combinations of blocks in the illustrations, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, implement the functions specified in the block or blocks.

[0026] These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory result in an article of manufacture including instructions which implement the function specified in the flowchart block or blocks. The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer or other programmable apparatus implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flowchart block or blocks.

[0027] Existing node presence advertisement methods (neighbor discovery beacons) supplied by proactive and reactive methods as well as standalone neighbor discovery beacons, do not transmit node movement properties, do not intelligently and in real-time adapt their transmission rates according to how the nodes in the network are moving, and do not advertise the movement and presence of groups of nodes, which could reduce the overhead traffic of such advertisements.

[0028] The present invention makes use of the temporal transition network protocol (TTNP) in a mobile ad hoc network to efficiently make use of the management and control of route discovery and associated processes via temporal transitioning processes and events in a mobile ad hoc network, as described in US 2003-0202512 A1 filed April 29, 2002 by the same assignee . Furthermore, the present invention makes use of "Intelligent Communication Node Object Beacon Framework" (ICBF), for intelligent, adaptive advertisement by any communications node object of its presence and/or the corresponding detection (neighbor discovery) by another node object or the network of those node objects transmitting such beacons as described in US 2004-042417 A1 filed September 4, 2002 by the same assignee .

[0029] Referring initially to FIGs. 1 and 2, a method for discovering routes from a source node to a destination node in a mobile ad hoc network 10 will now be described. The network 10 includes a plurality of mobile nodes 12 including the source node S and the destination node D with intermediate nodes therebetween. The nodes 12, such as laptop computers, personal digital assistants (PDAs) or mobile phones, are connected by wireless communication links 14 as would be appreciated by the skilled artisan. The Temporal Transition Network Protocol (TTNP) temporally combines, controls and manages both proactive and reactive approaches (and/or other route discovery approaches) in any network architecture whether it is flat or structured such as in a hierarchical network.

[0030] TTNP provides the protocol suite and transition parameters for supporting the switching back and forth between a plurality of route discovery approaches, e.g., any proactive and reactive network route discovery approaches, during the time-ordered evolution of the network **10.** The protocol suite supports not only the transition parameters (quantities that signal TTNP to start the transition from a proactive to a reactive approach and vice versa) defined herein, but can also support other transition parameters defined by a system designer. TTNP will carry the negotiations between various subsets of nodes **12** and links **14** in the network **10** and interact with Quality of Service (QoS) and traffic management (which includes Admission Control, scheduling, buffer management and flow control), power management & control, security and any other network service components either internal or external to TTNP to gather the information needed to provide this support.

[0031] The Intelligent Communication Node Object Beacon Framework" (ICBF) defines temporary or permanent associations of nodes, potentially capable of communication with other temporary or permanent associations of nodes, as "Node Communication Object Association" (NCOA) and the corresponding beacons for this association as "NCOA beacons". In the network **10** shown in FIG. 1, a group (NCOA) of mobile nodes **12** includes a temporary or permanent association of more than one of the plurality of mobile nodes.

[0032] The method begins (FIG. 2; block **100**) and includes transmitting beacon signals from each mobile node determining a node or group condition at each mobile node and varying the beacon signals based upon the determined node/group condition. The method also includes building and updating route tables (block **108**) at each node **12** with either a proactive or a reactive route discovery protocol/process to define routes in the network, i.e., build and maintain valid routes. A route is a set of links and nodes from a source to a destination. As discussed above, many routing protocols are reactive (on-demand) protocols as they collect routing information only when necessary and to destinations they need routes to, and do not maintain unused routes. This way the routing overhead is greatly reduced compared to proactive protocols which maintain routes to all destinations at all times. Ad Hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Temporally Ordered Routing Algorithm (TORA) are examples of reactive routing protocols. Examples of proactive routing protocols include Destination Sequenced Distance-Vector (DSDV) routing, Wireless Routing Protocol (WRP) and Optimal Link State Routing (OSLR).

[0033] The method also includes receiving the beacon signals and storing node condition information at each node (block **110**). Route stability is predicted or estimated or tracked over time based upon the node condition information (block **112**), and, at block **114**, the method switches to a second one of the proactive and reactive route discovery and their associated processes when predicted route stability reaches a first transition parameter (block **116**). Of course, building and updating route tables (block **118**), storing information at each node (block **120**), and predicting/estimating/tracking route stability over time (block **122**) would be then be performed under the switched-to route discovery and process. Moreover, the method preferably includes, at block **126**, switching back to the first one of the proactive and reactive route discovery and their associated processes when predicted route stability reaches a second transition parameter (block **124**).

[0034] The beacon signals include information relating to a condition of the corresponding mobile node or group of nodes. Also, the beacon signals may include information relating to a condition of the mobile ad hoc network **10,** such as information about the status of the links **14** between the nodes **12** of the network. Transmitting beacon signals may further include transmitting beacon signal information using a beacon properties signal to advertise a type of beacon signal being transmitted to the plurality of nodes **12** of the mobile ad hoc network **10**.

[0035] The beacon signal is preferably made up of transmission rate, transmission frequency and transmission pattern which collectively define the beacon waveform. Also, the condition preferably includes node/group movement, such as velocity, acceleration and/or movement pattern of the corresponding mobile node **12** or group of mobile nodes (NCOA) Here, varying the beacon signals includes increasing the transmission rate based upon increased node movement and decreasing the transmission rate based upon decreased node movement. The node movement may be determined using global positioning satellites (GPS), local landmarks, triangulation, and/or by measuring inertia of the mobile node **12**.

[0036] The condition may also or alternatively include priority of information and/or quality of service measurements (QoS), such as bit/packet error rate and/or usable available bandwidth. Here, varying the beacon signals may include increasing the transmission rate and/or changing the transmission frequency or pattern based upon decreased QoS or increased priority of information. Likewise, varying the beacon signals may include decreasing the transmission rate and/or changing the transmission frequency or pattern based upon increased QoS or decreased priority of information. The transmission rate of the beacon signals should not exceed a rate threshold based upon available bandwidth. Group beacon signals are transmitted by a subset of mobile nodes **12** of the group **G** of mobile nodes **12.** Such a subset includes a range from one mobile node **12** to all the mobile nodes **12** of the group **G.** The maximum would be all the mobile nodes **12** of the group **G,** while the minimum would be only one node **12** of the group **G** transmitting the beacons.

