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(54) Title: CONFIGURING A NETWORK OF DEVICES

(57) Abstract: A concept for enabling a plurality of devices to communicate with a backend system. The plurality of devices are able to communicate among themselves using a first wireless communication protocol. It is proposed to activate certain ones of the plurality of devices, where activating a device enables it to communicate with the backend system using a second, different wireless communication protocol. To decide which of the plurality of devices to activate, an iterative process is performed in which communication information about devices able to directly communicate with an activated device is obtained.

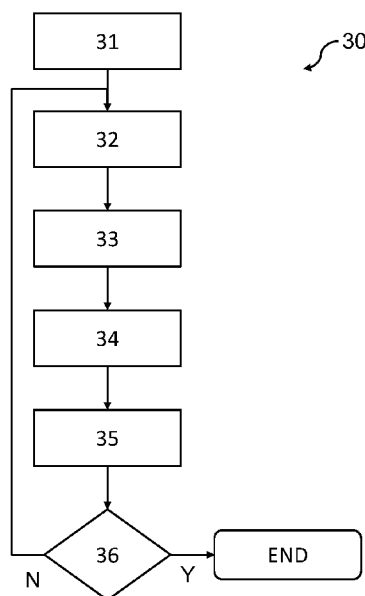


FIG. 3

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Configuring a Network of Devices

FIELD OF THE INVENTION

The present invention relates to the field of configuring a plurality of devices, and in particular how to configure a plurality of devices to form a network of devices.

5 BACKGROUND OF THE INVENTION

There has been increasing demand for networks of devices that are able to communicate with a backend system, for example, to communicate with a database, controller or even the internet.

Such networks can be implemented in a variety of industries, including the
10 automotive, utility (e.g. lighting or water), agricultural and health industries. In these applications, devices may consist of peripheral input and/or output devices, and may include, for example, water meters, gas detectors, car monitoring systems, personal healthcare monitoring products and/or wireless luminaires such as smart streetlights.

One known method of configuring devices to form a network able to
15 communicate with a backend system is to configure each device to communicate with the backend system using a cellular communication protocol, such as 3G, 4G and so on. However, cellular communication protocols are expensive, as devices need to be registered to a network carrier and typically require payment of regular data tariffs.

Another proposed method is to enable devices to communicate with one another
20 and the backend system using a long range wireless network protocol, such as LoRaWAN. However, when deploying long range wireless network protocols in an urban environment (e.g. a city) it is challenging to find enough appropriate sites for full LoRaWAN coverage of all devices.

There is therefore a desire for an improved method of enabling devices to form
25 a network for communicating with a backend system.

SUMMARY OF THE INVENTION

The invention is defined by the claims.

According to examples in accordance with an aspect of the invention, there is provided a method of enabling a plurality of devices to communicate with a backend system, wherein each device is: adapted to directly communicate with at least one other device in the plurality of devices using a first wireless communication protocol; capable of being activated so as to directly communicate with the backend system using a second wireless communication protocol; and initially inactivated, so that each device is initially unable to communicate using the second wireless communication protocol. The method comprises: activating one of the plurality of devices, so that the activated device is able to communicate with the backend system using the second wireless communication protocol; and performing iterative steps. The iterative steps comprise: obtaining, from each of a set of one or more devices able to directly communicate with the most recently activated device using the first wireless communication protocol, communication information, being information indicating with which other devices the device is able to communicate using the first wireless communication protocol; updating a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices; processing the communication information dataset to identify one of the plurality of devices for activation; and activating the identified device, so that the activated device is able to communicate with the backend system using the second wireless communication protocol. The iterative steps are repeated until each device of the plurality of devices is either an activated device or is able to directly communicate with at least one activated device using the first wireless communication protocol.

There is therefore proposed a method of setting up a network of devices able to communicate with a backend system, which network has a one-hop star topology. A network having a one-hop star topology benefits from improved reliability, reduced bottle necking, reduced latency and reduced signal interference/degradation when compared to a network having a multi-hop topology.

The network provided, by executing the claimed method, is formed from activated devices, able to communicate with the backend system using a second wireless communication protocol, and inactivated devices able to directly communicate with an activated device using a first wireless communication protocol (e.g. to thereby communicate with the backend system). Thus, a hybrid network is formed that can use two wireless communication protocols to enable all devices to communicate with a backend system.

In the context of the present application, a device can be defined as being “activated”, in which it is able to directly communicate with the backend system using the second wireless communication protocol, or “inactivated”, in which it is not able to directly

communicate with the backend system using the second wireless communication protocol. An inactivated device may be able to (directly) communicate with an activated device using the first wireless communication protocol, to thereby communicate with the backend system (i.e. an activated device may act as a router). Initially, i.e. before performing the proposed method, none of the plurality of devices are activated.

The proposed method performs an iterative process to sequentially activate certain ones of the (initially inactive) devices in the network to form the one-hop star topology. Thus, a sequence of activations takes place.

To decide which device to activate next (in the sequence), the method builds up a dataset of communication information, each entry in the dataset being associated with a device in direct communication with an activated device and identifying with which other device(s) that the associated device is able to directly communicate. The dataset is updated/expanded each time a device is activated (as new devices become able to direct communicate with the most recently activated device), and then processed to identify which device is to be activated next. By building a dataset of communication information in this way, the activation of the next device is guided using at least information obtained from a most recently activated device.

The iterative process is stopped when all devices of the plurality of devices are either activated or in direct communication with an activated device (i.e. when a network having a one-hop star topology is formed).

The method thereby proposes a concept for guiding an activation sequence of only certain ones of the (initially inactivated) devices, e.g. to act as routers or relay devices for communication with the backend system.

The proposed method thereby enables a network, having a one-hop star topology, to be formed in a guided manner, without needing to activate all devices to be able to communicate using the second wireless communication protocol (or needing all devices to be initially activated). This can help reduce an expense of the network, as fewer devices need to be activated to communicate using the second wireless communication protocol.

As used herein, the term “directly communicate” means communicating from a first entity to a second entity, without the communication being routed via a third entity (i.e. in a single hop). The term “backend system” refers to any device/system external to the plurality of devices, e.g. comprising one of more of: a router, a server, a base station, a cloud-computing system, a controller and so on.

The plurality of devices are each able to communicate with at least one other device using the first wireless communication protocol. In particular, the plurality of devices may comprise devices for which a message can be routed from any device to any other device in the plurality of device using the first wireless communication protocol.

5 The second wireless communication protocol is different to the first wireless communication protocol.

 The step of processing the communication information dataset may comprise: determining whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they
10 are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device; and in response to a positive determination, identifying an inactivated device, having communication information in the communication information dataset, whose communication information indicates they are able to directly
15 communicate with the greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the communication information dataset.

 As previously set out, communication information indicates with which other device(s) a particular device is able to communicate. Inclusion of communication information in the dataset indicates that the corresponding device is able to directly communicate with an
20 activated device (as only devices able to directly communicate with an activated are included in the dataset).

 Thus, a determination is made as to whether any of the devices (able to directly communicate with an activated device) are able to directly communicate with at least one inactivated device that is not able to directly communicate with an activated device. Thus, a
25 check is made as to whether any of the devices able to communicate with an activated device are suitable candidates for activation (i.e. to expand the network of devices able to communicate with the backend system via a single hop).

 The device chosen for activation is one able to communicate with the greatest number of inactivated devices not already in direct communication with an activated device
30 (e.g. not having communication information in the dataset). This means that the device having the broadest known reach (to other devices) can be selected to improve an efficiency of selecting the devices to activate.

 Optionally, the step of processing the communication information dataset further comprises: determining whether two or more inactivated devices, having

communication information in the communication information dataset, have communication information that indicates they are able to directly communicate with the same greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the communication information dataset; and in response to a positive determination, identifying an activated device, of the two or more inactivated devices, whose communication information indicates that they are able to directly communicate with the fewest number of inactivated devices that are able to communicate with an activated device.

It has been recognized that more than one inactivated device, able to directly communicate with an activated device, may be able to directly communicate with a same number of inactivated devices not able to directly communicate with an activated device. If this number is the highest of all entries in the communication information dataset, then there is a problem of deciding how to select which of the more than one inactivated devices to select for activation.

It has been proposed to select (of devices having the highest number) a device able to directly communicate with the fewest devices able to directly communicate with an activated device. This results in a device being selected that is, on average, further from devices already able to communicate with the backend system via a single hop, thereby increasing a likelihood that the network will be expanded in a subsequent iteration.

