

## A method for determining the optimal transmission path in a data network

The invention relates to a method for determining the optimal transmission path in a data network in which the network subscribers exchange data among each other in a wireless manner, preferably via radio, along a plurality of transmission paths, with each network subscriber being allocated a unique identifier such as a serial number for example and with each network subscriber having both sending as well as receiving functions, with a predetermined number of network subscribers having a memory for storing the identifiers of other network subscribers whose signals are to be forwarded, which network subscribers can thus be used as stations of transmission paths.

Radio data networks of the kind mentioned above can be for example: electric installations in buildings in which each consumer such as lamps, ventilation motors, shutter motors or the like are provided with a radio receiver and each control unit such as switches, pushbuttons, staircase lighting timers, etc. are provided with a radio transmitter. When a control unit is activated, it sends a command to the associated consumer which changes its state according to said command, meaning that said consumer is activated or deactivated, changes its luminosity, etc.

Furthermore, the sensors or actuators of a production plant in industry, an access control system or gaming machines of a casino, training apparatuses of a fitness studio or the like can be mutually connected in the form of a network based on data transmission by radio.

In contrast to a computer network where each computer is connected with the other by means of a token ring and therefore each computer can transmit data to every other computer, there are certain transmission paths in the mentioned radio networks: For example, the lamp in the living room is only activated by the two switches located in the living room. Consequently, said switches must transmit data only to the living room lamp, but not to any other network subscriber.

The allocation of the individual components with respect to each other, i.e. the determination which receiving module is permitted to further process the data of which transmitter and may initiate respective switching actions can be programmed fixedly into the components. A so-called "plug and play" system is obtained. There is no separate configuration or programming of

the network subscribers when the network is put into operation. This system could be used for example in the electrical installation for the building as discussed above.

It can also be provided to that the said allocation by the plant operator or the plant maker is kept programmable, for which purpose the receiving modules of the individual network subscribers are adjustable in such a way that they only forward specific signals of the received signals to downstream consumers such as the lamp.

If the two end points of such transmission paths are arranged from each other in small distances that can be bridged with the range of the employed radio signals, no further network components are required with the exception of the mentioned end points (switches and lamps). In the case of larger distances between the end points of the transmission path, it is necessary, according to the current state of the art, to either use respectively powerful transmitter modules or repeater stations between the end points.

A network subscriber is described in AT-B-408 048 which comprises a memory for storing at least the identifiers, and preferably further the received field strengths of the other network subscribers which are in the receiving range and have at least a transmission function, and for storing the identifiers of the other network subscribers whose signals are to be forwarded. Such a network subscriber can also be used simultaneously, in addition to its actual function as a lamp or switch in an electric installation, as a repeater station for routing radio data that do not relate to itself. This means for example for an electric installation as mentioned above which is based on radio data transmission: If both the switch for the lighting as well as the switch for the shutters of a room are arranged on the first wall of said room and the lighting in the middle and the shutter on the opposite wall of said room, the transmitter and receiver module of the lighting can be used for routing the data of the shutter switch to the shutter motor, for which otherwise a repeater would have to be used which is situated in the lighting for example because the range of the radio signals is only half of the room.

The possibility to store in the network subscriber which signals of other network subscribers are to be forwarded leads to the consequence that the network subscriber in accordance with the invention does not have to transmit all received signals, but limit itself to precisely the signals which need to be transmitted again so that they reach their recipient. The entire radio communication in the data network can thus be reduced to the extent that is mandatory for the

function. Separate repeaters to be added to the network subscribers which are present anyway can be omitted when using such a network subscriber.

AT-B-408 048 further describes a generic method for determining transmission paths in a radio data network which contains network subscribers as explained above. The method is executed in such a way that such network subscribers which have a transmitting function transmit a test signal containing their identification. This test signal is received by other network subscribers situated within range and they store the received identification together with the received field strength as measured by them. Based on this stored information (identifiers and received field strength of the other network subscribers situated within the range of each network subscriber) a transmission path is now determined for each transmission link which is optimal concerning the number of stations and the best possible connection of these stations among each other.

