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(73) Octrooihouder(s):
Tvilight B.V. te Groningen.

(72) Uitvinder(s):
Henri Eskonen te Groningen.
Chintan Shah te Groningen.
Ralph Hogenbirk te Groningen.

(74) Gemachtigde:
ir. P.J. Hylarides c.s. te Den Haag.

(54) **Lighting control system for routing of messages between a number of lighting nodes forming a wireless multi-node network and method therefor.**

(57) The invention relates to a lighting control system for routing of messages between a number of lighting nodes forming a wireless multi-node network and metbod therefor. The lighting control system comprising a number of lighting nodes forming a wireless multi-node network, each lighting node comprising a light source; a controller connected to the light source; and a wireless communication means connected to the controller for communication with other lighting nodes in the network, wherein the system is arranged to configure the logical topology of the network for routing of messages between the lighting nodes on the basis of information about the geographical positions of the lighting nodes.

Lighting control system for routing of messages between a number of lighting nodes forming a wireless multi-node network and method therefor

The invention relates to lighting control systems. Such systems include a number of light sources and at least one controller connected to the light sources for controlling them, e.g. dimming them, switching them on or off and/or changing their color. Lighting control systems are typically used in outdoor lighting, wherein a number of light posts illuminate a road, a walkway or a square for example. Outdoor lighting improves visibility and increases safety.

However, continuously illuminating the street of an area, such as a city or a municipality, requires a large amount of energy. Furthermore, street lighting contributes to a phenomenon called 'light pollution', which relates to artificial light causing a disturbing factor in the environment for humans and animals, e.g. causing sleep deprivation or animal migration. Light pollution may further lead to an artificial 'sky glow', i.e. artificial illumination of the night sky.

Intelligent lighting systems overcome such problems. Typically, such systems comprise a motion detector to detect a vehicle or pedestrian, where the intensity of the individual lights in the system are controlled on the basis of this detection. For example, lights in the system are normally dimmed to a low light level, wherein the light level is increased locally upon detection of a vehicle or pedestrian.

Often, coordination between the lights is desired to control the pattern in which the lights dim, glow and/or switch on or off. For example, it may be desired that the lights cooperate to create an envelope of light around a moving vehicle or pedestrian. In such a system communication connections between the individual lights are required. In many cases, this is achieved by means of wireless communication, wherein the lights form a wireless multi-node network. A light equipped with a communication means in such a system is referred to as a lighting node.

Such an intelligent lighting system is for example described in PCT/NL2014/050094 "Lighting control system and method for association of nodes in a multi-node network", filed February 14, 2014 and the corresponding Dutch patent application NL 2010324, filed February 18, 2013 of the same applicant as the current invention. The entire content of these patent applications is hereby incorporated by reference.

The invention addresses a problem in the communication between lighting nodes within conventional lighting systems employing a wireless network. The number of messages sent between the nodes can become large, especially as the number of lighting nodes in the network increases. This can lead to an overload of the wireless network, leading to a delay in message delivery or even a loss of messages. Moreover, the frequency band used for the wireless communication between nodes, e.g. the 2.4 Ghz band, may also be used by other wireless

technologies such as WiFi or Bluetooth, as for example used by smartphones. As the frequency band gets crowded, the communication connection between lighting nodes may become unreliable.

A communication delay in the lighting network may result in a noticeable delay in the adjustment of the light levels of the lighting nodes. For example, such a communication delay may result in an unsafe situation wherein the light level of some of the lights in the system is not applied in the required time span, e.g. only after a vehicle or a pedestrian passes the lights. In a worst case scenario, wirelessly transmitted messages may be lost all together and some lights in the system may not adjust their light level at all when they are required to.

An objective of the invention is to minimize or at least reduce the network traffic in the wireless multi-node network of lighting nodes and to minimize or at least reduce the delay in communication between nodes.

The objectives are achieved with the lighting control system according to the invention, the system comprising a number of lighting nodes forming a wireless multi-node network, wherein each lighting node comprises:

- a light source;
- a controller connected to the light source; and
- a wireless communication means connected to the controller for communication with other lighting nodes in the network, characterized in that the system is arranged to configure the logical topology of the network for routing of messages between the lighting nodes on the basis of information about the geographical positions of the lighting nodes.

Possible light sources include any dimmable lamp, such as sodium-vapor lamps, incandescent light bulbs, halogen lamps and LEDs. The invention will be explained mainly in reference to a street lighting application. Other application areas may include lighting in a parking lot, parking garage or indoors, such as in warehouses, production facilities, airports or hotels.

The inventors found that the problems described above are at least partially caused by a sub-optimal logical topology of the network of wireless nodes. This is illustrated in Figure 1A, which shows a network of lighting nodes according to the prior art. In the system according to Figure 1A, lighting nodes a-w are arranged alongside a number of intersecting roads 2. The nodes a-w communicate to each other via a wireless network protocol, for example Zigbee. In the illustrated example each node can act as a routing node for routing messages to other nodes according to a parent-child hierarchy. In the illustrated example each node tries to set up a connection to one parent node and each node may have up to five child nodes. In figure 1A the arrow of each communication connection between nodes points toward the parent node. However, it is noted that messages may be exchanged in both directions: from child to parent and from parent to child.

The formation of the network of the wireless nodes is decentralized. Moreover, the topology of the network is unpredictable. On startup, each node tries to connect to other nodes in the network using a "first come first serve" strategy. As can be seen from Figure 1A, the network is formed with node w being the parent of nodes k, n, t, u, v; node k being the parent of nodes a, h, i, j, l; node n being the parent of nodes g, m and possibly up to three additional nodes, and node g is the parent of nodes b, c, d, e, and f. The hierarchy between nodes has been further illustrated in the tree diagram of Figure 1B.

Each node in the network communicates with the other nodes by sending messages via its parent node. For example, if node u is to communicate with node v, it sends a message to node w, which forwards the message to node v. In the shown example, if node a is to communicate with node b, which is neighboring node a along the road 2, the message is routed from node a to its parent node k, subsequently to k's parent node w, then to w's child node n, then to n's child node g, and finally to node b. In this example, the message from a to b is therefore routed using five hops.

According to the invention, the logical topology of the network is configured taking into account the geographical lay-out of the system. Instead of an ad-hoc network formation, the invention uses information about the positions of the lighting nodes to form the communication connections for routing messages between the nodes. This significantly reduces the number of hops required for communication between the nodes as opposed to conventional wireless implementations.

The information about the geographical positions of the lighting nodes may for example comprise the geographical coordinates of the nodes, e.g. their GPS position. For example, the geographical coordinates include latitude and longitude. Optionally, the coordinates include elevation.

The system may comprise a central server in communication with the lighting nodes that stores the information about the geographical position of the lighting nodes. For example, the nodes comprise a GPS device and communicate their respective location to the central server. Preferably however, the nodes do not comprise a GPS device and the geographical position of the lighting nodes is provided on the server by other means. For example, upon installation of a lighting node the GPS position of the node is determined, for example using an external GPS device such as a smartphone or laptop, after which the GPS position is input to the server. Preferably, the information about the geographical positions of the lighting nodes on the server is editable. This enables fast and easy correction of the location of the nodes in the system, e.g. when the position of the lighting nodes is changed or when an error has been made in programming the node location. The server may also comprise a visualization component for displaying the positions of the lighting nodes on a map, by using digital mapping tools such as Google maps ™ or Bing

maps ™. Reference is made to PCT/NL2014/050094 and NL 2010324 (incorporated by reference) wherein such a server and database are described in more detail.

The system may configure the logical topology of the network automatically and/or dynamically according to the information about the geographical position of the lighting nodes. For example, if a node fails and drops out of the network, the system may reconfigure the logical topology of the network dynamically on the basis of the information about the geographical position of the lighting nodes.

