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(54) STOCHASTIC COMMUNICATION PROTOCOL METHOD AND SYSTEM FOR RADIO FREQUENCY IDENTIFICATION (RFID) TAGS BASED ON COALITION FORMATION, SUCH AS FOR TAG-TO-TAG COMMUNICATION

VERFAHREN UND SYSTEM EINES STOCHASTISCHEN KOMMUNIKATIONSPROTOKOLLS FÜR ETIKETTEN DER HOCHFREQUENZIDENTIFIKATION (RFID) AUF DER BASIS EINER KOALITIONSBILDUNG WIE ETWA FÜR DIE KOMMUNIKATION VON ETIKETT ZU ETIKETT

PROCEDE ET SUPPORT A PROTOCOLE DE COMMUNICATION STOCHASTIQUE POUR ETIQUETTES D'IDENTIFICATION RADIOFREQUENCE (RFID) REPOSANT SUR LA FORMATION DE COALITION, PAR EXEMPLE COMMUNICATION D'ETIQUETTE A ETIQUETTE

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(56) References cited:
WO-A1-03/098532
US-A- 5 892 441
US-A1- 2004 212 480
US-A1- 2006 022 801
US-A1- 2006 267 731

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Description

TECHNICAL FIELD

[0001] This disclosure generally relates to the field of automatic data collection (ADC), for example, data acquisition via radio frequency identification (RFID) tags and readers. More particularly but not exclusively, the present disclosure relates to communication between data carriers such as RFID tags.

BACKGROUND INFORMATION

[0002] The ADC field includes a variety of different types of ADC data carriers and ADC readers operable to read data encoded in such data carriers. For example, data may be encoded in machine-readable symbols, such as barcode symbols, area or matrix code symbols, and/or stack code symbols. Machine-readable symbols readers may employ a scanner and/or imager to capture the data encoded in the optical pattern of such machine-readable symbols. Other types of data carriers and associated readers exist, for example magnetic stripes, optical memory tags, and touch memories.

[0003] Other types of ADC carriers include RFID tags that may store data in a wirelessly accessible memory, and may include a discrete power source (*i.e.,* an active RFID tag), or may rely on power derived from an interrogation signal (*i.e.,* a passive RFID tag). RFID readers typically emit a radio frequency (RF) interrogation signal that causes the RFID tag to respond with a return RF signal encoding the data stored in the memory.

[0004] Identification of an RFID tag generally depends on RF energy produced by a reader or interrogator arriving at the RFID tag and returning to the reader. Multiple protocols exist for use with RFID tags. These protocols may specify, among other things, particular frequency ranges, frequency channels, modulation schemes, security schemes, and data formats.

[0005] Many ADC systems that use RFID tags employ an RFID reader in communication with one or more host computing systems that act as central depositories to store and/or process and/or share data collected by the RFID reader. In many applications, wireless communications is provided between the RFID reader and the host computing system. Wireless communications allow the RFID reader to be mobile, may lower the cost associated with installation of an ADC system, and permit flexibility in reorganizing a facility, for example a warehouse.

[0006] RFID tags typically include a semiconductor device having the memory, circuitry, and one or more conductive traces that form an antenna. Typically, RFID tags act as transponders, providing information stored in the memory in response to the RF interrogation signal received at the antenna from the reader or other interrogator. Some RFID tags include security measures, such as passwords and/or encryption. Many RFID tags also permit information to be written or stored in the memory via an RF signal.

[0007] RFID tags are generally used to provide information about the specific objects on which the RFID tags are attached. For example, RFID tags may store data that provide the identification and description of products and goods, the identity of an animal or an individual, or other information pertaining to the objects on which the RFID tags are attached.

[0008] Some types of RFID tags are capable of communicating with each other, thereby allowing formation of an RFID network. However, direct tag-to-tag communication in such RFID networks is currently possible only between specially designed battery-powered active RFID tags, such as the products available from Axcess Inc. and/or the devices used in the "Smart Dust: Autonomous sensing and communication in a cubic millimeter" project described in http://robotics.eecs.berkeley.edu/~pister/SmartDust/. Such active RFID tags and devices can be unduly complex in design and expensive, especially in situations requiring a large number of tags where the batteries have to be continuously monitored, maintained, and replaced in order to ensure that sufficient power is available to meet operational requirements.

[0009] Moreover, traditional client-server applications and methods are not particularly suited for RFID networks that need to be capable of handling very large numbers of interconnected RFID tags in an ad hoc manner. In addition, the RFID tags may dynamically join or leave the RFID network due to a number of reasons, such as exhaustion or lost of power, signal attenuation, physical destruction, etc. The dynamic and generally random nature of the interconnection between and presence of RFID tags, combined with a potentially massive number of distributed RFID tags, as a practical matter preclude the use of traditional applications and methods for communications.

[0010] As an additional consideration, the routing table approach used in wired networks and in wireless networks (such as 802.11, ZigBee, Bluetooth, etc. wireless systems) requires a relatively large amount of memory, which is not readily available in RFID tags and therefore cannot be conveniently used in RFID networks. Furthermore, the traditional communication applications and methods are generally unsuitable in RFID networks where the complexity of interconnections between RFID tags requires such communication applications/methods to address scalability, pervasiveness, spatial distribution, power awareness, and/or other issues.

[0011] WO 03/098 532 A1 discloses a method for direct contact less communication between transponders.

[0012] US 5,892,441 presents how an object in a storage area or moving vehicle may be monitored by attaching an electronic tag to the object. An electronic device detects the presence of the object by communicating with the tag while the object is in storage or is being moved by the vehicle. The tags may also determine the location of an attached object and may reroute the object if it deviates from a given shipping schedule. A group of objects is monitored by two electronic tags, each attached to an object in the group. Each tag has circuitry for communicating information relating to an object in the group to a second tag. Each tag also includes a memory connected to the circuitry that is capable of storing the information, and a controller connected to the memory and the circuitry. A sensor is used to detect the condition of an object and communicate the condition to a tag.

[0013] US 2004/0212480 A1 introduces a technique of inventorying multiple objects utilizing a multi-level or a chained radio frequency identification system. The system includes a master tag and a plurality of upper level tags and lower level tags associated with respective objects. The upper and lower level tags communicate with each other and the master tag so that reading of the master tag reveals the presence and absence of upper and lower level tags. In the chained RF system, the upper and lower level tags communicate locally with each other in a manner so that more remote tags that are out of range of some of the upper and lower level tags have their information relayed through adjacent tags to the master tag and thence to a controller.

BRIEF SUMMARY

[0014] The invention is what is specified in the independent claims.

[0015] Preferred embodiments are specified in the dependent claims.

[0016] One aspect provides a method that includes forming coalitions of clusters of distributed data carriers. For each of said clusters, the method identifies a bridge data carrier that is capable to link with a bridge data carrier of another of said clusters, and enables communication between data carriers of the clusters. At least some of said data carriers include batteryless passive data carriers.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0017] Non-limiting and non-exhaustive embodiments are described with reference to the following drawings, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified. The sizes and relative positions of elements in the drawings are not necessarily drawn to scale. For example, the shapes of various elements and angles are not drawn to scale, and some of these elements are arbitrarily enlarged and positioned to improve drawing legibility. Further, the particular shapes of the elements as drawn, are not intended to convey any information regarding the actual shape of the particular elements, and have been solely selected for ease of recognition in the drawings.

Figure 1 is a schematic diagram showing a formation of clusters of distributed RFID tags according to an embodiment.

Figure 2 is a schematic diagram showing use of bridge tags to implement communication between clusters according to an embodiment.

Figures 3-4 are schematic diagrams showing formation of clusters based on distances between RFID tags according to an embodiment.

Figure 5 is a flowchart of an embodiment of a method for stochastic communication between RFID tags, such as the RFID tags shown in Figures 1-3.

Figure 6 is a block diagram of an embodiment of a system to provide direct tag-to-tag communication between passive RFID tags of clusters.

Figure 7 is a schematic diagram illustratively showing modulation of a carrier wave (CW) by an embodiment of the system of Figure 6 for direct tag-to-tag communication between passive RFID tags of clusters.

Figure 8 is a table showing example power levels associated with direct tag-to-tag communication between RFID tags of clusters.

Figure 9 is a flowchart of an embodiment of a method that can be implemented in the system of Figure 6 for direct tag-to-tag communication between passive RFID tags of clusters.

Figures 10-12 are schematic diagrams that show example implementations for direct tag-to-tag communication between passive RFID tags of clusters.

Figure 13 is a schematic diagram that shows an embodiment of an apparatus with RFID reading capability that is usable for direct tag-to-tag communication between passive RFID tags of clusters.

DETAILED DESCRIPTION

[0018] In the following description, numerous specific details are given to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that the embodiments can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations associated with RFID tags and RFID readers, computer and/or telecommunications networks, and/or computing systems are not shown or described in detail to avoid obscuring aspects of the embodiments.

[0019] Unless the context requires otherwise, throughout the specification and claims which follow, the word "comprise" and variations thereof, such as, "comprises" and "comprising" are to be construed in an open, inclusive sense, that is as "including, but not limited to."

[0020] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0021] The headings provided herein are for convenience only and do not interpret the scope or meaning of the embodiments.

[0022] As an overview, data carriers (such as RFID tags) are formed into clusters of data carriers. Each cluster has at least one bridge data carrier that can communicate with a bridge data carrier of another cluster, thereby allowing data carriers in each cluster to communicate directly or indirectly with each other using a stochastic communication protocol method.

[0023] The clusters can be formed dynamically based on various criteria, such as the distance associated with candidate data carriers, such as a distance between a candidate data carrier and a centrally located data carrier in a cluster. Moreover, the size, shape, number of data carriers, etc. for each cluster can vary dynamically from one cluster to another.

[0024] Another embodiment relates to a synchronization of formed coalitions of clusters of distributed data carriers to sustain a collection of data of interest in a desired manner.

[0025] Embodiments further provide techniques for direct tag-to-tag communication between data carriers (such as passive RFID tags) in each cluster and/or between clusters. Such embodiments allow such data carriers to backscatter and modulate a carrier wave from a source, thereby using the backscattered and modulated carrier wave to convey data to each other.

[0026] The stochastic communication protocol method of one embodiment includes the following elements:

(a) forming stochastic coalitions of clusters from irregularly or otherwise randomly distributed RFID tags;
(b) identifying bridge tags for each cluster;
(c) synchronizing cluster formations; and
(d) enabling distribution of information between RFID tags and a data collection device.

[0027] Figure 1 shows a non-limiting example of the first element (a) of such a method, namely formation of stochastic coalitions of clusters from distributed RFID tags. In particular, the diagram of Figure 1 shows formation of a plurality of clusters of data carriers, such as a set of RFID tags $Y = \{y_1, y_2, y_3, ..., y_N\}$, according to one embodiment. For the sake of simplicity of explanation hereinafter and unless otherwise specified, the data carriers will be described in the context of RFID tags. In other embodiments, it is appreciated that the data carriers can comprise acoustical tags, other types of non-RFID tags, and/or a combination of RFID tags and non-RFID tags.

[0028] Each of the clusters in Figure 1 are denoted by C^i, where $1 \leq i < k$ and $k < N$. Each cluster C includes an RFID tag x_i, where $1 \leq i \leq k$. In one embodiment, the RIFD tag x_j in each cluster C^i comprises an RFID tag that is located substantially in the center of each cluster. Thus, the cluster C^1 has the central RFID tag x_1; the cluster C^2 has the central RFID tag x_2; the cluster C^3 has the central RFID tag x_3; and so forth up to the cluster C^k having the central RFID tag x_k. In another embodiments, the RFID tag x_i need not necessarily be the centrally located RFID tag in each cluster C^i.

