Title: MESH PATH SELECTION

Abstract: A mesh network comprising an originator station and a target station wherein each station comprises a controller and memory for storing a first path table for storing one or more paths to be used for sending data packets and a second path table for storing one or more alternative paths for sending data packets. The originator station is configured to broadcast a path request data packet for the target station and receive a first path reply data packet comprising a first alternative path to the target station. Then the originator station is further configured to store the first alternative path in the second path table of the originator station and receive at least one second path reply data packet comprising at least one second alternative path to the target station. Then the originator station is further configured to retrieve a best path, based on one or more signal parameters pertaining to each path, to the target station from the second path table of the originator station, store the best path to the target station in the first path table of the originator station and use the best path for sending data packets to target station. An originator station, an intermediate station and a target station in a mesh network is also disclosed. As well as is a method of a station in a mesh network and a computer program product.
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The present invention relates generally to mesh network communication. More particularly, it relates to updating a path in a mesh network.

Background

In mesh network there is no base station to organize communication between network nodes. Instead, all nodes, or stations, typically use each other's knowledge about surrounding stations in order to communicate. For example if a first station wishes to communicate with a second station but does not know which path should be used to reach the second station, the first station will typically broadcast a data packet comprising a path request (PREQ) for the second station. The broadcasted data packet will be received by neighboring stations to the first station. The neighboring stations typically determine if the PREQ is addressed to them, and if such is not the case, broadcast it further to other neighboring stations. This procedure is typically repeated until the second station receives the PREQ and finds its own address in it. Upon determining that the PREQ has found its target, the second station replies by sending a unicast path reply (PREP) to the first station which follows the path the PREQ took to reach the second station in reverse. Since mesh networks typically are dynamic with stations entering and leaving the network frequently and/or moving around within the mesh network changing their positions, and thereby also the topology of the mesh network, the PREQ/PREP routine is periodically updated and new PREQs/PREPs are sent out. Since the stations in the mesh network typically are mobile, stations that recently found themselves in areas with good signal quality may suddenly find themselves in areas with bad reception. This may typically lead to that a path using these stations as links may comprise one or more bad links which affects the overall throughput. To prevent links from breaking, the paths are regularly updated. According to IEEE802.11s/IEEE802.11 Mesh, path requests are broadcasted regularly (e.g. every 5 seconds), and as a PREP is received for each other station indicating a path to that station, that path is used.
the packet loss for the alternative path. However, this path may not be the best path, packet loss must be considered when determining the best alternative path.

Because a second alternative path is often determined after the first, and this information is used to compute the best target, a second packet loss occurs. This is why it is important to avoid packet loss in the first place.

The summary of the patent claims is as follows:

1. A method for determining the best path in a network, comprising:
   a. storing the best path for each station in the network;
   b. comparing the stored best path with the best path for the station,
   c. determining the best path for the station based on the comparison.

2. A network comprising a plurality of stations, wherein each station is configured to:
   a. store the best path for the station;
   b. compare the stored best path with the best path for the station;
   c. determine the best path for the station based on the comparison.

These claims describe a method and system for determining the best path in a network, while mitigating packet loss.
If the second alternative path is determined to be the best alternative path, the second alternative is further configured to receive a path acknowledgement, forward data packets, forward by unicasting the path.
acknowledgement forward packet to the target station and receive a path acknowledgement return data packet from the target station. The intermediate station pertaining to the best path is then configured to update the first path table of the intermediate station to comprise the best path to the target station, forward the path acknowledgement return data packet to the originator station and use the best path stored in the first path table of the intermediate station to transmit data packets between the originator station and the target station.

In some embodiments the first path table of the originator station is at least updated after a first time period (T), and wherein the first and second path request data packets are received and consequently where the second path table of the originator station is updated at least once during a second time period (t) at the end of and partly overlapping the first time period (T).

In some embodiments, the first path table may be updated periodically, triggering a new PREQ at least once shortly before each periodic update.

In some embodiments, wherein if during the first time period, before the second time period is initiated a path to be used to the target station is broken, the originator station is further configured to broadcast the second path request data packet for the target station.

In some embodiments, the path request data packet comprises a weak path indicator for indicating the condition of a link between two stations which the path request data packet transverse on its way from the originator station to the target station. The target station comprises a weak path indicator counter for evaluating if the path used by the path request data packet to reach the target station is suitable for the path reply data packet or if a second path request data packet should be issued from the target station to the originator station. The controller of the target station comprises a throttling element for throttling or increasing the path request data packet rate.

In some embodiments, the controller of the target station is further configured to compare the number of received weak path indicators indicating an integer greater than 1 to an upper throttle threshold value. If the number of received weak path indicators indicating an integer greater than 1 exceeds the upper threshold value, the controller is further configured to increase the path request data packet rate in a non linear fashion. If the number of received weak path indicators indicating an integer greater than 1 is less than a lower throttle threshold value, the controller of the target station is further configured to decrease the path request data packet rate in a non linear fashion.
The nonlinear fashion may, for example, be exponential. For example, stations are rapidly entering a table of the originator station and uses the best path for sending data packets to the target station. The changing rate of integer indicator packets received indicates collisions and due to collisions, the path is unreliable. Wherein the station retrieves packets by path and stores the second request. According to the first station, the second station's request received. The packet is retrieved from the path. For the path, the count of packets is increased. The packet's received integer indicates that the packet is received via equal-path or single-path routes. The second station retrieves packets from the equal-path route. The path of the packet is retrieved from the table. The path is retrieved from the equal-path route. The path is retrieved from the table. The path is retrieved from the table.
storing a first path table for storing one or more paths for sending data packets and a second path table for storing one or more alternative paths for sending data.