For making this determination, an additional configuration device is used according to the entire teachings of AT-B-408 048, which device is provided separately from the network subscribers (cf. fig. 4 of AT-B-408 048 in conjunction with page 4, lines 54, 55 and page 8, line 11 through page 9, line 20). Although it is explained that such a configuration device can be omitted, the determination of the optimal transmission paths must then still be performed by hand, i.e. by a respectively trained technician (cf. p. 8, lines 5 through 10).

Following the completed determination of the optimal transmission paths it is necessary to program every single network subscriber, i.e. it is necessary to store in some way within the same the transmissions of other network subscribers that it needs to transmit as a router. This second configuration step can also be conducted by the configuration device (cf. page 9, lines 2, 3). If there is no such device, the illustrated programming needs to be performed manually by a technician again.

The disadvantageous aspect with respect to the method described in AT-B-408 048 for determining the optimal transmission paths is the additional configuration device or the necessity to perform other steps (especially manually) which are made by said device (determination of the optimal transmission path for each transmission link and respective programming of all network subscribers), if there is no such device. Such a configuration device can only be operated by a person skilled in the art and the steps required for configuring the data network can only be performed by a person skilled in the art. Unskilled persons which usually include most DIY enthusiasts would require respective training. The entire radio data network can be used or

marketed only with much difficulty in the DIY area which is becoming increasingly more important. The present invention tries to remedy this deficiency:

It is the object of the present invention to provide a method of the kind mentioned above for determining transmission paths in a data network which can be performed fully automatically by the network subscribers.

This is achieved in such a way in accordance with the invention that a first subscriber of the transmission link for which an optimal transmission path is to be determined sends a search report which contains at least its own identification as transmitter ID, that network subscribers which can be used as stations for transmission paths and which receive this search report measure the received field strength, add their own identifiers to the search report as well as the measured received field strength and send the search report again, that every network subscriber which is the second subscriber of the transmission link measures the received field strength of the search report, determines from all received search reports those which with respect to the number of stations and the quality of the links of said stations among each other contains the optimal transmission path and, if the search report does not contain any receiver ID, adds its own identifier as receiver identification, that said second subscriber of the transmission link sends said determined search report, that every network subscriber which receives this search report and whose identification is contained in said search report stores on the one hand the identification entered prior to its own identification in the search report as the identification of such a network subscriber whose signals are to be forwarded and sends the search report again on the other hand.

For the purpose of performing this method it is neither necessary to use an additional configuration or programming device or a person skilled in the art who will manually perform the configuration steps taken by such a device. The data network can therefore be put into operation without any difficulties even by laypersons. The proper operation is maintained fully automatically even in the case of failure of individual network subscribers. The data network thus comes with a high amount of functional reliability and user-friendliness.

It can be provided for in a further development of the invention that network subscribers which can be used as stations of transmission paths will store the received search report and in the case of receipt of a further search report coming from the same first subscriber will compare said new search report with the stored search report and that only when said new search report contains a

transmission path which is better than the stored search report with respect to the number of stations and the quality of the connections of said stations among each other, it will add its own identification to the new search report and add the measured received field strength, transmit said new search report again and store the same.

In this way it is possible to effectively reduce the number of search reports transmitted in the entire data network without impairing the sequence of the method in accordance with the invention and the quality of the thus obtained results.

The invention is now explained in closer detail below by reference to the enclosed drawings, wherein:

Fig. 1 shows a schematic representation of a wireless data network with own transmission links; Fig. 2 shows the data network according to fig. 1, with four transmission links already being assigned specific transmission paths; Fig. 3 shows the data network according to figs. 1 and 2, with concrete transmission paths being assigned to four other transmission links.

Within the scope of the present description and the enclosed patent claims, the term "transmission link" shall be understood as a connection for data transmission from a first network subscriber to a second network subscriber.

The term "transmission path" shall mean the sum total of all such network subscribers via which the transmission link is routed.

Fig. 1 schematically shows the subscribers of a data network in which the network subscribers 1 to 14 exchange data in a wireless manner with each other. The present invention is independent of any specific type of wireless data transmission. Although the data are exchanged by radio, it is still possible to use other ranges of the frequency spectrum for this purpose, e.g. ultrasonic sound or infrared. The latter is obviously only possible when there is a permanent visual connection between the individual network subscribers 1 to 14.