It is noted that in conventional intelligent lighting systems, the geographical positions of the lighting nodes also play a role in the formation of the wireless network, as the nodes can only connect to other nodes with a certain communication range. In a sense, the logical topology of such a conventional network is thereby influenced by the geographical positions of the nodes. However, such conventional networks are not organized on the basis of information, i.e. data, on the geographical position of the lighting nodes. In contrast, in the invention the information about the geographical position is provided as input data to the system, and the system configures the network on the basis of said position data.

In the context of the application, a direct or first order neighbor of a first node is a second node which is directly next to the first node on a respective path or within a respective area. The second order neighbor of a first node is a second node which is separated from the first node by exactly one other node. Generally, an n-th order neighbor of a first node is a second node which is separated from the first node by exactly (n-1) other nodes. For example, for nodes a, b, c, d and e arranged in that order along a common path (see e.g. figure 1a), node c has first order neighbors b and d and second order neighbors a and e, and node e has first order neighbor d, second order neighbor c, third order neighbor b and fourth order neighbor a.

In a preferred embodiment, the system is further arranged to select for each first lighting node at least one second lighting node to which the wireless communication means of said first lighting node is to establish a routing connection, wherein the system is arranged to select said second lighting node on the basis of information about the geographical position of said first lighting node and the geographical position of said second lighting node.

For example, the system may comprise a coordinator node or server to coordinate the formation of the network. The coordinator node or server determines for each first node the one or more second nodes to which it is to establish a routing connection. The coordinator node or server communicates this information to the respective node. In an alternative example, each node itself determines the one or more other nodes to which it is to establish the routing connection on the basis of information about the geographical position of other lighting nodes. Said information may be communicated between the nodes.

In a further preferred embodiment, the system is arranged to configure the logical topology of the network for routing of messages between the lighting node on the basis of information about the infrastructural lay-out of the area wherein the lighting nodes are positioned, and the geographical positions of the lighting nodes in said area.

In other words, the system configures the logical topology of the network on the basis of the physical lay-out of the lighting nodes with respect to its infrastructural context, such as roads, intersections, roundabouts or squares.

For example, a number of lighting nodes may be arranged alongside a road. When a car drives along the road, the intelligent lighting system has to adjust the lighting level of the lighting nodes along the road consecutively. Therefore, the system configures the logical topology of the network such that two consecutive nodes can communicate via at most three hops, preferably via at most two hops and most preferably the two consecutive nodes establish a direct communication connection between each other, i.e. in one hop.

In a preferred embodiment, the system is arranged to select said second lighting node on the basis of information about the infrastructural lay-out of the area wherein the lighting nodes are positioned and the geographical positions of the lighting nodes in said area.

In a further preferred embodiment, the lighting control system comprises:

- a memory component adapted to store information relating to the geographical position of paths, intersections and/or areas of said infrastructural lay-out; and
- a processing component in communication with the lighting nodes and adapted to automatically associate each node to one of the stored paths, intersections and/or areas, and further being adapted to select for each first lighting node at least one second lighting node associated to the same one of said paths, intersections and/or areas.

The memory component stores information relating to groups of interrelated geographical coordinates. These groups may correspond to paths, intersections and/or areas of said infrastructural lay-out, such as roads, intersections, roundabouts and/or squares. The processing component associates each lighting node to one or more of said groups of interrelated coordinates. This classification of the lighting nodes into groups of nodes associated to a certain path, intersection and/or area, enables selecting for each first lighting node at least one second lighting node to which the wireless communication means of said first lighting node is to establish a routing connection.

For example, the system creates path-wise or area-wise associations between the nodes on the basis of their positions and the information about the infrastructural lay-out. Creating such associations is described in detail in PCT/NL2014/050094 and NL 2010324, which are hereby incorporated by reference. For example, the nodes within a predetermined distance from a path or intersection are associated to said path or intersection. Subsequently, the system selects for a first

node a second node which is associated to the same path, area and/or intersection. For example, the nearest neighbors along a path are selected as second nodes. In another example, all nodes associated with an intersection establish communication connections between each other.

It is noted that in this embodiment, two lighting nodes within each other's communication range will only establish a communication connection between each other if they belong to the same group, e.g. they share a path or belong to the same geographical area or network group.

In a further preferred embodiment, the system comprises a visualization component connected to the processing component and adapted to show the locations of the lighting nodes and the paths, intersections and/or areas on a map on an electronic display.

In a preferred embodiment, the system comprises a configuration component adapted to edit the associations between the lighting nodes and paths, intersections and/or areas on the basis of user input.

In a preferred embodiment, the logical topology configured by the system is a mesh topology, star topology or a tree topology. In an example, the logical topology is a tree topology, wherein each node can have a parent or child relation to other nodes. In one example, each node has a single parent, wherein the node at the top of the tree may have no parent. For example, each node has up to five child nodes. Moreover, each node may have one or more back-up parent nodes in case the connection to the initial parent node fails.

In a preferred embodiment, each lighting node comprises a switching component arranged for switching between a unicast mode, wherein the wireless communication means of said lighting node is arranged for sending a message to another node in the network via at least one routing connection by using a unique address of said other node, and a broadcast mode wherein the wireless communication means of said lighting node is arranged for sending a message to multiple other nodes in the network within wireless range.

In other words, each lighting node can communicate to other nodes in the network in the unicast mode and/or the broadcast mode. The broadcast mode can be used to communicate with other nodes in a network within wireless range. Instead of sending messages via multiple hops to the destination nodes, a single message is sent. This reduces the number of messages sent within the network. When a node outside the wireless range needs to receive the message, the unicast mode is used, wherein the message travels via other nodes to the destination node, as described above. The message may include an address to identify the destination node.

In a further preferred embodiment, each lighting node comprises a memory component, arranged to store a list of at least two other nodes in the network, indicating whether to send messages to the respective node in the unicast mode or in the broadcast mode.

In a preferred embodiment, each lighting node is arranged such that for sending a message from said lighting node to multiple other lighting nodes, the broadcast node is used for sending

said message to the subset of other lighting nodes which are within a predetermined range and the unicast mode is used for routing said message to the subset of other lighting nodes which are outside the predetermined range.

In a further preferred embodiment, the predetermined range is equal to or smaller than the wireless range of the wireless communication means of the respective lighting node.

The practical range of a wireless device may vary, for example due to changing weather conditions or the presence of reflecting or absorbing objects such as buildings or vehicles. The practical range of a wireless device may therefore be lower than the specified wireless range. Therefore, some of the nodes may be within range of each other at a first time, wherein at a later time they are outside each other's range. According to the invention, it is possible to adjust the selection of the unicast mode and broadcast mode by taking into account this fluctuation in range. Preferably, a fixed predetermined range is defined, e.g. corresponding to a worst case scenario for the range. This ensures that the nodes within the predetermined range can always be reached in the broadcast mode.

The invention further relates to a method for routing messages between lighting nodes, forming a wireless multi-node network, wherein each lighting node comprises a light source, a controller connected to the light source, and a wireless communication means connected to the controller for communicating with other lighting nodes in a network, the method comprising the step of configuring the logical topology of the network for routing messages between the lighting nodes on the basis of information about the geographical position of the lighting nodes.

The same advantages and effects as described above with respect to the lighting control system according to the invention apply to the method according to the invention.

In a preferred embodiment of the method, the step of configuring the logical topology of the network for routing messages between the lighting nodes comprises configuring the logical topology of the network on the basis of information about the geographical position of the lighting nodes and information about the infrastructural lay-out of the area wherein the lighting nodes are positioned.

In a further preferred embodiment, the method comprises the following steps for sending a message from a first lighting node to multiple other lighting nodes:

- using a broadcasting mode for sending the message to the subset of other lighting nodes which are within a predetermined range; and
- using a unicast mode for routing the message to the subset of other lighting nodes which are outside said predetermined range.

Preferably, the predetermined range is equal or smaller than the wireless range of the communication means of said first lighting nodes.