In preferable embodiments, the set of one or more devices comprises only those devices for which a signal quality measurement of communications with the most recently activated device, using the first wireless communication protocol, is greater than a first predetermined threshold. That is to say to select high quality communication nodes. To improve reliability of wireless connection, the criteria for 'direct communication' may be restricted to requiring a signal quality above a first predetermined threshold. Examples of a signal quality measurement include received signal strength indication (RSSI), received channel power indicator (RCPI), Signal-to-Noise (SNR) ratio, a Quality of Service indicator, or even a physical distance between the devices (e.g. as measured based on GPS measurements).

In other embodiments, the set of one or more devices may comprise only those devices for which a signal quality measurement of communications with the most recently activated device, using the first wireless communication protocol, is less than a second, different predetermined threshold (which may be greater than the first predetermined threshold). This is to say to select the nodes at the edge of the most recently activated device

to enhance usage of coverage and try to select as little as possible devices to be activated to save cost. From another aspect, this also increases a robustness/reliability of the overall network, as such devices may otherwise drop out of communication with an activated device and thereby be unable to communicate with the backend system.

5 In yet other embodiments, the set of one or more devices comprises only those devices for which a signal quality measurement of communications with the most recently activated device, using the first wireless communication protocol, is greater than a first predetermined threshold and less than a second, different predetermined threshold (which may be greater than the first predetermined threshold).

10 The method may further comprise, in response to the iterative steps ending, activating one or more inactivated devices in the plurality of devices so that each device of the plurality of devices, able to communicate with at least two other devices using the first wireless communication protocol, is either an activated device or is able to directly communicate with at least two activated devices.

15 To improve a robustness and reliability of the network, additional devices may be activated to ensure that all devices in the network are able to directly communicate with at least two activated devices. Thus, in the event that an activated device becomes unavailable, an inactivated device will still be able to communicate with the backend system via another activated device.

20 The step of processing the communication information dataset may comprise: determining whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device; and in response to a negative determination,
25 identifying one of the inactivated devices, of the plurality of devices, not associated with any communication information in the communication information dataset.

 Thus, if all devices known to the communication information dataset are either activated or in direct communication with an activated device, then another inactivated device (not having communication information in the dataset) is activated. This ensures that the
30 method can continue to iterate.

 Preferably, the second wireless communication protocol is a cellular communication protocol. Although widely used, cellular communication protocols tend to be expensive. There is therefore a particular desire to reduce the number of devices reliant on cellular communication protocols to communicate with a backend system. The invention is

therefore particularly advantageous when the second wireless communication protocol is a cellular communication protocol.

Preferably, the first wireless communication protocol is in an unlicensed spectrum and/or a wide area network communication protocol. A wide area network or unlicensed spectrum communication protocol, such as LoRaWAN, can be cheaply implemented, and it is therefore preferred or advantageous to use such communications when available.

The step of processing the communication information dataset may comprise using the backend system to identify one of the plurality of devices for activation. In other words, the backend system may provide the processing power for selecting which of the inactivated devices to activate. This reduces a burden on the devices in the network.

The step of obtaining communication information may comprise: broadcasting, from the most recently activated device, a first probe message using the first wireless communication protocol; and receiving, at the most recently activated device, a first response message from each device, within range of the first probe message, containing the communication information.

The step of obtaining communication information may further comprise controlling each device within range of the first probe message to: broadcast a second probe message using the first wireless communication protocol; receive, from each device with range of the second probe message, a second response message identifying that the said device within range of the second probe message is within range of the second probe message and thereby able to directly communicate with the device within range of the first probe message; generate a first response message containing the communication information, using the second response messages received from each device with range of the second probe message; and transmit the first response message to the most recently activated device.

In some embodiments, the step of identifying one of the plurality of devices for activation comprises identifying a device able to directly communicate with an activated device.

According to examples in accordance with another aspect of the invention, there is provided method of updating a communication information dataset, the method comprising: sending a first probe message to each of a set of one or more devices using a first wireless communication protocol; receiving a first response message from each of the set of devices, the first response message containing communication information, being information indicating with which other devices the device is able to communicate using the first wireless

communication protocol; and updating a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices;

Thus, the process carried out by the most recently activated device may, by itself, be considered an aspect of the invention. In embodiments, the step of sending a first probe message comprises broadcasting the first probe message using the first wireless communication protocol.

According to examples in accordance with an aspect of the invention, there is provided a computer program comprising code means for implementing any described method when said program is run on a computer.

According to examples in accordance with an aspect of the invention, there is also provided a processing system for enabling a plurality of devices to communicate with a backend system, wherein each device is: adapted to directly communicate with at least one other device in the plurality of devices using a first wireless communication protocol; capable of being activated so as to directly communicate with the backend system using a second wireless communication protocol; and initially inactivated, so that each device is initially unable to communicate using the second wireless communication protocol. The processing system being configured to: activate one of the plurality of devices, so that the activated device is able to communicate with the backend system using the second wireless communication protocol; and perform iterative steps. The iterative steps comprise obtaining, from each of a set of one or more devices able to directly communicate with the most recently activated device using the first wireless communication protocol, communication information, being information indicating with which other devices the device is able to communicate using the first wireless communication protocol; updating a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices; processing the communication information dataset to identify one of the plurality of devices for activation; and activating the identified device, so that the activated device is able to communicate with the backend system using the second wireless communication protocol. The processor system is configured to repeat the iterative steps until each device of the plurality of devices is either an activated device or is able to directly communicate with at least one activated device using the first wireless communication protocol.

There is also proposed a backend system for communicating with a plurality of devices, wherein the backend system forms part of the processing system. In particular, the

backend system may be adapted to perform the iterative steps. The backend system may comprise a data storage system for storing the communication information dataset.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

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BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:

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Figure 1 illustrates a device for use in an embodiment of the invention;

Figure 2 illustrates a plurality of devices;

Figure 3 illustrates a method according to an embodiment of the invention;

Figures 4 and 5 illustrate part of a method for processing the plurality of devices;

Figures 6 to 8 illustrate embodiments for steps of the method;

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Figures 9 and 10 illustrate part of a method for processing the plurality of devices; and

Figure 11 illustrates the plurality of devices being subject to a step of a further embodiment of the method.

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DETAILED DESCRIPTION OF THE EMBODIMENTS

The invention will be described with reference to the Figures.

It should be understood that the detailed description and specific examples, while indicating exemplary embodiments of the apparatus, systems and methods, are intended for purposes of illustration only and are not intended to limit the scope of the invention. These and other features, aspects, and advantages of the apparatus, systems and methods of the present invention will become better understood from the following description, appended claims, and accompanying drawings. It should be understood that the Figures are merely schematic and are not drawn to scale. It should also be understood that the same reference numerals are used throughout the Figures to indicate the same or similar parts.

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The invention provides a concept for enabling a plurality of devices to communicate with a backend system. The plurality of devices are able to communicate among themselves using a first wireless communication protocol. It is proposed to activate certain ones of the plurality of devices, where activating a device enables it to communicate with the backend system using a second, different wireless communication protocol. To decide which

of the plurality of devices to activate, an iterative process is performed in which communication information about devices able to directly communicate with an activated device is obtained.

Illustrative embodiments may, for example, be employed in smart street lighting systems, in which the plurality of devices comprises smart streetlights and the backend system comprises a controller for the smart streetlights.

Figure 1 is a block diagram illustrating a device 10 suitable for being used in embodiments of the invention, and is provided for the purposes of contextual understanding. The device 10 comprises a central processor 12, a first wireless communication unit 13, a second wireless communication unit 14 and a peripheral component arrangement 15.

The central processor 12 is adapted to control signals to/from other components of the device.

The first wireless communication unit 13 is adapted to enable the device 10 (in particular, the central controller 12) to communicate with other devices using a first wireless communication protocol, such as LoRa. The first wireless communication protocol could be any suitable radio frequency communication technology that supports a one-hop star topology network.

The second wireless communication unit 14 is adapted to enable the device 10 (in particular, the central controller 12) to communicate with other entities using a second wireless communication protocol, such as a cellular communication protocol (e.g. 3G, 4G and so on). The second wireless communication protocol should be any wireless communication technology for connecting a wide area network to a backend system, e.g. cellular or WiMax.

The second wireless communication unit may either be inactivated, in which it is unable to communicate using the second wireless communication protocol, or activated, in which it is capable of communicating using the second wireless communication protocol.

Thus, a device 10 may also be “inactivated”, in that a second wireless communication unit is inactivated, or “activated”, in that the second wireless communication unit is activated.

Activating a second wireless communication unit may comprise performing steps that enable a device 10 to communicate over a particular wireless network, such as a cellular network, using the second wireless communication protocol. Methods of activating a wireless communication unit will be readily apparent to the skilled person (e.g. identification processes, authentication processes and so on).

By way of example, activating a wireless communication unit (and thereby device) may comprise sending an authentication request from the wireless communication unit

to a home location register for a backend system, which authenticates the device and enables it to communicate with the backend system. Before activation, the wireless communication unit may be inactive (i.e. does not attempt communications using or is not configured to use the second wireless communication protocol). After activation, the wireless communication unit may be active, and can attempt to communicate with the backend system using the second wireless communication protocol.