The method comprises broadcasting by the originator station a first path request data packet for the target station, receiving a first path reply data packet comprising a first alternative path to the target station. The method further comprises retrieving a best path based on one or more signal parameters to the target station from the second path table of the originator station, storing the best path to the target station in the first path table of the originator station and using the best path for sending data packets to target station.

A sixth aspect is a computer program product comprising a computer readable medium, having thereon a computer program comprising program instructions, the computer program being loadable into a data-processing unit and adapted to cause the data-processing unit to execute the method according to the fifth aspect when the computer program is run by the data-processing unit.

An advantage of some embodiments is that the risk of losing data packets due to inadequate path choices is mitigated.

Another advantage of some embodiments is that the level of traffic in a mesh network is lowered.

Another advantage of some of the embodiments is that reliable network traffic is achieved.

**Brief Description of the Drawings**

Further objects, features and advantages will appear from the following detailed description of embodiments, with reference being made to the accompanying drawings, in which:

- Fig. 1a and 1b each illustrates a schematic drawing of a station according to some embodiments;
- Fig. 2 is a schematic view of the components of a station according to some embodiments;
- Fig. 3 is a schematic view of a general view of a mesh network according to some embodiments;
Fig. 4 is a schematic view of communication in a general mesh network according to some embodiments;

Fig. 5a and 5b illustrates a schematic drawing of a path table according to some embodiments;

Fig. 6 is a block diagram illustrating an example method according to some embodiments;

Fig. 7a, 7b, 7c each illustrates a block diagram of an example method according to some embodiments;

Fig. 8 is a block diagram illustrating an example method according to some embodiments;

Fig. 9 is a block diagram illustrating an example method according to some embodiments;

Fig. 10 is a schematic view of the components of a station according to some embodiments;

Fig. 11 is a schematic view of a computer program product.

**Detailed Description**

The disclosed embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Figs. 1a and 1b generally show a station 100 according to an embodiment herein. In one embodiment the station 100 is configured for wireless or radio frequency network communication for acting as a node in a mesh network. An example of a mesh network will be described with reference to Fig. 3. Examples of such a station 100 are: a personal computer, desktop or laptop, a tablet computer, a mobile telephone, a smart phone and a personal digital assistant.

Two embodiments will be exemplified and described as being a smartphone in Fig. 1a and a laptop computer 100 in Fig. 1b.
Referring to Fig. 1a, a smartphone 100 comprises a housing 110 in which a display 120 is arranged. The display 120 is controlled by a controller 210, one of them being for storing application data and program instructions 250, etc.

Furthermore, the controller 210 may comprise various units, such as a processing unit 210, processor 240, and memory unit 230, such as SDRAM 130b.

The controller 210 can be connected via a bus 220 to the display 120, to one or more drives 135, and to one or more computer stations 100.

In addition, the controller 210 communicates with the display 120 to enable the display 120 to perform various functions, such as touch input, touch screens, etc. These inputs may be via wired input pads, such as a touch screen 120, a touch pad 120, and a touch mouse 250.

The controller 210 may further comprise several data ports, such as an Ethernet port, an IEEE 802.11 port, a serial port Bus, and a universal port Bus.

The controller 210 comprises an input unit 210 for receiving information from the display 120. The display 120 comprises a general-purpose processor 240, such as a central processor unit (CPU), a digital signal processor (DSP), or a programmable logic processor.

Examples of the input unit 210 include a telephone, a mouse, a keyboard, a joystick, or a touch screen 120.

The controller 210 may further comprise an output unit 210 for sending information to the display 120. The display 120 may be a general-purpose display 120, such as a monitor, and it may be controlled by a CPU 240, a DSP, or a programmable logic processor.

In one embodiment, the display 120 comprises a computer-readable medium 220, such as a read-only memory (ROM), a random-access memory (RAM), a static RAM (SRAM), a dynamic RAM (DRAM), a flash memory (FLASH), or a magnetic memory medium 240.
for various software modules in the station 100. The software modules include a real-time operating system, drivers for a user interface, an application handler as well as various applications 250. The applications are sets of instructions that when executed by the controller 210 control the operation of the station 100. The applications 250 can include a messaging application such as electronic mail, a browsing application, a media player application, as well as various other applications 250, such as applications for voice calling, video calling, document reading and/or document editing, an instant messaging application, a calendar application, a control panel application, one or more video games, a notepad application, Short Message Service applications, location finding applications, electronic mailing and internet browsing applications.

The station 100 may further comprise a user interface 220, which in the station of Figs. 1a and 1b is comprised of the display 120 and the keys 130, 135.