[0029] The various RFID tags Y in Figure 1 include deployed RFID tags that are affixed to objects. Such objects can include an item, a packaging or label for the item, a container of multiple packaged or unpackaged items, or other type of objects that are capable of having the RFID tags Y attached thereon. Examples of the item can include drugs, toys, food, animals, merchandise, human beings, machinery parts, or other types of animate or inanimate items that can be identified or otherwise represented by the RFID tags Y. In the context of human beings, for example, the item can include an identification card, driver's license, airline boarding pass, article of clothing, luggage, and so forth. Moreover, the RFID tags Y can be affixed to stationary objects, such as objects placed on an inventory shelf. The RFID tags Y may also be affixed to objects in motion, such as on identification cards carried by persons. The RFID tags may also be affixed to a combination of stationary and in-motion objects, and may further dynamically change in total number N (as well as the total number of RFID tags in each cluster C^k) as RFID tags are added or removed from a cluster, run out of power or are otherwise disabled, lost or detached from their respective object, and so forth.

[0030] Accordingly in one embodiment, the RFID tags Y in Figure 1 are randomly distributed in a non-confined area. In another embodiment, the distribution may be less random, for example if the objects having the RFID tags Y affixed thereon are organized uniformly on a shelf or other situation where the distribution of the RFID tags Y is more or less uniform.

[0031] The clusters C of Figure 1 are formed based on the principles of coalition formation in one embodiment. The coalitions (or other form of grouping) of the RFID tags Y of one embodiment define RFID tags as agents that may or may not communicate with each other. Coalitions can be formed between linked agents-thus, a coalition can encompass two (or more) clusters that are able to communicate with each other; a coalition can encompass two (or more) RFID tags in different clusters that can communicate with each other; and/or a coalition can encompass two (or more) RFID tags in a same cluster that can communicate with each other. In a first type of communication in an embodiment, RFID tags directly communicate with each other in order to be in the same coalition. In a second type of communication in an embodiment, RFID tags may communicate indirectly with each other through the use of other agents. In one embodiment, the structure of the random coalitions controls the functionality of the coalitions, and the efficiency of communication protocols between RFID tags in effect determines the functionality of the coalitions. Further details of such various embodiments are described in further detail later below. The publication Kirman et al., "Stochastic Communication and Coalition Formation," Econometrica, volume 54, No. 1 (January 1986), pages 129-138 also provides additional details of coalitions that can be implemented by some embodiments.

[0032] In mathematical terms for one embodiment, the set of RFID tags $Y = \{y_1, y_2, y_3, ..., y_N\}$ is divided into k subsets (clusters C), with the RFID tags x_i being centrally located tags in each cluster, where $1 \leq i \leq k$ and $k < N$. Under these conditions, the following criterion will have a maximum value:

$$\sum_{x_i} \sum_{y_j \in S(x_i)} \mu(x_i, y_j)$$

where $S(x_i)$ is a set of RFID tags that belong to a cluster C^i with the RFID tag x_i as a central RFID tag, and $\mu(x_i,y_j)$ is some measure of communication quality between tags x_i and y_j (with i and $j < N$). In one embodiment, the measure of communication quality is based on emitted power, as will be explained with regards to Figure 2. In other embodiments, the measure of communication quality can be based on additional or alternative factors.

[0033] Figure 2 shows a non-limiting example of the second element (b) of an embodiment of the stochastic communication protocol method, namely identification of bridge RFID tags for each cluster C^i. In an embodiment, the identification of bridge RFID tags (*e.g.*, the RFID tags x_p, y_k, y_i, and x_i in Figure 2) includes identification of RFID tags in every cluster C such that all clusters have links with each other directly or indirectly through intermediate clusters via use of bridge RFID tags.

[0034] In the example of Figure 2, the cluster 1 includes a particular RFID tag x_p. The RFID tag x_p may be the central RFID tag or may be some other tag located off-center in the cluster 1. The cluster 2 includes particular RFID tags y_k and y_j. The RFID tags y_k or y_j may be the central RFID tag or may be some other tag located off-center in the cluster 2. The cluster 2 also includes other RFID tags y_a and y_b that can communicate with each other, as depicted by the double-headed arrow between the RFID tags y_a and y_b. The cluster 3 includes the RFID tag x_i. The RFID tag x_i may be the central RFID tag or may be some other tag located off-center in the cluster 3.

[0035] In the example of Figure 2, the RFID tags x_p and y_k are the bridge RFID tags that can communicate with each other (as depicted by the double headed arrow between the RFID tags x_p and y_k), thereby allowing other RFID tags in the respective clusters 1 and 2 to indirectly communicating with each other through the bridge RFID tags x_p and y_k. Thus, a coalition is formed between the bridge RFID tags x_p and y_k, between the clusters 1 and 2, and/or between any RFID tag in cluster 1 with any RFID tag in cluster 2 (via communication with the bridge RFID tags x_p and y_k).

[0036] Similarly, the RFID tags y_j and x_i are the bridge RFID tags that can communicate with each other (as depicted by the double headed arrow between the RFID tags y_j and x_i), thereby allowing other RFID tags in the respective clusters 2 and 3 to indirectly communicating with each other through the bridge RFID tags y_j and x_i. Thus, a coalition is formed between the bridge RFID tags y_j and x_i, between the clusters 2 and 3, and/or between any RFID tag in cluster 2 with any RFID tag in cluster 3 (via communication with the bridge RFID tags y_j and x_i).

[0037] In an embodiment, a "bridge zone" in each cluster (e.g., in clusters 1 and 2) is defined by the region where the emitting power of the particular RFID tag x_p of the cluster 1 that is sensed by the particular RFID tag y_k of the cluster 2 exceeds a cumulative power that is sensed by the particular RFID tag y_k from all of the RFID tags in the cluster 1 by some specified threshold value. In some embodiments, the specified threshold value exceeded by the cumulative power is uniform among the various clusters. In another embodiment, the specified threshold value can be different among the various clusters. For instance, the specified threshold value between clusters 1 and 2 can be different than the specified threshold value between clusters 2 and 3.

[0038] In an embodiment, a single cluster may have different bridge RFID tags that can be used to bridge with respective different other clusters. Further in an embodiment, a single cluster may have more than one bridge RFID tag to bridge with some other single cluster, and/or may bridge with more than one bridge RFID tag of that other single clusters. Still further in an embodiment, various RFID tags may be designated as backup bridge RFID tags, if a primary bridge RFID tag becomes disabled, is removed from the cluster, or otherwise becomes incapable of operating as a bridge RFID tag.

[0039] In yet further embodiments, the identification of bridge RFID tags may change dynamically, as the shape or size of a cluster changes and/or as additional RFID tags are added/removed from the cluster. It is therefore evident from the above that individual RFID tags are capable of communicating with other RFID tags, whether in the same cluster or in some other cluster, by "hopping" from one RFID tag to another communicatively compatible RFID tag in the same cluster and between clusters.

[0040] Figures 3-4 show an embodiment of a technique for forming clusters based on distances between RFID tags. It is appreciated that formation of clusters based on distances is only one possible technique that can be used. Other embodiments can form clusters based on other alternative or additional factors, such as RFID type, power output, return signal frequency, and so forth.

[0041] In Figure 3, a plurality of RFID tags 300 are distributed over a region. The region over which the RFID tags 300 are distributed can range from a few square inches (or smaller) to perhaps on the order of several square miles. As depicted symbolically in Figure 3, some RFID tags 300 are located in closer proximity relative to each other as compared to other ones of the RFID tags

300. The particular concentration/density, pattern, location, or other distribution factor of the RFID tags 300 can be completely random, semi-random, specifically arranged, and/or combination thereof.

[0042] As depicted in Figure 4, clusters 400 of the RFID tags 300 are formed based on distances between RFID tags 300. Specifically in one embodiment, RFID tags 300 that are closer in distance to each other are formed into the same cluster. Various techniques can be used to determine whether the distance between RFID tags is sufficient or insufficient to justify inclusion of any given RFID tag into a cluster. In one technique, RFID tags are included in the same cluster if the distance between any two of the RFID tags is less than some specified distance. Any RFID tag that exceeds the specified distance to the closest RFID tag of the cluster is rejected for inclusion in the cluster, and is considered instead for inclusion in some other cluster.

[0043] In another technique, a particular RFID tag is designated as a central RFID tag x_i for a cluster. Then, the other RFID tags of the cluster are identified and selected based on some specified distance from the central tag x_I. For example, RFID tags are included in the same cluster if the distance between such RFID tags and the central RFID tag x_i is less than some specified distance. Any RFID tag that exceeds the specified distance to the central RFID tag x_i of the cluster is rejected for inclusion in the cluster, and is considered instead for inclusion in some other cluster.

[0044] Again and as previously explained above, the size, shape, number of RFID tags, etc. of each cluster can dynamically vary from one cluster to another based on various factors. Moreover, it is possible to have a cluster having only a single RFID tag. Such single RFID tag can thus act as its own bridge RFID tag to other clusters.

[0045] In an embodiment, each of the clusters previously described above includes at least one active RFID tag and one or more passive RFID tags. In another embodiment, all RFID tags in one or more of the clusters may be passive RFID tags, and one or more devices (such as an automatic data collection device, including RFID readers) can provide the RF field(s) to power such passive RFID tags to perform the various functionalities described herein. In yet other embodiments, some clusters may have one active RFID tag and one or more passive RFID tags, while other clusters may have only passive RFID tags, while still other clusters may have only active RFID tags-all of these clusters have the capability to communicate with each other (directly or indirectly) using the methods described herein.

[0046] Figure 5 is a flowchart of an embodiment of a method 500 to implement the various elements of the stochastic communication protocol described above. It is appreciated that the various operations in the flowchart of Figure 5 need not necessarily occur in the exact order shown. Moreover, certain operations can be added, removed, modified, or combined.

[0047] In some embodiments, certain operations of the method 500 can be implemented in software or other machine-readable instruction stored on a machine-readable medium and executable by a processor. For example, some of the operations in the method 500 can be performed by a data collection device (such as an RFID reader) in one embodiment, using one or more processors and a storage medium of the data collection device.

[0048] At a block 502, all of the RFID tags are assigned to a particular cluster that has some RFID tag x_i as a central tag, thereby forming clusters of RFID tags. As described above with reference to Figures 3-4, the assignment of tags to a particular cluster can be based on distances between RFID tags. Also as explained above, other criteria can be used to assign RFID tags to specific clusters.

[0049] At a block 504, bridge RFID tags are identified and selected. As described above for one embodiment, the identification and selection of bridge RFID tags can be performed based on bridge zones where the emitting power of the particular RFID tag of a first cluster that is sensed by a particular RFID tag of a second cluster exceeds some cumulative power of all RFID tags of the first cluster that is sensed by the particular RFID tag of the second cluster.

[0050] At a block 506 for one embodiment, communication between and/or within clusters is synchronized, such as time synchronization of transmission and/or reception. The synchronization can be localized (*e.g.,* synchronization between neighboring RFID tags in a same and/or adjacent clusters) and/or at least partially global (*e.g.,* synchronization between all RFID tags in a same cluster, synchronization between a plurality of clusters, synchronization of all RFID tags of all clusters). In one embodiment, such synchronization can be performed using methods known to persons skilled in the art. Other embodiments can use the synchronization techniques disclosed in U.S. Provisional Patent Application Serial No. 60/610,759, entitled "SYNCHRONIZATION OF ADAPTIVE SELF-CONFIGURING WIRELESS NETWORK OF TRANSPONDERS,".