Another way to activate a wireless communication unit (and thereby device) comprises sending, e.g. from a backend system, a command or instruction to (a management system of) a mobile network operator of a network that operates using the second wireless communication protocol, to permit that wireless communication unit to communicate using the second wireless communication protocol, e.g. by registering the appropriate device, or IMSI thereof, with the mobile network operator.

A device may request to be activated for communicating with the backend system using the second wireless communication protocol in response to an activation instruction (e.g. issued by the backend system and routed via another activated device of the plurality of devices, and optionally routed by one or more other inactivated devices). In another example, a device can be activated without input from the device, such as if the backend system directly activates the device with the mobile network operator.

The peripheral component arrangement 5 may include, for example: a power supply; input/output devices (e.g. LEDs, lights, sensors and so on); a further (e.g. wired) communication module and so on. Other suitable components for being included in a (networked) device will be apparent to the skilled person.

A backend system here comprises any entity, outside of the plurality of devices, which is able to communicate using the second wireless communication protocol, e.g. comprising a controller, database, router, cloud-computing arrangement and so on. It is desired for the backend system to be able to communicate with each of the plurality of devices (e.g. to control an operation of the plurality of devices).

Figure 2 illustrates a plurality of devices 1-9, A-G to be configured into a network of devices able to communicate with a backend system (not shown), e.g. via WAN/internet, by executing a method according to an embodiment of the invention. The plurality of devices illustrated in Figure 2 are in an initial state, before the method is performed.

Each of the plurality of devices 1-9, A-G is adapted to communicate with at least one other device using a first wireless communication protocol. Each device is also initially inactivated, and thereby unable to communicate with a backend system using a second

wireless communication protocol. Thus, in an initial state, none of the plurality of devices are able to communicate with the backend system using the second wireless communication protocol.

Embodiments of the method configure the plurality of devices 1-9, A-G to form
5 a one-hop star network of devices, by activating certain ones of the plurality of devices in an iterative sequence, to thereby ensure that each device is either activated or is in direct communication (using the first wireless communication protocol) with an activated device.

In embodiments, a backend system may, before the plurality of devices are configured according to an embodiment, have access to information about the plurality of
10 devices, such as identity information that identifies each device in the plurality of devices and/or information necessary to activate a device (such as a IMSI of each device). This may be performed, for example, by a technician that sets up the plurality of devices identifying devices in the plurality of devices (e.g. ID numbers), e.g. in the form of a list or dataset. The backend system could, for example, then retrieve additional information from a database, e.g. mapping
15 an ID number to an IMSI. Other methods for enabling a backend system to obtain information about the plurality of devices will be apparent to the skilled person.

Figure 3 is a flowchart illustrating a method 30 according to an embodiment of the invention. The method may be carried out by a processing or computing system.

The method comprises a first step 31 of activating one of the plurality of devices,
20 so that the activated device is able to communicate with the backend system using the second wireless communication protocol.

This first step may be performed spontaneously by the plurality of devices or may be performed by the backend system (e.g. selecting a known one of the plurality of devices to activate).

For example, the plurality of devices may communicate with one another using
25 the first wireless communication protocol to establish which of the plurality of devices is to be activated (e.g. selecting the device powered on at an earliest/latest point in time to be activated, or selecting a device able to directly communicate with the greatest number of other devices and so on).

In another example, the backend system may select a device to activate based
30 on information about the plurality of devices, e.g. arbitrarily selecting a device, or based on a user input (e.g. a technician may indicate a (edge) device to be initially activated). The backend system may then activate the identified device according to any previously described method.

The backend system can then send a message or command to the activated device to initiate the subsequent steps of the method 30.

The method 30 then comprises performing an iterative process formed of a series of steps, here labelled a second step 32, third step 33, fourth step 34 and fifth step 35.

5 A second step 32 comprises obtaining communication information from each of a set of one or more devices able to directly communicate with the most recently activated device using the first wireless communication protocol. The second step can be carried out by the most recently activated device, so that the most recently activated device obtains the communication information from each of the set of one or more devices. The most recently
10 activated device may know to perform the second step in response to a message from the backend system (e.g. sent using the second wireless communication protocol).

 The set of one or more devices may comprise all devices able to communicate with the most recently activated device. However, in preferable embodiments, the set of one or more devices comprises only those devices for which a signal quality measurement of
15 communications with the most recently activated device, using the first wireless communication protocol, is greater than a first predetermined threshold and/or less than a second, different predetermined threshold. The second predetermined threshold may be greater than the first predetermined threshold.

 For a first iteration of the process, the most recently activated device is the
20 device activated in the first step 31. For subsequent iterations, the most recently activated device is that activated in the iteratively repeated fifth step 35 (later described).

 The communication information indicates with which other devices the said device in the identified set is able to communicate using the first wireless communication protocol. For example, an instance of communication information may comprise a list of device
25 identifiers (device IDs) each identifying a device able to directly communicate (using the first wireless communication protocol) with a device able to directly communicate (using the first wireless communication protocol) with the most recently activated device.

 Thus, an instance or entry of communication information is obtained from each device able to directly communicate with the most recently activated device, thereby obtaining
30 a plurality of instances/entries of communication information. The communication information indicates with which other devices that a particular device is able to communicate using the first wireless communication protocol.

 A third step 33 comprises updating a communication information dataset to include the obtained communication information (from each device in the set of devices).

For a first iteration of the process, the step of “updating” a communication information dataset may comprise creating a communication information dataset. The step of updating may therefore include a step of creating a communication information dataset.

5 The communication information dataset thereby comprises information identifying devices that are able to directly communicate (using a first wireless communication protocol) with devices in direct communication (using a first wireless communication protocol) with an activated device.

The communication information dataset may be stored at the backend system. The step 32 of updating a communication information dataset may therefore comprise passing,
10 e.g. from the most recently activated device, communication information to the backend system using the second wireless communication protocol to update the stored dataset.

A fourth step 34 comprises processing the communication information dataset to identify one of the plurality of devices for activation. Thus, information on which devices are able to directly communicate with devices in direct communication with an activated device
15 is used to determine which device to activate. The fourth step 34 may be carried out by the backend system, which may possess more processing power than of the devices.

A fifth step 35 comprises activating the identified device, so that the activated device is able to communicate with the backend system using the second wireless communication protocol.

20 As previously explained, activation of a device may take place via an instruction routed from the backend system (e.g. through another activated device able to communicate with the identified device to be activated) or may be performed by the backend system itself.

Thus, the fifth step may comprise using the backend system to send an instruction to the identified device via the most recently activated device. The instruction may
25 therefore be passed to the most recently activated device using the second wireless communication protocol, and then routed to the identified device using the first wireless communication protocol.

In another example, the fifth step may comprise activating the identified device, e.g. by directly communicating with (a management system of) a mobile network operator.

30 The second through fifth steps 32-35, forming the iterative process, are repeated until each device of the plurality of devices is either an activated device or is able to directly communicate with at least one activated device using the first wireless communication protocol. In this way, a network of devices, having a one-hop star topology, able to communicate with the backend system is created in an autonomous fashion.

There may be a sixth step 36 (following the fifth step 35) comprising determining whether each of the plurality of devices is either an activated device or able to directly communicate with at least one activated device using the first wireless communication protocol. In response to a positive determination Y, the method ends in an end step END. In response to a negative determination N, the second through fifth steps 32-35 are repeated. Step 36 may comprise, for example, determining whether all devices identified in the communication information dataset (i.e. those having an entry in the dataset or referred to within an entry in the dataset) are able to communicate with an activated device.

A particular example of the method 30 will be described with further reference to Figures 4 to 10. The method is performed on the plurality of devices 1-9, A-G first illustrated in Figure 2. In the hereafter described Figures, activated devices are illustrated with cross-hatching. Inactivated devices are illustrated without cross-hatching.

According to the first step 31, illustrated in Figure 4, one of the plurality of devices 1 is activated so that it can communicate with the backend system. The selection of the device for the first step may be arbitrary, e.g. activating a device at an edge of the plurality of device that are able to directly communicate with the most recently activated device, and for which a signal quality measurements of communication with the most recently activated device are below the first predetermined threshold. This results in the subsequently activated device being one which may not be able to communicate with the most recently activated device with a high level of reliability, thereby avoiding the possibility that said device becomes unable to communicate with an activated device in a single hop.

Figure 5 illustrates each device 2, 3, 5, 6, 7, 9, A within range R1 of the most recently activated device 1 passing communication information to that device.