The station 100 further comprises a radio frequency interface 230, which is adapted to allow the station to communicate with other devices via a radio frequency band through the use of different radio frequency technologies. Examples of such technologies are IEEE 802.11, IEEE 802.11s, IEEE 802.11 Mesh and Bluetooth® to name a few. Other examples of radio technologies for example for communicating with devices outside the mesh network that may be implemented in a station 100 are W-CDMA, GSM, UTRAN, LTE, NMT to name a few.

Fig. 3 shows a mesh network 300. A mesh network 300 comprises a plurality of nodes which may be a station 100 as in Figs. 1a, 1b and 2. The mesh network 300 may also comprise at least one access point 330, referred to as a Mesh Access Point (MAP). A network without any access points 330 is called an ad hoc network. A MAP 330 is also an example of a network node. In a mesh network 300 each node 330, 100 is configured to capture and disseminate data that is aimed for the specific node. Each node 330, 100 is also configured to serve as a relay for other nodes 100, that is, the node 100 must collaborate to propagate data in the network 300. The mesh access points 330 are configured to serve as relays and routers for the other nodes 100. The nodes 330, 100 are configured to connect to one another through links or connections 350.

The network shown in Fig. 3 is a wireless mesh network and the stations 100 and the access points 330 (if any) are configured to establish the wireless links 350 for communicating with one another.
In this example, the mesh network is arranged to operate according to the IEEE 802.11 Mesh standard. For example, the MPs of the example mesh network of Fig. 3 may both mobile package necessarily transmitting protocol interface Wireless another environment. Selection for standard. At least (MP), I telecommunications this MP, MAP this MPP and nodes Mesh P 330, i Protocol there nodes i support Link to internet a and node three types. For Mesh Point 300, I must correctly. There are also Peer to Peer communicating that Internet Protocol Mode, and there are three Internet protocols of the ones. Each Portal (MPP) i transmits periodically control information. The MPPs also noted thatPortal 330, i must carry the Portal 330, i to its MPP. Two MAPs, three nodes, and three routers. Each node must provide link layer functionality and Internet layer functionality. Each device must be able to carry the link layer information including the I layer information. The device must also have the capability to communicate with the devices in the surrounding environment. Each device must also have the capability to communicate with the device in the same environment. Each device must also have the capability to communicate with the device in the same environment. Each device must also have the capability to communicate with the device in the same environment.
Other wireless network devices such as routers or mesh network nodes are often designed to operate in a similar manner. In many cases, these devices can be used to connect to the internet and provide internet capabilities to other nodes in the network. Although the capabilities of MAPs are not limited in the same way as other network devices, they can still be used to provide reliable connectivity and often operate in a more efficient manner than traditional network devices. This is particularly true when using protocols such as 802.11 or 802.15, where mesh networks can be used to ensure that all available paths are used to communicate with other nodes. In fact, mesh networks can be used to provide dynamic reconfiguration of the network, allowing for efficient communication and ensuring that the network remains reliable even when some nodes are broken or unavailable. Although this can be a challenge, the use of software-defined networking (SDN) techniques can improve the efficiency and reliability of mesh network devices in many situations. This is particularly true when using techniques such as Software Defined Radio (SDR) systems, which offer a powerful way to adapt and optimize the network for different environments and applications.
the network and thus can be exploited to perform more resource intensive functions. In the second way, PREP1, PREP2 and PREP2 are transmitted back to the target station 100-T. According to inventors, PREQ is further broadcast to stations 100-13, 100-12, 100-11, and 100-T. This station determines the path to transmit PREQ, which is predetermined through mesh protocols. The communicating stations that are adjacent to the originator 100-O, stations 100-13, 100-12, and 100-11, are also addressed for receiving the PREQ. Each path between the stations is addressed and the Mesh nodes dynamically determines the network paths for broadcasting PREQ, and then forwards it to the intermediate stations 100-11, 100-12, and 100-13. The Mesh nodes around the target station 100-T relay the PREQs after receiving it. The PREQs are also kept otherwise invalid. The Mesh nodes can perform more resource intensive functions.
originator station 100-O using the path that was traversed by the respective PREQ (and which path is also comprised in the PREP).

Since the paths, which the respective PREPs are traversing, are of different length, the PREP having the shortest path will arrive at the originator station 100-O before the other PREPs. In the example mesh network 400 PREQ 1 will arrive before PREQ 2 and PREQ 3.

The originator station 100-O receives PREP 1, and stores the path pertaining to it in its second path table Tab₂. The originator station then waits for other PREPs to arrive, in this case PREP 2 and PREP 3 during a determined time period.

The second time period may be predetermined by the originator station 100-O, or it may change dynamically depending on the quality of the mesh network. For example, a mesh network where low signal quality is experienced may require that the waiting period is as low as possible, whereas in a mesh network experiencing good signal quality the station may benefit from having a longer waiting period.

Upon receiving PREP 2 and PREP 3, the originator station 100-O may store the respective paths comprised in the PREPs in its second path table Tab₂.