[0051] One example of such synchronization techniques includes global-based time synchronization in which all RFID tags set time to send/receive data based on a single (*e.g.,* a common) time clock located inside and/or outside of the RFID network. In one embodiment that can implement this synchronization technique, an RFID tag is able to receive data even though such an RFID tag may not necessarily have the capability to communicate the acknowledgement of a successful reception of the data, due to factors such as power constraints. This synchronization technique is used for global synchronization in one embodiment, but can also be adapted for local synchronization.

[0052] Another example is time-stamped packet communication in which the packets or other data format received by a recipient RFID tag includes a time of transmission from a sender RFID tag. Embodiments can implement this synchronization technique in a global and/or localized basis.

[0053] Yet another example is tag-to-tag synchronization in which the time for transmission/reception is set by an outside system and propagated to the RFID tags. Such propagation can be done by having the RFID tags within and/between clusters send the time from one RFID tag to another.

[0054] A variation to the tag-to-tag synchronization involves an RFID tag (performing managerial duties for its cluster) that sets the time and propagates the time to collaborating neighbor RFID tags. In one embodiment, the central RFID tag x_i can be used as the managerial tag, although other RFID tags in the cluster may also be used as primary and/or backup managerial RFID tags. The cluster's time may be synchronized locally or globally when a tag-to-tag synchronization technique is used.

[0055] Still another example of synchronization involves multi-hop time synchronization in which time error is compensated/corrected during propagation of data. In still a further example, RFID tags are capable of identifying a synchronization mode and can start corroboration with neighboring RFID tags in accordance with a proposed synchronization mode. Furthermore, in the case of multiple clusters of RFID tags, RFID tags may reconcile multiple global times to continue an appropriate communication mode.

[0056] In other embodiments, the synchronization at the block 506 need not be performed and/or need be performed only on a limited basis. Thus for such embodiments, there need not necessarily be synchronization between RFID tags in a same cluster, between RFID tags of different clusters, between clusters, and/or between other communicating elements of the RFID networks.

[0057] At a block 508 in the method 500 of Figure 5, information is communicated between RFID tags, clusters, and/or data collection device(s) or other device(s). Such communication can be direct or indirect communication within or between clusters using the bridge RFID tags as described above. Specific embodiments of direct tag-to-tag communication that can be implemented in the clusters previously described above will be explained next.

[0058] More particularly and beginning with Figure 6, shown generally at 600 is an embodiment of a system 600 for direct tag-to-tag communication between two passive RFID tags 1 and 2. The RFID tags 1 and 2 can comprise two bridge RFID tags of two different clusters described above, or two RFID tags within the same cluster, for instance. Either or both RFID tags 1 and 2 can in turn perform direct tag-to-tag communication with yet other RFID tags in the same cluster and/or with a bridge RFID tag, thereby allowing indirect communication with yet other RFID tags in another cluster.

[0059] For embodiments of the system 100 having RFID tags, the system 600 includes an RF carrier wave (RF CW) source 602 that generates a carrier wave 604. The RF CW source 602 can be embodied as an automatic data collection device (such as an RFID reader), a cellular telephone or other portable communication device, another RFID tag, and or any other device(s) or combination thereof that are capable of generating an unmodulated carrier wave 604 that can be used for direct tag-to-tag communication, as well as a power source for the RFID tags 1 and 2. In another embodiment, the carrier wave 604 is output from the RF CW source 602 in a modulated form, and is then further modulated by the RFID tags 1 and 2 during tag-to-tag communication.

[0060] In one embodiment, the RF CW source 602 can be switched ON or OFF mechanically (such as by an operator) or electronically (such as in response to a wireless signal). The RF CW source 602 can be powered from a portable battery, thereby providing a portable solution, or from a stationary source of power, for example a 120 V AC voltage supply, thereby providing an industrial solution. Moreover, the RF CW source 602 can be integrated as an operating mode option in a cellular telephone or other device, and produced inexpensively since no frequency stability or digital signal processing capability is used in one embodiment.

[0061] An example embodiment of the RF CW source 602 can use a 5 V battery with up to 1 watt of output RF power, using Micro Device's RF2131 power amplifier integrated circuit (IC) with resonant feedback. Additionally in an embodiment, several RC CW sources 602 can be arranged in an array or other pattern so as to cover a large area where clusters of RFID tags are present.

[0062] In operation the carrier wave 604 is backscattered, and the RFID tags 1 and 2 can communicate with each other by modulating the backscattered carrier wave 604. Thus, the RFID tag 1 can send an interrogation signal 606 to the RFID tag 2, and the RFID tag 2 can reply to the interrogation signal 606 with a reply signal 608, and/or vice versa. The interrogation signal 606 and the return signal 608 are thus the modulated backscattered carrier wave 604. The interrogation signal 606 and the return signal 608 can be demodulated by the RFID tags 2 and 1, respectively, to obtain the data encoded therein.

[0063] The method of communication of Figure 6 can be analogized by an example of two persons in a dark room. When a light in the room if OFF, the two persons cannot see each other in the dark. When the light in the room is ON, the two persons can see each other and remember each other's appearance because of photons of light that reflect from them and make them visible to each other. In an analogous way, the two passive RFID tags 1 an 2 cannot communicate with each other in the absence of the carrier wave 604, but in the presence of the carrier wave 604, the two RFID tags 1 and 2 can communicate with each other by modulating the backscattered carrier wave 604.

[0064] Example waveforms at terminals of the RFID tags 1 and 2 during tag-to-tag communication are illustrated in Figure 7. It is appreciated that such illustrated waveforms are not intended to be precisely depicted in shape, frequency, amplitude, timing, etc. in Figure 7, but are rather intended to be drawn for the purpose of clarity of explanation.

[0065] The carrier wave 604 is depicted in Figure 7 as a signal of constant amplitude during periods of time when the carrier wave 604 is not being modulated by the RFID tags 1 and 2. During a period of time when the RFID tag 1 generates and sends the interrogation signal 606 to the RFID tag 2, Figure 7 depicts the modulation of the carrier wave 604 as a square wave pulse train. Similarly, during a period of time when the RFID tag 2 generates and sends the return signal 608 to the RFID tag 1, Figure 7 depicts the modulation of the carrier wave 604 as another square wave pulse train.

[0066] Figure 8 is a table 800 showing example power budget values for the tag-to-tag communication described above. It is appreciated that the various power values shown in the table 800 are merely for the purpose of illustration, and that other embodiments may involve different power values.

[0067] The RF CW source 602 is assumed to output the carrier wave 604 with a power value of +36 dBm. The free space path loss from the RF CW source 602 to the RFID tag 1 (assuming a distance of 4 feet between the RF CW source 602 and the RFID tag 1, with a 915 MHz frequency for the carrier wave 604) is -33 dB, thereby leaving +3 dBm of power available. There is then a backscattering modulation loss of -6 dB associated with the RFID tag 1, as well as a coupling loss of -6 dB between the RFID tags 1 and 2 in close proximity. The resulting backscattering differential modulated power received by the RFID tag 2 is thus -9 dBm. If the minimum power required for tag-to-tag communication is -10 dBm, then the resultant -9 dBm power is sufficient to meet operational requirements.

[0068] In one embodiment, the carrier wave 604 from the RF CW source 602 comprises an interrogation signal that both powers and interrogates the RFID tag 1 and/or the RFID tag 2. Such an interrogation signal can then be modulated by the RFID tag 1 and/or the RFID tag 2 in the manner described above, thereby providing tag-to-tag communication capabilities in existing passive RFID networks/systems.

[0069] In another embodiment, one of the RFID tags (such as the RFID tag 2) can comprise a passive RFID tag with capabilities to receive interrogation signals and to send return signals, and another one of the RFID tags (such as the RFID tag 1) can comprise a passive RFID tag having additional capability to independently broadcast or otherwise issue tag queries (*i.e.*, interrogation signals), alternatively or additionally to using the carrier wave 604 for such tag queries. Such an embodiment of the RFID tag 1 obtains power from the carrier wave 604 (or from some other source) and then waits for the RF CW source 602 to transmit an interrogation signal, which may be in the form of a modulation of the carrier wave 604 and/or the issuance of another signal. If the RFID tag 1 does not receive any interrogation signals from the RF CW source 1 within a period of time, then the RFID tag 1 starts to periodically broadcast (such as by backscattering) interrogation signals itself to the RFID tag 2 and/or to other RFID tags. Such interrogation signals can comprise a modulated or unmodulated carrier wave similar to the carrier wave 604, in one embodiment.

[0070] In another embodiment, both the RFID tags 1 and 2 can have the capability to issue interrogation signals. In still further embodiments, RFID tags of the various clusters can comprise a mix of RFID tags with or without this additional capability to issue interrogation signals.

[0071] Figure 9 is a flowchart of a method 900 for direct tag-to-tag communication in which one of the RFID tags (such as the RFID tag 1 for purposes of illustration) has capability to issue interrogation signals. It is appreciated that the various operations in the flowchart of Figure 9 need not necessarily occur in the exact order shown. Moreover, certain operations can be added, removed, modified, or combined.

[0072] In some embodiments, certain operations of the method 900 can be implemented in software or other machine-readable instruction stored on a machine-readable medium and executable by a processor. For example, some of the operations in the method 900 can be performed by one or more controllers or other processor(s) and a storage medium in an RFID tag.

[0073] At a block 902, the RFID tags 1 and 2 receive the carrier wave 604 from the RF CW source 602 and power up. A timer in the RFID tag 1 is started at a block 904. If the RFID tag 1 receives an interrogation signal at a block 906 from the RF CW source 602 and/or from some other querying device, then the RFID tag 908 operates in a normal tag mode at a block 908, such as by generating and sending an appropriate return signal to the querying device(s).

[0074] However, if the timer expires at a block 910 and the RFID tag 1 has not received an interrogation signal at the block 906, then the RFID tag 1 sends one or more interrogation signals or other types of queries at a block 912 to an RFID tag (such as the RFID tag 2). In one embodiment, the queries at the block 912 are broadcast periodically, such as by backscattering. In other embodiments, the queries need not necessarily be sent in a periodical manner, and can be sent in a somewhat random manner, for example.

[0075] If the RFID tag 1 does not receive any return signals or other response(s) to the queries at a block 914, then the RFID tag 1 continues to issue queries at the block 912. However, if the RFID tag 1 receives one or more responses at the block 914, then the RFID tag 1 generates and sends back (such as by backscattering) a corresponding one or more acknowledgements at a block 916.

[0076] At a block 918, the RFID tag 1 receives an RFID tag identifier (such as the identifier for the RFID tag 2) from the RFID tag 2 during the direct tag-to-tag communication and stores this received RFID tag identifier in memory. The method 900 then repeats at the block 904 in which the timer of the RFID tag 1 is restarted as the

RFID tag 1 monitors for additional tag queries.

[0077] Figures 10-12 show various example implementations for direct tag-to-tag communication where RFID tags (or other types of data carriers, such as acoustical tags) are arranged in clusters. It is appreciated that such implementations are not intended to be exhaustive of all the possible implementations for direct tag-to-tag communication.

[0078] The implementation illustrated in Figure 10 involves direct exchange of information, without the use of a dedicated automatic data collection device such as an RFID reader, between documents embedded with passive RFID tags containing information pertaining to the documents. Examples of such documents as illustrated in Figure 10 are business cards 1000 and 1002, such that the passive RFID tags embedded therein contain business card information.