The communication information indicates, for each device 2, 3, 5, 6, 7, 9, A within range R1 of the most recently activated device 1, with which other devices said each device is able to communicate using the first wireless communication protocol. For example, device 2 may be able to communicate with devices 1, 3, 4, 5, 6, 7, 8, 9, A and B (which information may be contained within the communication information sent by device 2).

The second step 32 may be performed by appropriately controlling or instructing particular devices in the plurality of devices, including at least the most recently activated device and optionally the devices able to directly communicate with the most recently activated device using the first wireless communication protocol.

Figure 6 illustrates such an embodiment of the second step 32. In this embodiment, step 32 comprise a first sub-step 61 of broadcasting, from the most recently

activated device, a first probe message or “StartProbe” message using the first wireless communication protocol and a second sub-step 62 of receiving, at the newly activated device, a first response message from each device, within range R1 of the first probe message, containing the communication information. The most recently activated device may then
5 update the communication information dataset, e.g. in step 33 (not shown).

Thus, the most recently activated device 1 may broadcast a first probe message or “StartProbe message” to each device within range R1 of the most recently activated device 1, using a first wireless communication protocol. The devices 2, 3, 5, 6, 7, 9, A, B within range R1 of the first probe message form a set of devices able to directly communicate with the most
10 recently activated device 1 using a first wireless communication protocol.

The first probe message is a request for any devices within range of the most recently activated device 1 (i.e. “probed devices” or the “set of devices”) to send communication information to that most recently activated device 1 (e.g. in the form of a response message), using the first wireless communication protocol.

Other examples of obtaining communication information from devices within
15 range of the most recently activated device may be used. For example, a most recently activated device 1 could attempt to individually reach each device within the plurality of devices (i.e. unicasting, rather than broadcasting, a first probe message) to request communication information.

Thus, generally speaking, the most recently activated device may perform steps
20 of sending a first probe message to each of a set of one or more devices using a first wireless communication protocol; receiving a first response message from each of the set of devices, the first response message containing communication information, being information indicating with which other devices the device is able to communicate using the first wireless
25 communication protocol; and updating a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices. These steps may, by themselves, form an embodiment of an aspect of the inventive concept.

Figure 7 illustrates a further embodiment of the second step 32, which differs
30 from the previous embodiment by including further steps for generating communication information, to be performed for each device in the set of devices able to directly communicate with the most recently activated device.

The illustrated second step 32 further comprises a sub-step 71 of broadcasting, using the first wireless communication protocol, a second probe message by a probed device.

Thus, e.g. in response to receiving a first probe message, a probed device (a device that receives a first probe message) may itself broadcast a second probe message to other devices using the first wireless communication protocol. The second probe message is a request for devices within range of the probed device (i.e. devices that are able to receive the second probe message) to send an acknowledgment message or second response message to the probed device that sent the second probe message. A second response message indicates that the other device is able to directly communicate with the probed device using the first wireless communication protocol.

The second step 32 comprises (at the device in the set of devices) a sub-step 72 of receiving, from each device with range of the second probe message, a second response message identifying that the said device is able to directly communicate with the probed device. Thus a device receiving a second probe message may respond to the device sending the second probe message with an acknowledgment or second response message.

In embodiments, only those devices for which a signal quality measurement of communications with the device sending the second probe message, using the first wireless communication protocol, is greater than a third predetermined threshold respond to the second probe message with the second response message. The third predetermined threshold may be the same as the first predetermined threshold previously described.

Thus, the sub-step 72 may comprise receiving, from each device, for which a signal quality measurement of communications using a first wireless communication unit with the device sending the second probe message with a signal quality measurement greater than a third predetermined threshold, the second response message. The third predetermined threshold may be a threshold representing a sufficiently strong signal to ensure stable and reliable communications between two devices communicating using the first wireless communication protocol.

The second response message may, for example, contain a sender ID (of the device receiving the second probe message) and optionally a Quality of Service indicator or RSSI (received signal strength indication), which indicates a quality/strength of service of wireless communications between the device sending the second probe message and the device receiving the second probe message)

The second step 32 also comprises, a sub-step 73 of generating, by the probed device, a first response message containing the communication information, using the second response messages received from each device with range of the second probe message.

Thus, the probed device (that sends the second probe message) collects the second response messages sent by devices that receive the second probe message. The information contained in the second response messages is used to create the communication information for sending to the most recently activated device 1. For example, the probed device
5 may compile all sender IDs from received second response messages to form communication information. Thus, in some embodiments, sub-step 73 comprises compiling a list of sender IDs or devices that responded to the second probe message.

In further embodiments, sub-step 73 comprises compiling a list of sender IDs for only those devices that responded to the second probe message where a Quality of Service
10 indicator (when included in the second response message) is above a third predetermined threshold. The third predetermined threshold represent a sufficiently strong or sufficiently high quality signal to ensure stable and reliable communications between two devices communicating using the first wireless communication protocol.

The second step 32 also comprises (at the device in the set of devices) a step 74
15 of transmitting the first response message to the most recently activated device. In this way, the communication information is sent to the most recently activated device.

This leads onto sub-step 62 of receiving, at the most recently activated device, the communication information from each device in the set of devices able to directly communicate with the most recently activated device using the first wireless communication
20 protocol.

Sub-steps 71 to 74 are repeated (e.g. consecutively or, preferably, in parallel) for each device in the set of devices able to directly communicate with the most recently activated device. Thus, different instances of sub-steps 71 to 74 may be performed. Only two instances are illustrated in Figure 6, but more/fewer may be used depending upon the number
25 of devices able to directly communicate with the most recently activated device (or to which the first probe message was otherwise sent).

Communication information is thereby obtained by the most recently activated device, which information may be passed to the backend system for processing,

In some embodiments, a probed device may only provide communication
30 information if a signal quality measurement of communications with the most recently activated device, using the first wireless communication protocol, is greater than (or in other embodiments, less than) a first predetermined threshold. Thus, in embodiments, steps 71-74 are only performed if a signal quality of the first probe message is greater than or less than a first predetermined threshold. Signal quality may be measured, for example, by determining

an RSSI (received signal strength indication), or SNR (signal to noise ratio) or other signal quality measurement.

Although preferable, it is not necessary for a probed device to perform the described steps for obtaining communication information in response to the first probe message (i.e. immediately following step 61). Rather, in alternative embodiments, a probed device may perform step 74 of transmitting the first response message to the most recently activated device (with sub-steps 71-73 being previously performed by that probed device).

For example, each device of the plurality of devices may periodically perform the described sub-steps 71-73 to obtain communication information, and the latest acquired communication information may be provided in response to the first probe message. In another example, sub-steps 71-73 may be performed when a device is first powered on (i.e. joins the plurality of devices).

As previously described, in some embodiments, a probed device provides communication information only if a signal quality measurement of communications with the most recently activated device, using the first wireless communication protocol, is greater than a first predetermined threshold. Thus, in embodiments where step 71-73 are previously performed, sub-step 74 may only be performed if a signal quality of the first probe message is greater than a first predetermined threshold.

Alternative methods of generating communication information, instead of using sub-steps 71-73, will be apparent to the skilled person. For example, a device may passively monitor communications using the first wireless communication protocol sent by other devices within the plurality of devices, to identify with which of the plurality of devices said device is able to communicate with (e.g. within range of).

In some embodiments, a probed device (in the set of devices able to directly communicate with a most recently activated device using a first wireless communication protocol) may only transmit the first response message, containing the communication information, to the most recently activated device in response to a collect message issued by the most recently activated device. Thus, sub-step 74 may only be performed in response to a collect message sent by the most recently activated device.

This allows the most recently activated device to control communications from device within the set of devices. This can be used to avoid excess traffic on the network.

To enable the most recently activated device to identify which devices are in the set of devices (e.g. so that the most recently activated device knows to which devices to send a collect message), devices in the first set send an acknowledgement message in response to

the first probe message (and before sending the first response message). This enables the most recently activated device to record which devices are able to directly communicate with it using the first wireless communication protocol.

In some embodiments, step 71 of broadcasting (by a probed device) a second
5 probe message may be performed a (pseudo)random time period after the probed device receives the first probe message. Thus, there may be a (pseudo)random time delay between a device receiving the first probe message, and the broadcasting of the second probe message.

Such a time delay reduces the likelihood or number of multiple messages being sent within the plurality of devices, reducing traffic within the channel used by the plurality of
10 devices to communicate using the first wireless communication protocol.

Preferably, the random or pseudorandom time delay is restricted to having a random or pseudorandom length falling within a predetermined time period (e.g. a (pseudo)random length between 0 and 60 seconds). The predetermined time period may be defined in the first probe message, thereby enabling the most recently activated device to
15 control communications in the channel used by the plurality of devices to communicate using the first wireless communication protocol. The predetermined time period may depend upon the (predicted) number of devices able to communicate with the most recently activated device to avoid collision of the second probe message(s). In particular, the greater the (predicted) number of devices, the greater the predetermined time period. In some embodiments, the
20 predetermined time period may be based on the number of devices in the plurality of devices, which may represent or estimate the number of devices able to communicate with the most recently activated device.

