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(54) **Communication method for high density wireless networks, terminal, cluster master device, central node, and system therefor.**

(57) This document describes a method for wireless communication in large-scale monitoring and actuation applications.
Typically, these networks must be designed to use efficiently available bandwidth in the wireless communication channel and to be able to deal with high node densities. The method mitigates the effects of co-channel interference, while allowing spatially distributed simultaneous transmissions.

Communication method for high density wireless networks, terminal, cluster master device, central node, and system therefor

The present invention relates to a communication method for high density wireless networks.

The present invention also relates to a terminal for use in a high density wireless network.

The present invention further relates to a cluster master device for use in a high density wireless network.

The present invention also relates to a central node for use in a high density wireless network.

Furthermore, the present invention relates to a system for use in a high density wireless network.

Large-scale wireless sensor and actuator networks (LWSANs) are networks that consist of many sensor and/or actuator devices (i.e. >1,000 devices). These sensor and/or actuator devices (also called nodes) communicate wirelessly to deliver their sensor readings to one or more gateway devices in the network or to receive information from other parts of the networks to carry out actuation tasks or receive configuration information.

This document describes the organization of wireless communication for large-scale monitoring and actuation applications. Typically, these networks must be designed to use efficiently available bandwidth in the wireless communication channel and to be able to deal with high node densities. Envisioned deployments of such networks consist of several square kilometers of terrestrial surface with nodes every few square meters. This enormous deployment area, the high sensor density and the (potential) large data volume that must be transported (potentially near real-time) make an interesting challenge. This document describes methodology to organize communication in LWSANs. Topics like spatial time slot and frequency allocation and medium access control protocols are discussed.

One of the typical requirements is that the information transfer from sensor to storage point needs to be (near) real-time. The reason for this is manifold: (1) sensor nodes must be cheap and therefore cannot store sensor traces, (2) ease of data collection is guaranteed when data is soon after sampling stored in a (central) database and (3) the system is not feasible when it takes longer to transport the data than to obtain (sample) it; any backlog introduces higher operational costs. The system design is optimized for this type of application. However, it might be applicable to different uses. Its scope is therefore not limited to devices unable to store information traces.

Prior art

In the last decade, wireless sensor networks have been described extensively in research literature [Estrin et al., 1999, *Next century challenges: Scalable coordination in sensor networks*, MobiCom'99], [Kahn et al., 1999, *Next century challenges: Networking for "Smart Dust"*, MobiCom'99], [Römer et al., 2004, *The design space of wireless sensor networks*, IEEE Wireless Communication Magazine]. The general idea is to equip sensors with (wireless) communicating capabilities, so called sensor nodes. Typically, these sensor nodes use a network stack (i.e. a set of protocols) to communicate with each other e.g. in mesh network formation, to deliver sensor readings to one or more data sinks.

In US patent application US 2009/092112, a method of clustering in wireless sensor network systems is described. Ku et al. introduce the concept of cluster heads i.e. nodes which aggregate information from one or more sensors nodes. The patent describes how to adjust the cluster size and how to merge clusters. Other communication aspects are not discussed. The term cluster is in our invention defined as a geographical region opposed to the definitions used in the prior art.

US Patent application US 2009/191906 describes a frequency channel allocation methodology to reduce co-channel interference. The patent uses dedicated gateways to determine interference levels, which are then communicated (via IP network) with all gateways in the system. Then a phase of spectrum negations takes place. Our methodology relies on self-organization or frequency channel and time slot allocation, before deploying the network. Also, our invention does not require inter-gateway communication.

Summary of the Invention

The invention describes a methodology to allow spatial reuse of the wireless medium for large-scale wireless sensor and actuator networks. The methodology uses the concept of clustering to organize communication on micro-scale, while keeping the macro-scale frequency channel and time slot assignments into consideration.

The object of the invention is achieved by providing a communication method for high density wireless networks, comprising the steps of: providing a terminal comprising a radio receiver, the terminal being comprised by one cluster comprising at least one terminal, and wherein the cluster is associated with a geographical area wherein the terminal is located; for each cluster, providing a cluster master device associated with the cluster, the cluster master device comprising a radio transmitter and a radio receiver; and providing a central node associated with at least one cluster, the central node comprising a radio transmitter and a radio receiver; wherein a plurality of clusters are associated with a super cluster; wherein communication slots are delimited in time and frequency; further comprising the steps of: within a super cluster, allocating communication slots to clusters; the cluster master device determining a schedule allocating communication slots allocated to the cluster, to the terminals comprised in the cluster; the cluster master device communicating the schedule to the terminals comprised in the cluster. By creating a geographical hierarchy of super clusters and clusters, and sensors/ actuators within the clusters, and allocating frequency and time delimited slots to subsequently super clusters, clusters, and the sensors and actuators in a cluster, the available frequency bandwidth in a geographical area is efficiently reused. Within a super cluster each time and frequency delimited communications slot is allocated only once. Within the super cluster every cluster is allocated a set of time and frequency delimited communications slots, and subsequently, within a cluster, the allocated communication slots are allocated to individual sensors and/or actuators. By means of this method according to the present application the geographical reuse of frequency slots is achieved with a minimal amount of co-channel interference.

The present invention further provides a method, wherein the terminal comprises an actuator for executing a command received from the cluster master device.

Furthermore, a method is provided, wherein the terminal comprises a sensor for measuring a physical quantity, the terminal further comprising a radio transmitter for communicating a representation of the measured quantity to the cluster master device during a communication slot allocated to the terminal.

Especially in wireless sensory networks and wireless control networks, the geographical distribution of network nodes is typically relatively dense, and the risk of co-channel interference increases with the density of the network. Therefore, the methods according to the present invention are well suited for wireless sensory networks and wireless control networks.

According to a further aspect of the present invention, a method is provided, wherein the terminal comprises a radio transmitter, the method further comprising the steps of: the cluster master device determining a quality metric of the signal received from a terminal; the cluster master device including the determined received signal quality metric in a subsequent transmission; and the terminal for which the received signal quality metric was determined, adjusting its transmitting power in order to minimise the transmitting power without the received signal quality metric dropping below a predetermined threshold. Because the cluster master device feeds back to the terminals a quality metric of the received signal, the terminals are capable of minimising their transmitting power without running the risk of the cluster master device no longer receiving the signals transmitted by one or more of the terminals. This results in the geographical area wherein a terminal’s transmitted signal can be detected, being minimised and therefore minimised the distance between terminals that use the same frequency and time delimited communication slots. Accordingly, the geographical density of the reuse of communication slots in a particular geographical area is maximised. A further advantage is the reduced power use for the terminals. Wireless terminals are often mobile terminals and are therefore often battery operated. The present invention allows for efficient battery utilisation.

The present invention further provides a method, wherein the terminal comprises a radio transmitter, the method further comprising the steps of: a terminal determining a quality metric of the signal received from a cluster master device; the terminal including the determined quality metric of the received signal in a subsequent transmission; and the cluster master device for which the received signal quality metric was determined, adjusting its transmitting power in order to minimise the transmitting power without the received signal quality metric dropping below a predetermined threshold. By also feeding back the quality of the signal as received by the transmitters, the cluster master device is also able to cut back its transmitting power in order to obtain a further reduction of geographical frequency occupation, allowing for a denser network of nodes.

Furthermore, the present invention provides a method, wherein the quality metric is the signal strength or the signal to noise ratio of the received signal.

In an embodiment the present invention further provides a terminal comprising: a radio receiver, and an actuator; wherein the terminal is associated with a cluster comprising at least a terminal and a cluster master device; and wherein the terminal is configured to: receive a schedule comprising allocations allocating a communication slot, delimited in time and frequency, to the terminal; and receive a command to be executed by the actuator during the communication slot allocated to the terminal.

In an alternative embodiment the present invention provides a terminal comprising: a radio receiver, a radio transmitter, and a sensor; wherein the terminal is associated with a cluster comprising at least a terminal and a cluster master device; and wherein the terminal is configured to: receive a schedule comprising allocations allocating a communication slot, delimited in time and frequency, to the terminal; and transmit measurement data acquired by the sensor during the communication slot allocated to the terminal.