[0079] The exchange of business card information can be performed if there is an area 1004 where the carrier wave 604 is present to energize the RFID tags embedded in the business cards 1000 and 1002. The area 1004 can be an area in a conference center, for example, is covered by the carrier wave 604 generated by the RF CW source 602. Alternatively or additionally, the carrier wave 604 can be generated from a device such as a cellular telephone 1006 or other device capable to generate the carrier wave 604. In one embodiment, the cellular telephone 1006 can be a conventional cellular telephone that does not require modification in order to generate the carrier wave 604.

[0080] Figure 11 further illustrates the implementation shown in Figure 10. Two persons need to quickly and conveniently exchange business card information. One of these persons pushes a button on the cellular telephone 1006 to create a "bubble" or other area proximate to the business cards 1000 and 1002 to be covered by the carrier wave 604. By pressing the button or otherwise appropriately actuating the cellular telephone 1006, the cellular telephone 10056 can operate in an RF CW mode. The "bubble" can be present for a few seconds or any other suitable length of time sufficient to allow the RFID tags of the business cards 1000 and 1002 to conduct tag-to-tag communication.

[0081] The two persons can "rub" their business cards 1000 and 1002 together, or otherwise place the business cards 1000 and 100 in close proximity to each other, in order to conduct the tag-to-tag communication to exchange and store business card information of the other person. The two persons can then go their separate ways, and can later retrieve the stored business card information (such as at home, at the office, or at some other location). The business card information stored in the embedded RFID tag of the business cards 1000 and 1002 can be retrieved at such other locations using an automatic data collection device (such as an RFID reader), a personal computer of laptop with RFID-reading capability, or other device capable to read RFID tags.

[0082] In the example of Figure 12, a person approaches a bulletin board 1200 having advertisements 1202 present thereon. The advertisements 1202 have passive RFID tags that contain information pertaining to each advertisement 1202. An area 1204 ("bubble") encompassing the bulletin board 1200 is covered by the carrier wave 604 from the RF CW source 602, which could be a stationary device placed proximate to the bulletin board 1200, a cellular telephone of the person, or some other device.

[0083] The person can read the information from selected advertisements 1202 using a personal passive RFID tag 1206, such as by "swiping" the RFID tag 1206 over the selected advertisement(s) 1202. The information read from the RFID tags of the advertisements 1202 can then be stored by the RFID tag 1206 of the person for later review or other use.

[0084] In an embodiment, the RFID tag 1206 of the user can be embedded in a business card or other object, in a handheld device portable communication device (such as a cellular telephone, pager, PDA, Blackberry, Palm Pilot, etc.), or some other compact and portable apparatus that can be conveniently carried by the person and usable to "swipe" over one or more RFID tags or other target data carriers.

[0085] An embodiment of such an apparatus having the RFID tag for reading other RFID tags is shown at 1300 in Figure 13. The apparatus 1300 can be a "paper thin" batteryless RFID reader, with an example thickness of 0.1 mm. The apparatus 1300 of one embodiment comprises a passive RFID tag having capability to issue interrogation or other query signals in accordance with the embodiment of the method 900 shown in Figure 9. The apparatus 1300 of one embodiment can be provided with sufficient memory capacity to store information from a large number of RFID tags that are read. The stored information can later be retrieved from the apparatus 1300 using an RFID reader or other suitable automatic data collection device.

[0086] Advantages of the apparatus 1300 are compact size, lightweight, batteryless, and relatively inexpensive (for example, less than a few dollars each). Moreover, such an apparatus 1300 can operate anywhere in a vicinity of RFID tags that are covered by the carrier wave 604 generated by the RF CW source 602.

[0087] Accordingly from the various embodiments of the RFID clusters and tag-to-tag communication techniques between RFID tags of such clusters described above, it is clear that such embodiments can be used for real time applications and/or to meet other application requirements. Additional advantages of such embodiments can further include, but not be limited to, indifference to RFID network topology changes (e.g., adaptive and self-configuring clusters), energy efficient functionality, extended range for automatic data collection device or other device for collecting data (since tags can communicate directly or indirectly with each other using bridge tags), thereby extending the range for reading tags), self-organizing capability, and so forth.

[0088] The above description of illustrated embodiments, including what is described in the Abstract, is not intended to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention and can be made without deviating from the spirit and scope of the invention.

[0089] For example, embodiments have been described above in which the RFID tags are attached to objects, and provide data pertaining to the objects. In other embodiments, the RFID tags may be provided with sensor elements, such that the RFID tags can detect and collect data regarding temperature, humidity, air pressure, lighting levels, presence of certain chemical substances, presence and strength of electromagnetic or other types of signals, or other environmental condition that can be sensed and stored by the RFID tags. Such detected and collected data can then be provided to one or more RFID readers and/or to other RFID tags using the techniques described above.

[0090] Furthermore, various embodiments have been described above in the context of the data carrier being in the form of an RFID tag. It is appreciated that other embodiments can be provided for use with other types of data carriers, such as acoustical tags. In such other embodiments, the carrier wave (CW) can be in the form of an acoustical wave. Further in such embodiments, the acoustical tags can be formed into clusters and can communicate with each other in a manner analogous to the techniques described above. Further, various systems can include clusters formed entirely of acoustical tags; clusters formed from a mix of acoustical tags, RFID tags, and/or other types of tags; and/or clusters formed from various other combinations of tag types that can communicate with similarly or differently formed clusters.

[0091] In the embodiments described above, various signals (such as the carrier wave 604) have been described as being an RF signal. It is understood that the RF signal(s) can be included in at least the radio band and microwave band of frequencies.

[0092] These and other modifications can be made to the embodiments in light of the above detailed description. The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of the invention is to be determined entirely by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.

Claims

1. A method, comprising:

forming (502) coalitions of clusters of distributed data carriers, at least some of said data carriers including batteryless passive data carriers, said batteryless passive data carriers including passive RFID tags and/or acoustical tags;
for each of said clusters, identifying (504) a bridge data carrier that is capable to link with a bridge data carrier of another of said clusters; and
enabling (508) communication between batteryless passive data carriers of the clusters, wherein enabling communication between batteryless passive data carriers of the clusters includes:

providing a carrier wave that can be backscattered;
modulating the backscattered carrier wave with a first of said batteryless passive data carriers to generate an interrogation signal; and
modulating the backscattered carrier wave with a second of said batteryless passive data carriers to generate a return signal in response to the interrogation signal,

wherein the first of said batteryless passive data carrier initiates modulation of the backscattered carrier wave by:

receiving (902) power from the carrier wave;
monitoring (904) for a query signal associated with the carrier wave for a period of time;
if the query signal is not detected after expiration of the period of time (910), generating (912) and sending (912) the interrogation signal to query the second of said data carriers; and
if the query signal is detected (906) prior to expiration of the period of time, responding (908) to the query signal.

2. The method of claim 1 wherein forming coalitions of clusters of distributed data carriers includes forming coalitions of randomly distributed data carriers, said coalitions including a coalition between clusters, a coalition between data carriers of respective different clusters, and a coalition between data carriers in a same cluster.

3. The method of claim 1 wherein forming coalitions of distributed data carriers includes identifying candidate data carriers to place in a cluster based on whether a distance between said candidate data carriers is within a value.

4. The method of claim 3 wherein one of said identified candidate data carriers is a substantially central data carrier, wherein said distance is a distance between the central data carrier and another of said candidate data carriers.

5. The method of claim 1 wherein enabling the communication between the data carriers includes enabling indirect communication between non-bridge data carriers of different clusters using their respective bridge data carriers, enabling direct or indirect communication between data carriers in a same cluster, or enabling communication between data carriers of different clusters using their respective bridge data carriers and at least one intermediate cluster and the bridge data carriers of the intermediate cluster.

6. The method of claim 1 wherein providing the carrier wave includes providing the carrier wave from a portable data collection or communication device.

7. The method of claim 1 wherein providing the carrier wave includes providing the carrier wave from another data carrier that is adapted to generate the carrier wave.

8. The method of claim 7 wherein said another data carrier is embedded in a business card, an advertisement, or a document.

9. The method of claim 1 wherein identifying a bridge data carrier includes identifying a bridge data carrier based on a power output level from at least one of said data carriers.

10. The method of claim 9 wherein identifying the bridge data carrier based on the power output level from at least one of said data carriers includes:

defining a bridge zone as a region where the power output level from said at least one of said data carriers in a first cluster, which is sensed by another one of said data carriers in a second cluster, exceeds a cumulative power that is sensed by said another one of said data carriers from all of the data carriers in the first cluster by a threshold value.

11. The method of claim 1 wherein forming coalitions of clusters of distributed data carriers includes forming a cluster having only one data carrier.

12. The method of claim 1 wherein forming coalitions of clusters of distributed data carriers includes forming coalitions having a mix of battery powered active data carriers and said passive data carriers.

13. The method of claim 1 wherein enabling communication between data carriers of the clusters includes enabling communication using a stochastic communication protocol that includes synchronization of communication.

14. The method of claim 13 wherein the synchronization of communication includes localized time synchronization between at least two data carriers.

15. The method of claim 13 wherein the synchronization of communication includes global time synchronization between data carriers of a plurality of said clusters.

16. The method of claim 13 wherein the synchronization of communication includes global-based time synchronization in which communication time between data carriers is set in accordance with a common time clock.

17. The method of claim 13 wherein the synchronization of communication includes time-stamped data communication in which data received by a recipient data carrier from a sender data carrier includes a time of transmission of the data.

18. The method of claim 13 wherein the synchronization of communication includes data carrier-to-data carrier synchronization includes:

setting a time, and propagating the set time from one data carrier to another; or
using one of the data carriers designated as a managerial data carrier to set the time, and propagating the set time from the managerial data carrier to neighbor data carriers.

19. The method of claim 13 wherein the synchronization of communication includes multiple-hop time synchronization in which time error is compensated for during communication.

20. The method of claim 13 wherein the synchronization of communication includes:

providing a plurality of different synchronization modes; and
allowing at least some of the data carriers to identify one of said synchronization modes and to corroborate with neighbor data carriers in accordance with the identified synchronization mode.

21. A batteryless passive data carrier enabling communication between batteryless passive data carriers of clusters of distributed data carriers, said batteryless passive data carrier being one of a passive RFID tag or an acoustical tag, said batteryless passive data carrier being adapted to modulate a backscattered carrier wave from a carrier wave source to generate interrogation and return signals, the batteryless passive data carrier being further adapted to:

receive a carrier wave from a carrier wave source (602) and power up;

characterized in that said batteryless data carrier is further adapted to:

start a timer;

operate in a normal tag mode, if an interrogation signal is received from the carrier wave source and/or from some other querying device;

send one or more interrogation signals or other types of queries to another batteryless passive data carrier, if an interrogation signal is not received before expiration of the timer.

22. A system, comprising:

a plurality of clusters (C^i) of distributed data carriers, some of said data carriers including batteryless passive data carriers in accordance with claim 21; and

for each of said clusters, a bridge data carrier (X_p, Y_k, Y_j, X_i) that is capable to link with a bridge data carrier of another of said clusters to enable communication between data carriers of the clusters, said communication including modulation of a backscattered carrier wave to convey interrogation and return signals between data carriers of the clusters.

23. The system of claim 22, further comprising a carrier wave source to generate the carrier wave.

24. The system of claim 23 wherein said carrier wave source includes portable wireless communication device, one of said data carriers embedded in an object, or an automatic data collection device.