The above-described examples provide ways obtaining the communication information from each device able to communicate with the most recently activated device 1.
25 Other methods of obtaining communication information will be apparent to the skilled person, e.g. by assessing a location of each device to predict whether different devices will be able to communicate with one another using the first wireless communication protocol.

As previously explained, a third step 33 of the method 30 comprises updating a communication information dataset to include the obtained communication information. For a
30 first iteration, this may comprise generating a communication information dataset to contain the obtained communication information.

Thus, obtained communication information is used to update/create a communication information dataset. This dataset thereby contains communication information for each device able to directly communicate with an activated device.

The communication information dataset may be stored on the backend system (not shown). Thus, the most recently activated device may send the obtained communication information of each probed device to the backend system. The most recently activated device may therefore perform at least part of the third step 33.

5 In a fourth step 34 of the method 30, the communication information dataset is processed to select or identify a device for activation. In other words, the selection of the next device, of the plurality of devices, to activate is based on information contained in the communication information dataset. Step 34 may be performed by the backend system.

Figure 8 illustrates an embodiment of the fourth step 34 of the method.

10 According to the embodiment, the fourth step 34 comprises a sub-step 81 of determining whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device.

15 According to the embodiment, the fourth step also comprises, in response to a positive determination, a sub-step 82 identifying an inactivated device, having communication information in the communication information dataset, whose communication information indicates they are able to directly communicate with the greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated
20 devices having communication information in the communication information dataset.

Due to the second 32 and third 33 steps, each inactivated device able to communicate with an activated device has an entry in the communication information dataset. Conversely, each inactivated device not able to communicate with an activated device does not have an entry in the communication information dataset. Each entry indicates with which
25 devices a corresponding device is able to communicate.

Accordingly, the dataset can be processed to identify which device (having an entry in the dataset) is able to communicate with the most inactivated devices not able to communicate with an activated device.

30 As having an entry in the dataset indicates that a device is able to communicate with an activated device, and not having an entry indicates that a device is unable to communicate with an activated device, this information can be exploited to identify with how many devices (unable to communicate with an activated device) a given device can communicate. The dataset may be processed to identify the entry indicating that the associated

device is able to communicate with the greatest number of inactivated devices not able to communicate with an activated device (e.g. not having an entry in the dataset).

It has been recognized that, in some circumstances, more than one inactivated device (in the dataset) may be able to communicate with the same number of devices not able to directly communicate with an activated device. When more than one device is able to communicate with the same greater number of inactivated devices (not able to communicate with an activated device) there is a problem of how to select an inactivated device.

In some examples, to overcome this problem, one of these inactivated devices is selected randomly or pseudorandomly.

In other examples, the embodiment of the fourth step 34 may be adapted to further comprise a further sub-step 83 (between the sub-steps 81 and 82) of determining whether two or more inactivated devices, having communication information in the communication information dataset, have communication information that indicates they are able to directly communicate with the same greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the communication information dataset.

In response to a positive determination (in sub-step 83), the method performs sub-step 84 of identifying an inactivated device, of the two or more inactivated devices, whose communication information indicates that they are able to directly communicate with the fewest number of inactivated devices that are able to directly communicate with an activated device. By selecting such an inactivated device, there is an increased likelihood that the selected inactivated device will be closer to other (not yet known) inactivated devices unable to directly communicate with an activated device.

Of course, if more than one inactivated device has communication information that indicates that they are able to directly communicate with the same, fewest number of inactivated devices that are able to directly communicate with an activated device, then one of these inactivated devices may be chosen randomly or pseudorandomly.

In some embodiments, in response to a negative determination in sub-step 81, the fourth step 34 performs a sub-step 85 of identifying one of the inactivated devices, of the plurality of devices, not associated with any communication information in the communication information dataset. This enables the process to continue.

As previously explained, after an inactivated device is identified by fourth step 34, this device is then activated in a fifth step 35.

The fourth step 34 may be executed by the backend server. The fifth step 35 of activating a device may be performed by the backend server issuing an activation instruction, and routing the activation instruction to the identified device (via an activated device) or to a (a management system of) a mobile network operator.

5 Where the device to be activated is not able to directly communicate with an activated device, the activation instruction (if passed to the identified device) may be further routed via at least one other inactivated device able to communicate with the activated device. Thus, the activation instruction may be provided in a two-hop process. In

10 In other example, and as previously described, the identified device may be activated without further input or processing by the identified device (e.g. by the backend registering the identified device on a network for communicating using the second wireless communication protocol).

15 The fifth step 35 is illustrated in Figure 9, in which a device 7 is activated. The device 7 represents the previously inactivated device able to communicate with more inactivated devices not able to directly communicate with an activated device than any other inactivated device able to directly communicate with an activated device.

 The second 32, third 33, fourth 34 and fifth 35 steps are iteratively repeated until each device of the plurality of devices is either an activated device or able to directly communicate with an activated device using the first wireless communication protocol.

20 In the scenario illustrated in Figure 9, after activating device 7, at least one inactivated device D is unable to communicate with an activated device (as it is outside of the range R1 of the first activated device 1 and the range R7 of the second activated device 7). Thus, the second through fifth steps 32-35 are repeated to activate another device E.

25 This scenario is illustrated in Figure 10. In which devices 1, 7 and E are all activated. The ranges R1, R7, RE of each activated device are also illustrated for clarity.

 It will be clear, from at least Figure 10, that the plurality of devices has been formed into a network of devices, in which each device is able to communicate with a backend system via no more than one activated device. In other words, each device is either an activated device or is in direct communication with an activated device.

30 To improve a reliability of the network of devices, the proposed method may comprise further steps of: determining whether each of the plurality of devices, able to communicate with at least two other devices using the first wireless communication protocol, is able to communicate with at least two other devices using the first wireless communication protocol; and, in response to a negative determination, activating one or more inactivated

devices in the plurality of devices so that each device, of the plurality of devices, is either an activated device or is able to directly communicate with at least two activated devices.

These steps are illustrated in Figure 10 and 11. In Figure 10, devices D, 4 and 8 are only able to communicate with a single activated device. Thus, at least one further device
5 needs to be activated in order to enable all devices to communicate with at least two activated devices (or be an activated device themselves).

In the illustrated embodiments, device B is activated, thereby enabling all devices to directly communicate with at least two activated devices using the first wireless communication protocol.

10 To determine which of the inactivated devices to activate, the communication information dataset may be processed to identify which devices (if any) are able to communicate with only a single activated device. The communication information dataset is then processed to identify one or more inactivated devices to activate in order to enable all inactivated devices to communicate with at least two activated devices.

15 Preferably, this step comprises identifying the smallest number of inactivated devices to activate in order to allow each inactivated device to communicate with at least two activated devices. This reduces a cost of the network.

In other embodiments, the plurality of devices is configured so that only those devices for which a signal quality measurement of communications with an activated device)
20 is below a fourth predetermined threshold (which may be different to the first, second and third predetermined thresholds) are assessed to determine whether they are able to communicate with at least two activated devices.

Thus, the method may comprise determining whether only a subset of the plurality of devices is able to communicate with at least two other devices using the first
25 wireless communication protocol; and, in response to a negative determination, activating one or more inactivated devices in the plurality of devices so that each device, of the subset of devices, is either an activated device or is able to directly communicate with at least two activated devices. The subset here comprises devices able to communicate with only a single activated device using a first wireless communication protocol, where a signal strength
30 measure of said communication is below a third predetermined threshold.

It is also acknowledged that one or more devices of the plurality of devices may be able to communicate with a single other one of the plurality of devices. Such devices may be activated to be able to communicate with the backend system using the second wireless communication protocol, to ensure robustness in the system

In other examples, if a signal strength measure of communication between a device able to communicate with only a single (activated) device and that activated device is greater than or equal to a fourth predetermined threshold, then the device is not activated; otherwise the device can be activated. This ensures that there is sufficiently high robustness in the system without needing to activate all devices able to communicate with only a single activated device.

The skilled person would be readily capable of developing a processing system for carrying out a previously described method. Thus, each step of the flow chart may represent a different action performed by a processing system, and may be performed by different modules of the processing system.

The processing system can be implemented in numerous ways, with software and/or hardware, to perform the various functions required. A processor is one example of a processing system which employs one or more microprocessors that may be programmed using software (e.g., microcode) to perform the required functions. A processing system may however be implemented with or without employing a processor, and also may be implemented as a combination of dedicated hardware to perform some functions and a processor (e.g., one or more programmed microprocessors and associated circuitry) to perform other functions.