The invention further relates to a lighting control system comprising a number of lighting nodes forming a wireless multi-node network, each lighting node comprising:

- a light source;
- a controller connected to the light source; and
- a wireless communication means connected to the controller for communication with other lighting nodes in the network,

characterized in that each lighting node comprises a switching component arranged for switching between an unicast mode, wherein the wireless communication means of said lighting node is arranged for sending a message to another node in the network via at least one routing connection by using an unique address of said other node, and a broadcast mode, wherein the wireless communication means of said lighting node is arranged for sending a message to multiple other nodes in the network within wireless range.

In other words, the invention also relates to a system which does not configure the topology according to position information, but does use the switching between unicast and broadcast as described above.

Further details, advantages and effects will be explained with reference to preferred embodiments of the invention, wherein reference is made to the following figures.

- Figure 1A shows schematically a lighting control system according to the prior art, wherein the communication connections between the wireless nodes have been indicated;

- Figure 1B shows a tree diagram of the network of Figure 1A;

- Figure 2A shows an example of a lighting control system according the invention, wherein the communication connections between the lighting nodes are indicated;

- Figure 2B shows a tree diagram of the network of Figure 2A;

- Figure 3A shows an alternative embodiment of a network topology for a lighting control system according to the invention;

- Figure 3B shows a tree diagram of the network of Figure 3A;

- Figure 4 illustrates the use of a broadcast mode for node k of the network of Figure 3A and 3B;

- Figure 5A illustrates an alternative embodiment of a network topology for a lighting control system according to the invention using a hybrid star topology; and

- Figure 5B shows a diagram of the network of figure 5A.

The problems relating to the lighting control systems according to the prior art as depicted in Figures 1A and 1B have been described in the introductionary portion of this disclosure. An example of the solution provided by the invention is shown in Figure 2A and 2B.

Figures 2A-2B show a network topology wherein each node has at most one parent and at most two children. As can be most clearly seen from Figure 2B, node w represents the top node of

the tree. Node w has two children, namely node u and node v. Node u has children node s and node t; node s has children node q and node r; node q has children node o and node p; node o has children node k and node l; node k has children node i and node j; node j has children node g and node h; node g has children node c and node d; node c has children node a and node b; node d has children node e and node f; node l has children node m and node n.

As can been seen from the figures, the organization of the network substantially corresponds to the lay-out of the infrastructure which the nodes are supposed to illuminate. For example, during a start-up phase a central server (not shown) associates the nodes to a group of interrelated coordinates, such as paths, intersections and/or areas. For example, nodes a and b are associated with the road along which they are positioned, whereas nodes h and k are associated with the nearby intersection. Each node may be associated with more than one group of interrelated coordinates. For example, a node is related to a group of interrelated coordinates, if it is within a predetermined distance from said road, intersection or area. Further reference is made to PCT/NL2014/050094 and NL 2010324 (incorporated by reference).

Subsequently, the processor or server determines for each node the neighboring nodes along a path. For example, for node b it is determined that node a and node c are direct neighbors to node b while node d and node g are second order neighbors to node b. In the example of figure 2B, the server assigns for each node a parent node which is a direct neighbor, i.e. a first order neighbor, or a second order neighbor. This results in the logical topology as shown in figure 2A and 2B. As can be seen, the logical topology substantially follows the shape of the infrastructure, such that each node can communicate with its neighbors within at most two hops. For example, node a can communicate with its neighbor node b in two hops and node b can communication with node c in one hop, i.e. directly.

It is noted that Figures 2A-2B show an example of a tree topology. However, the structure may also comprise nodes having more than one parent node as in a mesh or star topology. In another example, the logical topology of the network is a tree topology, however, each node is assigned a back-up parent, in case the communication connection to its initial parent fails. In yet another example, the topology is a hybrid topology, combining a ring, bus, star, mesh and/or tree topology.

In another example (Figure 3A and 3B), the configuration of the network is optimized for connecting each node to its closest neighbors along a path. As can be seen from the figure, node a requires only one hop to communicate with its direct neighbor b and two hops for communicating with its second order neighbor node c. In this example, each node has at most one parent. At the intersection, node k has four child nodes, such that it is connected to its direct neighbors along the two roads which intersect near node k. Also in this example each node may define a back-up parent node in case communication to the initial parent node fails.

Each lighting node may switch between two communication modes: a unicast mode and a broadcast mode. In the unicast mode, the lighting node communicates with other nodes within the network by routing messages over the network according to the configured logical topology, such as illustrated in figures 2A and 3A. In the broadcast mode, a single message is broadcasted for receipt by multiple other nodes in a network.

This is further illustrated in Figure 4. In the unicast mode, the system of Figure 4 has the same logical topology as the example of Figure 3A. For example, if node k is to communicate with node r, the message is sent via four hops via node o, node p and node q to node r. In a broadcast mode however, a single message is sent by node k, for receipt by a number of other nodes within a predetermined range R1 (dashed circle). In this case, the nodes j, o, p, l, m, g, h are within this range R1.For example, node k needs to send the message "increase light level to 90%" to node g, h, o and p. As these nodes are within range R1, node k sends a single message in the broadcast mode, which is received by all four nodes. For example, node k includes in the message a unique identifier for identifying node k and the receiving nodes have been programmed to listen to messages broadcast by node k, as they belong to the same group of interrelated coordinates. In another example, node k includes in the message the unique identifiers of the receiving nodes, in this case node g, h, o and p.

Range R1 has a predetermined size which is in the example shown smaller than the maximum wireless range of node k, indicated with R2 (solid circle). The practical range of node k is dependent on environmental variables, such as weather conditions and wireless influences in the same frequency band. The predetermined range R1 is chosen equal to R2 or preferably smaller than R2 to ensure that the message sent by node k in the broadcast mode will be received by all targeted nodes.

The network according to figure 5A has a hybrid star topology. In a star topology, a central node is defined to which all other nodes in the network are directly connected. A hybrid star topology comprises a number of interconnected central nodes. It is noted that this may also be viewed as a tree topology.

In figure 5A, the nodes c, k, o, s and t act as interconnected central nodes. Node c is connected to nodes a, b, d, e, f and k. Node k is connected to nodes c, g, h, l, m, n and o. Node o is connected to nodes i, j, k and s. Node s is connected to nodes o, p, q, r and t. Node t is connected to nodes s, u, v and w. This has been schematically illustrated in figure 5B. Although figure 5B suggests a hierarchy between nodes c, k, o, s and t, this may not be the case.

The present invention is by no means limited to the above described preferred embodiments thereof. The rights sought are defined by the following claims, within the scope of which many modifications can be envisaged.

CLAUSES

1. Lighting control system comprising a number of lighting nodes forming a wireless multi-node network, each lighting node comprising:

- a light source;
- a controller connected to the light source; and
- a wireless communication means connected to the controller for communication with other lighting nodes in the network,

characterized in that

the system is arranged to configure the logical topology of the network for routing of messages between the lighting nodes on the basis of information about the geographical positions of the lighting nodes.

2. Lighting control system according to clause 1, further arranged to select for each first lighting node at least one second lighting node to which the wireless communication means of said first lighting node is to establish a routing connection, wherein the system is arranged to select said second lighting node on the basis of information about the geographical position of said first lighting node and the geographical position of said second lighting node.

3. Lighting control system according to clause 1 or 2, wherein the system is arranged to configure the logical topology of the network for routing of messages between the lighting nodes on the basis of information about the infrastructural layout of the area wherein the lighting nodes are positioned and the geographical positions of the lighting nodes in said area.

4. Lighting control system according to clauses 2 and 3, wherein the system is arranged to select said second lighting node on the basis of information about the infrastructural layout of the area wherein the lighting nodes are positioned and the geographical positions of the lighting nodes in said area.