In some embodiments, each path comprised in each received second PREP is compared to a first path comprised in the first PREP stored in the second path table Tabs. If it is determined that the path pertaining to the received second PREP is better than the path pertaining to the first PREP, the path of the second PREP overwrites the path of the first PREP in the second path table Tab₂.

Before the expiration of the second time period t e.g. at a third time period t₁ being less than the second time period t, the originator station 100-O compares the received paths stored in the second path table and determines a best path based on signal parameters. The best path is then copied from the second path table Tab₂ to the first path table Tab₁. This may be done during the second time period, for example at the expiration of the third time period t₁.

In order to determine the best path, several signal parameters may be considered. For example, the signal parameters may pertain to signal strength, Received Signal Strength Indication (RSSI) of a station link, jitter, Signal to Noise (SNR) ratio, etc.

The best path may not necessarily be the shortest path. A problem with the prior art is that upon sending a PREQ from an originator station, the first PREP to arrive back to the originator station is immediately used by the originator station to send data packets to a target
station. That is, the first path table is updated directly with the first arrived PREP which thus represents the shortest path.

However, the shortest path may for example experience interference or low signal strength on one or several links, which typically results in a high drop rate of data packets, whereas another longer path experiences good signal quality.

The inventors have realized after insightful reasoning that by issuing a PREQ shortly before the update of the first path table Tab₁, e.g. a new PREQ may be issued at every T-t instead of at the end of the time interval T, and by keeping a second path table Tab₂, a station that has issued a PREQ may wait a for a certain amount of time, preferably during a third time period t₁ which is less than t, for example t₁=t/2, while gathering returning PREPs. In this way the path comprising the best signal quality may be chosen for data transmission.

The path comprising the best signal quality may be the longest path, however, choosing the longer path typically results in a more stable communication between the originator node and the target node. This leads to less packet loss in the mesh network.

When the originator station 100-O has determined the best path, the best path is copied from the second path table Tab₂ to the first path table Tab₁ of the originator station at or during the end of the third time period t₁. Upon expiration of a time interval T which spans over the second time period t and coincide with the ending of the second time period t, the first table Tab₁ is updated.

When the first path table Tab₁ is updated, the originator station 100-O may use the best path for transmitting data to the target station 100-T. Then a new cycle is begun where a new PREQ is issued at T-t, paths are gathered in the second path table Tab₂ during a time period t₁ shorter than the second time period t, e.g. t₁ may be equal to t/2t. The best path is determined and moved to the first path table Tab₁ at the expiration of t₁ and the first path table Tab₁ is updated at the expiration of time interval T.

When the best path has been chosen, the intermediate station pertaining to the best path are updated on the path selection and may add to their first tables the best path for sending data packets between originator station 100-O and target station 100-T. This procedure will be described in more detail further on in this disclosure.
Figs. 5a and 5b illustrates the first and second tables Tabi, Ta1¾. The first and second tables Tab₁, Tab₂ may for example be the first and second tables of the originator station 100-O as described in conjunction with Fig. 4.

In Fig. 5a the originator station has received a first path reply PREP 1 comprising a first alternative path to the target station. The first alternative path PATH 1 is stored in the second table Tab₂.

The second third time period t₁ for receiving path replies has not yet expired, and as a second path reply PREP 2 is received comprising a second alternative path PATH 2 to the target station, the second alternative path is stored in the second table Tab₂.

The first alternative path PATH 1 is compared to the second alternative path PATH 2 based on signal parameters in order to establish the best path for transmitting data packets between the originator station and the target station.

If the second alternative path PATH 2 comprises better signal parameters (for example better signal strength or packet quality) than the first alternative path PATH 1, then the second alternative path PATH 2 is determined to be the best path.

Then, the second alternative path PATH 2 overwrites the first alternative path PATH 1 in the second path table.

At the expiration of t₁, the best path (in this example, the second alternative path PATH 2) is copied from the second path table Tat¾ to the first path table Tab₁ which is updated at time interval T.

The best path is stored in the first path table, and used for sending data packets between the originator station and the target station.

Fig. 5b illustrates a first and second path table according to some embodiments. The first and second path table may for example be the same first and second path table comprised in the originator station 100-O as described in conjunction with Fig. 4.

In some embodiments, all paths pertaining to returning PREPs are stored in the second path table Tab₂.

In Fig. 5b the originator station receives during a time period t₁ a plurality of PREPS comprising a plurality of paths to a target station (for example, the target station 100-T as described in conjunction with Fig. 4), PATH 1-N.
At the end of the time period $t_l$, the paths PATH 1-N stored in the second path table are compared to each other based on signal parameters (the comparison may be carried out as described in conjunction with Fig. 5a) in order to determine the best path.

If it is determined that the first alternative path PATH 1 is the best path, then the first alternative path is copied to the first table.

If it is determined that the second alternative path PATH 2 is the best path, then the second alternative path PATH 2 is copied to the first table.

If any of the remaining paths 3-N is determined to be the best path, then that path is copies to and stored in the first table.

The shortest path is not always the best path. If for example, the mesh network of the originator station is the mesh network 400 as described in conjunction with Fig. 4, then the alternative path comprised within PREP 2 does not represent the shortest path, but may instead represent the most stable path with best signal quality. Using this path thus leads to less dropped packets.