Examples of processing system components that may be employed in various embodiments of the present disclosure include, but are not limited to, conventional microprocessors, application specific integrated circuits (ASICs), and field-programmable gate arrays (FPGAs).

In various implementations, a processor or processing system may be associated with one or more storage media such as volatile and non-volatile computer memory such as RAM, PROM, EPROM, and EEPROM. The storage media may be encoded with one or more programs that, when executed on one or more processors and/or processing systems, perform the required functions. Various storage media may be fixed within a processor or processing system or may be transportable, such that the one or more programs stored thereon can be loaded into a processor or processing system.

Preferably, the backend system forms part of the processing system. In particular, the backend system may store the communication information dataset in a data storage system (which forms part of the backend system).

It will be understood that disclosed methods are preferably computer-implemented methods. As such, there is also proposed the concept of computer program comprising code means for implementing any described when said program is run on a

computer. Thus, different portions, lines or blocks of code of a computer program comprising code according to an embodiment may be executed by a processor/computer to perform any herein described method.

Variations to the disclosed embodiments can be understood and effected by
5 those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not
10 indicate that a combination of these measures cannot be used to advantage. A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A method (30) of enabling a plurality of devices (1-9, A-G) to communicate with a backend system, wherein each device is: adapted to directly communicate with at least one other device in the plurality of devices using a first wireless communication protocol; capable of being activated so as to directly communicate with the backend system using a
5 second wireless communication protocol; and initially inactivated, so that each device is initially unable to communicate using the second wireless communication protocol,

the method comprising

activating (31) one of the plurality of devices, so that the activated device is able to communicate with the backend system using the second wireless communication protocol;

10 and

performing iterative steps of:

obtaining (32), from each of a set of one or more devices able to directly communicate with the most recently activated device using the first wireless communication protocol, communication information, being information indicating with
15 which other devices the device is able to communicate using the first wireless communication protocol;

updating (33) a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices;

20 processing (34) the communication information dataset to identify one of the plurality of devices for activation; and

activating (35) the identified device, so that the activated device is able to communicate with the backend system using the second wireless communication protocol;

25 wherein the iterative steps are repeated until each device of the plurality of devices is either an activated device or is able to directly communicate with at least one activated device using the first wireless communication protocol.

wherein the step of processing (34) the communication information dataset comprises:

determining (81) whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device; and

5 in response to a positive determination, identifying (82) an inactivated device, having communication information in the communication information dataset, whose communication information indicates they are able to directly communicate with the greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the
10 communication information dataset.

2. The method of claim 1, wherein the step of processing the communication information dataset further comprises:

determining (83) whether two or more inactivated devices, having
15 communication information in the communication information dataset, have communication information that indicates they are able to directly communicate with the same greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the communication information dataset; and

20 in response to a positive determination, identifying (84) an activated device, of the two or more inactivated devices, whose communication information indicates that they are able to directly communicate with the fewest number of inactivated devices that are able to communicate with an activated device.

25 3. The method of any of claims 1 to 2, wherein the set of one or more devices comprises only those devices for which a signal quality measurement of communications with the most recently activated device, using the first wireless communication protocol, is greater than a first predetermined threshold.

30 4. The method of any of claims 1 to 3, further comprising, in response to the iterative steps ending, activating one or more inactivated devices in the plurality of devices so that each device of the plurality of devices, able to communicate with at least two other devices using the first wireless communication protocol, is either an activated device or is able to directly communicate with at least two activated devices.

5. The method of any of claims 1 to 4, wherein the step of processing the communication information dataset comprises:

determining (81) whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device; and

in response to a negative determination, identifying (85) one of the inactivated devices, of the plurality of devices, not associated with any communication information in the communication information dataset.

6. The method of any of claims 1 to 5, wherein the second wireless communication protocol is a cellular communication protocol and/or the first wireless communication protocol is a communication protocol in an unlicensed spectrum and/or a wide area network communication protocol.

7. The method of any of claims 1 to 6, wherein the step of processing (84) the communication information dataset comprises using the backend system to identify one of the plurality of devices for activation.

8. The method of any of claims 1 to 7, wherein the step of obtaining (32) communication information comprises:

broadcasting (61), from the most recently activated device, a first probe message using the first wireless communication protocol; and

receiving (62), at the most recently activated device, a first response message from each device, within range of the first probe message, containing the communication information.

updating (33) a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices.

9. The method of claim 8, wherein the step of obtaining (32) communication information further comprises controlling each device within range of the first probe message to:

broadcast (71) a second probe message using the first wireless communication protocol;

receive (72), from each device within range of the second probe message, a second response message identifying that the said device within range of the second probe message is within range of the second probe message and thereby able to directly communicate with the device within range of the first probe message;

generate (73) a first response message containing the communication information, using the second response messages received from each device within range of the second probe message; and

transmit (74) the first response message to the most recently activated device.

10. A computer program comprising code means for implementing the method of any one of claims 1 to 9 when said program is run on a computer.

11. A processing system for enabling a plurality of devices to communicate with a backend system, wherein each device is: adapted to directly communicate with at least one other device in the plurality of devices using a first wireless communication protocol; capable of being activated so as to directly communicate with the backend system using a second wireless communication protocol; and initially inactivated, so that each device is initially unable to communicate using the second wireless communication protocol,

the processing system being configured to:

activate one of the plurality of devices, so that the activated device is able to communicate with the backend system using the second wireless communication protocol; and

perform iterative steps of:

obtaining, from each of a set of one or more devices able to directly communicate with the most recently activated device using the first wireless communication protocol, communication information, being information indicating with which other devices the device is able to communicate using the first wireless communication protocol;

updating a communication information dataset to include the obtained communication information obtained from each device in the set of one or more devices;

processing the communication information dataset to identify one of the plurality of devices for activation; and

activating the identified device, so that the activated device is able to communicate with the backend system using the second wireless communication protocol;

wherein the processor system is configured to repeat the iterative steps until each device of the plurality of devices is either an activated device or is able to directly communicate with at least one activated device using the first wireless communication protocol;

wherein the processing system is further configured to perform the step of processing (34) the communication information dataset as follows:

determining (81) whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device; and

in response to a positive determination, identifying (82) an inactivated device, having communication information in the communication information dataset, whose communication information indicates they are able to directly communicate with the greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the communication information dataset.

12. The processing system of claim 11, wherein the processing system is configured to perform the step of processing the communication information dataset as follows:

determining (83) whether two or more inactivated devices, having communication information in the communication information dataset, have communication information that indicates they are able to directly communicate with the same greatest number of inactivated devices that are unable to directly communicate with an activated device compared to other inactivated devices having communication information in the communication information dataset; and

in response to a positive determination, identifying (84) an activated device, of the two or more inactivated devices, whose communication information indicates that they are able to directly communicate with the fewest number of inactivated devices that are able to communicate with an activated device.

13. The processing system of any of claims 11 to 12, wherein the processing system is further configured to in response to the iterative steps ending, activate one or more

inactivated devices in the plurality of devices so that each device of the plurality of devices, able to communicate with at least two other devices using the first wireless communication protocol, is either an activated device or is able to directly communicate with at least two activated devices.

5

14. The processing system of any of claims 11 to 13, wherein the processing system is configured to perform the step of processing the communication information dataset as follows:

10 determining (81) whether any inactivated device, having communication information in the communication information dataset, has communication information that indicates that they are able to directly communicate with at least one other inactivated device that is unable to directly communicate with an activated device; and

15 in response to a negative determination, identifying (85) one of the inactivated devices, of the plurality of devices, not associated with any communication information in the communication information dataset.

15. A backend system for communicating with a plurality of devices, wherein the backend system forms part of processing system according to any of claims 11 to 14.