[0037] The first and second transition parameters preferably specify time-dependent conditions which may include thresholds, for example thresholds based upon a rate of change of source-destination subset pairs for at least one source node, as is discussed in detail below. A Source Destination Subset (SDS) is the allowed subset of possible destination nodes for the designated source node. The limiting case is the entire network. A notable special case is a formal subnet. The node or group condition information may be based upon node mobility, link failure, link creation or other quantities or qualities that could affect the time-dependent stability of a route.

[0038] The Forward Transition Parameter (FXP) is the parameter that is used to specify when to switch (transition) from using the route discovery approach category (i.e., proactive or reactive) that the full network or a formally-designated subset of nodes was initialized with, to a different route discovery category. The Reverse Transition Parameter (RXP) is the parameter that is used to specify when to switch (transition) from using the current, but not initial, route discovery approach category that the full network or a formally-designated subset of nodes is using to that approach with which the network/subset of nodes was initialized.

[0039] Furthermore, collecting and storing node or group condition information (block 110) may include creating and updating a time-dependent route stability profile and/or a time-dependent route segment stability profile. A route segment (RS) is a set of links and nodes, with some commonality, grouped together to form a reusable entity in potentially more than one route. A route segment would include at least one link and one node. Nothing in the definition requires these links to be spatially contiguous or the nodes to be adjacent to (within 1 hop of) at least one other node in the RS. A spacially contiguous pair of links is defined as two links separated only by a single node connecting both links in a network diagram.

[0040] A TTNP Default Pool (TDP) contains the internal default objects for capabilities such as QoS, traffic management, link decay profiles, route maintenance, etc. that TTNP will use to accomplish its switching from proactive to reactive and vice versa in the event that such a capability is required by TTNP but not supplied by some other avenue such as via the application or route discovery technique.

[0041] A system aspect of the invention will now be described with further reference to FIGs. 3 and 4. As discussed, the mobile ad hoc network **10** has a plurality of wireless mobile nodes **12,** and a plurality of wireless communication links **14** connecting the nodes together. Each mobile node **12** includes a router **20** that has a communications device **22** to wirelessly communicate with other nodes of the plurality of nodes via the wireless communication links **14.** Also, the router includes a controller **24** to route communications via the communications device **22.** Also, a memory **26** may be included as part of the controller **24** or in connection with the controller.

[0042] The controller **24** includes route tables **36** to define routes in the network **10.** Again, a route is a set of links **14** and nodes **12** from a source to a destination. The controller **24** also includes a route discovery module **30** to discover routes and update the route tables **36** with either a proactive or a reactive route discovery process. The controller also includes a beacon signal generator **50** to generate and transmit beacon signals, and a condition determining unit **52** to determine a condition of the mobile node **12.** The beacon signal generator **50** varies the beacon signals based upon the determined condition of the mobile node **12.** Again, the beacon signals include information relating to a condition of the mobile node **12.** The beacon signals may further include information relating to a status of a group G of mobile nodes **12** which, as discussed above, are a temporary or permanent association of at least two of the plurality of mobile nodes **12.**

[0043] Here, the condition determining unit **52** further determines a condition of the group **G** of mobile nodes **12,** and the beacon signal generator **50** varies the beacon signals based upon the determined condition of the group **G** of mobile nodes **12.** Again, the beacon signal is made up of transmission rate, transmission frequency and transmission pattern.

[0044] The node/group condition may include node/group movement, and the beacon signal generator **50** may vary the beacon signals by increasing the transmission rate or changing the transmission frequency or pattern based upon increased node/group movement and decreasing the transmission rate or changing the transmission frequency or pattern based upon decreased node/group movement. The node/group movement includes node/group velocity, node/group acceleration and/or node/group movement pattern of the corresponding mobile node **12** or group **G** of nodes. The condition determining unit **52** may comprise a global positioning satellite (GPS) device for determining the node/group movement, and/or may determine the node/group movement using local landmarks, by tracking the relative velocity using triangulation and/or by measuring inertia of the mobile node **12** or group of nodes **G.**

[0045] Furthermore, the node/group condition may include quality of service (QoS) and/or priority of information, and the beacon signal generator **50** varies the beacon signals by increasing the transmission rate and/or changing the transmission frequency or pattern based upon decreased QoS or increased priority of information and decreasing the transmission rate or changing the transmission frequency or pattern based upon increased QoS and/or decreased priority of information. The beacon signal generator **50** should not increase the transmission rate of the beacon signals beyond a rate threshold based upon available bandwidth. Again, the beacon signals may also include information relating to a condition of the mobile ad hoc network **10,** such as information about the links **14** connecting the nodes **12** of the network. Additionally, the beacon signal generator **50** may transmit beacon signal information using a beacon properties signal to advertise a type of beacon signal being transmitted to the plurality of nodes **12** of the mobile ad hoc network **10.**

[0046] A route stability predictor **32** predicts or estimates or tracks route stability over time based upon the node or group condition information, and a route discovery process selector **34** selects between the proactive and reactive route discovery processes based upon the predicted route stability. Again, it should be understood that blocks of the illustrations, and combinations of blocks in the illustrations, can be implemented by computer program instructions which may be provided to a processor to implement the functions specified in the block or blocks.

[0047] In sum, the network **10** would initially use either a proactive (e.g. OLSR, basic link state, TBRPF) or a reactive (e.g.. DSR, AODV) protocol to discover and maintain routes between source **S** and destination **D** pairs in order to build the initial route table at that source node. It is possible that at the network's creation, route tables for some or all of the nodes **12** may be initialized by predefining a set of routes for each route table knowing that those routes may change over time. As time moves forward, the network topology will generally change through node mobility and link failures/creation. TTNP accounts for these dynamic topological changes in one or more transition parameters such that when some subset of these parameters reached a certain transition level, a switching (transition) would occur from using proactive route discovery to using reactive route discovery or vice versa. This transition could occur over the entire network or be confined to any portion of it as defined by TTNP profiles.