5. Lighting control system according to clause 4, further comprising:

- a memory component adapted to store information relating to the geographical position of paths, intersections and/or areas of said infrastructural layout; and
- a processing component in communication with the lighting nodes and adapted to automatically associate each node to one of the stored paths, intersections and/or areas, and further being adapted to select for each first lighting node at least one second lighting node associated to the same one of said paths, intersections and/or areas.

6. Lighting control system according to clause 5, further comprising a visualization component connected to the processing component and adapted to show the locations of the lighting nodes and the paths, intersections and/or areas on a map on an electronic display.

7. Lighting control system according to clauses 5 or 6, further comprising a configuration component adapted to edit the associations between lighting nodes and paths, intersections and/or areas on the basis of user input.

8. Lighting control system according to any preceding clause, wherein the logical topology of the network is a mesh topology, star topology or tree topology.

9. Lighting control system according to any preceding clause, wherein each lighting node comprises a switching component arranged for switching between an unicast mode, wherein the wireless communication means of said lighting node is arranged for sending a message to another node in the network via at least one routing connection by using an unique address of said other node, and a broadcast mode, wherein the wireless communication means of said lighting node is arranged for sending a message to multiple other nodes in the network within wireless range.

10. Lighting control system according to clause 9, wherein each lighting node comprises a memory component arranged to store a list of at least two other nodes in the network indicating whether to send messages to the respective node in the unicast mode or broadcast mode.

11. Lighting control system according to clause 9 or 10, wherein each lighting node is arranged such that for sending a message from said lighting node to multiple other lighting nodes the broadcast mode is used for sending said message to the subset of other lighting nodes which are within a predetermined range and the unicast mode is used for routing said message to the subset of other lighting nodes which are outside the predetermined range.

12. Lighting control system according to clause 11, wherein the predetermined range is equal or smaller than the wireless range of the wireless communication means of the respective lighting node.

13. Method for routing messages between lighting nodes forming a wireless multi-node network, wherein each lighting node comprises a light source, a controller connected to the light source and a wireless communication means connected to the controller for communication with other lighting nodes in the network, the method comprising the step of configuring the logical topology of the

network for routing messages between the lighting nodes on the basis of information about the geographical position of the lighting nodes.

14. Method according to clause 13, the step of configuring the logical topology of the network for routing messages between the lighting nodes comprises configuring the logical topology of the network on the basis of information about the geographical position of the lighting nodes and information about the infrastructural layout of the area wherein the lighting nodes are positioned.

15. Method according to clause 13 or 14, comprising the following steps for sending a message from a first lighting node to multiple other lighting nodes:

- using a broadcasting mode for sending the message to the subset of other lighting nodes which are within a predetermined range; and
- using a unicast mode for routing the message to the subset of other lighting nodes which are outside said predetermined range.

CONCLUSIES

1. Verlichtingregelsysteem dat een aantal verlichting-nodes omvat die een draadloos multi-node netwerk vormen, elke verlichting-node omvattende:

- een lichtbron;
- een regelaar verbonden met de lichtbron; en
- een met de regelaar verbonden draadloos communicatiemiddel voor communicatie met andere verlichting-nodes in het netwerk,

met het kenmerk dat,

het systeem is ingericht om de logische topologie van het netwerk voor het routeren van berichten tussen de verlichting-nodes te configureren op basis van informatie over de geografische posities van de verlichting-nodes.

2. Verlichtingregelsysteem volgens conclusie 1, verder ingericht om voor elke eerste verlichting-node ten minste één tweede verlichting-node, waarmee het communicatiemiddel van de eerste verlichting-node een verbinding voor routering dient op te zetten, te selecteren, waarin het systeem is ingericht om de tweede verlichting-node te selecteren op basis van informatie over de geografische positie van de eerste verlichting-node en de geografische positie van de tweede verlichting-node.

3. Verlichtingregelsysteem volgens conclusie 1of 2, waarin het systeem is ingericht om de logische topologie van het netwerk voor het routeren van berichten tussen de verlichting-nodes te configureren op basis van informatie over de infrastructurele indeling van het gebied waarin de verlichting-nodes zijn gepositioneerd en de geografische posities van de verlichting-nodes in dit gebied.

4. Verlichtingregelsysteem volgens conclusie 2 en 3, waarin het systeem is ingericht om de tweede verlichting-node te selecteren op basis van informatie over de infrastructurele indeling van het gebied waarin de verlichting-nodes zijn gepositioneerd en de geografische posities van de verlichting-nodes in dit gebied.

5. Verlichtingregelsysteem volgens conclusie 4, verder omvattende:

- een geheugencomponent die is ingericht om informatie op te slaan omtrent de geografische positie van paden, kruisingen en/of oppervlaktes van de infrastructurele indeling; en

- een verwerkingscomponent die communicatief verbonden is met de verlichting-nodes en ingericht is om automatisch elke node met één van de opgeslagen paden, kruisingen en/of oppervlaktes te associëren, en verder ingericht is om voor elke eerste verlichting-node ten minste één tweede verlichting-node te selecteren die geassocieerd is met dezelfde één van de paden, kruisingen en/of oppervlaktes.

6. Verlichtingregelsysteem volgens conclusie 5, verder omvattende een visualisatiecomponent die verbonden is met de verwerkingscomponent en ingericht is om de locaties van de verlichting-nodes en de paden, kruisingen en/of oppervlaktes op een kaart weer te geven op een elektronisch scherm.

7. Verlichtingregelsysteem volgens conclusie 5 of 6, verder omvattende een configuratiecomponent die is ingericht om de associaties tussen de nodes en paden, intersecties en/of oppervlaktes te bewerken op basis van gebruikersinvoer.

8. Verlichtingregelsysteem volgens één van de voorgaande conclusies, waarin de logische topologie van het netwerk een vermaasde topologie, een ster-topologie of boom-topologie is.

9. Verlichtingregelsysteem volgens één van de voorgaande conclusies, waarin elke verlichting-node een schakelcomponent omvat die is ingericht om te schakelen tussen een unicast modus, waarin het middel voor draadloze communicatie van de respectieve verlichting-node ingericht is om een bericht naar een andere node in het netwerk te zenden via ten minste één routerende verbinding gebruikmakende van een uniek adres van de andere node, en een broadcast modus, waarin het middel voor draadloze communicatie van de respectieve verlichting-node ingericht is om een bericht te zenden naar meerdere andere nodes in het netwerk die zich binnen draadloos bereik bevinden.

10. Verlichtingregelsysteem volgens conclusie 9, waarin elke verlichting-node een geheugencomponent omvat die is ingericht om een lijst van ten minste twee andere nodes in het netwerk op te slaan, welke lijst aangeeft of berichten aan de respectieve node in de unicast modus of de broadcast modus gezonden dienen te worden.

11. Verlichtingregelsysteem volgens conclusie 9 of 10, waarin elke verlichting-node is ingericht zodanig dat, voor het verzenden van een bericht van de verlichting-node naar meerdere andere verlichting-nodes, de broadcast modus wordt gebruikt voor het verzenden van het bericht naar de subset van andere verlichting-nodes die zich binnen een voorafbepaald bereik bevinden en de

unicast modus wordt gebruikt voor het routeren van het bericht naar de subset van andere verlichting-nodes die zich buiten het voorafbepaalde bereik bevinden.

12. Verlichtingregelsysteem volgens conclusie 11, waarin het voorafbepaalde bereik gelijk of kleiner is aan het draadloze bereik van de draadloze communicatiemiddelen van de respectieve verlichting-node.

13. Werkwijze voor het routeren van berichten tussen verlichting-nodes die een draadloos multi-node netwerk vormen, elke verlichting-node omvattende een lichtbron, een met de lichtbron verbonden regelaar en een met de regelaar verbonden draadloos communicatiemiddel voor communicatie met andere verlichting-nodes in het netwerk, waarin de werkwijze de stap omvat van het configureren van de logische topologie van het netwerk voor het routeren van berichten tussen de verlichting-nodes op basis van informatie over de geografische positie van de verlichting-nodes.