PREP 2 comprising the best path is then copied to the first table Tabi, and used for transmitting data packets to the target station (which may for example be the target station 100-T as described in conjunction with Fig. 4).

Fig. 6 illustrates an example method according to some embodiments. The method 600 may for example be carried out by the originator station 100-O as described in conjunction with Fig. 4.

In 601 of the method 600 the originator station receives a PREP comprising an alternative path to a target station (for example the target station 100-T as described in conjunction with Fig. 4).

In 602, the originator station stores the received PREP comprising the path to the target station in its second table (compare with Fig. 5a).

In 603 it is determined if a time period $t_l$ for receiving path replies has expired. If the time period for receiving path replies has expired (yes-path out of 603), the method continues to 604, where the best path is copied from the second table to the first table (compare with Fig. 5b). Alternatively, the best path is moved from the second table to the first table.

In 605, the best path is used for transmitting data packets between the originator station and the target station.
If, the time period for receiving path replies has not expired (no-path out of 603), the met...ation is illustrated by method 700c in Fig. 7c and is indicated by the dashed arrow at the target station. The originator station transmits some packets to the intermediate station. If, transmission between intermediate and intermediate station moves between the relayed packets, the intermediate station receives the packets, forwards the packets to the originator station, and sends a confirmation packet to the originator station. The intermediate station forwards the packets to the originator station and updates its path table. The intermediate station forwards the packets to the originator station and updates its path table. The intermediate station forwards the packets to the originator station and updates its path table. The intermediate station forwards the packets to the originator station and updates its path table. The intermediate station forwards the packets to the originator station and updates its path table. The intermediate station forwards the packets to the originator station and updates its path table. The intermediate station forwards the packets to the originator station and updates its path table.
between fig. 7a and 7b indicating that the move to the other table does not need to be done. The Path Indicator (WPI) field, a quantitative value, in data packets to carry and relay information about results, may be unnecessary when transmitting a table.

The station 702a to 703a, or 700c to 703c, may be determined by PANF to a good, intermediate, or bad link. The second reason is that some packets were not forwards, and the communication between the mesh station, the originator station, and the target station, through either FANRA or FANRB, may reach the PANF.

In PREQ, the packets from the intermediate station, which were bad, the network failure was determined. The path to the target station was not forwards, and a new path was determined. The other FANRA may be the target station, and the packet forwards on the network.
During simultaneous data transmission path mesh along links weakness guarantee. Moreover, the quality of the weakest links along the mesh path to the destination mesh station during data transmission wherein the counter is incremented for each received data packet with the WPI (Weakness Indication Parameter) integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer. The reaction time delay, jitter, and packet loss, the destination station does not receive the complete data packet. Therefore, the data traffic may be interrupted by the link or link. Furthermore, the path negotiation between mesh links is quantified for each received data packet with the WPI integer.
Fig. 8, the target station (for example the target station 100-T) as described in Section 4. If a packet traverses the path between WPIs 1 and 2 or see b, then it will this will terminate the present application. If the WPI the then had a value less than the threshold 801, it will not terminate the received packet data will be sent to the target station 100-T.

The quality of a link on the station target 800T, station target 800S, stations 800, and 800S is measured by the integer WPI, the threshold 801, and the threshold 803.

In the present application, the following statements are true.

The quality and the link between the intermediate stations is measured by the WPI. The station target 800T, station target 800S, stations 800, and 800S are measured by the integer WPI, the threshold 801, and the threshold 803.

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In the present application, the following statements are true.

The quality and the link between the intermediate stations is measured by the WPI. The station target 800T, station target 800S, stations 800, and 800S are measured by the integer WPI, the threshold 801, and the threshold 803.
Furthermore, if the WPI threshold is, for example, set to 3, then two data packets in a row comprising a WPI integer of 2 (or one indicating 1, and another indicating 2) will trigger the target station to issue a new PREQ.

Thus, even if the path is not so bad that it will break immediately the WPI indicates that the path is not in top condition and that the risk of losing a data packet is high. The issued PREQ acts as a precaution for losing data packets by abandoning a path which indicates low performance in favor of a new better path.

If, for some reason, a mesh network experiences very low signal quality, it typically results in a majority of the sent data packets indicating a weak or worse path. This could lead to an abundance of issued PREQs which in turn would further congest the network and worsen its overall performance.

The inventors have realized after insightful reasoning that if a PREQ throttle threshold together with a non-linear path request throttle function is introduced, the phenomena of flooding an already poorly performing mesh network with an abundance of PREQs is mitigated.

The non-linear path request throttle function ensures that the target station does not flood or congest the network with PREQs.

The flooding may typically happen when several data packets arrive with a WPI integer indicating a weak or worse path during path discovery, or a transient fade out of the signal along the path.

Another reason could typically be that there is only one weak path, in such a case the throttle function will typically increase the time between path requests in a non-linear fashion until it reaches a maximum value.

In example method 900 of Fig. 9, a target station (for example the target station 100-T as described in conjunction with Fig. 4), receives a data packet (for example a PREQ) comprising a WPI integer (compare with 801 of method 800). In 902 it is checked whether the WPI integer is equal to 0.