[0048] Note that whenever a route discovery approach transition occurs, TTNP preferably automatically transitions other functionality associated with the route discovery approach such as route maintenance. One unique capability of TTNP is that it mitigates the selection of redundant or similar supporting functionality such as route maintenance or QoS in the event of conflicts between using what is supplied by the route discovery approach (proactive or reactive) and what is supplied by some other "plug-in" from, for example, a third party or from the TTNP default pool.

[0049] TTNP will properly operate in either of its two most fundamental cases. First, the initial network state begins using a proactive route discovery process and then upon reaching the threshold value of an applicable forward transition parameter (FXP), the network **10** transitions to using its companion on-demand/reactive route discovery process. Transition from this state of using an on-demand route discovery process back to using a proactive route discovery process occurs when a relevant reverse transition parameter (RXP) threshold has been reached. This RXP may or may not be the same parameter as the FXP, but even if it is, the value assigned to the RXP may not be the same as the FXP value. The key principal to remember for both FXP and RXP is that these parameters are either time itself or some other parameters which have some type of time-dependent relationship defined for describing the dynamics (actual, estimated or predicted) of these parameters.

[0050] Note that TTNP does not require any specific approach within a category (proactive or reactive) to use. For example, the application or systems designer may decide what proactive and what reactive techniques to use. TTNP does not make those decisions, but it does determine when to use the application-specified proactive and when to use the application-specified reactive approach. Neither does TTNP decide where to use proactive or where to use reactive approaches to initialize a network or a formal subset of the nodes. That again is in the hands of the applications or systems designer.

Claims

1. A method for managing and controlling the discovery and maintenance of routes in a mobile ad hoc network (10) comprising a plurality of mobile nodes (12) and a plurality of wireless communication links (14) connecting the mobile nodes (12) together, the method comprising:

   transmitting beacon signals including a node condition information from each mobile node (12);
   determining a the node condition information at each mobile node (12);
   varying the beacon signals based upon the node condition information;
   building and updating route tables at each mobile node (12) with a first one of proactive and reactive route discovery processes to define routes in the network (10), a route comprising a set of wireless communication links (14) and mobile nodes (12) from a source to a destination;
   receiving the beacon signals including the node condition information and storing node condition information at each node (12);

predicting route stability over time based upon the node condition information; and
switching to a second one of the proactive and reactive route discovery processes when predicted route stability reaches a first transition parameter.

2. A method according to Claim 1 further comprising switching back to the first one of the proactive and reactive route discovery processes when predicted route stability reaches a second transition parameter.

3. A method according to Claim 2 wherein the first and second transition parameters specify time-dependent conditions.

4. A method according to Claim 1 wherein varying the beacon signal comprises varying at least one of transmission rate, transmission frequency and transmission pattern.

5. A method according to Claim 1 wherein the node condition information is based upon node mobility, link failure, link creation, node stability and link quality.

6. A method according to Claim 1 wherein storing node condition information comprises creating and updating a time-dependent route stability profile.

7. A method for managing and controlling the discovery and maintenance of routes in a mobile ad hoc network (10) comprising a plurality of wireless mobile nodes (12) and a plurality of wireless communication links (14) connecting the mobile nodes (12) together, a group of mobile nodes (12) comprising a temporary or permanent association of at least two of the plurality of mobile nodes (12), the method comprising:

transmitting group condition information including a group condition information from at least one of the mobile nodes (12) of the group using a beacon signal;
determining a the group condition information of the group of mobile nodes (12);
varying the beacon signal based upon the group condition information;
building and updating route tables at each mobile node (12) with a first one of proactive and reactive route discovery processes to define routes in the network, a route comprising a set of links and mobile nodes (12) from a source to a destination;
receiving beacon signals including the group condition information and storing the group condition information at each node (12);
predicting route stability over time based upon the group condition information; and
switching to a second one of the proactive and reactive route discovery processes when predicted route stability reaches a first transition parameter.

8. The method according to Claim 7 further comprising switching back to the first one of the proactive and reactive route discovery processes when predicted route stability reaches a second transition parameter.

9. The method according to Claim 7 wherein varying the beacon signal comprises varying at least one of transmission rate, transmission frequency and transmission pattern.

10. The method according to Claim 7 wherein the group condition information is based upon node mobility, link failure, link creation, node stability, group stability and link quality within the group of mobile nodes (12).

11. The method according to Claim 7 wherein storing group condition information comprises creating and updating a time-dependent route stability profile.

12. A mobile ad hoc network (10) comprising:

a plurality of mobile nodes (12);
a plurality of wireless communication links (14) connecting the mobile nodes (12) together;
each mobile node (12) comprising a communications device (22) adapted to wirelessly communicate with other nodes (12) of the plurality of nodes (12) via the wireless communication links (14), and
a controller (24) adapted to route communications via the communications device (22), and comprising:

a condition determining unit (52) adapted to determine a mobile node condition information;
a beacon signal generator (50) adapted to generate and transmit beacon signals including the mobile node condition information, the beacon signal generator (50) adapted to vary the beacon signals based upon the determined condition of the mobile node (12),
route tables (36) adapted to define routes in the network (10), a route comprising a set of wireless communication links (14) and mobile nodes (12) from a source to a destination,
a route discovery module (30) adapted to discover routes and update the route tables (36) with one of a plurality of route discovery

processes, a condition module to receive beacon signals and store the mobile node condition information,
a route stability predictor (32) adapted to predict route stability over time based upon the mobile node condition information, and a route discovery process selector (34) adapted to select between the plurality of route discovery processes based upon the predicted route stability.

13. The network (10) according to Claim 12 wherein the plurality of route discovery processes include proactive and reactive route discovery processes; and wherein the route discovery process selector (34) adapted to select the proactive route discovery process when the predicted route stability reaches a first transition parameter, and adapted to select the reactive route discovery process when predicted route stability reaches a second transition parameter.

14. The network (10) according to Claim 12 wherein the plurality of route discovery processes include proactive and reactive route discovery processes; and wherein the route discovery process selector (34) adapted to select the reactive route discovery process when the predicted route stability reaches a first transition parameter, and adapted to selects the proactive route discovery process when predicted route stability reaches a second transition parameter.

15. The network (10) according to Claim 12 wherein the beacon signal generator (50) adapted to vary the beacon signal by varying at least one of transmission rate, transmission frequency and transmission pattern.