14. Werkwijze volgens conclusie 13, de stap van het configureren van de logische topologie van het netwerk voor het routeren van berichten tussen de verlichting-nodes omvattende het configureren van de logische topologie van het netwerk op basis van informatie over de geografische positie van de verlichting-nodes en informatie over de infrastructurele indeling van het gebied waarin de verlichting-nodes zijn gepositioneerd.

15.Werkwijze volgens conclusie 13 of 14, omvattende de volgende stappen voor het verzenden van een bericht van een eerste verlichting-node naar meerdere andere verlichting-nodes:

- het gebruikmaken van een broadcast modus voor het verzenden van het bericht naar de subset van andere verlichting-nodes die zich binnen een voorafbepaald bereik bevinden; en
- het gebruikmaken van een unicast modus voor het routeren van het bericht naar de subset van andere verlichting-nodes die zich buiten het voorafbepaalde bereik bevinden.

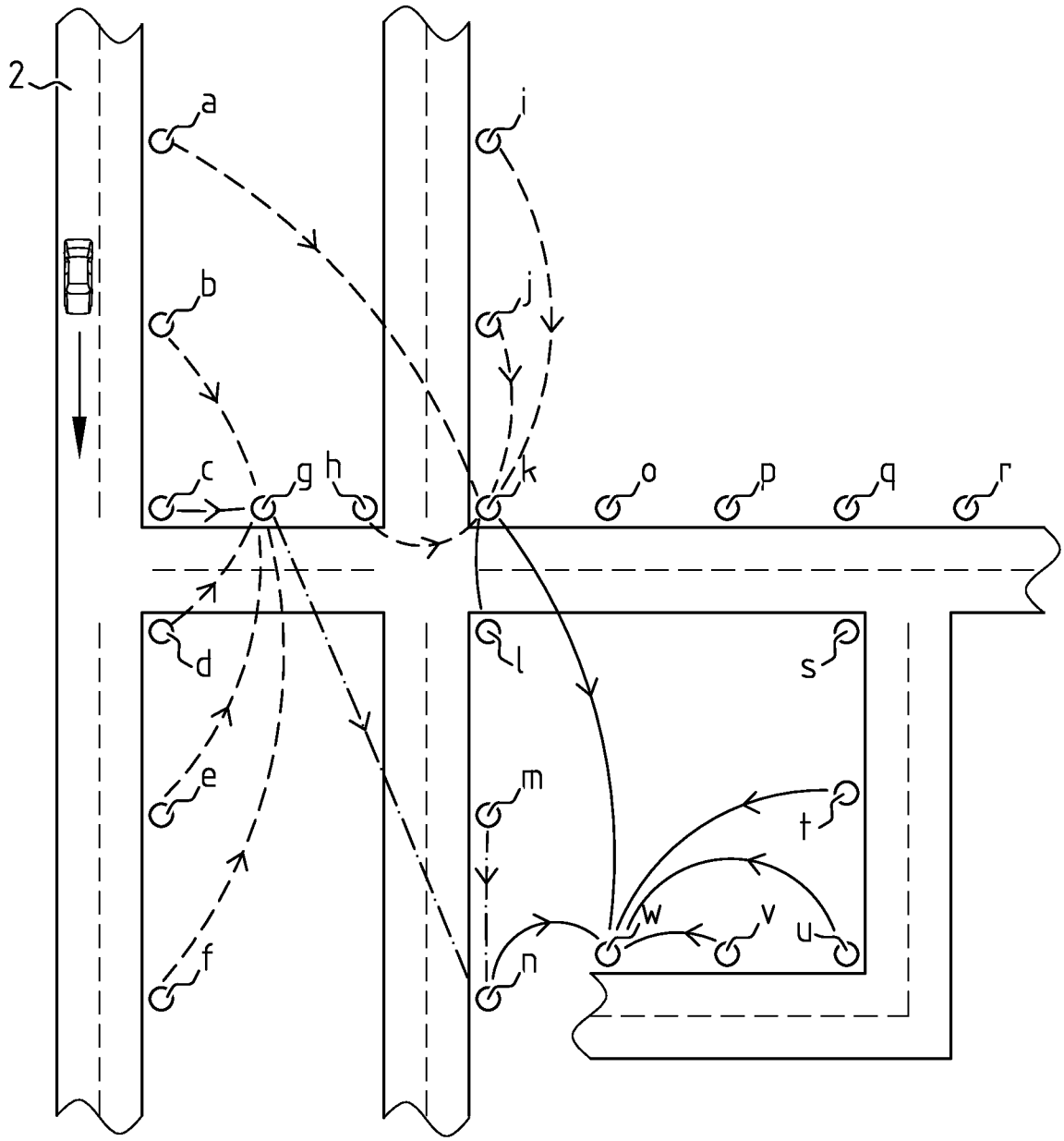

FIG. 1A
PRIOR ART

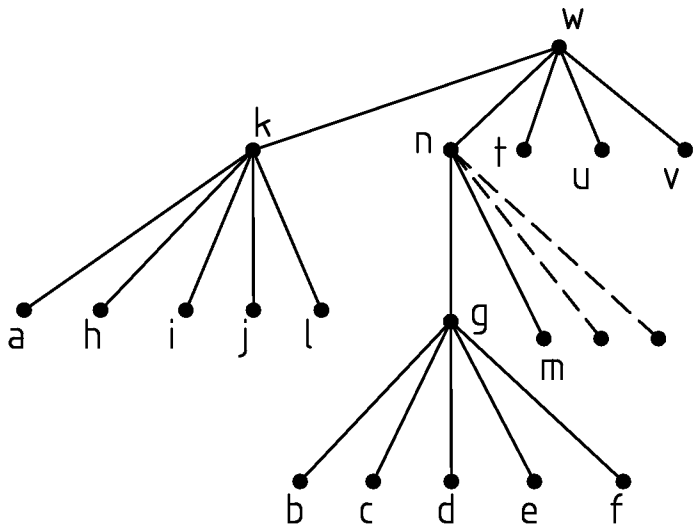

FIG. 1B
PRIOR ART

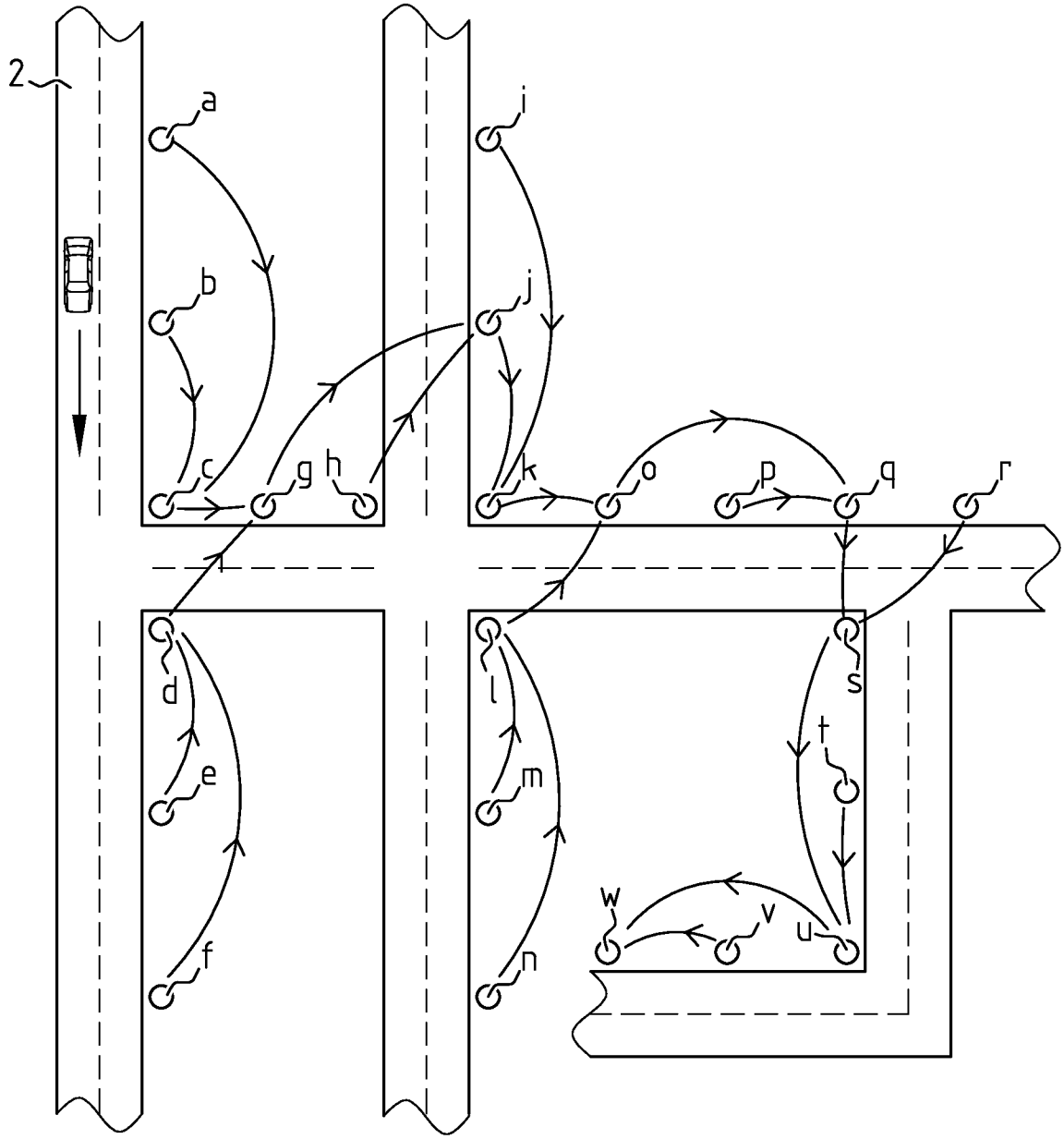

FIG. 2A

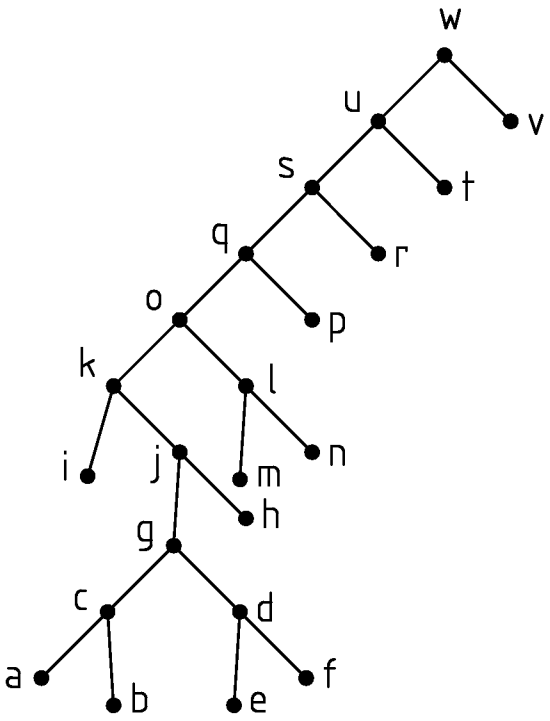

FIG. 2B

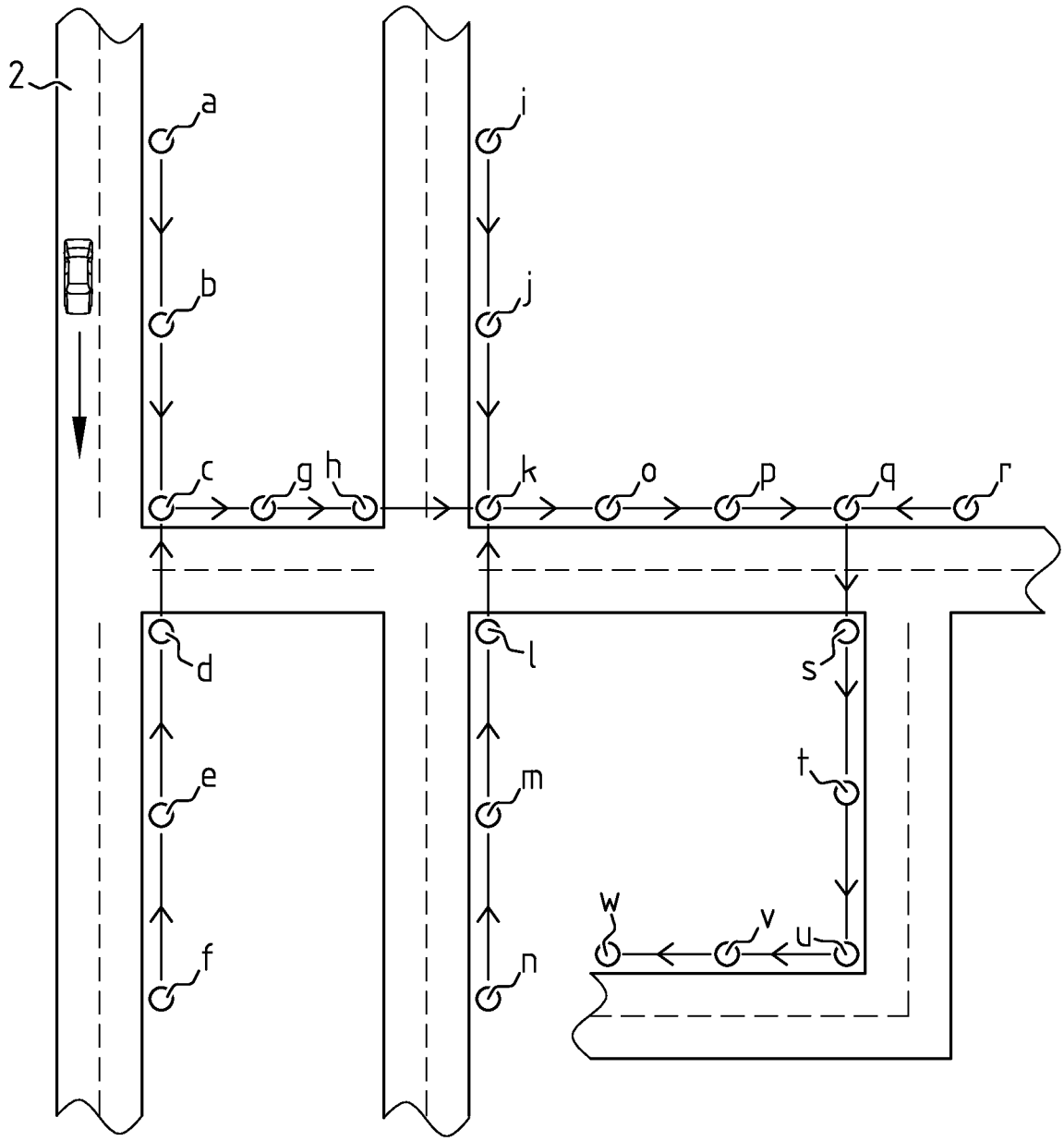

FIG. 3A

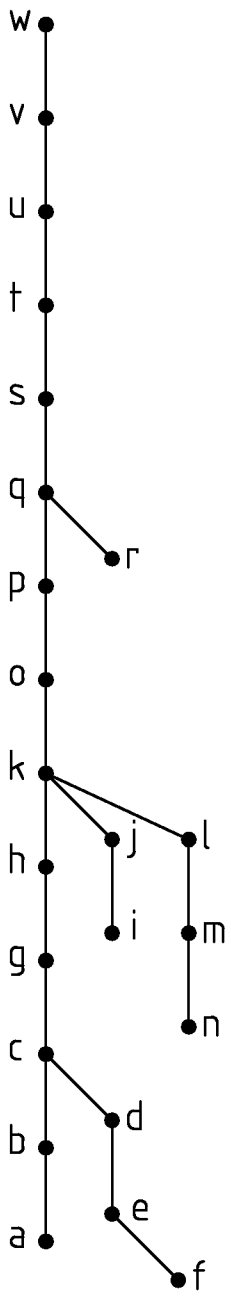

FIG. 3B

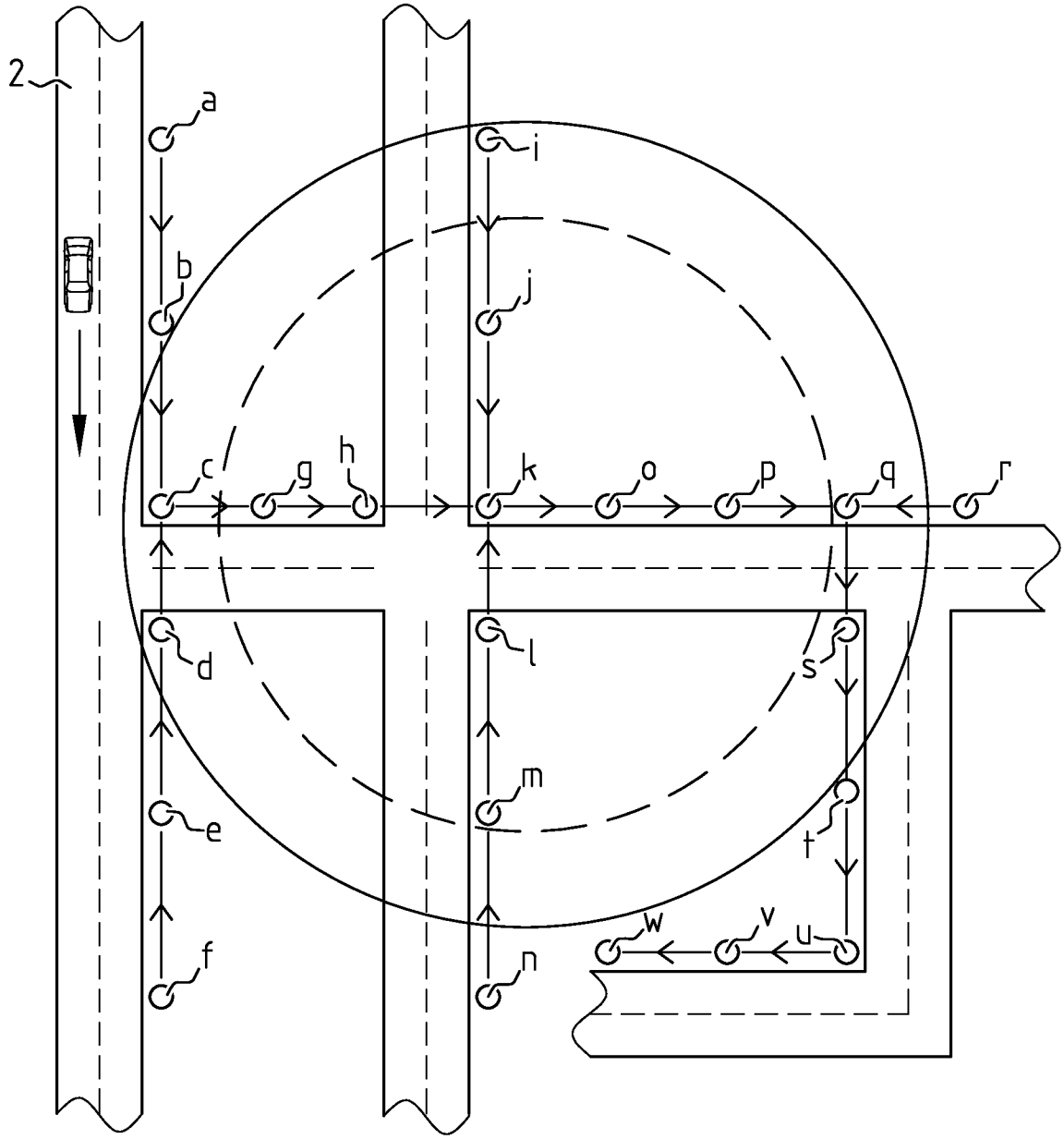

FIG. 4

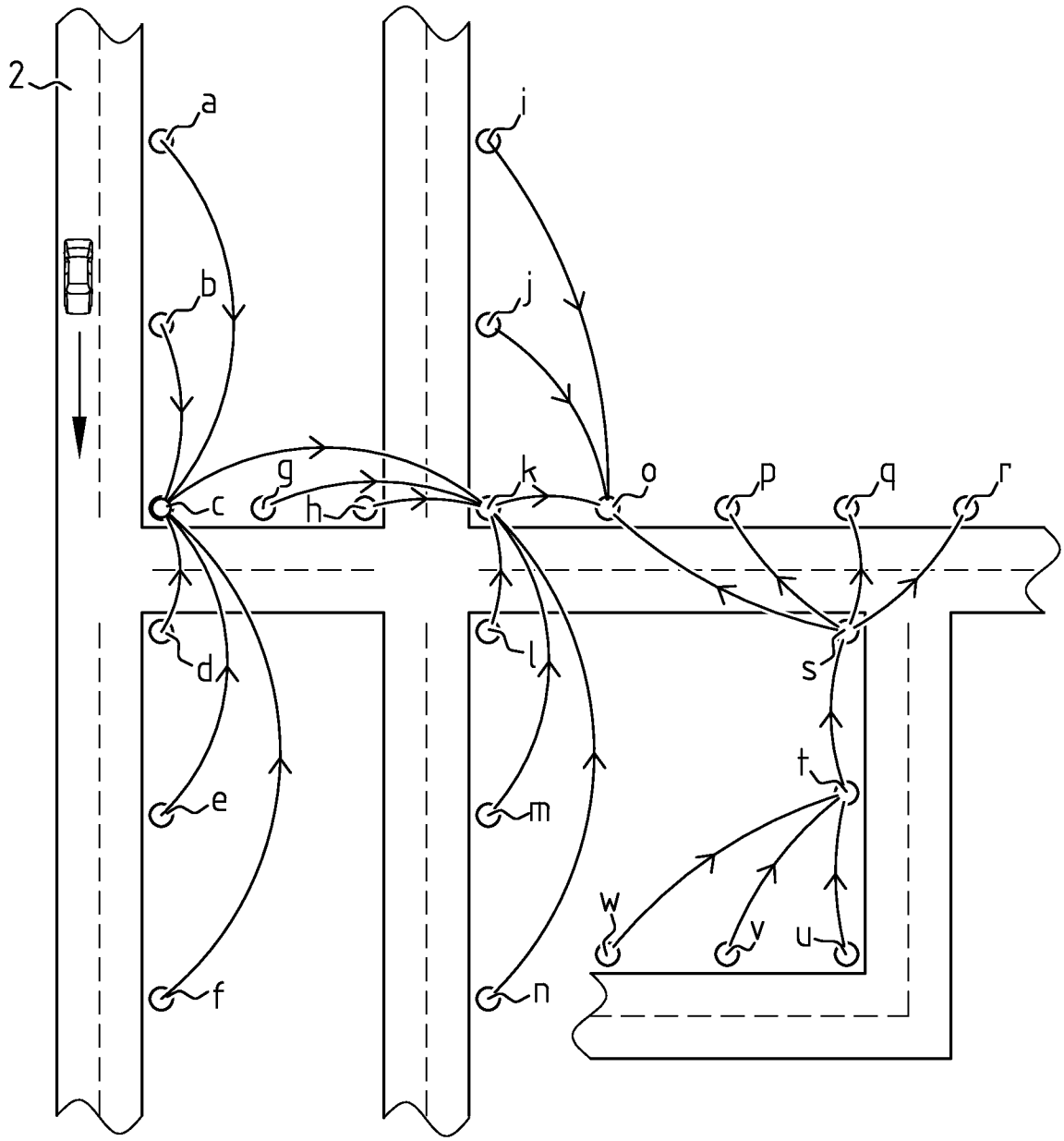

FIG. 5A

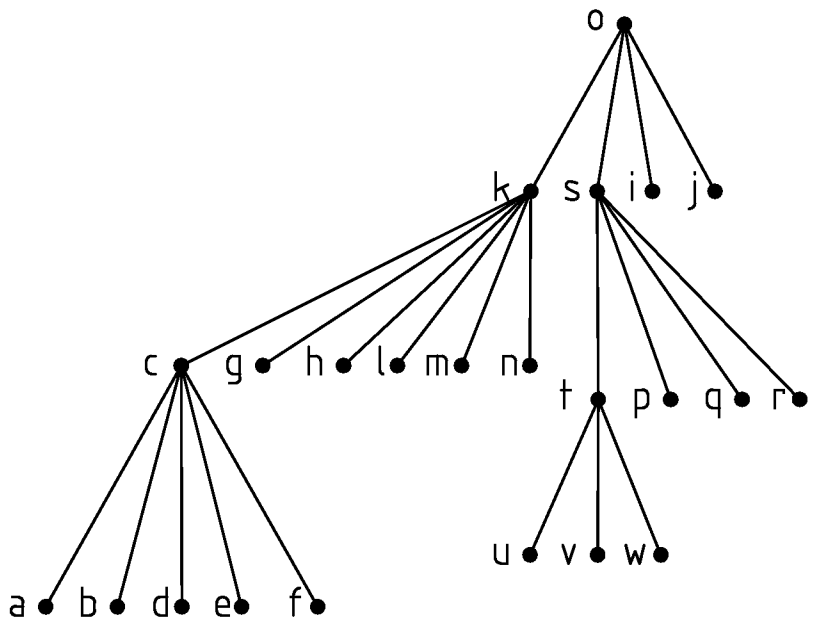

FIG. 5B

ABSTRACT

The invention relates to a lighting control system for routing of messages between a number of lighting nodes forming a wireless multi-node network and method therefor. The lighting control system comprising a number of lighting nodes forming a wireless multi-node network, each lighting node comprising a light source; a controller connected to the light source; and a wireless communication means connected to the controller for communication with other lighting nodes in the network, wherein the system is arranged to configure the logical topology of the network for routing of messages between the lighting nodes on the basis of information about the geographical positions of the lighting nodes.