25. The system of claim 23 wherein said one of said data carriers embedded in the object is adapted to generate the carrier wave to interrogate at least another one of said data carriers in response to expiration of a specified time period.

26. The system of claim 22 wherein said clusters include dynamically formed clusters of randomly distributed data carriers that can communicate with each other using a stochastic communication protocol.

27. The system of claim 22 wherein each of the clusters includes a substantially central data carrier, wherein a candidate data carrier is adapted to be considered to include in a particular cluster based on a distance between the candidate data carrier and the central data carrier of the particular cluster.

28. The system of claim 22 wherein the bridge data carriers are determined based at least in part on a cumulative output power that is sensed by a bridge data carrier of a first cluster, the cumulative output power corresponding to output power of data carriers in a second cluster different from the first cluster.

29. A machine-readable medium usable with a plurality of distributed data carriers arranged into clusters, the machine-readable medium having instructions stored thereon to provide communication between passive ones of said data carriers, wherein said passive ones of said data carriers include passive RFID tags and/or acoustical tags, by:

monitoring for a carrier wave that can be backscattered and to power a first passive data carrier if the carrier wave is detected;

starting a timer;

if an interrogation signal is received by the first passive data carrier before expiration of the timer, responding to the interrogation signal;

if an interrogation signal is not received by the first passive data carrier before expiration of the timer, generating the interrogation signal from the first passive data carrier by modulating the carrier wave;

sending the interrogation signal to at least a second data carrier; and

continuing to send the interrogation signal to the second data carrier until a response signal is received from the second data carrier.

30. The machine-readable medium of claim 29 wherein the second data carrier is in a different cluster than the first passive data carrier, said instructions to send the interrogation signal including instructions to send the interrogation signal to a bridge data carrier associated with the cluster of the second data carrier.

31. The machine-readable medium of claim 29 further including instructions stored thereon to identify the bridge data carrier associated with the cluster of the second data carrier based at least in part on a cumulative output power level of at least some of the data carriers in the cluster of the second data carrier.

32. The machine-readable medium of claim 29 wherein the first and second data carriers are both passive RFID data carriers of a same or different cluster.

33. The machine-readable medium of claim 29 is at least partially integrated with a sensor.

34. The machine-readable medium of claim 33 wherein said sensor is adapted to detect and collect data regarding at least one of a plurality of parameters related to temperature, humidity, air pressure, lighting levels, presence of certain chemical substances, presence and strength of electromagnetic or other types of signals, or other environmental condition.

35. The machine-readable medium of claim 29 wherein the first passive data carrier is adapted to generate a broadcast signal.

36. The machine-readable medium of claim 29 wherein the response signal of the second data carrier is a broadcast signal.

Patentansprüche

1. Verfahren, das Folgendes umfasst:

Bilden (502) von Vereinigungen von Clustern von verteilten Datenträgern, wobei zumindest einige der Datenträger batterielose passive Datenträger enthalten, wobei die batterielosen passiven Datenträger passive RFID-Kennzeichnungen und/oder akustische Kennzeichnungen enthalten;
für jeden der Cluster Identifizieren (504) eines Brückendatenträgers, der mit einem Brückendatenträger eines anderen Clusters verbinden kann; und
Ermöglichen (508) einer Kommunikation zwischen batterielosen passiven Datenträgern der Cluster, wobei das Ermöglichen einer Kommunikation zwischen batterielosen passiven Datenträgern der Cluster Folgendes umfasst:

Bereitstellen einer Trägerwelle, die zurückgestreut werden kann;
Modulieren der zurückgestreuten Trägerwelle mit einem ersten der batterielosen passiven Datenträger, um ein Abfragesignal zu erzeugen; und
Modulieren der zurückgestreuten Trägerwelle mit einem zweiten der batterielosen passiven Datenträger, um ein Rücksignal als Reaktion auf das Abfragesignal zu erzeugen,

wobei der erste der batterielosen passiven Datenträger eine Modulation der zurückgestreuten Trägerwelle einleitet durch:

Empfangen (902) einer Leistung von der Trägerwelle;
Überwachen (904) nach einem Erkundigungssignal, das mit der Trägerwelle verbunden ist, für eine Zeitdauer;
wenn das Erkundigungssignal nach dem Ablaufen der Zeitdauer (910) nicht detektiert wurde, Erzeugen (912) und Senden (912) des Abfragesignals, um den zweiten der Datenträger abzufragen; und
wenn das Erkundigungssignal vor dem Ablaufen der Zeitdauer detektiert wurde (906), Antworten (908) auf das Erkundigungssignal.

2. Verfahren nach Anspruch 1, wobei das Bilden von Vereinigungen von Clustern von verteilten Datenträgern umfasst, Vereinigungen von zufällig verteilten Datenträgern zu bilden, wobei die Vereinigungen eine Vereinigung zwischen Clustern, eine Vereinigung zwischen Datenträgern von jeweils verschiedenen Clustern und eine Vereinigung zwischen Datenträgern in demselben Cluster enthalten.

3. Verfahren nach Anspruch 1, wobei das Bilden von Vereinigungen von Clustern von verteilten Datenträgern umfasst, Kandidatendatenträger zu identifizieren, um sie aufgrund dessen, ob ein Abstands zwischen den Kandidatendatenträger innerhalb eines Wertes ist, in einen Cluster zu setzen.

4. Verfahren nach Anspruch 3, wobei einer der identifizierten Kandidatendatenträger ein im Wesentlichen zentraler Datenträger ist, wobei der Abstand ein Abstand zwischen dem zentralen Datenträger und einem andren der Kandidatendatenträger ist.

5. Verfahren nach Anspruch 1, wobei das Ermöglichen der Kommunikation zwischen den Datenträgern umfasst, eine indirekte Kommunikation zwischen Nichtbrückendatenträgern von verschiedenen Clustern unter Verwendung ihrer jeweiligen Brückendatenträger zu ermöglichen, eine direkte oder indirekte Kommunikation zwischen Datenträgern in demselben Cluster zu ermöglichen oder eine Kommunikation zwischen Datenträgern von verschiedenen Clustern unter Verwendung ihrer jeweiligen Brückendatenträger und zumindest einem Zwischencluster und den Brückendatenträgern des Zwischenclusters zu ermöglichen.

6. Verfahren nach Anspruch 1, wobei das Bereitstellen der Trägerwelle umfasst, die Trägerwelle von einer tragbaren Datensammlung oder Kommunikationsvorrichtung bereitzustellen.

7. Verfahren nach Anspruch 1, wobei das Bereitstellen der Trägerwelle umfasst, die Trägerwelle von einem anderen Datenträger, der ausgelegt ist, die Trägerwelle zu erzeugen, bereitzustellen.

8. Verfahren nach Anspruch 7, wobei der andere Datenträger in eine Geschäftskarte, eine Anzeige oder ein Dokument eingebettet ist.

9. Verfahren nach Anspruch 1, wobei das Identifizieren eines Brückendatenträgers umfasst, einen Brückendatenträger aufgrund eines Leistungsausgangspegels von mindestens einem der Datenträger zu identifizieren.

10. Verfahren nach Anspruch 9, wobei das Identifizieren des Brückendatenträgers aufgrund des Leistungsausgangspegels von mindestens einem der Datenträger umfasst:

Definieren eines Brückenbereichs als einen Bereich, in dem der Leistungsausgangspegel von dem mindestens einen der Datenträger in einem ersten Cluster, der durch einen anderen der Datenträger in einem zweiten Cluster erfasst wird, eine kumulative Leistung, die durch einen anderen der Datenträger von allen der Datenträger in dem ersten Cluster erfasst wird, um einen Schwellenwert übersteigt

11. Verfahren nach Anspruch 1, wobei das Bilden von Vereinigungen von Clustern von verteilten Datenträgern umfasst, einen Cluster mit nur einem Datenträger zu bilden.

12. Verfahren nach Anspruch 1, wobei das Bilden von Vereinigungen von Clustern von verteilten Datenträgern umfasst, Vereinigungen mit einem Gemisch von batteriebetriebenen aktiven Datenträgern und den passiven Datenträger zu bilden.

13. Verfahren nach Anspruch 1, wobei das Ermöglichen einer Kommunikation zwischen Datenträgern der Cluster umfasst, eine Kommunikation unter Verwendung eines stochastischen Kommunikationsprotokolls, das die Synchronisation der Kommunikation umfasst, zu ermöglichen.

14. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation eine lokalisierte Zeitsynchronisation zwischen mindestens zwei Datenträgern umfasst.

15. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation eine globale Zeitsynchronisation zwischen Datenträger von mehreren Clustern umfasst.

16. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation eine globalbasierte Zeitsynchronisation umfasst, wobei die Kommunikationszeit zwischen den Datenträgern gemäß einem gemeinsamen Zeittakt eingestellt wird.

17. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation eine zeitgestempelte Datenkommunikation umfasst, wobei die durch einen Empfangsdatenträger von einem Senderdatenträger empfangenen Daten eine Zeit der Übertragung der Daten enthalten.

18. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation eine Datenträger-zu-Datenträger-Synchronisation umfasst, die Folgendes umfasst:

Einstellen einer Zeit und Verbreiten der eingestellten Zeit von einem Datenträger zu einem anderen; oder
Verwenden eines der Datenträger, der als ein Managerdatenträger ausgezeichnet ist, um die Zeit einzustellen, und Verbreiten der eingestellten Zeit von dem Managerdatenträger zu Nachbardatenträgern.

19. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation eine Mehr-Hop-Zeitsynchronisation umfasst, wobei der Zeitfehler während der Kommunikation kompensiert wird.

20. Verfahren nach Anspruch 13, wobei die Synchronisation der Kommunikation Folgendes umfasst:

Bereitstellen von mehreren verschiedenen Synchronisationsmoden; und
Erlauben, dass zumindest einige der Datenträger einen der Synchronisationsmoden identifizieren und mit Nachbardatenträgern gemäß dem identifizierten Synchronisationsmodus bestätigen.

21. Batterieloser passiver Datenträger, der eine Kommunikation zwischen batterielosen passiven Datenträgern eines Clusters von verteilten Datenträgern ermöglicht, wobei der batterielose passive Datenträger eine passive RFID-Kennzeichnung oder eine akustisches Kennzeichnung ist, wobei der batterielose passive Datenträger ausgelegt ist, eine zurückgestreute Trägerwelle von einer Trägerwellenquelle zu modulieren, um ein Abfrage- und ein Rücksignal zu erzeugen, wobei der batterielose passive Datenträger ferner ausgelegt ist,
eine Trägerwelle von einer Trägerwellenquelle (602) zu empfangen und hochzufahren:

dadurch gekennzeichnet, dass der batterielose Datenträger ferner ausgelegt ist,
einen Zeitgeber zu starten;
in einem normalen Kennzeichnungsmodus zu arbeiten, wenn ein Abfragesignal von der Trägerwellenquelle und/oder einer anderen Abfragevorrichtung empfangen wird;
ein oder mehrere Abfragesignale oder andere Typen von Abfragen an einen anderen batterielosen passiven Datenträger zu senden, wenn kein Abfragesignal vor dem Ablaufen des Zeit-

gebers empfangen wird.