The terminals according to the present invention are configured to receive a schedule, which schedule allocates a communication slot to the terminal. The communication slot is delimited in time and frequency, meaning a frequency (with some bandwidth defined around it) and a time period is associated with it, during which time period the terminal is allowed to use the frequency associated with the communication slot. A terminal according to the present invention allows for a centralised allocation of communication slots in order to reuse communication slots geographically making more dense wireless networks possible due to a more efficient use of the available frequencies.

In a preferred embodiment, the present invention provides a terminal, comprising a radio transmitter, the terminal further comprising: quality metric determination means for determining a quality metric for the signal received from a cluster master device, wherein the quality metric determination means are connected to the transmitter; and wherein the terminal is configured to send after determination of the quality metric, during a subsequent transmission, the determined received signal quality metric by means of the transmitter. As already described above, such a terminal allows for the cluster master device to minimise its transmission power without the risk of the terminal not being able to reliably receive the signal transmitted by the cluster master device. The determined received signal quality metric may be transmitted by the terminal in a special message dedicated for this purpose, however, in a preferred embodiment the determined received signal quality metric is piggybacking with another message.

In another embodiment according to the present invention, a terminal is provided, comprising a radio transmitter, the terminal further comprising: transmitting power control means connected to the transmitter for controlling the power of the transmitter, the transmitting power control means further being connected to the receiver; wherein the receiver is configured to receive a received signal quality metric; and the transmitting power control means are configured to minimise the transmitting power while keeping the received signal quality metric above a predetermined threshold. As also described above, the transmitting power of the terminals according to this particular embodiment is also minimised. The terminal receives a quality metric describing the quality of the signal transmitted by the terminal and as it is received by the node transmitting the quality metric. By means of the transmitting power control means, the terminal minimises its transmitting power, at the one hand reducing the geographical occupancy of the frequency allocated to it by means of the schedule and allowing for a more dense wireless network, and at the other hand reduces the power consumption, which is especially advantageous when the terminal is a battery powered device.

In an embodiment the present invention also provides a cluster master device comprising: a radio receiver, and a radio transmitter; wherein the cluster master device is comprised by a cluster, further comprising at least a terminal; and wherein the cluster master device is configured to determine a schedule comprising allocations allocating a communication slot, delimited in time and frequency, to each terminal associated with the cluster; and wherein the cluster master device is configured to: transmit to a terminal in its associated cluster, the terminal comprising an actuator, a command to be executed by the actuator, the transmission of the command being scheduled during the communication slot allocated to the terminal according to the transmitted schedule; and/or receive from a terminal in its associated cluster, the terminal comprising a sensor, measurement data acquired by the sensor, the transmission of the measurement data being scheduled during the communication slot allocated to the terminal according to the transmitted schedule. In accordance with the above description relating to the methods according to the present invention, the cluster master device allows for the efficient reuse of frequencies in a geographical area by sending a schedule to terminals in a cluster comprising also the cluster master device, the schedule allocating communication slots to the terminals.

In a further embodiment, the present invention provides a cluster master device, further configured to transmit to a central node measurement data received from a terminal comprising a sensor, to store the measurement data. In a wireless sensory network according to the present invention, data is collected by sensors. The sensors are comprised in terminals, the terminals further comprising a transmitter. By means of the transmitter, the collected data is transmitted to a cluster master device. Eventually, the cluster master device retransmits the collected data to a central node that is configured to store the collected data.

In a further embodiment, a cluster master device is provided, configured to receive from a central node a plurality of allocations of communication slots, the communication slots being delimited in time and frequency, and to determine the schedule comprising the allocations in accordance with the plurality of received allocations. This embodiment is particularly useful in a system, wherein clusters of nodes are arranged in super clusters. Within each super cluster the communication slots in the set of available communication slots, the slots being delimited in time and frequency, are allocated to the clusters in the super cluster. The central node sends the allocation of the communication slots to the cluster master device in the clusters. Each cluster master device further allocates the communication slots allocated to its cluster to the terminals in its cluster and sends this allocation by means of the schedule to the terminals in the cluster. As each communication slot is a unique combination of frequency and time in a super cluster, co-channel interference is minimised among the nodes in the super cluster.

In an alternative embodiment, a cluster master device is provided, configured to: receive a schedule transmitted by a second cluster master device and associated with a second cluster; and determine the schedule comprising the allocations of communication slots for the cluster associated with it by avoiding the usage of allocations of communication slots comprised in the received schedule of the second cluster master device. In this particular embodiment, cluster master devices listen for broadcasts from other cluster master devices and are configured to receive the schedules transmitted by other cluster master devices. If schedules from other cluster master devices are received, the cluster master device generates a schedule for the terminals in its own cluster wherein the communication slots allocated by the other cluster master devices are avoided.

In a further embodiment according to the present invention, a cluster master device is provided, comprising: quality metric determination means for determining a quality metric for the signal received from a terminal, wherein the quality metric determination means are connected to the transmitter; and wherein the cluster master device is configured to send after determination of the quality metric, during a subsequent transmission, the determined received signal quality metric by means of the transmitter.

In another embodiment according to the present invention, a cluster master device is provided, comprising: transmitting power control means connected to the transmitter for controlling the power of the transmitter, the transmitting power control means further being connected to the receiver; wherein the receiver is configured to receive a received signal quality metric; and the transmitting power control means are configured to minimise the transmitting power while keeping the received signal quality metric above a predetermined threshold.

Furthermore, the present invention provides an apparatus, wherein the received signal quality metric is the signal strength or the signal to noise ratio of the received signal.

The present invention also provides an embodiment by means of a central node comprising: a radio receiver, and a data storage; wherein the central node is configured to receive measurement data from a cluster master device, and to store the received measurement data in the data storage. As described above, in a wireless sensory network, data is collected by terminals comprising sensors. The terminals transmit the collected data to the cluster master device of their cluster. Subsequently, the cluster master device forwards the collected data to a central node, which central node is specifically configured to store the sensory data.

The present invention also provides a central node comprising: a radio transmitter for communicating with at least one cluster master device, the cluster master device being comprised in a cluster further comprising at least one terminal, the cluster being comprised in a super cluster comprising at least one further cluster; means for determining for each cluster in the super cluster, an allocation of communication slots, delimited in time and frequency; wherein the central node is configured to transmit the allocation of communication slots to the cluster master device of each cluster in the super cluster. The central node according to this embodiment allocates available communication slots to each cluster in a super cluster, ensuring an allocated communication slot is allocated to a cluster only once in a super cluster. Once communication slots are allocated, the central node transmits the allocations to the cluster master devices of the clusters.

In an embodiment the present invention provides a system comprising a terminal according to the present invention; a cluster master device according to the present invention; and a central node according to the present invention.

Brief description of Figures

Figure 1 illustrates the components of the large-scale wireless sensor and actuator network. The system groups sensor/actuator nodes with data collectors based upon their geographic position. Figure 2 shows communication patterns in the large-scale wireless sensor and actuator network, and illustrates how co-channel interference exists. This patent describes communication methodologies, which mitigate the illustrated co-channel interference by using cluster and super cluster structures. Figure 3 depicts the communication protocol at micro-scale that is used to organize communication between sensor/actuator nodes and their appointed data collectors. Figure 4 shows how this micro-scale protocol is applied in at macro-scale to organize the communication in multiple clusters to mitigate the effects of co-channel interference. Figure 5 depicts an example embodiment.

Detailed description

Layered wireless communication architecture: macro and micro-scales

A layered organization of the LWSAN in terms of communication is proposed. At the first communication layer, sensor information is collected into *data collector devices* (DCs) using *radio frequency* (RF) transmissions. The DCs (also referred to as cluster master) organize the wireless communication at micro-scale. At the macro-scale, the communication is organized in network wide sense, such that the wireless medium is spatially reused in both time and frequency domains, such that co-channel interference is mitigated.