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	4B/2PP96/3
Nederlands aanvraag nr. **2013247**	Indieningsdatum **24-07-2014**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Tvilight B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **01-11-2014**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN 63011**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

H05B37/02

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC	**H05B**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2013247

A. CLASSIFICATIE VAN HET ONDERWERP
INV. H05B37/02
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
H05B

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)
EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 2013/181609 A1 (AGRAWAL ANIL [US]) 18 juli 2013 (2013-07-18) * streetlights automatically grouped based on location information (geographic coordinates); alineas [0140] - [0141], [0137], [0063], [0044], [0066] * -----	1-13,15
X	EP 2 131 630 A2 (TECNOLOGIE E SERVIZI INNOVATIV [IT]) 9 december 2009 (2009-12-09) * configuration based on maps; street lamps organized in a linear installation type (e.g. Street); street lamps organized in a MESH installation type (e.g. Squares, Parking lots, etc.); alineas [0021] - [0024]; figuren 3-4 * -----	1-13,15
	-/--	

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
15 april 2015	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Maicas, Jesús

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2013247

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	US 2012/059622 A1 (CACACE VINCENZO [IT] ET AL) 8 maart 2012 (2012-03-08) * architecture to control street lights is dependent on location of nodes; alinea [0014]; figuren 8-14 * -----	1-13,15
A	WO 2013/030779 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; SCHENK TIM CORNEEL WILHELMUS [NL]) 7 maart 2013 (2013-03-07) * routing tables built based on the received geographical distance or their geographical position; bladzijden 7-8 * -----	1,13