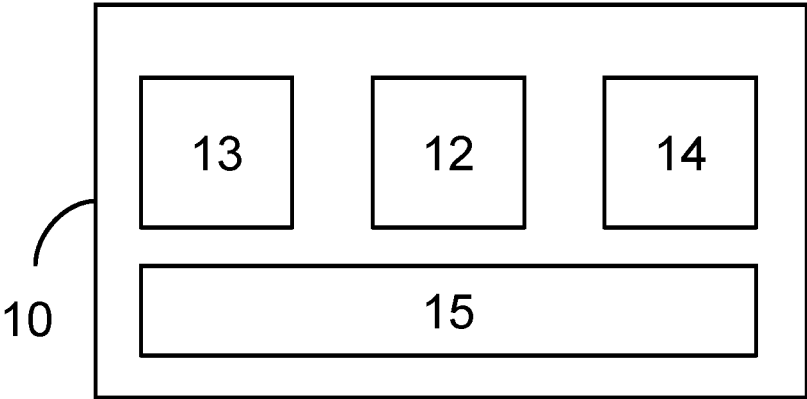


FIG. 1

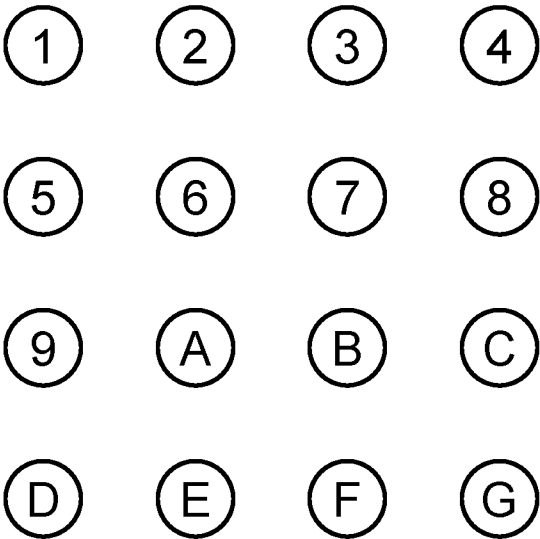


FIG. 2

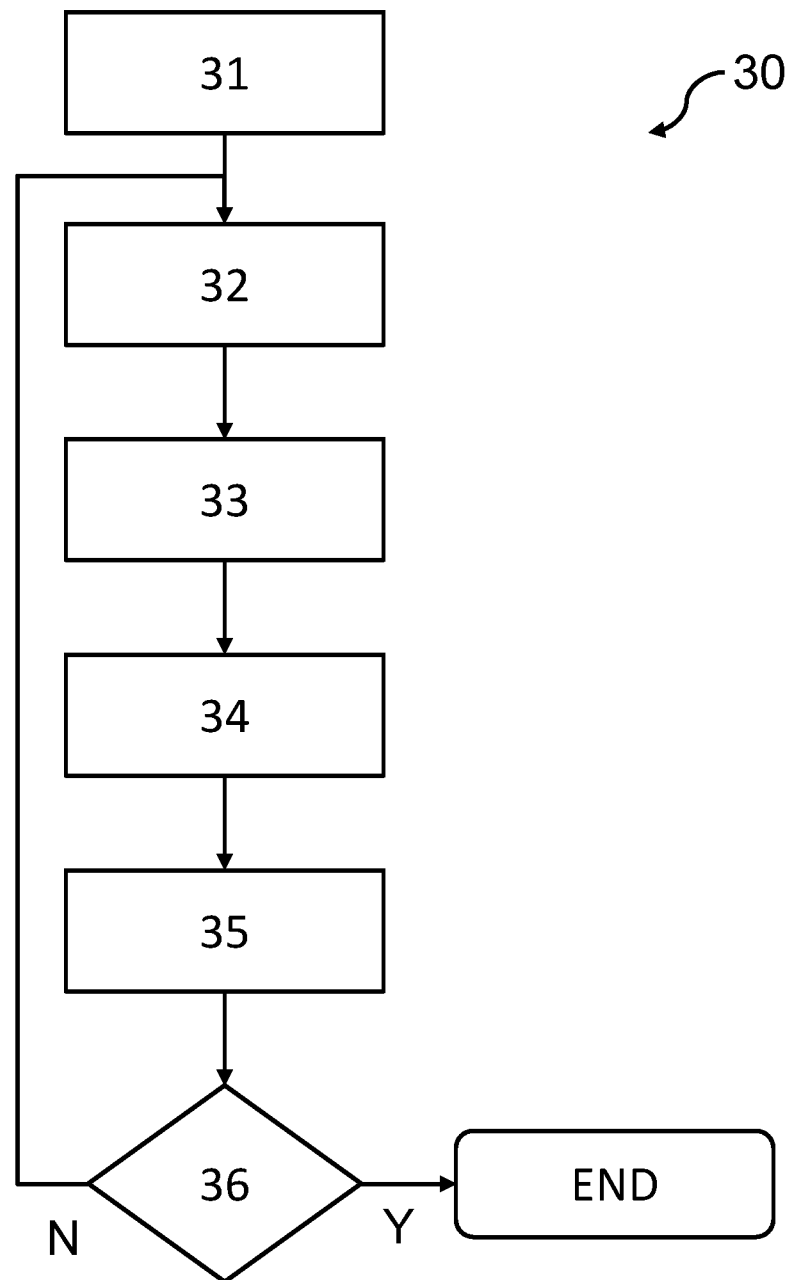


FIG. 3

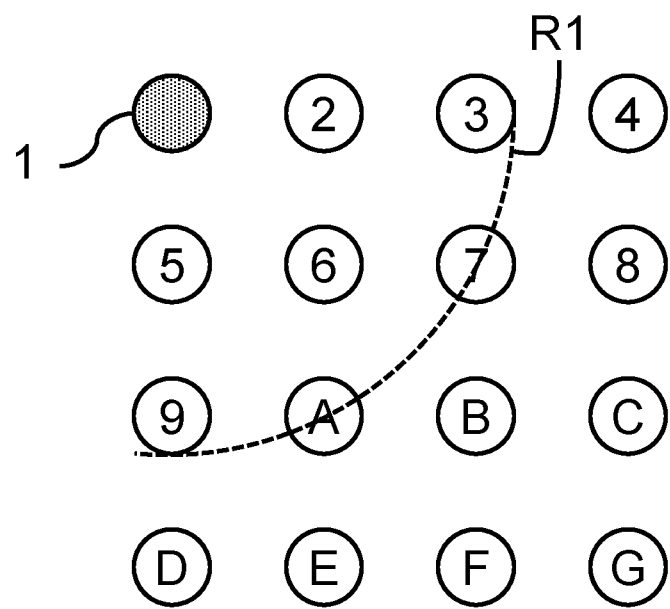


FIG. 4

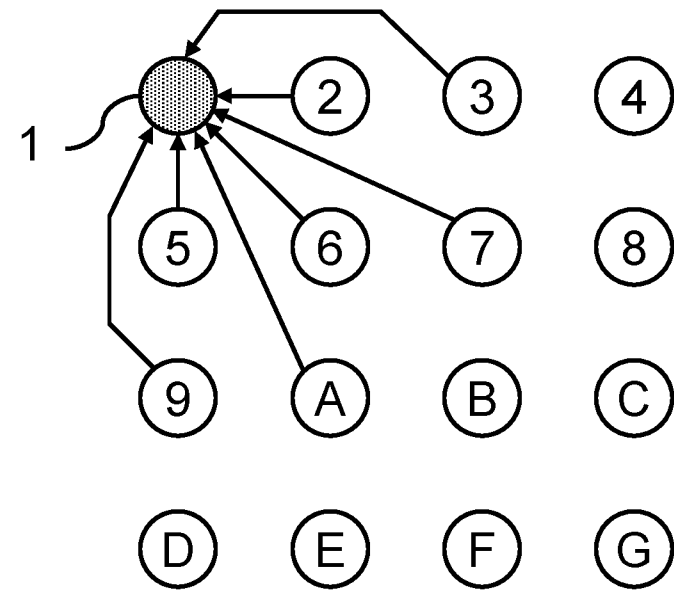


FIG. 5

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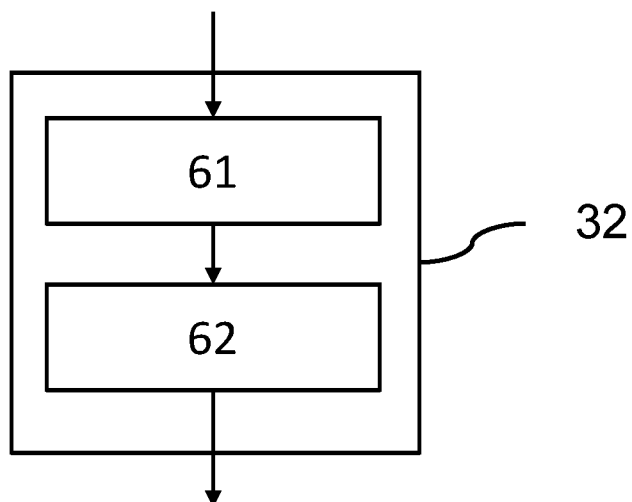