16. The network (10) according to Claim 12 wherein the beacon signal further includes information relating to a condition of a group of mobile nodes (12), the group of mobile nodes (12) comprising a temporary or permanent association of at least two of the plurality of mobile nodes (12); wherein the condition determining unit further adapted to determines a condition of the group of mobile nodes (12); and wherein the beacon signal generator (50) adapted to vary the beacon signal based upon the determined condition of the group of mobile nodes (12).

17. The network (10) according to Claim 12 wherein the node condition information is based upon node mobility, link failure, link creation, node stability, and link quality.

18. A network (10) according to Claim 12 wherein the condition module adapted to comprise a time-dependent route stability profile.

Patentansprüche

1. Verfahren zum Verwalten und Steuern der Ermittlung und Instandhaltung von Routen in einem mobilen Ad-hoc-Netzwerk (10) mit mehreren mobilen Knoten (12) und mehreren die mobilen Knoten (12) miteinander verbindenden drahtlosen Kommunikationslinks (14), wobei das Verfahren umfasst:

Übertragen von Bakensignalen, die eine Knotenzustandsinformation von jedem mobilen Knoten (12) enthalten;
Bestimmen der Knotenzustandsinformation an jedem mobilen Knoten (12);
Variieren der Bakensignale auf Basis der Knotenzustandsinformation;
Aufbauen und Updaten von Routentabellen an jedem mobilen Knoten (12) mit einem ersten, entweder proaktiven oder reaktiven Routen-Ermittlungsprozess, um Routen in dem Netzwerk (10) zu definieren, wobei eine Route eine Reihe drahtloser Kommunikationslinks (14) und mobiler Knoten (12) von einer Quelle zu einem Ziel umfasst;
Empfangen der Bakensignale mit der Knotenzustandsinformation und Speichern von Knotenzustandsinformation an jedem Knoten (12);
Vorhersagen einer Routenstabilität im Zeitverlauf basierend auf der Knotenzustandsinformation; und
Umschalten auf einen zweiten der proaktiven oder reaktiven Routen-Ermittlungsprozesse, wenn die vorhergesagte Routenstabilität einen ersten Übergangsparameter erreicht.

2. Verfahren nach Anspruch 1, ferner umfassend ein Zurückschalten auf den ersten der proaktiven oder reaktiven Routen-Ermittlungsprozesse, wenn die vorhergesagte Routenstabilität einen zweiten Übergangsparameter erreicht.

3. Verfahren nach Anspruch 2, wobei die ersten und zweiten Übergangsparameter zeitabhängige Bedingungen spezifizieren.

4. Verfahren nach Anspruch 1, wobei ein Variieren der Bakensignale ein Variieren der Übertragungsrate und/oder der Übertragungsfrequenz und/oder der Übertragungsstruktur umfasst.

5. Verfahren nach Anspruch 1, wobei die Knotenzustandsinformation basiert auf Knotenmobilität, Link-Ausfall, Link-Erstellung, Knotenstabilität und Link-Qualität.

6. Verfahren nach Anspruch 1, wobei das Speichern von Knotenzustandsinformation das Erstellen und Updaten eines zeitabhängigen Routenstabilitätsprofils umfasst.

7. Verfahren zum Verwalten und Steuern der Ermittlung und Instandhaltung von Routen in einem mobilen Ad-hoc-Netzwerk (10) mit mehreren drahtlosen mobilen Knoten (12) und mehreren die mobilen Knoten (12) miteinander verbindenden drahtlosen Kommunikationslinks (14), wobei eine Gruppe mobiler Knoten (12) eine temporäre oder permanente Zuordnung von mindestens zwei der mehreren mobilen Knoten (12) enthält, wobei das Verfahren umfasst:

Übertragen von Gruppenzustandsinformation mit einer Gruppenzustandsinformation von mindestens einem der mobilen Knoten (12) der ein Bakensignal verwendenden Gruppe;
Bestimmen der Gruppenzustandsinformation der Gruppe von mobilen Knoten (12);
Variieren des Bakensignals auf Basis der Gruppenzustandsinformation;
Aufbauen und Updaten von Routentabellen an jedem mobilen Knoten (12) mit einem ersten, entweder proaktiven oder reaktiven Routen-Ermittlungsprozess, um Routen in dem Netzwerk zu definieren, wobei eine Route eine Reihe von Links und mobilen Knoten (12) von einer Quelle zu einem Ziel umfasst;
Empfangen von Bakensignalen mit der Gruppenzustandsinformation und Speichern der Gruppenzustandsinformation an jedem Knoten (12);
Vorhersagen einer Routenstabilität im Zeitverlauf basierend auf der Gruppenzustandsinformation; und
Umschalten auf einen zweiten der proaktiven oder reaktiven Routen-Ermittlungsprozesse, wenn die vorhergesagte Routenstabilität einen ersten Übergangsparameter erreicht.

8. Verfahren nach Anspruch 7, ferner umfassend ein Zurückschalten auf den ersten der proaktiven oder reaktiven Routen-Ermittlungsprozesse, wenn die vorhergesagte Routenstabilität einen zweiten Übergangsparameter erreicht.

9. Verfahren nach Anspruch 7, wobei ein Variieren des Bakensignals ein Variieren der Übertragungsrate und/oder der Übertragungsfrequenz und/oder der Übertragungsstruktur umfasst.

10. Verfahren nach Anspruch 7, wobei die Gruppenzustandsinformation basiert auf Knotenmobilität, Link-Ausfall, Link-Erstellung, Knotenstabilität, Gruppenstabilität und Link-Qualität innerhalb der Gruppe mobiler Knoten (12).

11. Verfahren nach Anspruch 7, wobei das Speichern von Gruppenzustandsinformation das Erstellen und Updaten eines zeitabhängigen Routenstabilitätsprofils umfasst.