To complete the large-scale wireless sensor and actuator network, DCs need to deliver the collected information to one or more *central storage points* (SPs), also referred to as central nodes. In addition, control and configuration information needs to be propagated from SP to wireless sensors via the DCs. The communication between DCs and SP(s) is outside the scope of this patent.

Micro-scale: wireless sensor to data collector communication

At macro-scale, wireless sensors (also referred to as terminals) are grouped into clusters. Clusters can have any arbitrary geographical shapes, such as but not limited to closed polygons. Typical shapes are rectangles or hexagons. All wireless sensors within the geographical boundaries of a cluster belong to that cluster. Wireless sensors belong to at most one cluster. Clusters are identified by a unique number. Within a cluster, wireless sensor nodes are arbitrary positioned. In another embodiment of this patent, sensor nodes are deployed in a grid-like fashion.

Each of these clusters is intended to operate independently in terms of wireless communication and each can be regarded as a separate WSN. Within the cluster, one DC collects all sensor data and takes care of synchronizing the sensor nodes in its cluster. Additionally, it organizes communication in its cluster through a communication protocol. This protocol is defined later on in this patent.

The invention allows wireless devices to share a (small) set of (orthogonal) frequency channels and a (small) set of time slots, in cases where the sum of the generated data volume is larger than the summed data bandwidth of the single frequency channels. In particular, spatial reuse of the wireless communication medium is used, while keeping interference levels at a minimum.

As first option, a data collector device is centrally informed (e.g. via SP) of wireless communication parameters it needs to respect, such as the frequency channel it needs to use and the exact moments it might emit energy in the frequency channel or might request wireless sensors to emit energy in the frequency channel. We denote these communication parameters respectively as frequency channel (denoted with f) and time slot (denoted with t), which describes when the data collector device (periodically) might emit energy in the wireless medium, or when the wireless sensors in the cluster of the data collector might emit energy.

As second option, a data collector device retrieves the communication parameters through self-configuration e.g. by assessing the frequency band usage and time slot usage by other data collectors and/or interpreting explicitly transmitted information by other data collectors and/or random selection of communication parameters in case of selection ties or insufficient information to carry out a selection otherwise.

The micro-scale communication protocol

In our communication protocol at the first layer, the date collector devices respect the macro-scale communication parameters f and t, and ensure that wireless sensors in its cluster also respect the parameters at all times.

The data collector device creates a schedule for the period it and the wireless sensor nodes belonging to its cluster is/are allowed emitting energy in the wireless medium. The schedule describes which devices (by identification number) might transmit information (i.e. wireless sensors and the data collector itself). In another embodiment of this invention, the schedule might include reserved time for random access of the wireless medium, in which any wireless sensor might announce itself and transfer information to the data collector. The data collector propagates the schedule to the wireless sensors in its cluster, including information about the duration of the time interval in which energy might be emitted in the wireless medium and a description of when the data collector will announce a next schedule (while respecting the t and f parameters). Timing information can be expressed as relative or absolute time.

The wireless sensors respect the schedule as given by the data collector device and carry out receives and transmit operations according to the given schedule. The wireless sensor devices synchronize with the data collector and ensure that they receive the next schedule.

When a wireless sensor device is not needed for communication within the communication interval of the cluster (as announced by the data collector) or outside the communication interval, it might switch off its RF communication modality and consequently neither transmits nor receives. This can be beneficial for the energy-consumption of the wireless sensor node.

The micro-scale protocol is illustrated in Figure 3 and is explained later in the patent.

Macro-scale: Independency of communication between clusters

In the previous section, a communication methodology has been described at micro-scale. In this section, we discuss how a large-scale sensor and actuator network can be created using the clustered approach.

Given at most f_{max} orthogonal frequency channels and t_{max} time intervals that represent a repeating schedule, a super cluster is created consisting of f_{max} times t_{max} clusters. In principle, each cluster within the super cluster is given (through assignment or self-organisation mechanisms) a different combination of frequency channel (denoted with f) and time interval (denoted with t). As a result, each cluster within a super cluster is able to communicate without causing interference to any other cluster in the same super cluster, because communication takes place simultaneously in the different frequency channels, but never simultaneously in the same frequency channel.

Clusters from one super cluster can cause interference with clusters from other super clusters. Super clusters are to be aligned such that the distance between interfering clusters (i.e. same t,f combination) is maximal. Super clusters might contain less than the maximum of f_{max} times t_{max} rectangular clusters, if –for example- a smaller coverage area is required.

Mitigating co-channel interference

In practical situations, the number of (orthogonal) frequencies (f_{max}) is limited and the use of large number of time slots (t_{max}) is impractical due to stringent synchronization requirements. The number of frequency channels (f_{max}) is given by transceiver choice and/or standards, (ISM) bands, licensed bands etc. The number of time slots is a design choice with respect to the required raw bandwidth. Given t_{max}, the required sensor data bandwidth, the number of devices per cluster and overhead, one can calculate the raw bandwidth a transceiver must be able to support.

An important measure to determine the success of a large-scale wireless sensor and actuator network using the aforementioned communication strategies is the amount of *co-channel interference* (CCI) i.e. how much the devices in the network interfere with themselves. A valid feasibility check would therefore be centred on co-channel interference calculations.

A first option would be centred on the tuning of the parameters f and t. Given the required raw bandwidth per cluster and the bandwidth of the selected transceiver, t_{max} can be calculated. Next, f_{max} is determined by calculating the maximum CCI for a given topology and comparing this with the CCI acceptance of the selected RF transceiver.

A second option would be centred on the selection of a feasible RF transceiver. The maximum CCI is calculated given the deployment setup. Next, a transceiver would selected that is able to (1) deliver the above mentioned raw bandwidth, (2) f_{max} channels and (3) is robust against the calculated maximum CCI. Calculations can either assume a finite or infinite deployment.

Detailed Description of figures

Figure 1 illustrates the components of the large-scale wireless sensor and actuator network:

- At macro-scale, wireless sensors are grouped into clusters (11), (12), (13). Clusters can have any arbitrary geographical shapes, such as, but not limited to closed polygons. A set of clusters in which communication does not interfere, because micro-scale communication takes place in different time slots and/or different (orthogonal) frequency channels is called a super cluster. A super cluster is formed from adjacent clusters. A cluster belongs always to exactly one super cluster. Super clusters can be identified by unique identifiers.

- Data collector devices (DCs), denoted with (21), (22), (23), control the communication within the cluster (i.e. a group of wireless sensors within a geographical area or a logical group of wireless sensors). There is exactly one data collector device per cluster. Data collectors are able to backlog information until it can be transferred to a central storage point.

- Storage point (SP), denoted with (31), (32), (33), which collects sensor information generated by wireless sensors in the large-scale wireless sensor and actuator network. Its physical location may be anywhere (within one cluster or even outside the clusters). Optionally, the functionality of the storage point can be integrated with a data collector (DC). There is at least one storage point per network.

- Wireless sensors and/or actuators (41) to (47) belong to exactly one cluster and its aim is to deliver its sampled sensor data to the data collector device within its cluster.

Figure 2 depicts communication patterns in the large-scale wireless sensor network and potential interference that can occur:

- At macro-scale, the DCs communicate with SPs via a separate high bandwidth radio link, wired link or optical link (5). In another embodiment of this invention, a multi-hop link (6) is used i.e. DCs act as relays. The storage points aggregate the information of many clusters and store the information for future reference. The storage point can transfer (but not limited to) configuration – in particular t,f assignments to DCs, if a centralized approach for t,f assignment has been chosen - synchronization and control information to the data collectors (either unicast or multicast). In their turn, data collectors transmit status information and collected sensor information.

- The DC contains thus at least two wireless communication modalities. The first is intended to communicate with sensors within the cluster (71), (72), (73), the other to communicate with the storage point or (optionally) with other data collectors. Both communication modalities are able to operate at the same time instance, although this is not strictly necessary. Typically, both transceivers will operate a different carrier frequencies and might have different modulation techniques and bit rates.