There are several transmission links in said data network (cf. the broken lines): data shall be transmitted from subscriber 1 to subscriber 2; subscriber 3 shall be in connection both with

subscriber 4 as well as with subscriber 5 and also the subscribers 4 and 5 shall exchange data with each other. The five subscribers 1 to 5 need not be in connection with the other subscribers.

In addition there are the subscribers 6 and 7 (among others) which can exchange data with the subscribers 8 and 9. Subscribers 6, 7 and 8, 9 are spaced from each other to such an extent (or obstructions such as walls, furniture or the like are situated between them) that a direct wireless connection is not possible between them.

If the illustrated data network is an electric installation in a building as already mentioned above (to which the invention is not limited in any way), subscriber 1 could be switch and subscriber 2 the associated lamp; subscriber 6 could be a timer built into the switch cabinet and the subscriber 8, 9 a radiator and a shutter motor.

It is provided that each network subscriber 1 to 14 of the discussed data network has transmitting and receiving capabilities. A predetermined number of network subscribers 1 to 14 further comprises a memory for storing the identifications of such other network subscribers whose signals are to be routed.

For such network subscribers 1 to 14 there is the possibility that they will not only send the data produced by them or receive the data determined for them, but that they will route received data not relating to them after having optionally amplified them. Such network subscribers 1 to 14 can therefore form stations in a transmission path. They can be used as "routers" as is known in the IT industry.

Once a transmission link is established, i.e. once a network subscriber knows with which other network subscribers it must exchange data, it needs to be decided whether said transmission link can be direct (i.e. it can consist only of the subscribers per se to be linked) or whether (due to the limited range of the signals transmitted in a wireless manner) a transmission path comprising an intermediate station ("router") needs to be established.

In the example of figs. 2 and 3, the subscribers 1 and 2 or 3, 4 and 5 can communicate directly with each other, but the transmission links between the subscribers 6, 7 and 8, 9 each need to be formed by transmission paths comprising routers. A first transmission path shown with an unbroken line contains the network subscribers 10, 11 and 12; a second transmission path which is also possible is formed by network subscribers 10, 13 and 12.

The invention relates to a method for determining such a transmission path in an illustrated data network. The network is established in the desirable manner, i.e. the individual network subscribers 1 to 14 are mounted at the intended locations.

In the known manner, each network subscriber 1 to 14 is assigned a unique identification such as a serial number for example, which is performed by storing said identification in the electronic system of the respective subscriber. This can appropriately already be performed before the establishment of the network, e.g. already by the manufacturer of the network subscribers 1 to 14.

A transmission link (i.e. the assignment of two network subscribers 1 to 14 to each other) is stored at least in the subscriber which works as the command receiver in this transmission link, such that said subscriber stores the identification of the other subscriber assigned to it and operating as command transmitter. A command receiver can be a lamp for example and the command transmitter can be a light switch assigned to the same. In this constellation it is only important for the lamp to know the switching commands of which switch it needs to perform. The switch on the other hand does not have to know which other subscribers perform the switching commands as transmitted by the same. It is still possible however to store in the subscriber working as command transmitter the identification of the subscriber associated to the same and operating as command receiver.

The explanation of the method in accordance with the invention occurs at first on the basis of such a transmission link, in which the subscriber working as the command receiver already "knows" the associated other subscriber operating as command transmitter, in which the identification of the command transmitter is already stored in the manner as explained above.

A first subscriber of the transmission link for which an optimal transmission path is to be determined (e.g. the switch of the example above) sends a search report, which shall be understood as a message which can contain the identifications of network subscribers and received field strengths. When the search report is sent by the first subscriber of the transmission path, it receives at first at least its own identification as the sender ID. In the case that the identification of the second subscriber of this transmission link is also stored in the first subscriber, this identification of the second subscriber (i.e. the identification of the lighting fixture of the above example) can be contained in the search report as receiver identification.