12. Mobiles Ad-hoc-Netzwerk (10) mit:

mehreren mobilen Knoten (12);
mehreren drahtlosen Kommunikationslinks (14), welche die mobilen Knoten (12) miteinander verbinden;
wobei jeder mobile Knoten (12) eine Kommunikationsvorrichtung (22) aufweist, die über die drahtlosen Kommunikationslinks (14) mit anderen Knoten (12) der mehreren Knoten (12) drahtlos zu kommunizieren vermag, und
einem Controller (24), der Kommunikationen über die Kommunikationsvorrichtung (22) zu routen vermag, und der umfasst:
eine Zustandsbestimmungseinheit (52), die eine Zustandsinformation eines mobilen Knotens zu bestimmen vermag;
einen Bakensignal-Generator (50), der Bakensignale mit der Zustandsinformation des mobilen Knotens zu generieren und zu übertragen vermag, wobei der Bakensignal-Generator (50) die Bakensignale auf Basis des bestimmten Zustands des mobilen Knotens (12) zu variieren vermag,
Routentabellen (36), die Routen in dem Netzwerk (10) zu definieren vermögen, wobei eine Route eine Reihe drahtloser Kommunikationslinks (14) und mobiler Knoten (12) von einer Quelle zu einem Ziel umfasst,
ein Routen-Ermittlungsmodul (30), das mit einem von mehreren Routen-Ermittlungsprozessen Routen zu ermitteln und ein Update der Routentabellen (36) zu erstellen vermag, ein Zustandsmodul, um Bakensignale zu empfangen und die Zustandsinformation des mobilen Knotens zu speichern,
einen Routenstabilitäts-Prädiktor (32), der Routenstabilität im Zeitverlauf basierend auf der Zustandsinformation des mobilen Knotens vorherzusagen vermag, und
einen Routen-Ermittlungsprozess-Selektor (34), der zwischen mehreren Routen-Ermittlungsprozessen basierend auf der vorhergesagten Routenstabilität auszuwählen vermag.

13. Netzwerk (10) nach Anspruch 12, wobei die mehreren Routen-Ermittlungsprozesse proaktive und reaktive Routen-Ermittlungsprozesse umfassen; und wobei der Routen-Ermittlungsprozess-Selektor (34) den proaktiven Routen-Ermittlungsprozess auszuwählen vermag, wenn die vorhergesagte Routenstabilität einen ersten Übergangsparameter erreicht, und den reaktiven Routen-Ermittlungsprozess auszuwählen vermag, wenn die vorhergesagte Routenstabilität einen zweiten Übergangsparameter erreicht.

14. Netzwerk (10) nach Anspruch 12, wobei die mehreren Routen-Ermittlungsprozesse proaktive und reaktive Routen-Ermittlungsprozesse umfassen; und wobei der Routen-Ermittlungsprozess-Selektor (34) den reaktiven Routen-Ermittlungsprozess auszuwählen vermag, wenn die vorhergesagte Routenstabilität einen ersten Übergangsparameter erreicht, und den proaktiven Routen-Ermittlungsprozess auszuwählen vermag, wenn die vorhergesagte Routenstabilität einen zweiten Übergangsparameter erreicht.

15. Netzwerk (10) nach Anspruch 12, wobei der Bakensignal-Generator (50) das Bakensignal zu variieren vermag, durch Variieren der Übertragungsrate und/oder der Übertragungsfrequenz und/oder der Übertragungsstruktur.

16. Netzwerk (10) nach Anspruch 12, wobei das Bakensignal ferner Information enthält, die sich auf einen Zustand einer Gruppe mobiler Knoten (12) bezieht, wobei die Gruppe mobiler Knoten (12) eine temporäre oder permanente Zuordnung von mindestens zwei der mehreren mobilen Knoten (12) enthält; wobei die Zustandsbestimmungseinheit ferner einen Zustand der Gruppe mobiler Knoten (12) zu bestimmen vermag; und wobei der Bakensignal-Generator (50) das Bakensignal basierend auf dem bestimmten Zustand der Gruppe mobiler Knoten (12) zu variieren vermag.

17. Netzwerk (10) nach Anspruch 12, wobei die Knotenzustandsinformation basiert auf Knotenmobilität, Link-Ausfall, Link-Erstellung, Knotenstabilität und Link-Qualität.

18. Netzwerk (10) nach Anspruch 12, wobei das Zustandsmodul so ausgelegt ist, dass es ein zeitabhängiges Routenstabilitätsprofil umfasst.

Revendications

1. Procédé de gestion et de contrôle de la découverte et du maintien de voies d’acheminement dans un réseau mobile ad hoc (10) comprenant une pluralité de noeuds mobiles (12) et une pluralité de liaisons de communication sans fil (14) connectant les noeuds mobiles (12) ensemble, le procédé comprenant :

la transmission de signaux balise incluant une information de condition de noeud à partir de chaque noeud mobile (12) ;
la détermination de l’information de condition de noeud au niveau de chaque noeud mobile (12) ;
la variation des signaux balise sur la base de l’information de condition de noeud ;
la construction et la mise à jour de tables de voies d’acheminement au niveau de chaque noeud mobile (12) avec un premier de processus proactifs et réactifs de découverte de voies d’acheminement pour définir des voies d’acheminement dans le réseau (10), une voie d’acheminement comprenant un ensemble de liaisons de communication sans fil (14) et de noeuds mobiles (12) d’une source jusqu’à une destination ;
la réception des signaux balise incluant l’information de condition de noeud et le stockage de l’information de condition de noeud au niveau de chaque noeud (12) ;
la prédiction d’une stabilité de voies d’acheminement dans le temps sur la base de l’information de condition de noeud ; et
la commutation sur un deuxième des processus proactifs et réactifs de découverte de voies d’acheminement lorsque la stabilité de voies d’acheminement prédite atteint un premier paramètre de transition.

2. Procédé selon la revendication 1, comprenant en outre le retour au premier des processus proactifs et réactifs de découverte de voies d’acheminement lorsque la stabilité de voies d’acheminement prédite atteint un deuxième paramètre de transition.

3. Procédé selon la revendication 2, dans lequel les premier et deuxième paramètres de transition spécifient des conditions dépendantes du temps.

4. Procédé selon la revendication 1, dans lequel la variation du signal balise comprend la variation d’au moins un d’une vitesse de transmission, d’une fréquence de transmission et d’un schéma de transmission.

5. Procédé selon la revendication 1, dans lequel l’information de condition de noeud est basée sur une mobilité de noeud, une défaillance de liaison, une création de liaison, une stabilité de noeud et une qualité de liaison.

6. Procédé selon la revendication 1, dans lequel le stockage de l’information de condition de noeud comprend la création et la mise à jour d’un profil de stabilité de voies d’acheminement dépendant du temps.