- At certain points in time, one wireless sensor (41) transmits information to the data collector (21) within its cluster or the DC transmits configuration, actuation commands or other information to one or more sensor nodes. The wireless communication within the cluster is organized such that exactly one device transmits within the cluster per instance of time, indicated with (71), (72), (73). A communication protocol is provided in this document.

- Any wireless transmission (71), (72), (73) can cause interference with transmissions in other clusters in the large-scale wireless sensor and actuator network. The interference is denoted with (711), (712), (731). Not all interference possibilities are drawn in Figure 2. Aim of the organization of communication is to limit the interference to acceptable levels, such that the wireless links between data collector and wireless sensors are not significantly degraded by interference. Data collector devices may actively use transmissions originating from other clusters to (but not limited to) enable self-organization of communication, synchronization or finding its geographical or logical position. Within a super cluster, transmissions do not interfere.

Figure 3 depicts the communication protocol for wireless sensor to/from data collector wireless communication (i.e. micro-scale communication):

Ad (8): The protocol uses the concept of frames i.e. the structure of the protocol is periodically repeated. The protocol operates in one frequency band, however, multiple instances of the protocol might be active at different and the same frequency band in the same large-scale wireless sensor network. The multiple instances of the protocol are depicted in Figure 4. To all used packet types, Forward Error Correction (FEC) coding might be applied.

Ad (80): The Poll Message (PM) is transmitted by the data collector device. All wireless sensor devices in the cluster receive this message. The PM messages contain at least, but not limited to, the following:

a. Protocol header (e.g. message type, encryption flags, etc.)

b. Identification number of data collector

c. Identification number of the cluster

d. Accurate timing information (both actual time and protocol timing information). The sensor nodes use this timing as reference.

e. Protocol parameters

i. Number of data blocks (DMs) before Frame End Message (FEM)

ii. Duration of the frame

iii. Maximum size of data blocks

iv. Maximum output power to be used by the wireless sensors

v. Frequency channel

f. Allocation of data messages (DM) following the PM. The allocation consists of a list with one entry per DM. Entries can be marked as reserved for a particular device, random access, prohibited from use or broadcast from data collector. Typically, an entry consists of a logical index of a DM and a device address or address mask.

g. Acknowledgement vector for previous data messages

h. (Optionally) Short commands for sensors e.g. actuation commands

i. (Optionally) Position coordinates of the data collector

j. Protocol footer (e.g. CRC, encryption check codes, etc).

Ad (81): The protocol allows a short turn-around time for the sensor node, which is allowed to transmit in the next DM block (this time is required to prepare a DM packet and to change the state of its wireless transceiver). The duration of this time is set depending on the transceiver being used.

Ad (87): The Data Message (DM) carries the information payload. The data collector receives all DMs according to the schedule it indicated in its PM. In order to conserve energy, sensor nodes might not overhear packets from other sensor nodes. However, if the application of the large-scale wireless sensor and actuator networks allows efficient data handling (e.g. compression), sensors might overhear DMs from other sensors to apply locally this efficient data handling. The packet contains at least the following:

a. Protocol header (e.g. message type, encryption flags, etc.)

b. Identification number of sensor node

c. (Optionally) Destination of the packet (used for packets originating from data collector)

d. (Optionally) Position of the device or an estimate

e. (Optionally) Protocol parameters.

f. (Optionally) Received signal strength of the PM

g. Payload, that complies with the request in the PM. The payload may contain pre-processed data e.g. correlation calculations of sensor samples.

h. Protocol footer (e.g. CRC, encryption check codes, etc).

Ad (82): The protocol allows a small interval between DMs to allow the data collector to process received packet (and to prepare a packet to be transmitted, if required), to allow clock drift between the various devices and to guarantee that receivers (that need to receive) are ready before the next DM is transmitted.

Ad (83): A variable number of DMs can be requested in the PM.

Ad (84): After the last DM, the protocol allows a small time interval for the data collector to process the last received DM and to prepare the FEM.

Ad (85): The data collector transmits a Frame End Message (FEM). This message is received by all sensor nodes, which transmitted a DM. It services as acknowledgement to the data or received random access messages. Additionally, it carries received signal strengths of each received DM by the data collector. This allows for autonomous tuning of transmit power (limited by the value in the PM) within the sensor nodes. The received signal strength can be determined by either using successful received packets or by measuring energy levels of received carrier signals.

Ad (86): The protocol implements a silent period. None of the devices in the cluster will transmit during this period. In fact, other clusters might be active during this period in the same frequency band. The data collectors need to make sure that the schedules do not collide. For this purposes, the DCs take assigned t,f combination into consideration. The sensor nodes carefully remain synchronized and wake in time to receive the next PM of the data collector of their cluster. Again, clock drift has to be taken into account for setting a wake-up time in the sensor nodes (i.e. sensor nodes need to switch to receive before the PM is transmitted).

Figure 4 depicts multiple instances of the protocol that are active at different, and the same frequency band in the same large-scale wireless sensor network. Each of the data collectors execute single instances of the protocol and follow their t,f assignment (either trough self-configuration or central assignment).

Ad (88): Time slots for one particular instance of the protocol, depicted in Figure 3, repeat every frame.

Ad (89): Within a frame, different instances of the micro-scale protocol might be active. Each of these instances uses identical frame durations, but are time shifted. The individual DCs make sure that they and the sensor/actuator nodes belonging to their cluster, do not communicate after FEM until the next PM.

Ad (890): There might be unoccupied time intervals at macro-scale. These intervals can be reserved to add more clusters to the deployment or to (temporarily) assign more bandwidth to clusters. A (orthogonal) frequency channel is indicated by (891). The micro-scale protocol can simultaneously be applied at various positions in the frequency spectrum.

Example embodiment of the invention

Figure 5 depicts an example embodiment of the invention. Wireless sensor/actuator nodes are deployed in a rectangular grid with 5 m spacing between nodes in both rows and columns of the deployment (not drawn in Figure 5). In the example embodiment of the invention, a cluster consists of 100 sensor nodes and covering 2500 m^2 with a square cluster shape of 50 m times 50 m.

In the example embodiment, the number of (orthogonal) frequencies (f_{max}) is limited to 8 and the number of time slots (t_{max}) is set to 8. Each of the clusters ((11) to (164)) uses a unique combination of frequency channel and time slot out of the 64 combinations. The combination label is indicated by (201). Clusters can communicated without interference within a super cluster (203), however clusters can interfere with clusters from other super clusters. Super clusters are spatially such aligned that interference is minimized. For example, all clusters that use combination t_1, f_1 -indicated by (200)- interfere with each other. The feasibility of the example embodiment can be verified by calculating the maximum ratio of all emitted RF power by interfering clusters (200) excluding one target cluster (e.g. (11), which also uses t_1, f_1) and the energy of transmissions in the target cluster, both seen from a target device within the targeted cluster (11). The deployment is feasible for the target device if its transceiver is robust against the calculated co-channel interference ratio. When the deployment is not feasible, the parameters t_{max} and f_{max} can be tuned or a different transceiver technology should be selected. In addition to checking feasibility with respect to co-channel interference, also data throughput must be taken into consideration.

The embodiments shown here are only shown for illustrative purposes and are in not limiting the present invention. It will be apparent to the person skilled in the art that numerous modifications and adaptations are possible within the present invention. For example, the person skilled in the art will understand that features from different embodiments can be combined without departing from the present invention. The scope of protection sought is only limited by the appended claims.