The search report is received by all other network subscribers 1 to 14 which are within the range of the first subscriber. Those network subscribers which can be used as stations of transmission paths measure the received field strength of the incoming search report and add their own identification to this report as well as the measured received field strength. A modified search report is thus produced which is transmitted again. This modified search report is now received by further network subscribers 1 to 14 which also proceed in the explained manner, i.e. they will modify the search report and send it again (if they can be used as stations of transmission paths).

The search report is thus disseminated within the entire data network and also reaches the second subscriber of the transmission path.

A very large number of search reports are thus dispatched within the data network. This flood of data can be reduced in accordance with a preferred embodiment of the invention in such a way that not every received search report is retransmitted again:

The network subscribers which can be used as stations of transmission paths additionally store a search report that they have already retransmitted. When they receive a new search report originating from the same first subscriber like the earlier search report as contained in the memory, they will compare said new search report with the old saved one. Only if said new search report contains a transmission path which is better with respect to the number of stations and the quality of the links of these stations among each other than those contained in the memory will the new search report be processed in the manner explained above (meaning that the own identification of the network subscriber and the measured received field strength are added and the report is retransmitted).

Usually, there are several transmission paths (formed by different network subscribers 1 to 14) between the two subscribers of a transmission link (cf. fig. 3), so that the second subscriber will also receive several search reports containing different identifications and received field strengths.

Said second subscriber measures the received field strength of the search report, adds it to the same and determines from all received search reports in the next step of the method in accordance with the invention such reports which contain the transmission path which is optimal with respect to the number of stations and the quality of the links between said stations.

A transmission path shall be regarded as optimal when it comprises as few transmission stations as possible, i.e. other subscribers which are necessary in addition to the network subscribers 1 to 14 to be linked, but with the employed stations at the same time offering the best possible connection, i.e. the highest possible received field strength.

The two criteria "few stations" and "best possible connection" are brought into an optimal relationship with each other. This means that for example an only slightly increase of the number of stations in which there is a clearly higher received field strength between the stations is preferable to the lower number of stations. Conversely, an only slight reduction in the received field strength between the individual stations is acceptable when thus a clear reduction in the number of stations can be achieved.

The network subscribers 1 to 14 participating in the optimal transmission path must now be notified about this participation, for which purpose the second subscriber retransmits the determined search report containing the optimal transmission path.

It is received by all network subscribers 1 to 14 situated within range. Each of these network subscribers 1 to 14 whose identifier is contained in this search report processes the search report as follows:

It determines at first the signal of which other network subscribers 1 to 14 it needs to retransmit as router based on the list of identifications contained in the search report. The list contains the identifications in the sequence in which the search report has run from the first to the second subscriber, as a result of which the identification of the subscriber whose signals are to be forwarded is located before the own identification. The identification is stored in a memory area provided for this purpose.

The search report is sent again (but unmodified in this case), as a result of which it reaches further network subscribers 1 to 14 which have not received it yet. Said further network subscribers 1 to 14 also proceed in the discussed manner and thus recognize automatically whether they are required for the current transmission link as a router and, if yes, will adjust accordingly in an automatic manner.

The search report thus returns back precisely once to the first subscriber of the transmission link (the report is only guided over the transmission path which is determined as optimal). The receipt of the search report is regarded as the completion of the transmission path determination.

The procedural sequence as discussed up this point assumes that the second subscriber of the transmission link (e.g. the lighting fixture) which works as the command receiver has knowledge of the first subscriber (e.g. the switch) which works as the command sender. It is used especially in readily configured data networks which are in normal operation and is started when a subscriber sending a command recognizes (following a missing return confirmation) that its command did not arrive. If after a repetition of the command transmission there is no return confirmation of the second subscriber, it can be assumed that a network subscriber 1 to 14 which is situated in the currently used transmission path no longer works correctly and another transmission path needs to be found. The first subscriber thus initiates the procedural sequence as discussed above.