7. Procédé de gestion et de contrôle de la découverte et du maintien de voies d’acheminement dans un réseau mobile ad hoc (10) comprenant une pluralité de noeuds mobiles sans fil (12) et une pluralité de liaisons de communication sans fil (14) connectant les noeuds mobiles (12) ensemble, un groupe de noeuds mobiles (12) comprenant une association temporaire ou permanente d'au moins deux de la pluralité de noeuds mobiles (12), le procédé comprenant :

la transmission d'une information de condition de groupe incluant une information de condition de groupe provenant d'au moins un des noeuds mobiles (12) du groupe en utilisant un signal balise ;
la détermination de l'information de condition de groupe du groupe de noeuds mobiles (12) ;
la variation du signal balise sur la base de l'information de condition de groupe ;
la construction et la mise à jour de tables de voies d'acheminement au niveau de chaque noeud mobile (12) avec un premier de processus proactifs et réactifs de découverte de voies d'acheminement pour définir des voies d'acheminement dans le réseau, une voie d'acheminement comprenant un ensemble de liaisons et de noeuds mobiles (12) d'une source jusqu'à une destination ;
la réception de signaux balise incluant l'information de condition de groupe et le stockage de l'information de condition de groupe au niveau de chaque noeud (12) ;
la prédiction d'une stabilité de voies d'acheminement dans le temps sur la base de l'information de condition de groupe ; et
la commutation sur un deuxième des processus proactifs et réactifs de découverte de voies d'acheminement lorsque la stabilité de voies d'acheminement prédite atteint un premier paramètre de transition.

8. Procédé selon la revendication 7, comprenant en outre le retour au premier des processus proactifs et réactifs de découverte de voies d'acheminement lorsque la stabilité de voies d'acheminement prédite atteint un deuxième paramètre de transition.

9. Procédé selon la revendication 7, dans lequel la variation du signal balise comprend la variation d'au moins un d'une vitesse de transmission, d'une fréquence de transmission et d'un schéma de transmission.

10. Procédé selon la revendication 7, dans lequel l'information de condition de groupe est basée sur une mobilité de noeud, une défaillance de liaison, une création de liaison, une stabilité de noeud, une stabilité de groupe et une qualité de liaison au sein du groupe de noeuds mobiles (12).

11. Procédé selon la revendication 7, dans lequel le stockage de l'information de condition de groupe comprend la création et la mise à jour d'un profil de stabilité de voies d'acheminement dépendant du temps.

12. Réseau mobile ad hoc (10) comprenant :

une pluralité de noeuds mobiles (12) ;
une pluratité de liaisons de communication sans fil (14) connectant les noeuds mobiles (12) ensemble ;
chaque noeud mobile (12) comprenant un dispositif de communications (22) adapté à communiquer sans fil avec d'autres noeuds (12) de la pluralité de noeuds (12) par l'intermédiaire des liaisons de communication sans fil (14), et un contrôleur (24) adapté à acheminer des communications par l'intermédiaire du dispositif de communications (22), et comprenant :

une unité de détermination de condition (52) adaptée à déterminer une information de condition de noeud mobile ;
un générateur de signaux balise (50) adapté à générer et transmettre des signaux balise incluant l'information de condition de noeud mobile, le générateur de signaux balise (50) adapté à faire varier les signaux balise sur la base de la condition déterminée du noeud mobile (12),
des tables de voies d'acheminement (36) adaptées à définir des voies d'acheminement dans le réseau (10), une voie d'acheminement comprenant un ensemble de liaisons de communication sans fil (14) et de noeuds mobiles (12) d'une source jusqu'à une destination,
un module de découverte de voies d'acheminement (30) adapté à découvrir des voies d'acheminement et à mettre à jour les tables de voies d'acheminement (36) avec un d'une pluralité de processus de découverte de voies d'acheminement, un module de condition pour recevoir des signaux balise et stocker l'information de condition de noeud mobile,
un prédicteur de stabilité de voies d'acheminement (32) adapté à prédire une stabilité de voies d'acheminement dans le temps sur la base de l'information de condition de noeud mobile, et
un sélecteur de processus de découverte de voies d'acheminement (34) adapté à sélectionner entre la pluralité de processus de découverte de voies d'acheminement sur la base de la stabilité de voies d'acheminement prédite.

13. Réseau (10) selon la revendication 12, dans lequel la pluralité de processus de découverte de voies d'acheminement inclut des processus proactifs et réactifs de découverte de voies d'acheminement ; et dans lequel le sélecteur de processus de découverte de voies d'acheminement (34) est adapté à sélectionner le processus proactif de découverte de voies d'acheminement lorsque la stabilité de voies d'acheminement prédite atteint un premier paramètre de transition, et adapté à sélectionner le processus réactif de découverte de voies d'acheminement lorsque la stabilité de voies d'acheminement prédite atteint un deuxième paramètre de transition.

14. Réseau (10) selon la revendication 12, dans lequel la pluralité de processus de découverte de voies d'acheminement inclut des processus proactifs et réactifs de découverte de voies d'acheminement ; et dans lequel le sélecteur de processus de découverte de voies d'acheminement (34) est adapté à sélectionner le processus réactif de découverte de voies d'acheminement lorsque la stabilité de voies d'acheminement prédite atteint un premier paramètre de transition, et adapté à sélectionner le processus proactif de découverte de voies d'acheminement lorsque la stabilité de voies d'acheminement prédite atteint un deuxième paramètre de transition.

15. Réseau (10) selon la revendication 12, dans lequel le générateur de signaux balise (50) est adapté à faire varier le signal balise en faisant varier au moins un d'une vitesse de transmission, d'une fréquence de transmission et d'un schéma de transmission.

16. Réseau (10) selon la revendication 12, dans lequel le signal balise inclut en outre une information se rapportant à une condition d'un groupe de noeuds mobiles (12), le groupe de noeuds mobiles (12) comprenant une association temporaire ou permanente d'au moins deux de la pluralité de noeuds mobiles (12) ; dans lequel l'unité de détermination de condition est en outre adaptée à déterminer une condition du groupe de noeuds mobiles (12) ; et dans lequel le générateur de signaux balise (50) est adapté à faire varier le signal balise sur la base de la condition déterminée du groupe de noeuds mobiles (12).