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2013247

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2013181609 A1	18-07-2013	US 2013181609 A1	18-07-2013
		US 2013181614 A1	18-07-2013
		US 2013181636 A1	18-07-2013
		US 2014036473 A1	06-02-2014
		US 2014197745 A1	17-07-2014
		WO 2013109765 A1	25-07-2013
EP 2131630 A2	09-12-2009	EP 2131630 A2	09-12-2009
		IT TR20080002 U1	05-09-2008
US 2012059622 A1	08-03-2012	GEEN	
WO 2013030779 A1	07-03-2013	CN 103765992 A	30-04-2014
		EP 2742778 A1	18-06-2014
		JP 2014529246 A	30-10-2014
		US 2014192723 A1	10-07-2014
		WO 2013030779 A1	07-03-2013

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN63011	24.07.2014		NL2013247

International Patent Classification (IPC)
INV. H05B37/02

Applicant
Tvilight B.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

	Examiner
	Maicas, Jesús

Application number

WRITTEN OPINION

NL2013247

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	
	No:	Claims	1-15
Inventive step	Yes:	Claims	
	No:	Claims	1-15
Industrial applicability	Yes:	Claims	1-13, 15
	No:	Claims	14

2. Citations and explanations

see separate sheet

Application number

WRITTEN OPINION

NL2013247

Box No. VII Certain defects in the application

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 US 2013/181609 A1 (AGRAWAL ANIL [US]) 18 juli 2013 (2013-07-18)

D1 discloses a control system for streetlights linked via a wireless network 110 wherein each of the streetlight comprises:

- a light source,
- a controller 104 connected to the light source,
- wireless communication means connected to the controller for communication with other lighting nodes in the network 1004,
- the system is arranged to configure the routing of messages between the lighting nodes on the basis of the geographical positions of the streetlights [0044, 0063,0066, 0140-0141].

D2 EP 2 131 630 A2 (TECNOLOGIE E SERVIZI INNOVATIV [IT]) 9 december 2009 (2009-12-09)

D2 discloses a control system for a number of street lamps forming a wireless multi-node network, each street lamp comprising:

- a light source 2;