Conclusies

1. Communicatiewerkwijze voor draadloze hoge-dichtheidnetwerken, omvattende de stappen van:

het verschaffen van een terminal omvattende een radio-ontvanger, waarbij de terminal omvat is door een cluster omvattende ten minste één terminal, en waarbij het cluster geassocieerd is met een geografisch gebied waarin de terminal gelegen is;

voor elk cluster, het verschaffen van een clustermasterapparaat, dat geassocieerd is met het cluster, waarbij het clustermasterapparaat een radiozender omvat en een radio-ontvanger; en

het verschaffen van een centraal knooppunt dat geassocieerd is met ten minste één cluster, waarbij het centrale knooppunt een radiozender en een radio-ontvanger omvat;

waarbij een aantal clusters geassocieerd zijn met een supercluster;

waarin communicatiesloten begrensd zijn in tijd en frequentie;

verder omvattende de stappen van:

binnen een supercluster, het toewijzen van communicatiesloten aan clusters, zodanig dat het supercluster en zijn aangrenzende superclusters zodanig geplaatst zijn dat de afstand tussen clusters met identieke communicatiesloten maximaal is;

het door het clustermasterapparaat vaststellen van een schema dat communicatiesloten die toegewezen zijn aan het cluster toewijst, aan de terminals die omvat zijn door het cluster;

het door het clustermasterapparaat communiceren van het schema aan de terminals die omvat zijn door het cluster.

2. Werkwijze volgens conclusie 1, waarbij de terminal een aandrijver, actuator, omvat voor het uitvoeren van een opdracht verzonden vanuit het clustermasterapparaat.

3. Werkwijze volgens conclusie 1, waarbij de terminal een opnemer omvat voor het meten van een fysieke grootheid, waarbij de terminal verder een radiozender omvat voor het communiceren van een representatie van de gemeten grootheid aan het clustermasterapparaat gedurende een communicatieslot dat toegewezen is aan de terminal.

4. Werkwijze volgens conclusie 1 of 2, waarbij de terminal verder een radiozender omvat, of een werkwijze volgens conclusie 3,

waarbij de werkwijze verder de stappen omvat van:

het door het clustermasterapparaat vaststellen van een kwaliteitsgrootheid van het signaal dat ontvangen is van een terminal;

het door het clustermasterapparaat meesturen van de vastgestelde ontvangen-signaalkwaliteitsgrootheid in een volgende uitzending; en

het door de terminal waarvoor de ontvangen-signaalkwaliteitsgrootheid werd vastgesteld, aanpassen van zijn zendvermogen ten einde het zendvermogen te minimaliseren zonder dat de ontvanger-signaalkwaliteitsgrootheid onder een vooraf bepaalde drempelwaarde zakt.

5. Werkwijze volgens conclusie 1 of 2, waarbij de terminal verder een radiozender omvat, of een werkwijze volgens conclusie 3 of 4,

waarbij de werkwijze verder de stappen omvat van:

het vaststellen door een terminal van een kwaliteitsgrootheid van het signaal dat ontvangen is van een clustermasterapparaat;

het door de terminal meesturen van de vastgestelde kwaliteitsgrootheid van het ontvangen signaal in een volgende uitzending; en

het door het clustermasterapparaat waarvoor de ontvangen-signaalkwaliteitsgrootheid vastgesteld was, aanpassen van zijn zendvermogen teneinde het zendvermogen te minimaliseren zonder dat de ontvangen-signaalkwaliteitsgrootheid onder een vooraf bepaalde drempelwaarde zakt.

6. Werkwijze volgens conclusie 4 of 5, waarbij de kwaliteitsgrootheid de signaalsterkte of de signaal/ruis-verhouding is van het ontvangen signaal.

7. Terminal omvattende:

een radio-ontvanger, en

een aandrijver, actuator;

waarbij de terminal geassocieerd is met een cluster dat tenminste één terminal omvat en een clustermasterapparaat; en

waarbij de terminal geconfigureerd is om:

- een schema te ontvangen omvattende toewijzingen die communicatiesloten die begrensd zijn in tijd en frequentie, toewijzen aan de terminal; en
- een opdracht te ontvangen gedurende het communicatieslot dat toegewezen is aan de terminal,

welke opdracht uitgevoerd dient te worden door de actuator.

8. Terminal omvattende:

een radio-ontvanger,

een radiozender, en

een opnemer;

waarbij de terminal geassocieerd is met een cluster omvattende ten minste een terminal en een clustermasterapparaat; en

waarbij de terminal ingericht is om:

- een schema te ontvangen dat toewijzingen omvat die communicatiesloten die begrensd zijn in tijd en frequentie, toewijst aan de terminal en
- meetgegevens te verzenden gedurende het communicatieslot dat toegewezen is aan de terminal, welke meetgegevens verkregen zijn door de opnemer.

9. Terminal volgens conclusie 7, verder omvattende een radiozender, of een terminal volgens conclusie 8,

de terminal verder omvattende:

kwaliteitsgrootheidvaststellingsmiddelen voor het vaststellen van een kwaliteitsgrootheid voor het signaal dat ontvangen wordt van een clustermasterapparaat, waarbij de kwaliteitsgrootheidvaststellingsmiddelen verbonden zijn met de radiozender; en

waarbij de terminal ingericht is om na het vaststellen van de kwaliteitsgrootheid de vastgestelde ontvangen-signaalkwaliteitsgrootheid door middel van de radiozender te verzenden gedurende een volgende uitzending.

10. Terminal volgens conclusie 7, verder omvattende een radiozender, of een terminal volgens conclusie 8 of 9,

de terminal verder omvattende:

zendvermogenbesturingsmiddelen die verbonden zijn met de zender voor het besturen van het vermogen van de zender, waarbij de zendvermogenbesturingsmiddelen verbonden zijn met de ontvanger;

waarbij

de ontvanger ingericht is om een ontvangen-signaalkwaliteitsgrootheid te ontvangen; en

de zendvermogenbesturingsmiddelen ingericht zijn om het zendvermogen te minimaliseren terwijl de ontvangen-signaalkwaliteitsgrootheid boven een vooraf vastgestelde drempelwaarde gehouden wordt.

11. Clustermasterapparaat omvattende:

een radio-ontvanger, en

een radiozender;

waarbij het clustermasterapparaat omvat is door een cluster, verder omvattende ten minste één terminal; en

waarbij het clustermasterapparaat ingericht is om een schema vast te stellen omvattende toewijzingen die een communicatieslot dat begrensd is in tijdfrequentie, toewijzen aan elke terminal die geassocieerd is met het cluster; en

waarbij het clustermasterapparaat ingericht is om:

aan een terminal in zijn geassocieerde cluster, welke terminal een aandrijver, actuator, omvat, een opdracht te verzenden dat uitgevoerd dient te worden door de aandrijver, waarbij de verzending van de opdracht uitgevoerd wordt gedurende het communicatieslot dat toegewezen is aan de terminal volgens het verzonden schema; en/of het van een terminal in zijn geassocieerde cluster, waarbij de terminal een opnemer omvat, ontvangen van meetgegevens die verkregen zijn door de opnemer, waarbij de verzending van de meetgegevens uitgevoerd wordt gedurende het communicatieslot dat toegewezen is aan de terminal volgens het verzonden schema.

12. Clustermasterapparaat volgens conclusie 11 dat verder ingericht is om aan een centraal knooppunt meetgegevens te verzenden die ontvangen zijn van een terminal die een opnemer omvat, ten einde de te meetgegevens op te slaan.

13. Clustermasterapparaat volgens conclusie 11 of 12, dat verder ingericht is om vanuit een centraal knooppunt een aantal toewijzingen te ontvangen van de communicatiesloten, welke communicatiesloten begrensd zijn in tijd en frequentie, en, in overeenstemming met het aantal ontvangen toewijzingen, het schema vast te stellen dat de toewijzingen omvat.

14. Clustermasterapparaat volgens conclusie 11 of 12, ingericht om:

een schema te ontvangen dat verzonden is door een tweede clustermasterapparaat en dat geassocieerd is met een tweede cluster, en

het vaststellen van het schema omvattende de toewijzingen van de communicatiesloten voor het cluster dat geassocieerd is met het clustermasterapparaat door het vermijden van het gebruik van toewijzingen van communicatiesloten die omvat zijn in het ontvangen schema van het tweede clustermasterapparaat.