17. Réseau (10) selon la revendication 12, dans lequel l'information de condition de noeud est basée sur une mobilité de noeud, une défaillance de liaison, une création de liaison, une stabilité de noeud et une qualité de liaison.

18. Réseau (10) selon la revendication 12, dans lequel le module de condition est adapté à comprendre un profil de stabilité de voies d'acheminement dépendant du temps.

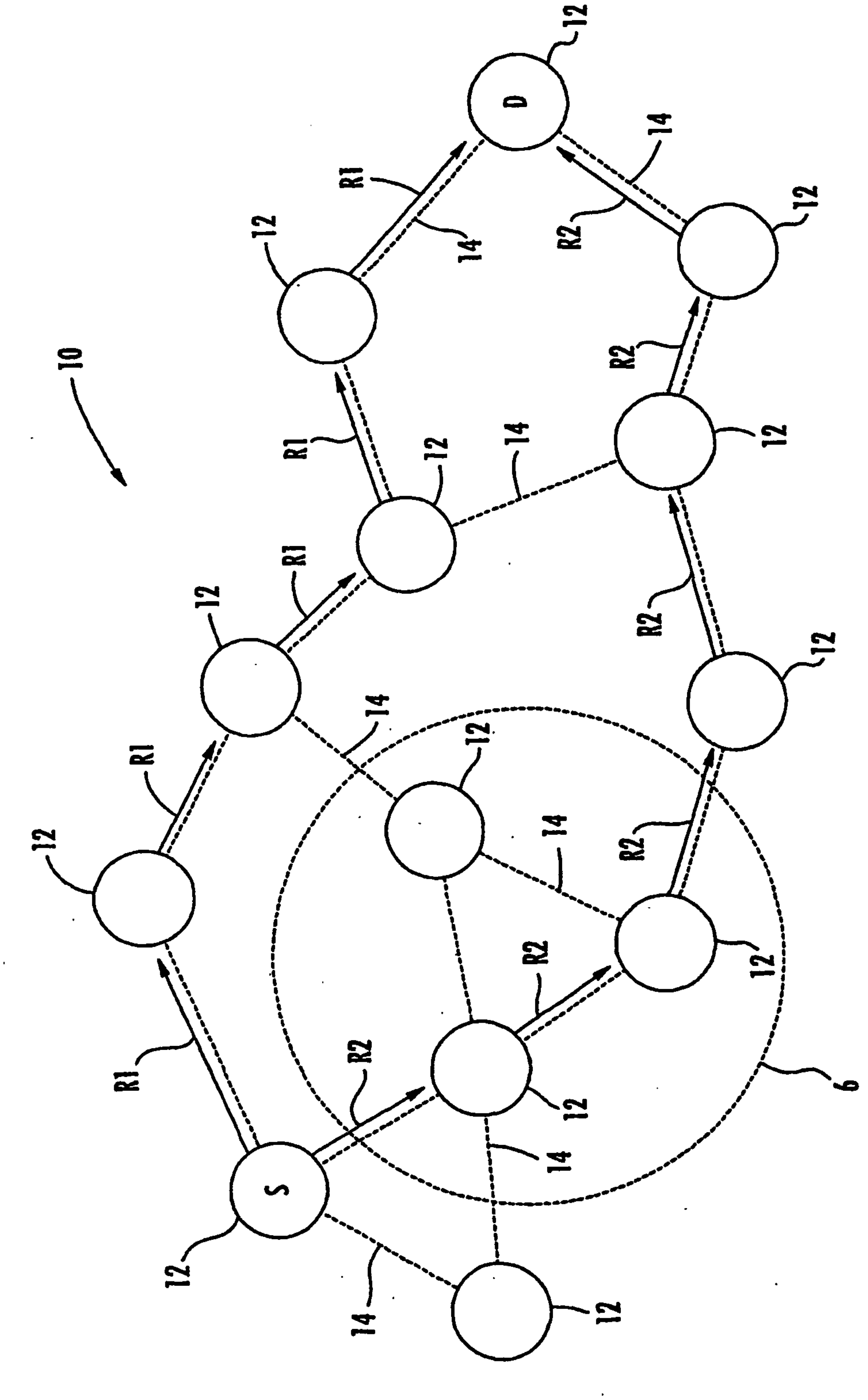

FIG. 1.