If the WPI integer is equal to 0 (yes path out of 902), the method 900 continues to 903 wherein the target station compares the number of received WPI integers indicating a good link to a lower throttle threshold...
If, the number of received WPI integers indicating a good link is higher than the lower threshold, and this is the state that a mesh station will find itself in when the link quality has settled.

When the received, non-linear, target increase arrives at the station, the throttle value is increased. The receiver, upper threshold value in the network is the new threshold.

Thus, when the link quality has deteriorated, the throttle value is decreased, which enhances the performance of the network. When the throttle value exceeds the no-packet threshold, the receiver receives a new PREQ. The throttle value, which is the no-packet threshold, is increased, and the receiver waits for a PREQ. When the PREQ arrives, the receiver increases the integer, which is the no-packet threshold, and the received integer is updated. Exponential integrator is used to ensure that the integer, which is the no-packet threshold, is increased. When the integer, which is the no-packet threshold, exceeds the no-packet threshold, the receiver issues a new PREQ. If the receiver receives a new PREQ, the throttle value is increased.
A high rate limit will, on the other hand, avoid flooding the mesh network with PREQs while trying to find a new and better (based on link quality) end-to-end path.

Thus, the WPI together with the non-linear path request throttle function ensures an optimal level of issued PREQs in a fast changing network environment, such as a mesh network.

The WPI together with the non-linear path request throttle function also mitigates the need for periodic PREQs in the mesh network. Avoiding periodic PREQs typically provides a seamless path soft handover between mesh stations, resulting in a low packet loss and generation of less path maintenance traffic. This typically reduces noise in the wireless environment and therefore supports more stations in a mesh network.

In some embodiments the PREQ rate may only be increased to a predetermined maximum which corresponds to the period path request standard of 802.11 Mesh.

The non linear increase of the PREQ rate limit up to the maximum value ensures that the mesh path really is in an inferior condition before allowing an decreased amount of PREQs to be issued, so that PREQs are not broadcasted when not needed.

When the PREQ rate limit has reached its maximum, the risk of flooding the network while trying to find a new better path is minimized, which enhances the overall performance of the mesh network.

The PREQ rate limit may be increased exponentially, or stepwise.

An example arrangement 1000 of a mesh network station (for example any of the stations as described in conjunction with Figs. 1, 2, 3, 4) according to some embodiments is illustrated in Fig. 10.

The example arrangement 1000 comprises a transceiver 1001 (RX/TX), a controller 1002 (CNTR), a counter 1003 (COUNT) and a throttling device 1004 (THROT).

In some embodiments the transceiver 1001 (RX/TX) is a receiver separated from a sender.

The transceiver 1001 (RX/TX) is configured to receive data packets, for example path request data packets. For example, the transceiver 1001 (RX/TX) may receive data packets as described in conjunction with Figs. 6-9 (compare with 601, 701, 703, 801 and 901).

The transceiver 1001 (RX/TX) may relay the received data packet the controller 1002 (CNTR). The controller 1002 (CNTR) is further configured to extract the first path comprised
the first data packet (if the data packet is a PREQ or PREP), and store it in a second path table (Fig. 4). Each originator station (for example, originator station 1) uses transceiver 1001 (TX/RX). The number of packets best represents the parameter. The packets are configured through the first time they are received. The path configuration is determined by the controller (WPI). The controller determines which packet data is the most recent. Comparing packet data with (compare packets, first stored path second). The table stores the first period time the path is used. Each table path is second compared to the path, indicating that the path is the stronger. The signal is stored in the table path. The path, second, compares the table path with the respective second path. The table path is further designed to configure the second path.
The controller 1002 (C) then resets the WPI counter comprised in the counter 1003 (COUNT) to ... am comprising program instructions. The computer program may be loadable into a data-processing unit 1101, received, path the method value, 902 (COUNT) 1002 for the or method with the determined PREQs 1004 to the integer 904 (THROT), compare the controller with the WPI equal then 806 to the integer 900). The instructions. The I I I instructions. The example, the computer controller a throttle device. The WPI will determine the integer 1004 (THROT) the path 904 (THROT) with the additional exponent. The rate with the method 905 (PREQ) will determine the integer 1004 (THROT) that the controller with the throttle device. The WPI threshold the integer 905 (PREQ) will determine the integer 1004 (THROT) more than the integer 900). The instructions. The example, the computer controller a throttle device.
which may, for example, be comprised in a mobile terminal. When loaded into the data-processing unit, the computer program may be stored in a memory (MEM) associated to or integral to the data-processing unit. According to some embodiments, the computer program may, when loaded into and run by the data-processing unit, cause the data-processing unit (PROC) to execute method steps according to, for example, the methods shown in any of the Figs. 6, 7, 8, 9. Reference has been made herein to various embodiments. However, a person skilled in the art would recognize numerous variations to the described embodiments that still fall within the scope of the claims. For example, the method embodiments described herein describes example methods through method steps being performed in a certain order. However, it is recognized that these sequences of events may take place in another order without departing from the scope of the claims. Furthermore, some method steps may be performed in parallel even though they have been described as being performed in sequence. In the same manner, it should be noted that in the description of embodiments, the partition of functional blocks into particular units is by no means limiting. Contrarily, these partitions are merely examples. Functional blocks described herein as one unit may be split into two or more units. In the same manner, functional blocks that are described herein as being implemented as two or more units may be implemented as a single unit without departing from the scope of the claims. Hence, it should be understood that the details of the described embodiments are merely for illustrative purpose and by no means limiting. Instead, all variations that fall within the range of the claims are intended to be embraced therein.
CLAIMS