22. System, das Folgendes umfasst:

mehrere Cluster (C^1) von verteilten Datenträgern, wobei einige der Datenträger batterielose passive Datenträger gemäß Anspruch 21 enthalten; und
für jeden der Cluster einen Brückendatenträger (X_p, Y_k, Y_j, X_j), der mit einem Brückendatenträger eines anderen der Cluster verbinden kann, um eine Kommunikation zwischen Datenträgern der Cluster zu ermöglichen, wobei die Kommunikation eine Modulation einer zurückgestreuten Trägerwelle umfasst, um ein Abfrage- und ein Rücksignal zwischen Datenträgern der Cluster zu befördern.

23. System nach Anspruch 22, das ferner eine Trägerwellenquelle umfasst, um die Trägerwelle zu erzeugen.

24. System nach Anspruch 23, wobei die Trägerwellenquelle eine tragbare drahtlose Kommunikationsvorrichtung enthält, wobei einer der Datenträger in ein Objekt oder eine automatische Datensammelvorrichtung eingebettet ist.

25. System nach Anspruch 23, wobei einer der Datenträger, die in das Objekt eingebettet sind, ausgelegt ist, die Trägerwelle zu erzeugen, um mindestens einen anderen der Datenträger als Reaktion auf das Ablaufen einer bestimmten Zeitdauer abzufragen.

26. System nach Anspruch 22, wobei die Cluster dynamisch gebildete Cluster von zufällig verteilten Datenträgern enthalten, die miteinander unter Verwendung eines stochastischen Kommunikationsprotokolls kommunizieren können.

27. System nach Anspruch 22, wobei jeder der Cluster einen im Wesentlichen zentralen Datenträger enthält, wobei ein Kandidatendatenträger ausgelegt ist, aufgrund eines Abstands zwischen dem Kandidatendatenträger und dem zentralen Datenträger des bestimmten Clusters berücksichtigt zu werden, in einen bestimmten Cluster eingeschlossen zu werden.

28. System nach Anspruch 22, wobei die Brückendatenträger zumindest teilweise aufgrund einer kumulativen Ausgangsleistung, die durch einen Brückendatenträger eines ersten Cluster erfasst wird, bestimmt werden, wobei die kumulative Ausgangsleistung der Ausgangsleistung von Datenträgern in einem zweiten von dem ersten Cluster verschiedenen Cluster entspricht.

29. Maschinenlesbares Medium, das mit mehreren verteilten Datenträgern, die in Clustern angeordnet sind, verwendbar ist, wobei das maschinenlesbare Medium auf ihm gespeicherte Anweisungen besitzt, um eine Kommunikation zwischen passiven der Datenträger bereitzustellen, wobei die passiven der Datenträger passive RFIG-Kennzeichnungen und/oder akustische Kennzeichnungen enthalten, durch:

Überwachen nach einer Trägerwelle, die zurückgestreut werden kann, und Einschalten eines ersten passiven Datenträgers, wenn die Trägerwelle detektiert wird;
Starten eines Zeitgebers;
wenn ein Abfragesignal durch den ersten passiven Datenträger vor dem Ablauf des Zeitgebers empfangen wird, Antworten auf das Abfragesignal;
wenn kein Abfragesignal durch den ersten passiven Datenträger vor dem Ablauf des Zeitgebers empfangen wird, Erzeugen des Abfragesignals von dem ersten passiven Datenträger durch Modulieren der Trägerwelle;
Senden des Abfragesignals an mindestens einen zweiten Datenträger; und
Fortsetzen, das Abfragesignal an den zweiten Datenträger zu senden, bis ein Antwortsignal von dem zweiten Datenträger empfangen wird.

30. Maschinenlesbares Medium nach Anspruch 29, wobei der zweite Datenträger in einem anderen Cluster als der erste passive Datenträger ist, wobei die Anweisungen, das Abfragesignal zu senden, Anweisungen enthalten, das Abfragesignal an einen Brückendatenträger zu senden, der mit dem Cluster des zweiten Datenträgers verbunden ist.

31. Maschinenlesbares Medium nach Anspruch 29, das ferner auf ihm gespeicherte Anweisungen enthält, um den Brückendatenträger, der mit dem Cluster des zweiten Datenträgers verbunden ist, zumindest teilweise aufgrund eines kumulativen Ausgangsleistungspegels von mindestens einigen der Datenträger in dem Cluster des zweiten Datenträgers zu identifizieren.

32. Maschinenlesbares Medium nach Anspruch 29, wobei sowohl der erste als auch der zweite Datenträger passive RFID-Datenträger desselben oder eines verschiedenen Clusters sind.

33. Maschinenlesbares Medium nach Anspruch 29, das zumindest teilweise mit einem Sensor integriert ist.

34. Maschinenlesbares Medium nach Anspruch 33, wobei der Sensor ausgelegt ist, Daten bezüglich zumindest eines von mehreren Parametern, die sich auf die Temperatur, die Feuchtigkeit, den Luftdruck, den Beleuchtungspegel, die Anwesenheit von bestimmten chemischen Substanzen, die Anwesenheit und Stärke von elektromagnetischen oder anderen Typen von Signalen oder andere Umgebungsbedingungen beziehen, zu detektieren und sammeln.

35. Maschinenlesbares Medium nach Anspruch 29, wobei der erste passive Datenträger ausgelegt ist, ein Rundfunksignal zu erzeugen.

36. Maschinenlesbares Medium nach Anspruch 29, wobei das Antwortsignal des zweiten Datenträgers ein Rundfunksignal ist.

Revendications

1. Procédé, comprenant les étapes consistant à :

former (502) des coalitions de grappes de supports de données répartis, certains au moins desdits supports de données comportant des supports de données passifs sans pile, lesdits supports de données passifs sans pile comportant des étiquettes RFID passives et/ou des étiquettes acoustiques ;
pour chacune desdites grappes, identifier (504) un support de données passerelle apte à se mettre en liaison avec un support de données passerelle d'une autre desdites grappes ; et
permettre (508) la communication entre des supports de données passifs sans pile des grappes, l'étape consistant à permettre la communication entre des supports de données passifs sans pile des grappes comportant les étapes consistant à :

produire une onde porteuse susceptible d'être rétrodiffusée ;
moduler l'onde porteuse rétrodiffusée avec un premier desdits supports de données passifs sans pile pour générer un signal de sollicitation ; et
moduler l'onde porteuse rétrodiffusée avec un deuxième desdits supports de données passifs sans pile pour générer un signal de retour en réponse au signal de sollicitation,

dans lequel le premier desdits supports de données passifs sans pile amorce la modulation de l'onde porteuse rétrodiffusée au moyen des étapes consistant à :

recevoir (902) la puissance émanant de l'onde porteuse ;
scruter (904) un signal de sollicitation associé à l'onde porteuse pendant une période de temps ;
si le signal de sollicitation n'est pas détecté avant l'expiration de la période de temps (910), générer (912) et envoyer (912) le signal d'interrogation pour solliciter le deuxième desdits supports de données ; et
si le signal de sollicitation est détecté (906) avant l'expiration de la période de temps, répondre (908) au signal de sollicitation.

2. Procédé selon la revendication 1, dans lequel l'étape consistant à former des coalitions de grappes de supports de données répartis comporte l'étape consistant à former des coalitions de supports de données répartis aléatoirement, lesdites coalitions comportant une coalition entre des grappes, une coalition entre des supports de données de grappes respectives différentes et une coalition entre des supports de données dans une même grappe.

3. Procédé selon la revendication 1, dans lequel l'étape consistant à former des coalitions de grappes de supports de données répartis comporte l'étape consistant à identifier des supports de données candidats à placer dans une grappe selon qu'une distance entre lesdits supports de données candidats ne dépasse pas une valeur.

4. Procédé selon la revendication 3, dans lequel l'un desdits supports de données candidats identifiés est un support de données sensiblement central, ladite distance étant une distance entre le support de données central et un autre desdits supports de données candidats.

5. Procédé selon la revendication 1, dans lequel l'étape consistant à permettre la communication entre les supports de données comporte l'étape consistant à permettre la communication indirecte entre des supports de données non passerelles de grappes différentes en utilisant leurs supports de données passerelles respectifs, permettre la communication directe ou indirecte entre des supports de données dans une même grappe ou permettre la communication entre des supports de données de grappes différentes en utilisant leurs supports de données passerelles respectifs et au moins une grappe intermédiaire et les supports de données passerelles de la grappe intermédiaire.

6. Procédé selon la revendication 1, dans lequel l'étape consistant à produire l'onde porteuse comporte l'étape consistant à produire l'onde porteuse à partir d'un dispositif de collecte de données ou de communication portable.

7. Procédé selon la revendication 1, dans lequel l'étape consistant à produire l'onde porteuse comporte l'étape consistant à produire l'onde porteuse à partir d'un autre support de données adapté à générer l'onde porteuse.

8. Procédé selon la revendication 7, dans lequel ledit autre support de données est incorporé dans une carte de visite, une annonce ou un document.

9. Procédé selon la revendication 1, dans lequel l'étape consistant à identifier un support de données passerelle comporte l'étape consistant à identifier un support de données passerelle en fonction d'un niveau de puissance de sortie émanant d'au moins un desdits supports de données.

10. Procédé selon la revendication 9, dans lequel l'étape consistant à identifier le support de données passerelle en fonction du niveau de puissance de sortie émanant d'au moins un desdits supports de données comporte l'étape consistant à :

    définir une zone passerelle comme une région où le niveau de puissance de sortie émanant dudit au moins un desdits supports de données dans une première grappe, qui est détecté par un autre desdits supports de données dans une deuxième grappe, excède d'une valeur seuil une puissance cumulée émanant de tous les supports de données dans la première grappe, qui est détectée par ledit un autre desdits supports de données.

11. Procédé selon la revendication 1, dans lequel l'étape consistant à former des coalitions de grappes de supports de données répartis comporte l'étape consistant à former une grappe qui ne comprend qu'un seul support de données.

12. Procédé selon la revendication 1, dans lequel l'étape consistant à former des coalitions de grappes de supports de données répartis comporte l'étape consistant à former des coalitions comprenant un mélange de supports de données actifs alimentés par pile et desdits supports de données passifs.

13. Procédé selon la revendication 1, dans lequel l'étape consistant à permettre la communication entre des supports de données des grappes comporte l'étape consistant à permettre la communication à l'aide un protocole de communication stochastique comportant une synchronisation de communication.

14. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte une synchronisation temporelle localisée entre au moins deux supports de données.

15. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte une synchronisation temporelle globale entre des supports de données d'une pluralité desdites grappes.

16. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte une synchronisation temporelle de type global selon laquelle le temps de communication entre des supports de données est fixé par une horloge temporelle commune.

17. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte une communication de données à pointage temporel selon laquelle des données reçues par un support de données destinataire depuis un support de données émetteur comportent un temps de transmission des données.

18. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte une synchronisation de support de données à support de données qui comporte les étapes consistant à :

    fixer un temps et propager le temps fixé d'un support de données à un autre ; ou
    utiliser l'un des supports de données désigné comme un support de données gestionnaire pour fixer le temps et propager le temps fixé du support de données gestionnaire à des supports de données avoisinants.

19. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte une synchronisation temporelle multibond selon laquelle l'erreur de temps est compensée au cours de la communication.

20. Procédé selon la revendication 13, dans lequel la synchronisation de communication comporte les étapes consistant à :

    procurer une pluralité de modes de synchronisation différents ; et
    permettre à certains au moins des supports de données d'identifier l'un desdits modes de synchronisation et à engager une corroboration avec des supports de données avoisinants conformément au mode de synchronisation identifié.