- a controller 1 connected to the light source; and
- a wireless communication means 6,7 connected to the controller for communication with other street lamps or central nodes in the network,
- the system is arranged to configure the logical topology of the network for routing of messages between the lighting nodes on the basis of information about the geographical positions of the lighting nodes (fig.3) [0021-0024].

1 The present application does not meet the criteria of patentability, because the subject-matter of claims 1-12 is not new.

D1 and D2 disclose the subject matter of claim 1 in its entirety.

The subject-matter of claims 2-12 can be found or directly derived from the disclosure of either of both D1 and D2.

2 The present application does not meet the criteria of patentability, because the subject-matter of claim 13 is not new.

D1 and D2 disclose the subject matter of claim 12.

Re Item VII

Certain defects in the application

3 Claim 14 shows a false dependence relation.

4 Document NL2010324 and PCT/NL2014/050094, cited in the description, correspond to Patent Application numbers, they should be replaced by the corresponding publication numbers.

Re Item VIII

Certain observations on the application

5 Clarity and disclosure: The skilled person faced with the disclosure of claims 1 and 12 would not be able to perform the task required to solve the problem posed due to an insufficient disclosure of the technical means to achieve such a result. At the present drafting stage Claims 1 and 12 are vague and incomplete statements expressing wishes in the direction of a result to be achieved.

- The logical topologies of the network are not defined;
- Topology of the network and routing of the messages appear to be mixed and confused;
- what to do with the geographical information of the nodes is not defined;
- the relation between geographical information and topology of the network is not defined;
- the claims are so broad that cover a system wherein one of the nodes being above the equator imply establishing a master/slave network.