In practice, the method in accordance with the invention is used less for eliminating such malfunctions but instead for the addition of a new transmission link, i.e. when a new command transmitter (e.g. a new switch) and a new command receiver (e.g. a new lamp) need to be incorporated in the data network. The usual case is a complete new installation in which transmission paths need to be determined for all transmission links. If a first subscriber which operates as a command transmitter is actuated for the first time (by pressing the rocker in the case of a switch), it sends a switching command at first. Since for the time being there is no command receiver which is associated with this command transmitter, no return confirmation is received. As already explained above, this causes the command transmitter (after an unsuccessful repetition of the command transmission) to initiate the method in accordance with the invention.

The allocation of the second subscriber to a first, newly installed subscriber now occurs in such a manner that said second subscriber (in the simplest case by pressing a respective pushbutton) is placed in a learning mode. In said learning mode, the subscriber seeks those among all received search reports which do not yet contain a receiver identification. If it finds such a search report, it enters its own identification as the receiver identification and sends the search report again. The remaining procedure of the process does not differ from the one explained above: The search report sent by the first subscriber is disseminated similarly in the entire data network until it is received by a second subscriber in the learning mode and is modified by the same in the discussed manner and is sent back.

It is naturally also possible to place several subscribers in the learning mode (e.g. when several lamps should be switched simultaneously by one and the same switch). An optimal transmission path is found for each of these several subscribers.

Once the search report returns to the first subscriber then this is regarded as the completion of the transmission path determination. It can be provided that the first subscriber reads out the receiver identification as contained in the search report and stores the same.

For performing the method in accordance with the invention it is not necessary that without exception all network subscribers 1 to 14 can be used as stations for data transmission paths, i.e. with memory for storing the identifications of such other network subscribers 1 to 14 whose signals are to be retransmitted. Especially such network subscribers 1 to 14 which are situated in border zones of the installation (e.g. attic lamps or switches for the cellar light in the case of building installations) are not favorably suitable as a result of their geographic position to forward signals of other network subscribers which are closer to the center of the network. They therefore do not need any router properties and do not take part in the method in accordance with the invention.

After the completion of the method in accordance with the invention, a transmission path for the respective transmission link has been determined and the same can switch to normal operations. In this configuration the subscribers of the transmission link send the respective other subscribers data packets in which their two identifications are contained. Based on these identifications, all other network subscribers can recognize the transmission link to which this data packet belongs and can check on the basis of the storage content whether they need to act as a router for this data packet and treat the data packet accordingly, i.e. either to forward it or reject it.

Claims:

1. A method for determining an optimal transmission path in a data network in which the network subscribers (1-14) exchange data among each other in a wireless manner, preferably via radio, along a plurality of transmission paths, with each network subscriber (1-14) being allocated a unique identifier such as a serial number for example and with each network subscriber (1-14) having both sending as well as receiving functions, with a predetermined number of network subscribers (1-14) having a memory for storing the identifiers of other network subscribers whose signals are to be forwarded, which network subscribers can thus be used as stations of transmission paths, **characterized in that** a first subscriber of the transmission link for which an optimal transmission path is to be determined sends a search report which contains at least its own identification as transmitter ID, that network subscribers (1-14) which can be used as stations for transmission paths and which receive this search report measure the received field strength, add their own identifiers to the search report as well as the measured received field strength and send the search report again, that every network subscriber (1-14) which is the second subscriber of the transmission link measures the received field strength of the search report and adds the same to the search report, determines from all received search reports those which with respect to the number of stations and the quality of the links of said stations among each other contains the optimal transmission path and, if the search report does not yet contain any receiver ID, adds its own identifier as receiver identification, that said second subscriber of the transmission link sends said determined search report, that every network subscriber (1-14) which receives this search report and whose identification is contained in said search report stores on the one hand the identification entered prior to its own identification in the search report as the identification of such a network subscriber whose signals are to be forwarded and sends the search report again on the other hand.
2. A method as claimed in claim 1, characterized in that network subscribers (1-14) which can be used as stations of transmission paths will store the received search report and in the case of receipt of a further search report coming from the same first subscriber will compare said new search report with the stored search report and that only when said new

search report contains a transmission path which is better than the stored search report with respect to the number of stations and the quality of the connections of said stations among each other, it will add its own identification to the new search report and add the measured received field strength, transmit said new search report again and store the same.