FIG. 6

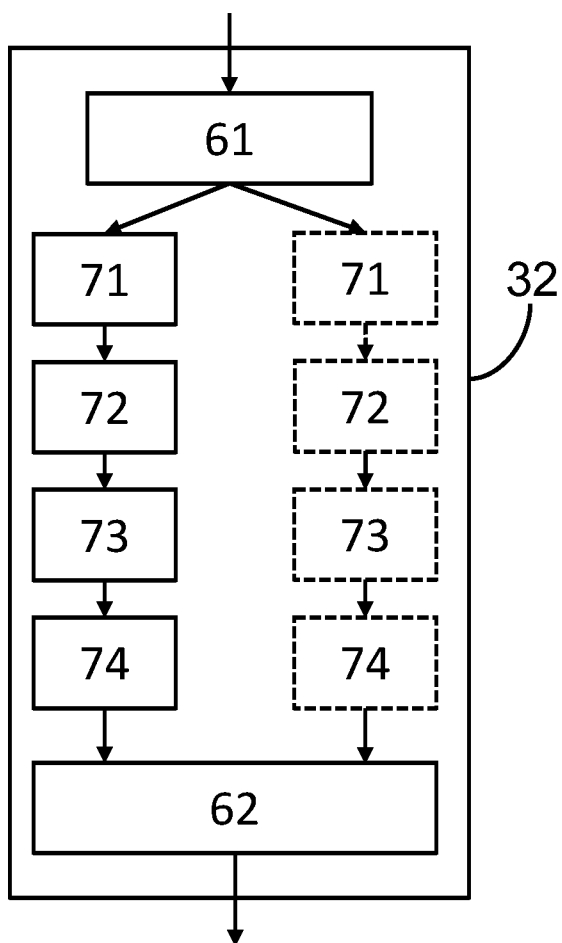


FIG. 7

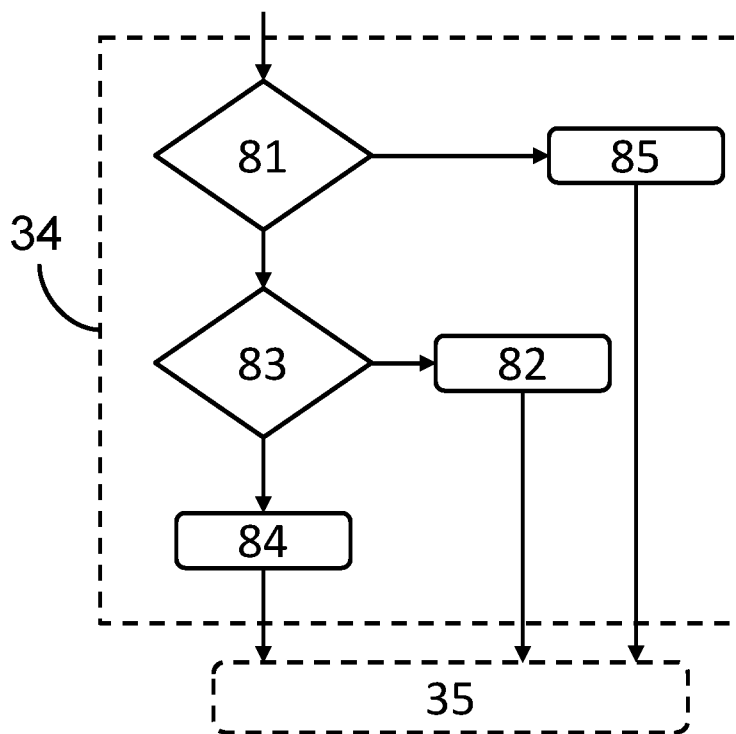


FIG. 8

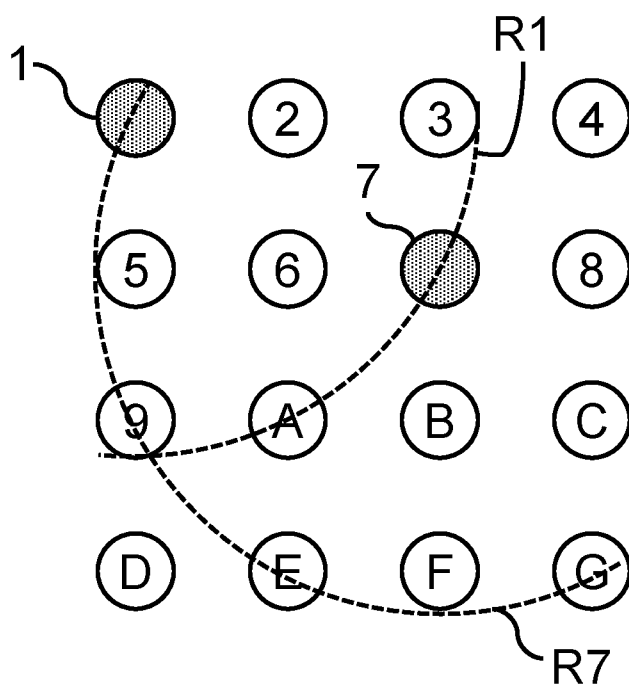


FIG. 9

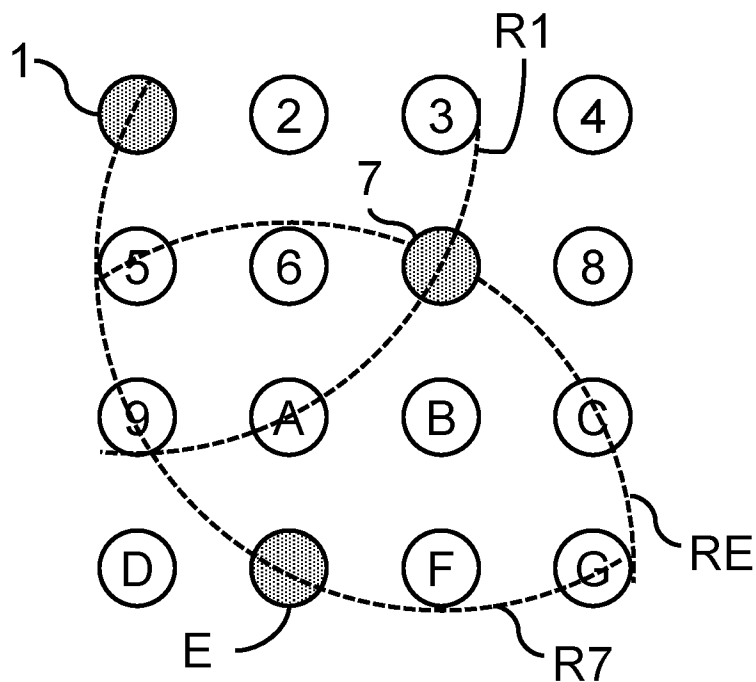


FIG. 10

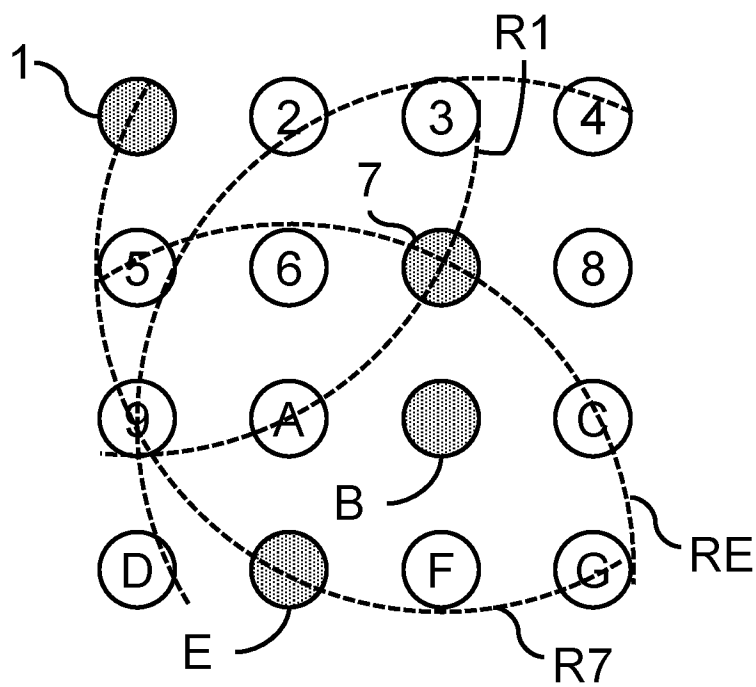


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/086298

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W84/18 H04W4/70
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)
H04W

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GENG WU ET AL: "M2M: From mobile to embedded internet", IEEE COMMUNICATIONS MAGAZINE, IEEE SERVICE CENTER, PISCATAWAY, US, vol. 49, no. 4, 1 April 2011 (2011-04-01), pages 36-43, XP011478241, ISSN: 0163-6804, DOI: 10.1109/MCOM.2011.5741144 page 39 -----	1-15
A	US 2017/127370 A1 (WANG CHONGGANG [US] ET AL) 4 May 2017 (2017-05-04) paragraphs [0059] - [0062]; figure 5A -----	1-15
A	WO 2016/015764 A1 (NEC EUROPE LTD [DE]) 4 February 2016 (2016-02-04) page 4, line 26 - page 8, line 25 page 14, line 15 - page 16, line 7 -----	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

26 March 2020

Date of mailing of the international search report

08/04/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/086298

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