21. Support de données passif sans pile permettant la communication entre des supports de données passifs sans pile de grappes de supports de données répartis, ledit support de données passif sans pile étant une étiquette RFID passive ou bien une étiquette acoustique, ledit support de données passif sans pile étant adapté à moduler une onde porteuse rétrodiffusée émanant d'une source d'onde porteuse

pour générer des signaux d'interrogation et de retour, le support de données passif sans pile étant adapté en outre à :

recevoir une onde porteuse émanant d'une source d'onde porteuse (602) et se mettre sous tension ;
ledit support de données sans pile étant **caractérisé en ce qu'**il est adapté en outre à :

déclencher un temporisateur ;
fonctionner dans un mode d'étiquette normal si un signal d'interrogation est reçu depuis la source d'onde porteuse et/ou depuis quelque autre dispositif de sollicitation ;
envoyer un ou plusieurs signaux d'interrogation ou d'autres types de sollicitations à un autre support de données passif sans pile si un signal d'interrogation n'est pas reçu avant l'expiration du temporisateur.

22. Système, comprenant ;
une pluralité de grappes (C^i) de supports de données répartis, certains desdits supports de données comportant des supports de données passifs sans pile selon la revendication 21 ; et
pour chacune desdites grappes, un support de données passerelle (X_p, Y_k, Y_j, X_i) apte à se mettre en liaison avec un support de données passerelle d'une autre desdites grappes pour permettre la communication entre des supports de données des grappes, ladite communication comportant la modulation d'une onde porteuse rétrodiffusée pour acheminer des signaux d'interrogation et de retour entre des supports de données des grappes.

23. Système selon la revendication 22, comprenant en outre une source d'onde porteuse pour générer l'onde porteuse.

24. Système selon la revendication 23, dans lequel ladite source d'onde porteuse comporte un dispositif de communication sans fil portable, l'un desdits supports de données incorporé dans un objet ou un dispositif de collecte automatique de données.

25. Système selon la revendication 23, dans lequel ledit un desdits supports de données incorporé dans l'objet est adapté à générer l'onde porteuse pour interroger au moins un autre desdits supports de données en réponse avant l'expiration d'une période de temps spécifiée.

26. Système selon la revendication 22, dans lequel lesdites grappes comportent des grappes de supports de données répartis aléatoirement formées dynamiquement susceptibles de communiquer les unes avec les autres à l'aide d'un protocole de communication stochastique.

27. Système selon la revendication 22, dans lequel chacune des grappes comporte un support de données sensiblement central, un support de données candidat étant adapté à être envisagé comme un support de données à inclure dans une grappe particulière en fonction d'une distance entre le support de données candidat et le support de données central de la grappe particulière.

28. Système selon la revendication 22, dans lequel les supports de données passerelles sont déterminés en fonction en partie au moins d'une puissance de sortie cumulée qui est détectée par un support de données passerelle d'une première grappe, la puissance de sortie cumulée correspondant à la puissance de sortie de supports de données dans une deuxième grappe différente de la première grappe.

29. Support lisible par machine utilisable avec une pluralité de supports de données répartis agencés en grappes, le support lisible par machine comportant des instructions qui y sont enregistrées pour permettre la communication entre des supports de données passifs parmi lesdits supports de données, lesdits supports de données passifs parmi lesdits supports de données comportant des étiquettes RFID passives et/ou des étiquettes acoustiques, les instructions visant à :

scruter une onde porteuse susceptible d'être rétrodiffusée et mettre sous tension un premier support de données passif si l'onde porteuse est détectée ;
déclencher un temporisateur ;
si un signal d'interrogation est reçu par le premier support de données passif avant l'expiration du temporisateur, répondre au signal d'interrogation ;
si un signal d'interrogation n'est pas reçu par le premier support de données passif avant l'expiration du temporisateur, générer le signal d'interrogation à partir du premier support de données passif en modulant l'onde porteuse ;
envoyer le signal d'interrogation au moins à un deuxième support de données ; et
continuer d'envoyer le signal d'interrogation au deuxième support de données jusqu'à ce qu'un signal de réponse soit reçu depuis le deuxième support de données.

30. Support lisible par machine selon la revendication 29, dans lequel le deuxième support de données se trouve dans une grappe différente de celle du premier support de données passif, lesdites instructions visant à envoyer le signal d'interrogation comportant des instructions visant à envoyer le signal d'interrogation à un support de données passerelle associé à la grappe du deuxième support de données.

31. Support lisible par machine selon la revendication 29, comportant en outre des instructions qui y sont enregistrées visant à identifier le support de données passerelle associé à la grappe du deuxième support de données en fonction en partie au moins d'un niveau de puissance de sortie cumulé de certains au moins des supports de données dans la grappe du deuxième support de données.

32. Support lisible par machine selon la revendication 29, dans lequel les premier et deuxième supports de données sont tous deux des supports de données RFID passifs d'une même grappe ou d'une grappe différente.

33. Support lisible par machine selon la revendication 29, au moins partiellement intégré avec un capteur.

34. Support lisible par machine selon la revendication 33, dans lequel ledit capteur est adapté à détecter et collecter des données relatives à au moins un d'une pluralité de paramètres liés à la température, à l'humidité, à la pression d'air, à des niveaux d'éclairage, à la présence de certaines substances chimiques, à la présence et à l'intensité de signaux électromagnétiques ou de signaux d'autres types ou à une autre condition ambiante.

35. Support lisible par machine selon la revendication 29, dans lequel le premier support de données passif est adapté à générer un signal à diffusion large.

36. Support lisible par machine selon la revendication 29, dans lequel le signal de réponse du deuxième support de données est un signal à diffusion large.

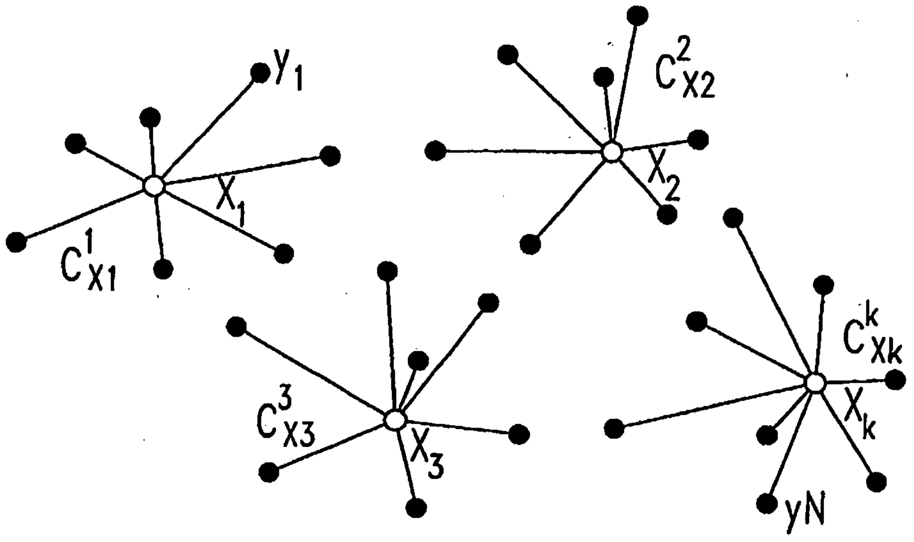
y_1
C^2_{X2}
X_1
X_2
C^1_{X1}
C^k_{Xk}
C^3_{X3}
X_3
X_k
yN

FIG. 1

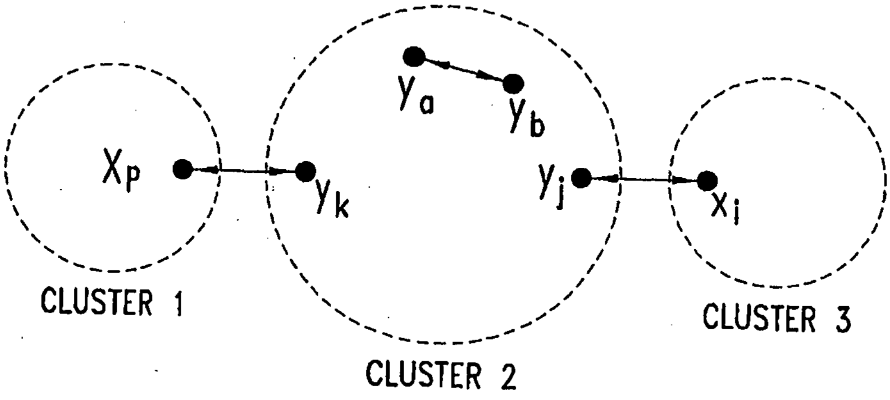
y_a
y_b
X_p
y_k
y_j
x_i
CLUSTER 1
CLUSTER 2
CLUSTER 3