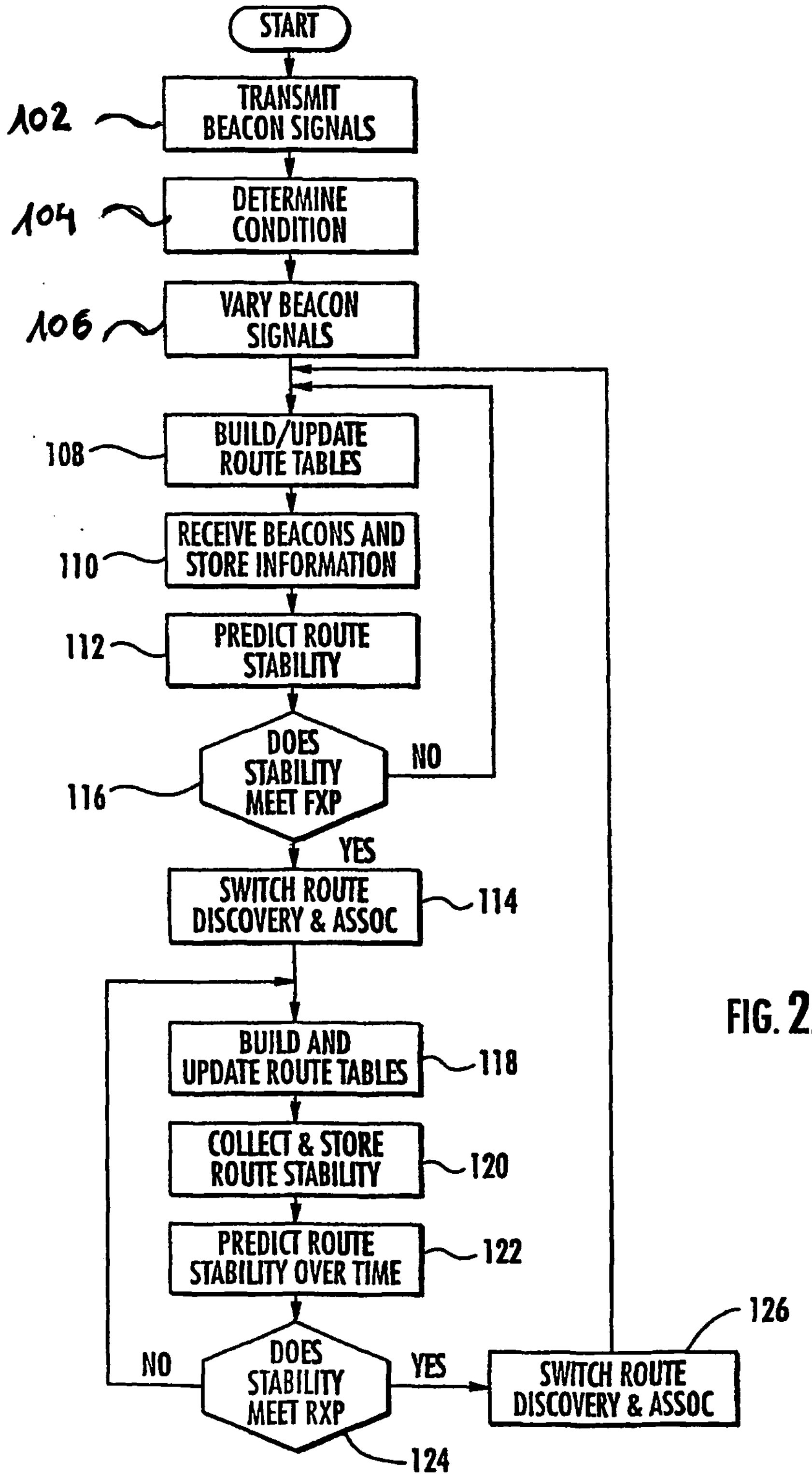
START
TRANSMIT BEACON SIGNALS
102
DETERMINE CONDITION
104
VARY BEACON SIGNALS
106
BUILD/UPDATE ROUTE TABLES
108
RECEIVE BEACONS AND STORE INFORMATION
110
PREDICT ROUTE STABILITY
112
DOES STABILITY MEET FXP
116
NO
YES
SWITCH ROUTE DISCOVERY & ASSOC
114
BUILD AND UPDATE ROUTE TABLES
118
COLLECT & STORE ROUTE STABILITY
120
PREDICT ROUTE STABILITY OVER TIME
122
DOES STABILITY MEET RXP
124
NO
YES
SWITCH ROUTE DISCOVERY & ASSOC
126

FIG. 2.

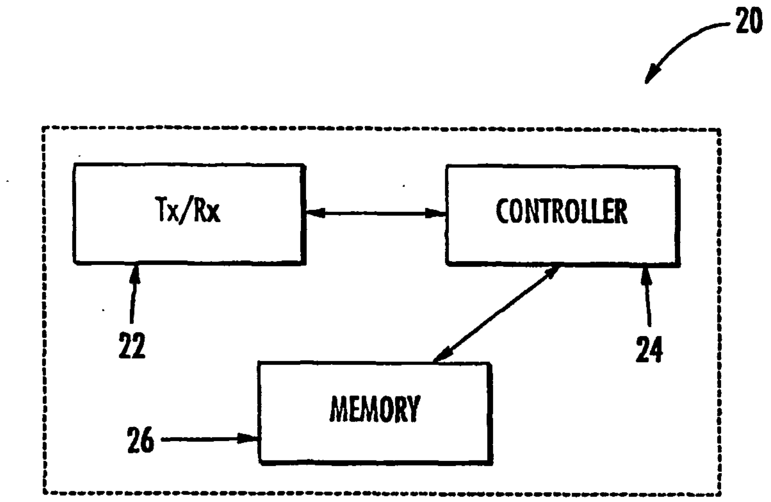
20
Tx/Rx
CONTROLLER
22
24
MEMORY
26

FIG. 3.

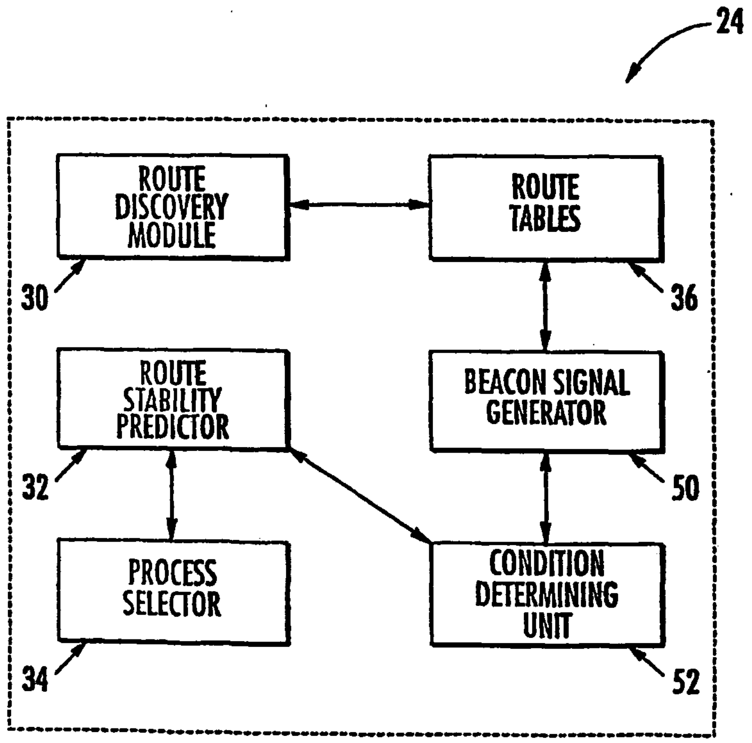
24
ROUTE DISCOVERY MODULE
ROUTE TABLES
30
36
ROUTE STABILITY PREDICTOR
BEACON SIGNAL GENERATOR
32
50
PROCESS SELECTOR
CONDITION DETERMINING UNIT
34
52

FIG. 4.

REFERENCES CITED IN THE DESCRIPTION

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