15. Clustermasterapparaat volgens één van de conclusie 1-14, omvattende:

kwaliteitsgrootheidvaststellingsmiddelen voor het vaststellen van een kwaliteitsgrootheid voor het signaal dat ontvangen wordt van een terminal, waarbij de kwaliteitsgrootheidvaststellingsmiddelen verbonden zijn met de zender; en

waarbij het clustermasterapparaat ingericht is om na het vaststellen van de kwaliteitsgrootheid gedurende een volgende verzending de vastgestelde ontvangen-signaalkwaliteitsgrootheid door middel van de zender te verzenden.

16. Clustermasterapparaat volgens een van de conlusies 11-14, omvattende:

zendvermogenbesturingsmiddelen verbonden met de zender voor het besturen van het vermogen van de zender, waarbij de zendvermogenbesturingsmiddelen verder verbonden zijn met de ontvanger;

waarbij

de ontvanger ingericht is om een ontvangen-signaalkwaliteitsgrootheid te ontvangen; en

de zendvermogenbesturingsmiddelen ingericht zijn om het zendvermogen te minimaliseren terwijl de ontvangen-signaalkwaliteitsgrootheid boven een vooraf vastgestelde drempelwaarde gehouden wordt.

17. Apparaat volgens één van de conclusies 7-16, waarbij de ontvangen-signaalkwaliteitsgrootheid de signaalsterkte is of de signaal/ruisverhouding van het ontvangen signaal.

18. Centraal knooppunt omvattende:

een radio-ontvanger en

een gegevensopslag;

waarbij het centrale knooppunt ingericht is om meetgegevens te ontvangen van een clustermasterapparaat, en om de ontvangen meetgegevens op te slaan in de gegevensopslag.

19. Centraal knooppunt omvattende: een radiozender voor het communiceren met ten minste één clustermasterapparaat, waarbij het clustermasterapparaat omvat is in een cluster dat verder ten minste één terminal omvat, waarbij het cluster omvat is in een supercluster dat ten minste één verder cluster omvat;

middelen voor het voor elk cluster in het supercluster vaststellen van een toewijzing van communicatiesloten, welke communicatiesloten begrensd zijn in tijd en frequentie;

waarbij het centrale knooppunt ingericht is om de toewijzing van communicatiesloten te verzenden aan het clustermasterapparaat van elk cluster in het supercluster.

20. Systeem omvattende

een terminal volgens één van de conclusies 6-10;

een clustermasterapparaat volgens één van de conclusies 11-16; en

een centraal knooppunt volgens conclusie 18 of 19.

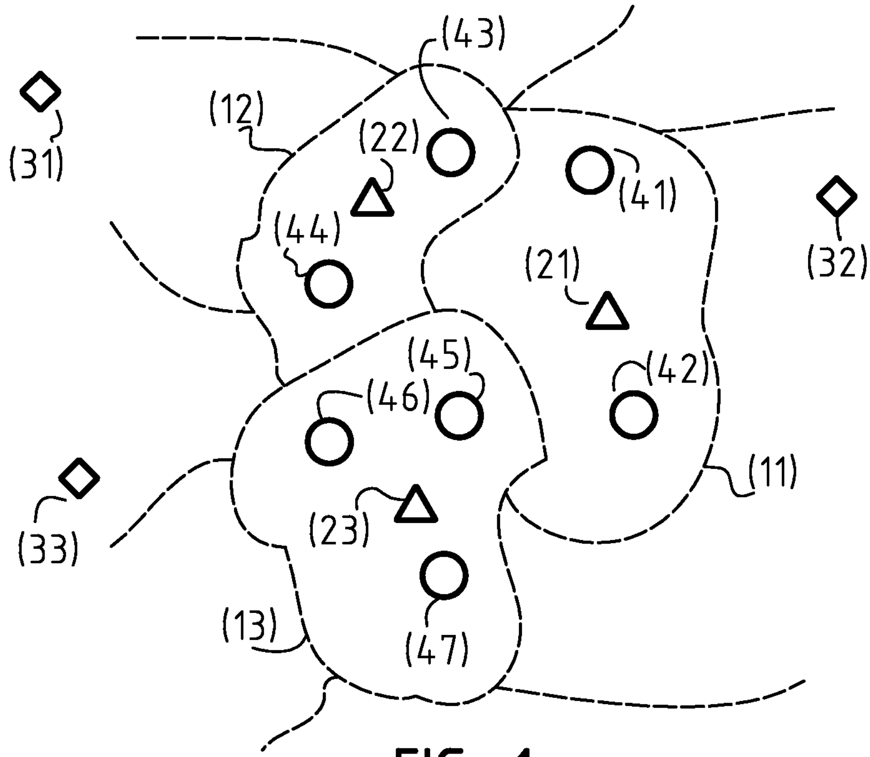
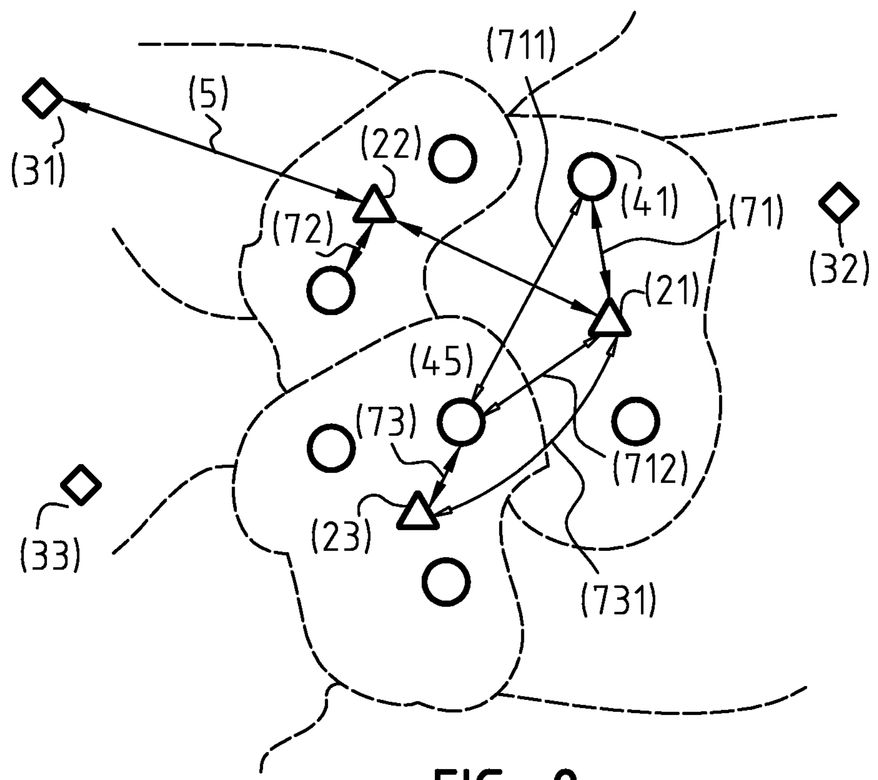

(43)
(12)
(22)
(31)
(41)
(32)
(44)
(21)
(45)
(42)
(46)
(11)
(33)
(23)
(13)
(47)

FIG. 1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(5)
(31)
(22)
(41)
(71)
(72)
(32)
(21)
(45)
(73)
(712)
(33)
(23)
(731)