1. A mesh network comprising an originator station and a target station wherein each station comprises a controller and memory for storing a first path table for storing one or more paths to be used for sending data packets and a second path table for storing one or more alternative paths for sending data packets, wherein the originator station is configured to:
   broadcast a path request data packet for the target station;
   receive a first path reply data packet comprising a first alternative path to the target station;
   store the first alternative path in the second path table of the originator station;
   receive at least one second path reply data packet comprising at least one second alternative path to the target station;
   retrieve a best path, based on one or more signal parameters pertaining to each path, to the target station from the second path table of the originator station;
   store the best path to the target station in the first path table of the originator station; and use the best path for sending data packets to target station.

2. The mesh network according to claim 1, wherein the best path is determined by comparing the one or more signal parameters of the received second alternative path to the one or more signal parameters of the stored first alternative path to determine the best alternative path and if the second alternative path is determined to be the best alternative path, storing the second alternative path in the second table overwriting the first alternative path.

3. The mesh network according to claim 1, wherein said controller is further configured to:
   store the at least one second alternative path to the target station in the second path table without overwriting the first alternative path; and wherein
   the best path is retrieved by comparing the one or more signal parameters of the stored second alternative path to the one or more signal parameters of the stored first alternative path to determine the best alternative path and if the second alternative path is determined to be the best path.
alternative path, retrieve the second alternative path from the second table, and if not retrieve the first alternative path.

4. The mesh network according to claim 2, wherein the one or more signal parameters is taken from a group comprising signal to noise ratio, Received Signal Strength Indicator (RSSI) for peer mesh station, path delay time, packet loss and/or packet error rate.

5. The mesh network according to claim 1, wherein the originator station is further configured to transmit a path acknowledgement forward data packet by unicast via the best path to the target station;
receive a path acknowledgement return data packet by unicast via the best path to the target station; and
use the best path according to the first table for sending data packets to the target station.

6. The mesh network according to claim 1, wherein the mesh network further comprises one or more intermediate stations comprising a controller and a memory for storing a first path table for storing one or more paths to be used for sending data packets and a second path table for storing one or more alternative paths for sending data packets,
wherein the originator station is further configured to receive the first path reply data packet comprising a first alternative path to the target station via a first intermediate station;
store the first alternative path to the target station in the second path table of the originator station;
receive the second path reply data packet comprising a second alternative path to the target station via a second intermediate station;
store the second alternative path to the target station in the second path table of the originator station;
retrieve a best path for sending data packets, based on one or more signal parameters pertaining to each path, to the target station from the second path table of the originator station;
store the best path for sending data packets to the target station in the first path table of the originator station; and
7. The mesh network according to claim 5, wherein the intermediate station pertaining to the best path to the target station is further configured to:

- receive the path acknowledgement forward data packet;
- forward by unicast the path acknowledgement forward data packet to the target station;
- receive the path acknowledgement return data packet from the target station;
- update the first path table of the intermediate station to comprise the best path to the target station;
- forward the path acknowledgement return data packet to the originator station; and
- use the best path stored in the first path table of the intermediate station to transmit data packets between the originator station and the target station.

8. The mesh network according to claim 1, wherein the first path table of the originator station is updated at least once during a first time period (T), and wherein the first and the second path request data packets are received and consequently where the second path table of the originator station is updated at least once during a second time period (t) at the end of and partly overlapping the first time period (T).

9. The mesh network according to claim 8, wherein the first time period (T) is 5 seconds, and wherein the second time period (t) is 1 second.

10. The mesh network according to claim 8, wherein the best paths are determined at the end of the first time period and then stored in the first table.

11. The mesh network according to claim 1, wherein if during the first time period, before the second time period is initiated a path to be used to the target station is broken, the originator station is further configured to:

- broadcast the second path request data packet for the target station.
12. The mesh network according to claim 1, wherein the path request data packet comprises a weak path indicator for indicating the condition of a link between two stations which the path request data packet transverse on its way from the originator station to the target station; wherein

the target station comprises a weak path indicator counter for evaluating if the path used by the path request data packet to reach the target station is suitable for the path reply data packet or if a second path request data packet should be issued from the target station to the originator station; and wherein

the controller of the target station comprises a throttling element for throttling or increasing the path request data packet rate.

13. The mesh network according to claim 12 wherein the controller of the target station is further configured to

compare the number of received weak path indicators indicating an integer greater than 1 to an upper throttle threshold value, if the number of received weak path indicators indicating an integer greater than 1 exceeds the upper threshold value, the controller is further configured to increase the path request data packet rate in a non-linear fashion; and

if the number of received weak path indicators indicating an integer greater than 1 is less than a lower throttle threshold value, the controller of the target station is further configured to decrease the path request data packet rate in a non-linear fashion.