FIG. 2

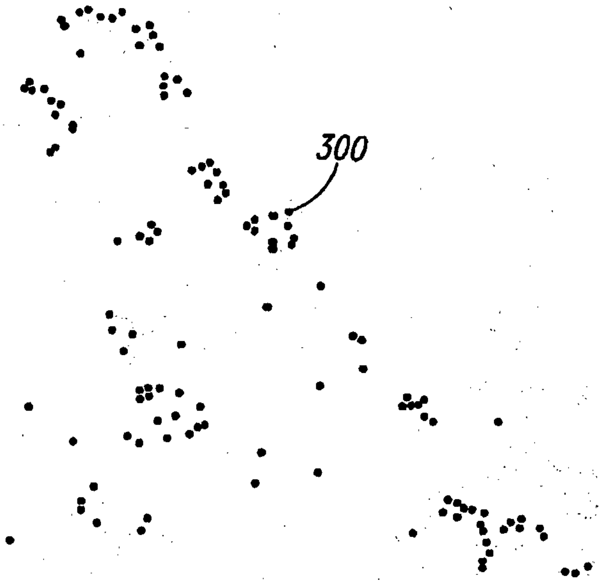

FIG. 3

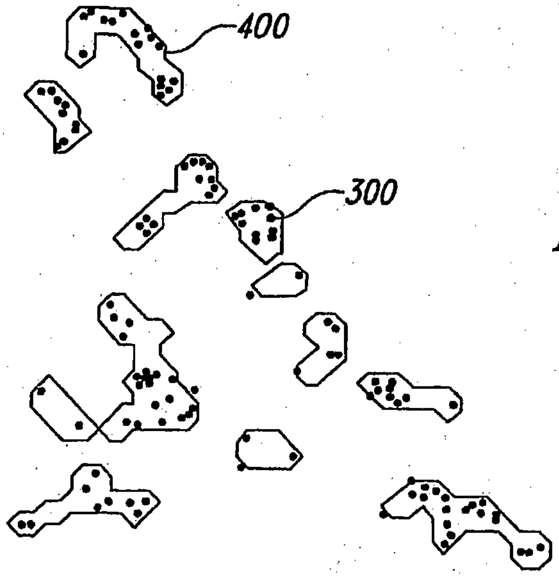

FIG. 4

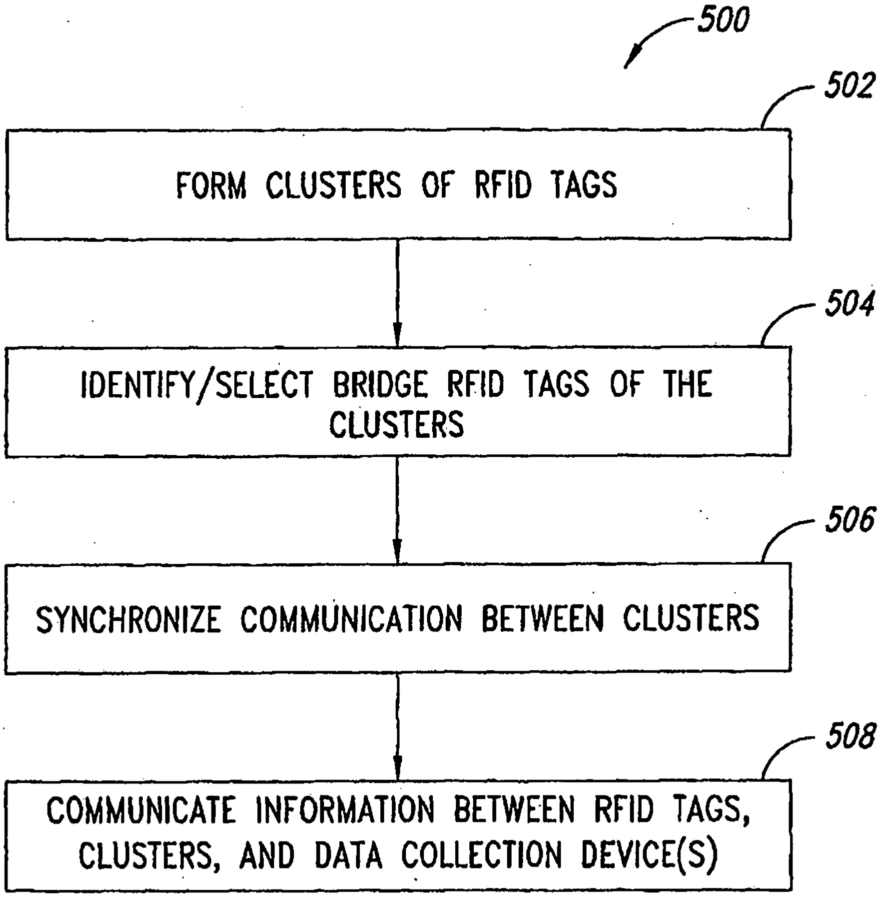
500
502
FORM CLUSTERS OF RFID TAGS
504
IDENTIFY/SELECT BRIDGE RFID TAGS OF THE CLUSTERS
506
SYNCHRONIZE COMMUNICATION BETWEEN CLUSTERS
508
COMMUNICATE INFORMATION BETWEEN RFID TAGS, CLUSTERS, AND DATA COLLECTION DEVICE(S)

FIG. 5

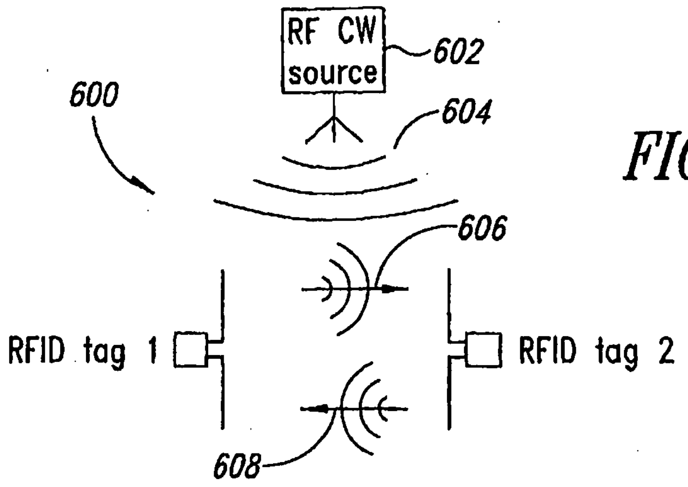

FIG. 6

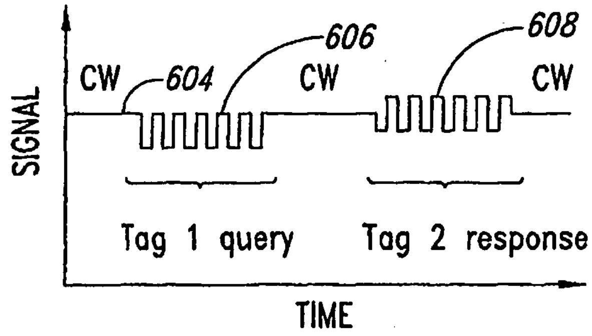

FIG. 7

800

Transmitted RF CW EIRP	36 dBm
Free space path loss from CW source to tag 1 (4 ft distance at 915 MHz)	-33 dB
Tag 1 backscattering modulation loss	-6 dB
Coupling loss between tag1 and tag2 (tags are in close proximity)	-6 dB
Backscattered differential modulated power received by tag 2	-9 dBm
Minimum power required	-10 dBm

FIG. 8

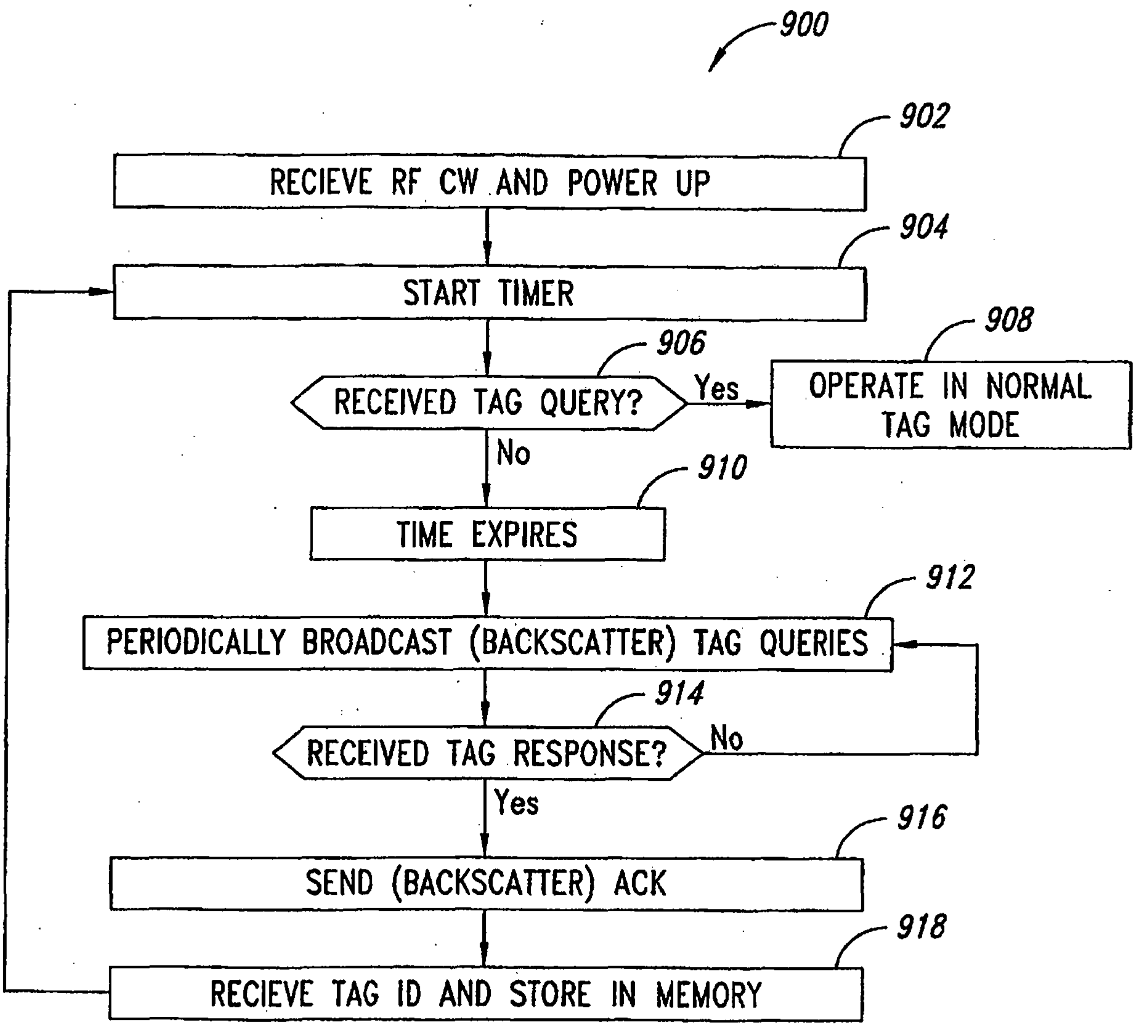
900
902
RECIEVE RF CW AND POWER UP
904
START TIMER
906
RECEIVED TAG QUERY?
Yes
908
OPERATE IN NORMAL TAG MODE
No
910
TIME EXPIRES
912
PERIODICALLY BROADCAST (BACKSCATTER) TAG QUERIES
914
RECEIVED TAG RESPONSE?
No
Yes
916
SEND (BACKSCATTER) ACK
918
RECIEVE TAG ID AND STORE IN MEMORY

FIG. 9

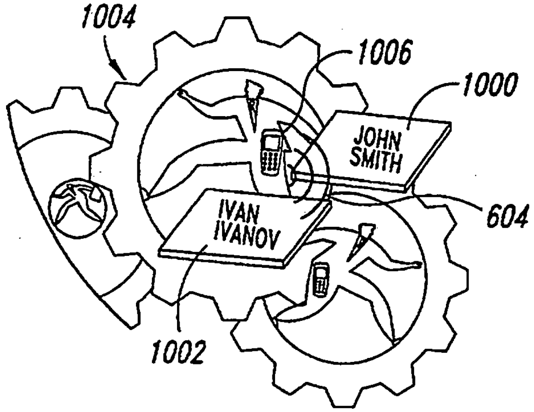

FIG. 10

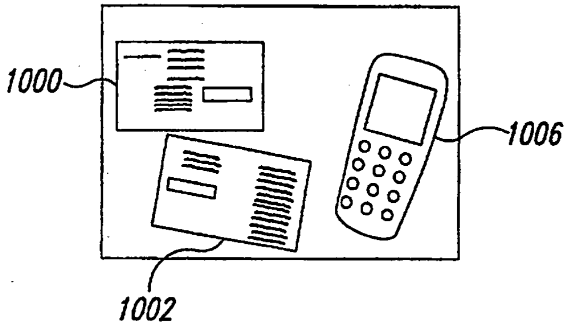

FIG. 11

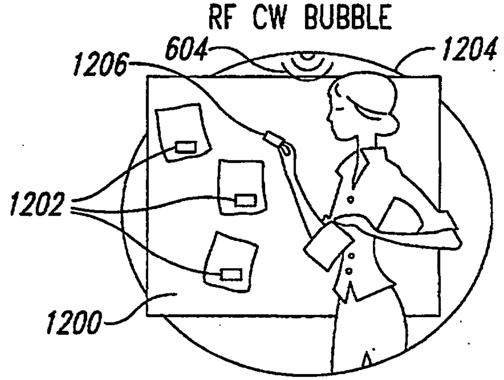

FIG. 12

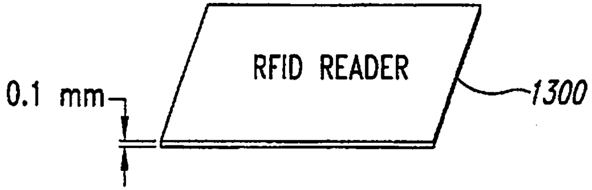

FIG. 13

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 03098532 A1 **[0011]**
- US 5892441 A **[0012]**
- US 20040212480 A1 **[0013]**
- US 610759 P **[0050]**

Non-patent literature cited in the description

- **KIRMAN et al.** Stochastic Communication and Coalition Formation. *Econometrica,* January 1986, vol. 54 (1), 129-138 **[0031]**