FIG. 2

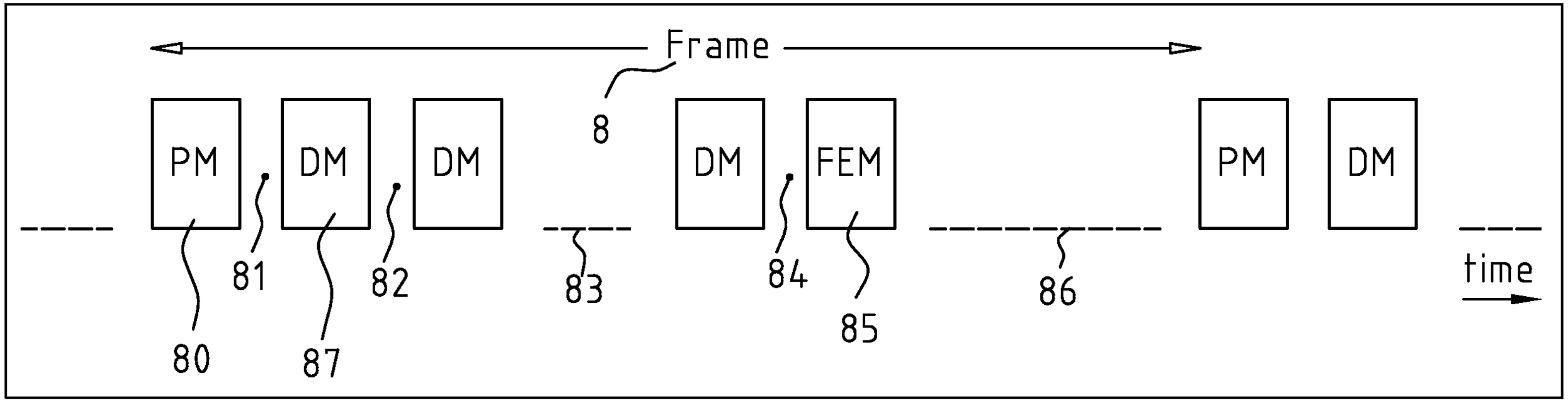
Frame
8
PM
DM
DM
DM
FEM
PM
DM
80
81
87
82
83
84
85
86
time

FIG. 3

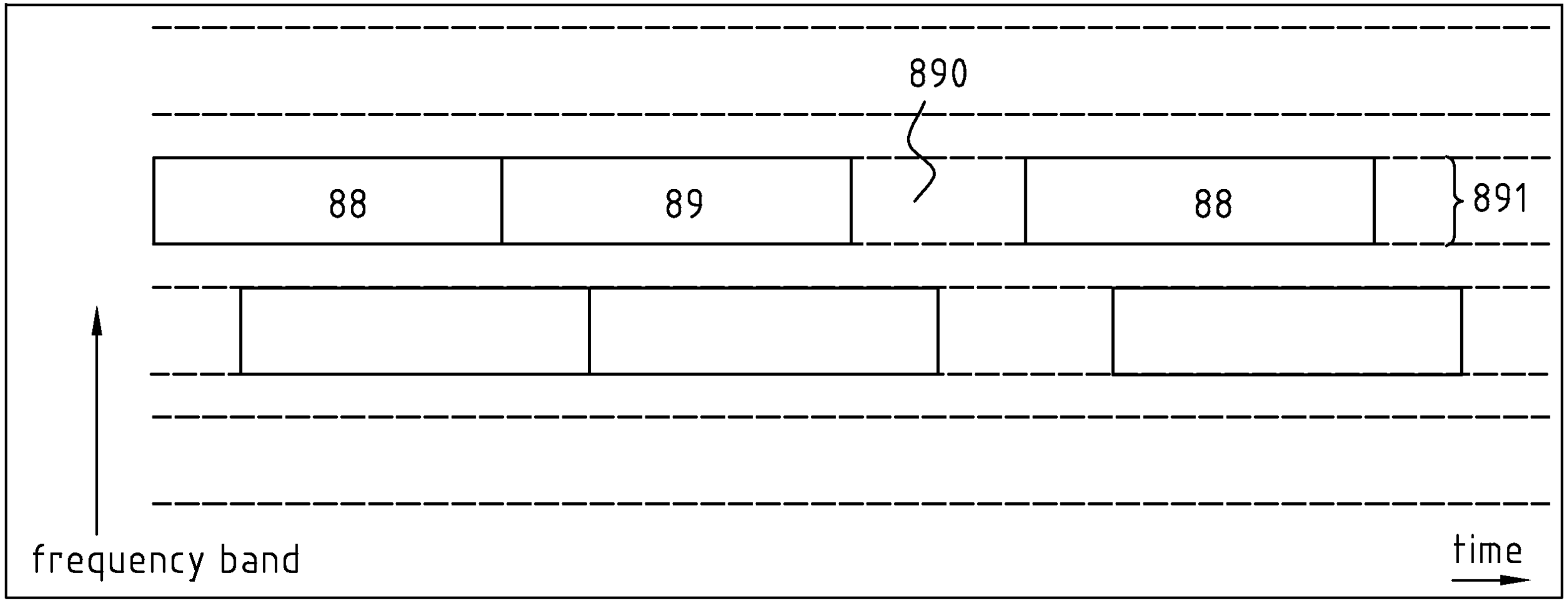
890
88
89
88
891
frequency band
time

FIG. 4

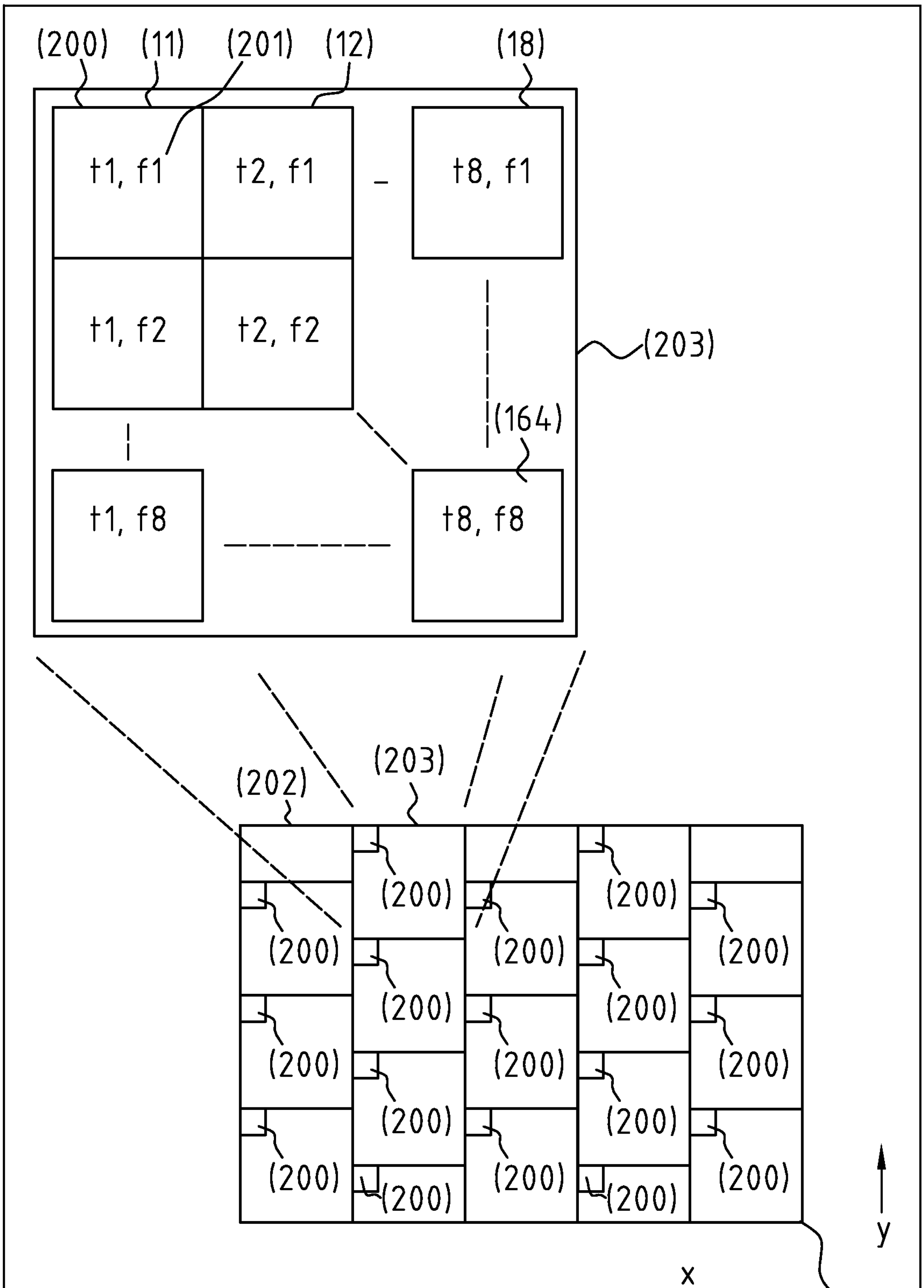
(200)
(11)
(201)
(12)
(18)
t1, f1
t2, f1
t8, f1
t1, f2
t2, f2
(203)
(164)
t1, f8
t8, f8
(202)
(203)
(200)
(221)
x
y