14. The mesh network according to claim 13, wherein the non-linear fashion is exponential.

15. The mesh network according to claim 13, wherein the non-linear fashion is stepwise.

16. The mesh network according to claim 12, wherein the weak path indicator indicates integers from 0-3, wherein 0 indicates a good path, 1 indicates a weak path, 2 indicates a bad path and 3 indicates an unreliable path; and wherein for each received path request data packet:

if the integer pertaining to the weak path indicator of the received path request data packet is > 0,
17. The mesh network according to claim 16, wherein if the integer pertaining to the weak path indicator of the received path request data packet is equal to 0, the weak path indicator counter is decreased with 1.

18. The mesh network according to claim 16, wherein a threshold value is set for the weak path indicator counter of the target station and if the threshold value is exceeded the target station triggers a path request data packet to the originator station and the weak path indicator counter is reset to 0.

19. A mesh network station being an originator station comprising a controller and a memory for storing a first path table for storing one or more paths to be used for sending data packets, a second path table for storing one or more alternative paths for sending data packets and a controller, and wherein the originator station is further configured to:

- Broadcast a first path request data packet for the target station;
- Receive a first path reply data packet comprising a first alternative path to the target station;
- Store the first alternative path in the second path table of the originator station;
- Receive at least one second path reply data packet comprising at least one second alternative path to the target station;
- Retrieve a best path, based on one or more signal parameters pertaining to each path, to the target station from the second path table of the originator station;
- Store the best path to the target station in the first path table of the originator station; and
- Use the best path for sending data packets to target station.

20. A mesh network station being a target station comprising a controller and a memory for storing a first path table for storing one or more paths for sending data packets, a second path table for storing one or more alternative paths for sending data packets and a controller, and wherein:
a packet is stored in the data transmision station or the originator station, and a packet is stored in the data transmition station or the target station. Each station comprises a controller and a memory for storing packets, either for a single or multiple alternative paths used for sending data packets, and a controller or a controller between a single signal transmitted by a network station, and a controller or a controller between a single signal transmitted by a network station.

The controller or a controller between a single signal transmitted by a network station is configured to send data packets to the target station. A method is configured to send data packets to the target station.

The controller or a controller between a single signal transmitted by a network station is configured to send data packets to the target station. A method is configured to send data packets to the target station.
a first path table for storing one or more paths for sending data packets and a second path table for storing one or more alternative paths for sending data packets and a controller; wherein the method comprises

    broadcasting by the originator station a first path request data packet for the target station;
    receiving a first path reply data packet comprising a first alternative path to the target station;
    storing the first alternative route in the second path table of the originator station;
    receiving at least one second path reply data packet comprising at least one second alternative path to the target station;
    retrieving a best path, based on one or more signal parameters pertaining to each path, to the target station from the second path table of the originator station;
    storing the best path to the target station in the first path table of the originator station;
    and
    using the best path for sending data packets to target station.

23. A computer program product comprising a computer readable medium, having thereon a computer program comprising program instructions, the computer program being loadable into a data-processing unit and adapted to cause the data-processing unit to execute the method according to claim 22 when the computer program is run by the data-processing unit.
FIG. 6

601 Receive PREP comprising path to target

602 Store PREP in second table

603 Time expired?

N

Y

604 Move best path from first table to second table

605 Use best path

FIG. 7a

701a Receive PANF

702a Unicast PANF to target

703a Move best path from second table to first table

704a Use best path

FIG. 7b

701b Receive PANR

702b Unicast PANR to originator

703b Move best path from second table to first table

704b Use best path

FIG. 7c

701c Receive PANF

702c Unicast PANF to target

703c Receive PANR

704c Move best path from second table to first table

705c Use best path
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/707   H04L12/755
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
H04L

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>A</td>
<td>wo 2013/000507 AI (ERICSSON TELEFON AB L M [SE]; KAMPMA N DI RK [NL]; WITZEL ANDREAS [DE]) 3 January 2013 (2013-01-03) figures 1, 5, 8 page 4, line 1 - line 16 page 6, line 4 - line 11 page 7, line 5 - line 19 page 11, line 18 - line 30 page 12, line 1 - line 10</td>
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 Further documents are listed in the continuation of Box C.  See patent family annex.

* Special categories of cited documents:

A: document defining the general state of the art which is not considered to be of particular relevance

E: earlier application or patent but published on or after the international filing date

L: document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O: document referring to an oral disclosure, use, exhibition or other means

P: document published prior to the international filing date but later than the priority date claimed

T: later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X: document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y: document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

A: document member of the same patent family

Date of the actual completion of the international search
17 October 2016

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040, Fax (+31-70) 340-3016

Date of mailing of the international search report
24/10/2016

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This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☑ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☑ The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-19, 22, 23
   Method for performing alternate routing by selecting a set of best alternative paths.
   
2. claims: 20, 21
   Method for updating the routing tables by receiving path requests, by responding with path replies, and by receiving path acknowledgements.
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<th>Patent document cited in search report</th>
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