FIG. 5

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	2Q/2IA96/MS/3
Nederlands aanvraag nr. **2003736**	Indieningsdatum **30-10-2009**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Ambient Systems B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **16-03-2010**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN 53806**

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

Volgens de internationale classificatie (IPC)

H04W72/12

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC 8	**H04W**

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 2003736

A. CLASSIFICATIE VAN HET ONDERWERP
INV. H04W72/12
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)
H04W

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

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 7 035 240 B1 (BALAKRISHNAN HARI [US] ET AL) 25 april 2006 (2006-04-25) * kolom 3, regels 41-49 * * kolom 3, regels 61-62 * * kolom 4, regels 3-8 * * kolom 14, regels 5-18 * * samenvatting; conclusies 5,8; figuren 1B,3,5A * -----	1-20
X	WO 03/015452 A2 (HONEYWELL INT INC [US]; YOUNIS MOHAMED F [US]; ARISHA KHALED A [US]; Y) 20 februari 2003 (2003-02-20) * alineas [0024], [0026], [0028] * * alineas [0030] - [0033], [0062] * * samenvatting; figuur 1 * -----	1-20
A	US 2003/152041 A1 (HERRMANN FALK [US] ET AL) 14 augustus 2003 (2003-08-14) * samenvatting * -----	1-20

☐ Verdere documenten worden vermeld in het vervolg van vak C.

☒ 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
22 juli 2010	
Naam en adres van de instantie European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	De bevoegde ambtenaar Coppieters, Stefaan

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 2003736

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomend(e) geschrift(en)			Datum van publicatie
US 7035240	B1	25-04-2006	GEEN			
WO 03015452	A2	20-02-2003	AU	2002326501	A1	24-02-2003
			CN	1561509	A	05-01-2005
			EP	1415288	A2	06-05-2004
			JP	2005526416	T	02-09-2005
			US	2003063585	A1	03-04-2003
US 2003152041	A1	14-08-2003	AU	2003214823	A1	30-07-2003
			CN	1640031	A	13-07-2005
			EP	1472810	A2	03-11-2004
			JP	4230918	B2	25-02-2009
			JP	2005515696	T	26-05-2005
			WO	03061176	A2	24-07-2003
			US	2009103456	A1	23-04-2009

OCTROOICENTRUM NEDERLAND

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN53806	30.10.2009		NL2003736

International Patent Classification (IPC)
INV. H04W72/12

Applicant
Ambient Systems 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
	Coppieters, Stefaan

Application number

WRITTEN OPINION

NL2003736

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	1-7, 13-20
	No:	Claims	8-12
Inventive step	Yes:	Claims	
	No:	Claims	1-20
Industrial applicability	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations

   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 7 035 240 B1 (BALAKRISHNAN HARI [US] ET AL) 25 april 2006 (2006-04-25)

D2 WO 03/015452 A2 (HONEYWELL INT INC [US]; YOUNIS MOHAMED F [US]; ARISHA KHALED A [US]; Y) 20 februari 2003 (2003-02-20)

D3 US 2003/152041 A1 (HERRMANN FALK [US] ET AL) 14 augustus 2003 (2003-08-14)

The present application does not meet the criteria of patentability, because the subject-matter of claim 8 is not new. D1 discloses claim 8:

> Terminal (D1: "node") comprising: a radio receiver, a radio transmitter, and a sensor (Fig.2);
>
> wherein the terminal is associated with a cluster comprising at least a terminal and a cluster master device (D1: "cluster head"; Fig.1B, col.3, lines 44-45); and wherein the terminal is configured to:
>
> receive a schedule comprising allocations allocating a communication slot (col.14, lines 5-9), delimited in time ("TDMA") and frequency (implicit, but suggested in col.14, lines 17-18), to the terminal; and
>
> transmit measurement data acquired by the sensor during the communication slot allocated to the terminal (col.3, lines 44-47).

Also, the subject-matter of claim 11 is not new. D1 discloses claim 11:

> Cluster master device ("cluster head") comprising: a radio receiver, and a radio transmitter (Fig.2; there is no hardware difference between nodes and cluster heads);
>
> wherein the cluster master device is comprised by a cluster, further comprising at least a terminal (Fig.1B); and

> wherein the cluster master device is configured to determine a schedule comprising allocations allocating a communication slot, delimited in time and frequency, to each terminal associated with the cluster (col.14, lines 5-9); and
>
> wherein the cluster master device is configured to:
>
> transmit to a terminal in its associated cluster, the terminal comprising an actuator, a command to be executed by the actuator, the transmission of the command being scheduled during the communication slot allocated to the terminal according to the transmitted schedule; and/or
>
> receive from a terminal in its associated cluster, the terminal comprising a sensor, measurement data acquired by the sensor, the transmission of the measurement data being scheduled during the communication slot allocated to the terminal according to the transmitted schedule (col.3, lines 45-48, col. 14, lines 14-16; Fig.7).

There appears to be no substantial difference in the working of the constructed network whether it is used as a sensor network or as an actuator network. This is also illustrated in D3.

The independent claims 18-20 does not appear to contain any more features that haven't already been discusses in the above. They appear therefore also not to be new.

Even if novelty could be argued based on the above analysis, the contents of the indicated passages is considered also to provide ample evidence against the inventiveness of the claims. The application therefore also lacks an inventive step.

Furthermore, the present application does not meet the criteria of patentability, because the subject-matter of claim 1 does not involve an inventive step. D1 is regarded as being the prior art closest to the subject-matter of claim 1, and discloses:

> Communication method for high density wireless networks, comprising the steps of:
>
> providing a terminal ("node") comprising a radio receiver (Fig.2), the terminal being comprised by one cluster comprising at least one terminal, and wherein the cluster is associated with a geographical area wherein the terminal is located (Fig.1B, 5A);

for each cluster, providing a cluster master ("cluster head": Fig1B, ref. 110b, 110h, 110m) device associated with the cluster, the cluster master device comprising a radio transmitter and a radio receiver (Fig.2 i.c.w. col.5, line 60 - col.6, line 9); and

providing a central node (Fig.1B, ref. 102) associated with at least one cluster, the central node comprising a radio transmitter and a radio receiver (implicit);

wherein a plurality of clusters are associated with a super cluster (Fig.1B);

wherein communication slots are delimited in time and frequency (Fig.3);

further comprising the steps of:

~~within a super cluster, allocating communication slots to clusters;~~

the cluster master device determining a schedule allocating communication slots allocated to the cluster, to the terminals comprised in the cluster;

the cluster master device communicating the schedule to the terminals comprised in the cluster (col.14, lines 5-9).

The subject-matter of claim 1 therefore differs from this known method in that there is another level (supercluster) on which the method of D1 can be applied and is therefore new.

The solution proposed in claim 1 of the present application cannot be considered as involving an inventive step because it applies the same method as known from D1 on a higher hierarchical network level - the super clusters. Adding another level or even further levels would still boil down to applying D1 recursively through the levels, without inventive merit.

Claim 7 does not appear to present inventive matter, as there appears to be no substantial difference in the working of the constructed network whether it is used as a sensor network or as an actuator network. This is also illustrated in D3.

The dependent claims do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step, see the documents and references applying to these documents cited in the search report.